Report From The
Spectrum Inventory Working Group
Of The
Commerce Spectrum Management Advisory Committee

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May 19, 2010

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Introduction

The demand for new telecommunications spectrum is increasing exponentially, and this growth is expected to continue indefinitely. Any solution to spectrum scarcity that relies alone on the redistribution of a fixed amount of spectrum is, in the long term, a strategy that will not succeed. Ultimately, most services will continue to experience increased demand, and pitting one service against another will become a zero-sum game. The purpose of an inventory should be to add to the policy maker's toolkit in efforts to enable and promote more intensive use of existing allocations and assignments, rather than solely for the reallocation or repurposing of spectrum. Even if some spectrum is repurposed, industry or government users should be encouraged to deploy known and proven methods for increasing spectral efficiency or effectiveness of use. For example, data compression, smart antenna, MIMO, and new emerging sharing technologies will allow existing spectrum holders to enhance spectrum capacity and manage growth without the need for additional spectrum assets. In some cases, these techniques may create new spectrum access opportunities, if spectrum sharing is proven to be technically feasible and does not undercut a spectrum holder's ability to manage future growth. Spectrum gained through such capabilities is an important long-term, sustainable solution to fulfilling exponential spectrum demand by existing holders and, in some instances, new services.

In addition to this overriding point and the other suggestions that follow in this paper, the Spectrum Inventory Working Group nevertheless agrees that there are substantial benefits that would result from the creation of an automated and accessible Spectrum Inventory. The FCC previously sought information in its initial Notice of Inquiry (NOI) on the National Broadband Plan,[1] and commenters responded positively to the NOI's questions on whether and how the Commission should conduct a "spectrum census" or "spectrum inventory"[2].

Working Group Advice

The Commerce Spectrum Management Advisory Committee (CSMAC) Spectrum Inventory Working Group (SIWG) has been tasked with answering a number of questions that will provide policy advice to NTIA regarding the development of a Spectrum Inventory. These questions are addressed below. In addition, the working group has the following general comments regarding the two pending Spectrum Inventory bills. (For background on the Spectrum Inventory Acts, please see the end of this document.)

Carrier, public safety and business enterprise demand for spectrum for land mobile services in heavily populated areas is increasing rapidly. Furthermore, the mobile wireless industry has articulated a need for additional spectrum to support broadband wireless services, while the Federal Government has also articulated increasing demand for bandwidth intensive capabilities (e.g., UAV, radar), both civil and

[1] *A National Broadband Plan for Our Future*, Notice of Inquiry, GN Docket No. 09-51, 24 FCC Rcd 4342 (2009) (*NOI*).

[2] *NOI* at ¶ 44. *See, e.g.,* Comments of New America Foundation et al. at 15-30, Google at 16, Dell at 11-12, Southern Company at 6-12, Computer & Communications Industry Association at 22, Motorola at 9, Intel at 20, Rural Telecommunications Group at 4, Wireless Internet Service Providers Assoc. at 17, and T-Mobile at 16.

military. The plans to review both federal and non-federal spectrum holdings may provide a better understanding of the possible options to address these needs. Potential results may include:

- Redistribution of existing spectrum assignments from entities that are not using their entire spectrum;
- Encouragement of capacity-enhancing techniques for existing spectrum holders to permit them to manage future growth and curtail the need for additional spectrum assets;
- Introduction of spectrum sharing technologies in specific frequency bands so that underused spectrum can be shared between compatible, non-interfering uses in those cases where sharing is determined to be technically feasible and where it will not undercut the existing spectrum holder's ability to manage future growth.

Concerning the first approach, we respectfully suggest that the fundamental precept of redistribution needs to be challenged. Redistribution is not the only option for the long-term need for spectrum. The effective size of the spectrum is not fixed and unchanging. There has been a continual growth in the need for spectrum since radio technology was created more than 100 years ago. As new services have created new demands for spectrum, technology has increased the capacity of the spectrum to accommodate these new demands. Particularly in the context of fixed and mobile wireless communications, technological innovation allows capacity to stay ahead of demand by enabling greater use of the same amount of assigned spectrum at a faster rate than the assigned spectrum became congested.

For example, when cellular communication was introduced in 1983, cellular systems effected an immediate 10 times or greater increase in spectrum availability -compared to the previous techniques used for mobile communications (30 MHz of spectrum was allocated to cellular communications in 1983 but had an equivalent capacity of 300 MHz). Within five years, a new generation of digital-cellular systems provided at least three times more capacity. Today, cellular systems are more than 100 times more efficient than the mobile telephones of the 1980s.

And yet demand for spectrum continues to grow. New applications in commercial wireless sector alone have the potential to increase demand by a factor of at least two or three within the next ten years. This does not take into account federal or other non-federal growth in spectrum requirements. Without creating any new spectrum access opportunities through new spectrum efficient, sharing or other technologies, there would be an unmet demand for an additional 2500 to 5000 MHz of spectrum.

Obviously, existing spectrum cannot fulfill current demands of industry and the federal government. But much of the new technology required to enhance the efficient use of existing spectrum to address this demand already exists and is in various stages of testing. The communications industry is beginning the implementation of a new generation of cellular technology that incorporates smart antennas, Internet protocol, and other new techniques for content compression. Over the next 10 to 20 years, these new technologies will effectively multiply existing cellular-communications spectrum allocations by at least an additional 10 times. This is the equivalent of finding an additional 2500 MHz of spectrum for mobile wireless use. However, this type of insight, valuable to policy makers, is not the result of an inventory; rather, the inventory will yield a baseline on spectrum holdings in the federal and non-federal spectrum bands reviewed.

But to encourage this greater intensity of use, it is crucial that regulators consider whether licensees should be obliged to use advanced techniques to increase spectrum capacity. Consequently, the spectrum-audit process must include not only an analysis of who has a license to what spectrum, but also an understanding of what that spectrum is being used for. We understand that measurement of spectrum efficiency is difficult and that different measurements are necessary for different services. But measurement of spectrum efficiency in land mobile services (including cellular services) is achievable with known techniques that can, in fact, identify potential solutions for improved spectral efficiency in that service.

Achieving a useful spectrum inventory should be a goal for both the FCC and NTIA. A useful inventory would:

- Create a navigable database that is accessible to the public and outlines the holders of frequency assignments/licenses in what spectrum bands, where, and for what types of service – however, the degree of transparency of an NTIA database is addressed in a separate working group's set of recommendations; and

- As appropriate for the type of services, identify areas of the country and times of the day when peak usage results in poor service or when services cannot be implemented.

The results of the inventories can then inform policymakers as to the consequences as they consider what options are available to them, including requirements for the use of better technology for improved spectral efficiency, spectrum sharing opportunities, or the allocation of additional spectrum.

While this may not apply to spectrum being used for non-communications services, identification of potential opportunities for existing spectrum holders to make more efficient use of their spectrum assets through capacity enhancing techniques should be encouraged. In addition, spectrum sharing in areas of the country (e.g., underserved rural) and times of the day where and when assigned spectrum is unoccupied and potentially available to entities introducing non-interfering services, systems or devices may result. Of course, spectrum sharing should not be deployed if it detracts from existing spectrum holders' ability to manage future growth and deploy new and innovative services, or if it creates an unacceptable level of interference that degrades service offerings.

In this way, we suggest that the government create and implement policy and regulations that stimulate and encourage uses that benefit the national interest (rather than trying to legislate technologies or services), and create an environment that stimulates the most effective use of radio frequency spectrum.

Questions and Answers

1. What information is needed from a spectrum inventory to reach policy decisions?

   Answer – We recommend that the public portions of the FCC and NTIA inventories being be available through a common portal. We also recommend that the inventories be a common format for ease of use, common data standards to facilitate exchange of information between the agencies. They should also contain, to the extent consistent with the Transparency WG recommendations, information on: frequency assignments, geographic coverage of assignments, use, international coordination requirements, harmonization of frequencies, Host Nation Agreements. In the cases of government or critical infrastructure(CI) licenses, care must

be taken to balance the benefits of providing public access to the inventories against any potential problems that could arise from revealing strategic geographic or functional information that could compromise national or CI energy and water system security.

Enabling access to the available allocation and assignment databases from the NTIA and FCC through a single, unified portal would provide the public, innovators, Congress and the agencies' themselves with a much better understanding of spectrum usage. However, it may also be important to supplement this data with all available information regarding the actual use of the spectrum to the extent that creating and sustaining such a database is useful and feasible. A number of spectrum occupancy studies have been conducted over the last few years that document the actual utilization of LMR spectrum in certain frequency bands. For example, the FCC's Enforcement Bureau, NTIA's Institute for Telecommunication Sciences, academic institutions (with the support of the National Science Foundation) and individual companies have measured spectrum use with interesting, but incomplete results.[3]

NTIA and the FCC should continue their efforts to study the extent to which each frequency band is being utilized. As would be required by the pending legislation, the agencies and spectrum licensees should, based on available or new data, analyze and disclose appropriate metrics that provide information on their usage of the their spectrum.

NTIA personnel should be able to see how Government spectrum resources are used/un-used anywhere in the country, down to the "County" level. By knowing if and where any frequency assignments are under-utilized, alternative uses can be explored. This information should be visible to anyone via a web viewer.

The cost of creating and sustaining a comprehensive infrastructure measurement and database would be substantial and would offer minimal benefit. The actual usage of the spectrum is highly varied with regard to service, technology, and a myriad of other factors. A comprehensive measurement system would not be achievable within reasonable time and budget limitations.

Specific to the NTIA and the agencies it serves, the assignment of spectrum either permanent or on-demand should be quantifiable and qualified down to the specific frequency, channel size and geography at a date certain. The format of an inventory should be designed by NTIA to improve its ability to see how Federal spectrum resources are used/un-used anywhere in the

[3] For NTIA spectrum occupancy reports, *see, e.g.,* John E. Carroll, J. Randy Hoffman, Robert J. Matheson, "Measurements to Characterize Land Mobile Channel Occupancy for Federal Bands 162–174 MHz and 406–420 MHz in the Denver, CO Area," NTIA Report TR-08-455, September 2008, available online at http://www.its.bldrdoc.gov/pub/ntia-rpt/08-455/; J. Randy Hoffman, Robert J. Matheson, Roger A. Dalke, "Measurements to Characterize Land Mobile Channel Occupancy for Federal Bands 162–174 MHz and 406–420 MHz in the Washington, D.C., Area," NTIA Report TR-07-448, July 2007, available online at http://www.its.bldrdoc.gov/pub/ntia-rpt/07-448/. *See also* FCC Spectrum Policy Task Force, Report of the Spectrum Efficiency Working Group, (2002) at 10-16, available online at http://www.fcc.gov/sptf/files/SEWGFinalReport_1.pdf; R. Bacchus, A. Fertner, C. Hood, D. Roberson, "Long-term, wide-band spectral monitoring in support of Dynamic Spectrum Access Networks at the IIT Spectrum Observatory", in proceedings of IEEE DySPAN, Chicago, IL, October 2008, available online at http://www.cs.iit.edu/~wincomweb/publications.html; Shared Spectrum Company Reports available at http://www.sharedspectrum.com/measurements/.

United States of America down to the "County" level, if not more specific by contour. By knowing both the geography and the frequency span, NTIA will be able to see if there is any fallow spectrum assigned to a Federal agency, why it is fallow, and determine how and why it might be used either temporarily or permanently by another Federal or non-federal user. Further, the same policy should apply to all FCC commercially assigned; auctioned spectrum should also be viewable with similar ease, but to the public via a web viewer.

The NTIA should endeavor to see these capabilities and determine within a short time frame how to implement this capability rapidly and cost-effectively, consistent with the recommendations on transparency provided by the Transparency Working Group.

While it is now neither economically or technically feasible to measure actual spectrum use in all bands, for all times, and over the entire country, the Working Group suggests that selected actual measurements can have value in spot checking of the data base and to provide useful data for those engaged in promulgating and creating spectrally efficient technology. At some time in the future, it may be practical to measure spectrum use. (See Appendix B, Potential Use of Spectrum Measurements)

Spectrum usage and assignment data will likely be very helpful for purposes of fulfilling the agencies' overall spectrum management duties and responsibilities to ensure effective spectrum management.

2. What do technology innovators need? For example, do groups seeking access to spectrum need information about system characteristics?

   Answer – We recommend that NTIA, and the FCC through the NTIA, undertake to determine what information regarding existing and planned system characteristics, receiver information (ability to reject interference) and duty-cycle information (near-constant transmission or intermittent use), in addition to relevant transmitter locations, emitted power and transmit masks, can be made available in any public inventory.

   We recommend that system characteristics for licensed spectrum should include, among others, the number and location of authorized sites, power levels, transmitter technology, spectrum bandwidths, NTIA frequency assignment/FCC application-volume trends, whether the spectrum is used for national-security or public-safety purposes, and, for unlicensed bands, the number of manufacturers that have received type-acceptance (FCC approval of a company's type of equipment) for products used within the specific band. We also recommend that licensees verify annually their location and actual use of the spectrum for which they are licensed.

   NTIA and the FCC should examine the system characteristics list to determine which items of information could potentially reveal sensitive operational or security aspects of government or CI energy and water licensees. This examination should particularly focus on characteristics that relate directly to mission-critical functions. In some cases, NTIA and the FCC might need to coordinate with other government agencies, such as the Department of Homeland Security or the Department of Energy, to ensure that the inventory does not reveal licensing characteristics that jeopardize the security of certain government or CI energy and water mission critical functions.

We further recommend that each agency seek information from their respective licensees on any spectrum assigned for planned systems or systems in development by federal, state and local agencies that would include a synopsis of the system or equipment to be deployed and the associated timeframe. An analysis of current systems, system/mission life, and application might also be useful. This set of information should be viewable by those within NTIA and FCC with appropriate security clearance for analysis of their respective license holders.

Today, many public-safety organizations, utilities, municipalities, Internet-service providers (to name a few) lack the "spectrum" resources to bring new and urgent data communications to their current and/or future subscribers. Identification of, and exploration of "inventive" access to, any un-used assignments or allocations is not only logical but should be a key priority at both the FCC and NTIA.

A comprehensive list of technical characteristics that could be useful to technologies and groups seeking access to spectrum appears in Appendix A entitled "Illustrative List of Spectrum Inventory Elements". This list needs to take into account that there are terrestrial, aeronautical, maritime, and space-based uses that will have different, but relevant technical characteristics that impact use of the assigned or allocated spectrum. For example, list should clearly include requirements for unique satellite elements, such as two-degree spacing, dual polarization, and spatial separation. This list, which is illustrative, includes regulatory, administrative and technical information.

3. How can the inventory process be conducted in as timely, cost-effective, and efficient a manner as possible?

   Answer – We recommend that NTIA, and through NTIA to the FCC, that each agency seek federal appropriations to support the development of their respective databases/inventories; however, each database should be based on a common data format, standards, so that information can be easily exchanged between the agencies.

Background Information

Both the House and the Senate have introduced legislation entitled the "Radio Spectrum Inventory Act" which would, if enacted, require an "inventory of radio spectrum bands managed by the National Telecommunications and Information Administration and the Federal Communications Commission." The Senate bill (S.649) was introduced on March 19, 2009; and the House bill (H.R. 3125) was introduced on July 8, 2009. The House version provides a broad strategic objective, specifically to "promote the efficient use of the electromagnetic spectrum", while the Senate version remains silent as to the purpose of the legislation. These pieces of legislation are virtually identical, including among other requirements, the following:

- Within 180 days, create an inventory of radio spectrum band managed by the National Telecommunications and Information Administration (NTIA) and the Federal Communications Commission (FCC);
- Identify the radio services authorized to operate in each band and provide the identity of the licensees and government users;

- Provide the total amount of spectrum, by band of frequencies, allocated to each Federal or non-Federal user in percentage terms and in sum, and the geographic areas covered by the respective allocations;

- Provide the approximate number of transmitters, repeaters, end-user terminals or receivers, or other radio-frequency devices authorized to operate, as appropriate to characterize the extent of use of each radio service in each band of frequencies;

- For non-Federal users, any commercial names under which facilities-based service is offered to the public using the spectrum of the non-Federal user, including where the spectrum is being offered via resale and under what commercial names;

- Provide, to the greatest extent possible contour maps or other information that illustrates coverage areas, receiver performance; other parameters relevant to an assessment of the availability of spectrum in each band; for each band or range of frequencies, the identity of each entity offering unlicensed services; and the types and general number of unlicensed intentional radiators or radiators certified by the Commission that are authorized to operate; and

- Create a centralized portal or website to make the inventory of the bands of frequencies available to the public via an Internet-accessible website.

The legislation differs in the scope of the spectrum inventory and the definition of what information may be excluded in the inventory. The NTIA and the FCC would be required to do an inventory of spectrum between 225 MHz and 3.7 GHz, under H.R. 3125 approved on a unanimous vote of the House Communications Subcommittee. Chairman Rick Boucher, D-Va., submitted an Amendment in the Nature of a Substitute to H.R. 3125, which was unanimously voted out of the House Subcommittee on January 21, 2010. The mandatory range was reduced to 3.7 GHz and the required report to Congress on the results of the inventory is to include a "recommendation of which spectrum, if any, should be made available for reallocation" or shared access, not just reallocation. Further, this legislation was modified to provide the agencies a year to do the inventory, up from six months in the original bill, and would require the report to Congress every two years rather than annually. The reduction in the upper limit of the spectrum range to 3.7 GHz from 10 GHz, places the House Bill more in line with the Senate Bill that would audit spectrum from 300 MHz to 3.5 GHz. The agencies would be allowed to audit up to 10 GHz if they decide the benefits outweigh the costs. The House is willing to exclude proprietary information, while the Senate is willing to exclude information of importance to the national security.

Funding

The House bill would require NTIA and the FCC to "first use agency resources, including existing databases, field-testing, and recordkeeping systems, and only request information from Federal and non-Federal users if such information cannot be obtained using such agency resources." The Working Group recommends that additional funding be provided by Congress to the NTIA and the FCC to design, develop, implement and maintain their respective spectrum inventories that will better inform policy-making regarding spectrum, giving stakeholders an opportunity to better understand the overall spectrum environment.

Future Considerations

While a spectrum inventory is very valuable, and for some allocations such as broadcast stations, radars, and passive listening bands can characterize the band usage reliably and for long periods of time, it is less helpful in understanding band loading in more dynamic environments. It is worth noting that all modern radios have some amount of computing capability. This creates a possibility of utilizing deployed client and base station radios to assist in the creation of a continuous frequency survey for at least some of these more dynamic bands. For example, if a large number of 802.11 access points were to periodically sample the interference levels and utilization of their band and report this information to a central server, then correlating this information with geo location of the stations would give evidence of the spectrum demand at that location. Already such information is available in enterprise deployments to assist in managing the enterprise system. Similar use could be made of the large numbers of deployed mobile systems and their base stations to survey mobile voice and data bands. Unlike a static spectrum inventory such an approach could yield a continuously updated picture of spectrum utilization.

Creating an infrastructure to actually do this would certainly be challenging. Standards would be needed for the nature of the reports; servers would have to be put in place and maintained; decisions about whether such reporting would be voluntary or mandatory and under what condition would need to be debated. Clearly there are privacy and security issues with such a scheme as well and suitable tradeoffs between anonymity and privacy of reports and reliability of the resulting data would need to be made. However, with a large amount of such data smart data fusion approached could likely extract highly reliable summary information that may be impossible to get in any other practical manner. It would be useful to have the NTIA and FCC charter an investigation into whether such automated data collection approaches might be feasible and what steps would be needed to achieve them if so.

Conclusion

The spectrum audit process must include not only a measure of occupancy or of license for such occupancy, but also to the extent feasible a measure of how effectively that spectrum is being used. While an audit of spectrum occupancy may identify who is licensed to use spectrum in a given area, it will reveal nothing about the effectiveness of that occupancy. We understand that measurement of spectrum efficiency is difficult and that different measurements are necessary for different services. Measurement of spectrum usage at peak times may indicate that the spectrum is fully occupied, but this measurement is only part of the story. It is crucial that wireless communications licensees have an incentive to use advanced techniques that increase the capacity and efficiency of the spectrum utilized, thereby allowing more traffic to be carried in a fixed amount of spectrum. In fact, as noted above, the commercial wireless industry has proven over time to be highly adaptable to a challenging spectrum environment and has repeatedly deployed the most sophisticated capacity-enhancing technologies in their networks. Other non-commercial spectrum users should also be encouraged to integrate advanced, capacity enhancing technologies into their networks so that all spectrum holders make the most of a scarce resource.

Appendix A
Illustrative List of Spectrum Inventory Elements

General Spectrum Use Guidelines (Band by Band)

- Applicable FCC/NTIA technical rules governing spectrum use
  - Spectrum access methods
  - Type of spectrum, licensed or unlicensed
  - License terms
  - Technical use requirements and limitations
  - Reporting obligations
  - Construction requirements, if any
  - International use agreements and/or treaties

- Type acceptance (FCC) or spectrum certifications (NTIA)
  - Manufacturers
  - Identifying emission type or other designations
  - Description of communications devices
  - Transmission mask
  - Receiver selectivity

Administrative Data (For each authorized licensed spectrum user)

- Name of entity or agency
- Primary accountable point of contact
- Contact information (Phone, email, etc.)
- Primary contact's mailing address
- Location where spectrum authorizations are maintained
- Affiliated organizations that may be using authorized spectrum on a primary or shared use basis
- Organizational documents providing subsidiary and/or affiliated spectrum use authority

Technical Use Information (For each licensed or authorized wireless system)

- Authorized channels
- Approved build out plans
- Service codes
- Channel bandwidths
- Geographic coordinates
- Control points
- Special use conditions, if any
- Area of operation
- Station classifications or codes
- Emission or Spectrum certifications
- Number and type of authorized devices
- Power levels (fixed, temporary and mobile)
- Variability of signal bandwidths

- Transmission duty cycles
- Antenna type, gain and direction (Transmit and receive)
- Antenna make and model numbers
- Antenna heights
- HAAT
- Ground elevation
- Antenna structure
- FAA clearance
- Frequency plan (i.e., TDD or FDD)
- Frequency pairing description, if any
- Receiver noise figure
- Minimum detectable signal used for link analyses
- Type of dynamic transmit power control used, if any
- Guard bands, if any
- Propagation models used to determine exclusive spectrum use and interference prediction
- Transmit duty cycle
- System architecture

Appendix B
Potential Use of Spectrum Measurements

For unclassified, non-FOIA exempt assignments and licenses available in the spectrum inventory, some of the parameters may be appropriate to verify and, if necessary ascertain, via actual measurements. Examples of such measurements include what assignments/licenses are built out and in use, where and when actual transmissions occur, the transmit duty cycle; the temporal transmit variations, the signal bandwidths, the use of frequency guard bands, and available information on deployment (mobile, fixed, number of users via the signal amplitude statistics). Examples of where measurements may be particularly useful include:

- Usage in unlicensed bands where many user parameters are not directly known to regulators,
- Parameters that are not known by the users or contained in the frequency assignment, but are determined to be relevant by the regulator. For example, many users do not know their own temporal usage and their mobility,
- In some cases, particularly in the case of public safety, day-to-day spectrum management decisions have been delegated to regional authorities and in some cases delegated further to local authorities,
- There are signals that may not be known or authorized by regulators. For example, understanding the man-made noise, "rogue" illegal or accidental signals, anomalous propagation loss events involving licensed signals that create unexpected signal levels, signals coming from across the US borders that are not well known and spurious transmissions can be relevant to spectrum decision-making.

It is also important to also recognize that spectrum measurements will not accurately capture sensing only technology, which is deployed for a range of military and civil uses. Moreover, measurements and sampling may yield a further incomplete picture of intended and planned uses of the band. Therefore, spectrum measurements initially will best serve as an auditing function for certain assignments/licenses in the inventory, as determined by the relevant regulator.