Executive Summary

Introduction. The Federal Communications Commission's Laboratory Division has completed a second phase of its measurement studies of the spectrum sensing and transmitting capabilities of prototype "TV white space" devices. These devices have been developed to demonstrate capabilities that might be used in unlicensed low power radio transmitting devices that would operate on frequencies in the broadcast television bands that are unused in each local area. At this juncture, we believe that the burden of "proof of concept" has been met. We are satisfied that spectrum sensing in combination with geo-location and database access techniques can be used to authorize equipment today under appropriate technical standards and that issues regarding future development and approval of any additional devices, including devices relying on sensing alone, can be addressed.

The Commission is conducting a rulemaking proceeding to consider authorization of new, low power transmitting devices in the television broadcast spectrum at locations where channels are not being used for TV or other authorized services (ET Docket No. 04-186). This locally unused spectrum is often referred to as "TV white space." As established thus far by the Commission, white space devices (WSDs) that operate from a fixed location will be allowed into the TV spectrum simultaneous with the completion of the transition from analog to digital television broadcasting on February 17, 2009. This action will open for use a significant amount of spectrum with very desirable propagation characteristics that has heretofore lain fallow. It will also allow the development of new and innovative types of unlicensed devices that provide broadband data and other services for businesses and consumers without disrupting the incumbent television and other authorized services that operate in the TV bands. The Commission is considering whether to also allow "personal/portable" WSDs to operate in the TV spectrum.

One of the principal considerations in the white space proceeding is how to reliably determine the availability of unused frequencies in local areas. A number of parties participating in the proceeding have suggested an approach for identifying unused frequencies whereby a WSD would employ a "listen before talk" or "detect and avoid" strategy. This approach would use "spectrum sensing" techniques that listen for the signals of TV stations, wireless microphones, and other incumbent services. The Commission has requested comment on whether to require that the sensing capability of devices using this approach be able to detect signals as low as -116 dBm, or some alternative value. A second technical consideration in this matter is the potential for WSDs to interfere with TV reception and wireless microphone operations. To address these issues, the Commission announced that it would perform testing of the spectrum sensing and transmitting capabilities of the prototype WSDs.

The purpose of the testing program is to provide additional information for the record that will be considered along with other information in developing the Commission's final decision on white space devices. The tests are not intended for equipment authorization or to determine whether the devices would comply with any

possible standards that the Commission might adopt. Rather, they will provide information in support of the Commission's action in this matter. Initial tests (Phase I) under this program were completed in July of 2007.[1] This report describes the tests performed during the second (Phase II) series of tests and provides a compilation of the results of measurements of the spectrum sensing and transmitting functions of various prototype WSDs.

In October 2007, the Commission's Office of Engineering and Technology (OET) issued a Public Notice announcing that it would perform additional laboratory and field tests of white space devices and invited interested parties to submit such devices for testing at the FCC Laboratory in Columbia, Maryland.[2] Subsequently, OET issued a second Public Notice announcing that the second phase testing would begin on January 24, 2008.[3]

WSD Prototype Devices Submitted for Evaluation. Five devices were submitted for examination in the Phase II tests. These devices were provided by Adaptrum, the Institute for Infocomm Research (I2R), Microsoft Corporation, Motorola Inc., and Philips Electronics North America (Philips). These devices are not intended as actual consumer products but rather are development tools for evaluating the viability of spectrum sensing and potential interference. They do not communicate with other devices. Not all tests were performed on all devices. For example, the Microsoft device was available only for limited tests in the laboratory and the I2R device was submitted after the initial tests were completed.

Spectrum Sensing for TV Broadcast Signals. This portion of the study examined the ability of the WSDs to detect whether channels are occupied by ATSC (digital) TV signals. All of the prototype devices had capabilities for detecting TV broadcast signals on UHF channels 21-51, the operating range of the prototype devices. The tests were initially performed in the laboratory under various controlled conditions. Spectrum sensing sensitivity to clean digital TV signals in isolation and also in the presence of other TV signals on adjacent channels was measured. In addition, sensitivity tests were performed using recorded TV signals to simulate "real world" conditions. Spurious emissions generated by the prototype WSDs were also measured. The laboratory tests were followed by field tests at nine sites in Maryland and the District of Columbia to evaluate the DTV sensing performance.

Spectrum Sensing for Wireless Microphones. The wireless microphone portion of the testing looked at the ability of the WSDs to detect wireless microphones authorized

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[1] S. Jones and T. Philips , "Initial Evaluation of the Performance of Prototype TV-Band White Space Devices,", OET Report FCC/OET 07-TR-1006, July 31, 2007.

[2] FCC Public Notice DA 07-4179, "Office of Engineering and Technology Announces Additional Testing of TV White Space Devices, ET Docket No. 04-186," October 5, 2007.

[3] FCC Public Notice DA 08-118, "Office of Engineering and Technology Announces Plans for Conducting Measurements of Additional Prototype TV White Space Devices, ET Docket No. 04-186," January 17, 2008.

under Part 74 of FCC rules. Microsoft, Philips and I2R indicated that their devices were capable of sensing wireless microphones. Tests of this capability were initially performed in a controlled environment in the laboratory. Those tests were followed by field tests at two sites, one in Maryland and one in New York City, to evaluate the capability of the devices to detect wireless microphones under field conditions.

Transmitter Characterization and Interference Testing. The Adaptrum device included transmitting capability.[4] Laboratory tests were performed to characterize the transmitter's signal, which is an important element for assessing the interference potential of WSD devices. Field tests were also performed to evaluate potential interference from the Adaptrum transmitter; however, these tests were limited.

Observations:

- All of the devices were able to reliably detect the presence a clean DTV signal on a single channel at low levels in the range of -116 dBm to -126 dBm; the detection ability of each device varied little relative to the channel on which the clean signal was applied. These measurements did not take into account the antenna that would be used with personal/portable devices.

- The detection threshold sensitivity of the devices varied from -106 dBm to -128 dBm when recorded off-air DTV signals, which included multi-path fading and other "real-world" distortion, were used. The impact on detection ability varied considerably among the WSDs and with the characteristics of the different recorded signals.

- Several tests were performed with DTV signals present in adjacent channels. These tests showed that in the presence of moderate-to-strong signals in a first adjacent channel, the detection threshold sensitivity of all of the devices was severely impacted. For some of the devices, the degradation in the detection sensitivity was as much as 60-70 dB. In some cases, the degradation was such that the detection threshold could not be measured. This could impact significantly the ability of the devices to reliably detect TV signals within stations' service areas.

- The Microsoft, Philips and I2R devices were tested for their ability to sense for the presence of wireless microphones (both FM/analog and digital) operating within UHF TV channels. With no other signals present, the devices were able to detect wireless microphones at levels ranging from -103 dBm to -129 dBm depending on the type of microphone, and the device. In the presence of DTV signals in adjacent channels, the detection threshold was degraded such that it affected the ability of the devices to reliably detect the microphone signals.

[4] The Microsoft device also had a transmitting capability but that device was withdrawn from the test program before the transmitter tests were conducted.

- Scan time for the devices varied from 0.1 second per channel (Motorola) to 185 seconds per channel (Adaptrum). The Adaptrum device was modified during the tests and its scan time changed from 37 seconds per channel to 185 seconds per channel.

- Channel Occupancy (TV sensing) field tests were performed at nine locations for the Adaptrum, I2R, Motorola, and Philips devices.
    - In most cases, the devices correctly reported channels as occupied when the device was operated within the service contour of the stations broadcasting on those channels and viewable signals were observed on the channels.
    - In some instances, the Adaptrum, I2R, and Motorola (in sensing only mode) devices incorrectly reported channels as unoccupied (available) when the WSD was operated within a station's service contour and the signal was viewable.
    - All of the devices reported some channels as occupied when the WSD was operated outside of the service contours of stations broadcasting on those channels whether the signal was viewable or not.
    - The Philips device generally reported most channels occupied, whether the WSD was operating inside or outside any service contours whether the signal was viewable or not.
    - During the field tests, the Motorola device's geolocation/database feature was used in combination with its sensing capabilities. In those tests, the Motorola device correctly reported all occupied channels used by stations within whose contours the WSD was operated.

- Wireless microphone sensing tests were performed using the I2R and Philips devices at two field locations. The tests were conducted first with microphones off, and then turned on, in pre-determined channels to determine if the devices could sense the presence of wireless microphones. At both sites and all the test locations, the Philips device reported all the channels on which the microphones were designated to transmit as occupied whether the microphone was transmitting or not. The I2R device indicated several channels as available even when the microphones were on.

- The Adaptrum device's transmitter was characterized in the laboratory and was used to investigate interference potential to DTV signal reception. Anecdotal tests demonstrated that co-channel interference would occur at line-of-sight distances of up to 360 meters at an EIRP of approximately +7 dBm when the DTV was receiving a weak signal using a receive antenna at a height of 9.3 meters. No interference was observed when the Adaptrum device transmitted on an immediate adjacent channel even with the transmitter in close proximity to the receiver with a roof-top antenna. No other configurations were tested for interference.

- Anecdotal tests were performed at two field sites to assess the interference potential from WSD transmitters to cable television reception via direct pick-up of signals by cable system components. These tests showed that under certain

circumstances, when the transmit antenna was placed in close proximity to a cable connected TV, direct pick-up interference was observed. The direct pick-up interference potential appears to be highly dependent on the interconnection among various system components (*e.g.,* cable amplifiers, splitters and set-top boxes) being used.