Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Unlicensed Operation in the TV Broadcast Bands	)	ET Docket No. 04-186
	)	
Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band	)	ET Docket No. 02-380

COMMENTS OF MSTV AND NAB TO THE OET REPORT ON THE PERFORMANCE OF PROTOTYPE TV-BAND WHITE SPACE DEVICES

August 15, 2007

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EXECUTIVE SUMMARY

The Commission's most recent reports in this proceeding lead to an inevitable conclusion: if let loose in the DTV band, personal/portable unlicensed devices will cause widespread disruption of digital television service. The "spectrum sensing" scanners used by these devices cannot reliably detect occupied digital television channels and are easily broken. There is thus no basis for authorizing personal/portable devices. The Commission should instead move forward with its proposal to authorize *fixed* devices, as proposed by IEEE 802 and supported by a diverse coalition of rural broadband providers, broadcasters, consumer electronics manufacturers and others.

Proponents of personal/portable devices are asking the Commission to risk the future of America's television broadcasting system – and the ultimate success of the DTV transition – on whether a few "prototype" devices work in a laboratory. In the Commission's recent testing, the Microsoft device failed to detect occupied television channels at the -114 dBm level suggested by the White Spaces Coalition, and both devices failed to sense effectively at the *Further NPRM*'s minimum detection level of -116 dBm. As MSTV and NAB demonstrate in the attached Field Measurement Report, even if devices were able to sense at the *Further NPRM*'s detection threshold, they would still fail to protect television services from harmful interference. Sensing has never been proven to work in the real world to prevent interference from unlicensed personal/portable devices.

If the custom-built devices submitted for Commission testing were unable to effectively sense in a laboratory, one can only imagine the consumer outrage if personal/portable devices are allowed to enter the market and result in millions of Americans losing access to DTV signals. Authorizing personal/portable devices to operate in the television spectrum is extremely risky because if sensing fails, the interference in the television spectrum can go for miles. The Commission and the American public cannot afford to take this risk.

It is time to stop experimenting with the 100 million digital TV sets that will be purchased by 2009. It is time to stop playing 'interference roulette' with government-subsidized digital-to-analog converter boxes. It is time to focus engineering efforts and resources on successfully completing the DTV transition and moving forward to adopt appropriate protections for the authorization of fixed devices. Such action will both protect the public's investment in DTV receivers (including digital cable-ready sets) and converter boxes *and* promote the deployment of broadband access to rural and other underserved areas. MSTV and NAB look forward to working with the Commission to ensure that American consumers continue to receive high quality, interference-free broadcast DTV service.

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TO THE OET REPORT ON THE PERFORMANCE
OF PROTOTYPE TV-BAND WHITE SPACE DEVICES

The Association for Maximum Service Television, Inc. ("MSTV")[1] and the National Association of Broadcasters ("NAB")[2] commend the Commission's Office of Engineering and Technology ("OET") and its Laboratory Division for performing thorough and comprehensive tests on the performance of the prototype unlicensed devices submitted to the OET for testing. The Commission's findings in its recent report on the Performance of Prototype TV-Band White Space Devices ("FCC Report") confirm MSTV and NAB's previously filed concerns about interference from personal/portable unlicensed devices and the studies demonstrating the inadequacy of spectrum sensing to protect television viewers and other incumbent users of that spectrum.[3] Further, the Commission's report on the Direct-Pickup Interference of Consumer Digital Cable Television Receivers ("FCC Direct-Pickup Report")

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[1] MSTV is a non-profit trade association of local broadcast television stations committed to achieving and maintaining the highest technical quality for the local broadcast system.

[2] NAB is a nonprofit trade association that advocates on behalf of more than 8,300 free, local radio and television stations and also broadcast networks before Congress, the Federal Communications Commission and other federal agencies, and the Courts.

[3] *See Initial Evaluation of the Performance of Prototype TV-Band White Space Devices*, OET Report, FCC/OET 07-TR-1006 (July 31, 2007) ("FCC Report").

demonstrates that personal/portable devices will also cause significant interference to cable television services.[4]

As the Commission moves forward with this proceeding, it must not lose sight of the importance of ensuring a successful transition to digital television ("DTV"). In preparation for this transition, consumers and broadcasters will continue to spend billions of dollars on new digital equipment. In addition, the government has allocated 1.5 billion dollars to fund digital-to-analog-converter boxes. Millions of viewers will depend upon these boxes to continue over-the-air service at the end of the transition. Further, as the digital television world unfolds, new opportunities are emerging for free, over-the-air television services. As Senator Daniel K. Inouye, Chairman of the Senate Commerce Committee, recently urged, "we need to get the digital transition right."[5] The DTV transition, as well as these technological developments, will be seriously jeopardized if these unlicensed personal/portable devices are allowed to operate in the television spectrum.

Proponents of allowing personal/portable devices in the DTV spectrum have consistently promised that such new devices will not interfere with television services, but the comprehensive record in this proceeding tells a different story. Indeed, Edmond Thomas, a representative for the White Spaces Coalition, stated in February after the Commission issued a public notice seeking prototype devices, "we're absolutely certain [the prototype] won't interfere

[4] *Direct-Pickup Interference Tests of Three Consumer Digital Cable Television Receivers Available in 2005*, OET Report, FCC/OET 07-TR-1005 (July 31, 2007) ("FCC Direct-Pickup Report").

[5] *Hearing on Preparing Consumers for the Digital Television Transition Before the Senate Committee on Commerce, Science & Transportation*, 110th Cong. (July 26, 2007) (statement of Sen. Daniel K. Inouye, Chairman).

with television."[6] The Commission *did not* agree with the White Spaces Coalition, and in fact found that the prototype devices submitted would fail to protect cable television *and* over-the-air reception from harmful interference.

In light of the FCC's recent reports and the importance of the DTV transition, the Commission must not allow unlicensed personal/portable devices to operate in the TV band; as shown in the reports, these devices will cause harmful interference to licensed services. By putting to rest the contentious question of personal/portable devices, the Commission can move forward promptly with rules to allow fixed unlicensed devices – with sufficient protections including geolocation – after the end of the DTV transition. Such action will both protect the public's investment in DTV receivers and converter boxes *and* promote the deployment of broadband access to rural and other underserved areas.

I. THE FCC REPORT CONFIRMS THAT SPECTRUM SENSING IS INEFFECTIVE AT PREVENTING HARMFUL INTERFERENCE TO TELEVISION SERVICES.

A. The Commission's Tests Revealed That the Prototype Devices Failed to Sense Effectively in the Laboratory and Field.

The results of the Commission's initial tests on the prototype devices submitted by both Microsoft and Philips confirm that sensing will be ineffective at preventing interference to television services. If these had been real-world devices operating in the television spectrum, digital television viewers would have experienced significant and widespread interference.

Microsoft. The Commission's laboratory and field tests of the Microsoft devices clearly demonstrate that the devices are incapable of sensing television channels at the manufacturer's suggested -114 dBm detection level, let alone the Commission's proposed -116

[6] *The White Spaces Coalition's Plans for Fast Wireless Broadband*, Eric Bangeman, April 27, 2007, *available at* http://arstechnica.com/articles/paedia/hardware/white-space.ars.

dBm threshold.[7] In fact, the Commission found in its laboratory testing that the Microsoft devices were only able to reliably detect DTV signals at levels of -95 dBm or higher.[8] There is no question that this is insufficient to protect television services operating in the band. The field tests were no better, and Microsoft devices were not able to consistently identify whether a channel was or was not occupied.

Having failed this major test, Microsoft now claims that its device's scanner "broke" and caused the poor performance observed by the FCC Report.[9] This explanation is perhaps as troubling as the test results themselves. If the custom-built "prototype" device Microsoft created specifically for testing could not hold up, how can the Commission expect spectrum scanners in actual personal/portable devices to work for years after they are sold to consumers? If the FCC – a highly expert technical agency – could not detect or identify the degradation in the scanner's performance, then surely consumers will be unable to know when their unlicensed devices malfunction. Millions of consumers will, however, know that they can no longer receive digital television on the new DTV sets and converter boxes they have purchased. And given that manufacturers of unlicensed devices would surely seek to undersell one another, the actual unlicensed devices that would be manufactured and sold to consumers would surely be *more* fragile than the prototype submitted by Microsoft. The public's substantial investment in DTV receivers and converter boxes cannot be left vulnerable to such easily broken technology.

Moreover, even if the device had worked as Microsoft planned, it would not have reliably sensed the presence of occupied DTV channels. In the same filing in which it blamed

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[7] *See* FCC Report at vii.

[8] *Id.*

[9] *See* Letter from Edmund J. Thomas, Harris Wiltshire & Grannis LLP to Marlene H. Dortch, Secretary, FCC (filed Aug. 13, 2007).

the device's abysmal performance on a broken spectrum scanner, Microsoft disclosed that absent the breakdown the device's performance in the Commission's bench test would only have improved 13 dB, to -108 dBm.[10] This is far short of Microsoft's claim that its device could sense at a level of -114 dBm and even further short of the limits at which DTV signals often occur in a station's service area.[11] Whether "broken" or not, the results concerning Microsoft's device highlight the folly of allowing personal/portable devices into the DTV spectrum.

Philips. While the Commission's tests of the Philips device indicate that the device performed better in the laboratory than the Microsoft devices, these results are incomplete at best. Philips declined to subject its device to "real word" field trials, but rather elected to test its device in the laboratory under pristine signal conditions. Moreover, the Philips device failed to sense effectively at a level of -116 dBm.[12] The Commission found that the device was "generally able to reliably detect DTV signals at -115 dBm in the single channel tests and at -114 dBm in the two-channel tests," but that the device's "sensing performance declines rapidly as the signal levels are reduced."[13] As discussed below, these levels will be insufficient to protect television services.

Furthermore, both the Microsoft and Philips devices, despite their failure to meet minimum performance requirements, represent performance that would be superior than that of a typical consumer TV band device. For example, the Microsoft device included a high-performing external filter to achieve compliance with the Commission's current out-of-band emission limits. The performance of this filter was so severe that it actually reduced and

[10] *Id.* at figure 2.

[11] As discussed in Section II(B), neither the -114 dBm level proposed by the White Spaces Coalition nor the -116 dBm level proposed by the *Further NPRM* would be sufficient to protect DTV reception.

[12] FCC Report at viii.

[13] *Id.*

distorted in-band emissions from almost 200 milliwatts (22 dBm) to about 7 milliwatts (8 dBm). Moreover, Microsoft's filter could tune to only a single channel, DTV channel 30. There does not appear to exist a filter that could be practical for a consumer device (*e.g.*, of a small size and low cost), tune to all channels, *and* meet the out-of-band performance observed on DTV channel 30 in the Microsoft "prototype." The Commission could thus expect actual devices to generate significant out-of-band emissions to the detriment of the public's television service.

B. The -116 dBm Sensing Threshold Will Not Provide Adequate Protection to Television Services.

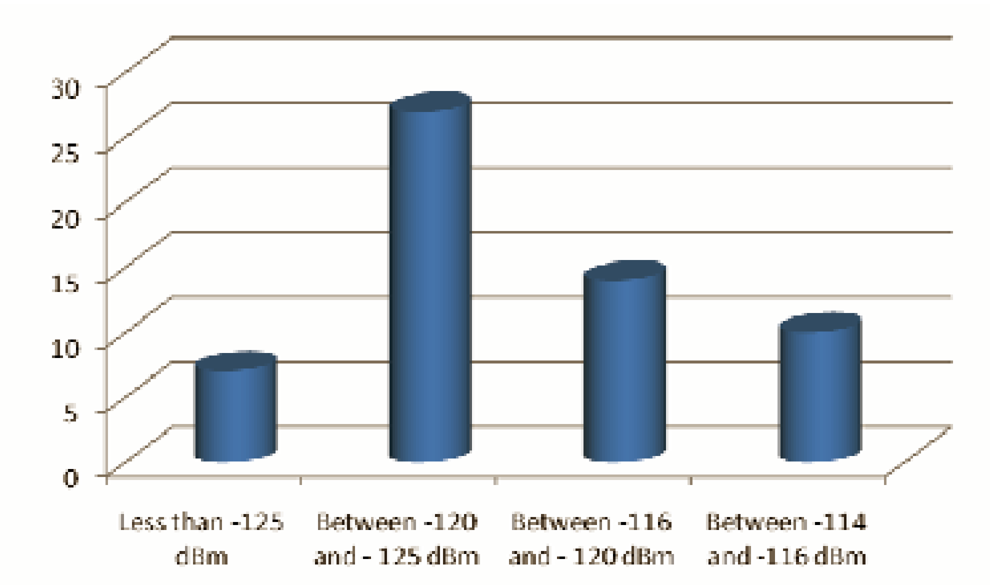
Even if the Microsoft and Phillips devices had been able to accurately sense at a level of -116 dBm, they would still have left digital television services vulnerable to harmful interference. At a minimum, a sensing detection level must ensure that a TV band device is a sufficient distance *outside* the protected contour of the TV station to prevent interference. As MSTV and NAB have previously demonstrated, the proposed -116 dBm sensing level will often allow operation *within* the protected contour, and is therefore insufficient to protect television viewers. While it is not yet clear what sensing level is necessary to ensure protection to all television viewers, what is certain is that the proposed -114 dBm and -116 dBm levels will fail to prevent harmful interference.

The attached Field Measurement Report, which reflects a signal measurement program conducted in the Washington, D.C. area, provides further evidence of the inadequacy of the -114 dBm sensing level proposed by the White Spaces Coalition as well as the -116 dBm level proposed by the *Further NPRM*.[14] Of 118 paired measurements taken, 58 (or 49%) showed signal levels below the -114 dBm level, with more than 34 (or 29%) of the measurements below

[14] *See Unlicensed Operation in the TV Broadcast Bands,* First Report and Order and Further Notice of Proposed Rulemaking, ET Docket No. 04-186, FCC 06-156, at App. B § 15.707(f) (rel. Oct. 18, 2006).

-120 dBm, as depicted in the chart below.[15] Thus, even if one assumes into existence a personal/portable device that operates to the parameters proposed by the White Spaces Coalition or the *Further NPRM*, at least half of the time the device would interfere with DTV receivers and converter boxes.

Table 1: Depiction of the 58 signals measured at levels below -114 dBm



Notably, of the 34 measurements taken within a home, 30 were below the -114 dBm level. In most cases, despite low signal levels, reliable DTV reception was available in at least some parts of the home using the homeowner's DTV receiving equipment and antenna. For example, in "residence 1", reception was available in a second floor bedroom on seven of the nine DTV channels tested, but the signal level in the kitchen and dining room of the home was below -114 dBm. In practical terms, the results mean that in this home, the scanner within a

[15] For eight of the nine outdoor sites, a total of eight DTV channels were measured at two nearby locations for a total of 64 measurement pairs. The distance between the two locations did not exceed one-half mile, well within the interference range of an unlicensed device. At the ninth site, twenty DTV channels were measured at two nearby locations for a total of 20 measurement pairs. For the 34 indoor measurements, signals were generally measured at two indoor locations and DTV reception was confirmed using the homeowner's DTV receiving equipment and antenna.

personal/portable device in the kitchen would fail to sense the viewable signal. The scanner would then erroneously allow the device to operate on the occupied DTV channel, preventing the family from watching DTV programming and services. Such would be the case in millions of homes throughout the country.

II. PERSONAL/PORTABLE DEVICES MUST NOT BE AUTHORIZED TO OPERATE IN THE BROADCAST SPECTRUM AT THIS TIME.

The findings of the FCC Report lead to an inevitable conclusion: the Commission cannot authorize personal/portable devices so long as serious interference concerns remain. While proponents of personal/portable devices appear willing to ignore this data and its impact on DTV reception, the Commission must not do the same. When viewing this most recent FCC Report in conjunction with the earlier OET Report on Interference Rejection Thresholds ("FCC Rejection Report"), it is clear that viewers will receive significant interference from personal/portable devices operating on co- and adjacent channels.[16] As a result, the Commission must move forward with this proceeding by only authorizing fixed devices to operate in the broadcast spectrum, accompanied by proper protections such as geolocation.

First, personal/portable devices present a series of problems that make them far more dangerous than fixed devices in the broadcast spectrum. Unlike fixed devices, which would be professionally installed, there can be no reliable means of knowing where a personal/portable device ends up once it is sold to a consumer. Consequently, once personal/portable devices are released into the hands of consumers, it will be impossible to recall them or prevent their harmful effects. This inability of the Commission to effectively oversee the proliferation of personal/portable devices will create greater economic incentives for

[16] *See Office of Engineering and Technology Report: Interference Rejection Thresholds of Consumer Digital Television Receivers Available in 2005 and 2006*, OET Report, FCC/OET 07-TR-1003 (March 30, 2007) ("FCC Rejection Report").

manufacturers to make products that violate the Commission's requirements, as occurred in the satellite radio space.[17]

Second, the interference ranges of personal/portable devices are extremely high. Prior analyses demonstrate that a personal/portable 100 mW transmitter operating on the first adjacent channel could cause interference to DTV viewers in 80 to 87% of a TV station's service area.[18] These concerns are amplified by the fact that the operating range reportedly targeted for personal/portable devices is channels 21-51, which is the area that also contains a significant portion of television stations' post-transition allotments.

Third, the Commission's recent studies illustrate that personal/portable devices will not only cause harmful interference to over-the-air television but will also interfere with digital cable services. The FCC's Direct-Pickup Report found interference to digital-cable ready receivers at distances of up to 10 meters.[19] As the Commission has recognized, successful deployment of digital cable ready sets is "an essential part of an effective digital transition."[20] The Commission must not allow personal/portable devices to jeopardize cable services and the millions of digital cable-ready sets that will be sold to consumers over the next few years.

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[17] It was discovered that "Part 15" FM transmitters, some of which were incorporated into XM and Sirius satellite radios, did not comply with Commission regulations. A study conducted by NAB found that of the 17 devices tested, 13 exceeded the field strength ceilings for operation of unlicensed devices under the Commission's Part 15 rules. Both XM and Sirius eventually admitted that their devices were noncompliant, and the Commission ordered the manufacturers to cease producing such devices. *See Report on Part 15 FM Modulator Device*, June 2, 2006, *available at* http://www.nab.org/xert/scitech/rd062606.htm (last visited August 15, 2007). It should be noted that the interference potential of TV band devices even at powers substantially below that proposed by the Commission is far greater than these non-compliant unlicensed FM devices.

[18] *See* FCC Rejection Report.

[19] FCC Direct-Pickup Report at iii.

[20] *Implementation of Section 304 of the Telecommunications Act of 1996, Commercial Availability of Navigation Devices*, Third Further Notice of Proposed Rulemaking, FCC 07-120 at ¶ 7 (June 29, 2007).

Fourth, in addition to interference with over-the-air and cable television services, the FCC Report documents the harm that personal/portable devices will cause to licensed microphones relied upon by major sports leagues and other providers of news and entertainment programming throughout the country. The FCC Report found that the Microsoft devices were generally incapable of sensing wireless microphones.[21] While the Philips device was able to sense some microphones when the microphone's signal was located in the center of the TV channel, the results were "mixed," and the ability of the device to sense decreased when signals were on the edge of a channel.[22]

Personal/portable devices could do even greater harm to wireless microphones than to DTV reception. In contrast to digital television stations, which will typically be on throughout the day, wireless microphones are constantly turned on and off. If the wireless microphone is temporarily off when the personal/portable device scans for available TV channels, it would suffer substantial interference until the device reaches the same channel in its next scan – up to 14 minutes later.[23] Wireless microphones are used in live performances, by sports teams to communicate with one another on the sidelines, and by news gatherers in the field. These critical uses will be threatened if the Commission does not take special care to protect the wireless microphone services operating within the TV band.

Simply put, in this proceeding the Commission must maintain as a priority the protection of over-the-air and cable television services, wireless microphones and the DTV transition. Contrary to claims by the proponents of personal/portable devices, this can be done,

[21] FCC Report at viii.

[22] *Id.*

[23] *Id.* at vii-viii ("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 it covers…the Prototype B device takes approximately 8 seconds to scan each channel or slightly more than 4 minutes to scan the full range of channels").

however, in harmony with the promotion of broadband deployment. MSTV and NAB have consistently expressed support for the Commission's goal of providing broadband services to rural areas. It is through *fixed* broadband access that the Commission can further that goal; personal/portable devices will not deliver broadband access to rural homes and businesses. IEEE 802 has already submitted a proposal for standards to enable use of fixed devices.[24] If the aim of allowing unlicensed devices to operate in the broadcast spectrum is truly about increasing broadband access in America, especially for rural areas, the Commission will be able to accomplish this goal without any delay by authorizing the appropriate, nonharmful operation of fixed devices.

Device proponents have had the opportunity to submit devices for testing, and even these custom-built devices, which are surely not representative of the real-world devices which will be produced *en masse*, failed to protect against interference. One can only imagine the interference that will occur once these personal/portable devices are released into the market. Representatives John D. Dingell, Chairman of the Committee on Energy and Commerce, and Edward J. Markey, Chairman of the Subcommittee on Telecommunications and the Internet, in a recent letter to the Commission, discussed the many benefits of the DTV transition but warned that "now is the time to get the job done, and done correctly." They added: the "Federal Government must work together to ensure that millions of American television sets do not go dark."[25] Yet allowing personal/portable devices in the television spectrum will undo all the hard

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[24] *See* Comments of IEEE 802.18, at 6 (Jan. 31, 2007) (submitting the results of the IEEE 802.22 standards development project) ("While we believe that spectrum sensing is essential, we also believe that sensing alone is insufficient to adequately and completely assure the required level of interference protection for licensed services").

[25] Letter from the Hon. John D. Dingell, Chairman, Committee on Energy and Commerce, and the Hon. Edward J. Markey, Chairman, Subcommittee on Telecommunications and the Internet, U.S. House of Representatives (May 24, 2007).

work the Federal Government has done to bring the benefits of the DTV transition to consumers. Given that device manufacturers have been unable to prove that personal/portable devices will not cause harmful interference, the Commission must move forward with this proceeding and the DTV transition without allowing personal/portable TV band devices to operate in the broadcast spectrum.

CONCLUSION

At stake in this proceeding is the public's ability to benefit from the Nation's multibillion dollar investment in DTV technology and services. MSTV and NAB accordingly commend the Commission for testing and reporting on the prototype devices submitted. As the results of those tests confirm, the Commission must not allow personal/portable devices into the broadcast spectrum. To promote broadband deployment in rural and other underserved areas, it should instead move forward with rules to authorize fixed devices with appropriate protections.

Respectfully submitted,

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DTV Signal Measurements in the Washington-Baltimore Area

A Field Study to Show that Current Sensing Proposals Will Not Ensure that Unlicensed Devices Operate Only on Vacant TV Channels

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Field Measurements Performed
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Executive Summary

MSTV and others have suggested that because of propagation variability, the large, high gain outdoor antennas used in TV reception and the very low signal detection levels needed to protect TV viewers and other licensed users, spectrum sensing is not a reliable technique to protect authorized users of this spectrum. This study presents results of recent field measurements conducted in the Washington-Baltimore television reception area. The measurements confirm that spectrum sensing at levels proposed by either the proponents of this technology (-114 dBm) or the FCC (-116 dBm) will *not ensure* that unlicensed devices operate only on vacant TV channels or so-called “white spaces”, and will *not protect* DTV viewers from harmful interference.

The methodology used in the study attempted to determine if locations within a television station’s service area could be found where the TV signal level at one location was below the signal level thresholds proposed for sensing, indicating that the channel was vacant; and, the TV signal level at a second nearby location, well within the interference range of an unlicensed device operating at the first location, was sufficient to provide reliable DTV service.

A total of nine outdoor and five indoor sites were investigated. For eight of the nine outdoor sites, a total of eight DTV channels were measured at two nearby locations for a total of 64 measurement pairs. The distance between the two locations did not exceed one-half mile, well within the interference range of an unlicensed device. At the ninth site, twenty DTV channels were measured at two nearby locations for a total of 20 measurement pairs. For the indoor measurements, signals were generally measured at two indoor locations within the residence and DTV reception was confirmed using the homeowner’s DTV receiving equipment and antenna.

The study found 58 measurements within the television station’s service areas had signal levels below the -114 dBm level, with values as low as -126.6 dBm. For the outdoor measurements, the study found that one-third or 28 of the paired 84 outdoor measurements were lower than the -114 dBm sensing level suggested by proponents of this technology, and more than 28% or 24 of the paired 84 outdoor measurements were below the -116 dBm level proposed by the FCC.

The indoor measurements showed 30 signal measurements below the -114 dBm level in some locations within the residences. In most cases, reliable DTV reception was available in the residences on the same channels using the homeowner’s DTV receiving equipment and antenna. For example, in residence 1, reception was available in a second floor bedroom on seven of the nine channels where signal levels in the kitchen and dining room area of the home were below -114 dBm. In residence 4, reception was available on all five channels using a typical outdoor TV antenna where the signal levels were below -114 dBm in the family and living room of the home. The results confirm that there can be significant differences in DTV signal levels within a home and that the typical television installation provides substantial increases in the received signal level due to antenna height and gain.

The study found that signal levels much lower than -116 dBm are present within a television station's service area. The study therefore concluded that the sensing levels proposed by sensing proponents (-114 dBm) and the FCC (-116 dBm) will not ensure that an unlicensed device can properly detect vacant television channels and will not prevent harmful interference.

The study also cautioned that due to its limited scope and the limited capability the hardware used (*i.e.,* the equipment used in the study could not measure lower than about -126 dBm), the results should not be used to establish a sensing level that would be appropriate for an unlicensed device. This task would require a more comprehensive measurement program that takes into account variations in terrain and urban, suburban and rural environments.

1. Introduction

The basic concept of spectrum sensing is that a specific field strength, i.e., "sensing" or "detection level", can be used to determine if portions of the radio spectrum or a specific communications channel is occupied or vacant and therefore available for use. That is, if the "sensed" field strength level is equal to or above the sensing level, the channel is deemed to be occupied and unavailable for use. If the field strength is below the sensing level, the channel is deemed to be vacant and available for use by the unlicensed device. The fundamental question to be answered is what sensing level is deemed to be appropriate and will this level actually ensure that the channel is really vacant or unoccupied. For example, if the sensing level chosen is too low, spectrum will not be available for use. If the sensing level is too high, interference will be caused to authorized users, i.e., TV viewers.

It is generally agreed by proponents of both spectrum sensing and incumbent users that co-channel unlicensed device operation within a TV station's service area is not permitted.[1] Therefore, sensing must ensure that the unlicensed device is not operated within a TV station's service area or protected contour.[2] More importantly, the sensing or detection level must also ensure that the unlicensed device is located far enough away from any TV receiver to avoid causing harmful interference. Certain unlicensed proponents have suggested that a sensing level of -114 dBm is sufficient to protect TV receivers and viewers.[3]

This paper investigates whether the sensing levels proposed by the FCC or the proponents of sensing are adequate to ensure that an unlicensed device will operate only on vacant TV channels and guarantee that the unlicensed device will be located far enough away from a TV receiver to avoid causing harmful interference.

2. Field Measurement Program

a. <u>Outdoor Measurements (Phase 1)</u>

A simple field measurement program was developed to determine if two locations could be found within a TV station's service area where the TV signal field strength level at one location was below the field strength level proposed for sensing (indicating that the

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[1] The concept of "white space" devices is premised on the claim that such devices would not operate on an occupied TV channel and would only operate outside of the service area of TV stations in geographic areas where a particular TV channel is unused, i.e., a so-called "white space."

[2] In fact, any unlicensed operation must actually be some nominal distance beyond the service area of the TV station. This distance would be determined by the interference potential of the device. For example, Intel, one of the proponents of spectrum sensing, had suggested at one time in its filings to the FCC that a 100 mW unlicensed device must be at least 5 miles beyond the protected contour of a TV station to avoid interference.

[3] The FCC proposed a sensing level threshold of -116 dBm and requested comment on this level.

TV channel was vacant) and the field strength at the second location was sufficient to provide reliable DTV service. If those two locations were within the interference range of an unlicensed device, sensing therefore would have failed and harmful interference could be caused to TV reception.

There was no attempt to provide exhaustive analysis of where such failures would occur within the service area of a television station or to determine sensing levels that would be appropriate to prevent interference.[4] Unlicensed devices are regulated under Part 15 of the Commission's rules and all operation of such devices is subject to not causing harmful interference to licensed services such as TV broadcasting and its viewers. It is completely inconsistent with the tenets of Part 15 operation if a number of locations could be simply and readily found where sensing fails and therefore interference would likely be caused to TV viewers. Therefore, it is assumed that the FCC would not adopt rules or permit such interference situations from occurring if this was the result of the study.

The first phase of the measurement program was conducted in the Washington, D.C., area in the winter of 2006. The Washington, D.C., area has a number of full power DTV stations in operation. In addition, not all of the Washington area television stations transmit from the same location, thus exposing each receive site to different propagation paths and a variety of signal conditions.[5] Eight outdoor sites in the Washington, D.C. area were chosen for investigation.[6] At each site, eight DTV channels (channels 27, 34, 35, 36, 39, 43, 48 and 51) were measured at two locations a small distance apart for a total of 128 measurements. The distance between measurement locations at each site was no more than 0.8 kilometers or one-half mile in all cases. This separation distance was chosen to be conservatively well within the interference range of a co-channel 100 mW

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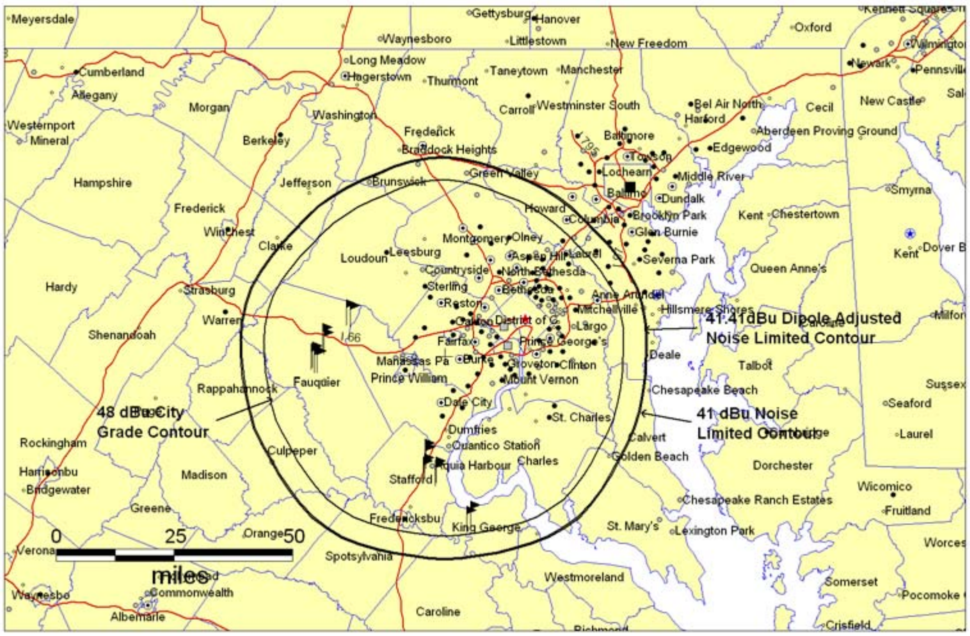
[4] A statistically significant sample would be necessary to develop such an appropriate sensing level. Such an effort would require extensive measurements in a variety of different terrain and urbanization conditions in many different television markets across the United States and is beyond the financial capability and resources available to MSTV. Furthermore, even if such a study were undertaken and an acceptable sensing level could be determined, the basic problem of shutting down illegal or even unintentionally non-compliant devices poses such a significant interference threat to TV viewers, to new mobile TV services and to auxiliary operations, such as wireless microphones, as to make personal and portable operation unacceptable to MSTV.

[5] The eight DTV channels are being transmitted from five separate locations. DTV channels 34 and 39 are transmitting from the same tower which is located in the northwest section of Washington, D.C., on Wisconsin Ave., NW. Channels 35 and 36 are also transmitting from the same tower that is located approximately ½ mile north of the channel 39 tower, while channel 48 is transmitting from a tower located approximately ¾ mile southwest of the channel 39 tower. Channel 50 is transmitting from a separate tower approximately 3 miles north of the channel 39 tower. Channel 27 is transmitting from a tower located in Arlington, VA, approximately 5 miles south west of the channel 39 tower, while the channel 43 tower is located in Fairfax, VA, Approximately 17 miles south/south west of the channel 39 tower.

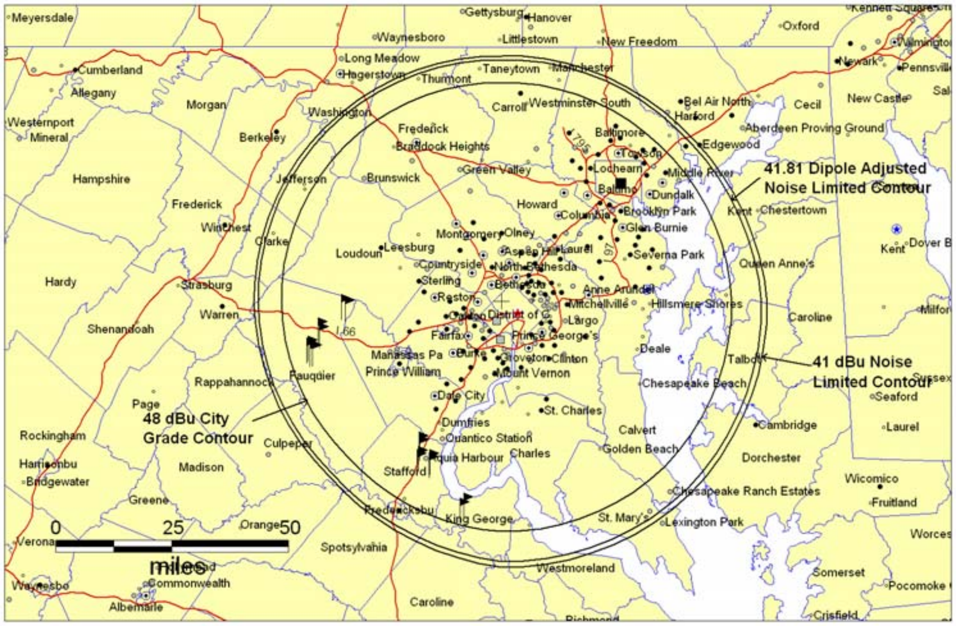
[6] A Longley-Rice propagation analysis was used to identify sites that have a predicted signal level below the signal level necessary for reliable DTV service.

device.[7] The following maps show the measurement locations and the respective TV station coverage areas for two of the DTV stations measured, WPXW, DTV channel 43 and WRC, DTV channel 48.



WPXW DTV Channel 43 Manassas, VA
Measurement Locations

[7] The interference range of a 100 mW unlicensed device is significantly greater than ½ mile. To avoid interference to a co-channel DTV receiver, the propagation loss between the two locations has to be well in excess of 100 dB. In recent tests of the prototype "white space devicSe" by the FCC's Office of Engineering and Technology, a co-channel interference distance of 87 meters was measured. OET noted, however, that "the interference distances are specific to the interaction scenario examined" and that "the measured DTV was more than 20 dB above the typical TOV signal level." OET stated that "a similar test performed with the DTV signal at TOV will likely result in ***much greater interference distances."*** (Emphasis added.) For example, taking into account that the DTV signal was about 20 dB above TOV and assuming that the interference distance would double for each 6 dB would yield an interference distance of about one kilometer. The test was also conducted with an indoor DTV antenna with only 4 dB gain at a relatively low antenna height and may have also included some antenna discrimination due to the horizontally polarized DTV signal and the vertically polarized interfering signal of the unlicensed device that may or may not be always present. Using a higher gain outdoor antenna at 10 meters would further increase the interference distance well beyond a kilometer.



WRC DTV Channel 48 Washington, DC
Measurement Locations

All measurements were made outdoors at six feet above ground using a high gain antenna directly connected to a spectrum analyzer. This configuration was employed to avoid the use of active elements (i.e., amplifiers) that could affect the results. The antenna was rotated through 360 degrees and the maximum received signal recorded. The pilot levels of the eight DTV channels (channels 27, 34, 35, 36, 39, 43, 48 and 51) were measured at both locations at each of the eight sites for a total of 128 measurements. The DTV pilot carrier was measured using a 3 kHz bandwidth (10 kHz video bandwidth) to take into account the processing gain in the spectrum analyzer and a sampling sweep time of 500 milliseconds averaged over many samples to minimize the effect of fading on the pilot carrier signal.[8] The measured values were then converted to the proper dBm value that would be seen by the TV receiver or by the unlicensed device taking into account appropriate adjustments for pilot carrier power, antenna gain and height.[9]

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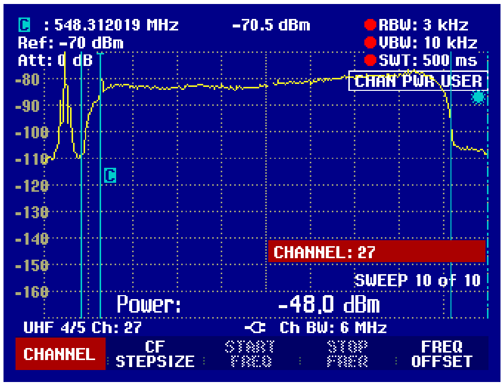
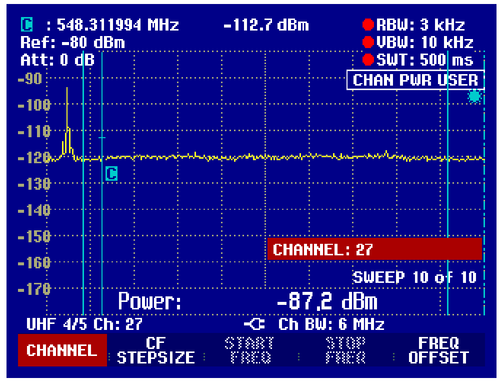
[8] The spectrum analyzer used was a Rhode and Schwarz (R&S) Model FSH-3-TV calibrated by R&S Lab in Columbia, MD on December 2006, before conducting the outdoor measurements.

[9] The pilot carrier is located 0.31 MHz above the lower edge of the DTV channel and the pilot carrier power is 11.3 dB less than the total power of the DTV signal. A conversion factor of 11.3 dB is therefore used to convert all pilot power measurements to power in a 6 MHz DTV channel. A 16 dBi high gain antenna was used for all measurements. Since the unlicensed device is suppose to have a 0 dBi antenna and the measurement was made with an antenna with a 16 dB gain, the signal level also has to be adjusted by 16 dB. In other words, the signal power seen by the unlicensed device would be 4.7 dBm lower than measured (16 dB – 11.3 dB) and therefore all pilot power measurements were adjusted by 4.7 dBm for the unlicensed device. A typical outdoor TV antenna is assumed to have a gain of 10 dB and a height of 30 feet. In addition to the 11.3 dB pilot power adjustment, this is a 1 dB difference between the signal seen by the TV receiver and the signal actually measured (antenna gain difference of 6 dB (10 dB versus 16 dB)

The lowest value measured at the site was assumed to be the location of the unlicensed device and the location with the highest value was assumed to be the location of the TV receiver.

Spectrum analyzer plots for all locations measured were captured and recorded. An example of captured spectrum analyzer plots are displayed below:





The above displays show the measured power of the pilot carrier on channel 27 at site 3 at both locations (Locations A and B). The pilot carrier power is displayed on the top center part of the spectrum analyzer display on the same line as the pilot carrier frequency.

As noted above, the higher signal level (-70.5 dBm) shown in the left chart, is assumed to be the location of the TV receiver. Converting the -70.5 dBm signal to the value that would be seen by a TV receiver using a typical outdoor antenna yields an actual received signal level of -58.2 dBm. This includes a 1 dB adjustment for antenna height and gain and an 11.3 dB adjustment for the difference between the power of the pilot carrier and the power across the entire 6 MHz channel. The right display shows the power of the pilot carrier on channel 27 measured at the second location at site 3, the assumed location of an unlicensed device. Converting the -112.7 dBm measured value to the value that would be seen by an unlicensed device with a 0 dBi antenna results in an actual received signal level of -117.4 dBm across the entire 6 MHz bandwidth. This value is derived by adjusting the measured signal to take into account the 16 dB of antenna gain of the measuring equipment and the 11.3 dB adjustment for the power of the pilot carrier.

As noted above, both sites are clearly within the interference range of a co-channel 100 mW transmitter. At location A, the measured signal level of -58.2 dBm level is well above the minimum level of about -84 dBm needed to produce a “perfect” picture in a DTV receiver and provide reliable DTV service. On the other hand, the -117.4 dBm level seen at the second location (location B) at site 3 is below the -114 dBm level proposed as the spectrum sensing level.   An unlicensed device at this location would therefore conclude that this channel was vacant and transmit on this channel, causing interference to a DTV receiver at location A.

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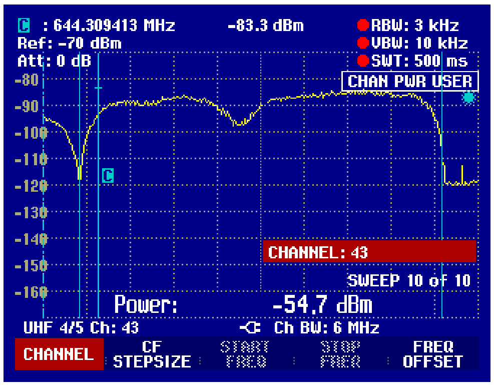
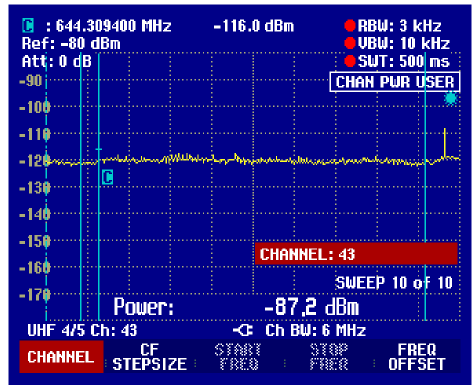
and a height difference of seven dB (6 feet versus 30 feet). Therefore, all TV receiver locations were adjusted by a factor of 12.3 dB.

The following analyzer plots show the measurement results for channel 43 at site 3. In this case, a DTV receiver at location A would receive a signal level of -71.3 dBm and an unlicensed device at location B would receive a signal level of -120.7 dBm after the appropriate measurement adjustments are made.





Both of these sets of measurements show locations and frequencies where spectrum sensing at levels below -114 dBm would result in harmful interference to nearby television reception.

The table below is a summary of the measurements taken at the eight sites and identifies locations and frequencies where spectrum sensing at the -114 dBm would have failed *and* a receivable DTV signal was within the interference range of the 100 mW device.

Site	Channel	Location A	Location B
1	39	-82.7 dBm	-115.4 dBm
2	51	-59.3 dBm	-115.1 dBm
3	27	-58.2 dBm	-116.7 dBm
	43	-71.0 dBm	-120.7 dBm
	51	-76.4 dBm	-123.7 dBm
4	27	-72.7 dBm	-124.9 dBm
	34	-63.2 dBm	-118.0 dBm
	35	-66.9 dBm	-120.1 dBm
	36	-66.3 dBm	-121.1 dBm
	39	-71.1 dBm	-125.3 dBm
	43	-77.5 dBm	-126.1 dBm
	48	-77.9 dBm	-124.7 dBm
5	27	-83.6 dBm	-123.0 dBm
	43	-75.7 dBm	-116.4 dBm
6	27	-74.4 dBm	-123.8 dBm
	35	-83.5 dBm	-114.6 dBm
	43	-64.6 dBm	-117.4 dBm
7	43	-72.5 dBm	-116.8 dBm
8	43	-81.1 dBm	-118.0 dBm

As can be seen from the above table, spectrum sensing at the -114 dBm level, as proposed by the proponents of spectrum sensing, would have failed on at least one DTV channel at every site. In fact, spectrum sensing would have failed at 19 or 30% of the 64 location pairs where measurements were made.[10] In other words, an unlicensed device at each of these sites would have failed to properly detect one or more DTV channels in use and would have transmitted on those channels causing interference to nearby TV viewers.

b. Outdoor Measurements (Phase 2)

In the summer of 2007, an additional ninth outdoor site in the Reston, VA, area was measured in conjunction with the indoor measurement program discussed below. The Reston site is within the protected contours of twenty DTV stations located in Washington, D.C., Northern Virginia, Baltimore, Annapolis and Frederick, MD. All twenty DTV channels were measured at this site. In addition to the eight Washington, D.C. channels measured at sites 1 through 8 identified above, three additional DTV signals from the Washington D.C. area DTV stations were measured, WFDC DTV channel 15, WNVT DTV channel 30, and WNVC DTV channel 57. Seven Baltimore stations, WMPB DTV channel 29, WJZ DTV channel 38, WNUV DTV channel 40, WUTV DTV channel 41, WBFF channel 46, WMAR DTV channel 52, were also measured, as well as, signals from WMPT DTV channel 42 in Annapolis, MD, and WFPT DTV channel 28 in Frederick, MD.

Similar to the procedure used for the above eight outdoor sites, DTV field strength measurements were made at two locations a short distance apart. Measurements were taken in a parking garage (Location B) in the Reston Towne Center area to simulate likely field strengths received using indoor reception within nearby condominiums and townhouses, and measurements were also taken at an outdoor site (Location A) at a nearby intersection. The two sites were approximately 200 meters apart.

The picture on the next page on the left shows the measurement setup for the outside site (Location A) with the parking garage (Location B) across the street in the background. The picture on the right is an aerial view of the area with both measurement locations designated on the map by blue dots.

[10] While 19 outdoor measurements are reported in the Table, the actual measurement data showed 36 of the 128 outdoor measurements were at a level of less than -114 dBm with values as low as -126.2 dBm. The 17 additional unreported measurements included locations where the signal at both locations was below the -114 dBm level providing further evidence that sensing at -114 dBm would not ensure that the unlicensed device was operated outside a TV station's service area.

Location A Location B

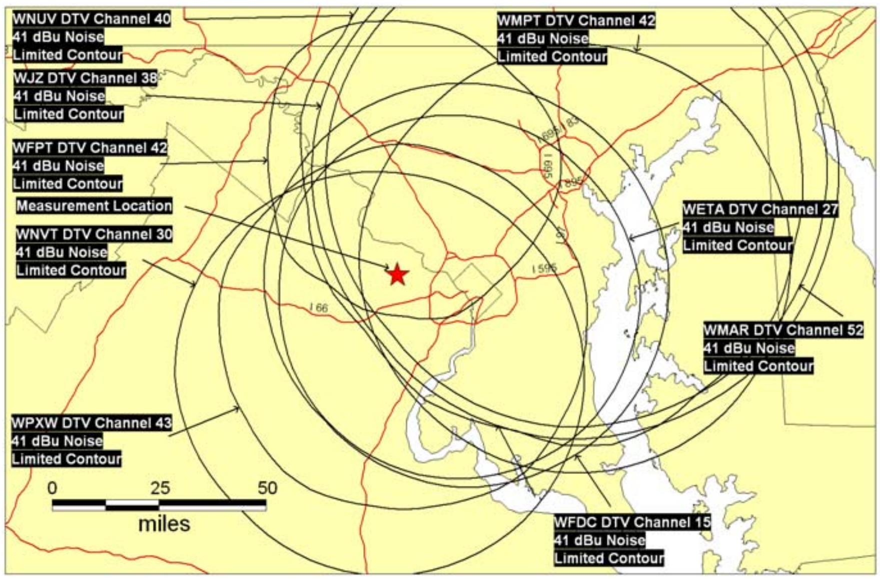
The measurement procedure for the Reston site was the same as used for the eight sites reported above.

The following Table shows that nine of the twenty DTV stations measured had a receivable signal at Location A and a signal level of less than -114 dBm at nearby Location B.

Station/DTV Channel	Location A	Location B
Baltimore, MD		
WJZ 38	-72.8 dBm	-123.1 dBm
WNUV 40	-76.2 dBm	-124.1 dBm
WMAR 52	-79.8 dBm	-125.4 dBm
Washington, DC		
WFDC 15	-77.7 dBm	-115.5 dBm
WETA 27	-82.9 dBm	-125.0 dBm
WNVT 30	-70.5 dBm	-124.5 dBm
WPXW 43	-80.9 dBm	-121.7 dBm
Annapolis, MD		
WMPT 42	-81.2 dBm	-120.5 dBm
Frederick, MD		
WFPT 28	-73.5 dBm	-124.7 dBm

The above table illustrates the signal levels received at Location B were far below the -114 and -116 dBm sensing level proposals. In order to prevent harmful interference as required by Part 15 of the FCC's rules, an unlicensed device would need to detect a signal at much lower levels. The lowest signal level measured for the Baltimore stations was a value of -125.4 dBm for WMAR, the lowest received signal level for the Washington, D.C. stations was – 125.0 dBm for WETA, the lowest received level for the Northern Virginia stations was -124.5 dBm for WNVT, and the Annapolis and Frederick stations had a signal level of -120.5 and -124.7 dBm, respectively.

The map below shows the predicted contour of the nine DTV stations for which measurements are shown in the table above.



Reston Towne Center Garage Reston, VA
Measurement Location

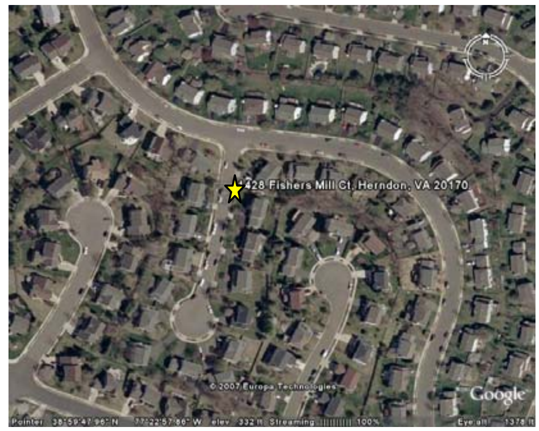
c. <u>In-Home Measurements</u>

An indoor measurement program was also conducted in the summer of 2007. Measurements were taken at five residential homes in the Washington, D.C. area. The homes included two residences of MSTV employees, two residences of employees of the consulting firm that performed the testing, and a residence of an NAB employee.

In each home, the field strength of the available local television stations were measured using a large high gain antenna connected to a spectrum analyzer. The procedure was identical to that used for the outdoor measurements. The pilot carrier levels of all local DTV channels were measured using a 3 kHz bandwidth (10 kHz video bandwidth) to take into account the processing gain in the spectrum analyzer and sampling sweep time of 500 milliseconds averaged over many samples to minimize the effect of fading on the pilot carrier signal. The antenna was rotated 360 degrees to maximize the received signal. After the direction of the maximum signal was determined, the high gain antenna was disconnected from the spectrum analyzer and the analyzer was connected to a simple combination dipole and loop antenna to confirm that the gain of the measurement antenna could be taken into account. The measured values were then converted to the proper dBm value that would be seen by the unlicensed device by adjusting the measured pilot carrier power by taking into account the antenna gain and the conversion factor of 11.3 dB to determine the actual received DTV signal power.[11]

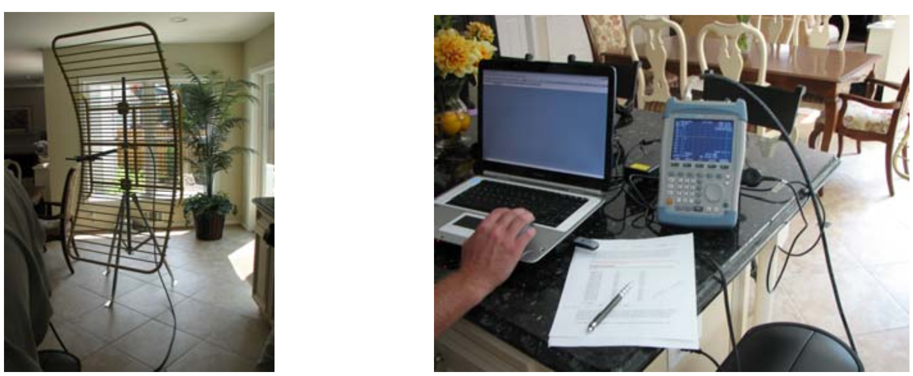
The DTV receiving equipment of the homeowner was used to confirm reception of the DTV signals and pictures were taken of the received picture on the homeowner's television set.

Residence 1. Residence 1 was a two-story single family home located in Herndon,VA. A picture of the residence and aerial view of the location of the residence is shown below (residence is identified by a yellow star):



Measurements were made in the kitchen and dining room areas located on the first floor of the home. The kitchen area is located in a single story addition at the rear of the home and measurements were made next to a double glass French door and double outside windows. The dining room is located adjacent to the kitchen area and measurements were taken in the area leading into the living room located in the front of the house.

The pictures below show the kitchen and dining room measurement locations and setup.



Kitchen Measurement Location

[11] The pilot carrier is located 0.31 MHz above the lower edge of the DTV channel and the pilot carrier power is 11.3 dB less than the total power of the 6 MHz DTV signal. A conversion factor of 11.3 dB is therefore used to convert all pilot power measurements to power in a 6 MHz DTV channel.

Dining Room Measurement Location

The results of these measurements are provided below:

Station/DTV Channel	Viewable Signal	Kitchen Measurement	Dining Room Measurement
WMAR 52	Yes	-125.1 dBm	-114.2 dBm
WBAL 59	Yes	-121.8 dBm	-117.7 dBm
WJZ 38	Yes	-120.2 dBm	***
WBFF 46	Yes	-120.2 dBm	***
WNUV 40	No	***	***
WMPB 29	No	-116.8 dBm	***
WUTB 41	No	-126.6 dBm	-125.1 dBm
WMPT 42	Yes	-121.5 dBm	-114.2 dBm
WNVT 30	Yes	***	***
WPXW 43	Yes	-121.7 dBm	***
WDCW 51	Yes	***	***
WNVC 57	No	-118.3 dBm	***
WETA 27	Yes	***	***
WUSA 34	Yes	***	***
WDCA 35	Yes	***	***
WTTG 36	Yes	***	***
WJLA 39	Yes	***	***
WRC 48	Yes	***	***
*** Designates signal level ≥ -114 dBm			

The DTV receiving system used to confirm over-the-air television reception was located in an upstairs bedroom and consisted of an indoor-mounted “smart antenna” feeding a DTV converter box connected to an analog TV receiver. The DTV installation is shown in the picture below. The antenna is located on the wooden dresser and the set-top box is located on the shelf below the television receiver.

Bedroom TV receiving Installation

The following are pictures of over-the-air reception. The field strength levels measured in the kitchen and dining room are provided for reference.

WMAR Reception
Kitchen Measurement of -125.1 dBm

WBAL Reception
Kitchen Measurement -121.8 dBm
Dining Room Measurement -117.7 dBm

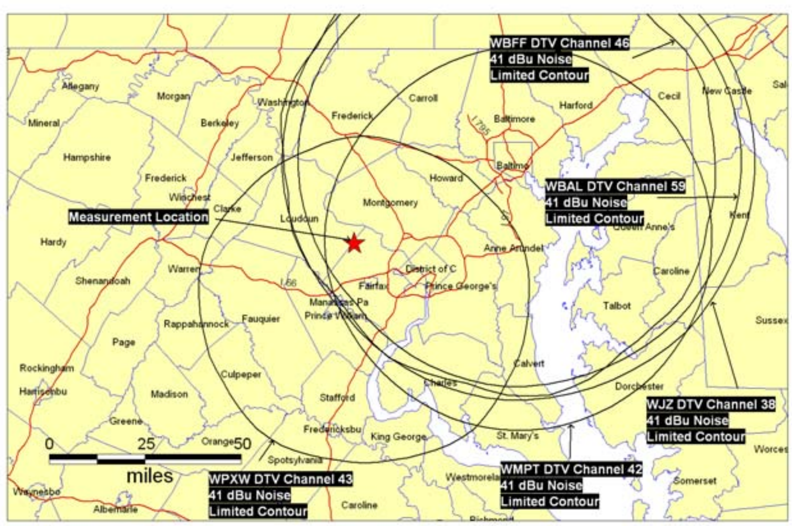
WJZ Reception
Kitchen Measurement of -120.2 dBm

WBFF Reception
Kitchen Measurement of -120.2 dBm

WMPT Reception
Kitchen Measurement of -121.5 dBm

WPXW Reception
Kitchen Measurement of -121.7 dBm

The map below shows the predicted contour of the stations where TV reception was successful.



Fishers Mill Ct Herndon, VA
Measurement Location

Residence 2 – Residence 2 was a single family home located in Hughesville, MD. A picture of the residence and an aerial view of the residence and nearby surrounding area is provided below (residence identified by a yellow star):

Measurements were made in the family room and living room areas located on the first floor of the home. The picture below shows the measurement antenna in the family room. The DTV receiving system used to confirm over-the-air television reception was a recent model LCD DTV receiver using an outdoor directional antenna located in the attic area of the home near the chimney shown in the picture above and pointed in the direction of the Washington, D.C. stations.

Family Room Measurements

Attic Antenna

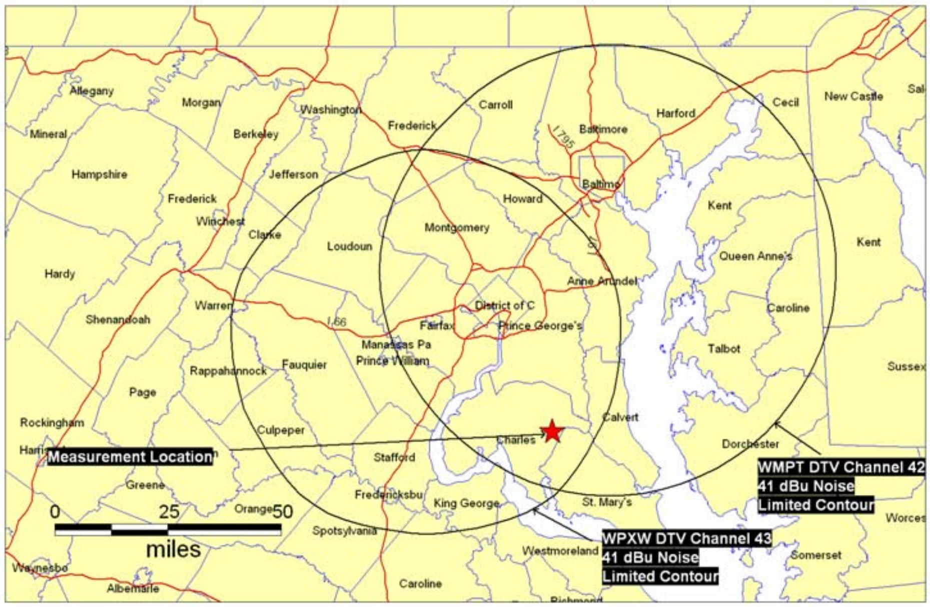
The results of the measurements of residence 2 are provided below:

Station/DTV Channel	Viewable Signal	Family Room Measurement	Living Room Measurement
WFDC 15	No	-117.2 dBm	***
WPXW 43	Yes	-118.8 dBm	***
WNVC 57	No	-115.8 dBm	-120.3 dBm
WMPT 42	Yes	-118.6 dBm	***
*** Designates signal level ≥ -114 dBm			

WPXW Reception
Family Room Measurement -118.8 dBm

WMPT Reception
Family Room Measurement -118.6 dBm

The map below shows the predicted contour of the two stations where TV reception was successful.



7510 Belle Ridge Ct. Hughesville, MD
Measurement Location

Residence 3. Residence 3 was a town house in Laurel, MD. A picture of the townhouse and an aerial photo of the townhome and surrounding homes are shown below (residence is indentified by a yellow star):

Measurements were made in the kitchen area of the townhouse. The measurement antenna is shown below. The owner did not have over-the-air reception capability in the home although several outdoor antennas were observed in the neighborhood.

Kitchen Measurement Location

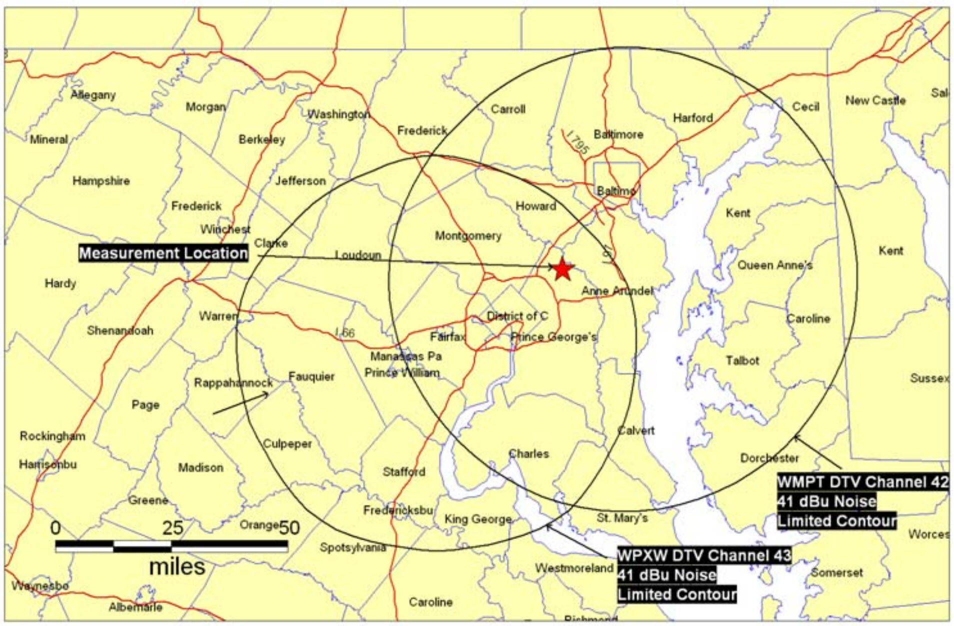
Outdoor Location

Measurements were therefore taken outside of the townhouse to determine the field strength levels that would be seen by an outdoor antenna. Only a single location was measured outdoors and no attempt was made to find a location that would maximize the received signal.

The measurement results are summarized in the following table. The kitchen measurements were adjusted to be consistent with those values that would be seen by an unlicensed personal/portable device while the outdoor measurements were adjusted to be consistent with a typical outdoor TV antenna.

Station/DTV Channel	Viewable Signal	Kitchen Measurement	Outdoor Measurement
WMPB 29	Yes	-122.2 dBm	-80.0 dBm
WUTB 41	Yes	-124.9 dBm	-81.1 dBm
WNVT 30	No	-119.5 dBm	-93.8 dBm
WPXW 43	No	-121.0 dBm	-90.3 dBm
WNVC 57	No	-124.5 dBm	-100.2 dBm
WFPT 28	No	-125.2 dBm	-107.7 dBm
*** Designates signal level ≥ -114 dBm			

The map below shows the predicted contour for which measurements are shown in the table above.



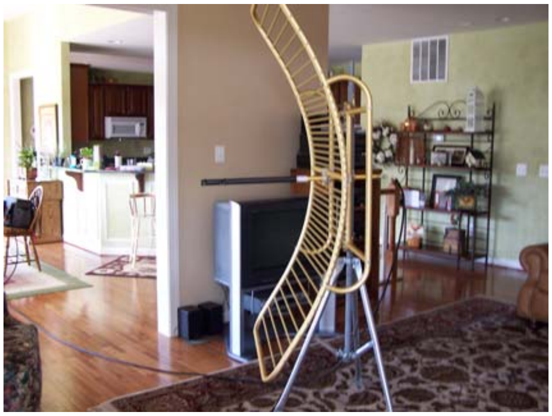
Laurelwalk Dr Laurel, MD
Measurement Location

Residence 4. Residence 4 was a single family home in the Warrenton area of Virginia. Pictures of the residence showing the outdoor antenna and an aerial photo of the home and surrounding homes are shown below (residence identified by a yellow star):

Residence with Outdoor Antenna

Aerial Photo of Residence

Measurements were made in the family room and living room of the home. Pictures of the measurement locations are provided below.



DTV reception was confirmed using a Toshiba laptop computer with a DTV USB receiver connected to the homeowners' outdoor antenna that was located on a backyard deck. As shown below, the DTV USB receiver was placed on top of their analog television set.

The following are pictures of over-the-air reception. The field strength levels measured in the family room and living room are provided for reference.

WFDC Reception
Family Room Measurement of -115.2 dBm

WETA Reception
Living Room Measurement of -115.6 dBm

WDCW Reception
Family Room Measurement of -115.1 dBm

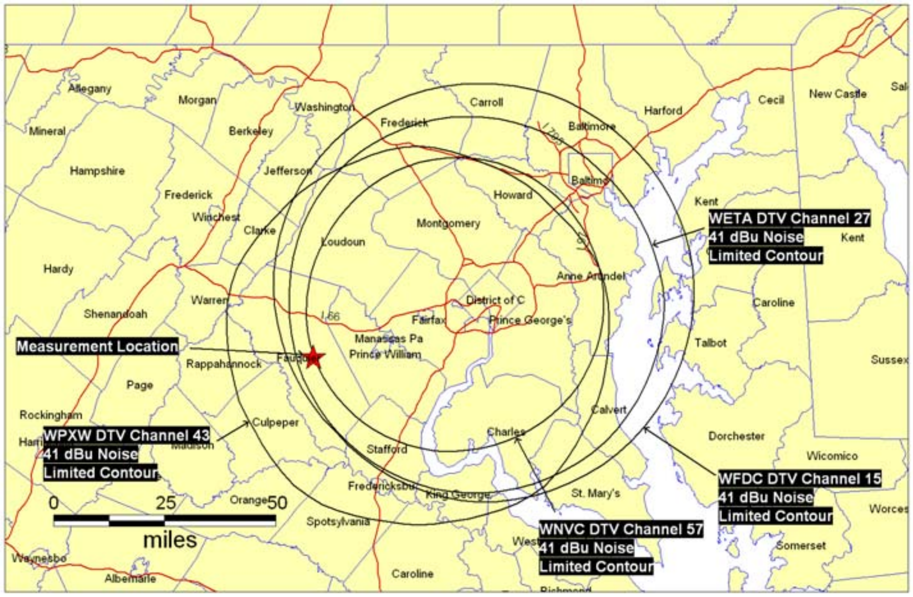
WPXW Reception
Family Room Measurement of -116.3 dBm

WNVC Reception
Family Room Measurement of -123.8 dBm

The results of the measurements for residence 4 are provided in the following table:

Station/DTV Channel	**Viewable Signal**	**Family Room Measurement**	**Living Room Measurement**
WFDC 15	Yes	-115.2 dBm	***
WETA/27	Yes	***	-115.6 dBm
WPXW 43	Yes	-116.9 dBm	***
WDCW 51	Yes	-115.1 dBm	***
WNVC 57	Yes	-123.8 dBm	***
*** Designates signal level ≥ -114 dBm			

The map below shows the predicted contour of the stations where TV reception was successful.



Redwinged Blackbird Warrenton, VA
Measurement Location

Residence 5. Residence 5 was a townhouse in Edgewater, MD. A picture of the town home and an aerial view of the surrounding area are provided below (residence identified by a yellow star).

In this case, measurements were made immediately outside the townhouse to simulate the operation of a portable unlicensed personal device passing by the home. The signal level of station WFDC, DTV channel 15, was measured at the antenna location shown above and found to be at a level of -120.7 dBm. Accordingly, an unlicensed portable device with a sensing level of -114 dBm would conclude that the DTV channel was vacant.

The TV set in the home was connected to a DTV set-top box converter and tuned to DTV channel 15 and a picture was taken of the received signal.

Reception of WFDC

The map below shows the predicted contour of the stations where TV reception was successful.

Riverton Place Edgewater, MD
Measurement Location

3. Summary and Analysis of Measurement Data

The study investigated nine outdoor and five indoor sites. The purpose of the study was to see if locations could be found where the signal level at one location was below the field strength proposed for sensing, indicating to an unlicensed device that the channel was vacant; and, the signal level at a second nearby location was sufficient to provide reliable DTV service as well as being well within the interference range of the unlicensed device operating at the first location.

For eight of the nine outdoor sites, a total of eight DTV channels were measured at two nearby locations for a total of 64 measurement pairs. The maximum distance between the two locations was one-half mile, well within the interference range of an unlicensed device. At the ninth site, 20 DTV channels were measured at two nearby locations for a total of 20 measurement pairs. The two locations in this case were about 200 meters apart. At all nine sites, at least one DTV signal was found below the proposed -114 dBm sensing level with a corresponding signal on the same channel at a nearby site strong enough to produce a viewable DTV picture. At site 4, seven of the eight measurement pairs had a signal below the -114 dBm level with a corresponding viewable DTV signal;

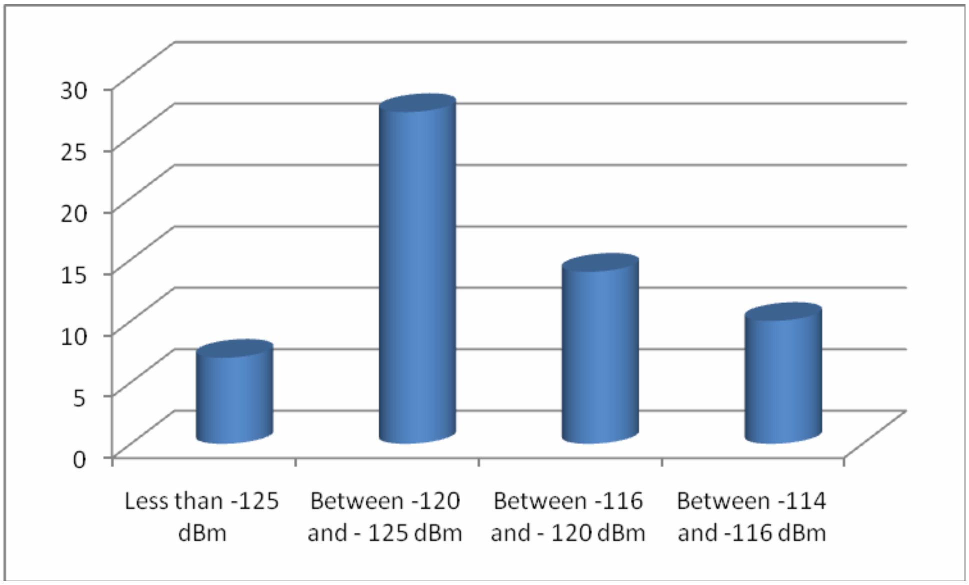
and at site 9, nine of 20 channels measured had a signal level below the -114 dBm level on one of the measurement pairs. Signal levels as low as -126.1 dBm were observed.

In summary, sensing at -114 dBm failed in more than 30% or 26 of the paired 84 outdoor measurements; and, sensing at -116 dBm failed in more than 26% or 22 of the paired 84 measurements. In all of these cases, failure is defined as a signal below the sensing level *and* a nearby location with a receivable DTV signal. Since sensing is actually supposed to ensure that an unlicensed device *operates outside the protected contour* of a TV station, the actual failure rate is higher than reported. In this regard, a number of measurements were made where the signal level at one location was below the sensing level and the signal level at the second location was below the level that is needed to produce a viewable DTV picture. Since all of the sites were well within the protected contour of all measured DTV stations, the results of these outdoor measurements further confirm that sensing at even the -116 dBm will not ensure that an unlicensed device operates in the so-called "white space" outside the protected contour of a DTV station.

Measurements were also conducted at five indoor sites. Indoor signal reception presents some unique challenges such as additional attenuation of the signal and multipath effects. In these indoor tests, the DTV signal levels were measured with the test equipment used for the outdoor measurements and television reception was confirmed using the homeowner's DTV receiving equipment and antenna. In general, two indoor locations within each residence were measured, where possible. The results of the indoor tests show that signals below the -114 dBm level were observed at all five residences. In Residence 1, measurements were made on eighteen DTV channels. Nine channels had signal levels below -114 dBm in the kitchen area of the home and four channels had signal levels below -114 in the dining room of the home. The lowest measured value was -126.6 dBm in the living room and -125.1 dBm in the dining room. Residence 2 had four channels where the signal level was below the -114 dBm level with the lowest observed signal level at -120.3 dBm. Residence 3 had six channels with signal levels below -114 dBm with the lowest value being -125.2 dBm. Residence 4 had five channels with signal levels below -114 dBm with the lowest value at -123.8 dBm. In Residence 5, a signal level of -120. 7 dBm was observed immediately outside the home.

The indoor tests show a large number of signal measurements below both the -114 and -116 dBm proposed sensing levels. Furthermore, in most cases, reliable DTV reception was available in the residences on the same channels where these low signal levels occurred. For example, in residence 1, reception was available on seven of the nine channels where the signal level was below -114 dBm. In residence 4, reception was available on all five channels where the signal level was -114 dBm. These results confirm that there can be significant differences in DTV signal levels within a home and that the typical television installation provides substantial increases in the received signal level due to antenna height and gain. The results of these tests clearly show that sensing even at levels as low as -125 dBm would result in interference within the same home.

This study shows that sensing at -114 or -116 dBm will not guarantee that an unlicensed device is actually operating on a vacant television channel or in a so-called "white space." Fifty-eight (58) measurements were made where the measured DTV signal strength value was below the -114 dBm level, with values as low as -126.6 dBm observed.



The above chart shows the distribution of measurements below -114 dBm. As can be seen from the above chart, seven measurements were at -125 dBm and below; 27 measurements were between -120 and -125 dBm; 14 measurements were between -116 and -120 dBm; and, ten measurements were between -114 and -116 dBm.

4. Conclusion

The study conclusively shows that signal levels much lower than -116 dBm are present within a television station's service area. The study further show that the sensing levels proposed by sensing proponents (-114 dBm) and the FCC (-116 dBm) will not ensure that an unlicensed device can properly detect vacant television channels and will not prevent harmful interference.

It is important to note that the study was not intended to propose or suggest a sensing level that would be appropriate for an unlicensed device. The current measurement program was limited in scope and the measurement equipment used was only capable of measuring signal levels to about -126 dBm. To undertake such an effort will require a more comprehensive measurement program that takes into account variations in terrain and urban, suburban and rural environments.