Before the
NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION
Washington, D.C. 20230

In the Matter of

Notice of Inquiry	)	**Docket No. 130809703**
Spectrum Monitoring Pilot Program	)	**RIN 0660-XC007**

<u>Comments of Shared Spectrum Company</u>

October 3, 2013

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COMMENTS OF SHARED SPECTRUM COMPANY

I. INTRODUCTION:

Shared Spectrum Company (SSC) is a leader in developing spectrum monitoring and sharing technologies including Dynamic Spectrum Access (DSA) radios, frequency sensors, and software applications. Founded in 2000, SSC is a small, entrepreneurial business that has been inventing and implementing a broad range of innovative capabilities that enable wireless devices to access or share multiple frequency bands for all types of applications.

For example, the company developed DSA over the past 13 years on several military projects, building prototype devices, and developing software. SSC performed successful DSA radio tests at Fort A.P. Hill, Virginia, demonstrating core spectrum access principles of the Defense Advanced Research Projects Agency (DARPA) NeXt Generation (XG) Communications program.[1]

In addition, SSC has been a leading voice in favor of spectrum sharing with the National Telecommunications and Information Administration (NTIA), at the Federal Communications Commission (FCC), and before decision-makers in Congress and within the Administration. In particular, SSC has been active before the NTIA in promoting more efficient use of our national spectrum resources through sharing.[2] Similarly, at the

[1] M. McHenry, E. Livsics, T. Nguyen, N. Majumdar, "XG Dynamic Spectrum Access Field Test Results," IEEE Communications Magazine, Vol. 45, no. 6, pp. 51-57 (June 2007), available at http://www.sharedspectrum.com/wp-content/uploads/2007-02_SSC_Description_Demonstrations_Ft_AP_Hill.pdf.

[2] Shared Spectrum Comments filed in response to NTIA's Test Bed Proposal, In the Matter of Spectrum Sharing Innovation Test-Bed

FCC, SSC filed extensive Comments and Reply Comments in the FCC's Notice of Inquiry concerning use of DSA technology.[3] There, SSC urged the Commission to: (1) develop a policy-based regulatory framework for spectrum sharing across multiple spectrum bands; and (2) propose spectrum sharing rules for Federal spectrum bands that take into account incumbent usage and incentives to share.[4]

In the TV White Spaces (TVWS), SSC first proposed TVWS sharing to the Commission and has been involved in most major aspects of that, and similar, sharing efforts over the past decade.[5] These efforts are aimed at the concept of monitoring, or "sensing" for available channels and then utilizing those open channels for communications at that particular time and place.

In addition, SSC was highly engaged in the development of the July 20, 2012 Report by the President's Council of Advisors on Science and Technology on Spectrum Technology (the PCAST Report).[6] The PCAST Report specifically concluded that, "The norm for spectrum use should be sharing, not exclusivity," noting that a new spectrum

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Pilot Program, NTIA Docket No. 120322212–2212–01.

[3] Promoting More Efficient Use of Spectrum Through Dynamic Spectrum Use Technologies, *Notice of Inquiry*, ET Docket No. 10-237, 25 FCC Rcd 13711 (Nov. 30, 2010) ("*DSA NOI*").

[4] Comments, Shared Spectrum Company, ET Docket No. 10-237, February 28, 2011, at 20-21.

[5] Shared Spectrum's previous filings with the Commission in Unlicensed Operation in the TV Broadcast Bands (ET Docket No. 04-186); Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies Authorization and Use of Software Defined Radios (ET Docket No. 03-108); Establishment of an Interference Temperature Metric to Quantify and Manage Interference and to Expand Available Unlicensed Operation in Certain Fixed, Mobile and Satellite Frequency Bands (ET Docket No. 03-237); Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band (ET Docket No. 02-380), and Spectrum Policy Task Force Report (ET Docket No. 02-135), Software Defined Radios (ET Docket No. 00-47) -- which are incorporated herein by reference.

[6] *Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth,* Report of the President's Council of Advisors on Science and Technology, July 20, 2012, http://www.whitehouse.gov/administration/eop/ostp/pcast/docsreports.

architecture and a corresponding shift in practices could greatly multiply the effective capacity of spectrum.[7]

It is against this background of development of spectrum sharing technology and promotion of policies for deployment of such leading-edge sensing technology, that SSC welcomes the opportunity to comment on the NTIA's Notice of Inquiry concerning a Spectrum Monitoring Pilot Program.

Spectrum monitoring is key to spectrum management policy because there are spatial and temporal "open channels" which comprise the bulk of spectrum, even in the most congested areas and even during peak usage times. So-called "cognitive radios", such as SSC's own DSA radios, are designed to gain access for communications purposes to these open channels. More to the point, SSC has been participating in measurements of such open channels in the National Science Foundation's National Radio Research Testbed project ("NTNRT") managed by the University of Kansas Information and Telecommunications Technology Center, and has taken spectrum measurements in a variety of locations.

Nearly a decade ago, on June 14, 2004, Shared Spectrum filed a report with the FCC detailing measurements SSC took from the rooftop of the National Science Foundation building in Arlington, Virginia and at Riverbend Park in Northern Virginia.[8] These measurements showed the low occupancy of different spectrum bands from

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7 Id., at vi.
8 *Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies*, FCC ET Docket No. 03-108 (2004).

30 MHz to 2.9 GHz at a "worst-case" location (good line-of-sight visibility in a dense urban area) and at a "baseline" rural location.

Encouraged by these results showing that there were many more open channels than occupied channels, Shared Spectrum took measurements at the most congested place in the USA-- New York City, -- and SSC did so at a time of particularly high congestion: during the Republican National Convention from August 31 to September 3, 2004, when security precautions and news coverage were at their peak.

Shared Spectrum's test results were surprising: even in a time and place of severe congestion, no more than 16% of the spectrum was employed.[9] While the 16% in New York City was much larger than the approximately 3% in Great Falls, Virginia, it makes clear that the great majority of spectrum capacity is being left unused even in the most high-use case. SSC achieved similar results when testing later in downtown Chicago, which had less than 20% spectrum usage.

These open channels can be identified and used by cognitive radios, also known as software defined radios ("SDR"), as described in Shared Spectrum's earliest filings with the FCC on this topic.[10] Improvements in detection equipment sensitivity permit

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[9] The New York City measurements were taken from the rooftop of the Stevens Institute of Technology Building in Hoboken, New Jersey.

[10] *Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies Authorization and Use of Software Defined Radios* (ET Docket No. 03-108), *Establishment of an Interference Temperature Metric to Quantify and Manage Interference and to Expand Available Unlicensed Operation in Certain Fixed, Mobile and Satellite Frequency Bands* (ET Docket No. 03-237), *Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band* (ET Docket No. 02-380), and *Spectrum Policy Task Force*

ready detection of existing spectrum uses on a dynamic basis. A cognitive radio using these capabilities can change its transmitter parameters based on interaction with the environment in which is operates.

This interaction may involve active negotiation or communications with other spectrum users and/or passive sensing and decision-making within the radio. Cognitive radio systems can be deployed in network-centric, distributed, ad hoc, and mesh architectures, and in both licensed and unlicensed applications.

II. SHARED SPECTRUM COMPANY'S TECHNOLOGY:

As noted above, SSC is the pioneer in developing DSA radio technology.[11] In addition, our Spectrum Sensing Toolbox (SST) is a commercial product that enables spectrum sharing through highly precise radio frequency sensing by wireless devices of all types that are operating in the TVWS and other spectrum bands. Attached as Exhibit A is an overview of the SST software solution.

Report (ET Docket No. 02-135), *Software Define Radios* (ET Docket No. 00-47) -- which are incorporated herein by reference.

[11] *See, e.g.*, M.A. McHenry, "System and Method for Reuse of Communication Spectrum for Fixed and Mobile Applications with Efficient Method to Mitigate Interference," U.S. Pat. 7,146,176 (Dec. 5, 2006); M.A. McHenry and A Leu, "Method and System for Determining Spectrum Availability within a Network," U.S. Pat. 7,564,816 (July 21, 2009) ; M.A. McHenry et. al, "Methods for Using a Detector to Monitor and Detect Channel Occupancy," U.S. Pat. App. 11/582,496 (Oct. 18, 2006); E. Livsics et. al, "Methods for Detecting and Classifying Signals Transmitted Over a Radio Frequency Spectrum," U.S. Pat. App. App. 11/839,503 (Aug. 15, 2007); F. Perich et. al, "Method and Device for Policy-Based Control of Radio," U.S. Pat. App. 11/783,563 (April 10, 2007).

We believe that sensing based technologies like the SST can play an important role in the full utilization of spectrum. As noted in more detail below, sensing can provide real time updates to databases with both macro and micro benefits.

Among its many features, the SST accurately detects wireless microphones, TV transmitters, LTE signals and other emitters while allowing devices to avoid false alarms, access more spectrum and improve quality of service. The SST is based on over a decade of research and field testing in harsh RF environments for defense, government and commercial users.

In its *DSA NOI,* the FCC examined the development of spectrum sensing, recognizing it as an "important component of dynamic spectrum use" and asked a series of questions on spectrum sensing techniques and issues, including ways to determine the appropriate detection threshold, avoid so-called "hidden nodes" or detect changes to the noise floor.[12] As mentioned in our Comments and Reply Comments in that proceeding, a key component of SSC's DSA system involves spectrum sensing through several types of detectors such as SST. SSC also pointed out that it has been a pioneer in developing cooperative sensing (or "group behavior") solutions.[13]

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[12] *DSA NOI* at ¶¶ 20-24.

[13] M. McHenry, K. Steadman, M. Lofquist, "Determination of Detection Thresholds to Allow Safe Operation of Television Band 'White Space' Devices", 3rd IEEE Symposium on New Frontiers in Dynamic Spectrum Access Networks (DYSPAN 2008), pp. 144-155 (Oct. 2008), *available at* http://www.sharedspectrum.com/publications/papers/2008- 10_SSC_White_Space_Devices.pdf. This paper was also submitted into the record of the TV White Space proceeding. *See* SSC Letter to Chairman Kevin J. Martin, *Unlicensed Operation in the TV Broadcast Bands*, ET Docket No. 04-186 (Oct. 23, 2008). Similar analysis performed by SSC was submitted into the record of the TV White Spaces proceeding by Microsoft Corporation. *See* Letter to Julius P. Knapp from Edmond Thomas, ET Docket No. 04-186 (Oct. 26, 2009).

Sensing can also be used on a macro level, such as the 3.5 GHz band or the TVWS band. Sensors can communicate with a database to limit or reduce exclusion zones. Thus, sensing enhances database awareness of open channels; this knowledge, in turn, could lead to permission for higher power devices to operate than those that are currently permitted under the TVWS rules for Mode II TVBDs and fixed devices.

In sum, sensing capabilities such as our SST solution resolve interference on the micro level and enhance real time updates to databases for more efficient macro level operations.

III. COMMENTS:

A. Spectrum Monitoring is Needed.

As noted above, Shared Spectrum Company engaged in a survey of usage of spectrum in major cities such as Chicago and New York City. The results of that limited spectrum monitoring survey were provided to the FCC; SSC found that less than 20% of the spectrum was utilized in places like New York and Chicago. Clearly, there is a great deal of fallow spectrum which could be harvested, even in major urban areas of the United States.

Thus, SSC applauds NTIA's proposal to conduct a pilot program to monitor spectrum usage. Combining monitoring spectrum with capabilities of utilizing open channels is the holy grail of spectrum sharing: if the additional 80% of spectrum not being used at any given time in Manhattan or Chicago could be utilized, without interfering of course with the licensee's use of their 20% at that time, then consumers, public safety users, manufacturers, and licensees will all benefit.

Consumers would have access to much more spectrum and higher speeds/throughput than they realize today. Public safety users such as FirstNet would be able to share with existing frequencies adjacent to their future LTE networks, for example. Licensees could realize revenues from the 80% or more of their spectrum which is unused at any given point in time in major markets like New York City and Chicago. Both software companies and equipment manufacturers would benefit by having access to greater bandwidth on which to sell their solutions.

The momentum in favor of sharing is evident at the FCC and the NTIA, which have proposed re-allocating 500 MHz of spectrum from Federal and non-Federal users. [14] The same momentum exists within the Administration, which in its recent PCAST Report advocated freeing up an additional 1,000 MHz immediately.[15] In a memorandum of June 28, 2010 (entitled "Unleashing the Wireless Broadband Revolution"), President Obama directed the Secretary of Commerce, working through the NTIA, to collaborate with the FCC to make 500 MHz of Federal and nonfederal spectrum available for

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[14] U.S. Dept. of Commerce, "An Assessment of the Viability of Accommodating Wireless Broadband Systems in the 1675-1710 MHz, 1755-1780 MHz, 3500-3650 MHz, and 4200-4220 MHz, 4380-4400 MHz Bands" (October 2010) ("Fast Track Report"), *available at* http://www.ntia.doc.gov/reports/2010/FastTrackEvaluation_11152010.pdf; U.S. Dept. of Commerce, "Plan and Timetable to Make Available 500 Megahertz of Spectrum for Wireless Broadband" (October 2010) ("Ten-year Plan"), *available at* http://www.ntia.doc.gov/reports/2010/TenYearPlan_11152010.pdf.

[15] The PCAST Report concluded that "As a result, the most urgent recommendation in this report is that the President issue a new memorandum that states it is the policy of the U.S. government to share underutilized Federal spectrum to the maximum extent possible that is consistent with the Federal mission, and requires the Secretary of Commerce to immediately identify 1,000 MHz of Federal spectrum in which to implement the new architecture and thereby create the first shared-use spectrum superhighways." PCAST Report at vii.

wireless broadband use within 10 years.[16] Then on June 14, 2013, the President issued a follow-on Memorandum directing the NTIA to conduct these pilot spectrum monitoring programs, among other items.[17]

In order to achieve the much greater level of sharing called for by the NTIA, FCC, and the Administration, significant rule changes must be made in spectrum allocation proceedings. Each time the Commission proposes to auction or otherwise reallocate spectrum, it should, in our view, adopt rules that promote spectrum monitoring and sharing as part of *its* core mission. In order to determine which bands will be best able to support sharing, and for future licensees to know how much spectrum available, the spectrum monitoring proposed here will be invaluable.

B. NTIA General Questions

1. NTIA is considering that the initial system for the pilot program include a small network of radiofrequency sensors installed at selected sites in up to ten major metropolitan areas to collect data across particular bands of interest. The measurement equipment would automatically feed data to a centralized database for storing, retrieving, and analyzing spectrum usage and occupancy information.

SSC supports the plan to install sensors at multiple sites in several cities as well as the plan for the data collected to be stored in a centralized database. SSC encourages NTIA to deploy a system that is scalable to multiple kinds of markets. Spectrum use varies widely with location, with different systems used in urban areas, suburban areas, remote areas, DoD test and training areas, etc.

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16 Please see, http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution.

17 Please see, http://www.whitehouse.gov/the-press-office/2013/06/14/presidential-memorandum-expanding-americas-leadership-wireless-innovation.

SSC encourages NTIA to ensure that the data is available in near-real time (within seconds) at the central location to support dynamic spectrum sharing experiments. Most spectrum measurement systems generate up to several GB/hour of data, which is too much for cost effective backhaul. Thus, the monitor should employ efficient and remotely adjustable data compression to reduce the backhaul requirements.

The software should permit easy data collection and analysis at the central database location; this analysis should consist of spectrum usage reports, occupancy information, etc.

Since the NTIA envisions a two year pilot test, SSC agrees that a number of sensors should be deployed throughout the ten markets. As data is collected, these sensors could easily be redeployed to other locations in the city in order to gather information from different areas of that city. In addition, NTIA may wish to consider deploying some portable sensors to help predict different areas of varying needs throughout a city.

Spectrum use varies by both time and location within a metropolitan area. By deploying a network of sensors throughout a market, more readings would be available, and from different locations of a city. Issues such as terrain or building blockage and signal strength at various locations will be identified.

There is off-the-shelf monitoring equipment available today from a variety of vendors, including SSC. These monitors range in price, portability and other features, depending upon the specific client needs and location of deployment. Many monitors are available with frequency coverage up to 6 GHz which seems to be the focus of the latest Presidential Memorandum, dated June 14, 2013. SSC urges NTIA to use available, commercial off-the-shelf technology for its sensors.

SSC believes that NTIA should deploy at least ten fixed sites in each of ten markets in order to get more comprehensive information about both the temporal and spatial variations than would be provided from fewer fixed sites. In addition, NTIA may wish to deploy portable units to augment the data from fixed locations. This overall data collection then would be fed to a computer and analyzed for a common operating picture of spectrum in that city or area in real time.

C. Specific NTIA Questions.

1. How should a measurement system be designed to measure a variety of emissions, including weak or intermittent signals, airborne platforms, and radar systems, while keeping incremental costs in check?

NTIA appropriately notes that a measurement system must be capable of measuring a variety of emissions, including weak or intermittent signals, airborne platforms and radar systems in order to fully capture the use of spectrum. For this to occur, the monitor should have integrated data processing using general purpose processors so that custom signal detectors and classifiers can be used on the data in real time. There is no requirement for 100% detection probability for this monitoring application, so expensive wide bandwidth spectrum monitoring systems are not required.

2. What types of measurement/monitoring techniques should be used for the different types of radio services?

The measurement/monitoring techniques to be used vary with the overall question to be addressed. Obtaining very high detection sensitivity is important, especially in spectrum bands where directional antennas are used. Blind classification algorithms are not necessarily needed since there is significant *a priori* information on existing emitters. SSC uses a library of waveform specific detectors/classifiers to obtain the best performance versus cost trade-off.

3. What frequency bands should initially be measured during the pilot phase of the program?

As the Presidential Memorandum of June 14th noted, agencies will be required to explain why they need new spectrum allocations in the valuable bands below 6 GHz. Therefore, NTIA may wish to examine the bands up to 6 GHz, because these high demand bands are particularly useful for broadband applications. The only constraint on resources is the huge amount of data collected: the more bands that are examined, the more data NTIA must retrieve, analyze and store. Technical capabilities exist, however, it requires more financial resources to work with large amounts of data and this will be true regardless of what method of monitoring spectrum is chosen. The amount of data can be both considerable and valuable. We provide a rough order-of-magnitude estimate for data collection rates and storage requirements in our response to question number 17 below.

4. How should measurement and monitoring parameters (e.g., resolution and video bandwidths, sampling rate, dwell time, detector selection, antennas, pre-selector filtering, dynamic range) be specified?

The values for these parameters must be balanced against system cost, revisit rate, background signal strength, minimum target signal strength and other parameters.

Based on our experience making spectrum measurements, SSC recommends that the system be set up to sample enough signals to make a determination of the types of signals and their characteristics rather than to sample all signals. This will avoid the need to acquire a monitor with 100's of MHz of instantaneous bandwidth. In fact, these large sample rate monitor systems create dynamic range challenges in high signal environments and are perhaps more challenging in terms of cost to acquire and operate given the large amounts of data received.

Conventional spectrum analyzers are designed as a powerful piece of lab equipment with a human operator interpreting signals in real-time. Often this results in much of the data being discarded and unavailable for future processing.

We recommend a spectrum monitoring system that collects and stores I/Q data. This capability will provide the greatest flexibility for analysis and interpretation of collected spectrum data, including the implementation of advanced detectors and classifiers.

The detector needs to be selected based on the signals of interest. The best approach (highest sensitivity and false alarm) is to use a variety of detectors/classifiers that are designed for specific signals and a flexible detector scheduler in the monitor software architecture.

Pre-selector filtering with less than octave frequency spacing is important to obtain high dynamic range.

A combination of omni-directional and directional antennas are needed to maximize detection probability. A flexible antenna switch matrix is needed for automated operation.

5. Which geographic locations within major metropolitan areas or other communities throughout the country would provide the greatest value for the pilot?

Since spectrum use varies spatially as well as temporally, measurements are needed at several locations within a single area to provide statistically valid data. For example, if the monitor location was not located near a public safety repeater tower, then the measurements would under-estimate the public safety spectrum usage. If the monitor location was near a television Electronic News Gathering (ENG) receiver, then the monitor may over-estimate the ENG spectrum use in other areas of the market. A broader spatial sampling provides greater confidence in spectral use results.

Measurements are needed at many locations because spectrum use varies widely with location with different systems used in urban areas, suburban areas, remote areas, DoD test and training areas, etc.

Spectrum measurements at highly elevated locations (large building tops or mountain tops) tend to overestimate the spectrum use throughout a market and do not adequately identify the opportunity to spectrum share on a more localized basis with low power, short-range transmissions. For the proposed initial monitoring networks, SSC proposes that each urban area be monitored with a distributed network. In general, those locations within a city that are highly congested with traffic and people would be the areas to focus upon.

6. How should individual measurement units be deployed in each community?

Measurement units, as noted above, should be deployed in areas of high congestion, and using rooftops or similarly accessible locations. Locating measurement units immediately adjacent to high power transmissions (e.g., broadcast, radar, etc.) should be avoided to minimize overloading the monitoring unit RF front-end.

7. How could the long- or short-term placement of multiple fixed units within the same general geographic area improve the accuracy and reliability of the data collected in each community and at what incremental cost?

Spectrum use varies both spatially and temporally within an area. A common operating picture of an urban landscape can be gathered using a network of ten or more sensors placed in and around an urban area. Use of multiple locations helps reduce the sensitivity of the data collection to the specific features of a single site. Use of multiple sites allows units to be placed at locations with different characteristics such as antenna height, urban density, surrounding building blockage, public meeting points, etc.

8. How could mobile or portable units be utilized to supplement data collected at fixed sites within a community and at what incremental cost?

Mobile or portable units are helpful to obtain a comprehensive picture of spectrum use. The mobile or portable monitors should be either nomadic (set up on a building roof for several weeks, and then moved to another location) or mobile (installed on a vehicle and driven continuously). The monitor hardware costs should be 'affordable' so that some level of sensor loss due to damage or theft is acceptable.

Mobile or portable monitor units are also important because LTE and other networks are continually being deployed and expanded. These mobile monitoring devices can help gauge the impact of new systems on neighborhoods or particular areas of interest such as government buildings.

In addition, special events such as concerts and parades can impact the availability of spectrum, and mobile monitors can help measure those usage needs. Moreover, terrorist attacks or other emergencies, such as hurricanes or tornadoes, are important events which require mobile monitoring of spectrum to learn what systems are on the air at the scene and what systems are not on the air, and how to improve spectrum usage and sharing before, during and after an attack, a storm, or some similar crisis. Mobile or portable sensors can help with that data collection.

Greater spatial sampling of the RF spectrum environment can be achieved with mobile units. One way to achieve wide geographic sampling at relatively low incremental cost may be to deploy the units on public or private transportation infrastructure such as trains, buses or taxi cabs.

9. How long should measurement data be collected to provide statistically relevant results, particularly for intermittent operations, at each geographic location?

Data from fixed locations would ideally be collected for a period of at least twelve months, to account for changes in ambient temperature, foliage, building conditions, and similar environmental factors. In addition, changes in behavior occur throughout the year: for example, school busses are not on their routes in July, but use their radios from August to June. Similarly, some military operations may only take place once a year, such as a joint exercise or a visit to port of a particular Navy vessel.

10. How should the measurement system design take into account variations in population densities, buildings, terrain and other factors within or surrounding selected measurement locations (i.e., in urban, suburban, and rural parts of a metropolitan area)?

Variations in population densities, terrain and other factors should be analyzed before deployment by using terrain maps, conducting proposed monitoring site visits in advance to determine line of sight and other factors, and meeting with local public safety and transportation officials about the congestion and flow of commuters and residents in and around the city.

A common operating picture of an urban landscape can be gathered using a network of ten or more fixed sensors placed in and around an urban area. Mobile or portable units could help to fill in the picture where buildings or challenging terrain may prevent an accurate street level view of spectrum usage and needs. In addition, such mobile or portable units could be valuable to better understand street by street changes in spectrum usage in densely populated areas or during special events such as concerts or parades, or after emergencies.

11. What steps can be taken to eliminate or minimize the possibility of ''hidden nodes'' when conducting measurements?

Portable and mobile field sensors should be used, particularly in urban areas with underground spaces that may have RF transmissions. Also, by placing declassified results online, users of such "hidden node" systems can check to see if their signals were in fact seen. If not, the users should have an easy method to contact the testing personnel so that the test can be modified to pick up the hidden node.

In addition, the monitor should employ 'sub-noise' detectors and classifiers to detect weak signals.

12. What kind of spectrum utilization and occupancy information (e.g., precise received field strength levels, time-of day occupancy percentages, times that signals are measured above specified thresholds) would be most useful to spectrum stakeholders?

The information should depict statistics of the band occupancy so that secondary loss of service due to spectrum sharing can be estimated. The lowest detection threshold with low false alarm that can be obtained with the equipment should be used. The measurements need to be made over a period of months to understand the worse case events (largest fraction of the spectrum band being used and for how long).

13. What detection thresholds should be used to measure and characterize the usage patterns of incumbent systems?

The detection threshold is inversely related to the signal detection distance. The distance factor depends on the propagation loss, with typical values of R4. Thus, reducing the detection threshold by 12 dB doubles the detection distance, and increases the detection area by a factor of four. Thus, a low detection threshold is critical to obtaining a cost effective monitoring system.

The achievable detection threshold is a function of system Noise Figure, signal bandwidth, algorithms to reject man-made noise, the acceptable false alarm rate, and the ability to detect weak legacy system features. A minimum Noise Figure of 7 dB is achievable.

14. What data and information would be useful in evaluating potential sharing compatibility with wireless broadband devices?

The most useful data related to spectrum sharing is to determine the characteristics of the legacy equipment that will be sharing spectrum in the future. What information is needed is how often they operate, where do they operate, what bandwidth do they use, what is the system architecture (TDD, FDD, etc.), and how many operate at a specific location/time. This information is needed to develop spectrum sharing technical approaches and to determine how much spectrum will be available to secondary users.

Additional useful information can be obtained by comparing the measured spectrum use with the frequency assignment database. If legacy users are reserving spectrum and rarely use it, then the data gathered from the network of monitors can enhance frequency assignment databases to obtain efficient spectrum sharing.

15. How can the gathered data and analysis better inform spectrum policy decisions, enhance research and development of advanced wireless technologies and services?

Frequency bands that are lightly used can be evaluated for spectrum sharing. The President has ordered federal government agencies to begin sharing spectrum where feasible, and this information will help determine which bands can best be shared. In addition, if manufacturers and users know that a particular band is lightly used, they can focus their research and development efforts on issues associated with that band. For example, the knowledge that the 3.5 GHz band would be made available for sharing has generated research into how to characterize the radar systems that are operating in that band to be able to share it with new entrants.

16. What data formats and evaluation tools should be employed?

The VITA 49 is a widely used, commercial standard. This standard enables portability from a wide range of spectrum measurement devices.

In general, there are many questions that can be addressed with spectrum measurements, and each question requires different analysis methods. This includes processing I/Q samples with high performance detectors/classifiers and combining data for geo-spatial and temporal analysis. SSC uses C++ software on each monitor to pre-process data, and SSC uses MATLAB to process recorded spectrum measurements. MATLAB provides the maximum flexibility to customize the data analysis and plotting. Using 'canned' spectrum analysis tools does not provide sufficient flexibility to answer many measurement-based questions.

17. How can the large amounts of measurement data be effectively managed, stored, and distributed?

The system should store I/Q time samples so that specialized analysis can be performed on the data. With approximately ten sensors per market trial, the total amount of data collected would be large, but workable. As an estimate assume that 5 GB per hour was collected per sensor. The total storage for that market would be 5 GB/hour x 24 hours /day x 365 days/year x 10 sensors = 438 TB. Hard disks cost approximately $100 per TB. Thus, the total storage cost would be $43,800 for that market trial.

This data would be distributed in small portions for specific research questions. These small portions would be distributed by download or by mailed hard disk.

The time series data could then be processed using FFTs to obtain frequency domain power spectral density and channelized (decimated) to a 1 kHz resolution bandwidth (RBW) for high resolution interpretation. Channelization to 100 kHz RBW results in much smaller data files suitable for wider distribution of coarser spectrum utilization information.

18. What steps can be taken to ensure that sensitive or classified information will not be revealed to unauthorized parties?

It is unclear what, if any, sensitive or classified information is at risk. Spectrum scanners are widely available and hundreds of thousands are deployed. Extensive lists of frequency assignments are available on the internet.[18] These databases allow scanners to identify 'interesting' signals that are measured but that do not exist in the database. Nevertheless, if DoD or other government agencies believe that classified information should not be available, that information should be available only to those entities authorized to see that portion of the data collected.

IV. CONCLUSIONS:

Monitoring of spectrum from a series of fixed points collected at a central location as part of a pilot should be just the initial step toward ubiquitous deployment of sensing technologies. Sensing in the field, as well as monitoring from a central location, would help the NTIA, the FCC, licensees, consumers, and database operators to better understand, and police where necessary, the real world environment. SSC supports such a comprehensive sensing option for databases, and SSC would suggest the inclusion into portable and fixed devices of software similar to its SST capability.

By deploying a network of fixed sensors in congested urban areas at given intervals, database operators could more efficiently gather results. Augmenting those results with mobile or portable sensors would increase the accuracy of the data. The FCC could use these combined results to update its channel records and permit database

[18] http://www.radioreference.com/apps/db/

operators to authorize additional channel sharing or usage in certain locations in conjunction with licenses, and unlicensed bands, and in cooperation with Federal and non-Federal spectrum allocations.

SSC requests that the NTIA incorporate into its pilot program provisions encouraging the use of state-of-the-art spectrum monitoring and sensing technologies consistent with the foregoing discussion, and that NTIA augment its network of fixed sensors with several mobile or portable sensors for deployment, particularly in areas of emergencies, after storms or similar events, and during large gatherings such as concerts or parades, to measure spectrum usage and availability for first responder purposes.

Respectfully submitted,

______/s/________________
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Exhibit A

SPECTRUM SENSING TOOLBOX

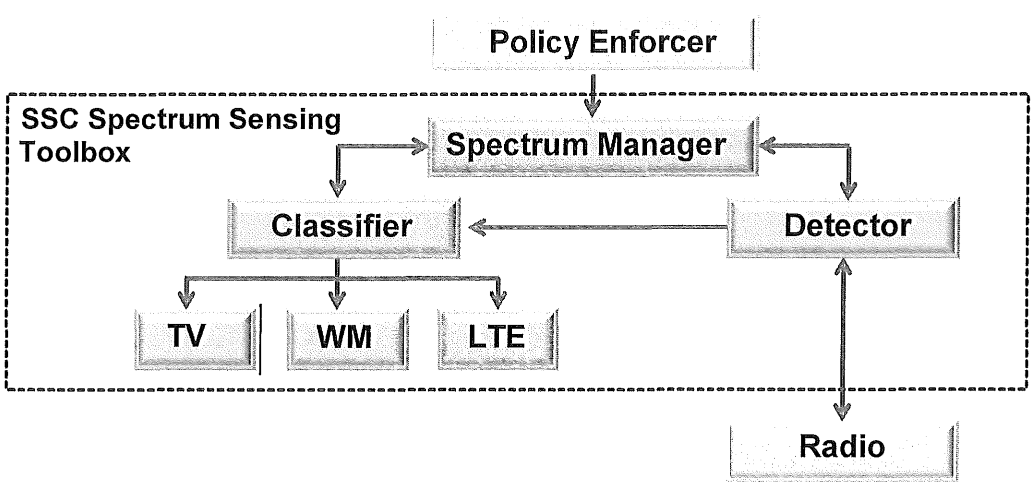
The SSC Spectrum Sensing Toolbox (SST) is an innovative software package that enables highly reliable radio frequency sensing by wireless devices operating in the TV White Spaces (TVWS) and other spectrum bands. The SST helps wireless devices access more spectrum and improve quality of service by accurately detecting TV transmitters, wireless microphones, long term evolution (LTE) devices, and other emitters that may cause interference.

KEY FEATURES

- Performs ATSC, NTSC, wireless microphone, LTE, and wideband signal detection, and classification functions on signals in TV and other bands
- Selects best frequency based on local sensing, database assignments, and user preference
- Low false alarm rate in high ambient man-made noise conditions
- Ranks channels based on user-defined quality of service
- Configurable scheduler targets designated frequencies, processes results, and maintains spectrum information
- Scan rate on the order of milliseconds
- No *a priori* information needed for the LTE classifier
- Over-the-air policy based control and configuration

ADVANTAGES

- Delivers quality of service beyond TVWS databases
- Access more available spectrum
- Rapid software integration via well-defined APIs
- Flexible framework to support additional detectors and classifiers
- Requires a fraction of a cell phone equivalent processor
- Over a decade of engineering and field testing for military and commercial customers
- Inexpensive reference platforms available now



For more information go to www.sharedspectrum.com

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