Spectrum Sharing Innovation Test-Bed Pilot Program

Examining Dynamic Spectrum Access Sharing Techniques

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***Abstract*—This paper describes the National Telecommunications and Information Administration Spectrum Sharing Innovation Test-Bed pilot program that is examining Dynamic Spectrum Access sharing techniques in the land mobile radio frequency band.**

Keywords-Dynamic Spectrum Access, Land Mobile Radio, Geo-Location, Government Master File, Spectrum Sensing, Test-Bed

I. INTRODUCTION

The radio frequency spectrum is a critical resource shared by the Federal Government to perform their missions; efficient spectrum use must be one of the primary goals of spectrum management in order to maximize the completion of the missions. Furthermore, spectrum use that is less efficient than that which is achievable, may not only hinder the completion of other Federal missions, it may deny opportunities for spectrum use for non-Federal operations. These uses often support the efficient operation of businesses and provide the general public necessary communications, thereby supporting the growth of the American economy. Spectrum efficiency is aimed at maximizing the ability of Federal agencies to perform their missions and to maximize the overall benefit that the American people draw from the spectrum resource.

Recognizing that Federal and non-Federal spectrum requirements will continue to grow, new technologies must be developed to enable more use in the same amount of spectrum. These new technologies can encourage and facilitate spectrum efficient and effective operations and can meet the need to rapidly exploit the various aspects of spectrum operations, for example, dimensions of frequency, time and location. Ultimately, these new technologies will provide the means to meet the increasing demand and, where appropriate, assure access to bandwidth, wherever required, whenever required.

The National Telecommunications and Information Administration (NTIA), in coordination with the Federal Communications Commission (FCC) and the Federal agencies, have established a Spectrum Sharing Innovation Test-Bed (Test-Bed) pilot program to examine the feasibility of increased sharing between Federal and non-Federal users. The pilot program is 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. This paper describes the Test-Bed pilot program.

II. DESCRITPION OF TEST-BED PILOT PROGRAM

A. Development of Test-Bed

On June 8, 2006, NTIA published a Notice of Inquiry (NOI) in the Federal Register seeking public comment on issues related to the Test-Bed pilot program [1]. The FCC also solicited public comment on issues related to the Test-Bed pilot program through a separate Public Notice (PN) [2].

The public comments filed in response to the NOI and PN were reviewed by the Commerce Spectrum Management Advisory Committee (CSMAC), which was established to advise the Assistant Secretary of Commerce for Communications and Information, Department of Commerce, on needed reforms to spectrum policies and management to enable the introduction of new spectrum dependent technologies and services.

NTIA also sought comments from the Interdepartment Radio Advisory Committee (IRAC), a committee of the Federal departments, agencies, and administrations that advises NTIA in developing and executing policies, programs, procedures, and technical criteria pertaining to the allocation, management, and use of the spectrum.

The public responses to the NTIA NOI and FCC PN as well as the comments provided by the CSMAC and the IRAC were used to develop the Test-Bed pilot program.

On February 5, 2008 NTIA published a Notice in the Federal Register describing the Test-Bed pilot program [3]. Concurrently, the FCC released a Public Notice designating 10 MHz of non-Federal spectrum to be used in the Test-Bed pilot program and providing guidance for participants [4]. As described in these notices, the Test-Bed pilot program will evaluate 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. To address potential interference to incumbent spectrum users the Test-Bed pilot program will include both laboratory and field measurements performed in three phases:

Phase I – Equipment Characterization. Equipment employing DSA techniques will be sent to the NTIA Institute for Telecommunication Sciences (ITS) in Boulder, Colorado to undergo characterization measurements of the DSA capabilities in response to simulated environmental signals.

Phase II – Evaluation of Capabilities. After completion of Phase I, the DSA spectrum sensing and/or geo-location capabilities of the equipment will be evaluated in the geographic area of the Test-Bed.

Phase III – Field Operation Evaluation. After 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.

B. Selection of Test-Bed Participants

On February 5, 2008, NTIA published a Federal Register Notice seeking expressions of interest from parties to participate in the Test-Bed. The following criteria were used to evaluate the solicitations to participate in the Test-Bed pilot program:

- How well does the proposed technology achieve the goal of the Test-Bed?
- How readily available is the equipment proposed for the Test-Bed?
- How well does the proposed technology explore creative and original concepts in spectrum sharing?
- For the proposed technology, can the results of the Test-Bed be disseminated broadly to enhance scientific and technologic understanding?
- How well does the proposed technology address the potential impact on the incumbent spectrum user(s)?
- Can the proposed technology be adapted for a variety of services and applications, including broadband, military/homeland security, and public safety?
- Are there any technical factors that limit the proposed technology to a specific frequency range?
- Will the necessary technical support be provided to assure performance of the equipment during the Test-Bed?

Eleven parties submitted solicitations of interest to participate in the Test-Bed pilot program. In June 2008 the following parties were notified they had met the selection criteria:

Adapt4 LLC;
Adaptrum Inc.;
BAE Systems;
Motorola Inc.;
Shared Spectrum Company; and
Virginia Polytechnic Institute and State University.

C. Development of Phase I Test Plan

During June 2008, NTIA, working in conjunction with the Federal agencies and the FCC developed technical questions and proposed test cases to be performed under Phase I. The technical questions and proposed test cases were used to develop the test plan for Phase I.

NTIA completed the coordination of the Phase I test plan with the Test-Bed participants in November 2008 and published the coordinated Phase I test plan in the Federal Register for public review and comment in December 2008 [5]. NTIA addressed the public comments on the test plan and published a final version in February 2009.

The Phase I test cases for each DSA device tested are broken down into five categories: DSA device emission characterization, DSA device sensor characterization, DSA device spectrum access behavior, LMR emission characterization, and LMR receiver performance characterization. An overview of the proposed test cases to be performed under Phase I are provided in the test plan.

III. DESCRIPTION OF FEDERAL LAND MOBILE RADIO BAND

The Federal agencies use the 410-420 MHz band for conventional and trunked LMR voice and low data rate communication systems in support of law enforcement, security, transportation, natural resources, emergency and disaster, and medical and administrative duties. The LMR communication systems operating in this frequency band are used for the delivery of mail, promoting public safety and efficiency in traveling via air, water, and land; interdicting entry of illegal persons and substances into the United States; establishing communications between disaster areas and relief forces; ensuring the swift search and rescue of human life; protecting the national forests, parks and farmlands; bringing to justice perpetrators of Federal crimes; and ensuring the security of energy generation and distribution networks. The LMR communication systems operating in this band are also used by Federal emergency response and public safety organizations which conduct large-scale exercises to prepare for and respond to a wide variety of emergencies and disasters, such as hurricanes, earthquakes, and chemical and nuclear power plant accidents.

A. *Overview of Federal Land Mobile Radio Systems*

The Federal agencies primarily use commercially available LMR equipment in the 410-420 MHz frequency band. The LMR systems employ analog and digital modulation techniques and operate on 25 kHz and 12.5 kHz channels. The Federal agencies are in the process of migrating from 25 kHz channelization to 12.5 kHz channelization [6].

Federal LMR systems operating in the 410-420 MHz band use conventional and trunking technology. Conventional LMR systems dedicate a single channel (radio frequency channel) to a specific group of users who share it. Since radios on conventional LMR systems transmit and receive on a single channel, the user must wait if the channel is occupied by another user. Trunking technology permits a large number of users to share a relatively small number of channels. Unlike conventional LMR technology, trunking allows for the automatic sharing of multiple channels. The trunked system dynamically allocates the mobile user access to the available channels.

Federal LMR systems can employ a single frequency (simplex) or two frequencies (duplex) for communications. There are systems that retransmit information (repeaters), and systems that transmit broadcast messages to many users (simulcast). A description of the different LMR technologies employed by the Federal agencies in the 410-420 MHz band is provided in NTIA Report 06-440 [7].

B. *Federal Land Mobile Radio Frequency Assignment Data*

Geographically, the largest concentrations of LMR frequency assignments are in and around major metropolitan areas where there is a higher presence of Federal users. Based on the frequency assignment data contained in the Government Master File, Figure 1 shows the channels unavailable for assignment in the vicinity of Washington, DC.[1]

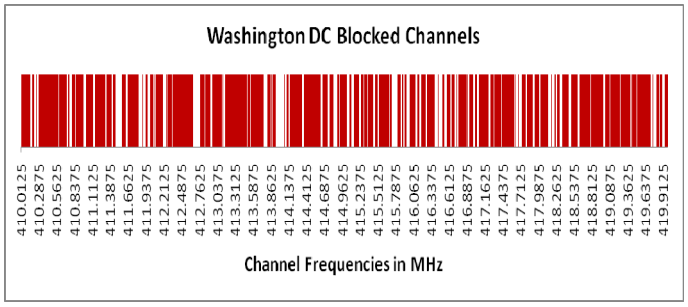

Figure 1. Channels Unavailable for Assignment in Washington, D.C.

These channels are unavailable for assignment due to interference from or to systems operating on existing frequency assignments. Of the 799 possible 12.5 kHz channels in the 410 to 420 MHz frequency range, only 209 are available for assignment in Washington, DC [8]. As it can be seen, in major use areas like Washington, the channels available for assignment are limited.

C. *Federal Land Mobile Radio Channel Usage Measurements*

Figure 2 provides an example of channel usage measurements made in the 406.1-420 MHz band by NTIA in the vicinity of Washington D.C. These measurements should be considered typical of a heavily used LMR signal environment. The measurement results are shown for 25 kHz and 12.5 kHz channelization. The daily usage is expressed in terms of percentage of time and total Erlangs. The curve labeled *All Channels* is typical of the actual use in the band.

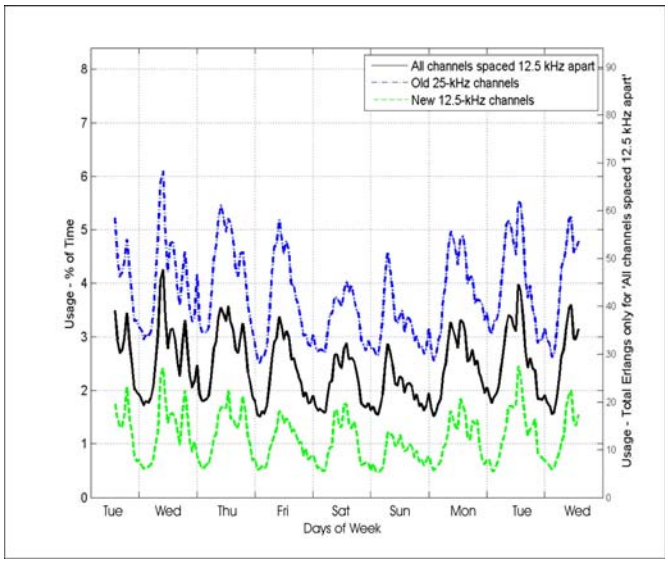

Figure 2. Daily Channel Usage for the 406.1–420 MHz Band in Washington D.C.

These channel occupancy measurements show that during the busy hour of the day, an individual frequency is used approximately 3 to 5 percent of the time or 2 to 3 minutes per hour on average. This means that the frequency is available for 57 or 58 minutes, thus providing a grade of service, expressed in terms of the probability of a call being blocked, of between 3 to 5 percent. The Public Safety Wireless Advisory Committee has recommended that the grade of service should not exceed 1 percent for public safety LMR systems [9]. This large amount of unused time is necessary so that a user with an urgent need to communicate does not have to wait an unreasonable amount of time for a channel to become available. For instance, a law enforcement officer must be able to communicate in an emergency without waiting for an available channel.

Factors that impact the measurement of channel usage are those that compose the emission environment – such as the range of in-band signal levels, out-of-band signal

1. The Government Master File contains records of the frequencies assigned to all Federal agencies in the United States and its possessions.

characteristics, and the nature of radio frequency noise. Because LMR systems by their very nature are mobile, the signal power can be time varying and span a range as great as 100 dB in power – the weakest signals typically coming from distant transmissions and the stronger signals typically coming from nearby base stations and local mobile and portables. Not only can a single frequency assignment vary greatly in power from time to time, but power can vary greatly between adjacent frequencies. Because of this broad range of signal powers, depending upon the degree of sensitivity the measuring system must have a wide instantaneous dynamic range (*i.e.*, be able to resolve the individual signal powers without varying the sensitivity of the system across the detection bandwidth). The methodology used to perform the channel usage measurements is described in NTIA Report TR-07-448.

IV. Examining DSA Sharing techniques

The Test-Bed pilot program is examining whether devices employing DSA spectrum sensing and geo-location sharing techniques can operate compatibly with LMR communication systems. If successful the results of the Test-Bed pilot program can be used as a basis for creating rules that would allow Federal and non-Federal systems employing DSA techniques to share the same spectrum on a time basis taking advantage of the intermittent usage of LMR systems.

In order to achieve meaningful results NTIA believes that the Test-Bed pilot program had to focus on a single technology that had the greatest opportunity for expansion of sharing between Federal and non-Federal users. NTIA believes that examining compatibility issues associated with devices employing DSA sharing techniques could create sharing opportunities with Federal and non-Federal users. The Test-Bed pilot program is not limiting itself to any particular form of technology. The technology being examined in the Test-Bed pilot program was chosen based on a process that was open to the public. The participants selected for the Test-Bed pilot program each implement their DSA sharing techniques differently, which should allow NTIA to gain a broad range of practical experience with this emerging technology. Depending on the success of the Test-Bed pilot program other test-beds could be established to examine other technologies that can improve spectrum efficiency.

The Phase I testing at the ITS laboratory began in March 2009 and is currently ongoing. The Phase I laboratory testing is scheduled to be completed in 2011. After coordinating the test results with the Test-Bed participants, NTIA will prepare and coordinate with the federal agencies on the IRAC, an interim report documenting the results. The interim report will be published in the Federal Register for public review and comment. The testing at the ITS Table Mountain facility will begin after the laboratory testing has been completed for each DSA device. NTIA will begin developing a test plan for Phase II and III that will be coordinated with the federal agencies, Test-Bed participants, and the public. NTIA will also develop analytical capabilities to assess the potential interference to LMR systems from DSA devices.

The annual progress reports as well as additional information related to the Test-Bed pilot program are available on the NTIA website at http://www.ntia.doc.gov/ntiahome/frnotices/2006/spectrumshare/comments.htm.

References

[1] National Telecommunications and Information Administration, Docket, No. 060602142-6142-01, Notice of Inquiry, 71 Fed. Reg. 33282 (June 8, 2006).

[2] Federal Communications Commission, ET Doc. No. 06-89, FCC 06-77, *Creation of a Spectrum Sharing Innovation Test-Bed*, 71 Fed. Reg. 35675 (June 21, 2006).

[3] National Telecommunications and Information Administration, Docket No. 080129095-8096-01, 73 FR 6710 (February 5, 2008).

[4] Federal Communications Commission Designates Spectrum and Provides Guidance For Participation In a Spectrum Sharing Innovation Test-Bed, ET Docket No. 06-89, Public Notice, FCC 08-295 (rel. February 5, 2008).

[5] Spectrum Sharing Innovation Test-Bed Pilot Program, 73 Fed. Reg. 76,002 (Dec. 15, 2008).

[6] National Telecommunications and Information Administration, Manual of Regulations and Procedures for Federal Radio Frequency Management, Washington, D.C., January 2008 edition, revised May 2008.

[7] National Telecommunications and Information Administration, NTIA Report 06-440, *Federal Land Mobile Operations in the 162-174 MHz Band in the Washington, D.C. Area Phase 1: Study of Agency Operations* (Aug. 2006) Section 3.

[8] National Telecommunications and Information Administration, NTIA Report TR-07-448, *Measurements to Characterize Land Mobile Channel Occupancy for Federal Bands 162-174 MHz and 406-420 MHz in the Washington, D.C., Area* (July 2007).

[9] Public Safety Wireless Committee Report, Spectrum Requirements Subcommittee (SRSC) Final Report, Appendix D, Public Safety Wireless Communications User Traffic Profiles and Grade-of-Service Recommendations (Sept. 1996) at 76 (676).