THE SPECTRUM SHARING INNOVATION TEST-BED PILOT PROGRAM FISCAL YEAR 2012 PROGRESS REPORT

NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION

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Executive Summary

The National Telecommunications and Information Administration (NTIA), in coordination with the Federal Communications Commission and the federal agencies, established a Spectrum Sharing Innovation Test-Bed (Test-Bed) pilot program in 2009 to evaluate new technologies to facilitate sharing between federal and non-federal spectrum users.

The Test-Bed pilot program provides an opportunity for the federal agencies to work cooperatively with industry, researchers, and academia to evaluate new technologies that can increase access to and improve management of the nation's spectrum. Specifically, the Test-Bed pilot program is examining the ability of Dynamic Spectrum Access (DSA) devices to share spectrum with federal and non-federal land mobile radio (LMR) systems. If sharing is successfully demonstrated, the results of the Test-Bed can be used as the basis to establish service rules for devices employing DSA sharing techniques. The Test-Bed pilot program will also develop and prove a testing methodology for systems employing DSA sharing techniques. Prior to the Test-Bed pilot program, no such methods existed to test the impact of DSA devices on incumbent systems. The Test-Bed pilot program is developing the specialized measurement techniques needed for DSA devices. These measurement techniques will be critical to the evaluation of new sharing technologies.

The Test-Bed pilot program is organized into three phases. Phase I consists of laboratory measurements to characterize the DSA devices' transmitter emissions, spectrum sensor and geo-location characteristics, spectrum access behavior, and impact on LMR receiver performance. Phase I also includes limited over-the-air testing in a live LMR signal environment. Phase II includes field tests that will determine the effectiveness of the DSA devices in detecting the presence of land mobile radios in a live signal environment. The DSA devices will not transmit during this test, or their transmissions will be suitably attenuated so as not to interfere with normal LMR operations. Phase III field testing will evaluate the ability of the DSA devices to operate in the presence of LMR systems in a live signal environment. These tests include a number of typical operational scenarios that DSA devices will experience when operating in the same frequency band and geographic area as incumbent LMR systems. NTIA will compare the results of the field tests to the laboratory tests to identify inconsistencies.[1]

The Test-Bed pilot program started with six participants whose DSA devices constituted a wide variety of technical approaches to spectrum sharing. The participants' DSA devices ranged from wide to narrow bandwidth, from fixed to variable bandwidth, and from contiguous to non-contiguous channel structure. Their DSA capabilities encompassed spectrum sensing, geo-location, or a combination of the two. The DSA devices employing spectrum sensing made use of a variety of sensing methods, and some DSA devices shared information about the radio frequency environment between all of the DSA devices in a network to further reduce potential interference to incumbent

1. All of the tests described in the Phase I/II/III test plans are not applicable to all DSA devices. Furthermore, additional tests may be performed to examine any unexpected behavior of the DSA device.

systems.[2] Since there are differences in the implementation of DSA sharing techniques, NTIA made adjustments to the measurement procedures for the tests described in the Phase I test plan.

The Phase I testing of the DSA devices from Participant A is complete. NTIA has prepared a report documenting the Phase I test results for the Participant A DSA devices and will publish it in the second half of Fiscal Year 2013. The report will show that procedures can be developed to measure spectrum sensing, geo-location, and spectrum access parameters for this implementation of DSA in response to simulated LMR signals. NTIA has also completed the Phase I testing for Participant B DSA devices and is currently preparing the report documenting the results that will be published in Fiscal Year 2014. Test-Bed Participants C and D submitted devices for Phase I testing that had to be returned for hardware and software modifications. NTIA is working with Participants C and D to determine when they will be ready to resubmit devices for Phase I testing. Test-Bed Participant F began Phase I testing; however, it withdrew from the pilot program in Fiscal Year 2012 due to technical problems with its DSA devices and control computers.

NTIA finalized the plan for the Phase II/III field testing and published it in July 2012. NTIA developed and tested the measurement systems that will be used for monitoring LMR transmissions and the corresponding behavior of the DSA devices in Phase II/III testing. NTIA has completed 70 percent of the Phase II testing for Participant A DSA devices and has started preparations for the Phase II testing of Participant B DSA devices.

Depending on the availability of devices from Participants C and D, NTIA will complete the Phase I laboratory testing of these devices in Fiscal Year 2013. NTIA will also complete the Phase II/III field testing of the DSA devices for Participants A and B, and will prepare test reports documenting the results. NTIA will continue to develop the analytical capabilities to assess potential interference from DSA devices during Fiscal Year 2013, which will further improve NTIA's ability to formulate service rules that lead to DSA devices sharing the spectrum with LMR systems, without a loss of critical existing and planned Federal government capabilities.

2. During Fiscal Year 2010, Participant E withdrew from the Test-Bed pilot program.

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I. BACKGROUND

The National Telecommunications and Information Administration (NTIA), in coordination with the Federal Communications Commission (FCC) and the federal agencies, established a Spectrum Sharing Innovation Test-Bed (Test-Bed) pilot program in 2009 to examine the feasibility of increased sharing between federal and non-federal users. This pilot program provides an opportunity for the federal agencies to work cooperatively with industry, researchers, and academia to examine objectively new technologies that can improve management of the nation's airwaves. The Test-Bed pilot program will also develop and prove a testing methodology for systems employing DSA sharing techniques. Prior to the Test-Bed pilot program, no such methods existed to test the impact of DSA devices on incumbent systems. The Test-Bed pilot program is developing the specialized measurement techniques needed for DSA devices. These measurement techniques will be critical to the evaluation of new sharing technologies.

The Test-Bed pilot program examines the ability of Dynamic Spectrum Access (DSA) devices employing spectrum sensing and/or geo-location techniques to share spectrum with land mobile radio (LMR) systems operating in the 410-420 MHz federal band and in the 470-512 MHz non-federal band.[1] To address potential interference to incumbent LMR spectrum users, the Test-Bed pilot program includes both laboratory and field measurements performed in three phases to characterize the interaction with DSA enabled devices:

> **Phase I – Equipment Characterization**. NTIA's Institute for Telecommunication Sciences (ITS) in Boulder, Colorado performs characterization measurements of the DSA capabilities of devices supplied by participants in response to simulated environmental signals.
>
> **Phase II – Evaluation of Capabilities**. After successful completion of Phase I, the DSA spectrum sensing and/or geo-location capabilities of the equipment will be examined in the geographic area of the Test-Bed.
>
> **Phase III – Field Operation Evaluation.** After successful completion of Phase II, the DSA equipment will be permitted to transmit in an actual radio frequency signal environment. An automatic signal logging capability will be used during operation of the Test-Bed to help resolve interference events if they occur. A point-of-contact will also be established to stop Test-Bed operations if interference is reported.

The laboratory and field testing for the Test-Bed pilot program is performed at the ITS facility.

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1. Dynamic Spectrum Access technology allows a radio device to (i) evaluate its radio frequency environment using spectrum sensing, geo-location, or a combination of spectrum sensing and geo-location techniques; (ii) determine which frequencies are available for use on a non-interference basis; and (iii) reconfigure itself to operate on the identified frequencies.

NTIA selected the following parties to participate in the Test-Bed pilot program: Adapt4 LLC, Adaptrum Inc., BAE Systems, Motorola Inc., Shared Spectrum Company, and Virginia Polytechnic Institute and State University.[2]

This progress report describes the activities related to the Test-Bed pilot program undertaken during Fiscal Year 2012.

II. OVERVIEW OF DYNAMIC SPECTRUM ACCESS TECHNOLOGIES

NTIA staff members met with each of the Test-Bed participants to discuss their DSA devices. Based on information provided by the participants, a high level overview of the different DSA implementations participating in the Test-Bed pilot program is provided in Table 1.

Table 1.

Parameter	Test-Bed Participants			
	A	**B**	**C**	**D**
DSA Capabilities	Spectrum Sensing and Geo-Location	Spectrum Sensing	Spectrum Sensing	Spectrum Sensing
Transmit Bandwidth	Fixed	Variable	Variable	Fixed
Channel Structure	Contiguous Channels	Non-Contiguous Channels	Non-Contiguous Channels	Single Channel
Monitoring Frequency Range	Variable	Fixed	Fixed	Fixed
Monitoring Time	Variable	Variable	Variable	Variable
Duplex Channel Monitoring Capability	Yes	No	No	No
Detection Method	Power Level Exceeding Threshold	Power Level Exceeding Threshold	Power Level Exceeding Threshold	Statistical Processing
Detection Threshold	Variable	Variable	Variable	Variable
Detection Time	Variable	Variable	Variable	Variable
Cooperative Sensing Capability	Yes	Yes	No	Yes
Feature Detection Capability	No	No	Yes	No
Control Channel	No	No	Yes	No
Channel Lock-Out Capability	Yes	Yes	Yes	Yes
Channel Clearance Time	Variable	Variable	Variable	Variable
Channel Re-Visit Time	Variable	Variable	Variable	Variable
Automatic Transmit Disable Capability	Yes	Yes	Yes	Yes

2. Motorola Inc. withdrew from the Test-Bed pilot program in February 2010 and Virginia Polytechnic Institute and State University withdrew from the Test-Bed pilot program in February 2012.

III. PHASE I TESTING

a. Phase I Test Plan

The Phase I test plan breaks the test cases down into five categories for each Device Under Test (DUT): emission characterization, sensor characterization, spectrum access behavior, LMR emission characterization, and LMR receiver performance characterization.[3] An overview of the proposed test cases to be performed under Phase I is shown in Figure 1.

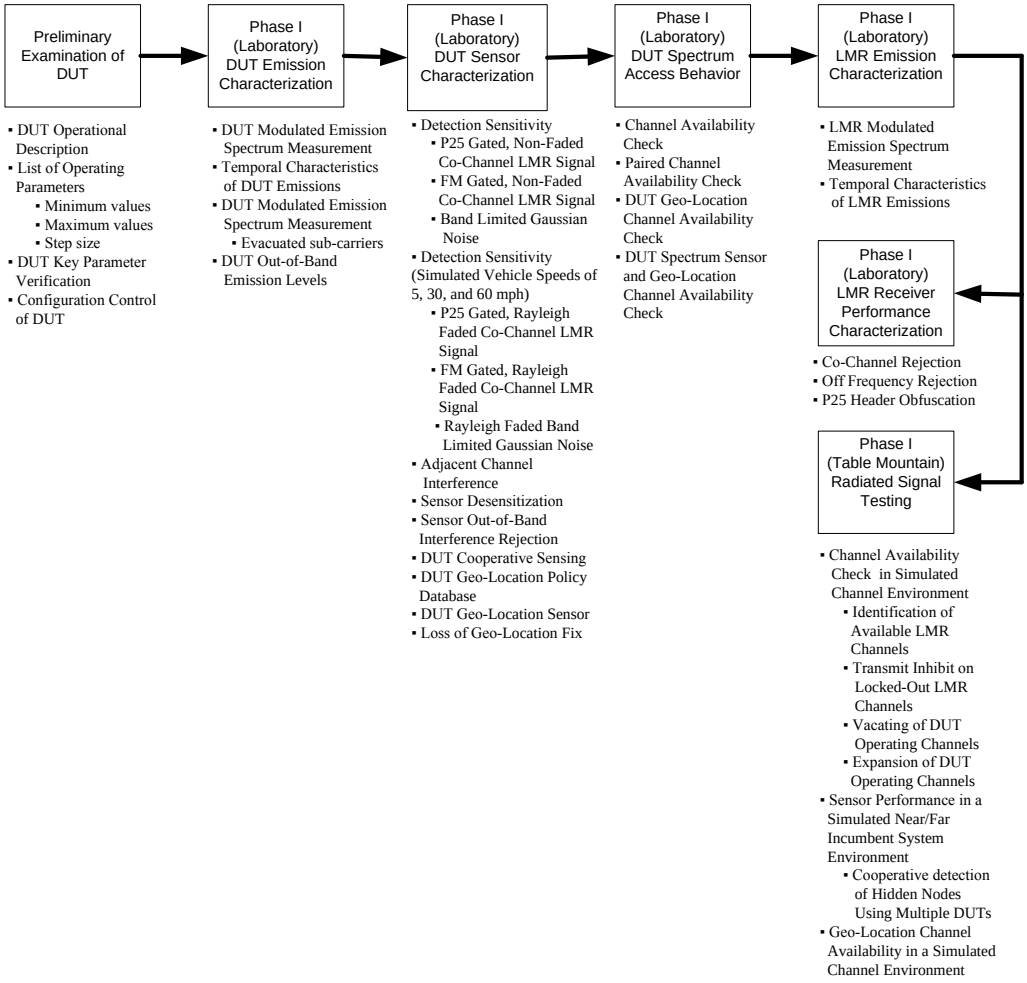

Figure 1.

3. The final Phase I test plan and additional information on the Test-Bed pilot program is *available at* http://www.ntia.doc.gov/federal-register-notice/2006/ntia-receives-public-comment-creation-spectrum-sharing-innovation-test-.

b. Status of Phase I Testing

During Fiscal Year 2012, NTIA completed the Phase I laboratory testing of the DSA devices from Test-Bed Participant A. NTIA prepared a test report for the Test-Bed Participant A devices based on the Phase I measurement data. The report will show that procedures can be developed to measure spectrum sensing, geo-location, and spectrum access parameters for this implementation of DSA in response to simulated LMR signals. NTIA will release the results of the Phase I testing once its draft report is reviewed with Participant A and the federal agencies.

NTIA has also completed the Phase I laboratory testing of DSA devices from Test-Bed Participant B. NTIA is currently preparing the report documenting the Phase I test results for the Participant B DSA devices and will publish it early in Fiscal Year 2014.

The ITS laboratory received DSA devices from Test-Bed Participant F in October 2010, but discontinued the Phase I laboratory testing of these DSA devices due to technical issues with Test-Bed Participant F's control computers and the spectrum sensing implementation of its DSA devices. NTIA returned the DSA devices and control computers to Participant F so that it might resolve these issues. After investigating the issues with its DSA devices and control computers, Test-Bed Participant F notified NTIA in February 2012 that it would withdraw its DSA devices from participating in the Test-Bed pilot program.

Test-Bed Participant C provided a demonstration of its DSA devices to NTIA staff in January 2011 and training on its DSA devices at the NTIA/ITS laboratory in July 2011. NTIA began the preliminary examination of the DSA devices from Participant C late in Fiscal Year 2011; however, Participant C has identified software changes to its devices that it would need to implement before Phase I laboratory testing of its devices could commence. Participant C provided software updates for the DSA devices in October 2011. NTIA determined that these updates were insufficient to reliably operate the DSA devices, and returned them to Participant C for additional software upgrades and testing in February 2012. Participant C delivered the upgraded DSA devices to NTIA in April 2012. NTIA testing uncovered additional functional issues with the DSA devices provided by Participant C. At the request of Participant C, NTIA returned its devices in May 2012. In August 2012 Participant C notified NTIA that it would modify its DSA devices. NTIA has not yet determined the schedule for resuming Phase I testing of Participant C's DSA devices.

Staff from Test-Bed Participant D informed NTIA in February 2011 that it would not provide DSA radios for the Test-Bed, but would instead provide a stand-alone DSA sensor with a selection of algorithms for processing incumbent LMR signals. Test-Bed Participant D continued to develop its DSA sensor and algorithms, and demonstrated it to NTIA staff in August 2012. NTIA has tentatively scheduled Phase I testing of the Participant D DSA sensor platform and algorithms to begin in Fiscal Year 2013.

IV. PHASE II/III TESTING

a. Phase II/III Test Plan

NTIA completed the coordination of the Phase II/III test plan with the Test-Bed participants and published the coordinated Phase II/III test plan in the *Federal Register* for public review and comment in March 2012.[4] NTIA addressed the public comments on the test plan and published a final version on the NTIA website in July 2012.[5]

The Phase II testing will determine the effectiveness of the DSA devices in detecting the presence of land mobile radios in a live operating environment. The DSA devices will not transmit during this test, or their transmissions will be suitably attenuated so as not to interfere with normal LMR operations. NTIA will observe the behavior of the DSA devices in the presence of LMR systems to assess their potential for sharing the spectrum.

The Phase III testing will evaluate the ability of the DSA devices to operate in the presence of LMR systems in a live environment. These tests include a number of typical operational scenarios that DSA devices will experience when operating in the same frequency band and geographic area as incumbent LMR systems. These tests will investigate the impact of DSA device operations on the received LMR signal quality for conventional LMR base-to-mobile and mobile-to-base transmissions. These tests will also investigate the impact of DSA device operations on the control channel signaling between the base station and mobile stations for a trunked LMR system. NTIA will consider scenarios where the LMR base station is a hidden node, and when a LMR mobile station is a hidden node.[6] The test plan includes a test scenario for geo-location-equipped DSA devices that can control their behavior as the devices move between two geographic regions, each associated with distinct transmission characteristics specified by policies within the DSA devices. The transmission characteristics will be monitored as the DSA devices move between the two regions.

b. Status of Phase II/III Testing

In addition to developing the Phase II/III test plan, in Fiscal Year 2012, NTIA developed and tested the measurement systems for monitoring LMR transmissions and the corresponding behavior of the DSA devices in Phase II and Phase III testing. Federal agencies contributed LMR radios for use in Phase II/III testing. NTIA completed spectrum surveys of the test area to determine incumbent LMR activity. To supplement the incumbent LMR activity in the test area, NTIA implemented two conventional LMR

4. *See* Spectrum Sharing Innovation Test-Bed Pilot Program, Notice, Request for Comments, 77 Fed. Reg. 18,793 (Mar. 28, 2012).
5. The final Phase II/III test plan is *available at* http://www.ntia.doc.gov/other-publication/2012/phase-iiiii-test-plan-spectrum-sharing-innovation-test-bed-pilot-program-fina.
6. A hidden node is radio whose transmissions are either too weak or too infrequent to be detected by a DSA device.

base stations and is preparing a trunked LMR base station. NTIA prepared LMR test messages and analyzed the coverage areas for the conventional LMR base stations.

NTIA began Phase II testing for the Participant A devices in July 2012 and has completed approximately 70 percent of the testing. NTIA will complete the remaining Phase II testing of the Participant A DSA devices after the trunked LMR system is operational. NTIA started preparations for Phase II testing of the Participant B DSA devices in September 2012.

V. DEVELOPMENT OF ANALYSIS CAPABILITIES

Because no proven methods exist to test the impact of DSA devices on incumbent LMR systems, the Test-Bed pilot program will develop the complicated measurement techniques needed for measuring the impact that DSA techniques will have on incumbent LMR users. However, these measurements will test a single device or pair of devices with specific DSA operational features. This testing does not address the aggregate interference due to a large number of DSA devices operating in LMR systems' coverage areas. The availability of a large number of DSA devices, the amount of test equipment, and the number of personnel required to perform these aggregate interference tests makes computer modeling and simulation the only effective approach. NTIA will begin development of analysis capabilities during Fiscal Year 2013 using the methodology described in NTIA Technical Memorandum TM-09-461 to assess the aggregate interference to LMR systems.[7]

VI. PLANNED FISCAL YEAR 2013 ACTIVITIES

NTIA expects to publish the Phase I test report Participant A DSA devices late in Fiscal Year 2013. NTIA is currently preparing the report documenting the Phase I test results for the Participant B DSA devices. The Phase I laboratory testing of DSA devices for Test-Bed Participant D began in December 2012; however, it is currently on hold while NTIA works with Participant D to determine how to resolve technical issues associated with its devices. NTIA will confirm with Participant C that its DSA devices can begin Phase I testing once Participant C delivers the devices to ITS.

NTIA expects to complete the Phase II testing of the DSA devices from Test-Bed Participant A and Participant B in Fiscal Year 2013. NTIA plans to perform the Phase III tests on the DSA devices from Participant A and Participant B during Fiscal Year 2013, and will prepare test reports documenting the results from Phase II/III testing. NTIA will continue to develop the analytical capabilities to assess the potential interference from DSA devices during Fiscal Year 2013.

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7. NTIA Technical Memorandum TM-09-461, *Description of a Model to Compute the Aggregate Interference from Radio Local Area Networks Employing Dynamic Frequency Selection to Radars Operating in the 5 GHz Frequency Range* (May 2009), *available at* http://www.ntia.doc.gov/legacy/osmhome/reports/2009/TM_09-461.pdf.

The status of the Test-Bed pilot program testing is provided in Table 2.

Table 2.

Test-Bed Participant	Status of Testing
A	Phase I testing complete. Phase II/III testing ongoing.
B	Phase I testing complete. Phase II/III testing ongoing.
C	Working with Test-Bed Participant to address hardware and software modifications necessary for Phase I testing.
D	Working with Test-Bed Participant to address hardware and software modifications necessary for Phase I testing.
E	Withdrew from Test-Bed Pilot Program in February 2010.
F	Withdrew from Test-Bed Pilot Program in February 2012.