Measurement/Quantification Subcommittee Report
Commerce Spectrum Management Advisory Committee

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Contents

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Question 1

How may general occupancy measurements be performed to reflect or validate actual federal spectrum use (particularly radars and intermittent operations) in a way that can support spectrum management decisions regarding relocation or sharing of spectrum?

(See 6/14/13 Executive Memorandum at Sec. 3(c) and NTIA 8/19/13 Notice of Inquiry)

It is recommended that NTIA make general occupancy measurements to support different phases of the spectrum management decision-making process.

Currently, analytical methods are used to estimate the required spatial and frequency separation between incumbent and entrant systems, which are critical to decisions regarding relocation or sharing of spectrum. These analytical methods are based on many incumbent system parameters (number of transmitters used, the transmitter locations, the number of channels used, the modes typically in use, time-of-day use, spurious emissions, etc). In general, these incumbent parameters are not well known for a variety of reasons, and general occupancy measurements can be used to obtain the needed information.

One issue with analytical methods is that many parameters are not included in the spectrum assignments; or worst case assumptions are made in the analytic models. For example, large aircraft operating areas and near continuous operating periods are often specified in frequency assignments, but the actual approximate locations and operating periods can be obtained with measurements. Another issue is that the incumbent users may report to the regulators parameter values that are very conservative to maximize their future spectrum use flexibility. General occupancy measurements provide verification of actual usage.

And finally, the parameters needed for the analytic methods are specific to certain incumbent system designs, and are not well known. For example, a networked test and training system might use multiple channels in a complex spatial spectrum sharing scheme. It would be difficult for regulators to anticipate a complex architecture with significant technical depth to identify what incumbent system parameters are important. Incumbent system measurements then become useful to help the regulatory analyst understand the system and to determine what analytical methods/models should be used. Thus, the objective of general occupancy measurements is to determine incumbent system parameters such as the number of transmitters, locations, number of channels used, modes typically in use, time-of-day use, etc for use in the above analytical methods.

General occupancy measurements have limitations, and the lack of measured energy doesn't necessarily mean that spectrum sharing is possible. Measurements don't detect receivers that are radio silent. The measurements can determine propagation losses values, but this requires knowledge of the transmitter's location parameters (location, power, antenna gain, etc). The measurements don't determine the interference protection criteria. As mentioned above, making spectrum management decisions regarding relocation or sharing of spectrum sharing without measurements has significant shortfalls. Measurements are component of a holistic and comprehensive approach to solve a difficult problem.

The measurements should be made by a third party not directly involved in the spectrum sharing such as NTIA or a contractor. The measurements should be made in close coordination with the incumbent system operators to insure that the measurements are representative of

typical uses. The measurements should be made in close coordination with the group developing the analytic spectrum sharing models. Each analytic model incumbent system assumption should be traced to the measurements for validation. For example, the received power level from an aircraft telemetry system could be predicted using the analytic model assumptions and validated with the measurements. It is critical that a test plan be created for each test to insure that planned data collection and data processing will provide the desired results. The test plan should be reviewed by the NTIA working groups involved in the spectrum sharing process.

It is recommended that NTIA make general occupancy measurements incrementally to support different phases of the spectrum management decision-making process (see Figure 1). The duration and the geographic scope of the measurements should increase if the process for a given set of frequencies moves forward. The purpose/triggers for measurement activity are:

- Level 0 – Measurement Applicability Analysis - **It is recommended that NTIA create a 'Measurement Applicability' analysis when considering a band for spectrum sharing.** This analysis is performed prior to making any determination to undertake any occupancy measurements, The measurement process needs to recognize and indicate where there are receive-only uses, and other low duty cycle transmissions that would not be adequately reflected in the measurement results, e.g., where there are receive only radars, or missile destruct signals; current analytic techniques are more appropriate for such situations as measurements would be potentially misleading. The analysis would define what parameters would be determined by the measurements and the data analysis approach. For example, the incumbent transmitter's transmit duty cycle, channel usage statistics within a band, and the approximate transmitter locations would be determined based on the predicted detection distance and the measurement location. This analysis would use the existing frequency assignment database to identify the good measurement locations (close enough to incumbent transmitters to assure detection), to determine the required scan rate, and to select effective detector types.

- Level 1 - General Incumbent System Characteristics - **It is recommended that NTIA do initial spectrum occupancy measurements.** These measurements inform the process of identifying and prioritizing bands for potential relocation or sharing by validating the analytical method assumptions and analysis approach. For example, the analytical method might assume that all incumbent aircraft operate at a maximum altitude (i.e. have a huge detection distance) while in reality the majority of operations are at lower altitudes (i.e. have a limited detection distance). Thus, the analytic model needs to be modified to have a distribution of altitudes instead is using the maximum altitude. These measurements would be conducted for a period of time and in places, appropriate for the incumbent operations in the band to determine features important to the amount of spectrum that would be available for sharing.

- Level 2 – Detailed Incumbent System Characteristics - **It is recommended that NTIA do detailed incumbent system characteristics measurements.** The purpose of these measurements is to determine the scope and technical feasibility of transitional or long-term sharing. The measurements are made at incumbent system locations for convenience and to interact with the incumbent system operator. The goal is to obtain information on unusual and unanticipated incumbent system parameters (waveforms, antenna rotation …) that would impact sharing. An example is that the incumbent transmitter automatically changes the signal bandwidth as the link distance increases. This would impact an entrant spectrum sensing approach where a certain waveform is detected to determine spectrum availability. In this case, the incumbent waveform dynamically and unpredictably changes.

- Level 3 – Site Specific Characteristics - **It is recommended that NTIA do site specific characteristics.** The goal is to inform commercial users (auction bidders) of the spectrum availability and the specific incumbent system operating locally. These measurements would be made in all of the entrant's high priority regions. These measurements would be at multiple locations (5 to 10) over long periods (3 to 6 months) to provide a comprehensive and detailed estimate of the existing transmitter's spatial and temporal characteristics. For example, the measurements would statistically determine how many simultaneous aircraft telemetry transmitters are active in a specific area.

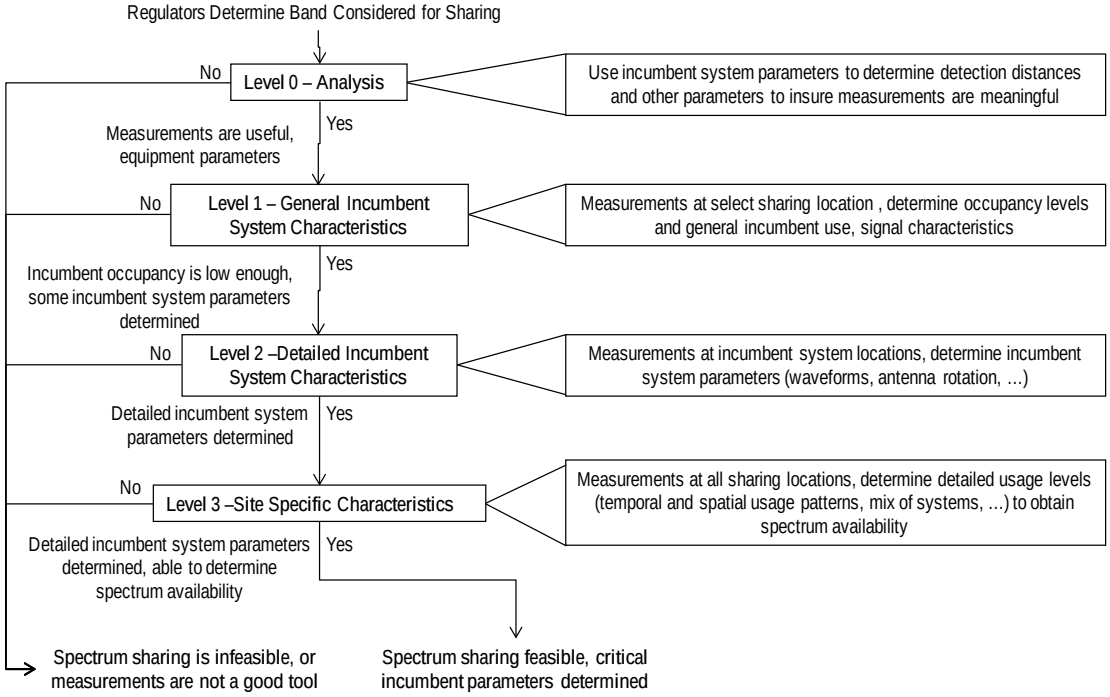

Figure 1. Spectrum occupancy measurements should be made incrementally to support different phases of the spectrum management decision-making process.

It is recommended that NTIA develop a multi-tier approach to release spectrum measurement data that accommodates security concerns. The detailed measurement data should be released to a limited group that is actively considering providing service in the specific areas. The NTIA should determine if this release approach should follow the methods recommended by the Database Subcommittee or the trusted agent method that was recently introduced. NTIA should investigate data processing methods to 'hide' critical measurement features (i.e. waveform type, specific frequencies, etc) and maintaining received power level, approximate location and time of day to enable public releasable data.

For example, the amplitude probability distribution of received power in 4 hours blocks over frequency range blocks could be provided, along with annotation that the source was an airborne transmitter, which would provide significant information for spectrum sharing analysis, but would reveal much less about the DoD systems.

It is recommended that NTIA analyze the measurement data collected at each of the above levels to extrapolate the usage in the future. These predictions would inform whether there is a potential for sharing or relocation. Measurement characteristics alone are not sufficient to determine future usage, but the spectrum needs of existing authorized, but not yet deployed, programs need also be reflected in future usage analysis, as well as any planned growth in current systems. This would be done via discussions with the incumbent system developers (programs of record) and the incumbent operators. This analysis would be documented in each spectrum measurement report.

Question 2

Recognizing resource limitations and the lack of real-time reporting of use built within the federal radio infrastructure, how should actual federal spectrum use be quantified with or without supplemental occupancy measurements?

(See 6/14/13 PM Sec. 3(a) and (d))

There are some inherent difficulties in relying only on occupancy measurements. They do not reflect any passive services, nor do they reflect planned or authorized systems in development or system upgrades. A fundamental premise to spectrum sharing is that spectrum bands already in operational or planned use by systems/services -- whether by federal, commercial, state or local users – are considered otherwise unavailable for new exclusive uses. Therefore, any frequency band – commercial or non-commercial -- requires that proposed new uses take into account the existing uses of the band.

It is recommended that the NTIA working with all of the spectrum management functions across the federal agencies, do the following to obtain the needed information to quantify spectrum use:

- Create a list of technical and operation parameters that are forecasted to be needed to determine spectrum usage that are in addition to the parameters needed for interference protection (i.e. the assignment data). Examples spectrum usage parameters include the typical transmission periods during different times of the day, the approximate number of transceivers in operation during typical use periods, the transmitter locations, the fraction of time that the system operates at maximum link distances, etc. These spectrum usage parameters would be application specific. For example, that amount of spectrum used by a telemetry system that uses a steerable directional ground receive antenna is highly dependent on the fraction of time that the antenna is pointed at low elevation angles and on the antenna azimuth angle. Thus, the antenna pointing angles would be provided. Another example is that that amount of spectrum used by an air-air communications system is highly dependent on the duration that the aircraft spends at specific locations and altitudes. Thus, approximate aircraft locations and altitudes would be provided. This information would not include detail time histories of parameters, but instead general descriptions (i.e. ~1% of the time the antenna is pointed at these angles, and 10% of the time at these angles, etc). It is worth noting that additional efforts would need to be taken to capture elements of actual use not captured with this method. For example, it would be beneficial to define typical use and how to capture atypical requirements, as well as in the context of aeronautical, reflect the missing transit use to reach typical altitudes.

- Determine what spectrum usage and assignment parameters are needed to be known by an entrant system to facilitate spectrum sharing with the federal user. For example, the federal user's operating frequency, antenna height, operating periods, receiver location and other similar parameters would be needed by an entrant if a database spectrum

sharing approach would be used. Many of these parameters need to be added to the list currently being developed by NTIA. [1]

- Send the federal users copies of their current spectrum assignments along with the list of spectrum usage parameters. The federal users would then be instructed to provide comments on the accuracy of the assignment data, and to provide the spectrum usage parameter values. The NTIA would include a statement that these assignments, supplemented by any updates, would be protected in future spectrum sharing arrangements. The goal of providing the federal users the current baseline of operational assignments is to reduce the administrative efforts to ensure that the records reflect current requirements; it also may provide an opportunity to update and correct assignment information. Any known planned spectrum use changes should be noted as an appendix. However, this does not adequately address authorized system developments, nor may it allow for technology evolution of existing systems. The latter remains a challenge for any users seeking to share spectrum.

- Request that the federal users provide estimates and procedures on what spectrum usage and assignment parameters that they will be authorized to provide by their respective agency information security policies to entrants. For example, in certain bands there may be proposals to use spectrum sensing, which would require federal users in the band to provide waveform description information; this would be provided periodically to enable the federal user to modify the waveform in the future. This information is critical to understanding the use, and to enabling spectrum sharing. If one federal system in a given band transmits for brief periods consistently over its lifecycle and is mobile, it could be difficult to determine how this spectrum may be shared.

- Request that the federal users provide the name and POC information of a technical lead for that system information so that NTIA can readily access information ensure accountability and accuracy of the information used in the spectrum user analysis. The technical lead is responsible to keep this information provided to the NTIA current during the analysis period.

It is recommended that the NTIA do the following analysis to quantify spectrum use:

- Consider the utility of a metric based on the amount of spectrum available with or without the federal government users in the band. The change in spectrum availability is then a metric used to determine the actual federal spectrum use.

- Develop a notional model(s) of entrant communications equipment. This could be a combination of LTE-type cellular use and unlicensed uses. This model would include desirable entrant use locations, receiver heights, antenna gain, transmit power, etc. These models potentially already exist as part of other NTIA spectrum sharing initiatives, but would have to be developed for future 5G use. NTIA should collaborate with industry to explore the utility and co-develop such models.

[1] 'Fourth Interim Progress Report on the Ten-Year Plan and Timetable and Plan for Quantitative Assessments of Spectrum Usage', U.S. Department of Commerce Report, Appendix A, 2014.

- Perform spectrum sharing modeling using the above spectrum usage and assignment parameters to estimate the change in spectrum usage. This approach could apply to both federal and commercial users of spectrum. In general, this calculation would be performed twice with different assumption on the spectrum usage and assignment parameters available to both the entrant and incumbent users. The first calculation (theoretical limit) would be performed assuming that both the entrant and incumbent had complete information. The second (info sharing limit) would be performed using the info that each is willing to provide to the other (due to security or proprietary data concerns) or that is practical (due to administrative burdens). Worse case values are used for scenarios where the information is limited. These two metric values (theoretical and information sharing limits) could provide policy makers with cost/benefit information on increasing the specificity of the information able to be shared between the entrant and incumbent users. As an example, this metric would have direct impact to the 3.5 GHz band type of sharing where information on legacy platform location and operating frequency may not be provide to entrant systems.

Occupancy Analysis[2]

Table A-2. Guidance on Time of Use		
TME Field Entry	**Description of Actual Use**	**Percentage of Time Frequency is Used per Day**
1	Constant or nearly	50 to 100
2	Regular/frequent	10 to 50
3	Intermittent	1 to 10
4	Sporadic/occasional	Less than 1

Table A-3. Transmitter Data Elements	
Parameter	**Units**
Frequency	Megahertz
Latitude and longitude	Degrees/Minutes/Seconds
Transmitter necessary bandwidth	Hertz
Transmitter power	Watts
Transmit mainbeam antenna gain	Decibels referenced to an isotropic antenna
Transmit antenna height	Meters
Area of operation (for mobile and transportable systems): Radius of operation defining area of operation Latitudes and longitudes defining area of operation Authorized state(s)/nationwide defining area of operation	 Kilometers Degrees/Minutes/Seconds Annex G[11]
Pulse width (for pulsed systems)	Microseconds
Pulse repetition interval (for pulsed systems)	Microseconds

Table A-4. Receiver Data Elements	
Parameter	**Units**
Frequency	Megahertz
Latitude and longitude	Degrees/Minutes/Seconds
Intermediate frequency receiver 3 dB bandwidth	Hertz
Receive mainbeam antenna gain	Decibel referenced to an isotropic antenna
Receive antenna gain pattern	Decibel referenced to an isotropic antenna as a function of off-axis angle in degrees
Receive antenna height	Meters
Receive antenna azimuth angle	Degrees
Receive antenna minimum elevation angle	Degrees

[2] 'Fourth Interim Progress Report on the Ten-Year Plan and Timetable and Plan for Quantitative Assessments of Spectrum Usage', U.S. Department of Commerce Report, Appendix A, 2014.