Initial Evaluation of the Performance of Prototype TV- Band White Space Devices

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Table of Contents

Figures

Tables

Executive Summary

Introduction. The Federal Communications Commission's (FCC) Laboratory has conducted a measurement study of the spectrum sensing and transmitting functions of prototype unlicensed low power radio transmitting devices that would operate on frequencies in the broadcast television bands that are unused in each local area. These locally unused frequencies are known as "white spaces." This research is part of the FCC's ongoing proceeding to consider rules for permitting such devices to operate on TV white spaces. As established previously by the Commission, fixed "white space devices" (WSDs) will be allowed into the TV spectrum simultaneous with the completion of the transition from analog to digital television broadcasts on February 17, 2009. The Commission is also considering whether to allow unlicensed "personal/portable" WSDs to operate in the TV spectrum.

One approach under consideration for determining the unused frequencies in local areas is for a WSD to employ a "detect and avoid" or "listen before talk" strategy. This approach would use "spectrum sensing" techniques that listen for the signals of TV stations, wireless microphones and perhaps 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 at -116 dBm. A second issue is the potential for WSDs to interfere with TV reception and wireless microphone operations. To address these issues, the Commission announced that it would conduct testing of WSD spectrum sensing and transmitting capabilities.

This report presents an initial evaluation of WSDs based on tests performed on prototype devices submitted by industry for evaluation by the FCC Laboratory. We recognize, however, that the devices we have tested represent an initial effort, and do not necessarily represent the full capabilities that might be developed with sufficient time and resources. Accordingly, we are open to the possibility that future prototype devices may exhibit improved performance.

WSD Prototype Devices Submitted for Evaluation. The Office of Engineering and Technology in December 2006 issued a Public Notice inviting interested parties to submit WSD prototype devices for testing at the FCC Laboratory in Columbia, Maryland.[1] Two parties provided prototype personal/portable WSDs to the Laboratory for testing. The devices submitted by these parties are designated "Prototype A" and "Prototype B" herein; both have a sensing capability but only the Prototype A device has a transmitter. The test project was provided three units of Prototype A and one unit of Prototype B. 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.

[1] FCC Public Notice DA 06-2571, Office of Engineering and Technology Invites Submittal of Prototype TV Band Devices for Testing, ET Docket No. 04-186, December 21, 2006.

Spectrum Sensing of TV broadcasting signals. This portion of the study examined the ability of the prototype devices to detect whether channels are occupied by TV signals. Measurements were limited to TV signals on UHF channels 21-51, the operating range of the prototype devices. Both bench and field tests were performed for the Prototype A devices. Only bench tests were performed for the Prototype B device because the supplier formally declared that the device was not suitable for field testing and requested that it not be included in those tests.

The bench testing of the sensing function of the Prototype A device found that this device is generally not able to detect DTV signals on any of the tested channels at the -116 dBm/6 MHz level detection threshold for DTV signals on which the Commission requested comment or at the -114 dBm level detection threshold suggested by the device's manufacturer. Prototype A is able to detect DTV signals reliably, that is, in a very high percentage of instances, at levels of -95 dBm or higher. The testing found that the Prototype A device takes approximately 27 seconds to scan each channel, or approximately 14 minutes to scan the full range of all 31 channels that it covers.

Field testing was performed with one unit of the Prototype A device (the last unit submitted) in order to assess the scanning/sensing capability under "real-world" conditions. The selected unit of the Prototype A device was tested at a number of sites representative of typical residences where over-the-air television broadcasts, including DTV, are currently being received. The sample sites were limited to residences already set up for and receiving over-the-air (OTA) DTV broadcasts in order to provide a means for verifying the OTA stations (and associated RF channels) that could actually be successfully received at the site using a typical DTV receiving system. Several independent test locations were identified within each test site (*e.g.*, the tests were performed within several rooms of each house). In these tests the prototype's scanning feature was activated and the scanning results were recorded for each location.

The sensing field tests investigated the Prototype A device's performance with respect to two aspects: 1) correct identification of channels as occupied and 2) correct identification of channel as available, *i.e.*, unoccupied. The field tests also investigated performance in certain subcategories for identification of occupied channels: 1) detection of analog TV signals, 2) detection of DTV signals where the signal could not be received on the site's TV receiver (in these cases it was assumed that the signal strength at the site was too low for the TV receiver to receive the signal), and 3) detection of DTV signals where the signal could be received on site's TV receiver.

In general, the Prototype A scanner did not provide consistently accurate determinations on an overall basis or with respect to any of the subcategories in the field tests. First, these tests found that the Prototype A scanner often reports a channel to be available, or vacant, when the broadcast signal is expected to be present. The summary results for the four subcategories in this area of performance are (note that in all cases the test site was within the predicted service contour of TV signals considered):

1. In the cases where the NTSC signal is being broadcast, the scanner reports the channel to be free or available between 11.1% and 27.8% of the time, with the average of 19.4% of the time.
2. Where a DTV signal was being broadcast but was not received on the site's TV set, the scanner reported its channel to be free or available 81.3% to 91.7% of the time, with an average of 85.4% of the time.
3. Where a DTV signal was strong enough to be received on the TV, the scanner reported its channel to be free or available 40% to 75% of the time with an average of 58.2% of the time. These percentages are particularly high for Sites 3 and 4.
4. When no signal was expected to be present, the scanner reported the channel to be free or available from 78.1% to 91.7 % of the time, with an average of 85.2 % of the time.

With respect the Prototype B, the bench tests results indicate that, under Laboratory conditions, this device is generally able to reliably detect DTV signals at -115 dBm in the single channel tests and at -114 dBm in the two-channel tests. Prototype B's sensing performance declines very rapidly as the signal levels are reduced. The testing found that the Prototype B device takes approximately 8 seconds to scan each channel or slightly more than 4 minutes to scan the full channel range.

<u>Spectrum Sensing of Wireless Microphones</u>. The wireless microphone portion of the testing looked at the ability of the Prototype A and Prototype B sensors to scan for and detect Part 74 wireless microphones. It also looked at the susceptibility of wireless microphones to the signals emitted by the Prototype A transmitter and simulated broadband signals modulated using several alternative methods. Wireless microphone testing was conducted in the laboratory only; no field tests were performed for these devices. Bench tests of the Prototype A and Prototype B devices ability to sense wireless microphones were performed using signals generated by wireless microphones. These signals were coupled directly to the input terminals of the prototype devices. Wireless Microphone interference testing was performed using both simulated signals and signals from the Prototype A transmitter. Three different Part 74 wireless microphone systems were used in these tests.

The results of these tests indicated that the Prototype A was generally unable to sense wireless microphones. This device was tested with wireless microphone signals at various power levels and locations within a TV channel, and with and without the presence of a DTV signal on a different channel at different power levels. In many cases, the device incorrectly sensed the wireless microphone signal as a DTV signal. In view of the performance of the Prototype A device in the initial tests under moderate conditions, there appeared to be no additional insight to be gained at this time from testing this device under other conditions and so further measurements were not performed.

The performance of Prototype B device was mixed when tested in a variety of situations and conditions. This device was found to be able to sense wireless microphone signals located in the center of a TV channel in all scans at a signal levels as low as

-120 dBm. However, on some scans it also incorrectly indicated the presence of a microphone on channel 24.   In addition, when the wireless microphone signal was at the -36.6 dBm level, Prototype B also incorrectly sensed wireless microphone signals on six additional channels. The testing further found that the device's ability to sense wireless microphones decreases somewhat as the location of the microphone signal is moved closer to the edge of the TV channel on which it operates. The test results show that Prototype A tends to make more false detections of microphone signals on adjacent channels as the power level of the operating microphone is increased. When tested in the presence of both DTV and wireless microphone signals the device also tends to make more false detections of DTV signals, analog TV signals, and wireless microphone signals as the level of the DTV signal increases.

Tests were conducted to characterize the susceptibility of Part 74 wireless microphone systems to possible interference from unlicensed WSDs. Before the Prototype A became available, this test project examined the potential for interference to wireless microphones using the three Part 74 wireless microphone systems and WSD signals that were simulated using an audio modulated FM signal, a wideband noise signal and a wideband OFDM signal. When the Prototype A WSD became available, it was tested for interference to a wireless microphone system. In these tests, interference was defined to occur at the point where the signal-to-noise plus distortion (SINAD) ratio reading at the audio output of the microphone receiver was 30 dB. The results show that in most cases the wireless microphones are generally at least 15 dB less susceptible to interference from the simulated WSD signals on first adjacent channels than on the same channel.

Transmitter Characterization and Interference Testing. Tests were performed to characterize the transmitter signal, which is an important element for assessing the interference potential of these devices.   Field tests were performed to evaluate potential interference, however, for reasons explained below these tests were quite limited.

The Commission has proposed to establish an average limit on power at the fundamental frequency of a device in terms of an equivalent isotropic radiated power (EIRP) as integrated over the 6-MHz TV channel bandwidth. Measurements of the fundamental power were performed on a conducted basis (via a coaxial connection between the transmit antenna output port and the input to the measurement instrument). These measurements showed that the adjusted output power of the prototype as integrated over the 6-MHz TV channel is approximately 22 dBm, which is slightly higher than the FCC proposed power level of 100 mW (20 dBm) EIRP, assuming an omni-directional antenna. However, when operated with an external filter required to achieve compliance with FCC's current out-of-band emissions limits, the power level was seen to be approximately 14 dB lower, or 8 dBm.

The prototype devices that were submitted do not lend themselves to extensive field tests for evaluating interference potential. Moreover, only the Prototype A device included a transmitter and it operated independently of the sensing function. While the transmitter's power level can be adjusted manually, its maximum level was below the

FCC proposed power level of 100 mW EIRP when used with the required filter. Certain techniques that are claimed to reduce interference potential, such as adaptive power control and reducing the transmitter power based on measurements of DTV signal levels in adjacent channels, were not implemented in the prototype device. The time to perform scans of the TV channels, which took up to 14 minutes, also impacted the pace of testing.

The record in the Commission's rule making proceeding includes differing views as to the appropriate analytical models and criteria that should be used to evaluate the interference potential of WSDs. This includes discussion of the signal levels that should be protected, physical relationship and separation distances between the devices, assumed path losses, etc. A large number of field tests would be required to be statistically valid relative to the scenarios and assumptions in the record. We anticipate the technical arguments will be fully explored in the Commission's rule making and that the data from this report will be one factor, together with a complete analysis of the record that is taken into account in arriving at a decision on final rules.

However, this project conducted limited, or anecdotal, tests in the field of the prototype WSD transmitter to provide information on its potential to interfere with TV reception. These tests were performed in a large outdoor area to evaluate the performance with an unobstructed line-of-sight (LOS) propagation path between the WSD transmit antenna and the DTV test receiver antenna. A test DTV receiver was placed in the area and connected to an indoor antenna with the antenna oriented towards a DTV transmitter on channel 29. The WSD transmitter was then placed in the "mainbeam" of the receive antenna, tuned to the same channel, and activated at incremental distances from the DTV receive antenna while observing for interference effects to the picture quality. Tests were also performed with the WSD tuned to a first (N+1) and second (N+2) adjacent channel. These adjacent channel tests were performed both with and without the use of the external transmit filter. Co-channel interference with the WSD transmitting without the transmit filter was observed out to a distance of 87 meters. First adjacent-channel interference with the WSD transmitting without the external filter was observed out to a distance of 47-50 meters, and second adjacent-channel interference was observed at a distance of 11-14 meters. First adjacent-channel interference with the external transmit filter applied was observed at a maximum distance of 2 meters, but as indicated above, the transmit power with the filter attached is attenuated by an additional 14 dB. In practice, the distance at which adjacent channel interference occurs would be expected to be greater if the device were operating at the proposed output power level of 100 mW EIRP.

Conclusions. This report determined that the sample prototype White Space Devices submitted to the Commission for initial evaluation do not consistently sense or detect TV broadcast or wireless microphone signals. Our tests also found that the transmitter in the prototype device is capable of causing interference to TV broadcasting and wireless microphones. However, several features that are contemplated as possible options to minimize the interference potential of WSDs, such as dynamic power control and adjustment of power levels based on signal levels in adjacent bands, are not implemented in the prototype devices that were provided. Given these results, further testing of these devices was not deemed appropriate at this time.

1 Introduction

The measurement project described herein was undertaken in support of the Federal Communications Commission's (FCC) ongoing proceeding to consider rules for permitting low power radio transmitting devices to operate on an unlicensed basis in the frequency bands that are currently allocated to the Television Broadcast and certain other licensed services.[2] Such unlicensed operations would be allowed on frequencies that are not used by TV stations or other services in each local area. These unused, or vacant, frequencies available in local areas are often termed spectrum "white spaces." As established previously by the Commission, fixed unlicensed "white space devices" (WSDs) will be allowed into the TV spectrum simultaneous with the completion of the transition from analog to digital television broadcasts on February 17, 2009.[3] The Commission is now considering whether to allow unlicensed "personal/portable" WSDs to operate in the TV spectrum.

An issue in the white spaces matter is how to ensure that unlicensed devices operate only on vacant frequencies. One approach under consideration for determining the unused frequencies at a WSD location is for the WSD to employ a "detect and avoid" or "look before talk" strategy. This approach would be dependent on the performance of "spectrum sensing" techniques for detection of signals of TV stations, wireless microphones and perhaps other incumbent services. A second issue is the interference potential from low power WSDs to TV reception and wireless microphone operations. The Commission indicated that it would perform testing to collect the information necessary to evaluate both of these issues.

Consistent with the Commission's plan for white space testing, the Office of Engineering and Technology (OET) issued a Public Notice on December 21, 2006, inviting interested parties to submit white space devices for testing at the FCC Laboratory.[4] The Public Notice indicated that the Laboratory intended to test these devices for their ability to operate on unused TV band frequencies without causing interference to broadcast television and other authorized services. Two parties responded to this notice and provided prototype personal/portable WSDs to the Laboratory for testing. The devices submitted by these two parties are designated "Prototype A" and

[2] *First Report and Order and Further Notice of Proposed Rule Making* in the Matter of Unlicensed Operation in the TV Broadcast Bands, ET Docket No. 04-186 and 02-380, October 18, 2006 (hereinafter *FNPRM*). While the focus of this proceeding is on unlicensed operation, the Commission has also requested comment on issues relevant to whether TV band low power devices should be allowed on a licensed or hybrid licensed/unlicensed basis. It also requested comment as to whether, if unused TV spectrum were made available on a licensed basis, licensed devices should be required to incorporate the same type of interference avoidance mechanisms and be subject to the same low power limits that it proposed for unlicensed devices.

[3] *Id*.

[4] FCC Public Notice DA 06-2571, *Office of Engineering and Technology Invites Submittal of Prototype TV Band Devices for Testing*, ET Docket No. 04-186, Dec 21, 2006.

"Prototype B" herein.[5] Both of these prototypes have a sensing capability but only one, the Prototype A device, has a transmitter.

This report describes the tests and measurements performed on the prototype WSDs to acquire the data needed for an electromagnetic compatibility (EMC) evaluation, with focus on broadcast television and wireless microphone operations. In particular, this report provides the results of tests of the spectrum sensing capabilities of the prototype devices as a means for identifying TV band channels unoccupied by TV or wireless microphone operations and, where the devices included transmission capability, their emissions characteristics and potential for causing interference to those services. While other incumbent services operate in the TV bands, those services were not specifically examined in this testing as the Commission has proposed other methods for protecting them from WSD operations.

1.1 TV Band Incumbent Uses

The TV bands are primarily occupied by stations in the broadcast television service, which operates under Part 73 of the FCC rules.[6] TV stations broadcast in 6-MHz channels and after the transition to all digital operation will operate on channels 2 to 51 in the very-high frequency (VHF) and ultra-high frequency (UHF) portions of the electromagnetic spectrum (54-72 MHz, 76-88 MHz, 174-216 MHz, and 470-698 MHz).[7] In addition to full-service TV stations operating under Part 73 of the rules, other related licensed services are also permitted to operate in the spectrum allocated to Broadcast TV. These include Class-A TV stations, low-power TV stations, TV translators and TV booster stations. Part 74 of the rules permits certain broadcast auxiliary and wireless microphone operations to operate on TV frequencies on a limited (*i.e.*, non-interference) basis. The prototype WSDs were designed to detect signals from TV and wireless microphone transmitters operating within these radio services.

In 13 metropolitan areas, one to three channels in the range of channels 14-20 are used by licensees in the Private Land Mobile Radio Service (PLMRS) under Part 90 of the rules and the Commercial Mobile Radio Service (CMRS) under Part 20 of the rules.[8] In addition, medical telemetry equipment is permitted to operate on an unlicensed basis on vacant TV channels 7-46, and unlicensed remote control devices are allowed to operate on any TV channel above 70 MHz (channel 4), except for channel 37.[9] TV

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[5] As discussed below, we received three units of the Prototype A device and one unit of the Prototype B device.

[6] 47 C.F.R. Part 73

[7] *See* 47 C.F.R. § 73.603(a). Television stations currently also operate on channels 52-69 (698-806 MHz), however, those channels have been reallocated to new uses and will not be available for use by WSDs, *see First Report and Order* in WT Docket No. 99-168, 15 FCC Rcd 476 (2000), *Report and Order* in ET Docket No. 97-157, 12 FCC Rcd 22953 (1998) and *Report and Order* in GN Docket No. 01-74, 17 FCC Rcd 1022 (2002).

[8] *See* 47 C.F.R. §§ 90.301-.317 and 47 C.F.R. § 20.625.

[9] *See* 47 C.F.R. §§ 15.231, 15.241 and 15.242. Effective October 16, 2002, the Commission ceased granting certification for new medical telemetry equipment that operates on TV channels, but there is no cutoff on the sale or use of equipment that was certified before that date. *See* 47 C.F.R. § 15.37(i).

channel 37 is allocated for radio astronomy and the wireless medical telemetry service (WMTS) and is not used for TV broadcasting. Under the Commission's proposals in the white space proceeding, these services would be protected by means other than spectrum sensing. Since it is not anticipated that WSDs would need to protect PLMRS, CMRS, and WMTS services by spectrum sensing, they were not tested for that functionality.[10]

1.2 Interference Concerns, and Test Objectives

When assessing the potential impact from the introduction of a new radio service into an occupied segment of the electromagnetic spectrum, a priority consideration is the preservation of electromagnetic compatibility with respect to spectrum incumbents (*i.e.*, the avoidance of harmful radio frequency interference (RFI) to the operations of existing radio services). In order to address the differences in the potential for RFI to incumbent operations from WSDs operating at different power levels and for somewhat different applications, the Commission proposed classifying unlicensed WSDs into two general functional categories.[11] The first category consists of low-power "personal/portable" WSDs that will function similar to WiFi applications in laptop computers and wireless in-home local area networks (LANs). The second category consists of higher-powered "fixed/access" WSDs that would typically be operated from a fixed location and used to provide a commercial service such as wireless broadband access.

The tests described herein focused exclusively on the ability of personal/portable category of unlicensed WSDs to detect TV and wireless microphone signals and to their potential to interfere with the reception of those signals. The interference mechanisms of principal concern to incumbent services from the introduction of WSDs involve co-channel and adjacent channel interactions.[12] The co-channel interference potential represents RFI that is likely to occur when a WSD transmits on the same 6-MHz channel that is also being locally used to receive over-the-air television broadcast programming or Part 74 wireless microphone signals.

Adjacent-channel RFI becomes a concern when a WSD transmits on a channel adjacent to one being used locally to receive over-the-air (OTA) television broadcast programming or to establish wireless microphone links. This interference potential is typically a function of the combination of the radio frequency (RF) filtering employed in

[10] *Notice of Proposed Rulemaking* in ET Docket Nos. 04-186 and 02-380, 19 FCC Rcd 10018 (2004), at paragraphs 33-37.

[11] *Notice of Proposed Rulemaking in ET Docket Nos. 02-380 and 04-186, 19 FCC Rcd 10018 (2004).*

[12] Direct pick-up of signals by receivers of WSDs signals is also a concern. Direct pick-up interference occurs when the output power of a transmitter is at a level high enough that interference occurs to a victim receiver via the unconventional means of cable- or case-penetration rather than through the typical antenna/receiver path. This interference mechanism is of particular concern to cable television providers, since unlike over-the-air (OTA) broadcast operations, cable operations can use all of the frequencies between 54 MHz and 698 MHz (cable operations also typically use additional, higher frequencies). Thus, regardless of the OTA scenario, a WSD may select a channel that is also being used to provide television content via coaxial cable. These DPU interactions were characterized in a separate study conducted by the FCC Laboratory as part of the Commission's white spaces testing program. *See* Stephen R. Martin, "Direct-Pickup Interference Tests of Three Consumer Digital Cable Television Receivers Available in 2005," OET Report FCC/OET 07-TR-1005, July 31, 2007.

both the victim receiver and the interfering transmitter and typically involves the immediately adjacent channels (relative to the victim receiver operating channel), but depending on the level of RF filtering employed in the transmitter circuit, can also extend to channels even further removed. All radio transmitters emit some level of energy into adjacent frequency bands, and it is, of course, desirable to minimize such emissions as they can cause interference. Out of band emissions (OOBE) are controlled with proper transmitter design and filtering.

The Commission has proposed to allow the RFI potential of personal/portable WSD devices to be controlled by implementing a "detect and avoid" or "look before talk" strategy whereby WSD operation on channels already occupied with television broadcasts or wireless microphone transmissions would be avoided, thus eliminating the possibility of co-channel interference interactions. The detection function in this approach would be performed by a spectrum scanning/sensing capability whereby the WSD will scan all TV channels in it's tuning range while real-time sensing for ambient signals, process the detected signals, and then use the resulting data to determine which channels are occupied and which are vacant. Those channels deemed to be vacant could then be utilized to provide the desired unlicensed services (*e.g.*, wireless LAN connectivity). 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 at -116 dBm, consistent with the most conservative threshold under consideration by IEEE 802.22.[13] The Commission also requested comment on alternative values for the sensing threshold and several parties representing the interests of incumbent TV band services have submitted comments arguing that the detection threshold should be significantly lower.

Other variations on this approach involve augmenting the scanning/sensing capability with geo-location (*e.g.*, an embedded Global positioning Satellite (GPS) receiver), database look-up, distributed sensing, and/or beacon identification techniques. Assuming that these "detect and avoid" strategies are adequate to identify any and all incumbent users, co-channel interference interactions can be avoided. Thus, control over the channel's RFI potential arising from the introduction of unlicensed WSDs will be predicated on the successful detection and avoidance of occupied channels.

1.3 Test Scope and Approach

This section describes the approach taken to collect data on the ability of the unlicensed personal/portable devices as represented by the prototype devices to detect whether channels are occupied by TV or wireless microphone signals and to assess the potential for the transmitters of those devices to cause interference to the reception of TV and wireless microphone signals. The TV portion of the sensor testing examined the

[13] *See First Report and Order and Further Notice of Proposed Rule Making* at paragraph 37; *see* also Institute of Electrical and Electronics Engineers (IEEE), Working Group 802.22; http://standards.ieee.org/announcements/pr_80222.html. The proposal under consideration by IEEE 802.22 is for fixed devices. Broadcasters and other parties representing incumbent services in the TV bands argue that the threshold should be lower than the -116 dBm level for personal/portable devices.

ability of the prototype devices to detect the signals of both analog and digital full service stations. The results of these tests are also applicable to analog and digital low-power television operations (Class A, low power TV, and TV translator stations) that use the same transmission standards as full service television stations. The transmitter of the Prototype A was evaluated for its potential to interfere with digital TV signals. The wireless microphone portion of the testing looked at the ability of the prototype sensors to detect wireless microphones. It also looked at the susceptibility of wireless microphones to the signals emitted by the Prototype A transmitter and simulated broadband signals modulated using several alternative methods. Testing was limited to TV and wireless microphone signals on UHF channels 21-51, the operating range of the prototype devices.

If portable/personal WSDs operate in the television spectrum on an unlicensed basis (*i.e.*, under Part 15 of the FCC rules), they must accept interference from licensed incumbents while not creating harmful interference to the licensed operations. The Commission's EMC concerns thus are only for potential interference interactions from WSD transmitters to those receivers associated with incumbent licensed operations (*i.e.*, there will be no requirement to assess the interference potential to WSD receivers). This test project therefore did not examine interference from TV and other signals to the prototype WSD receivers

1.3.1 Assessing Sensing Ability and Interference Potential with respect to Television Services

Under the proposed "detect and avoid" approach, control over co-channel, and to some extent, adjacent channel interference from personal/portable WSD transmitters is predicated on the successful detection of incumbent signals occupying TV band channels or frequencies. A television broadcast signal originating from a distant location (or as a result of terrain blockage) may be at very low power levels at the WSD location (particularly under conditions described by the "hidden node" scenario discussed in the record).[14] The scanner/sensor of WSDs therefore must be capable of reliably detecting TV signals (and particularly DTV signals) at extremely low levels.

Bench and field tests were performed to assess the scanning/sensing sensitivity and reliability of the prototype WSDs. In the case of bench testing, guidance and draft recommendations published to date by IEEE 802.22 for testing the spectrum sensing capability of fixed/access WSDs were considered where applicable. Two tests utilizing laboratory-grade DTV signals were used to determine 1) the baseline minimum discernable signal that could successfully be detected by the scanner/sensor component of the prototype and 2) the impact to the baseline from signals present on nearby channels.

Field tests were performed with one unit of the Prototype A device in order to assess the scanning/sensing capability under "real-world" conditions (the manufacturer of the Prototype B device formally declared that the device was not suitable for field testing and requested that it not be included in these tests). The scanning/sensing capability of the selected prototype device was tested at a number of sites representative of typical

[14] *See* FNPRM at 39

residences where over-the-air television broadcasts, including DTV, are currently being received. Several independent test locations were identified within each test site (*e.g.*, the tests were performed within several rooms of each house). In cases where the test site was located within the service contour of a station occupying a channel and where the content of that channel could be received and displayed on the existing DTV receiving system, it was expected that the scanning/sensing component of the WSD prototype should be able to reliably identify that channel as being occupied.[15]

In order to assess the interference potential of the WSD to TV receivers, an effort was made to characterize the transmitter's emission technical parameters through laboratory measurements. In addition, a recently published FCC report documents an extensive effort to determine the susceptibility of modern DTV receivers to interference.[16] The combined information from the study of the transmitters and the DTV receiver susceptibility to interference can provide a much better assessment of the interference potential when used for link budget analyses under various assumptions regarding the interaction scenarios.

Finally, an anecdotal test to demonstrate the interference potential from a WSD transmitter to a DTV receiver using live over-the air (OTA) broadcast was conducted. Since there were so many parameters of the tests which could not be controlled, the results only provide an illustration of interference.

1.3.2 Assessing Sensing Ability and Interference Potential with respect to Wireless Microphones

Wireless microphone testing was conducted in the laboratory only; no field tests were performed for these devices. Bench tests of the Prototype A and Prototype B devices' ability to sense wireless microphones were performed using signals generated by wireless microphones. These signals were coupled directly to the input terminals of the prototype devices. Wireless Microphone interference testing was performed using both simulated signals and signals from the Prototype A transmitter. Three different Part 74 wireless microphone systems were evaluated in these tests. The simulated signals consisted of an audio modulated FM signal, a wideband noise signal and a wideband OFDM signal.

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[15] The locus of points at the outer edge of the area served by a TV station is termed the station's "service contour" and corresponds to the range at which reception is noise-limited. At locations within its service contour, a station's signal is generally assumed to be receivable. TV service contours are defined on the basis of field strengths. For analog TV stations, service areas are based on the "Grade B" contour, which for UHF channels is the F(50,50) contour for a field strength of 64 dBu; for DTV stations service areas are based on the "noise-limited contour, which for UHF channels is the F(50,90) contour for a field strength of 41 dBu. *See* Sections 73.622(e), 73.683, 73.684, and 73.699 of the Commission's rules, 47 C.F.R. §§ 73.622(e), .683, .684, and .699.

[16] Stephen R. Martin, "Interference Rejection Thresholds of Consumer Digital Television Receivers Available in 2005 and 2006", Report FCC/OET 07-TR-1003, March 30, 2007 (hereinafter, "DTV Susceptibility Study").

2 White Space Prototype Devices

The two prototype personal/portable WSDs submitted for testing were both devices intended as product development platforms rather than finished products ready for the market. The Prototype A units had both sensing and transmitting capabilities, but the two features were not linked. There was no provision for these devices to transmit automatically on channels found to be vacant; rather the transmitter function was activated manually by the operator. The Prototype B device only had sensing capability. Further, as indicated by its manufacturer to the Laboratory staff, this Prototype was not likely to endure the rigors of field testing and therefore was exempted from the field tests.

2.1 Prototype A (Versions 1 and 2)

The Prototype A WSD platform consists of two core system subassemblies: 1) a wide-band spectrum scanner, a network processor and a tunable UHF half-duplex transceiver controlled by the network processor and 2) a Windows-based laptop computer that utilizes the Internet Explorer browser to establish a command and control user interface via an Ethernet connection.

The scanner/sensor function of the Prototype A devices consists of a broadband (521-698 MHz) computer-controlled frequency scanner and high-speed digitizer that is used to incrementally scan over UHF TV channels 21-51 in 6-MHz segments. The accumulated digitized time-domain information is then passed to the network analyzer where a 2048-point Fast Fourier Transform (FFT) is performed. Signal feature templates for DTV, analog TV, and wireless microphone waveforms are sequentially compared to the resulting FFT output to determine channels occupied by DTV or analog TV signals. Channels determined not to be occupied by DTV or analog TV signals are subsequently analyzed for potential narrowband incumbent signals such as wireless microphones. Those channels determined not to be occupied by either DTV, analog TV, or wireless microphone signals are declared to be available “white space” channels. User control and scanner results are provided via the laptop computer connection. Table 2-1 provides the manufacturer’s statement of the basic specifications for the scanner/sensor component of the Prototype A WSDs.

Table 2-1. Prototype A Manufacturer-Reported Scanner/Sensor Technical Specifications

Technical Parameter	Specification
Frequency Range	512-698 MHz (TV Channels 21-51)
Frequency Step	1 MHz
Scan Frame Bandwidth	8 MHz
Scan Frame FFT Size	2048 points
FFT Bin Size	3.9 kHz
Minimum Discernible DTV Pilot Tone Sensitivity	-114 dBm
Minimum Discernible Wireless Microphone Detection Sensitivity	-114 dBm
Gain Selections	In-line 20 dB, High-Intercept LNA
Measurement Accuracy	± 3 dB

The UHF transceiver assembly consists of three sub-components: 1) an S-Band (2.4 GHz) 802.11g OFDM modem; 2) a Half-duplex S-Band to UHF block converter; and 3) and a network processor browser to exercise control over frequency and power.

Two versions of the Prototype A personal/portable WSD were provided to the Laboratory. The first version (version 1) was delivered on March 13, 2007 and implemented a scanning/sensing capability and a UHF transceiver, with control between the two via a manual, human interface. This unit was used to become acquainted with Prototype A operation and to measure the output emissions of the UHF transmitter. However, problems were encountered with the operation of its sensing/scanning function (unintended emissions from the three separate power supplies in the device resulted in a high level of false detections) and therefore measurements were not made of the scanning performance of that unit. Two units of a second version of this prototype WSD (version 2) were provided on May 3, 2007. The two separate version 2 units were provided to enable simultaneous testing with respect to incumbent TV service and wireless microphone signals. The primary differences between versions 1 and 2 were: 1) the addition of an external transmission filter on channel 30 to improve the transmitter's OOBE (two separate external filters were provided),[17] 2) a change in the scanner receiver antenna from a separate tripod-mounted discone to the same whip antenna used by the transceiver, 3) the consolidation of the three separate power supplies into one (which eliminated the unintended emissions problem), and 4) some minor modifications to the user interface, primarily to enhance file management capability. The version 2 units were used in all of the measurements reported herein.

The algorithm associated with the sensor/scanner component of the Prototype A device is proprietary and was not disclosed to the FCC. Nonetheless, it can be discerned

[17] *Notice of Ex Parte Communication, ET Docket Nos. 04-186, 02-380*, submitted by Harris, Wiltshire & Grannis LLP on behalf of Dell, Inc., Earthlink, Inc., Google, Inc., the Hewlett-Packard Co., Intel Corp, Microsoft Corp., and Philips Electronics North America Corp submitted on March 14, 2007, *see also Notice of Ex Parte Communication, TV White Spaces Proceeding, ET Docket Nos. 04-186, 02-380*, submitted by Harris, Wiltshire & Grannis LLP on behalf of The White Spaces Coalition submitted on May 3, 2007 (herinafter "White Space Coalition Communications").

from observing the sensor/scanner operation that the basic premise of the algorithm is to correlate on anticipated spectral features associated with the signal being detected. For example, the pilot tone associated with a DTV signal appears to be the feature used to identify an ATSC waveform. Similarly, an analog TV signal appears to be identified based on the presence and location in the channel of the picture carrier, the audio carrier and/or the chrominance subcarrier associated with an NTSC waveform. Additionally, it appears that a scoring system is utilized whereby a score is applied based on the detection of these anticipated spectral features. A final determination as to whether the detected signal is a digital TV, analog TV, or wireless microphone signal is made based on the accumulated scores. The prototype WSD device reports the results via an Ethernet connection to a laptop computer.

User manuals, including a system description and equipment specifications, were entered into the proceeding record for both versions in *ex-parte* filings submitted on behalf of Dell, Inc., Earthlink Inc., Google, Inc., the Hewlett-Packard Co., Intel Corp, Microsoft Corp., and Philips Electronics North America Corp. (the "White Spaces Coalition" or "WSC").[18] Figure 1 shows a version 2 unit of the Prototype A device (with the external bandpass filter).

Figure 2-1. WSD Prototype A Sensing and Transmitting Device

[18] *See* White Space Coalition Communications.

2.2 Prototype B

The Prototype B WSD device contains only a sensing/scanning component with no UHF transmitter capability. This device consists of a desktop computer (for user-interface, control and processing), a commercial TV tuner card (for tuning to a specified TV channel and translating to an IF frequency), and a digital processing board (for A/D conversion and processing). The Prototype B device was delivered to the FCC laboratory on May 18, 2007. The manufacturer formally requested that this unit not be used in field tests since the device cannot tolerate much jostling.[19]

The Prototype B device provides a sensing capability representative of that which might be incorporated in personal/portable WSDs to implement a "detect and avoid" strategy to circumvent co-channel interference interactions. The manufacturer claims that the device can scan UHF channels (21-51) and detect DTV, analog TV, or wireless microphone signals down to -114 dBm signal strength within a 6-MHz channel.

User manuals for this device, with a system description and equipment specifications, were entered into the proceeding record in an *ex-parte* filing submitted on behalf of the White Spaces Coalition.[20] Figure 2-2 shows a photograph of the Prototype B WSD.

Figure 2-2. Prototype B WSD

[19] *Ex parte* letter to Steven K. Jones, FCC/OET Laboratory Division, June 6, 2007 (hereinafter "Philips Letter").

[20] *Notice of Ex Parte Communication, TV White Spaces Proceeding, ET Docket Nos. 04-186, 02-380*, submitted by Harris, Wiltshire & Grannis LLP on behalf of The White Spaces Coalition submitted on May 21, 2007.

3 DTV Scanning/Spectrum Sensing Capability Tests

The tests described in this section were intended to evaluate the performance of the scanner/spectrum sensing component of the prototype WSDs. In particular, these tests were designed to assess the ability of the scanning function to reliably detect occupied television channels and to determine the minimum signal level that can be successfully detected. A combination of bench tests and field tests were performed to assess the scanner/sensor performance under both laboratory and “real world” conditions.

3.1 Test Approach

There are no known procedures that have been established to guide the testing of this type of scanning/sensing capability. A working group within IEEE standards committee 802.22 is in the process of developing a measurement standard for similar scanning/sensing capabilities being implemented in fixed WSDs, but this effort is still in its early stages.[21]

While the fixed and personal/portable WSD applications are similar in many respects, subtle distinctions actually exist between the two, particularly with respect to their likely operational scenarios. One example is the slight inconsistency with respect to a proposed minimum threshold for the detection of low-level DTV signals. The 802.22 committee is considering a detection threshold of -116 dBm for fixed WSDs, assuming a rooftop or tower-mounted sensing antenna. However, the WSC has proposed a threshold of -114 dBm for portable devices using a small (inefficient) antenna and sensing from locations at or near ground level.[22] Both of the prototype devices delivered to the laboratory are manufacturer-specified with respect to the WSC-proposed minimum detection threshold of -114 dBm.[23]

Notwithstanding these subtle operational distinctions between fixed and personal/portable WSD applications, the existing recommendations from 802.22 were considered in the design and performance of the tests described herein.

The current 802.22 draft measurement standard recommends that “to fully characterize the detection threshold of an unlicensed device, three separate tests are required”. The first test is intended to determine the baseline performance of the WSD relative to an unimpaired, laboratory-generated DTV signal. The second test, a co-channel only test, is recommended to be performed with field-captured DTV input signals for testing the sensing algorithm and determining the detection threshold. The third test is to be performed using a combination of field-captured DTV signals with additional strong DTV signals on alternate (adjacent) channels.

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[21] *See* http://grouper.ieee.org/groups/802/22/Meeting_documents/2007_Jan/22-06-0202-02-0000_Sensing_Test_Plan.doc (last checked July 12, 2007)

[22] Comments of Dell Inc., Google, Inc., The Hewlett-Packard Company, Intel Corp., Microsoft Corp., and Philips Electronics North America Corp., Jan 31, 2007 @ 5-7.

[23] *See* White Spaces Coalition Communications

While the tests described herein deviated slightly from those recommended in the developing standard, the underlying objectives are similarly met. For example, the baseline tests recommended as the first test in the draft standard were effectively applied herein to determine a baseline minimum detection threshold using a single laboratory-generated DTV signal. Similarly, a limited set of tests were performed analogous to the third 802.22 test recommendation; however, the potential amplitude and channel spacing combinations associated with this test are nearly limitless and the draft standard offers no guidance on which are the most relevant. The scope of this project limited the examination herein to two possible channel spacing combinations with one signal amplitude combination.

The greatest deviation between the tests recommended in the draft standard and those performed herein is with regard to the second test recommended by the working group. The recommended detection threshold test utilizing a field-recorded DTV signal as the input was not performed as a part of this test program. Instead, an actual field test was performed to assess the scanning/spectrum sensing performance using live OTA signals rather than field-recorded OTA signals. This test was intended to be applied to both of the prototype devices, but the manufacturer of Prototype B requested that the device not be utilized in field tests.[24]

Through a combination of bench and field testing, the primary issues underlying the 802.22 draft test procedures are effectively addressed in the approach adopted for the tests described herein.

3.2 Bench Tests to Determine Minimum DTV Signal Detection Threshold

Two separate bench tests were performed to determine the minimum DTV signal detection threshold for each of the two prototype devices delivered to the laboratory. The first bench test utilized a single, unimpaired, laboratory-grade DTV signal as the test input. The second bench test utilized two unimpaired, laboratory-grade signals as the input, one on the detection channel and the other placed on one of two adjacent channels and held at constant amplitude.

3.2.1 Baseline Detection Threshold Tests (Single DTV Input Signal)

The baseline detection threshold tests were performed consistent with the first of three tests recommended in the developing IEEE 802.22 measurement standard. A clean laboratory-grade DTV signal was produced by the ATSC signal generator component of a Rhode and Schwarz Broadcast Test System (model SFU) and connected via coaxial cable through a bank of calibrated step attenuators and to the scanner antenna input of the prototype under test. Figure 3-1 provides a block diagram representation of the test system configuration and Figure 3-2 shows the spectral envelope of the laboratory-grade ATSC (DTV) signal used in the test.

[24] *See* Philips Letter

The input DTV signal was initially set to a low, but measurable, level and then further attenuated incrementally with the calibrated step attenuator bank while exercising the scanner over the occupied channel. At each attenuation step (input power level), thirty independent trials were performed in order to determine the percentage of successful detections with some statistical relevance. The percentage of successful detections observed over the thirty independent trials performed at each attenuator step was plotted as a function of the input power level.

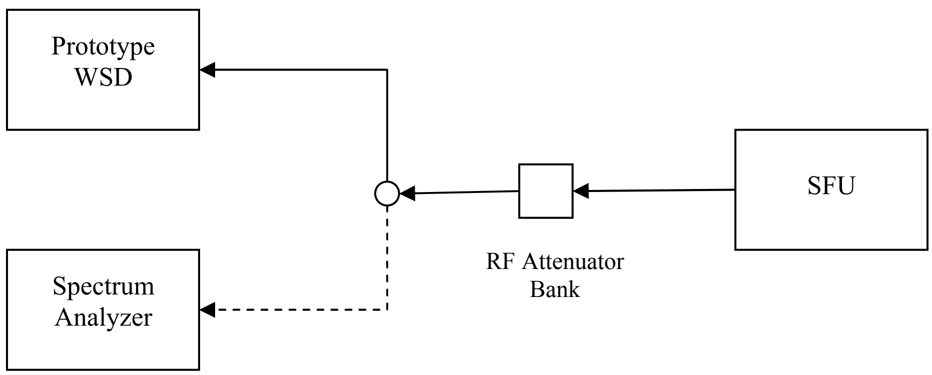

Figure 3-1. Baseline Detection Threshold Test Equipment Configuration.

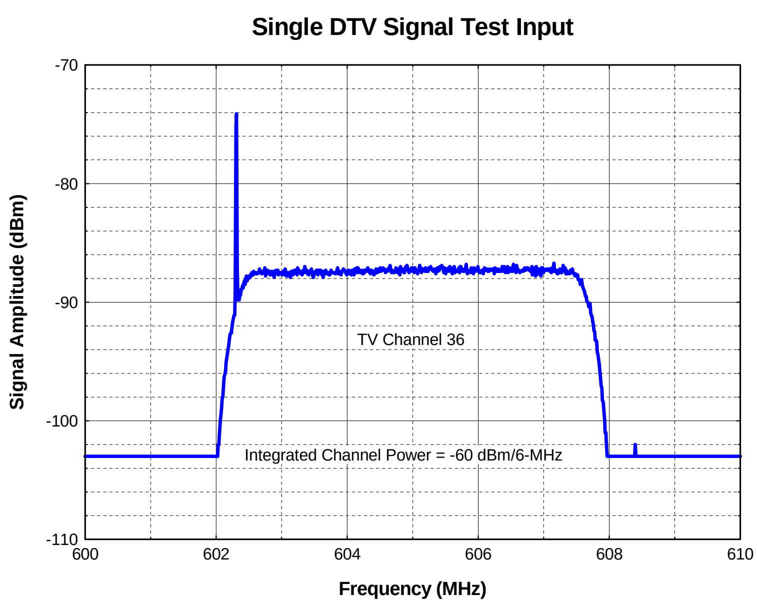

Figure 3-2. Single-Signal Laboratory-Generated DTV Input.

These tests were performed on three channels in the lower (channel 21), middle (channel 36) and upper (channel 51) portions of the WSD tuning range, in order to investigate potential frequency-related differences in performance. An analysis of the test results revealed that the sensing performance of the devices was consistent over the test channels. Therefore, the remaining tests were performed on a single channel in the middle of the tuning range. (*i.e.*, channel 36) for both prototype WSDs.

The results obtained from the baseline detection threshold tests are presented in Figures 3-3 and 3-4, for WSD Prototypes A and B, respectively.

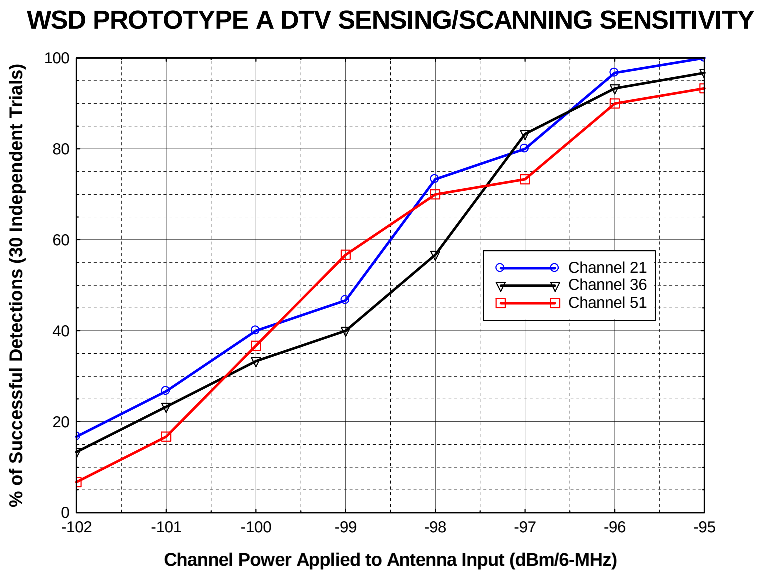

Figure 3-3. Baseline Detection Threshold Results for Prototype A.

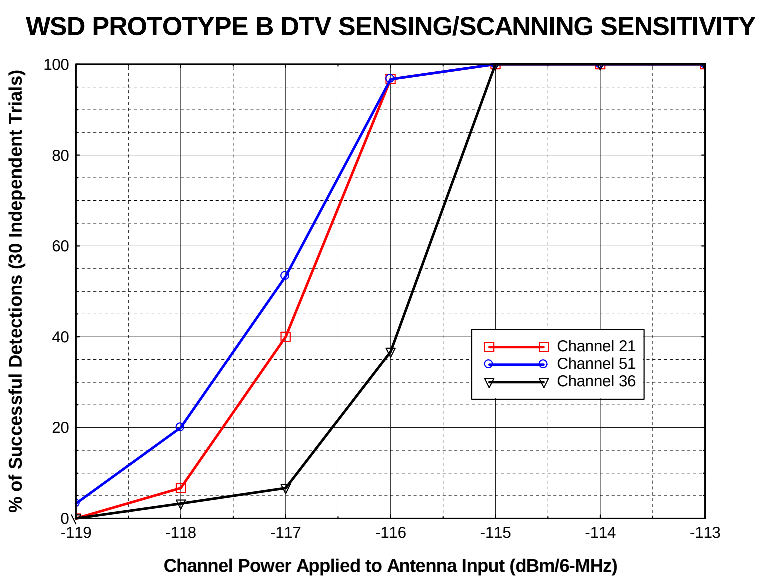

Figure 3-4. Baseline Detection Threshold Results for Prototype B.

The following information was also noted from these tests. The Prototype A WSD demonstrated a scan time of approximately 27-seconds per channel for a total scan period over the entire channel space (31 channels) of approximately 14 minutes. The Prototype B device scanned a single channel in approximately 8-seconds and was capable of performing a full scan over the available channel space in a period of approximately 4 minutes.

3.2.2 Multiple-Signal Detection Threshold Tests (Two DTV Input Signal).

This test is intended to examine the scanner/sensor performance in the presence of another DTV signal occupying an adjacent channel and is similar to the third test recommended in the draft 802.22 measurement standard. The draft standard recommends that a "strong" incumbent DTV signal be represented on an alternate TV channel but does not specify the level that constitutes a "strong" signal nor what alternate TV channels should be utilized.

A previous FCC test program, performed to assess the interference susceptibility of DTV receivers, demonstrated that receiver sensitivity can be degraded by the presence of out-of-channel signals.[25] The tests performed as a part of that program included both single-channel undesired signals and specific pairings of undesired signals spaced so as to generate third-order intermodulation distortion within the tuner. It was found that receiver sensitivity degradation was dependent on both channel spacing and signal amplitude.

Although receivers used for sensing the presence of DTV signals might also be subject to similar performance degradations, such an intricate test as was performed in the previous FCC effort was deemed to be outside the scope of this project. Rather, within this project, tests were performed with only one additional DTV signal placed first on an immediately adjacent channel (N-1) and then on a second adjacent channel (N+2).

Based on the channel consistency observed in the results of the baseline detection threshold tests, these tests were performed on only one detection channel in the WSD tuning range (*i.e.* channel 36) under the presumption that the observed performance will be representative of the anticipated performance on the remaining available channels.

The methodology used in these tests is similar to that used in the baseline detection tests but with the addition of a second DTV input signal (produced with a second, but identical SFU). Figure 3-5 provides a block diagram of the test system configuration and Figures 3-6 and 3-7 show the spectral envelope of the laboratory-generated ATSC (DTV) signals used in the test with the additional DTV channel placed first on the N-1 adjacent channel (35) and then with the additional DTV channel on the N+2 adjacent channel (38). Both prototype WSDs were subjected to this test.

[25] *See* DTV Susceptibility Study.

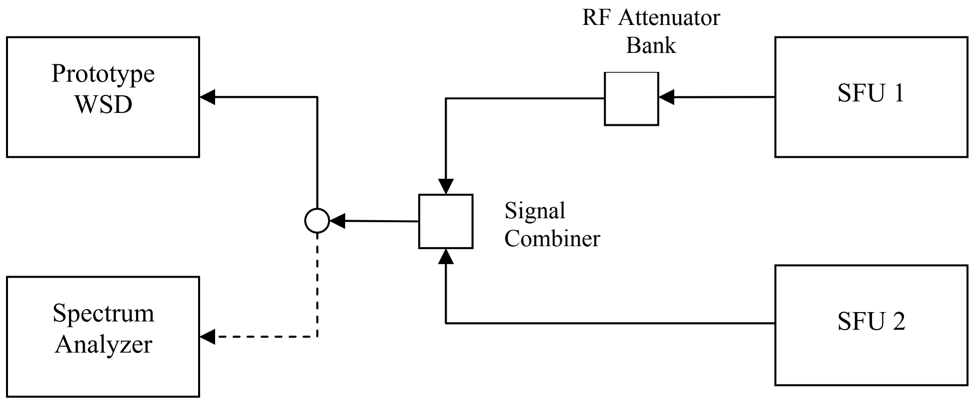

Figure 3-5. Multiple (Two)-Signal Detection Threshold Test Equipment Configuration.

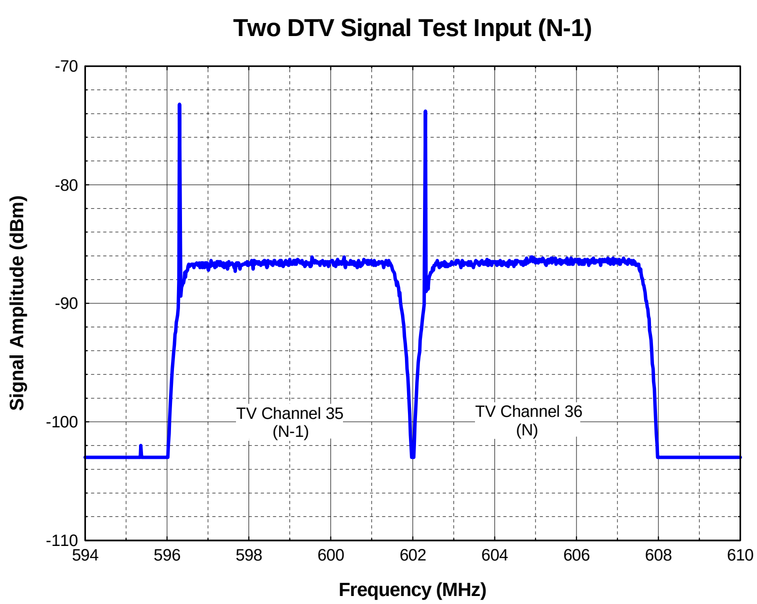

Figure 3-6. Lab-Grade DTV Signals Used in Two-Signal Detection Threshold Tests (N-1).

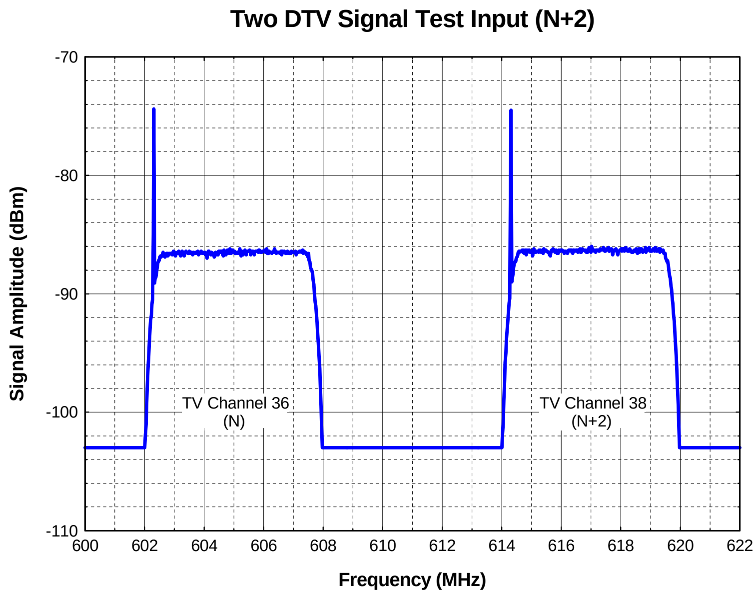

Figure 3-7. Lab-Grade DTV Signals Used in Two-Signal Detection Threshold Tests (N+2).

The DTV signal in the detection channel was initially set to a low but measurable level and then further attenuated incrementally with the calibrated step attenuator bank while exercising the scanner over the occupied channel. The second DTV signal was introduced on an adjacent channel and held at a constant level of -60 dBm ("strong" signal level relative to the amplitude in the detection channel). At each attenuation step (power level in detection channel), thirty independent trials were performed in order to determine the percentage of successful detections with some statistical relevance. The percentage of successful detections observed over the thirty independent trials performed at each attenuator step was plotted as a function of the input power level.

The results obtained from the baseline detection threshold tests are presented in Figures 3-8 and 3-9, for WSD Prototypes A and B, respectively.

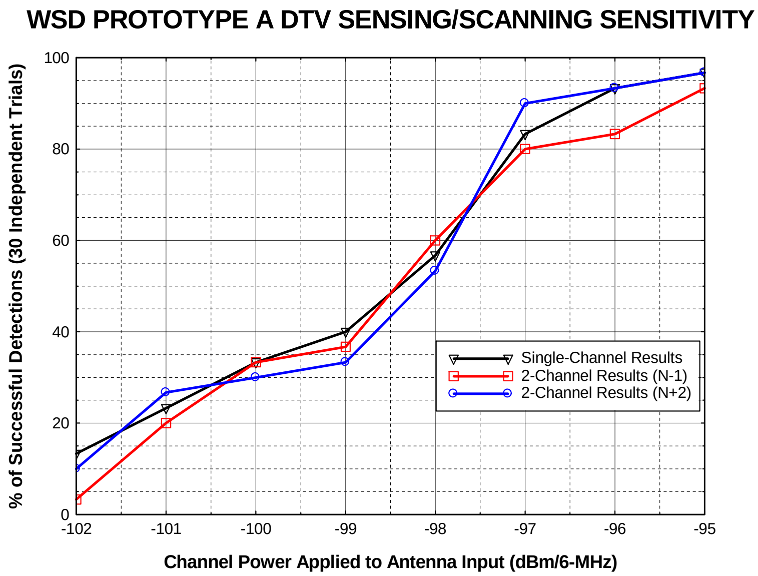

Figure 3-8. Two-Channel Detection Threshold Test Results for WSD Prototype A.

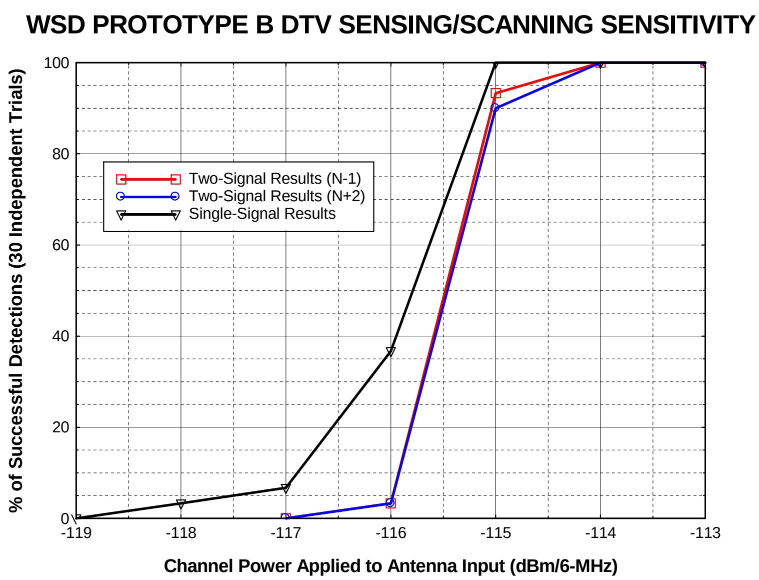

Figure 3-9. Two-Channel Detection Threshold Test Results for WSD Prototype B.

3.3 Field Tests with Over-the-Air Signals

This section presents a description of, and the results obtained, from field tests performed with the Prototype A personal/portable white space device. As previously explained, the Prototype B WSD was not subjected to these tests at the request of the manufacturer.

These tests were performed as an alternate to the 802.22-recommended bench test utilizing field-recorded DTV signals. The objective of both approaches is to assess the scanner/sensor performance under “real world” conditions, but the tests described herein utilized live rather than recorded OTA television signals (both DTV and NTSC) to assess the performance of the prototype scanner/sensor component.

The scanning/sensing performance of the prototype device was tested at a number of sites representative of typical residences where over-the-air television broadcasts, including DTV broadcasts, are currently being received. Residential sites were sought within the Washington/Baltimore TV markets and candidate test sites were limited to residences that were already set up for and receiving OTA DTV broadcasts in order to provide a means for verifying those OTA stations that could be successfully received at the site with a typical DTV receiving system.

At each test site, several independent locations were identified for testing (*e.g.*, tests were performed within several rooms of each house). At each of these independent locations, the prototype was used to scan over its entire channel space (21-51) and the results were recorded. This process was repeated to produce results from three independent trials at each test location. The results from each scan were manually recorded (the prototype did not provide the ability to electronically record the results from a scan) in a manner consistent with the way they were reported via the prototype's scanning program. For example, the device interface reports the results sequentially on a channel-by-channel basis, identifying each channel as either occupied by a DTV signal (D), an NTSC TV signal (N), a wireless microphone (W), or else as an available channel (A).

The received TV signal levels at each measurement location were not made. Instead, map-based plots showing the service contour associated with each licensed full service and low power TV broadcast station within a 150-km (94 miles) radius of the test site coordinates was generated for each test site. These plots are provided in Appendix B for each of the four sites where field tests were performed.

The information provided in the service contour plots in Appendix B provides a means for readily (*i.e.*, visually) identifying the obvious "white spaces" (unoccupied channels) at each test site as well as those channels assigned to TV broadcast stations with service contours that include the site. This information was used to provide an indication of those channels most likely to be occupied at each test site. However, it should be recognized that the contour plots do not include possible signal blockage from terrain, foliage, or man-made structures that may be present in the actual signal propagation path. Thus, a second technique was used to verify occupied channels at the site with the existing DTV receiver system.

This secondary channel occupancy check utilized the site's existing DTV receiver to tune through the WSD scanning range (21-51). Antenna adjustments were made as necessary in an attempt to successfully receive and decode the signal from each licensed TV station whose signal reached the site as indicated on the service contour plots. The first table under the reported test results for each site lists the stations whose contour encompasses that site. Each channel that could be verified as occupied by this method was recorded and is reported in the last column of those tables.

With this information, the fundamental premise underlying the tests was that for those cases where the test site is located within the interior of a television broadcast station's service contour and where the station's signal can be successfully received by the existing DTV receive system, then that station's channel should be reliably identified by the scanning/sensing component as being occupied.

The following subsections describe the particulars of the tests performed at each site, including a complete description of the site and those locations where tests were performed. A description of the existing OTA DTV receive system is also provided. In addition, three tables of information are provided for each of the four test sites. As indicated above, the first of these tables provides a listing of the full service broadcast TV stations (both digital and analog) whose service contours encompass the test site.[26] This information was extracted from licensee records contained within the FCC's Consolidated Database of Broadcast Stations (CDBS) and is publicly accessible at http://www.fcc.gov/mb/cdbs.html.[27]

The second table presents the raw sensing data obtained from running the prototype scanner/sensor at each test location. The channels are listed in sequential order to match the output format of the user interface. The information in the third table represents a summary of the raw data and an attempt to quantify the results in terms of a simple detection probability based on whether or not each channel identified as occupied was successfully detected. While results obtained from only three independent trials at each test location are of marginal statistical significance, this information nonetheless represents a useful metric for assessing the sensing capability of the prototype WSD.

3.3.1 Field Test Site 1

Test site 1 is located in Hanover, Maryland at GPS coordinates 39º 08.xxx' North latitude and 076º 43.xxx' West longitude.[28] The site is a single story home with an unfinished basement. It is considered to be within a suburban residential/commercial area. The DTV receiving system at this residence consisted of a long-range rooftop-mounted VHF/UHF antenna with an in-line amplifier in the coaxial cable feeding two DTV receivers, both with third-generation tuner capability. The antenna radial direction is controlled with an electronic rotor.

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[26] None of the test sites were within the service contour of any low power television stations (Class A TV stations, low-power television stations, and television translators). Thus, no low power stations appear on the list of stations in the first table of information for each test sire. Low power stations are, however, licensed and operating in the Baltimore and Washington market areas and their transmitter locations and service contours are depicted on the service contour plots in Appendix B (see description of this appendix below).

[27] Note that the CDBS is not a fixed database but rather is modified on a daily basis as changes are made to authorized station facilities through on FCC actions. The plots in Appendix B were prepared using this database as it existed in April, 2007.

[28] Note that we are not reporting the full coordinates of the test site residences to protect the privacy of their occupants.

The tests at this site were performed between 12:00 PM and 7:00 PM EDT on Wednesday, May 9, 2007. The scanning capability of the prototype WSD was tested at each of four locations within the site; a central location on the rooftop (L1), the first floor living room on the NW end of the house (L2), a first floor bedroom on the SE end of the house (L3), and in the basement (L4). Tables 3-1, 3-2, and 3-3 provide the TV station information and scanning/sensing results for this test site.

Table 3-1. Broadcast TV Stations within Prototype Tuning Range (21-51) with Service Contours that Include Test Site 1

RF Channel	Call Sign	TX Location	Tower Coordinates (NAD 83)	Tower Height (m above MSL)	Bearing (degrees)	Distance (mi/km)	Channel Reception Verified w/DTV
22	WMPT-TV	Annapolis, MD	39º 00' 36.7" N; 076º 36' 31.8" W	319.7	147	11.3/18.2	Y
24	WUTB-TV	Baltimore, MD	39º 17' 15.0" N; 076º 45' 37.0" W	458.7	349	9.9/15.9	Y
26	WETA-TV	Washington D.C.	38º 57' 50.1" N; 077º 06' 14.9" W	319.8	238	24.0/38.6	Y
27	WETA-DT	Washington D.C.	38º 53' 30.0" N; 077º 07' 54.0" W	263.8	231	28.1/45.2	Y
28	WFPT-DT	Frederick, MD	39º 15' 38.0" N; 077º 18' 43.6" W	308.7	284	32.4/52.2	N
29	WMPB-DT	Baltimore, MD	39º 26' 49.9" N; 076º 46' 47.2" W	472.1	352	20.9/33.6	Y
32	WHUT-TV	Washington D.C.	38º 57' 49.4" N; 077º 06' 16.9" W	290.0	238	24.0/38.6	Y
33	WHUT-DT	Washington D.C.	38º 57' 01.0" N; 077º 04' 46.0" W	335.8	235	23.4/37.7	N
34	WUSA-DT	Washington D.C.	38º 57' 01.0" N; 077º 04' 46.0" W	335.8	235	23.4/37.7	Y
35	WDCA-DT	Washington D.C.	38º 57' 22.0" N; 077º 04' 58.0" W	319.6	236	23.3/37.5	Y
36	WTTG-DT	Washington D.C.	38º 57' 22.0" N; 077º 04' 58.0" W	319.6	236	23.3/37.5	Y
38	WJZ-DT	Baltimore, MD	39º 20' 05.0" N; 076º 39' 02.0" W	401.0	17	13.5/21.8	Y
39	WJLA-DT	Washington D.C.	38º 57' 01.0" N; 077º 04' 46.0" W	335.8	235	23.4/37.7	Y
40	WNUV-DT	Baltimore, MD	39º 20' 10.0" N; 076º 38' 58.0" W	472.1	352	13.1/21.2	Y
41	WUTB-DT	Baltimore, MD	39º 17' 15.0" N; 076º 45' 37.0" W	458.7	349	9.9/15.9	Y
42	WMPT-DT	Annapolis, MD	39º 00' 36.7" N; 076º 36' 31.8" W	319.7	147	11.3/18.2	Y
43	WPXW-DT	Manassas, VA	38º 47' 16.2" N; 077º 19' 46.3" W	285.8	233	40.9/65.8	N
45	WBFF-TV	Baltimore, MD	39º 20' 10.0" N; 076º 38' 58.0" W	472.1	17	13.7/22.0	Y
46	WBFF-DT	Baltimore, MD	39º 20' 10.0" N; 076º 38' 58.0" W	472.1	17	13.7/22.0	Y
47	WPMT-DT	York, PA	40º 01' 41.4" N; 076º 35' 58.9" W	562.9	6	61.1/98.4	N
48	WRC-DT	Washington D.C.	38º 56' 24.0" N; 077º 04' 53.0" W	319.7	233	24.0/38.5	Y
50	WDCW-TV	Washington D.C.	38º 57' 44.0" N; 077º 01' 35.0" W	319.7	232	20.6/33.2	Y
51	WDCW-DT	Washington D.C.	38º 57' 44.0" N; 077º 01' 35.0" W	319.7	232	20.6/33.2	Y

Table 3-2. Test Site 1 Field Survey Data

Test Site: 1
Location: 39º 08.xxx' N; 076º 43.xxx' W
Description: Single Story Home with Unfinished Basement
DTV Installation: High-grade, long-range UHF/VHF rooftop-mounted antenna and electronic rotor with in-line amplifier feeding dual 3rd generation DTV receivers

RF Channel	TV Channel	Viewable On DTV Installation?	Location: Rooftop (L1)			Location: 1st flr LR (L2)			Location: 1st flr BR (L3)			Location: Basement (L4)		
			Trial #			Trial #			Trial #			Trial #		
			1	2	3	1	2	3	1	2	3	1	2	3
21	-	No	A	A	A	A	A	A	A	A	A	A	A	A
22	22	Yes	N	N	N	N	N	N	N	N	N	N	N	N
23	-	No	A	A	A	A	A	A	A	A	A	A	A	A
24	24	Yes	N	N	N	N	N	N	N	N	N	N	N	N
25	-	No	A	A	A	A	A	A	A	A	A	A	A	A
26	26	Yes	N	N	N	N	N	N	N	N	N	N	N	N
27	26.1	Yes	A	A	A	A	A	A	A	A	A	A	A	A
28	62.1	No	A	A	N	A	A	A	A	A	A	A	A	A
29	67.1	Yes	A	D	A	D	D	D	D	A	A	D	D	D
30	-	No	A	A	A	A	A	A	A	A	A	A	A	A
31	-	No	A	A	A	A	A	A	A	A	A	A	A	A
32	32	Yes	N	N	N	N	N	N	N	W	N	A	A	A
33[2]	33	No	A	A	A	A	A	A	A	A	A	A	A	A
34	9.1	Yes	A	D	D	A	A	A	D	A	A	A	A	A
35	20.1	Yes	A	A	A	D	A	A	D	A	A	A	A	A
36	5.1	Yes	A	A	A	D	A	A	D	A	A	A	A	A
38	13.1	Yes	D	D	D	D	D	D	D	A	A	D	D	D
39	7.1	Yes	D	A	D	D	A	A	D	A	A	D	D	A
40	54.1	Yes	A	D	D	D	A	D	D	A	A	D	D	D
41	24.1	Yes	D	A	D	D	A	A	D	A	A	D	A	A
42	22.1	Yes	D	D	D	D	A	A	D	A	A	D	A	A
43	-	No	A	A	N	N	A	A	N	A	A	N	A	A
44	-	No	A	A	D	D	A	A	D	A	A	D	A	A
45	45	Yes	N	N	N	W	N	N	N	N	N	N	N	N
46	45.1	Yes	A	A	D	D	A	A	D	A	D	D	D	A
47	-	No	A	A	D	D	A	A	D	A	A	D	A	A
48	4.1	Yes	A	A	D	D	A	A	D	A	A	D	A	A
49	-	No	A	A	N	N	A	A	N	A	A	A	A	A
50	50	Yes	N	N	N	N	N	N	N	A	A	A	A	A
51	50.1	Yes	A	A	D	D	A	A	D	A	A	A	A	A

NOTES:
1. A = available, D = occupied by DTV, N = occupied by NTSC, W = occupied by wireless microphone
2. Channel 33 not on the air during these tests

Table 3-3. Summary of Field Data Collected at Test Site 1

Channel	Call Sign	Successful Detections				Probability of Successful Detection			
		L1	L2	L3	L4	L1	L2	L3	L4
ATSC (DIGITAL TV)-OCCUPIED CHANNELS									
27	WETA-DT	0/3	0/3	0/3	0/3	0	0	0	0
28	WFPT-DT	1/3	0/3	0/3	0/3	0.33	0	0	0
29	WMPB-DT	1/3	3/3	1/3	3/3	0.33	1.00	0.33	1.00
33	WHUT-DT	-	-	-	-	-	-	-	-
34	WUSA-DT	2/3	0/3	1/3	0/3	0.67	0	0.33	0
35	WDCA-DT	0/3	1/3	1/3	0/3	0	0.33	0.33	0
36	WTTG-DT	0/3	1/3	1/3	0/3	0	0.33	0.33	0
38	WJZ-DT	3/3	3/3	1/3	3/3	1.00	1.00	0.33	1.00
39	WJLA-DT	2/3	1/3	1/3	2/3	0.67	0.33	0.33	0.67
40	WNUV-DT	2/3	2/3	1/3	3/3	0.67	0.67	0.33	1.0
41	WUTB-DT	2/3	1/3	1/3	1/3	0.67	0.33	0.33	0.33
42	WMPT-DT	3/3	1/3	1/3	1/3	1.0	0.33	0.33	0.33
43	WPXW-DT	1/3	1/3	1/3	1/3	0.33	0.33	0.33	0.33
46	WBFF-DT	1/3	1/3	2/3	2/3	0.33	0.33	0.67	0.67
47	WPMT-DT	1/3	1/3	1/3	1/3	0.33	0.33	0.33	0.33
48	WRC-DT	1/3	1/3	1/3	1/3	0.33	0.33	0.33	0.33
51	WDCW-DT	1/3	1/3	1/3	0/3	0.33	0.33	0.33	0
NTSC (ANALOG TV)-OCCUPIED CHANNELS									
22	WMPT-TV	3/3	3/3	3/3	3/3	1.00	1.00	1.00	1.00
24	WUTB-TV	3/3	3/3	3/3	3/3	1.00	1.00	1.00	1.00
26	WETA-TV	3/3	3/3	3/3	3/3	1.00	1.00	1.00	1.00
32	WHUT-TV	3/3	3/3	3/3	0/3	1.00	1.00	1.00	0
45	WBFF-TV	3/3	3/3	3/3	3/3	1.00	1.00	1.00	1.00
50	WDCW-TV	3/3	3/3	1/3	0/3	1.00	1.00	0.33	0
AVAILABLE CHANNELS									
21	-	3/3	3/3	3/3	3/3	1.00	1.00	1.00	1.00
23	-	3/3	3/3	3/3	3/3	1.00	1.00	1.00	1.00
25	-	3/3	3/3	3/3	3/3	1.00	1.00	1.00	1.00
30	-	3/3	3/3	3/3	3/3	1.00	1.00	1.00	1.00
31	-	3/3	3/3	3/3	3/3	1.00	1.00	1.00	1.00
44	-	2/3	2/3	2/3	2/3	0.67	0.67	0.67	0.67
49	-	2/3	2/3	2/3	3/3	0.67	0.67	0.67	1.00

NOTES:
1. Channel 33 not on the air during these tests

3.3.2 Field Test Site 2

The test site is located in Columbia, Maryland at GPS coordinates 39º 10.xxx' North latitude and 076º 49.xxx' West longitude. The site is a two-story farmhouse with an unfinished basement located on several acres of cleared property. The site is considered to be within a suburban residential area. The DTV receiving system at this residence consisted of an attic-mounted "smart" antenna with an in-line amplifier feeding a DTV converter box connected to an analog TV receiver. The converter box did not include an NTSC tuner thus it was not possible to not verify whether analog TV signals could be viewed on the DTV receiving system at this location.

The tests at site 2 were performed on Tuesday, May 15, 2007 between the hours of 11:30 AM and 5:30 PM EDT. The scanning capability of the prototype WSD was tested at each of five locations within this residence; a central location in the attic (L1), a second floor hallway on the N end of the house (L2), a second floor room on the S end of the house (L3), the first floor foyer (L4), and the basement (L5). Tables 3-4, 3-5, and 3-6 provide the TV station information and scanning/sensing results for test site 2.

Table 3-4. Broadcast TV Stations within Prototype Tuning Range (21-51) with Service Contours that Include Test Site 2

RF Channel	Call Sign	TX Location	Tower Coordinates (NAD 83)	Tower Height (m above MSL)	Bearing (degrees)	Distance (mi/km)	Channel Reception Verified w/DTV
22	WMPT-TV	Annapolis, MD	39º 00' 36.7" N; 076º 36' 31.8" W	319.7	133	15.9/25.5	N
24	WUTB-TV	Baltimore, MD	39º 17' 15.0" N; 076º 45' 37.0" W	458.7	22	8.9/14.3	N
26	WETA-TV	Washington D.C.	38º 57' 50.1" N; 077º 06' 14.9" W	319.8	227	20.7/33.2	N
27	WETA-DT	Washington D.C.	38º 53' 30.0" N; 077º 07' 54.0" W	263.8	221	25.3/40.7	Y
28	WFPT-DT	Frederick, MD	39º 15' 38.0" N; 077º 18' 43.6" W	308.7	284	27.0/43.5	Y
29	WMPB-DT	Baltimore, MD	39º 26' 49.9" N; 076º 46' 47.2" W	472.1	7	19.4/31.2	Y
32	WHUT-TV	Washington D.C.	38º 57' 49.4" N; 077º 06' 16.9" W	290.0	227	20.7/33.3	N
33	WHUT-DT	Washington D.C.	38º 57' 01.0" N; 077º 04' 46.0" W	335.8	223	20.4/32.8	N
34	WUSA-DT	Washington D.C.	38º 57' 01.0" N; 077º 04' 46.0" W	335.8	223	20.4/32.8	Y
35	WDCA-DT	Washington D.C.	38º 57' 22.0" N; 077º 04' 58.0" W	319.6	224	20.2/32.5	Y
36	WTTG-DT	Washington D.C.	38º 57' 22.0" N; 077º 04' 58.0" W	319.6	224	20.2/32.5	Y
38	WJZ-DT	Baltimore, MD	39º 20' 05.0" N; 076º 39' 02.0" W	401.0	39	14.8/23.8	Y
39	WJLA-DT	Washington D.C.	38º 57' 01.0" N; 077º 04' 46.0" W	335.8	223	20.4/32.8	Y
40	WNUV-DT	Baltimore, MD	39º 20' 10.0" N; 076º 38' 58.0" W	472.1	39	14.9/23.8	Y
41	WUTB-DT	Baltimore, MD	39º 17' 15.0" N; 076º 45' 37.0" W	458.7	22	8.9/14.3	Y
42	WMPT-DT	Annapolis, MD	39º 00' 36.7" N; 076º 36' 31.8" W	319.7	133	15.9/25.5	Y
43	WPXW-DT	Manassas, VA	38º 47' 16.2" N; 077º 19' 46.3" W	285.8	226	37.8/60.9	N
45	WBFF-TV	Baltimore, MD	39º 20' 10.0" N; 076º 38' 58.0" W	472.1	39	14.9/23.9	N
46	WBFF-DT	Baltimore, MD	39º 20' 10.0" N; 076º 38' 58.0" W	472.1	39	14.9/23.9	Y
47	WPMT-DT	York, PA	40º 01' 41.4" N; 076º 35' 58.9" W	562.9	11	60.5/97.4	N
48	WRC-DT	Washington D.C.	38º 56' 24.0" N; 077º 04' 53.0" W	319.7	221	21.0/33.8	Y
50	WDCW-TV	Washington D.C.	38º 57' 44.0" N; 077º 01' 35.0" W	319.7	218	17.9/28.8	N
51	WDCW-DT	Washington D.C.	38º 57' 44.0" N; 077º 01' 35.0" W	319.7	218	17.9/28.8	Y

Table 3-5. Test Site 2 Field Survey Data

Test Site: 2
Location: GPS (WGS-84) coordinates: 39º 10.xxx' N; 076º 49.xxx' W
Description: Two-story farmhouse with basement
DTV Installation: "Smart" antenna located in attic feeding an ATSC converter box with no NTSC tuner.

RF Channel	TV Channel	Viewable On DTV Installation?	Location Attic (L1)			Location 2nd floor, north end (L2)			Location 2nd floor, south end (L3)			Location 1st floor foyer (L4)			Location Basement (L5)		
			Trial #			Trial #			Trial #			Trial #			Trial #		
			1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
21	-	No	N	N	N	A	A	A	A	A	A	A	D	D	A	A	A
22	22	No[2]	N	N	N	N	W	N	N	N	N	W	N	N	W	N	N
23	-	No	A	A	A	A	A	A	N	N	N	N	A	A	N	A	A
24	24	No[2]	N	N	N	W	N	N	W	W	W	N	N	N	N	N	N
25	-	No	N	A	A	A	A	A	A	N	A	A	A	A	A	A	A
26	26	No[2]	N	N	N	W	N	N	W	W	N	N	N	N	N	N	N
27	26.1	Yes	D	A	A	A	A	A	D	D	A	A	A	A	A	A	A
28	62.1	Yes	A	A	A	A	A	A	D	D	A	A	A	A	A	A	A
29	67.1	Yes	W	A	A	A	A	A	D	D	A	D	A	A	A	A	A
30	-	No	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
31	-	No	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
32	32	No[2]	W	N	N	N	N	N	N	N	N	N	W	N	N	N	N
33[2]	33	No	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
34	9.1	Yes	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
35	20.1	Yes	D	A	A	D	D	A	D	D	D	D	D	D	D	A	A
36	5.1	Yes	D	D	D	A	D	D	D	D	D	D	D	D	D	A	A
38	13.1	Yes	D	D	D	D	D	A	D	D	D	D	D	A	D	A	A
39	7.1	Yes	D	D	D	D	A	A	D	D	D	D	D	D	D	D	D
40	54.1	Yes	D	A	D	D	D	D	N	N	N	D	D	D	N	N	N
41	24.1	Yes	D	A	A	A	A	A	D	D	D	D	A	A	A	A	A
42	22.1	Yes	D	A	D	D	D	A	D	D	D	D	D	A	D	D	D
43	-	No	D	A	A	A	D	A	D	D	A	D	D	A	A	A	A
44	-	No	D	A	A	A	A	A	D	W	A	D	D	A	A	A	A
45	45	No[2]	N	N	W	N	N	N	N	N	N	N	N	W	N	N	N
46	45.1	Yes	D	A	A	A	D	D	D	D	A	D	D	A	D	A	A
47	47	No	D	A	A	A	N	A	N	N	N	D	A	A	A	A	A
48	4.1	Yes	D	A	D	D	D	D	D	D	A	D	D	D	D	A	A
49	-	No	D	A	A	A	D	A	D	D	A	D	A	A	D	A	A
50	50	No[2]	N	N	N	N	N	N	N	N	N	W	N	N	N	N	N
51	50.1	Yes	D	A	A	A	D	A	D	D	A	D	A	A	D	A	A

Notes:
1. Scanner/Sensor data point indicators: A=available; D=occupied by DTV; N=occupied by NTSC; W=occupied by wireless microphone
2. OTA NTSC (analog) TV reception could not be verified on the television installation in place due to lack of an NTSC tuner (reliant on digital reception only)
3. Channel 33 not on the air during these tests

Table 3-6. Summary of Field Data Collected at Test Site 2

Channel	Call Sign	Successful Detections					Probability of Successful Detection				
		L1	L2	L3	L4	L5	L1	L2	L3	L4	L5
ATSC (DIGITAL TV)-OCCUPIED CHANNELS											
27	WETA-DT	1/3	0/3	2/3	0/3	0/3	.33	0	.67	0	0
28	WFPT-DT	0/3	0/3	2/3	0/3	0/3	0	0	.67	0	0
29	WMPB-DT	1/3	0/3	2/3	1/3	0/3	.33	0	.67	.33	0
33	WHUT-DT	-	-	-	-	-	-	-	-	-	-
34	WUSA-DT	3/3	3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0	1.0
35	WDCA-DT	1/3	2/3	3/3	3/3	1/3	.33	.67	1.0	1.0	.33
36	WTTG-DT	3/3	2/3	3/3	3/3	1/3	1.0	.67	1.0	1.0	.33
38	WJZ-DT	3/3	2/3	3/3	2/3	1/3	1.0	.67	1.0	.67	.33
39	WJLA-DT	3/3	1/3	3/3	3/3	3/3	1.0	.33	1.0	1.0	1.0
40	WNUV-DT	2/3	3/3	3/3	3/3	3/3	.67	1.0	1.0	1.0	1.0
41	WUTB-DT	1/3	0/3	3/3	1/3	0/3	.33	0	1.0	.33	0
42	WMPT-DT	2/3	2/3	3/3	2/3	3/3	.67	.67	1.0	.67	1.0
43	WPXW-DT	1/3	1/3	2/3	2/3	0/3	.33	.33	.67	.67	.33
46	WBFF-DT	1/3	2/3	2/3	2/3	1/3	.33	.67	.67	.67	.33
47	WPMT-DT	1/3	1/3	3/3	1/3	0/3	.33	.33	1.0	.33	0
48	WRC-DT	2/3	3/3	2/3	3/3	1/3	.67	1.0	.67	1.0	.33
51	WDCW-DT	1/3	1/3	2/3	1/3	2/3	.33	.33	.67	.33	.67
NTSC (ANALOG TV)-OCCUPIED CHANNELS[1]											
22	WMPT-TV	3/3	3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0	1.0
24	WUTB-TV	3/3	3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0	1.0
26	WETA-TV	3/3	3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0	1.0
32	WHUT-TV	3/3	3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0	1.0
45	WBFF-TV	3/3	3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0	1.0
50	WDCW-TV	3/3	3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0	1.0
AVAILABLE CHANNELS											
21	-	0/3	3/3	3/3	1/3	3/3	0	1.0	1.0	.33	1.0
23	-	3/3	3/3	0/3	2/3	2/3	1.0	1.0	0	.67	.67
25	-	2/3	3/3	2/3	3/3	3/3	.67	1.0	.67	1.0	1.0
30	-	3/3	3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0	1.0
31	-	3/3	3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0	1.0
44	-	2/3	3/3	1/3	1/3	2/3	.67	1.0	.33	.33	.67
49	-	2/3	2/3	1/3	2/3	2/3	.67	.67	.33	.67	.67

NOTES:
1. Channel 33 not on the air during these tests

3.3.3 Field Test Site 3

Test site 3 is located in Mount Airy, Maryland at GPS coordinates 39º 20.xxx' North latitude and 077º 05.xxx' West longitude. The site is a two-story colonial home with an unfinished basement surrounded by several acres of mostly wooded property. It is considered to be in a rural/suburban area.

The DTV receiving system consists of a roof-mounted two-element antenna array made from two individual long-range UHF/VHF log-periodic antennas; one points in the direction of the Baltimore market and the other points in the direction of the Washington D.C. market. An in-line amplifier is included in the coaxial connection between the antenna array and an ATSC converter box, which feeds a DTV receiver.

These tests were performed on Thursday, May 17, 2007 between the hours of 10:00 AM and 4:00 PM EDT. The scanning capability of the prototype WSD was tested at each of four locations; a central location in the attic (L1), the second floor foyer/hallway central to the house (L2), a dining room centrally located on the first floor with a sliding glass door representing one exterior wall (L3), and the basement (L4). Tables 3-7, 3-8, and 3-9 present the TV station information and scanning/sensing results for test site 3.

Table 3-7. Broadcast TV Stations within Prototype Tuning Range (21-51) with Service Contours that Include Test Site 3

RF Channel	Call Sign	TX Location	Tower Coordinates (NAD 83)	Tower Height (m above MSL)	Bearing (degrees)	Distance (mi/km)	Channel Reception Verified w/DTV
22	WMPT-TV	Annapolis, MD	39º 00' 36.7" N; 076º 36' 31.8" W	319.7	132	35.2/56.7	Y
24	WUTB-TV	Baltimore, MD	39º 17' 15.0" N; 076º 45' 37.0" W	458.7	103	18.7/30.0	Y
26	WETA-TV	Washington D.C.	38º 57' 50.1" N; 077º 06' 14.9" W	319.8	181	26.6/42.8	Y
27	WETA-DT	Washington D.C.	38º 53' 30.0" N; 077º 07' 54.0" W	263.8	183	31.6/50.9	Y
28	WFPT-DT	Frederick, MD	39º 15' 38.0" N; 077º 18' 43.6" W	308.7	242	13.0/20.8	Y
29	WMPB-DT	Baltimore, MD	39º 26' 49.9" N; 076º 46' 47.2" W	472.1	68	18.4/29.6	Y
30	WGCB-DT	Red Lion, PA	39º 54' 18.3" N; 076º 34' 57.2" W	413.9	35	47.2/76.0	N
31	WWPB-TV	Hagerstown, MD	39º 39' 04.0" N; 077º 58' 14.0" W	565.4	294	51.0/82.1	N
32	WHUT-TV	Washington D.C.	38º 57' 49.4" N; 077º 06' 16.9" W	290.0	181	26.6/42.8	Y
33	WHUT-DT	Washington D.C.	38º 57' 01.0" N; 077º 04' 46.0" W	335.8	178	27.6/44.4	N
34	WUSA-DT	Washington D.C.	38º 57' 01.0" N; 077º 04' 46.0" W	335.8	178	27.6/44.4	Y
35	WDCA-DT	Washington D.C.	38º 57' 22.0" N; 077º 04' 58.0" W	319.6	178	27.2/43.7	N
36	WTTG-DT	Washington D.C.	38º 57' 22.0" N; 077º 04' 58.0" W	319.6	178	27.2/43.7	Y
38	WJZ-DT	Baltimore, MD	39º 20' 05.0" N; 076º 39' 02.0" W	401.0	92	24.1/38.7	Y
39	WJLA-DT	Washington D.C.	38º 57' 01.0" N; 077º 04' 46.0" W	335.8	178	27.6/44.4	Y
40	WNUV-DT	Baltimore, MD	39º 20' 10.0" N; 076º 38' 58.0" W	472.1	92	24.1/38.7	Y
41	WUTB-DT	Baltimore, MD	39º 17' 15.0" N; 076º 45' 37.0" W	458.7	103	18.7/30.0	Y
42	WMPT-DT	Annapolis, MD	39º 00' 36.7" N; 076º 36' 31.8" W	319.7	132	35.2/56.7	Y
43	WPXW-DT	Manassas, VA	38º 47' 16.2" N; 077º 19' 46.3" W	285.8	198	40.7/65.5	N
44	WWPB-DT	Hagerstown, MD	39º 39' 04.0" N; 077º 58' 14.0" W	565.4	294	51.0/82.1	N
45	WBFF-TV	Baltimore, MD	39º 20' 10.0" N; 076º 38' 58.0" W	472.1	92	24.1/38.8	Y
46	WBFF-DT	Baltimore, MD	39º 20' 10.0" N; 076º 38' 58.0" W	472.1	92	24.1/38.8	Y
47	WPMT-DT	York, PA	40º 01' 41.4" N; 076º 35' 58.9" W	562.9	29	53.9/86.7	N
48	WRC-DT	Washington D.C.	38º 56' 24.0" N; 077º 04' 53.0" W	319.7	178	28.3/45.5	Y
50	WDCW-TV	Washington D.C.	38º 57' 44.0" N; 077º 01' 35.0" W	319.7	172	27.0/43.5	N
51	WDCW-DT	Washington D.C.	38º 57' 44.0" N; 077º 01' 35.0" W	319.7	172	27.0/43.5	Y

Table 3-8. Test Site 3 Field Survey Data

Test Site: 3
Location: GPS (WGS-84) coordinates: 39º 20.xxx' N; 077º 05.xxx' W
Description: Two-story Colonial with basement
DTV Installation: Roof-mounted antenna array (2-elements consist of VHF/UHF log-periodic antennas, one pointing in direction of Baltimore market and the other pointed in direction of Washington market) feeding a DTV with external ATSC converter box .

RF Channel	TV Channel	Viewable On DTV Installation?	Location: Attic (L1)			Location: 2nd Flr Foyer (L2)			Location: 1st Flr Dinette (L3)			Location: Basement (L4)		
			Trial #			Trial #			Trial #			Trial #		
			1	2	3	1	2	3	1	2	3	1	2	3
21	-	No	A	A	A	A	A	A	A	A	A	A	A	A
22	22	Yes	W	N	N	N	N	N	N	N	N	N	N	N
23	-	No	N	A	A	N	W	A	N	A	A	A	A	A
24	24	Yes	N	N	N	N	N	W	N	N	N	N	N	N
25	-	No	A	A	A	A	A	A	A	A	A	A	A	A
26	26	Yes	N	N	N	N	N	N	N	N	N	N	N	N
27	26.1	Yes	A	A	A	A	A	A	A	A	A	A	A	A
28	62.1	Yes[3]	A	A	A	A	A	A	A	A	A	A	A	A
29	67.1	Yes	D	D	D	A	A	A	D	A	A	A	A	A
30	-	No	A	A	A	A	A	A	A	A	A	A	A	A
31	-	No	A	A	A	A	A	A	A	A	A	A	A	A
32	32	Yes	A	A	A	A	A	A	A	A	A	A	A	A
33[2]	33	No	A	A	A	A	A	A	A	A	A	A	A	A
34	9.1	Yes	D	D	D	A	A	A	D	A	A	D	A	A
35	20.1	No	D	D	D	A	A	A	A	A	A	A	A	A
36	5.1	Yes	D	A	D	A	A	A	A	A	A	A	A	A
38	13.1	Yes	D	A	A	D	A	A	D	A	A	D	A	A
39	7.1	Yes	D	A	A	D	A	A	D	A	A	A	A	A
40	54.1	Yes	N	N	N	D	A	A	N	N	N	N	N	N
41	24.1	No	D	A	A	A	A	A	D	A	A	A	A	A
42	22.1	Yes	D	A	A	D	A	A	D	A	A	A	A	A
43	-	No	D	A	A	A	A	A	D	A	A	A	A	A
44	-	No	D	N	A	A	A	A	D	A	A	A	A	A
45	45	Yes	W	N	N	N	N	N	N	N	N	N	N	N
46	45.1	Yes	D	A	A	D	A	A	D	A	A	A	A	A
47	-	No	D	A	A	A	A	A	A	A	A	A	A	A
48	4.1	Yes	D	A	A	A	A	A	D	A	A	W	A	A
49	-	No	D	A	A	A	A	A	A	A	A	A	A	A
50	50	No	D	N	N	N	N	A	N	N	A	A	A	A
51	50.1	Yes[3]	D	A	A	A	A	A	A	A	A	A	A	A

Notes:
1. Scanner/Sensor data point indicators: A=available; D=occupied by DTV; N=occupied by NTSC; W=occupied by wireless microphone
2. Channel 33 not on the air during these tests
3. Intermittent reception observed on available DTV installation

Table 3-9. Summary of Field Data Collected at Test Site 3

Channel	Call Sign	Successful Detections				Probability of Successful Detection			
		L1	L2	L3	L4	L1	L2	L3	L4
ATSC (DIGITAL TV)-OCCUPIED CHANNELS									
27	WETA-DT	0/3	0/3	0/3	0/3	0	0	0	0
28	WFPT-DT	0/3	0/3	0/3	0/3	0	0	0	0
29	WMPB-DT	3/3	0/3	1/3	0/3	1.0	0	.33	0
30	WGCB-DT	0/3	0/3	0/3	0/3	0	0	0	0
31	WWPB-TV	0/3	0/3	0/3	0/3	0	0	0	0
33[1]	WHUT-DT	0/3	0/3	0/3	0/3	0	0	0	0
34	WUSA-DT	3/3	0/3	1/3	1/3	1.0	0	.33	.33
35	WDCA-DT	3/3	0/3	0/3	0/3	1.0	0	0	0
36	WTTG-DT	2/3	0/3	0/3	0/3	.67	0	0	0
38	WJZ-DT	1/3	1/3	1/3	1/3	.33	.33	.33	.33
39	WJLA-DT	1/3	1/3	1/3	0/3	.33	.33	.33	0
40	WNUV-DT	3/3	1/3	3/3	3/3	1.0	.33	1.0	1.0
41	WUTB-DT	1/3	0/3	1/3	0/3	.33	0	.33	0
42	WMPT-DT	1/3	1/3	1/3	0/3	.33	.33	.33	0
43	WPXW-DT	1/3	0/3	1/3	0/3	.33	0	.33	0
44	WWPB-DT	2/3	0/3	1/3	0/3	.67	0	.33	0
46	WBFF-DT	1/3	1/3	1/3	0/3	.33	.33	.33	0
47	WPMT-DT	1/3	0/3	0/3	0/3	.33	0	0	0
48	WRC-DT	1/3	0/3	1/3	1/3	.33	0	.33	.33
51	WDCW-DT	1/3	0/3	0/3	0/3	.33	0	0	0
NTSC (ANALOG TV)-OCCUPIED CHANNELS									
22	WMPT-TV	3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0
24	WUTB-TV	3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0
26	WETA-TV	3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0
32	WHUT-TV	0/3	0/3	0/3	0/3	0	0	0	0
45	WBFF-TV	3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0
50	WDCW-TV	3/3	2/3	2/3	0/3	1.0	.67	.33	0
AVAILABLE CHANNELS									
21	-	3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0
23	-	2/3	1/3	2/3	3/3	.67	.33	.67	1.0
25	-	3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0
49	-	2/3	3/3	3/3	3/3	.67	1.0	1.0	1.0

NOTES:
1. Channel 33 not on the air during these tests

3.3.4 Field Test Site 4

Test site 4 is located in King George, Virginia at GPS coordinates 38º 17.xxx' North latitude and 077º 17.xxx' West longitude. The site is a single-story ranch-style home with an unfinished basement. The home is located on the top of a relatively high ridge (~220 ft MSL) and is surrounded by several acres of wooded property. The site is considered to be in a rural population area.

The DTV receiving system at this residence consists of a set-top (indoor) antenna feeding a DTV receiver. These tests were performed on Thursday, June 14, 2007 between the hours of 10:00 AM and 4:00 PM EDT. The scanning capability of the prototype WSD was tested at each of four locations; the living room where the DTV and antenna are located (L1), an exterior deck off the back of the house (L2), a bedroom at the opposite end of the house (L3) and the basement (L4). Tables 3-10, 3-11, and 3-12 present the TV station information and scanning/sensing results for test site 4.

Table 3-10. Broadcast TV Stations within Prototype Tuning Range (21-51) with Service Contours that Include Test Site 4

RF Channel	Call Sign	TX Location	Tower Coordinates (NAD 83)	Tower Height (m above MSL)	Bearing (degrees)	Distance (mi/km)	Channel Reception Verified w/DTV
22	WRIC-DT	Petersburg, VA	37º 30' 45.5" N; 077º 36' 03.9" W	421.9	198	56.9/91.6	N
25	WTVR-DT	Richmond, VA	37º 30' 45.5" N; 077º 36' 03.9" W	421.9	198	56.9/91.6	N
26	WRLH-DT	Richmond, VA	37º 30' 45.5" N; 077º 36' 03.9" W	421.9	198	56.9/91.6	Y
27	WETA-DT	Washington D.C.	38º 53' 30.0" N; 077º 07' 54.0" W	263.8	12	41.7/67.1	Y
30	WNVT-DT	Goldvein, VA	38º 37' 43.1" N; 077º 26' 19.7" W	319.8	340	24.1/38.9	Y
32	WHUT-TV	Washington D.C.	38º 57' 49.4" N; 077º 06' 16.9" W	290.0	12	46.9/75.4	Y
33	WHUT-DT	Washington D.C.	38º 57' 01.0" N; 077º 04' 46.0" W	335.8	14	46.3/74.5	N
34	WUSA-DT	Washington D.C.	38º 57' 01.0" N; 077º 04' 46.0" W	335.8	14	46.3/74.5	Y
35	WDCA-DT	Washington D.C.	38º 57' 22.0" N; 077º 04' 58.0" W	319.6	14	46.6/75.0	N
36	WTTG-DT	Washington D.C.	38º 57' 22.0" N; 077º 04' 58.0" W	319.6	14	46.6/75.0	Y
39	WJLA-DT	Washington D.C.	38º 57' 01.0" N; 077º 04' 46.0" W	335.8	14	46.3/74.5	Y
43	WPXW-DT	Manassas, VA	38º 47' 16.2" N; 077º 19' 46.3" W	285.8	356	33.8/54.3	Y
47	WUPV-DT	Ashland, VA	37º 44' 32.0" N; 077º 15' 14.0" W	302.1	177	38.5/61.9	N
48	WRC-DT	Washington D.C.	38º 56' 24.0" N; 077º 04' 53.0" W	319.7	14	45.6/73.3	Y
50	WDCW-TV	Washington D.C.	38º 57' 44.0" N; 077º 01' 35.0" W	319.7	17	47.8/77.0	Y
51	WDCW-DT	Washington D.C.	38º 57' 44.0" N; 077º 01' 35.0" W	319.7	17	47.8/77.0	N

Table 3-11. Test Site 4 Field Survey Data

Test Site: 4
Location: GPS (WGS-84) coordinates: 39º 17.xxx' N; 077º 17.xxx' W
Description: Single-story Rancher with basement located on ridge-top.
DTV Installation: Set-top ("rabbit ears") antenna connected to DTV receiver.

RF Channel	TV Channel	Viewable On DTV Installation?	Location: LR (L1)			Location: Rear Deck (L2)			Location: BR (L3)			Location: Basement (L4)		
			Trial #			Trial #			Trial #			Trial #		
			1	2	3	1	2	3	1	2	3	1	2	3
21	-	No	A	A	A	A	A	A	A	A	A	A	A	A
22		No	N	A	A	A	A	A	A	A	A	A	A	A
23	-	No	N	A	A	A	A	A	N	A	A	N	N	N
24		No	A	A	A	A	A	A	A	A	A	A	W	A
25	-	No	A	A	A	A	A	A	A	A	A	A	A	A
26[2]	26	Yes	N	N	N	N	N	A	N	N	N	N	N	N
27	26.1	Yes	A	A	A	A	A	A	D	A	A	A	A	A
28	-	No	A	A	A	A	A	A	A	A	A	A	A	A
29	-	No	N	W	A	A	A	A	W	A	A	A	A	A
30	-	Yes	D	D	A	D	A	A	D	D	D	D	D	A
31	-	No	A	A	A	A	A	A	A	A	A	A	A	A
32		Yes	N	N	N	N	N	A	N	N	N	N	N	N
33		No	A	A	A	A	A	A	A	A	A	A	A	A
34	9.1	Yes	D	A	A	A	A	A	D	A	A	A	A	A
35		No	D	A	A	A	A	A	D	A	A	D	A	A
36	5.1	Yes	D	A	A	A	A	A	D	A	A	D	A	A
38		No	D	A	A	A	A	A	A	A	A	A	A	A
39	7.1	Yes	D	A	A	A	A	A	D	A	A	D	A	A
40		No	N	N	N	A	A	A	N	N	N	N	N	N
41		No	D	A	A	A	A	A	A	A	A	A	A	A
42		No	D	A	A	A	A	A	A	A	A	A	A	A
43	-	Yes	D	A	A	A	A	A	D	A	A	A	A	A
44	-	No	D	A	A	A	A	A	A	A	A	A	A	A
45		No	D	A	A	A	A	A	A	A	A	A	A	A
46		No	D	A	A	A	A	A	A	A	A	A	A	A
47	-	No	D	A	A	A	A	A	A	A	A	A	A	A
48	4.1	Yes	D	A	A	A	A	A	D	A	A	A	A	A
49	-	No	D	A	A	A	A	A	A	A	A	A	A	A
50	50	Yes	N	A	A	N	A	A	N	A	A	N	A	A
51		No	D	A	A	A	A	A	A	A	A	A	A	A

Notes:
1. Scanner/Sensor data point indicators: A=available; D=occupied by DTV; N=occupied by NTSC; W=occupied by wireless microphone
2. Site is located between the service contours of WETA-TV and WRLH-DT
3. Channel 33 not on the air during these tests

Table 3-12. Summary of Field Data Collected at Test Site 4

Channel	Call Sign	Successful Detections				Probability of Successful Detection			
		L1	L2	L3	L4	L1	L2	L3	L4
ATSC (DIGITAL TV)-OCCUPIED CHANNELS									
22	WRIC-DT	1/3	0/3	0/3	0/3	0.33	0	0	0
25	WTVR-DT	0/3	0/3	0/3	0/3	0	0	0	0
26[1]	WRLH-DT	-	-	-	-	-	-	-	-
27	WETA-DT	0/3	0/3	1/3	0/3	0	0	.33	0
30	WNVT-DT	2/3	1/3	3/3	2/3	.67	.33	1.0	.67
33	WHUT-DT	0/3	0/3	0/3	0/3	0	0	0	0
34	WUSA-DT	1/3	0/3	1/3	0/3	.33	0	.33	0
35	WDCA-DT	1/3	0/3	1/3	1/3	.33	0	.33	.33
36	WTTG-DT	1/3	0/3	1/3	1/3	.33	0	.33	.33
39	WJLA-DT	1/3	0/3	1/3	1/3	.33	0	.33	.33
43	WPXW-DT	1/3	0/3	1/3	0/3	.33	0	.33	0
47	WUPV-DT	1/3	0/3	0/3	0/3	.33	0	0	0
48	WRC-DT	1/3	0/3	1/3	0/3	.33	0	.33	0
51	WDCW-DT	1/3	0/3	0/3	0/3	.33	0	0	0
NTSC (ANALOG TV)-OCCUPIED CHANNELS									
26	WETA-TV	3/3	2/3	3/3	3/3	1.0	.67	1.0	1.0
32	WHUT-TV	3/3	2/3	3/3	3/3	1.0	.67	1.0	1.0
50	WDCW-TV	1/3	1/3	1/3	1/3	.33	.33	.33	.33
AVAILABLE CHANNELS									
21	-	3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0
23	-	2/3	3/3	2/3	0/3	.67	1.0	.67	0
24		3/3	3/3	3/3	2/3	1.0	1.0	1.0	.67
28		3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0
29	-	1/3	3/3	2/3	3/3	.33	1.0	.67	1.0
31		3/3	3/3	3/3	3/3	1.0	1.0	1.0	1.0
38		2/3	3/3	3/3	3/3	.67	1.0	1.0	1.0
40		0/3	3/3	0/3	0/3	0	1.0	0	0
41		2/3	3/3	3/3	3/3	.67	1.0	1.0	1.0
42		2/3	3/3	3/3	3/3	.67	1.0	1.0	1.0
44		2/3	3/3	3/3	3/3	.67	1.0	1.0	1.0
45		2/3	3/3	3/3	3/3	.67	1.0	1.0	1.0
46		2/3	3/3	3/3	3/3	.67	1.0	1.0	1.0
49		2/3	3/3	3/3	3/3	.67	1.0	1.0	1.0

NOTES:
1. Test site was between service contours of WRLH-DT and WETA-TV. Only the analog (WETA) signal could be received with existing DTV receiving configuration.
2. Channel 33 not on the air during these tests

3.4 Field Test Summary

Table 3-13. Summary of Field Test Data with Prototype A Version 2.

Site	Broadcast Signal Type	Viewable on TV	Total Number of Measurements	Scanner Report	
				No. of times Channel reported available (free) for each signal type	Percent Channel reported available (free) for each signal type
Site 1	None	No	84	77	91.7%
	ATSC	No	48	39	81.3%
	ATSC	Yes	156	93	59.6%
	NTSC	Yes	72	8	11.1%
Site 2	None	No	105	82	78.1%
	ATSC	No	45	33	73.3%
	ATSC	Yes	210	84	40.0%
	NTSC	N/A[29]	90	0	0.0%
Site 3	None	No	48	43	89.6%
	ATSC	No	96	85	88.5%
	ATSC	Yes	144	106	73.6%
	NTSC	Yes	72	17	23.6%
Site 4	None	No	168	143	85.1%
	ATSC	No	72	66	91.7%
	ATSC	Yes	84	63	75.0%
	NTSC	Yes	36	10	27.8%
Total	None	No	405	345	85.2%
	ATSC	No	261	223	85.4%
	ATSC	Yes	594	346	58.2%
	NTSC	Yes	180	35	19.4%

When no signal is expected to be present, the scanner reports the channel to be available or free from 78.1 % to 91.7 % of the time with average number at 85.4% of the time.

[29] At Site 2 there was no NTSC (analog) tuner available to verify the presence of the signal.

However, the scanner also reports the channel to be available or free when the broadcast signal is expected to be present. Three different cases are summarized in the results.

1. In the cases where the NTSC signal is being broadcast, the scanner reports the channel to be free or available between 11.1 % and 27.8 % of the time, with the average of 19.4 % of the time.
2. When the ATSC signal is broadcast two different situations were noted. The first the signal was such that the TV receiver was not able to detect the signal. It is assumed that the signal strength was low for the image not to be viewable on the TV set. In these cases, the scanner reported the channels to be available 81.3 % to 91.7% of the times, with the average at 85.4 % of the time.
3. When the ATSC signal is strong enough to result in a viewable image on the TV, the scanner reported the channel to be available 40 % to 75 % of the times, with the average at 58.2 % of the time. The numbers are particularly high for Sites 3 and 4.

4 Transmitter Emissions Characterization Measurements

This section describes the laboratory measurements performed to quantify the output spectral emissions associated with the Prototype A WSD transmitter (the Prototype B WSD does not have a transmit component). These measurements were not intended to empirically model every potential interference scenario; rather selected attributes of the prototype transmitter's performance were measured to acquire data that can be used in conjunction with previously published data on DTV interference susceptibility[30] in subsequent analytical models to assess the potential for co-channel and/or adjacent channel EMC under various interaction scenario assumptions.

4.1 Transmitter Description

The transmitter component of the prototype WSD utilizes an IEEE 802.11 compliant transceiver card that has been modified to down-convert the operating frequency from the S-band (2.4 GHz) to the relevant UHF frequency range (512-698 MHz) and clocked to occupy one-fourth of the 802.11 transmission bandwidth, or approximately 4.25 MHz. The transmitter power is variable between -10 and +20 dBm and is manually controlled via the computer interface. Since the data from these measurements are intended for future analytical use, the output power was kept constant at the maximum (worst-case) setting (this also represents the default setting). Data transmission is simulated with an OFDM-modulated pseudo-random packet stream, producing a spectral waveform very similar to additive white Gaussian noise (AWGN).

The transmitter is tunable to the center frequency of any TV channel from 21 to 51 (512-698 MHz). An external band-pass filter (BPF), fixed tuned to channel 30, was delivered with the second version of the Prototype A WSD so as to demonstrate the capability for improving the out-of-band emissions spilling into adjacent channels.

4.2 Measurement Approach

The transmitter emissions measurements were performed on a conducted basis (*i.e.*, a shielded RF coaxial cable was used to connect the WSD transmit antenna output port directly to the input port of the spectrum analyzer used to measure the emissions). As a result, the output power levels reported herein do not include any signal gain associated with the transmit antenna. The transmit antenna supplied with the prototype WSD is a small whip antenna and can reasonably be assumed to provide no directionality (gain) over an ideal omnidirectional pattern. No attempt was made to specifically characterize the pattern of the WSD antenna.

Measurements were first performed to assess the transmitter output consistency over the available tuning range. On each of channels 21 (lower), 36 (middle) and 51 (upper), the spectral envelope over the occupied channel and N±5 adjacent channels was

[30] *See* DTV Susceptibility Study.

measured. Spectral parameters, including the occupied bandwidth and the average channel power, were determined from the measured data and compared among each of the three test channels for consistency. The results of this test were examined to determine if the transmitter output was consistent across the test channels. As demonstrated in Section 4.3, the transmitter emission characteristics are consistent across all of the channels tested. Therefore, it was presumed that the results from remaining measurements performed on a single channel will be representative of the output on all available transmit channels.

Channel 30 was chosen as the representative channel for these measurements in order to accommodate an examination of the WSD spectral characteristics associated with the fixed-tuned BPF and also to facilitate the use of an available fix-tuned (channel 30) band-reject (notch) filter in order to improve the instrument sensitivity to accommodate the out-of-band emissions measurements. Subsequent measurements were made of the average power in the fundamental channel and in the N±5 adjacent channels, both with and without the external BPF inserted into the transmit circuit. The resulting data was summarized for use in future link budget analyses to be performed under various interference interaction scenario assumptions.

4.3 Measurement Equipment Configuration

The emissions produced by the WSD transmitter were measured by connecting the transmit antenna port directly to the measurement instrument (*i.e.*, no radiated measurements were performed). The instrument utilized for the measurements described in this section was a state-of-the art spectrum analyzer. Analyzer settings, including resolution bandwidth (RBW), video bandwidth (VBW), sweep time, number of measurement bins, etc., were maintained across all of the measurements for consistency. Data analysis functions available in the spectrum analyzer were utilized to determine parameters from the measured data such as the average broadband power in each 6-MHz TV channel examined.

Measurements of the emissions in the fundamental channel (without the external BPF) were performed utilizing the simple equipment configuration depicted in the block diagram shown in Figure 4-1.

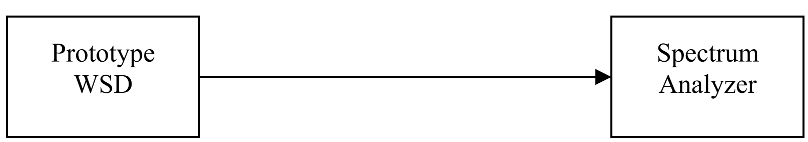

Figure 4-1. Fundamental Channel Measurement System (without BPF)

The equipment configuration used for measuring the fundamental emissions after insertion of the external BPF is represented by the block diagram in Figure 4-2. A 10-dB in-line attenuator (pad) was added to the transmit circuit to ensure impedance matching between the WSD antenna output port and the BPF input port (this set-up was specified by the manufacturer).

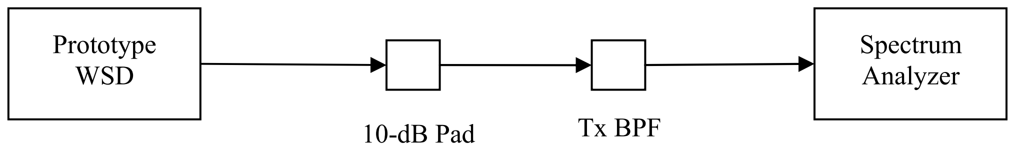

Figure 4-2. **Fundamental Channel Measurement System (with BPF)**

Figures 4-3 and 4-4 show the equipment configurations used for measuring the out-of-band spectral characteristics in the N±5 adjacent channels for the WSD transmitter without the external transmit BPF and with the BPF, respectively. The primary difference between this system relative to that used to measure in the fundamental channel is the incorporation of an RF band-reject (notch) filter. This filter was utilized to suppress the fundamental channel energy in order to improve the dynamic range of the amplitude space, facilitating the measurement of low out-of-band signal levels.

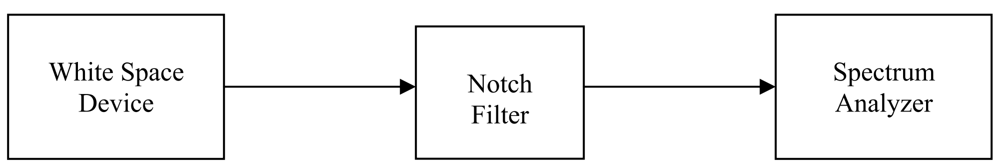

Figure 4-3. **Adjacent Channel Measurement on WSD without filter**

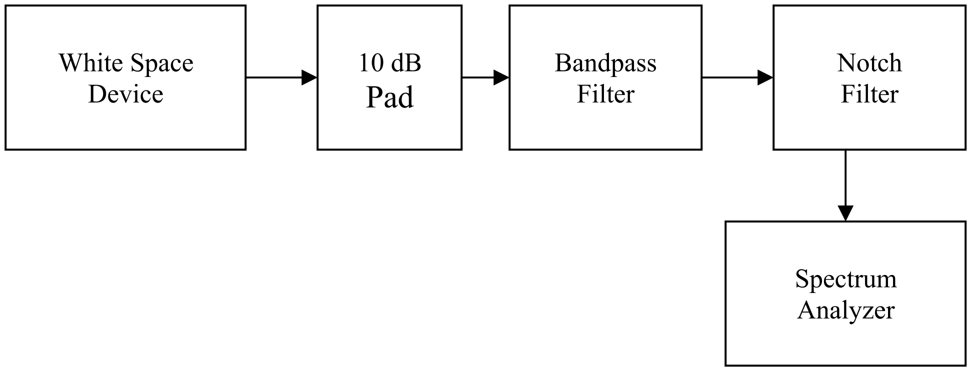

Figure 4-4. **Adjacent Channel Measurement on WSD with Filter**

4.4 Channel Consistency Test

On each of channels 21 (lower), 36 (middle) and 51 (upper), the spectral envelope over the occupied channel and N±5 adjacent channels was measured at the transmitter antenna output port. Spectral parameters including the occupied bandwidth and the average broadband power were determined from the measured data and compared among each of the three test channels for consistency. These tests were performed without the external BPF which is fixed-tuned to operate only on channel 30.

Figures 4-5 through 4-7 present the spectral plots obtained from these measurements and Table 4-1 summarizes the parameters used to assess consistency among the test channels. Based on these results, it was determined that the spectral output is consistent over the channels measured and thus, can be presumed to also be consistent across the entire transmit channel space (21-51). As a result, all subsequent emissions measurements were performed on channel 30 as previously discussed.

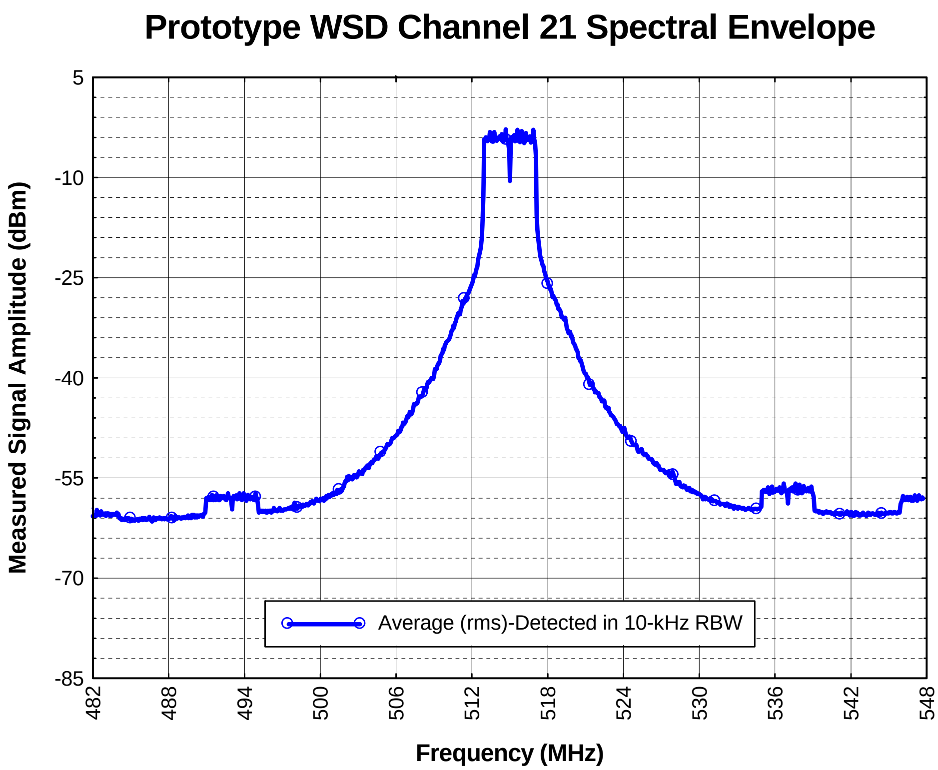

Figure 4-5. Prototype A Transmitter Spectral Envelope Centered in Channel 21.

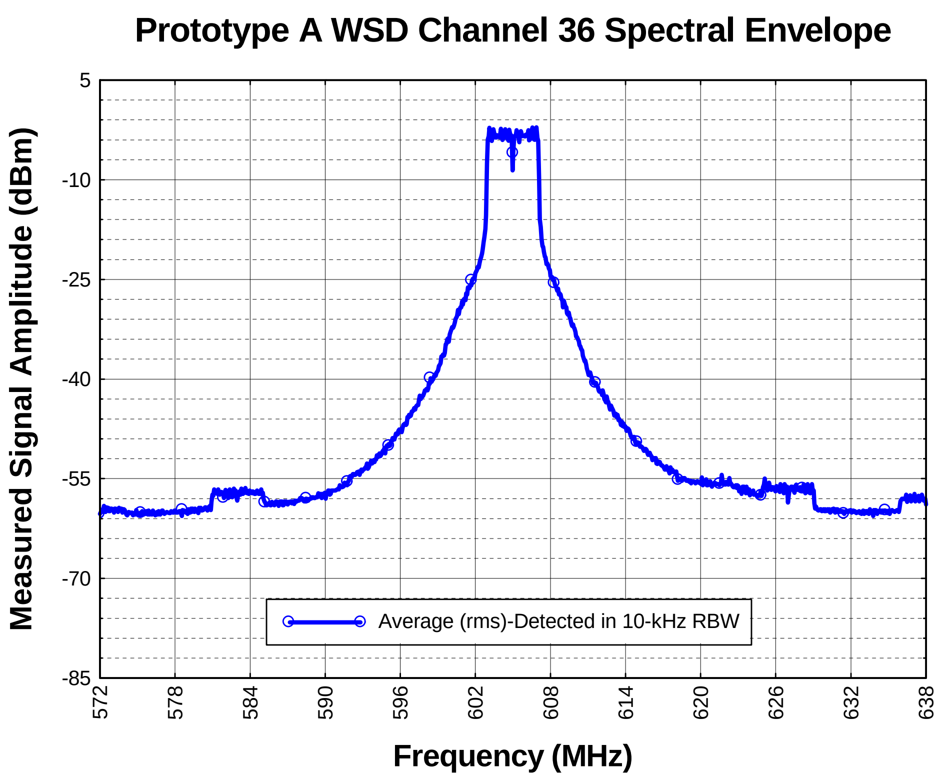

Figure 4-6. Prototype A Transmitter Spectral Envelope Centered in Channel 36.

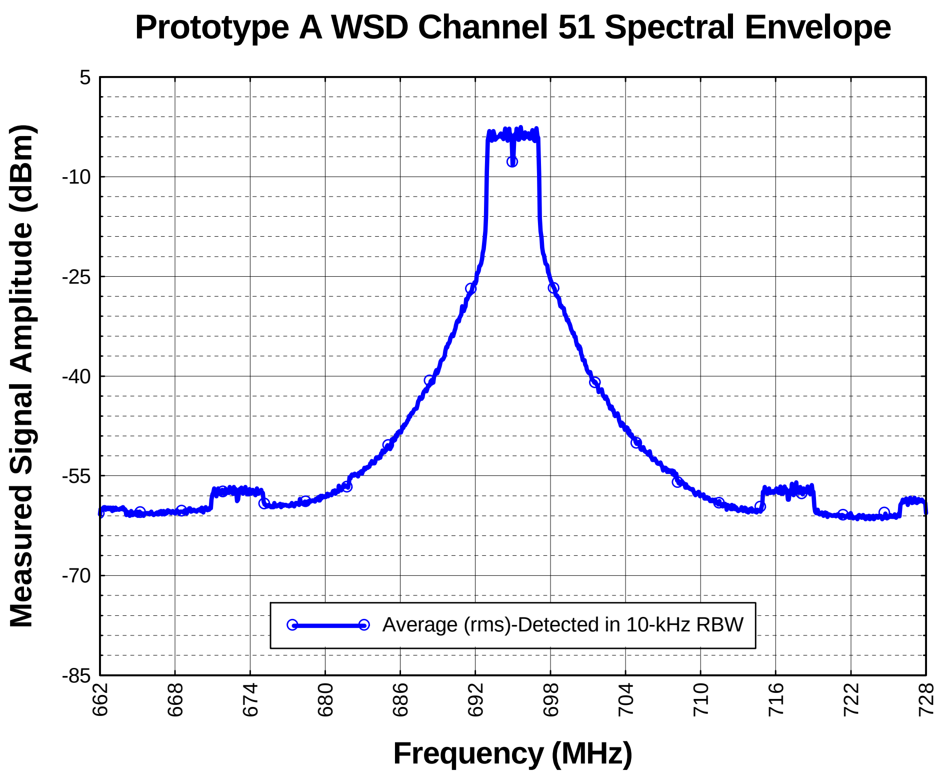

Figure 4-7. Prototype A Transmitter Spectral Envelope Centered in Channel 51.

Table 4-1. Summary of Prototype Transmitter Channel Consistency Test Data.

Test Channel	Center Frequency (MHz)	Measured Average Channel Power (dBm/6-MHz)	Occupied Bandwidth (MHz)	
			-3 dB	-20 dB
21	515	21.8	4.19	5.86
36	605	22.4	4.21	5.95
51	695	21.9	4.18	6.14

4.5 Fundamental Channel Emissions Measurements

Measurements were performed to characterize the spectral parameters associated with the WSD output signal as it appears within the television channel used for transmission (*i.e.*, the fundamental channel). These measurements were performed with the WSD transmitter tuned to the center frequency of TV channel 30 (569 MHz) in order to compare the spectral output with and without the use of the manufacturer-supplied fixed-tuned BPF. The spectral plots presented in Figure 4-8 show the output spectrum of the prototype WSD transmitter within the channel 30 bandwidth (566-572 MHz) as measured at the transmit antenna output port. Two curves are shown on this graph, one depicting the measured output spectrum with the external BPF transmit filter and one showing the output spectrum without the BPF. Similarly, Figure 4-9 shows an extended spectral envelope, both with and without the use of the external BPF, spanning over the fundamental channel and the N±5 adjacent channels.

The measured power in the fundamental channel can be seen to be approximately 14 dB less when the BPF is inserted into the transmission circuit (relative to the unfiltered spectra). This effective BPF insertion loss represents the sum of the actual insertion loss of the BPF, the 10-dB attenuation in the impedance-matching pad and any additional attenuation in the extra connections.

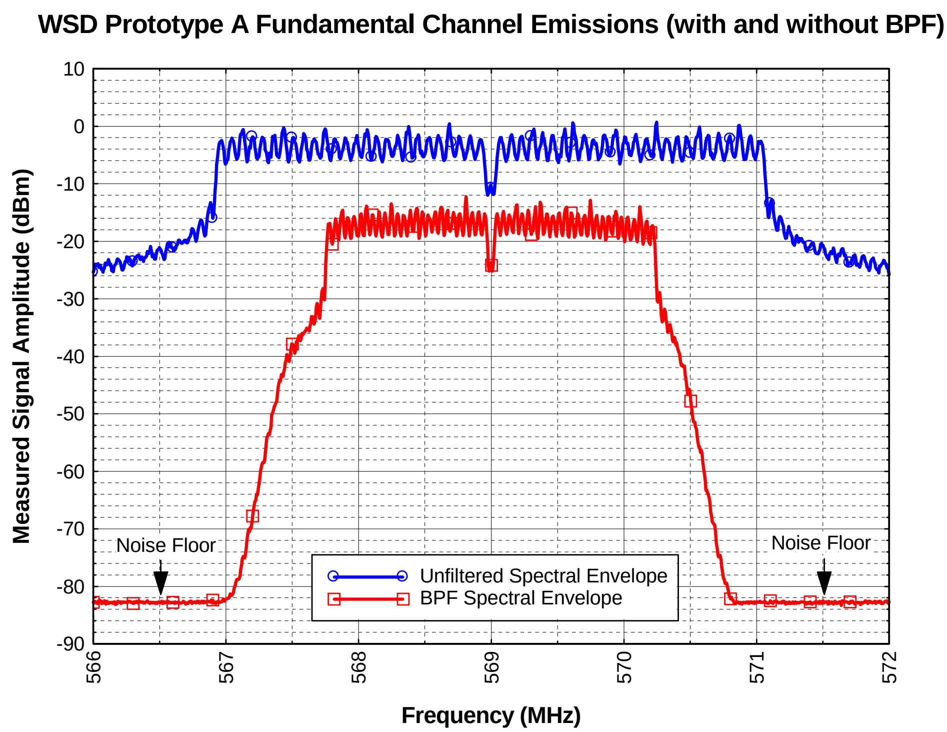

Figure 4-8. Prototype A Fundamental Channel Emissions in Channel 30.

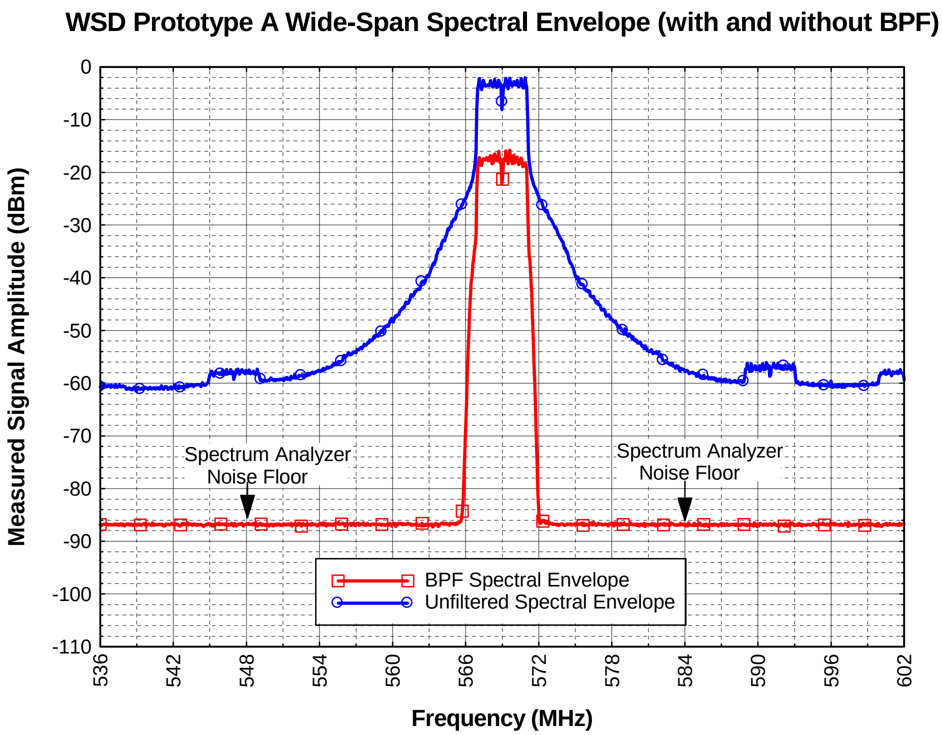

Figure 4-9. Prototype A Emissions on Channel 30 and N±5 Adjacent Channels.

4.6 Out-of-Channel Emissions Measurements

Measurements were performed to quantify the out-of-channel power in each of the five adjacent channels above and below the fundamental transmit channel (N±5). A fixed-tuned (channel 30) RF band-reject (notch) filter was utilized to suppress the fundamental channel energy in order to improve the dynamic range of the amplitude space, thus facilitating the measurement of the relatively low signal levels (with respect to the fundamental energy) in the adjacent channels. Figure 4-10 demonstrates the characteristics of the transmitter output with the notch filter as compared to the extended spectral envelope of the WSD prototype transmitter (without the external BPF). This notch filter suppresses the average broadband power by 25 dB over the channel and the measured insertion loss of the filter is 2.9 dB (including any loss due to cables).

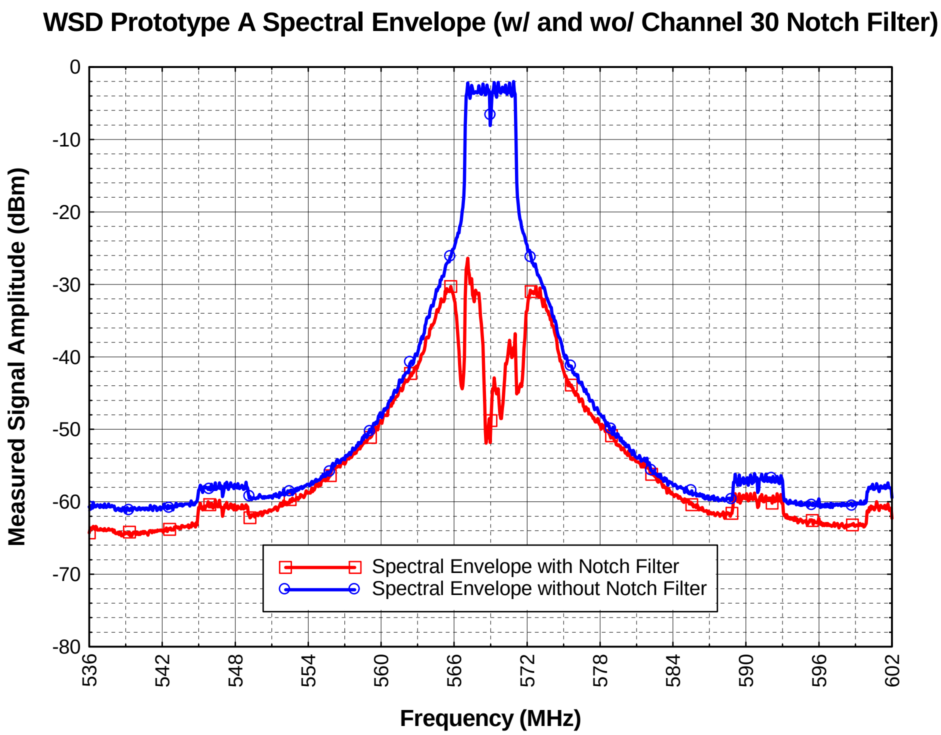

Figure 4-10. Prototype A Spectral Envelope with and without Notch Filter.

4.7 Emissions Characterization Data Summary

Table 4-2 summarizes the channel power data obtained from the emissions characterization measurements described in this section.

Table 4-3 shows the results of a comparison between the out-of-channel emissions from the WSD transmitter operating with and without the BPF. When assessing filter performance, one accepted notation is to express the power in an adjacent channel relative to the power in the carrier (i.e., in the fundamental channel). This convention facilitates a comparison of filter characteristics and is applied to the data presented in this table. Therefore, the power shown in the adjacent channels is expressed relative to the fundamental power in units of dBc.

Table 4-2. Summary of Emissions Characterization Data.

Test Channel	Center Frequency (MHz)	Average Channel Power (dBm/6-MHz)[2]	
		w/o BPF	w/ BPF
30/(N)	569	22.1	8.2
29/(N-1)	563	-6.1	-64.3
31/(N+1)	575	-5.7	-69.5
28/(N-2)	557	-23.0	-90.2
32/(N+2)	581	-23.0	-92.6
27/(N-3)	551	-31.1	< -95.5
33/(N+3)	587	-30.0	< -95.5
26/(N-4)	545	-31.4	< -95.5
34/(N+4)	593	-30.4	< -95.5
25/(N-5)	539	-33.7	< -95.5
35/(N+5)	599	-32.8	< -95.5

Notes:
1. WSD w/BPF channel power measurements noise-limited beyond N±2
2. Adjusted for notch filter insertion loss where appropriate.

Table 4-3. Summary of Emissions Characterization Data.

Test Channel	Center Frequency (MHz)	Channel Power relative to Fundamental Channel Power (dBc)	
		w/o BPF	w/ BPF
30/(N)	569	-	-
29/(N-1)	563	-28.2	-72.5
31/(N+1)	575	-27.8	-77.7
28/(N-2)	557	-45.1	-98.4
32/(N+2)	581	-45.1	-100.8
27/(N-3)	551	-53.2	< -103.7
33/(N+3)	587	-52.1	< -103.7
26/(N-4)	545	-53.5	< -103.7
34/(N+4)	593	-52.5	< -103.7
25/(N-5)	539	-55.8	< -103.7
35/(N+5)	599	-54.9	< -103.7

5 Over-The-Air Interference Test

An outdoor test was performed to demonstrate the potential for the transmitter emissions from the Prototype A WSD to cause radio interference to the OTA reception of DTV broadcasts under real-world conditions. An examination of a wide range of possible interference interaction scenarios was beyond the scope of this project. Thus, a simple interaction scenario was chosen for examination under the premise that the results can serve as a baseline for modeling more complex scenarios.

5.1 Test Approach

The interaction scenario assumed for this test can be considered to be near "worst-case" in that it utilized an unobstructed line-of-sight (LOS) propagation path between the WSD transmit antenna and the receive antenna used with the DTV test receiver. Additionally, main-beam coupling was assumed between the antennas and they were restricted to the same elevation plane. Live OTA DTV signals were utilized in the test and therefore no control could be exercised over desired signal parameters such as the received DTV power level. As a result of this limitation (and others, such as the statistical significance of a limited number of tests over a limited receiver sample space), this test should be considered anecdotal in nature and the results used accordingly.

The FCC Laboratory compound was utilized for the test because it permitted locating the prototype device at varying distances from the test receive antenna. In addition, these separation distances could be realized with little or no potential for interference to local residential OTA reception.

An open area test range was set-up over the Laboratory's parking lot and extending into an adjacent open field to accommodate this test (see Figure 5-6). The test range was marked in 10-meter increments, out to a maximum distance of 120 meters. The test DTV receiver (identified as DTV receiver sample I1 in a previous FCC study[31]) was connected to a tripod-mounted calibrated log-periodic antenna through 20 feet of RG-55 coaxial cable and tuned to the channel selected for the test. A spectrum analyzer with internal pre-amplifier was used to measure the DTV spectral signature and the average broadband channel power.

The orientation of the test site required that the DTV test receiver antenna be pointed north to avoid close in obstructions. Thus, the candidate OTA broadcast signals available for the test were limited to those located to the north of the test site (*i.e.*, stations in the Baltimore market). Table 5-1 lists relevant information for all of the available DTV stations broadcasting in the Baltimore market. The last column in the table shows the relative measured signal strength at the test location for each of the available DTV broadcasts (not adjusted for antenna gain or cable loss).

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[31] *See* DTV Susceptibility Study.

Table 5-1. Available DTV Test Channels.

RF Channel	Call Sign	Tx Location	Bearing	Distance (mi/km)	Received Power (dBm)
29	WMPB-DT	Baltimore	7º	19.4/31.2	-63.5
38	WJZ-DT	Baltimore	39º	14.8/23.8	-42.9
40	WNUV-DT	Baltimore	39º	14.9/23.8	-47.8
41	WUTB-DT	Baltimore	22º	8.9/14.3	-68.7
46	WBFF-DT	Baltimore	39º	14.9/23.9	-51.8

The selection of an appropriate test channel was also limited by the need to insert Prototype A's fixed-tuned bandpass filter (BPF) into the transmission circuit for a portion of these tests. This filter is tuned to channel 30, so tests for adjacent channel interactions can only be made on a test channel close to channel 30. Given these scenario limitations, channel 29 appeared to be the best available option for performing these tests, despite the fact that the signal power was observed to be lower in channel 41. In addition, the orientation of the test range better accommodated the use of this channel (i.e., 7º vs. 22º bearing). Thus, channel 29 was selected for use as the test channel. A plot depicting the noise-limited service contour of WMBP-DT, the DTV station assigned to channel 29, is provided in Figure 5-1.

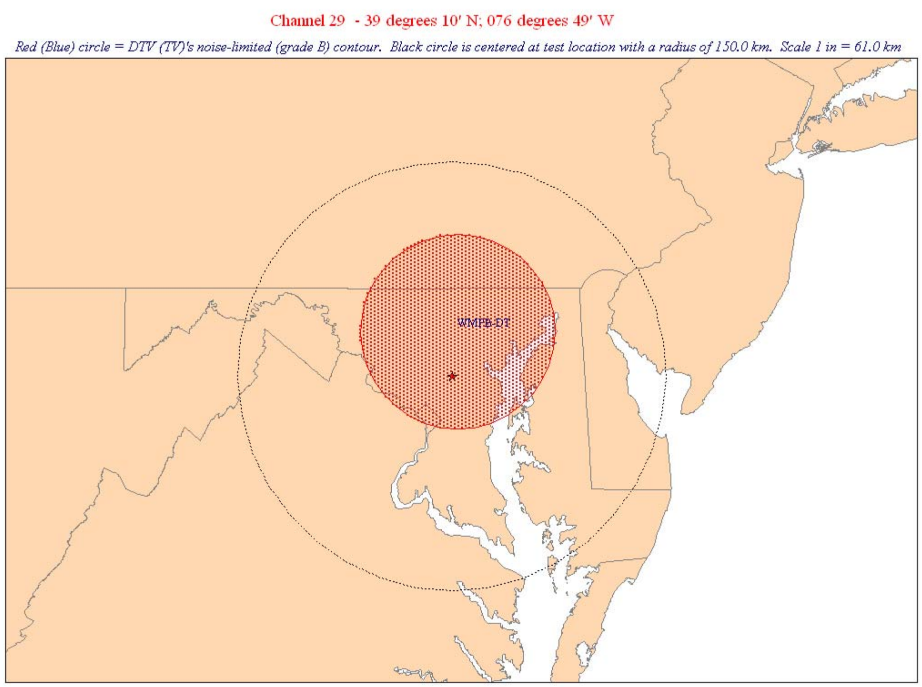

Figure 5-1. Service Contour for WMPB-DT on Channel 29.

Figure 5-2 shows the channel 29 broadcast DTV signal as measured with the test antenna. The average broadband channel power was determined to be -63.5 dBm for this signal at the DTV receive antenna input. This is 20.5 dB higher than the threshold of visibility (TOV) for a typical DTV receiver (-84 dBm).

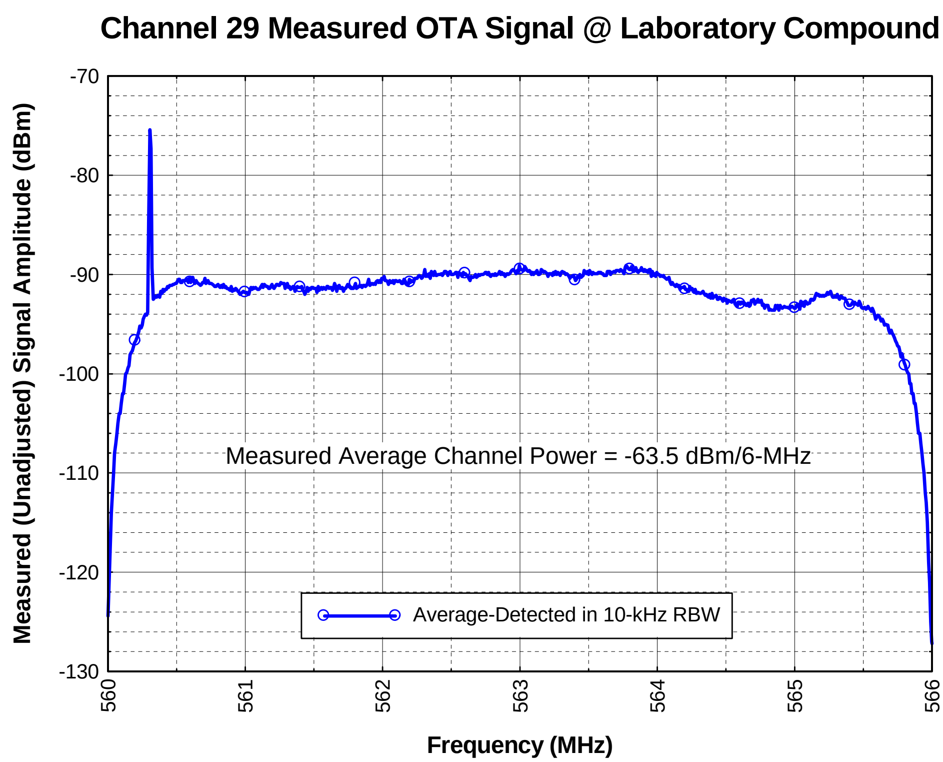

Figure 5-2. Measured DTV Signal in TV Channel 29 at DTV Test Receive Antenna Location.

5.2 Test System

Figure 5-3 presents a block diagram representation of the instrumentation system used to perform this test and Figures 5-4, 5-5 and 5-6 provide photographic documentation of the test set up. An Agilent E4440 Spectrum analyzer (with internal pre-amp) was used to measure the OTA signal levels. An A.R.A. log periodic antenna (model number LPB-2520/A) was connected to the test DTV receiver (or the spectrum analyzer for signal measurements) with a 20-ft length of RG-55 coaxial cable.

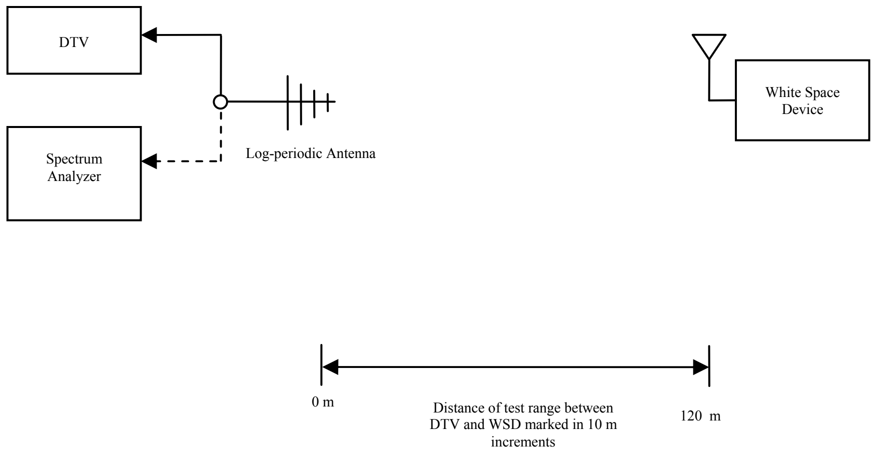

Figure 5-3. Test System Block Diagram.

Figure 5-4. Test Receive System.

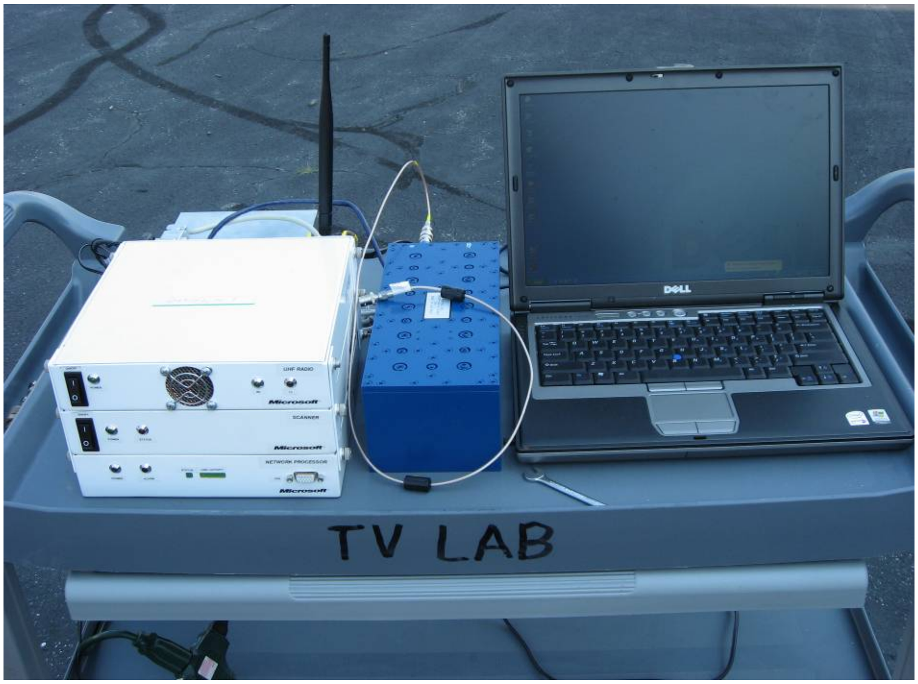

Figure 5-5. Prototype WSD Transmitter on Wheeled Cart.

Figure 5-6. WSD Prototype Transmitter Downrange from Test Antenna.

5.3 Test Procedure

The DTV receiver was tuned to channel 29 and the receive antenna oriented towards the WMPB-DT transmitter located at a bearing of 7º. The displayed picture quality was observed and found to be acceptable (no frame freeze or pixilation observed). The WSD transmit system was placed on a non-conductive wheeled cart (see Figure 5-5) and placed within the receive antenna main-beam at the far end of the test range (120 meters distant from test antenna).

The prototype transmitter (without the BPF) was first tuned to channel 29 in order to determine the maximum co-channel interference distance. While transmitting on channel 29, the cart was slowly moved toward the DTV test antenna until interference was observed. Although freeze-frame and/or pixilation were considered to be valid picture degradation metrics, the most common interference observation was a complete loss of picture. Once the distance was reached where interference was first observed, a fine tuning process was used to determine the precise interference distance. This process consisted of moving the transmitter towards and/or away from the test antenna in small increments while turning the transmitter on and off and observing the effect to the test DTV picture quality. The interference distance determined by this method was recorded.

This procedure was repeated to determine the interference distances associated with first adjacent channel interactions (N±1 or channels 28 and 30) and second adjacent channel interactions (N±2 or channels 27 and 31) without the external BPF.

Finally, the procedure was repeated once again to determine the interference distance with respect to an adjacent-channel interaction with the WSD transmitter utilizing the external BPF. Since the BPF is fixed-tuned to channel 30, the N+1 (first) adjacent channel interaction was the only one that could be examined as a part of this test. Also, since it was found from the measurements reported in Section 4 that there is an effective insertion loss of 14 dB associated with the external BPF circuit, a co-channel test was not performed with the WSD transmitter utilizing the external BPF.

5.4 Test Results

Table 5-2 presents a summary of the results obtained from this test. It is recognized that many of the variable parameters in this test are statistical in nature (*e.g.*, time-varying desired signal levels) and thus, multiple measurements would be needed to establish statistically-relevant results. In addition, the test was performed with a very small sample size of victim DTV receivers (one), so its results cannot be characterized as statistically representative of the population of DTV receivers. Nonetheless, these results provide a demonstration of the interference potential to DTV receivers that may be introduced by the operation of unlicensed personal/portable WSD applications in the broadcast television spectrum even under favorable DTV reception conditions (*e.g.,* with a received DTV signal level well above TOV).

Table 5-2. Summary of OTA Interference Test Results.

Interference Interaction	Interference Distance (meters)*
Prototype WSD without BPF	
Co-Channel	87
1st Adjacent Channel (N-1)	47
1st Adjacent Channel (N+1)	52
2nd Adjacent Channel (N-2)	11
2nd Adjacent Channel (N+2)	14
Prototype WSD with BPF	
1st Adjacent Channel (N-1)	2

***These interference distances are specific to the interaction scenario examined. The measured DTV signal level is more than 20 dB above the typical TOV signal level. Thus, a similar test performed with the DTV signal at TOV will likely result in much greater interference distances.**

6 Data Observations Relevant to TV Services

This section offers observations based on the data resulting from the tests and measurements performed on the prototype WSDs delivered to the FCC laboratory for evaluation. The observations offered are limited to the data resulting from 1) tests performed to assess the capability for detecting TV signals (Section 3), 2) measurements to characterize the transmitter emissions (Section 4) and 3) an anecdotal test to demonstrate the capability for introducing electromagnetic interference to broadcast DTV operations (Section 5). These observations are based on measurements performed both in the laboratory and in the field.

6.1 Scanning/Spectrum Sensing Capability Tests

Three separate tests were designed to assess the detection capability of the prototype WSDs. A bench test was performed on each prototype, utilizing a laboratory-generated DTV signal, to determine a baseline minimum detection threshold and associated detection reliability. A second bench test was performed on each prototype utilizing two laboratory-generated DTV signals with one signal in the channel to be scanned and the second placed in an adjacent channel to determine the minimum achievable detection threshold in the presence of nearby occupied channels. The third test involved a set of field measurements to assess the WSD scanner performance under "real world" conditions. Prototype B was exempted from the field test at the manufacturer's request.

6.1.1 Prototype A Results

The scanning/spectrum sensing component of prototype A did not meet expectations as demonstrated by these tests. The results of the bench test for determining the baseline minimum detection sensitivity demonstrates that the device will not meet the manufacturer-specified threshold of -114 dBm (or the IEEE 802.22 proposed threshold of -116 dBm for fixed devices) and in fact, fails to meet both of the thresholds by about 20 dB. The results of the field tests also demonstrate inconsistent performance. When consideration is limited only to relatively strong DTV signals (i.e., those that could be verified by reception on a DTV set), the likelihood of them being successfully detected and identified as occupied was very low. When consideration is extended to include broadcasts from distant stations (where the test site was at or near the service contour periphery), the demonstrated detection performance was poorer.

One possible explanation for the poor detection performance represented by this prototype may involve a misinterpretation of the detection threshold. The minimum detection threshold as specified in the manufacturer's literature is the "minimum discernible DTV pilot tone sensitivity." If this statement is interpreted literally then it may explain the observed performance demonstrated by the prototype device. The pilot signal amplitude is nominally 11.6 dB less than the integrated average power in the 6-

MHz channel (11.3 dB less than the data signal power[32]). Therefore, a threshold specification of -114 dBm relative to the pilot signal amplitude actually represents a detection threshold level of -102.7 dBm when expressed relative to the broadband channel power. But, the -114 dBm threshold put forth by the White Space Coalition in the proceeding record is predicated upon protecting DTV operation to a threshold of visibility (TOV) signal level of -84 dBm with an additional 30 dB included to offset worst-case interaction assumptions (*e.g.*, the hidden node scenario)[33] and the TOV is expressed in terms of the average broadband power in the channel. While this inconsistency may explain a large part of the discrepancy between the specified and observed detection thresholds, it is not a complete explanation (*i.e.*, it only explains 11.6 dB of the discrepancy).

The results of the field tests indicate that the scanning/spectrum sensing function of Prototype A for detecting TV channels occupied with NTSC signals is better than for the DTV signal but it is still not reliable.

The scan period of this prototype device is 27-seconds per channel for a total period of 14 minutes to complete a full-channel scan.

6.1.2 Prototype B Results

The results from the baseline detection threshold tests indicate that the scanning/spectrum sensing component of Prototype B performs as specified by the manufacturer. The test results verify the ability of the prototype to reliably detect television channels occupied with DTV signals down to the specified level of -114 dBm. However, it is also noted that the reliability begins to degrade below the threshold level. The two-signal test results seem to show that the detection reliability below -114 dBm may be even further degraded by the introduction of a second DTV signal on a nearby channel. Since this prototype was exempted from field tests, the scanning/spectrum sensing performance was not determined under real-world conditions. Therefore, the overall detection capability with live signals of this device is unknown.

The scan period of the Prototype B WSD is 8 seconds for an individual channel scan and 4 minutes to complete a scan of the full tuning range.

[32] The ATSC specifies that the power of the pilot tone of a transmitted 8-VSB DTV signal "shall be 11.3 dB below the average data signal power." (Advanced Television Systems Committee, "ATSC Digital Television Standard: Part 2—RF/Transmission System Characteristics", ATSC Doc. A/53 Part 2:2007, 3 January 2007, p.40). Because the presence of the pilot raises the total signal power by 0.3 dB, the pilot power is 11.6 dB below the total signal power. This specification applies to the transmitted signal. Multipath effects during transmission can cause the pilot level in the received signal to be higher or lower than this relative to the total received signal power.

[33] Comments of Dell Inc., Google, Inc., The Hewlett-Packard Company, Intel Corp., Microsoft Corp., and Philips Electronics North America Corp., Jan 31, 2007 @ 5-7.

6.2 Transmitter Emissions Characterization Measurements

Measurements were performed to characterize the spectral parameters associated with the WSD prototype transmitter. Since Prototype B did not have a transmit/receive capability, this discussion is limited to the transmitter contained in the Prototype A WSD. The spectral parameters associated with the prototype transmitter were characterized both for operation with and without the use of an external band-pass-filter (BPF) that was supplied with the prototype, apparently to demonstrate the level of transmission filtering that can be achieved.

The data produced from these measurements is intended for use in future analytical efforts. A previous report released by OET very thoroughly detailed the interference susceptibility associated with modern DTV receivers and can be utilized with the transmitter emissions data presented herein to perform link budget analyses performed to assess the potential for electromagnetic compatibility under various interaction scenario assumptions.[34]

The measured out-of-channel emissions data demonstrate that without additional filtering, the out-of-band emissions from the prototype transmitter are likely to be inadequately suppressed in the immediately adjacent channels (approximately -28 dBc) and the skirts fall off very gradually out to five channels removed from the fundamental channel (-55 dBc). With the external BPF, the out-of-channel emission performance is greatly improved (-75 dBc in the adjacent channel and more than -100 dBc five channels removed). This data demonstrates that such a band pass filter can significantly reduce the out-of-channel emissions. However, it remains to be seen whether or not this degree of filtering can actually be realized in a tunable BPF implemented at base-band.

6.3 OTA Interference Test

The results of the test to determine interference potential of a WSD to over-the-air TV reception must be treated as anecdotal given the many variable parameters that were beyond control. For example, an available OTA DTV signal broadcast on channel 29 was used to represent the desired signal in this test. However, the measured signal level was more than 20 dB above the TOV level typically assumed in worst-case interference analyses. Thus, the interference distances resulting from the test are likely to be considerably less than what would be determined for interactions with a desired DTV signal at the TOV level.

Notwithstanding the above caveats, this test does demonstrate that interference can occur at significant distances from a victim DTV receiver, even under favorable DTV reception conditions (*i.e.*, received signal significantly above TOV). This was seen to be particularly true for co-channel interactions that may occur as a result of unreliable detection of occupied channels.

[34] *See* DTV Susceptibility Study.

7 Wireless Microphones Measurements

7.1 Introduction

The WSD performance capabilities examined in this test project with respect to wireless microphones are the ability of the Prototype A and Prototype B devices to sense wireless microphones and the potential for the Prototype A device to interfere with wireless microphone signals when transmitting.

Three Part 74 wireless microphone systems, designated Systems 1, 2, and 3 were used in the testing with the WSD.[35] Systems 1 and 3 consist of a receiver and two microphones and System 2 is a receiver and one microphone. These microphone systems are capable of operating on TV channels 41 to 51. Measurement of the RF transmit spectrum of each of these microphones revealed that the signals of the System 1 and 3 microphones were virtually identical, including a 32 kHz pilot tone, while the signals of the System 2 microphone were similar to those of Systems 1 and 3, but with a 19 kHz pilot tone. The microphones' signals are frequency modulated and are limited to a 200 kHz occupied bandwidth. The results of tests for co-channel interference to the System 1 and 3 microphones using simulated undesired signals with each microphone/receiver combination (these were the first wireless microphone tests performed) were consistent with the assumption that the signals were similar. Thereafter, only one microphone was used for testing each system. The microphones used are designated WM1 for System 1, WM2 for System 2 and WM3 for System 3. The spectrum characteristics of the WM1 and WM2 units when modulated by a 1000 Hz tone at 24 kHz deviation are shown in Figures 7-1 and 7-2

[35] These wireless microphones are all Shure Incorporated products that were loaned to the Commission for this testing.

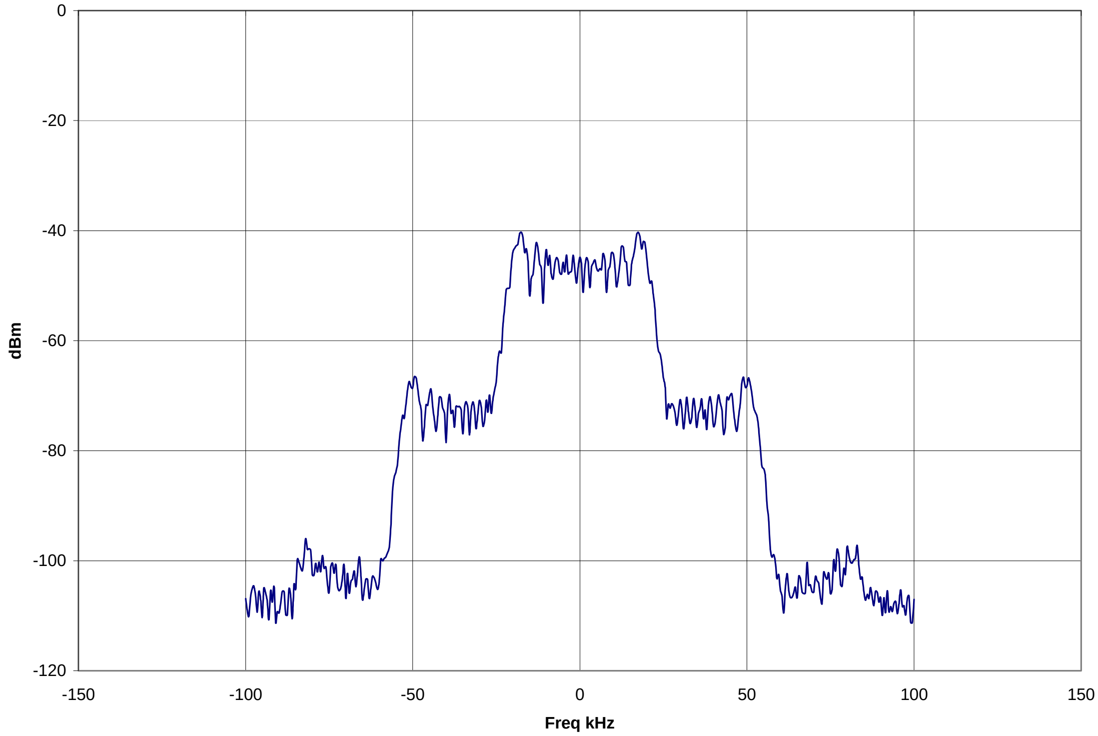

Figure 7-1. WM1 Wireless Microphone Spectrum Characteristics

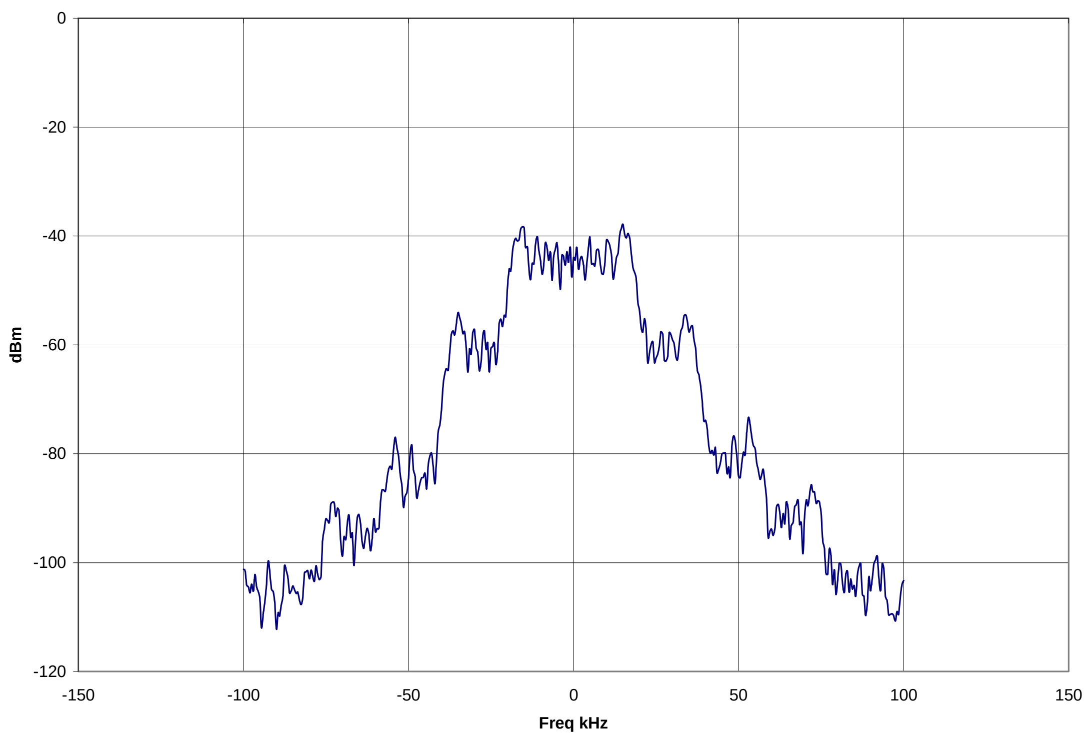

Figure 7-2. WM2 Wireless Microphone Spectrum Characteristics

7.2 Sensing of Wireless Microphones by White Space Devices

In the tests for sensing of wireless microphones, WM1 and WM2 were used to generate the signals to be sensed. The test signals were modulated at 1000 Hz with 24 kHz deviation as shown in Figures 7-1 and 7-2 above (note that WM1 has a pilot tone at 32 kHz and WM2 has a pilot tone at 19 kHz). It is recognized that the modulation used for testing may not represent the "best case" signal for detection by a white space device. For the wireless microphone tests which required a DTV signal, that signal was simulated with a Rohde & Schwarz SFU signal generator with a channel 48 filter. The emissions characteristics of this signal are shown in Figure 7-3 along with the emissions mask for DTV signals specified in Section 73.622(h) of the Commission's rules.[36] These tests were performed with the wireless microphone in the FCC Laboratory's anechoic chamber to isolate the microphone from the receiver which was found to be sensitive to direct pickup of radiated emissions from the microphone and to minimize interference from ambient signals. . The wireless microphone sensing measurements were performed with the test setup shown in Figure 7-4.

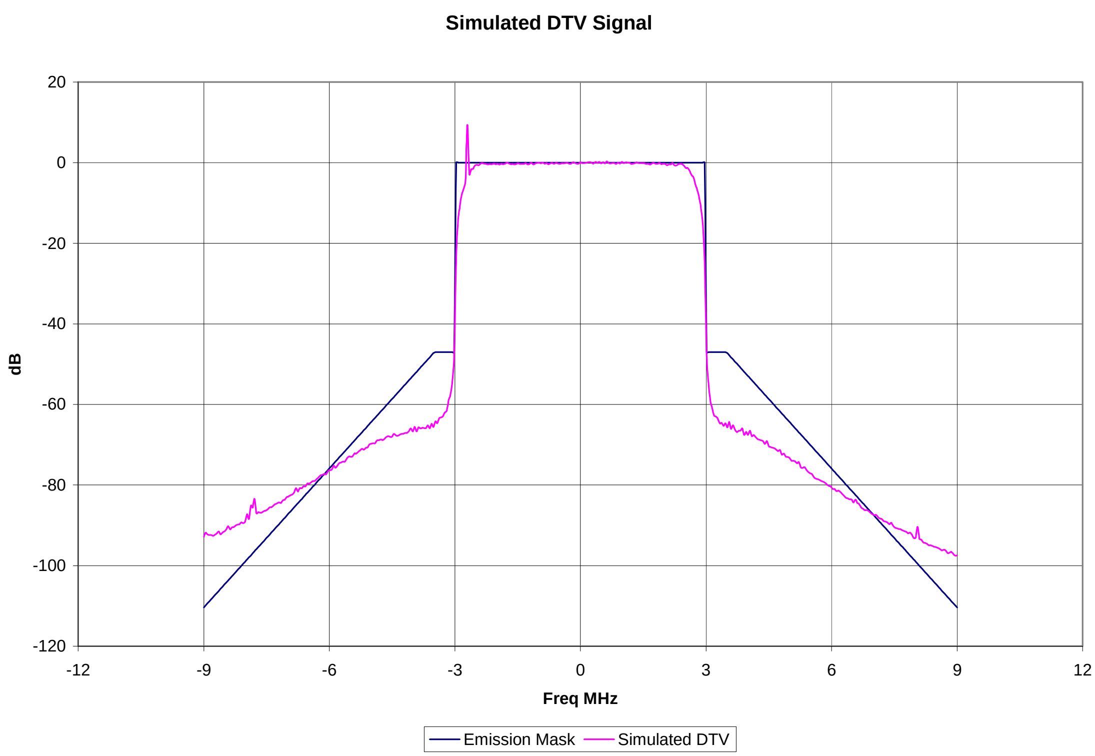

Figure 7-3. Simulated DTV Signal

[36] *See* 47 C.F.R. § 73.622(h).

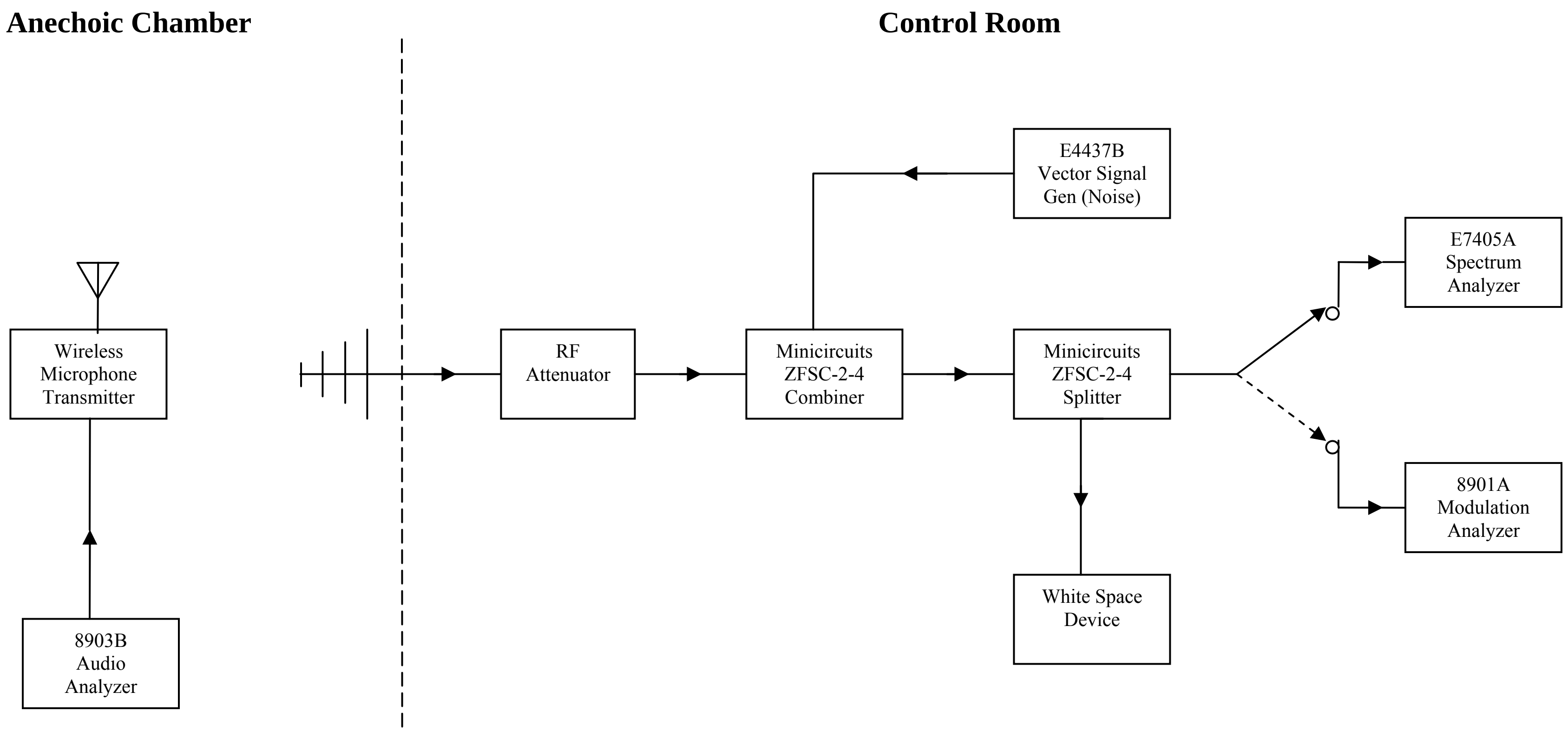

Figure 7-4. Sensing Test Setup

7.2.1 Prototype A Device

The Prototype A device was generally unable to sense wireless microphones. This device was tested with wireless microphone signals at various power levels and locations in a TV channel, and with and without the presence of a DTV signal on a different channel at different power levels. Table 7-1 shows the results of scanning channels 48 and 49 with the simulated DTV signal in channel 48 and the WM1 microphone signal in the center of channel 49 at a power level of -66 dBm. In many cases, the device incorrectly sensed the WM1 signal as a DTV signal on channel 49. The Prototype A device produces a score for the three different types of signals when it scans. It then declares a channel to be occupied or available depending on whether or not the score for each type of signal exceeds a predetermined threshold which is unknown.

Multiple scans were run with the DTV power level set at -84 dBm and the device reported a score of zero for the microphone, except once a score of 4, indicating the presence of a wireless microphone on Channel 49, as shown in the following table. The results in Table 7-1 were obtained after repeating the tests a number of times to ensure consistency in the results. In spite of the poor performance of the Prototype A device, further testing was performed using a higher modulation frequency and greater deviation and with no modulation to see if this would improve the sensing capability of the device. However, using a modulation frequency of 2500 Hz and a deviation of 40 kHz or using no modulation showed no improvement.

Table 7-1. Prototype A Sensing

DTV Power DBm	Scan	Channel	Detection
-53	1	48	D
		49	D
-68	1	48	D
		49	D
-84	1	48	D
		49	D,W
	2	48	D
		49	A
	3	48	D
		49	D

NOTES:
1. A = available, D = occupied by DTV, N = occupied by analog TV, W = occupied by wireless microphone

7.2.2 Prototype B Device

The Prototype B device was tested for its ability to sense wireless microphone signals using the same procedure and test set up as that used to test Prototype A's wireless microphone sensing ability. In these tests, the input signal to the receiver was adjusted to several power levels within its normal range. The Prototype B device was tested in a variety of situations and conditions and its performance was mixed. In the initial, informal testing of this device it was found that the device's performance did not vary significantly with the TV channel on which the wireless microphone was operated. Therefore the tests were conducted with the wireless microphones operating on only a few channels in the range of channels 44-49. Table 7-2 shows the results of the tests of Prototype B with the WM1 wireless microphone is operating at 653 MHz, which is the middle of channel 44. These results indicate that the Prototype B device is able to sense WM1 on this channel in all scans at signal levels as low as -120 dBm. However, on some scans from channel 21 to 51 the device also incorrectly indicated the presence of a microphone on channel 24. In addition, when WM1 signal was at the -36.6 dBm level, the prototype also incorrectly sensed wireless microphone signals on six additional channels. Using a modulation frequency of 2500 Hz and a deviation of 40 kHz showed no improvement in sensing capability, but with no modulation the device was able to sense the microphone at about a 5 dB lower signal level.

Table 7-2. Prototype B Sensing with WM1 Microphone at Center of Channel 44

Microphone Power dBm	Scan	Microphone Sensed on Channels
-36.6	1	26,28,29,31,35,44,46
-76.3	1	44
	2	44
	3	44
-106.3	1	44
	2	24,44
	3	44
-116.3	1	24,44
	2	24,44
	3	24,44
-120.3	1	24,44
	2	24
	3	24,44

As shown on Table 7-3, when the WM1 microphone frequency is changed to 650.05 MHz, which is 50 kHz from the low end of channel 44, the device senses a microphone on channels 43 and 44 at signal levels as low as -106 dBm, but senses nothing at signal levels of -110 dBm or lower.

Table 7-3. Prototype B Sensing with WM1 Microphone 50 kHz from Low End of Channel 44

Microphone Power dBm	Scan	Microphone Sensed on Channels
-36.6	1	26,29,31,40,43-47
-76.3	1	43,44
	2	43,44
	3	43,44
-106.3	1	43,44
	2	43,44
	3	43,44
-110.3	1	None
	2	None
	3	None
-116.3	1	None
	2	None
	3	None

Table 7-4 provides the results for the WM2 wireless microphone operating at 661.8 MHz, which is 200 kHz from the high end of channel 45. At low power levels the prototype correctly sensed a microphone on channel 45 and also incorrectly sensed a microphone on channel 46. With the WM2 signals at the moderate power level of -67.1 dBm, the device correctly sensed a wireless microphone on channel 45 and also incorrectly sensed microphones on channels 46 and 47. The tests for WM1 and WM2 were performed at their operating frequencies which are different.

Table 7-4. Prototype B Sensing with WM2 Microphone 200 kHz from High End of Channel 45

Microphone Power dBm	Scan	Microphone Channels Sensed
-67.1	1	45,46,47
	2	45,46,47
	3	45,46,47
-107	1	45
	2	45
	3	45
-114	1	45
	2	45
	3	45

Tests of the Prototype B devices ability to sense wireless microphones were also performed with the simulated DTV signal shown in Figure 7-3 on channel 48 and the

WM1 microphone signal on channel 49 at 680.125 MHz, which is 125 kHz from the low end of channel 49. In these tests, the device was again used to scan all channels from 21 to 51 searching for DTV, analog TV, and wireless microphone signals. The results of these tests with the microphone signal at -114 dBm and a variable DTV signal level are shown in Table 7-5.

Table 7-5. Prototype B Sensing - Channels Sensed As Occupied

DTV Power dBm	DTV Channels (48)	Analog TV Channels (none)	Microphone Channels (49)
-28	48,49,50	47,48,49,50	33,34,44,45,46,51
-53	48,49	48,49	47,50
-68	48	48	27,47,49,50
-84	48	48	44,46,49

On this table, the number in parentheses at the head of the column is the correct response. The device correctly identified the presence of DTV signal on channel 48 but also incorrectly indicated the presence of DTV signals on channels 49 and 50 when the DTV signal on channel 48 was at -53 dBm and higher. It incorrectly indicated the presence of an analog TV signal on the channel occupied by the DTV signal at all levels of the DTV signal actually present and also incorrectly indicated the presence of analog TV signals on other channels, especially as the level of the DTV signal present was raised. The prototype correctly sensed the wireless microphone only at the two lowest DTV power levels and incorrectly sensed its presence on several other channels at all power levels. In a separate trial in which the device was instructed to scan only channel 49 and to search only for microphones and with the microphone on channel 49 at -114 dBm and a DTV signal on channel 48, it correctly sensed the microphone signal on channel 49 over the DTV signal power range -28 to -84 dBm.

7.3 Interference to Wireless Microphones

Tests were conducted to gauge the susceptibility of Part 74 wireless microphone systems to possible interference from unlicensed WSDs. Before the Prototype A device became available, this test project first examined the potential for interference to wireless microphones using the three Part 74 wireless microphone systems described above and WSD signals that were simulated using an audio modulated FM signal, a wideband noise signal and a wideband OFDM signal. When the Prototype A WSD became available, it was tested for interference to a wireless microphone system. In these tests, interference was defined to occur at the point where the signal-to-noise plus distortion (SINAD) ratio reading at the audio output of the microphone receiver was 30 dB. The desired wireless microphone signals were modulated at 1000 Hz with 24 kHz deviation level and were input to the receiver at -80 dBm. The microphone transmitter spectrum characteristics for the System 1, 2, and 3 signals are shown in Figures 7-1 and 7-2. The undesired signals were: 1) an FM signal audio modulated with a 400 Hz tone at 24 kHz deviation, 2) a white Gaussian noise signal with a 3 dB bandwidth of 5.4 MHz, and 3) an OFDM signal with a 3 dB bandwidth of approximately 4.75 MHz. The signal from the Prototype A device was an OFDM signal with a 3 dB bandwidth of 4.125 MHz as shown in Figure 7-5. No additional filtering was used because no filters were available for the channels on which the wireless microphones operated.

Testing was performed using the test setup of Figure 7-6. Preliminary tests revealed that the Prototype A device was very susceptible to direct pickup of the RF signal from the microphone. It was therefore necessary to isolate the microphone from the Prototype A device and the test equipment. The test procedure consisted of modulating the microphone as specified and adjusting the band power to -80 dBm input to the microphone receiver. The undesired signal input to the receiver was then increased until the SINAD decreased to 30 dB as indicated on the audio analyzer. The band power of the undesired signal at the input to the receiver was then recorded. Tests were made for co-channel and first and second adjacent channel interference. For co-channel tests the desired signal was located near the center of the TV channel. For adjacent channel tests the desired signal was located near the center or the upper or lower edge of a TV channel and the undesired signal was located in the first or second adjacent channel nearest to the desired signal. The test results are shown on Tables 7-6, 7-7 and 7-8.

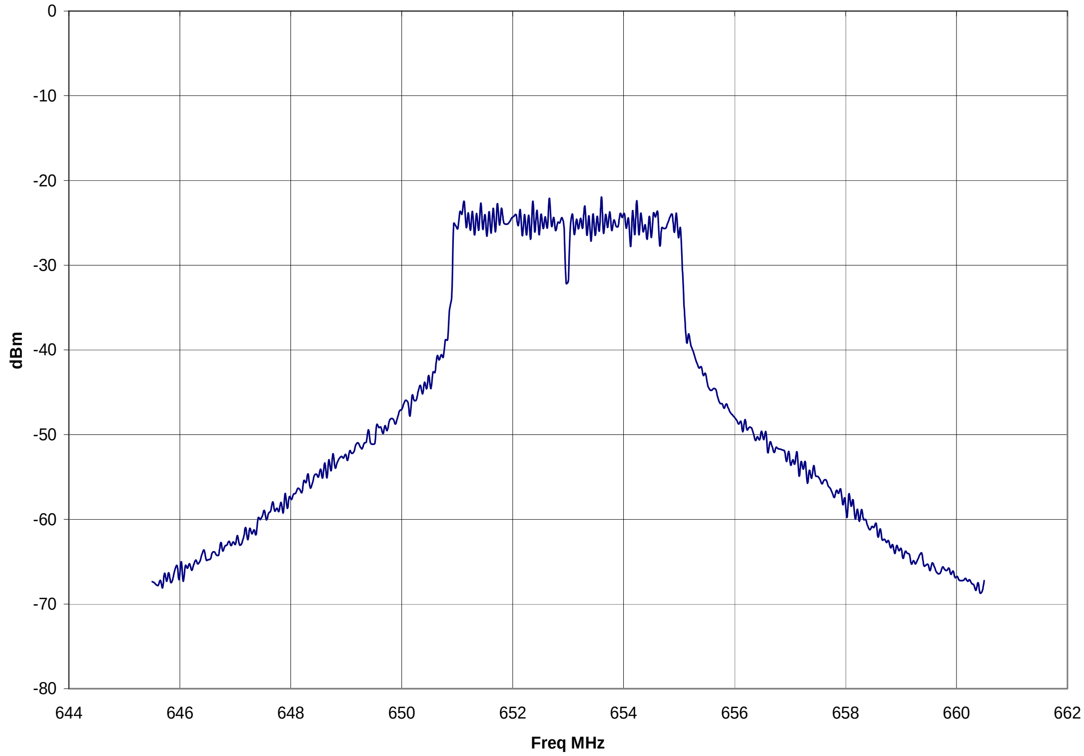

Figure 7-5. Prototype A Device Transmit Spectrum

Table 7-6 below shows the undesired signal power level for each type of signal above which the SINAD was less than 30 dB for co-channel interference for each microphone transmitter and receiver combination. Note that the power level for the undesired signals, except the FM signal, is for a wideband signal as compared to the relatively narrowband desired signal. The power of the broadband signals (noise, ODFM and Prototype A) is spread over a wider bandwidth compared to the FM signal. The difference in the power level below is because of the difference in the occupied bandwidth.

Table 7-6. Co-channel Undesired Interference Power Level (dBm)

Microphone	WM1	WM1-2	WM2	WM3	WM3-2
System	1		2	3	
FM	-87.0	-87.0	-88.0	-87.5	-87.0
Noise	-75.4	-75.3	-88.0	-74.3	-74.3
OFDM	-76.1	-76.0	-88.9	-74.2	-74.2
Prototype A	-76.5		-89.0	-76.7	

Table 7-7 shows the undesired signal power level above which the SINAD was less than 30 dB for first adjacent channel interference from the simulated WSD signals. In some cases the desired signal was lost before the SINAD indication decreased to 30 dB as the undesired signal level was increased. The undesired FM signal was located 50 kHz from the edge of the desired signal channel nearest to the desired signal. These measurements show wide variability in the microphone systems' susceptibility to both FM and wideband signals. These results show that in most cases the wireless microphones are 15 dB or more less susceptible to interference from the simulated WSD signals on first adjacent channels than on the same channel. As might be expected, the results for System 1 also show that this system tends to be more susceptible to an undesired signal on an adjacent frequency closer to the frequency used by the system. However, the System 1 measurements at the closer 50 kHz spacing show less susceptibility to interference than the wideband measurements for Systems 2 at greater frequency spacings.

Table 7-7. Adjacent Channel Undesired Interference Power Level (dBm) for Simulated WSD Signals

Microphone	WM1		WM2	WM3
System	1		2	3
Distance of desired signal from edge of channel	50 kHz	200 kHz	200 kHz	200 kHz
FM	-89.9	-22.8	-46.9	-45.0
Noise	-60.3	-55.4	-70.1	-51.5
OFDM	-26.0	-24.3	-35.9	-16.3

Table 7-8 shows the results from measurements with the Prototype A device operating in the first and second adjacent channels. These measurements show that wireless microphones susceptibility to interference from Prototype A's signals decrease significantly as the frequency difference between the desired and undesired channels increases.

Table 7-8. 1st and 2nd Adjacent Channel Prototype A Device Interference Power Level (dBm)

Microphone	WM1			WM2		WM3	
System	1			2		3	
Distance of desired signal from edge of channel	50 kHz	200 kHz	Center	200 kHz	Center	200 kHz	Center
1st Adj Channel	-51.8-	-52.6	-38.7	-63.3	-48.5	-51.5	-37.3
2nd Adj Channel	-32.0	-30.4	-28.4	-48.7	-35.4	-31.5	-27.4

Beside the white space device power level, the two main factors that determine the susceptibility of wireless microphone systems to interference from those devices are the RF spectrum occupied by the undesired signal and the selectivity of the microphone receiver. The spectrum characteristics of the Prototype A device as delivered to the FCC Laboratory for testing is as shown in Figures 7-5 above. The interference susceptibility data in Table 7-8 demonstrates the effect of these two factors. In all cases, interference occurs at lower device power levels when the microphone operating frequency is 200 kHz from the channel edge closest to the undesired signal than when it is at the center of the TV channel in which it is operating. This is caused by the out-of-channel skirts of the device spectrum. However, System 2 suffers interference at lower device power levels because of the wider selectivity of its receiver.

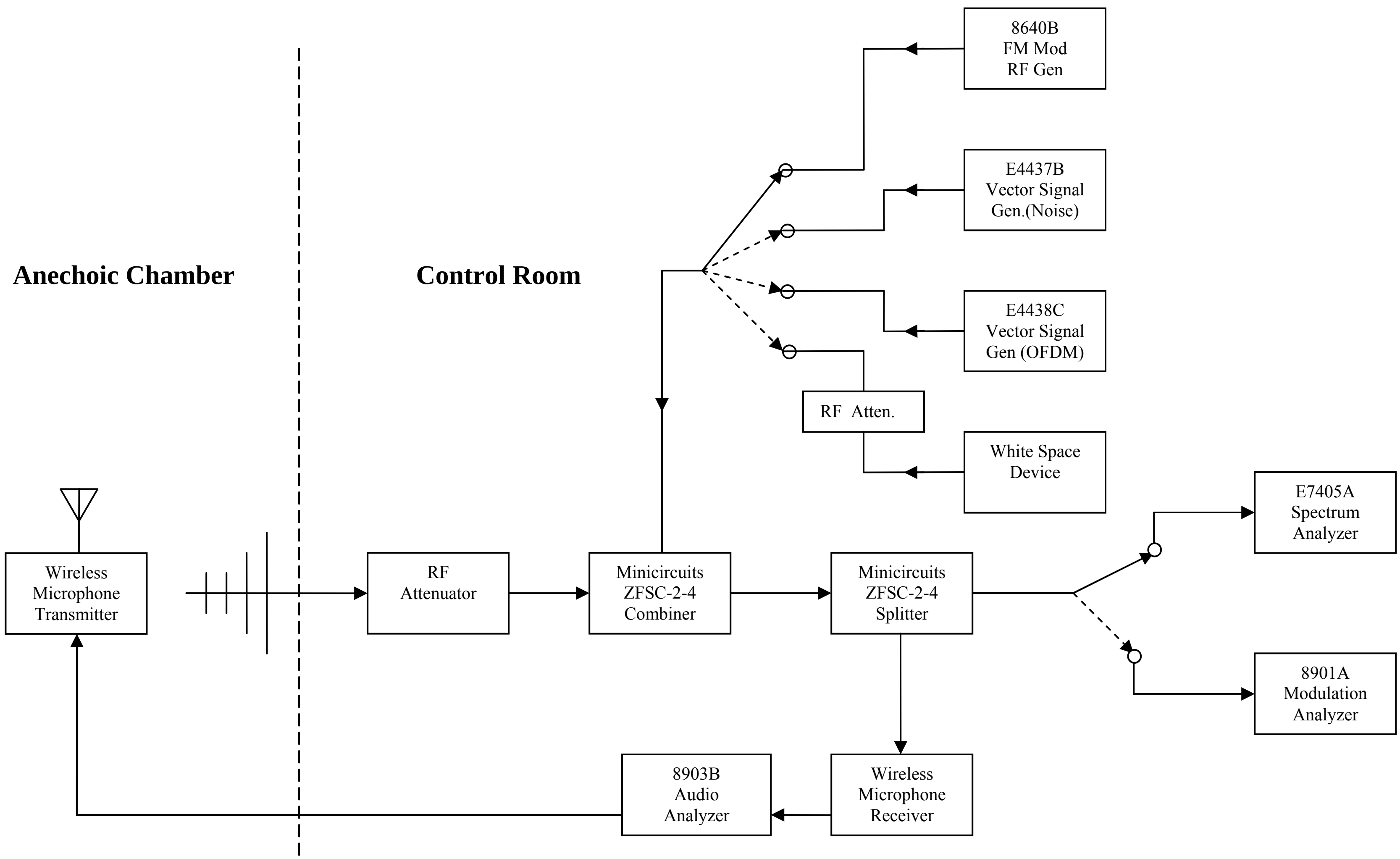

Figure 7-6. Interference Test Set Up

Appendix A – Measurement Systems

This appendix provides information regarding the measurement equipment used to perform this test/measurement program. Table A-1 provides a list of the equipment used, including the manufacturer and model number, a brief description and where appropriate, the most recent manufacturer calibration date. Calibration information resulting from measurements performed in the laboratory to determine the signal attenuation in various circuits used to support the test/measurements is also provided.

Table A-1. List of Measurement Equipment

Equipment	Quantity	Manufacturer and Model	Specifications	Last Calibrated
Spectrum Analyzer	1	Agilent E4448 PSA	3 Hz-50 GHz	06/09/06
Spectrum Analyzer	1	Agilent E4440 PSA	3 Hz – 26.5 GHz (w/ internal PA)	07/18/06
Spectrum Analyzer	1	Agilent E7405A EMC	9 kHz – 26.5 GHz	09/01/06
Modulation Analyzer	1	Agilent 8901A		02/27/06
Audio Analyzer	1	Agilent 8903B		09/25/03
Signal Generator	1	Agilent E4437B ESG	250 kHz-4 GHz	05/25/06
Signal Generator	1	Agilent 4438C ESG	250 kHz – 6 GHz	02/22/05
Signal Generator	1	Agilent 8640B	500 kHz – 1024 MHz	09/06
Broadcast Test System	2	Rhode and Schwarz SFU	w/ ATSC Signal Generator	-
Step Attenuator	1	Hewlett-Packard 355D	10-dB steps	-
Step Attenuator	1	Hewlett-Packard 355 C	1-dB steps	-
Step Attenuator	1	Agilent 8494B	0 to 11 dB DC – 18 GHz	11/09/04
Step Attenuator	1	Agilent 8495B	0 to 70 dB DC – 18 GHz	08/05/05
TV Channel Rejection Filter	1	TLE Model CE7569-N30	566-572 MHz	-
Signal Combiner	2	MiniCircuits ZFSC-2-1W	50 Ω	-
Log Periodic Antenna	1	A.R.A. LPB-2520/A	25 MHz – 2.0 GHz	-
Impedance Matching Transformer	1	Trilithic ZMT-57	75-50 Ω	-

The following information is provided with respect to calibrations performed as a part of this program to determine the signal attenuation (or gain) associated with the various components used to support the test/measurements.

The input signal level used in the detection threshold was set at the input to the WSD scanner antenna input port and thus, no signal calibration was necessary.

A short length (2-feet) of RG-223/U coaxial cable was used to connect the WSD transmitter output port directly to the spectrum analyzer for performing the transmitter emissions measurements. The signal attenuation in this cable was measured and found to exhibit a maximum loss of 0.4 dB over the frequency range involved (512-698 MHz). The insertion loss associated with the channel-reject (notch) filter is 2.9 dB, including the additional coaxial cable used to integrate into the measurements system.

The OTA interference test utilized a log periodic antenna as the test antenna and it was connected to the DTV receiver (or spectrum analyzer) with a 20-ft length of RG-55 coaxial cable. The signal attenuation in the cable run was measured and determined to be a maximum of 2.3 dB. In addition, there was a measured signal loss associated with the impedance-matching transformer of 0.9 dB and the antenna gain over the 512-698 MHz frequency range is 7.1-7.5 dBi.

Appendix B – Service Contours of TV Stations at Field Test Sites

This appendix contains plots depicting the service contours of each full service and low power TV station (including auxiliary transmitting antennas) on channels within the prototype WSD tuning range that have been authorized for use by a licensed television broadcaster relative to each site where field measurements were performed. The test location is represented on these plots by a red star. All broadcast licensees and construction permits within a 150-km (94-mile) of the test site were included in the contour plots. Red circles indicate DTV stations; blue circles indicate analog TV stations. There are a total of thirty plots provided for each test site, one for each channel in the WSD's tuning range.

(See Separate File)