Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

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

PETITION FOR RECONSIDERATION AND CLARIFICATION
MOTOROLA, INC.

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SUMMARY

Motorola is highly supportive of the Federal Communications Commission's decision to adopt rules that allow for the use of unoccupied spectrum allocated to the TV broadcast services by unlicensed devices and supports the vast majority of the technical framework adopted in the *Second Report and Order*. Nonetheless, there are several aspects of the decision that will have a negative impact on the ability of individuals or service providers to deploy systems altogether or that unnecessarily constrain the functionality and capability of unlicensed white space devices ("WSDs"). To that end, Motorola recommends that the Commission take the following actions to reconsider or clarify the following aspects of its decision:

- Modify the restrictions on the placement of fixed WSD antennas so that the maximum permitted height of transmitting antennas is increased from 30 to 100 meters and the minimum height for receive antennas is reduced from 10 to 3 meters.

- Eliminate the requirement that all WSDs use spectrum sensing to protect unregistered wireless microphones. In order to protect wireless microphones, the Commission should instead extend its decision to identify two television channels for wireless microphone use in 13 markets to nationwide.

- Clarify when a mode II personal/portable device must re-check the database based on its movement relative to information downloaded from the database.

- Allow for higher powered vehicle mounted personal/portable devices that rely on enhanced geo-location channel avoidance techniques to protect incumbent facilities.

- Clarify and reconsider its adopted policies and rules so that more precise prediction models can be incorporated into the data base of protected users to permit expanded adjacent channel use by fixed devices without need for excessive rulemaking delay.

- Eliminate the requirement that fixed WSDs transmit an identification signal that conforms to a yet-to-be developed industry standard.

- Clarify that the emissions requirements in the channels immediately adjacent to the operating channel is based on a 55 dB attenuation from the total average power transmitted by the WSD.

While the issues listed above individually may have limited impact, their cumulative effect can significantly affect the commercial viability of WSDs and unintentionally reduce the public interest benefits the Commission and industry seek to achieve.

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Motorola Inc. ("Motorola") hereby files this Petition for Reconsideration and clarification of the Commission's Second Report and Order and Memorandum Opinion and Order in the above-captioned proceeding.[1] Motorola urges the Commission to make further refinements to its rules authorizing the use of unlicensed devices in unoccupied portions of the TV broadcast spectrum in order for this spectrum to be best utilized to meet consumer demand for the provision of broadband services. The changes recommended herein can be made without negatively impacting TV viewers or authorized users of wireless microphones.

I. Introduction and Background.

Motorola applauds the Commission's leadership in adopting the *Second Report and Order* to allow for the use of unoccupied spectrum allocated to the TV broadcast services by unlicensed devices. The opportunity for this action to foster a variety of services and applications that make a real difference in people's lives is tremendous. The large amount of spectrum available on an unlicensed basis facilitates the deployment of a wide variety of cost-

[1] *In the Matter of Unlicensed Operations in the TV Broadcast Bands*, Second Report and Order and Memorandum Opinion and Order, 23 FCC Rcd 16807 (2008) ("Second Report and Order").

effective broadband solutions that will provide new opportunities to connect the unconnected and create jobs. For that reason, unlicensed white space devices ("WSDs") offer remarkable promise for helping this nation provide wireless broadband service to underserved and rural communities.

Motorola is highly supportive of the Commission's decision and appreciates the technical and political complexities involved in this proceeding. Motorola supports the vast majority of the technical framework adopted, including many provisions that are intended to protect broadcast services and wireless microphones from interference. Nonetheless, there are several aspects of the *Second Report and Order* that will have a serious negative impact on the ability of individuals or service providers to deploy systems altogether or that unnecessarily constrain the functionality and capability of WSDs. As further discussed below, Motorola recommends that the Commission reconsider or clarify certain aspects of its decision in order to assure that the over-protection of incumbents does not unduly restrict the full potential of WSDs. To this end, Motorola recommends that the Commission take the following actions:

- Modify the restrictions on the placement of fixed WSD antennas. The maximum permitted height of transmitting antennas should be increased from 30 meters to 100 meters and the minimum height for receive antennas should be reduced from 10 meters to 3 meters. These actions will significantly reduce the costs of deploying WSDs without increasing the risk of interference to incumbent facilities.
- Reconsider its requirement that all WSDs use spectrum sensing to protect unregistered wireless microphones. Testing proves that sensing for such low level signals will be highly unreliable and detrimental to WSD services. Rather than relying on sensing to protect wireless microphones, the Commission should instead extend its decision to identify two television channels for wireless microphone use in 13 markets to nationwide. The corresponding reduction in spectrum for WSDs can be compensated for by expanding WSD mobile use to frequencies below 512 MHz.
- Clarify when a mode II personal/portable device must re-check the database based on its movement relative to information downloaded from the database.

- Allow for higher powered personal/portable devices that are vehicle mounted and rely on enhanced geo-location channel avoidance techniques to protect incumbent facilities.
- Clarify and reconsider its adopted policies and rules so that more precise prediction models can be incorporated into the data base of protected users to permit expanded adjacent channel use by fixed devices without need for excessive rulemaking delay.
- Eliminate the requirement that fixed WSDs transmit an identification signal that conforms to a yet-to-be developed industry standard.
- Clarify that the emissions requirements in the channels immediately adjacent to the operating channel is based on a 55 dB attenuation from the total average power transmitted by the WSD.

As stated earlier, Motorola appreciates the complexities of this proceeding and believes that the Commission did an excellent job in exercising diligence and leadership to develop a workable framework for all parties involved. While the issues listed above individually may have limited impact, their cumulative effect can significantly affect the commercial viability of WSDs and unintentionally reduce the public interest benefits the Commission and industry seek to achieve. The changes proposed here either improve or do not negatively impact protection of legacy services, yet greatly enhance the opportunities for deploying WSDs. Accordingly, the Commission should reconsider these issues and provide for greater deployment opportunities for WSDs.

II. The Commission Should Reconsider Its Restrictions on TV Whitespace Device Antennas.

The *Second MO&O* imposed a 30 meter maximum antenna height limit on fixed WSDs.[2] The Commission reasoned that an antenna height limit of 30 meters will "appropriately balance"

[2] Second Report and Order, 23 FCC Rcd at 16886 (¶ 228).

the needs of unlicensed fixed WSDs to have sufficient range to provide service while bounding the range at which those operations could impact licensed services.[3]

The *Second Report and Order* imposes a second limitation on antenna deployment height of WSDs by requiring receive antennas of fixed devices to be installed no lower than 10 meters.[4] This policy is intended to ensure that fixed receive antennas are located at sufficiently high elevations to properly sense and detect nearby TV, LPTV stations and wireless microphones.[5]

Motorola believes that the Commission should reconsider both of these rules. In each case, the Commission's restrictions on WSD antenna placement will impose significant costs on broadband operators and consumers that will hamper the functionality and use of the devices – especially for rural broadband deployment – and are not necessary to protect primary services.

From our experience, unlicensed band wireless internet service providers ("WISPs"), who must strive to maximize their coverage and quality of service in rural areas, typically deploy antennas at heights of 250 ft (76 meters) to 328 ft (100 meters) so a 30 meter restriction is not consistent with typical deployment scenarios. Further, a 30 meter height restriction on fixed transmit antennas will require the deployment of more access points to cover the same geographic area. For example, increasing the transmitting antenna height from 30 meters to 100 meters increases the coverage area of a WSD by approximately 350 percent.[6] This greater coverage provides cost efficiencies for service providers intending to cover wide geographic areas – a 30 meter limit would require providers to install approximately 3.5 times more base

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3 *Id.*

4 Second Report and Order, 23 FCC Rcd at 16890 (¶ 241).

5 *Id.*

6 This estimate was derived using the Commission's F(50,50) curves with a UHF 4 watt transmitter and a HAAT of 30 meters or 100 meters.

stations to cover the same geographic area than would a 100 meter limit. For rural broadband applications, these increased costs will likely prove insurmountable for WISPs to launch successful business ventures. In short, increasing the height limit to 100 meters will greatly expand opportunities for rural broadband deployments.

While Motorola recognizes the Commission's desire to balance maximum service coverage with minimal interference risk to primary licensed services, similar protections can be afforded even at higher transmitting heights through a simple modification of rule section 15.712(a)(2).[7] That rule provides minimum separation distances for WSDs from co-channel and adjacent channel TV stations based on varying antenna heights for WSDs. Equivalent protection levels can be provided by simply adding rows to the table to accommodate higher antenna elevations.

[7] 47 C.F.R. § 15.712 (a)(2).

Motorola recommends that the upper limit for the transmitting antennas of WSDs be increased from 30 meters to 100 meters and that Section 15.712(a)(2) be revised to read as follows:[8]

Antenna Height of Unlicensed Device	Required separation distance (km) from Digital or Analog TV (Full Service or Low Power) Protected Contour	
	Co-Channel	Adjacent Channel
Less than 3 m	6.0 km	0.1 km
3 m – Less than 10 m	8.0 km	0.1 km
10 m – Less than 30 m	14.4 km	0.74 km
30 m – Less than 50 m	20.0 km	1.3 km
50 m – Less than 75 m	24.6 km	1.7 km
More than 75m – 100m	28.1 km	1.9 km

If the Commission agrees to modify the 30 meter limit, a corresponding change to Section 15.709(b)(2) is required.

Changing the limit for fixed transmitters from 30 meters to 100 meters above ground will allow for rural broadband coverage with fewer base stations and thus improve the utility of TV whitespace devices to satisfy important policy goals of the Commission and the U.S. Government. Motorola therefore urges the Commission to amend Section 15.709 and Section 15.712 accordingly in order to allow for the placement of fixed TV band antennas up to 100 meters above ground.

[8] The co-Channel separation distances were computed using F(50,10) propagation curves with 27.3 dBu interference level at approximately 16 dB C/I with 3 dB polarization mismatch. The computations do not include TV receiver antenna pattern discrimination; factors that would further reduce the potential for interference to TV reception. The adjacent channel separation distances were computed using simple two-ray propagation model (K=1) with -33 dB adjacent channel D/U for a -91 dBm DTV signal.

Motorola similarly urges the Commission to reconsider Section 15.709(b)(2) and revise the minimum receive antenna height for fixed WSDs from 10 meters to 3 meters. The existing minimum height requirement of 10 meters (approximately 33 feet) for receivers will substantially increase the installation cost for consumers, enterprises and WISPs. In many instances, placing the antenna more than 30 feet above the ground will require mechanically robust antenna masts or towers with additional costs ranging between $100 to as much as $1500 per installation.[9] Further such a requirement could often place would-be WSD users at odds with local zoning or neighborhood covenant restrictions.

According to the *Second Memorandum Opinion and Order*, the recommendation for a minimum receive antenna height limit was submitted by the IEEE 802.18 committee to ensure that the receiver is not shadowed by either terrain or man-made structures.[10] However, the IEEE comments presumed that TV whitespace devices would have only sensing operations associated with the device to prevent interference.[11] Under that assumption, the need to ensure that the receiver antenna was placed at a minimum height above ground to maximize detection by reducing the probability that the antenna is shadowed (*i.e.*, the hidden node issue) from licensed transmitters becomes the critical component for interference mitigation. However, the primary means through which a WSD protects primary options is through the use of geo-location database techniques, not through sensing. Because the sensing requirement adopted by the

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[9] In the best case, an antenna mount and a professional installation on a two-story building could cost as low as $100. On the other hand, one-story buildings could require the professional installation of a 30 foot communications tower, which can easily exceed $1500. This does not even consider wind loading issues which may require further installation costs for guy wire and other remedies.

[10] Second Report and Order, 23 FCC Rcd at 16890 (¶ 239). *See also,* Comments of IEEE 802.18, ET Docket No. 04-186, at 12 (submitted Jan. 31, 2007) ("Comments of IEEE 802.18").

[11] Comments of IEEE 802.18 at 11.

Commission provided little to no additional protection, it is unnecessary to impose onerous receive antenna height requirements based on sensing for WSDs that use geo-location techniques.[12] Motorola recommends that the Commission modify Section 15.709(b)(2) to reduce the minimum height restriction for fixed links from 10 meters to 3 meters. Maintaining a minimum height of 3 meters will ensure that, in most cases, deployment of fixed receive antennas will be economically viable and compliant with most local restrictions on the installation of over-the-air receiving devices.[13]

III. The Commission Should Eliminate Its Requirements to Sense For Wireless Microphones.

The *Second Memorandum Opinion and Order* adopted a requirement that fixed and personal/portable WSDs must have a capability to sense TV broadcasting and wireless microphone signals as a further means to minimize potential interference.[14] More specifically, all WSDs must be capable of detecting digital television stations, analog TV stations, and wireless microphones at a minimum signal level of -114 dBm. If wireless microphone signals are detected by the WSD, it must not transmit on that channel.

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[12] Requirements for WSDs that rely on only on sensing to provide protection may vary from requirements for devices that provide protection through the use of geo-location database.

[13] Reducing the minimum height for receive antennas should have little impact on the effectiveness of the technique for sensing and detecting wireless microphones. Wireless microphone operations are short range between the wireless microphone transmitter and its associated receiver. Therefore, there is a high likelihood that a WSD sensing the microphone transmitter would have approximately the same propagation loss to the wireless microphone receiver. Thus, if the path from the microphone transmitter to the WSD is shadowed, it is also likely that the path from the WSD to the microphone receiver is also shadowed. A 10 meter height limitation will not materially improve the ability to sense and detect wireless microphones over a 3 m height limitation. Furthermore, as discussed in the next section, the rules associated with the requirement that all WSDs sense for wireless microphone operations are problematic for a variety of reasons and should be eliminated.

[14] Second Report and Order, 23 FCC Rcd at 16852 (¶ 125).

Motorola previously stated that it is premature to rely on such methods because of the difficulties involved in implementing sensing technology in this environment and continues to recommend that database and location information should be the final source for determination on whether or not to transmit.[15] While Motorola believes that cognitive radios will inherently have sensing capabilities for determining which candidate channels (*i.e.*, those channels that are devoid of protected operations) provide the best communications opportunities (*i.e.*, those channels with the lowest measured interference levels), it has not been demonstrated whether those capabilities can be used for reliable independent identification and protection of licensed incumbents.[16]

Motorola has significant concerns with the adopted rules implementing the Commission's sensing requirements. As further discussed below, sensing of wireless microphones warrants reconsideration of the Commission's decision due to:

- The -114 dBm sensing level for wireless microphones will result in frequent false detections that will frustrate the deployment and use of WSDs;
- Omni-directional sensing requirements will constrain WSDs and will not provide any additional benefit to protection of wireless microphone operations;
- Distributed sensing will result in overly large areas where a wireless microphone sensing event could result in areas in excess of 5 km radius having to vacate a channel due to a localized event, greatly exceeding the 1 km keep-out radius found to be adequate for protecting microphones via geo-location techniques;[17] and,
- Wireless microphones (even unregistered wireless microphones) will inherently be afforded a high level of protection through the currently specified operation of geo-location databases.[18]

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15 Comments of Motorola, ET Docket No. 04-186, at 15 (submitted Nov. 30, 2004).

16 Comments of Motorola, ET Docket No. 04-186, at 18 (submitted Jan. 31, 2007).

17 *See* 47 C.F.R §15.712(f)(1).

18 Since all WSDs are prohibited from transmitting inside of co-channel contours, and fixed WSDs are also currently prohibited from transmitting inside of adjacent channel contours, many

Motorola recommends that the Commission eliminate the requirement that WSDs sense for wireless microphone operations. In order to avoid interference between the two classes of devices, the Commission should instead expand its previous decision and identify two television channels near channel 37 for wireless microphone use in all markets across the country.[19] The identification of these two channels should be made on a regional or state-wide basis in cooperation with affected licensees. Coupled with the protections that allow eligible wireless microphones to register in the database that WSDs are obligated to use for geo-location based protection,[20] these two policies obviate the need of the Commission to impose a "belt and suspenders requirement" on WSD devices and require sensing of wireless microphones.

If the Commission agrees with Motorola's recommendations and expands the scope of the wireless microphone channel designation nationwide, it would, of course, decrease the number of channels available for personal/portable devices. Consequently, Motorola recommends the Commission reconsider its decision to restrict geo-location enabled

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wireless microphone operations will be inherently protected from interference. For example, in OET Report FCC/OET 08-TR-1005 "*Evaluation of the Performance of Prototype TV- Band White Space Devices Phase II*" at pages 130 to 140, it can be seen that 6 of the 9 wireless microphone operations at Fed Ex field were operating co-channel to licensed TV operations, and would be precluded from *any* TVBD use or interference. Similarly, at the Majestic Theater test site, 5 of the 6 channels utilized by wireless microphones would be prohibited for TVBD use. These types of wireless microphone deployments appear to be typical. Portable WSDs operating on adjacent channels will typically have power spectral density levels of slightly over 1 mW in a 200 KHz bandwidth, posing limited risk of interference to wireless microphones that can operate at up to 250 mW transmit power levels.

[19] The *Second Report and Order* provided that in 13 major markets, two TV channels surrounding channel 37 would be made unavailable for WSDs and, therefore, more suitable for itinerant wireless microphone use. Second Report and Order, 23 FCC Rcd at 16906 (Appendix B).

[20] The Commission should clarify that for wireless microphones which are registered in the database that 1) the information provided under Section 15.713(h)(8)(F) is the center frequency of each registered low power auxiliary station within the registered channel, and 2) the WSD must avoid use of any frequency that is with in ±500 kHz of the center frequency within the registered channel of the wireless microphone.

personal/portable devices to operate on frequencies above 512 MHz and instead permit mobile operations throughout the entire WSD band.[21] Personal/portable devices that are geo-location enabled or wirelessly tethered to a geo-location enabled device should be permitted to operate in the bands below 512 MHz.

The Commission acknowledged that its decision to restrict personal/portable devices to frequencies above 512 MHz is "conservative" in protecting private and commercial land mobile services operating on portions of channels 14-20 in 13 major markets.[22] But the Commission reasoned that the "nomadic nature" and the "expected high numbers of personal/portable devices" renders them as a greater interference risk than fixed WSDs.[23] In Motorola's opinion, neither of these factors would indicate a higher potential for interference from personal/portable devices *provided that* the geo-location technique accurately assigns available white space spectrum.

No company is more concerned about protecting land mobile operators on TV channels 14-20 than Motorola. Motorola has supported that community ever since it led the effort to reallocate those channels for land mobile use back in the 1970s. Motorola is confident, however, that geo-location techniques can protect land mobile operations with a very high degree of certainty so that an outright prohibition on personal/portable devices on frequencies below 512 MHz is not warranted.

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[21] Second Report and Order, 23 FCC Rcd at 16906 (Appendix B).

[22] Second Report and Order, 23 FCC Rcd at 16861 (¶ 152).

[23] *Id.*

A. -114 dBm Sensing Level

Motorola agrees that geo-location database protection techniques are the primary source of interference protection to full power and low power television broadcast stations, registered cable headends and registered wireless microphone operations. Therefore, the need to sense and detect protected transmissions is largely to accommodate the operation of non-database wireless microphones operating throughout the TV bands.

Motorola believes that requiring sensing of such devices down to -114 dBm will result in frequent false detections and effectively turn any radiator or source of noise (intentional or unintentional) into a protective disabling beacon that will limit the utility and performance of WSDs. The -114 dBm sensing level is extremely low – it is at the noise floor level for the recommended 200 kHz bandwidth receiver with a 7 dB noise figure and is well below the noise floor when considering environmental noise effects that will be present in most locations.

While the Commission has provided appropriate protection for wireless microphone through inclusion in the database and the reservation of channels, the FCC WSD test report demonstrates that wireless microphone sensing is not yet a mature technology.[24] None of the prototype devices submitted for FCC testing reliably detected wireless microphones signals, either in the lab or in the field.[25] To further understand the impact that sensing for wireless microphones would have in operational scenarios, Motorola performed field testing in industrial and suburban outdoor environments to investigate the feasibility of the Commission's wireless microphone proposed sensitivity limit of -114 dBm and resulting WSD channel availability. Detailed results of this testing are shown in the attached Annex. In summary, these results lead

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[24] *See* OET Report FCC/OET 08-TR-1005 "*Evaluation of the Performance of Prototype TV- Band White Space Devices Phase II*".

[25] *Id.* at pages viii and 129.

us to conclude that sensing at such low levels (i.e. -114 dBm) will be unreliable and detrimental to WSD operations for the following reasons:

- Depending on the location, between 50 to 90 percent of candidate TV band channels are unavailable due to spurious narrowband peaks;
- Reliable sensing for low level wireless microphone signals is difficult in a typical operational environment, as confirmed by the FCC OET testing results;
- General emissions limits under Sections 15.109 and 15.209 and cable system leakage levels under Section 76.611 were observed during Motorola's field tests to provide enough energy to falsely trigger a detection event even though there are no wireless microphones nearby:
  - The general emission limits for both intentional and unintentional radiators in Sections 15.109 and 15.209 allow emission levels of -49 dBm EIRP per 120 kHz. It will require 65 dB of path loss, which is approximately 70 meters of separation at 605 MHz, for emissions to fall below the threshold of being mistaken for a licensed microphone. Since these emission levels apply to all electronic equipment, it would be unreasonable to set thresholds such that TVWS devices react to compliant emissions from these devices;
  - Cable system leakage levels permitted under Section 76.611 of the Commissions rules, combined with 45 dB of path loss, would result in sensing of -114 dBm signals in field operations.[26]

B. Omni-Directional Sensing

Based on input from IEEE 802.18, the Commission adopted a requirement that the -114 dBm detection threshold be referenced to a 0 dBi gain receive antenna for both fixed and personal/portable devices.[27] The Commission rationalized that this will "maximize the likelihood of sensing signal [*sic*] on an omni-directional basis."[28]

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[26] Section 76.611 permits cable television system egress of 20 uV/m at 3 meters. This field strength would be above the -114 dBm sensing level at distances less than 72.7 meters on TV channel 2 (57 MHz) and at distances less than 8.6 meters on TV channel 15 (479 MHz) for an omni-directional sensing antenna.

[27] Second Report and Order, 23 FCC Rcd at 16890 (¶ 239).

[28] *Id.* at ¶ 241.

The requirement for omni-directional sensing will result in additional costs for WSDs as it may require either a separate receive chain or more complex solutions for WSDs that have an antenna gain greater than 0 dB. These additional costs will hamper rural broadband deployment of fixed devices.

Also, the requirement for omni-directional sensing does not provide additional protection to typical wireless microphone operations. When an unregistered wireless microphone's transmit and receive antennas are co-located within typical distances (*e.g.*, 10 meters), there is little difference in the protection provided between using an omni-directional antenna and using a pattern with azimuthal variations, since for small angular changes the interference path pattern gain is essentially identical to the sensing path pattern gain and both paths are approximately reciprocal.

Due to these factors, the protection provided to the wireless microphone will be consistent regardless of the receive gain pattern of the antenna. As an example, if the interference/sensing path are in the peak gain of the antenna, the WSD will sense and protect at the specified level. If the sensing path is now in a side lobe that is 15 dB reduced from the peak gain, while the effective sensing level is degraded by 15 dB, the power radiated by the WSD is also reduced by this same amount and therefore provides a comparable level of protection.

C. Distributed Sensing

Based on the recommendation of wireless microphone interests, the Commission adopted a requirement for "distributed sensing" so that all WSDs that are in direct communication must react as if they all had sensed the wireless microphone. The Commission reasoned that use of this approach will better enable these devices to avoid using occupied channels when they are located in hidden nodes or areas where there are signal nulls.

A distributed sensing requirement could force access points to change frequencies for localized sensing events witnessed from client devices, including spurious sensing events such as 15.209(a) emissions being mistaken for microphones. In its most rigid application, this design would be very detrimental to the overall network operation. For example, a distant client device that is not even actively transmitting data may sense a wireless microphone, which could potentially force the network to abandon the channel if the interpretation of distributed sensing is strict. This frequency channel abandonment would occur even though the microphone would not be interfered with by the distant WSD. Furthermore, while the Commission established a 1 km keep-out zone for database protection of Part 74 devices, closing out an entire channel for an entire fixed access wide area network due to a localized detection could end up unintentionally providing keep-out zones in excess of 5 km, due to distant client TV band devices in a network detecting a wireless microphone (which includes the large detection range of the wireless microphone sensing applied in each device, as currently specified).

IV. The Commission Should Allow Certain Vehicle Mounted Devices to Operate With Higher Power.

The *Second Report and Order* adopted technical standards for two classes of WSDs – fixed and personal/portable devices.[29] Personal/portable devices, which, by definition, are designed to transmit and/or receive signals while in motion or at unspecified locations are further classified into two categories – mode I devices and mode II devices.[30] In mode I, client devices will be under control of a fixed or a mode II personal/portable device that has determined the available channels in the area.[31] In mode II, devices operating independently will use their own

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29 Second Report and Order, 23 FCC Rcd at 16845–855 (¶¶ 99-136).

30 *Id.* at 16852 (¶ 124).

31 *Id.*

internal geo-location/database access capabilities to determine the channels available for location in the area.[32] The *Second Report and Order* limits mode I and II personal/portable devices to power levels of 100 milliwatts EIRP and assumes the use of an integral antenna having 0 dBi gain.[33]

On numerous occasions prior to the adoption of the *Second Report and Order*, Motorola submitted recommendations to the Commission urging the accommodation of mobile WSDs operating with up to 4 watts EIRP.[34] Motorola indicated that such devices would fulfill a need for wide area mobile office/video solutions and vehicular area networks for local and state non mission-critical operations.[35] Permitting such mobile use will enable a wide variety of needed services, including new broadband options for critical infrastructure providers and enterprises that may operate in areas where no other broadband option exists.[36] Mobiles that are tethered wirelessly to a fixed WSD access point or that have access to the database can be controlled very similarly to fixed and personal/portable devices. Using the geo-location approach such mobile devices will provide the same level of interference protection to incumbents as TV band fixed devices.[37]

Without reference to Motorola's recommendations on mobile device power limits, the *Second Report and Order* adopted rules that limit mode I and II personal/portable non-fixed

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32 *Id.*

33 *Id.* at 16852-853 (¶¶ 126-127). If the antenna gain exceeds 0 dBi, the transmit output power must be reduced below 100 milliwatts accordingly.

34 *See, e.g.,* Motorola *ex parte* comments in ET Docket No. 04-186 (submitted Oct. 31, 2008); Motorola *ex parte* comments in ET Docket No. 04-186 (submitted Sept. 8, 2008).

35 Motorola *ex parte* comments in ET Docket No. 04-186 (submitted on Aug. 22, 2008).

36 *Id.*

37 Motorola *ex parte* comments in ET Docket No. 04-186 (submitted on Sept. 8, 2008).

WSDs to 100 milliwatts EIRP. Motorola urges the Commission to reconsider this decision and, instead, allow for some classes of TV band mobile devices to operate with up to 4 watts EIRP. Such devices hold significant promise for critical infrastructure industries and other enterprise users. Access to data through low cost, wide-area mobile broadband connections protect the American public and improve industrial efficiencies and productivity, increase competitiveness globally, and therefore, help build job strength. Such WSDs broadband mobile uses could help provide data when and where it is needed, especially in unserved and under-served areas. Mobile access to such data by enterprise and critical infrastructure users enable improvements in response times, situational awareness and overall customer service.[38]

Mobile devices that are under control of a fixed master device or connected to the database can be easily controlled using geo-location techniques to ensure that no greater risk of interference is presented to protected users. The 100 milliwatt output power limitation on mobile devices that are electronically tethered to fixed devices that are capable of operating at a power level of 4 watts presents an imbalance in designing a system and is overly restrictive, particularly when trying to deploy systems in rural and underserved areas. The restriction is unnecessary to provide interference protection yet severely affects the functionality of WSDs.

Rather than restricting all personal/portable WSDs to very low power, the Commission should consider allowing higher powered uses under certain operating conditions. Motorola recommends that the Commission allow a third class of personal/portable devices which are

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[38] Unlicensed mobile WSD use would be a supplement to, not a replacement for, dedicated licensed spectrum needed to support critical infrastructure applications. *See* "The Utility Spectrum Crisis: A Critical Need to Enable Smart Grids" by the Utilities Telecom Council, January 2009.

vehicle-mounted and permitted to operate with 4 watts EIRP.[39] Under this proposal, this class of device will have both a tethered client mode of operation and a non-tethered master mode of operation. In the tethered mode of operation, it would rely on another device to provide the direction on which channel to operate. In the non-tethered mode of operation, the device would access the database and operate similarly to a mode II personal/portable device with respect to database access.

Vehicle mounted devices are operated outdoors where the full benefits of geo-location based channel selection are most effective. These vehicle-mounted devices will have lower antenna heights than fixed devices and hence have shorter interference ranges compared to their fixed counterparts. Since vehicles are confined to streets, they will also generally be further from residences than a neighboring residence with a fixed WSD that is allowed to transmit 4 watts EIRP.

Should the Commission determine that further constraints on 4 watt mobile devices are needed, it could consider limiting the marketing of such devices to users as defined in Part 90 of the Commission's rules. The last spectrum allocation for business and industrial users occurred over twenty years ago in the 1980s and many of the larger enterprise groups now require more sophisticated broadband applications than can be provided on existing narrowband channels. WSDs are a good solution for users accustomed to coordinating frequency usage and sharing spectrum with TV broadcasters, which can address a portion of the unmet demand of enterprise users for additional spectrum. While eligibility restrictions are best regulated through the licensing processes such as those under Part 90 of the rules, the Commission can monitor and

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[39] Such devices could be classified as Mode III devices in keeping with the same nomenclature adopted in the *Second Report and Order*.

enforce these limitations through its existing rules on marketing of radiocommunication devices and its equipment authorization procedures

V. The Commission Must Clarify Personal/Portable Database Access.

The *Second Report and Order* adopted requirements that a mode II personal/portable device must access the database for a list of available channels each time it is activated from a power-off condition and, also, must re-check its location and the database for available channels if it changes location during operation.[40] The threshold for triggering the re-check once a device has moved is not clear in the Commission's rules. For example, one could consider that once a device has moved outside the 50 meter uncertainty distance specified in Section 15.711(b) it has moved beyond the information provided by the database and should re-check the database. Under this interpretation, it will be difficult to ensure protection for some use cases as a simple check of channels in a specific location may quickly be out-of-date.

For example, consider a mode II device operating in an automobile traveling down an interstate at 70 mph. While the device may be connecting to the geo-location database via a cellular network, the physical latency time in the network and database access could result in the device not receiving a channel update before traveling outside the 50 meter uncertainty distance (a distance which it would cover in about 1.5 seconds).

The Commission should clarify that mode II devices can contact the database and download multiple locations that surround and abut its current location. Only when the device has moved beyond the locations in which the downloaded information is valid would it be required to re-connect with the database for an updated list of available channels or cease operation. To ensure that database information downloaded to a WSD is up-to-date, the

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[40] Second Report and Order, 23 FCC Rcd at 16879 (¶ 207).

Commission should also specify that such download information is valid until 11:59 PM of the following day, when it was downloaded, similar to Section 15.711(b)(3)(iii) regarding how long fixed or mode II devices may continue operation since the last database access.

VI. The Commission Should Amend Rules That Restrict Use of Adjacent TV Channels by Fixed WSDs

The *Second Report and Order* does not provide provisions for fixed devices to operate on a channel adjacent to a TV station in order to protect the TV service from interference. The adopted rules provide separation distances that prohibit the deployment of fixed devices within the protected service contours of the various classes of primary stations in the TV band.[41]

The Commission recognized that not providing provisions for fixed devices to operate on first adjacent channels will have the effect of limiting the number of channels that are available for use by those devices in some markets.[42] The Commission indicated that it "will remain open to possible solutions for operating the higher power fixed devices on adjacent channels" and encouraged "interested parties to continue to explore possible options for operating on first adjacent channels that will not increase the potential for interference to television service."[43]

As Motorola previously indicated, the restrictions on adjacent channel use impose a severe constraint on spectrum availability for WSDs, in many cases there will be no channels available for WSDs if restrictions on adjacent channels use is retained.[44] These operating restrictions can be eased through the use of advanced propagation modeling techniques that take into account detailed terrain data, and more accurately predict TV signal field strength levels

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41 Section 15.712 of the Commission's Rules.

42 Second Report and Order, 23 FCC Rcd at 16867 (¶ 170).

43 *Id.*

44 Motorola *ex parte* comments in ET Docket No. 04-186 (submitted Sept. 8, 2008).

than even conservative use of the R-6602 family of curves. Modern modeling technology has advanced well beyond the R-6602 curves, and much higher accuracy modeling is possible at reasonable computational cost levels.

Motorola believes that the rules should allow for the use of highly detailed terrain modeling that takes advantage of high resolution (at least 30 meter) terrain databases to more accurately predict field signal strength levels, even in the presence of shadowing effects. Reliance on these methods can eliminate adjacent channel prohibition and provide for more spectrum availability in many markets without compromising the protection afforded to protected primary services.[45] In support of these efforts, the Commission should clarify and reconsider its adopted policies and rules so that more precise prediction models can be incorporated into the data base of protected users without need for excessive rulemaking delay.

VII. The Commission Should Modify its Requirements for Fixed WSDs to Transmit Identifying Signals.

The *Second Report and Order* requires fixed WSDs to transmit an identifying signal that conforms to an industry standard which carries sufficient information to identify the device and its geographic coordinates, in addition to requiring that fixed WSDs be registered in the database system.[46] Furthermore the *Second Report and Order* specifically excludes personal/portable devices from such a requirement since the Commission concludes that an identifying signal will

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[45] Note that even lower resolution terrain data is utilized by the Commission to allow high powered TV transmitters to operate within other TV transmitter's protected service contours. For example, WOCH-Ch. 41 in Chicago successfully operates with 25 kW ERP on the adjacent channel to W40BY-Ch 40, which operates with 37.2 kW ERP, even though the stations' protected service contours significantly overlap, and the transmitters are not co-located.

[46] Second Report and Order, 23 FCC Rcd at 16847 (¶ 108); 47 C.F.R §15.711(e). The registration information contains data beyond just the device location and the device itself.

not be of significant value in identifying or resolving interference such devices may cause.[47] While Motorola recognizes the important goal of being able to resolve situations in which an interfering WSD needs to be located, we believe that the requirement for fixed WSD to comply with this yet to be defined standard will place undue burdens on the development of systems as it may constrain such systems to support a particular modulation while offering little to no benefit. This requirement will also introduce delay in WSDs entering the marketplace due to the time required for development of a standard.

Motorola recommends the Commission delete the requirement of Section 15.711(e) for fixed WSDs to transmit such identifying signals. In the unlikely event that interference occurs, the Commission has the ability via the geo-location database to identify sources of interference and resolve any potential situations that primary services may experience from fixed WSD operations. Should the Commission decide not to eliminate the requirement for fixed devices to transmit an identifying signal, we recommend the Commission allow all WSD devices to transmit identifying information periodically (on the order of minutes) in a format which is consistent with their native (or primary) modulation techniques. Equipment providers (or other vendors) can supply receiver equipment to the Commission that can successfully demodulate the identifying signals, as needed.[48]

VIII. The Commission Must Clarify the Emission Requirements.

The *Second Report and Order* requires that the undesirable emissions limits for WSDs be at least 55 dB below the highest average power in the 6 MHz channels adjacent to the 6 MHz

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[47] Second Report and Order, 23 FCC Rcd at 16853 (¶ 128).

[48] Alternatively, a simple form of on-off keying during occasional quiet periods can readily identify either the WSD class (by its FCC ID) or the type of WSD system (for further demodulation with specific equipment). This will reduce the burden to WSDs for meeting the identifying signaling requirements.

channel in which the device is operating.[49] Motorola requests that the Commission clarify this requirement is based on the total in-band power level and is not a relative spectral power measurement. As an example, if a fixed WSD has a total average power of 1 W (30 dBm), then the emission requirement in the adjacent 6 MHz channels is 30 dBm – 55 dB = -25 dBm. This power level is measured in a 100 kHz bandwidth.

In the event that the Commission does interpret the undesirable emissions limits for WSDs to be a relative spectral measurement, we request that the Commission reconsider this decision and modify the emissions requirements of Section 15.709(c). For example, if the average power in any 100 kHz on the operating channel is 12.2 dBm measured in a 100 kHz bandwidth[50] then the emission level in the adjacent 6 MHz channels would have to be 12.2 dBm – 55 dB = -42.8 dBm. This power level is measured in a 100 kHz bandwidth and is 17.8 dB stricter than above interpretation and nearly 30 dB more restrictive than emissions for cellular equipment authorized under Part 22 of the Commission rules.[51] Such an interpretation of the emissions requirements are extremely difficult to implement in consumer equipment operating at the power levels permitted by the Commission.[52] In the case that undesirable emissions are specified as relative spectral measurements, Motorola requests the Commission modify its rules and specify that emissions be at least 35 dB below the highest average power in the 6 MHz channels adjacent to the 6 MHz channel in which the device is operating.

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[49] Second Report and Order, 23 FCC Rcd at 16889 (¶ 236).

[50] Assuming the on-channel band with is 6 MHz, a transmit power level of 30 dBm and a flat spectrum across the operating channel then the on-channel emission level is 30 dBm – 10*log(6000/100) = 12.2 dBm measured in a 100 kHz bandwidth.

[51] *See* 47 C.F.R. § 22.917 of the Commission's Rules.

[52] For example, the mask is approximately 35 dB tighter than the first shelf for the popular 802.11 wireless networking equipment.

IX. Conclusion.

The Commission has set the stage for the development and deployment of an incredible array of broadband devices in the TV white space spectrum. In order to fulfill the full potential of WSDs, the Commission should provide some additional flexibility so that the cost of design and implementation of these devices does not exceed the market's ability to pay. To this end, Motorola urges the Commission to reconsider and clarify its rules for unlicensed devices in the TV white space spectrum in accordance with the recommendation provided herein. Motorola believes that these modifications will not increase the potential for interference to broadcast facilities or wireless microphones but are necessary to help manufacturers develop white space devices and applications that meet the broadest range of consumer and industrial needs.

Respectfully Submitted,

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ANNEX
WIRELESS MICROPHONE SENSING TESTS: FIELD TESTING METHODOLOGY AND OBSERVATIONS NOTES

I. Executive Summary

The Motorola Cognitive Radio Prototype sensor was tested in the industrial and suburban outdoors environments, together with visual spectrum evaluation, to investigate feasibility of the FCC Wireless Microphone (WM) proposed sensitivity limit of -114 dBm and resulting WSD channel availability. Detailed conclusions from the testing, as well as recommendations are drawn in the conclusions section VI of this annex. The main points are:

- Depending on the location, from 50 to 90% of candidate WSD channels are unavailable due to narrow band peaks which were not the result of WM operation or required TV protection.
- Reliable sensing for low level WM signals in real world conditions with strong adjacent signals is difficult.

II. Goals

The goal of this testing is to investigate feasibility of sensing WM signals at the Commission proposed -114 dBm level with 90% probability of detection, while maintaining low false alarm rates. The main questions are:

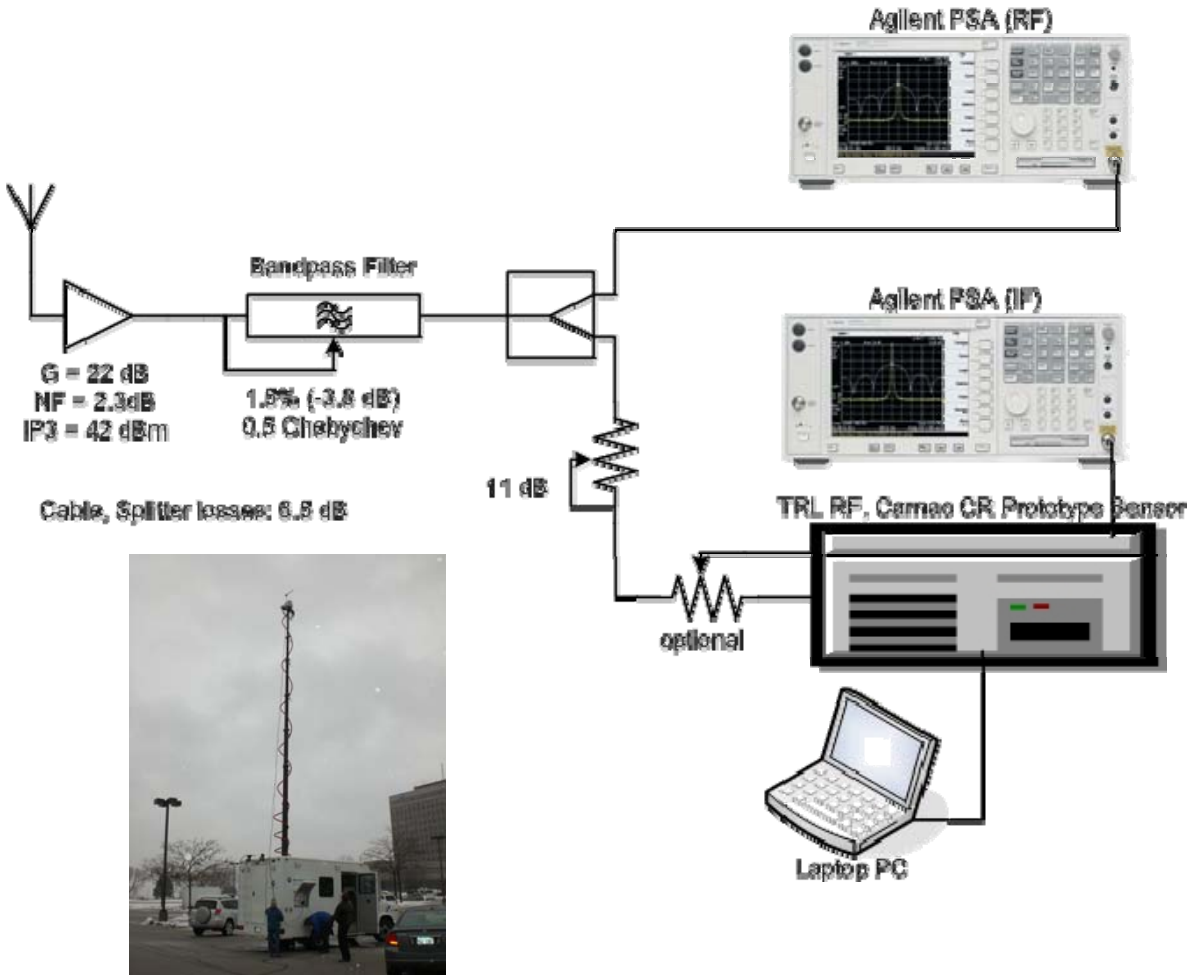
a) Will there be any available channels in WSD for use by unlicensed WSD in various operational environments, while sensing for WM signals at this level?
b) Are current prototype sensors efficient and reliable in detecting present WM signals in "real world" conditions? What is the false alarm rate?

III. Test Methodology & Setup

The following methodology considerations and procedures were used for the testing:

- Tests were performed at several representative locations: industrial, commercial, suburban.
- Measurements were taken with Front End (FE) preselect filter and preamp to minimize impact of the strong signals, i.e. DTV and NTSC stations, on the neighboring UHF channels.
- Sensing was done with the Motorola WM Prototype sensor. The NTSC and DTV channels at the testing locations were excluded from sensing and analysis.
- Before field tests, the Prototype sensor had been calibrated in the lab for -114 dBm, probability of detection (P_d) of 90%, via cabled RF. The resulting probability of false alarm (P_{fa}) was measured, and sensor's Receiver Operating Characteristics (ROC) determined.
- Visual spectral measurements were made with a PSA, connected before the sensor, to correlate sensor results with PSA measurements, and identify missed and false detections.

The Test setup diagram is shown below.

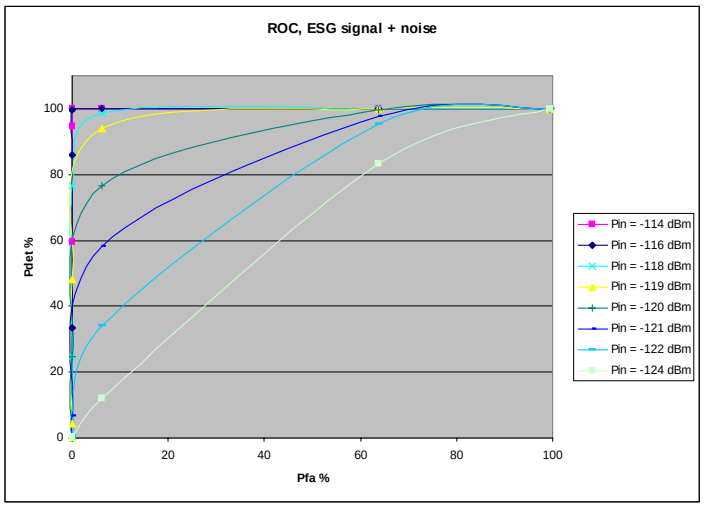


IV. Sensor Calibration and Parameters

Before field testing, lab calibrations were performed, the sensor was characterized and its parameters for use in tests identified. Using ESG and pre-recorded unmodulated WM waveform (Shure SLX Series Transmitter) the sensor's ROC, false alarm probability and sensitivity threshold requirements identified.

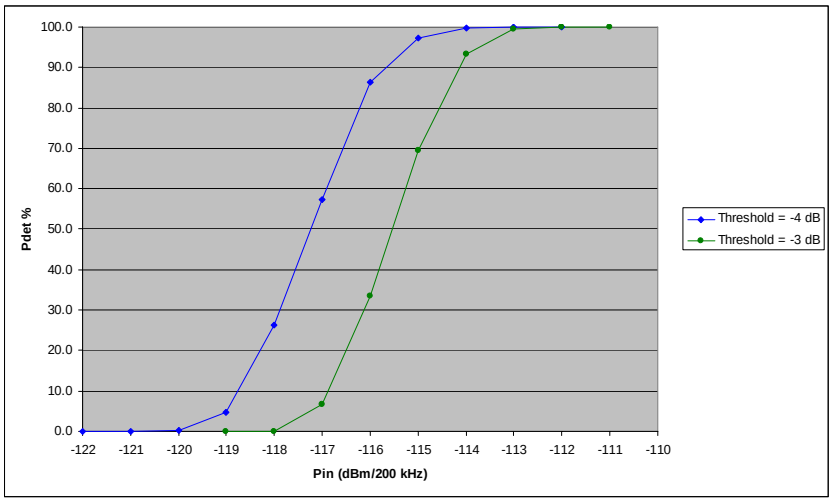
The Table and graph below show the data taken for varying sensing threshold vs. input power, and resulting sensor's ROC.

	Pin, dBm	Detection Threshold, dB							
		-9	-8	-7	-6	-5	-4	-3	-2
Pdet %	-114	100	100	100	100	100	100	94.6	59.6
	-115	100	100	100	100	100	96.2	74.4	14.6
	-116	100	100	100	100	99.6	85.8	33.4	0
	-117	100	100	100	100	94.4	56.4	7.0	0
	-118	100	100	100	98.7	76.6	24.8	0.2	0
	-119	100	100	99.9	93.8	48.0	4.2	0	0
	-120	100	100	99.7	76.6	24.6	0	0	0
	-121	100	100	97.5	58.2	6.8	0	0	0
	-122	100	100	95.2	34.0	0.8	0	0	0
	-123	100	100	90.7	22.4	0.4	0	0	0
	-124	100	99.9	83.3	12.0	0.4	0	0	0
P_{fa} %	-	99.5	99.3	63.7	6.2	0	0	0	0



Note that to measure more realistic false alarm characteristic, the "clean" WM waveform was combined with "pseudo-noise" (8vsb waveform) at the thermal AWGN level of PSD -111 dBm/200 kHz. These measurements determined prototype sensor's threshold parameter. From the Table above, for Pin = -114 dBm, the detection probability of 90% is achieved at the threshold value set to -3 dB. With this threshold, the P_{fa} in the lab setup is practically 0%. The calibration had to be partially repeated in the mobile test setup, with added FE bandpass filter and preamp. Instead of the ESG with WM waveform, a signal generator with simple tone was used. Due to addition of the preamp, not noise-calibrated with the prototype's RF, the second calibration results somewhat differed from lab measurements, and to achieve Pd = 90% at Pin = -114 dBm, the Threshold parameter was changed to +2 dB.

With the above defined sensor parameters, the sensitivity curves were also taken in the lab, as shown in the graph below (the Threshold parameter values of -4 and -3 dB in the legend correspond to the mobile test setup values +1 and +2 dB, respectively).



V. Observations and Results

The tests were performed at the following representative locations:

- V.A) Motorola parking lot, at the time when some WMs were active;
- V.B) Industrial location in Schaumburg, IL;
- V.C) Retail store parking lot in Schaumburg, IL;
- V.D) Suburban residential area in Schaumburg, IL; antenna positions low, high vertical, high horizontal;
- V.E) Place of worship in South Barrington, IL, with multiple WMs, first at the parking lot, and then at the close-by residential area to test WM sensing;
- V.F) Residential area

All sensing results are collected in the Tables below, along with the notes based on PSA visual observations. The observations and analysis were based on the visual observations of RF spectrum on a spectrum analyzer with correlation to sensing data.

In the data tables below, the following color scheme was used:

Light green – candidate channels, in column 1 according to the TV Database information, and in column 5 not rejected after sensing;
Bright green – channel(s) identified as best for WSD use after sensing;
Gray – channels forbidden for use (i.e. 37, reserved for Radio Astronomy);
Blue – channels with detected WMs and narrow band interferers;
Light blue – detected WMs;
Orange – WM operating inside TV Grade B contour; and
Light yellow – channels that showed some detection issues (i.e. limited sensitivity due to adjacent channels, or unstable signals).

A. Motorola parking lot

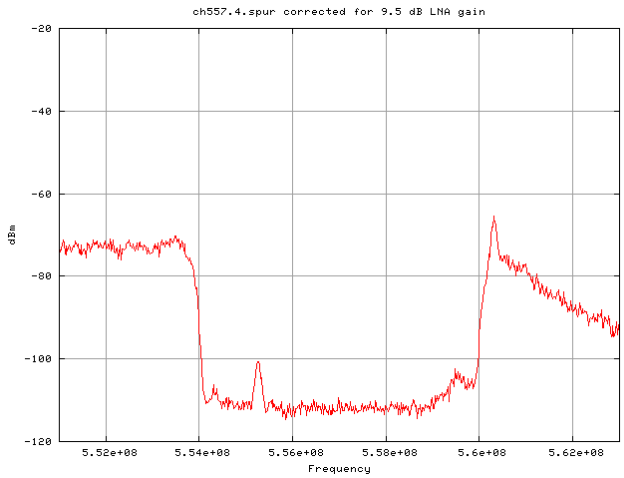
Location (42.064N, 88.050W), approximately 150 m from the Motorola building, between 3 and 5 pm on Tuesday 12/09/08. Some WM signals were observed on channels 28 and 30.

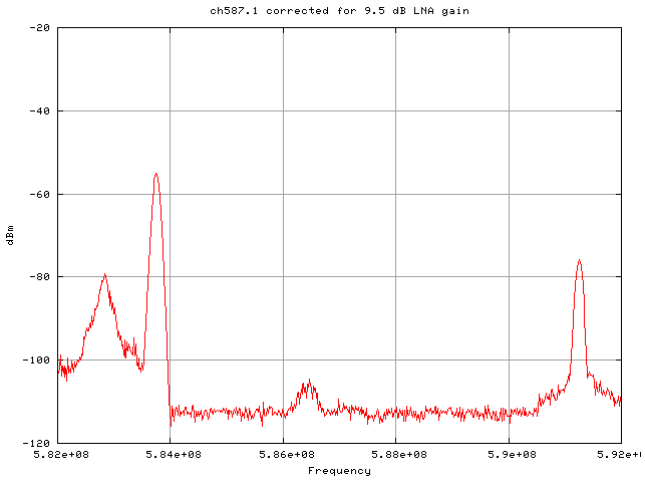
UHF Channel		Channel Pin, dBm		Narrow	Narrow peaks	Notes
#	Center MHz	min	max	peaks found	Pdet %	
21	515			-		Excluded (20.1 Chicago PBS DTV)
22	521	-81	-76	2	100.0	Strong NTSC (22 Arlington Heights TBN)
23	527	-42	-41	16	100.0	NTSC (23 Chicago IND WWME-CA)
24	533	-90	-86	2	98.0	Weak NTSC (24 Milwaukee MNT)
25	539	-89	-87	3	100.0	DTV (24.1 Milwaukee MNT), NTSC(?)
26	545	-42	-41	2	100.0	Strong NTSC (26 Chicago IND)
27	551			-		Excluded (26.1 Chicago IND DTV)
28	557	-92	-89	2	96.0	Wireless Mics, spurious
29	563			-		Excluded (5.1 Chicago NBC DTV)
30	569	-78	-76	0	0.0	Wireless Mics missed due to strong adjacent
31	575			-		Excluded (32.1 Chicago FOX DTV)
32	581	-52	-49	3	100.0	Strong NTSC (32 Chicago FOX)
33	587	-94	-86	0	10.0	Small bump, up and down - marginal
34	593	-78	-76	4	100.0	Weak NTSC (34 Arling. Hts REL)
35	599	-87	-86	2	100.0	Weak DTV (36.1 Milwaukee PBS), some NTSC
36	605			-		Excluded (62.1 Hammond IND DTV)
37	611	-106	-105	0		Radioastronomy, medical
38	617	-46	-45	32	100.0	Strong NTSC (38 Chicago ION)
39	623			-		Excluded (39.1Chicago MeTV DTV)
40	629	-77	-76	3	100.0	Weak NTSC/DTV (Palatine W40BY)
41	635	-69	-66	3	100.0	Weak NTSC (41 WOCH-CA)
42	641	-86	-85	0	0.0	
43	647			-		Excluded (38.1 Chicago ION DTV)
44	653	-43	-42	2	97.0	Strong NTSC (44 Chicago TEL)
45	659			-		Excluded (44.1 Chicago TEL DTV)
46	665	-79	-78	0	0.0	AGC attenuation ~20 dB due to adjacent DTV channels
47	671			-		Excluded (11.1 Chicago PBS DTV)
48	677	-65	-64	2	100.0	Weak NTSC (48 Blue Island IND)
49	683	-83	-81	2	100.0	Wide peaks (found with BW 50 kHz)
50	689	-46	-45	4	100.0	Strong NTSC (50 Gary MNT)
51	695			-		Excluded (50.1 Gary MNT DTV)
candidates		Max	-41			

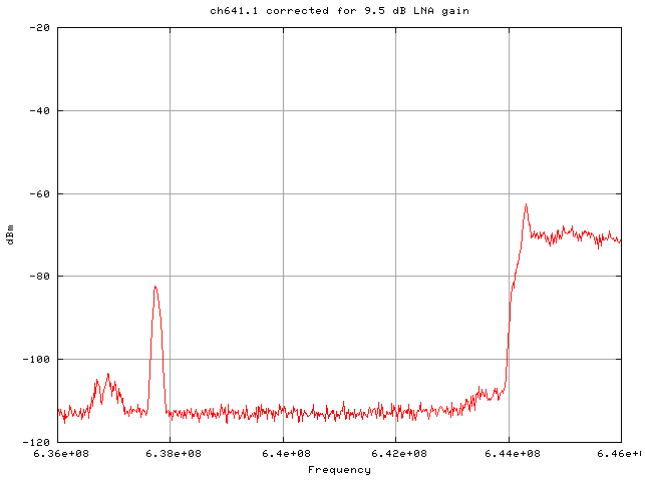
Out of 10 candidate channels from the TV Database, 4 channels were open after WM sensing. Note that the situation on channel 30 highlights one of the problems with sensing for WM, a WM was missed due to a strong adjacent channel.

The RF spectrum graphs below illustrate cases of:

a) Channel 28, with strong adjacent DTV signals and successfully detected WM;
b) Channel 33 with strong lower (Fox) and weaker higher adjacent NTSC channel, and a "bump", caused by the Fox station test transmission;
c) Channel 42 with weak lower adjacent NTSC channel and strong higher DTV, identified as available for WSD transmission.


ch557.4.spur corrected for 9.5 dB LNA gain
dBm
-20
-40
-60
-80
-100
-120
5.52e+08
5.54e+08
5.56e+08
5.58e+08
5.6e+08
5.62e+08
Frequency


ch587.1 corrected for 9.5 dB LNA gain
dBm
-20
-40
-60
-80
-100
-120
5.82e+08
5.84e+08
5.86e+08
5.88e+08
5.9e+08
Frequency


ch641.1 corrected for 9.5 dB LNA gain
dBm
-20
-40
-60
-80
-100
-120
6.36e+08
6.38e+08
6.4e+08
6.42e+08
6.44e+08
Frequency

B. Industrial park in Schaumburg, IL.

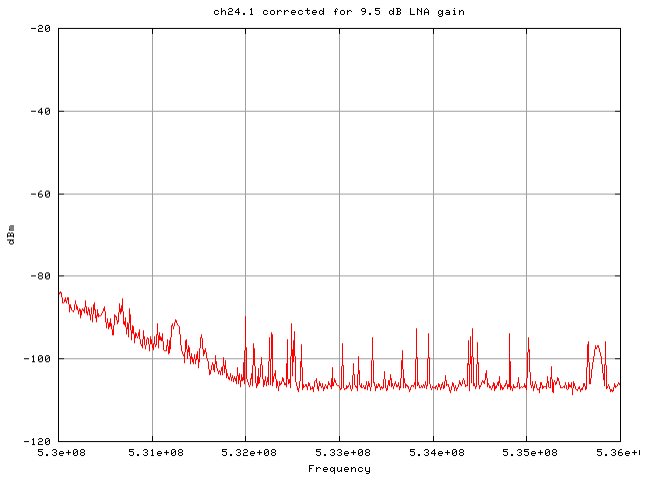
Location (41.997N, 87.977W), approximately 50-100 m from several small production facilities and storage loading areas, with semi and forklift trucks driving by, from 3 to 5 pm.

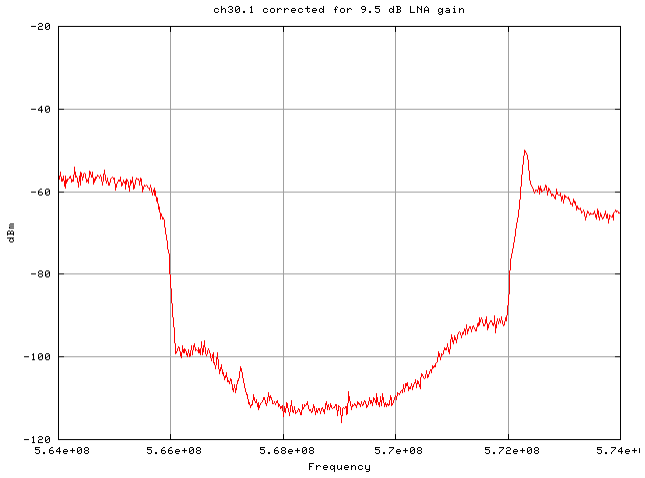
UHF Channel		Channel Pin, dBm		Narrow	Narrow peaks	Notes
#	Center MHz	min	max	peaks found	Pdet %	
21	515			-		Excluded (20.1 Chicago PBS DTV)
22	521	-69	-69	2	100.0	Strong NTSC (22 Arlington Heights TBN)
23	527	-35	-34	10	100.0	NTSC (23 Chicago IND WWME-CA)
24	533	-80	-75	3	99.0	Industrial!; Weak NTSC (24 Milwaukee MNT)
25	539	-72	-71	2	100.0	DTV (24.1 Milwaukee MNT), NTSC(?)
26	545	-35	-35	5	100.0	Strong NTSC (26 Chicago IND)
27	551			-		Excluded (26.1 Chicago IND DTV)
28	557	-75	-77	0	0.0	Strong adjacents; NTSC (?)
29	563			-		Excluded (5.1 Chicago NBC DTV)
30	569	-63	-62	0	0.0	AGC Att 28 dB strong adjacents; NTSC (?)
31	575			-		Excluded (32.1 Chicago FOX DTV)
32	581	-35	-35	3	100.0	Strong NTSC (32 Chicago FOX)
33	587	-78	-73	4	99.0	Bump (from low adjacent?)
34	593	-71	-68	3	100.0	Weak NTSC (34 Arling. Hts REL)
35	599	-88	-75	4	100.0	Weak DTV (36.1 Milwaukee PBS), some NTSC
36	605			-		Excluded (62.1 Hammond IND DTV)
37	611	-101	-94	2	94.0	Radioastronomy, medical; Very strong adjacent
38	617	-39	-39	4	100.0	Strong NTSC (38 Chicago ION)
39	623			-		Excluded (39.1Chicago MeTV DTV)
40	629	-94	-90	3	93.0	Weak NTSC/DTV (Palatine W40BY)
41	635	-39	-39	3	100.0	Weak NTSC (41 WOCH-CA)
42	641	-76	-72	0	0.0	
43	647			-		Excluded (38.1 Chicago ION DTV)
44	653	-36	-36	3	100.0	Strong NTSC (44 Chicago TEL)
45	659			-		Excluded (44.1 Chicago TEL DTV)
46	665	-68	-68	0	0.0	AGC attenuation ~20 dB due to adjacent DTV channels
47	671			-		Excluded (11.1 Chicago PBS DTV)
48	677	-59	-59	2	100.0	Weak NTSC (48 Blue Island IND)
49	683	-97	-85	2	100.0	Strong IMs
50	689	-39	-39	2	100.0	Strong NTSC (50 Gary MNT)
51	695			-		Excluded (50.1 Gary MNT DTV)
candidates		Max	-34			

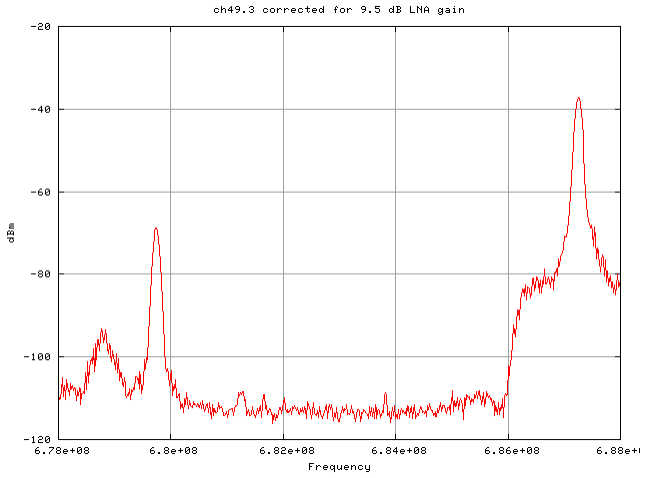
Out of 10 candidate channels from the TV Database, only 4 channels were open after WM sensing. At least 3 of the 6 channels rejected by sensing appear to be due to the problems with detection at this low level, not from actual WM operations or required protection of TV.

The RF spectrum graphs below illustrate cases of:

a) Channel 24, with strong lower adjacent NTSC signal and many spurious industrial signals;
b) Channel 30 with very strong adjacent DTVs, “leaking” into channel, causing high AGC attenuation and impaired sensitivity;
c) Channel 49 with the weak lower and strong higher adjacent NTSC channels and a couple of weak spurious (or IM) signals.


ch24.1 corrected for 9.5 dB LNA gain
-20
-40
-60
-80
-100
-120
dBm
5.3e+08
5.31e+08
5.32e+08
5.33e+08
5.34e+08
5.35e+08
Frequency


ch30.1 corrected for 9.5 dB LNA gain
-20
-40
-60
-80
-100
-120
dBm
5.64e+08
5.66e+08
5.68e+08
5.7e+08
5.72e+08
Frequency


ch49.3 corrected for 9.5 dB LNA gain
-20
-40
-60
-80
-100
-120
dBm
6.78e+08
6.8e+08
6.82e+08
6.84e+08
6.86e+08
Frequency

C. Schaumburg IL retail parking lot

Location (42.055N, 88.044W), approximately 120 m from a group of commercial buildings. Time: between 3 and 5 pm. Antenna was extracted only partially (about half height), resulting in lower measured signal input power, thus reducing sensitivity for weak remote signals.

UHF Channel		Channel Pin, dBm		Narrow peaks found	Narrow peaks Pdet %	Notes
#	Center MHz	min	max			
21	515			-		Excluded (20.1 Chicago PBS DTV)
22	521	-77	-75	2	100.0	Strong NTSC (22 Arlington Heights TBN)
23	527	-58	-57	2	100.0	NTSC (23 Chicago IND WWME-CA)
24	533	-100	-97	1	19.0	Weak NTSC (24 Milwaukee MNT)
25	539	-99	-96	3	100.0	DTV (24.1 Milwaukee MNT), NTSC(?), Spikes!
26	545	-52	50	2	100.0	Strong NTSC (26 Chicago IND)
27	551			-		Excluded (26.1 Chicago IND DTV)
28	557	-97	-88	3	92.0	Strong adjacents; NTSC (?); Weak DTV (Milwaukee)
29	563			-		Excluded (5.1 Chicago NBC DTV)
30	569	-98	-94	1	73.0	AGC Att 9 dB strong adjacents; NTSC (?)
31	575			-		Excluded (32.1 Chicago FOX DTV)
32	581	-58	-56	3	100.0	Strong NTSC (32 Chicago FOX)
33	587	-99	-94	1	97.0	Peak at 5 MHz - spur from our equipment
34	593	-93	-91	1	100.0	Weak NTSC (34 Arling. Hts REL)
35	599	-91	-89	2	100.0	Weak DTV (36.1 Milwaukee PBS), some NTSC
36	605	-93	-92	1	63.0	62.1 Hammond IND DTV
37	611	-102	-102	0	0.0	Radioastronomy, medical
38	617	-62	-60	3	100.0	Strong NTSC (38 Chicago ION)
39	623			-		Excluded (39.1Chicago MeTV DTV)
40	629	-96	-93	4	100.0	Weak NTSC/DTV (Palatine W40BY)
41	635	-70	-69	2	100.0	Weak NTSC (41 WOCH-CA)
42	641	-102	-101	1	8.0	
43	647			-		Excluded (38.1 Chicago ION DTV)
44	653	-59	58	2	100.0	Strong NTSC (44 Chicago TEL)
45	659			-		Excluded (44.1 Chicago TEL DTV)
46	665	-102	-98	0	0.0	
47	671			-		Excluded (11.1 Chicago PBS DTV)
48	677	-85	-81	2	100.0	Weak NTSC (48 Blue Island IND)
49	683	-103	-100	1	2.0	Weak IM
50	689			-		Excluded - Strong NTSC (50 Gary MNT)
51	695			-		Excluded (50.1 Gary MNT DTV)
candidates		Max	58			

Out of 10 candidate channels from the TV Database, 2 channels were open after WM sensing. At least 5 of the 8 channels rejected by sensing appear to be due to the problems with detection at this low level, not from actual WM operations or required protection of TV.

D. Residential area in Schaumburg, IL

Location (42.077N, 88.041W) – low antenna.

This and the following two locations were close (15-20 m) to two single houses in the suburban wooded area. Nearby to the testing location was a TV cable box (7-8 m from antenna), from a visual inspection there are input and output cables and some loose ends hanging. Testing performed between 1 and 3 pm.

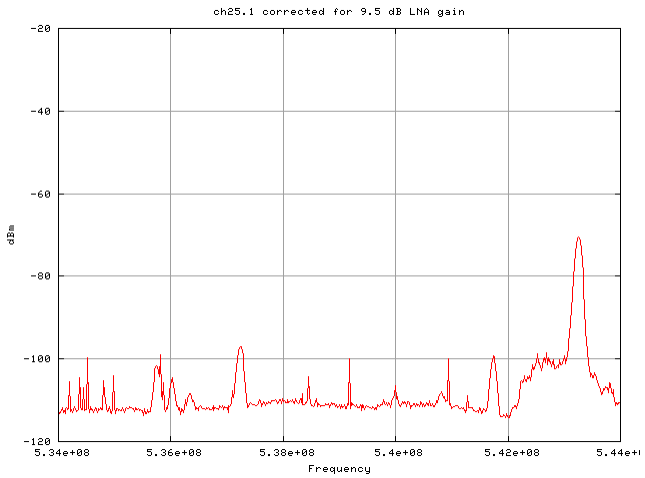
With the low antenna position, close to the cable box, several channels seemed to have leaking TV cable signals (channels 24, 42 – intermittent, 46 – weak, and 49 - strong).

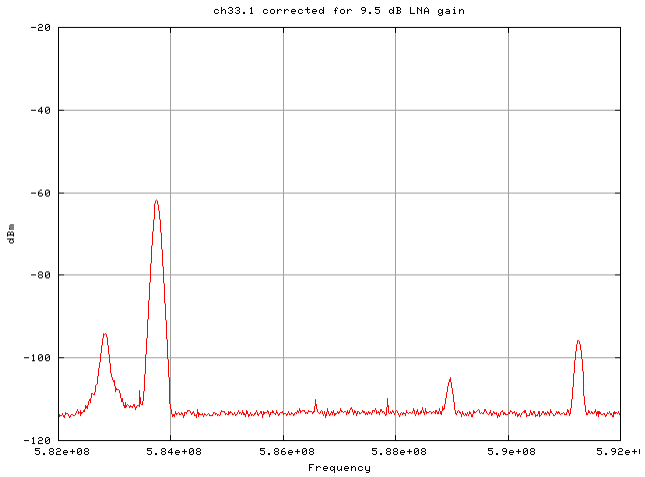
UHF Channel		Channel Pin, dBm		Narrow peaks found	Narrow peaks Pdet %	Notes
#	Center MHz	min	max			
21	515			-		Excluded (20.1 Chicago PBS DTV)
22	521	-100	-99	2	100.0	Strong NTSC (22 Arlington Heights TBN)
23	527	-87	-87	2	100.0	NTSC (23 Chicago IND WWME-CA)
24	533	-98	-96	2	100.0	Weak NTSC (24 Milwaukee MNT)
25	539	-95	-95	4	100.0	DTV (24.1 Milwaukee MNT), NTSC(?), Spikes!, NTSC!?
26	545	53	-51	3	100.0	Strong NTSC (26 Chicago IND)
27	551			-		Excluded (26.1 Chicago IND DTV)
28	557	-110	-106	0	0.0	Strong adjacents; Weak DTV (Milwaukee)
29	563			-		Excluded (5.1 Chicago NBC DTV)
30	569	-87	-85	0	0.0	AGC Att 13 dB strong adjacents; many intermittent spurious
31	575			-		Excluded (32.1 Chicago FOX DTV)
32	581	-51	-50	3	100.0	Strong NTSC (32 Chicago FOX)
33	587	-94	-88	1	37.0	Peak at 5 MHz - spur from our equipment
34	593	-93	-91	2	100.0	Weak NTSC (34 Arling. Hts REL)
35	599	-100	-99	3	99.0	Weak DTV (36.1 Milwaukee PBS). Cable leak @ 600 MHz!
36	605	-81	-80	1	100.0	62.1 Hammond IND DTV
37	611	-102	-102	0	0.0	Radioastronomy, medical
38	617	-63	-59	5	100.0	Strong NTSC (38 Chicago ION)
39	623			-		Excluded (39.1Chicago MeTV DTV)
40	629	-89	-88	2	100.0	Weak NTSC/DTV (Palatine W40BY)
41	635	-64	-63	2	100.0	Weak NTSC (41 WOCH-CA)
42	641	-103	-100	1	11.6	Cable leak?
43	647			-		Excluded (38.1 Chicago ION DTV)
44	653	-60	-59	2	100.0	Strong NTSC (44 Chicago TEL)
45	659			-		Excluded (44.1 Chicago TEL DTV)
46	665	-97	-93	1	12.5	Weak NTSC, fluctuates a lot
47	671			-		Excluded (11.1 Chicago PBS DTV)
48	677	-68	-67	2	100.0	Weak NTSC (48 Blue Island IND)
49	683	-101	-98	4	100.0	Cable leaks! - wider (80 kHz) (Jerry Springer :)
50	689			-		Excluded - Strong NTSC (50 Gary MNT)
51	695			-		Excluded (50.1 Gary MNT DTV)
candidates		Max	-50			

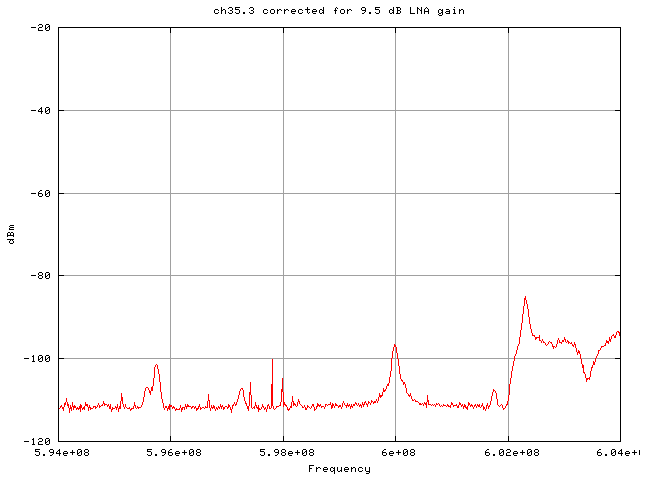
Out of 10 candidate channels from the TV Database, 3 channels were open after WM sensing. At least 6 of the 7 channels rejected by sensing appear to be due to the problems with detection at this low level, not from actual WM operations or required protection of TV.

The RF spectrum graphs below illustrate cases of:

a) Channel 25, with weak NTSC, strong higher adjacent NTSC channel, and spurious peaks;
b) Channel 33 with strong lower and weak higher adjacent NTSC channels, and a parasitic signal, leaked from our equipment and sensed on the low antenna;
c) Channel 35 with weak faded higher adjacent DTV, spurious noises, and a peak at 600 MHz.


ch25.1 corrected for 9.5 dB LNA gain
dBm
-20
-40
-60
-80
-100
-120
5.34e+08
5.36e+08
5.38e+08
5.4e+08
5.42e+08
Frequency


ch33.1 corrected for 9.5 dB LNA gain
dBm
-20
-40
-60
-80
-100
-120
5.82e+08
5.84e+08
5.86e+08
5.88e+08
5.9e+08
Frequency


ch35.3 corrected for 9.5 dB LNA gain
dBm
-20
-40
-60
-80
-100
-120
5.94e+08
5.96e+08
5.98e+08
6e+08
6.02e+08
Frequency

Residential area (42.077N, 88.041W) – high vertical antenna. Same location, time 2 to 3 pm.

With high antenna position, leaking TV cable signals were much less visible, compared to previous measurements. The best channel 42 was clean, but still some interference on channels 46 and 49.

UHF Channel		Channel Pin, dBm		Narrow peaks found	Narrow peaks Pdet %	Notes
#	Center MHz	min	max			
21	515			-		Excluded (20.1 Chicago PBS DTV)
22	521			-		Excluded (Strong 22 Arlington Heights TBN NTSC)
23	527			-		Excluded (23 Chicago IND WWME-CA NTSC)
24	533	-89	-84	1	100.0	Weak NTSC (24 Milwaukee MNT)
25	539	-88	-87	2	100.0	DTV (24.1 Milwaukee MNT); NTSC??
26	545			-		Excluded (Strong 26 Chicago IND NTSC)
27	551			-		Excluded (26.1 Chicago IND DTV)
28	557	-99	-94	1	21.0	Strong adjacents; Weak NTSC?
29	563			-		Excluded (5.1 Chicago NBC DTV)
30	569	-73	-71	0	0.0	AGC Att 18 dB strong adjacents
31	575			-		Excluded (32.1 Chicago FOX DTV)
32	581			-		Excluded (Strong 32 Chicago FOX NTSC)
33	587	-93	-87	2	97.0	Bump low adjacent NTSC Tx; small spur at 5 MHz (from our box)
34	593	-92	-90	2	100.0	Weak NTSC (34 Arling. Hts REL)
35	599	-99	-95	2	100.0	Weak NTSC - Cable leak? Weak Cable leak @ 600 MHz!
36	605	-102	-80	1	100.0	62.1 Hammond IND DTV
37	611	-112	-102	0	0.0	Radioastronomy, Medical
38	617			-		Excluded (Strong 38 Chicago ION NTSC)
39	623			-		Excluded (39.1Chicago MeTV DTV)
40	629	-94	-90	2	100.0	Weak NTSC/DTV (Palatine W40BY)
41	635	-54	-53	3	100.0	Weak NTSC (41 WOCH-CA)
42	641	-101	-95	0	0.0	
43	647			-		Excluded (38.1 Chicago ION DTV)
44	653			-		Excluded (Strong 44 Chicago TEL NTSC)
45	659			-		Excluded (44.1 Chicago TEL DTV)
46	665	-96	-88	0	0.0	Weak NTSC, fluctuates a lot; strong adjacent; AGC Att ~10dB
47	671			-		Excluded (11.1 Chicago PBS DTV)
48	677	-72	-70	2	100.0	Weak NTSC (48 Blue Island IND) or Cable leak
49	683	-84	-81	5	100.0	IMs
50	689			-		Excluded (Strong 50 Gary MNT NTSC)
51	695			-		Excluded (50.1 Gary MNT DTV)
candidates		Max	-53			

Out of 10 candidate channels from the TV Database, 3 channels were open after WM sensing. At least 2 of the 7 channels rejected by sensing appear to be due to the problems with detection at this low level, not from actual WM operations or required protection of TV.

Residential area (42.077N, 88.041W) – high horizontal antenna. Same location, 3 to 4 pm.

With horizontal antenna position, sensitivity to TV stations' signals is significantly reduced due to polarization. Due to reduced RF FE overload from adjacent power, AGC was setting higher gains, increasing sensitivity to local signals, including cable leakage (channels 35 and 40). In this case, four channels (28, 42, 46 and 49) were identified as available for WSD use.

UHF Channel		Channel Pin, dBm		Narrow peaks found	Narrow peaks Pdet %	Notes
#	Center MHz	min	max			
21	515			-		Excluded (20.1 Chicago PBS DTV)
22	521			-		Excluded (Strong 22 Arlington Heights TBN NTSC)
23	527			-		Excluded (23 Chicago IND WWME-CA NTSC)
24	533	-101	-98	1	76.0	Weak NTSC (24 Milwaukee MNT)
25	539	-88	-87	3	100.0	DTV (24.1 Milwaukee MNT); NTSC??
26	545			-		Excluded (Strong 26 Chicago IND NTSC)
27	551			-		Excluded (26.1 Chicago IND DTV)
28	557	-106	-103	0	0.0	
29	563			-		Excluded (5.1 Chicago NBC DTV)
30	569	-89	-82	0	0.0	AGC Att 14 dB strong adjacents
31	575			-		Excluded (32.1 Chicago FOX DTV)
32	581			-		Excluded (Strong 32 Chicago FOX NTSC)
33	587	-102	-100	1	20.0	Bump low adjacent NTSC Tx – small
34	593	-84	-82	3	100.0	Weak NTSC (34 Arling. Hts REL)
35	599	-94	-92	2	100.0	Weak NTSC - Cable leak?
36	605	-84	-83	1	100.0	62.1 Hammond IND DTV
37	611	-107	-106	0	0.0	Radioastronomy, Medical
38	617			-		Excluded (Strong 38 Chicago ION NTSC)
39	623			-		Excluded (39.1Chicago MeTV DTV)
40	629	-84	-83	3	100.0	Weak NTSC/DTV (Palatine W40BY) - Cable leak?
41	635	-63	-60	3	100.0	Weak NTSC (41 WOCH-CA)
42	641	-91	-89	0	0.0	
43	647			-		Excluded (38.1 Chicago ION DTV)
44	653			-		Excluded (Strong 44 Chicago TEL NTSC)
45	659			-		Excluded (44.1 Chicago TEL DTV)
46	665	-150	-124	0	0.0	
47	671			-		Excluded (11.1 Chicago PBS DTV)
48	677	-149	-121	0	0.0	
49	683	-81	-78	5	97.0	IMs
50	689			-		Excluded (Strong 50 Gary MNT NTSC)
51	695			-		Excluded (50.1 Gary MNT DTV)
candidates		Max	-60			

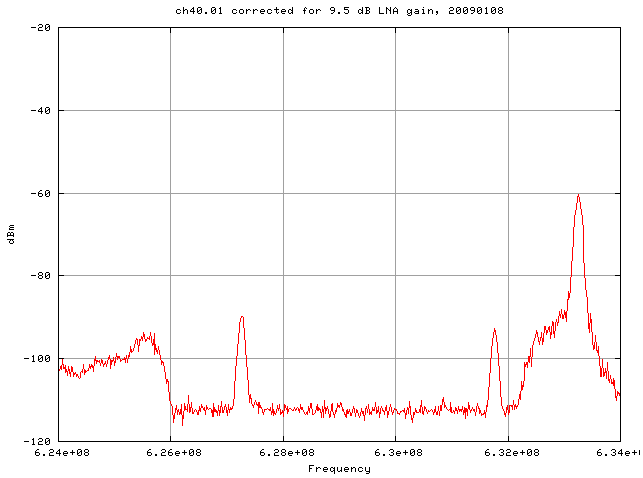
Out of 10 candidate channels from the TV Database, 5 channels were open after WM sensing. At least 3 of the 5 channels rejected by sensing appear to be due to the problems with sensing at this low level, not from actual WM operations or required protection of TV.

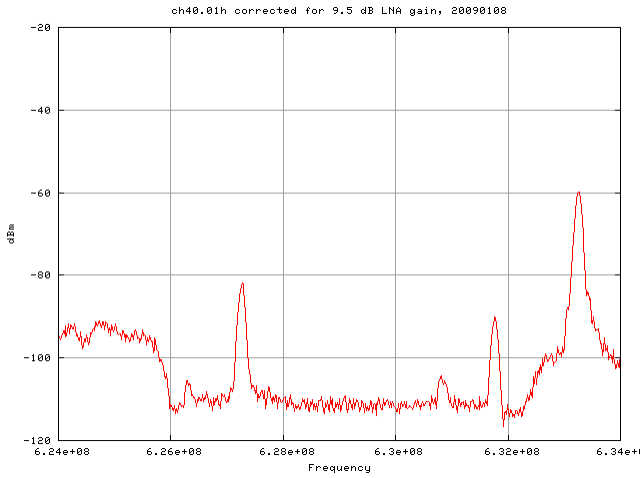
The RF spectrum graphs below illustrate cases of:

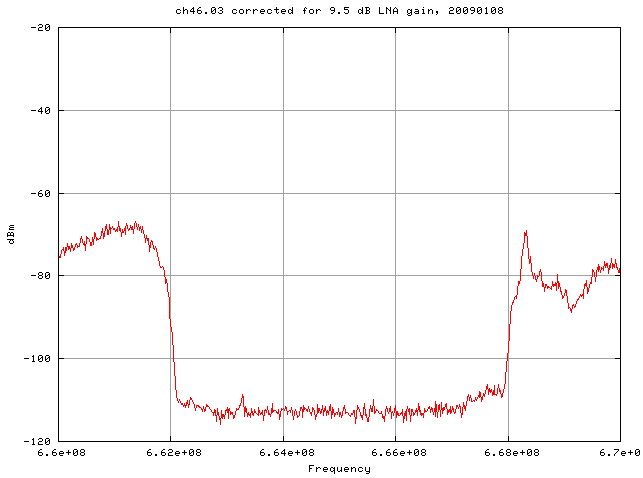
a) Channel 40 (vertical high antenna), with weak NTSC signal, adjacent lower DTV and higher NTSC signals;

b) Channel 40 (horizontal antenna) – additional in-channel growth (and higher measured Pin) is observed with horizontal polarization – probably the increased pick-up of cable box leakage;

c) Channel 46 (vertical high antenna) with strong adjacent DTVs (causing AGC attenuation ~10 dB and decrease in sensitivity) and spurious noises. On this channel, when the antenna was set to horizontal position, the adjacent channels' levels decreased, AGC attenuation fell and the spurious signals disappeared.


ch40.01 corrected for 9.5 dB LNA gain, 20090108
-20
-40
-60
-80
-100
-120
dBm
6.24e+08
6.26e+08
6.28e+08
6.3e+08
6.32e+08
6.34e+
Frequency


ch40.01h corrected for 9.5 dB LNA gain, 20090108
-20
-40
-60
-80
-100
-120
dBm
6.24e+08
6.26e+08
6.28e+08
6.3e+08
6.32e+08
6.34e+
Frequency


ch46.03 corrected for 9.5 dB LNA gain, 20090108
-20
-40
-60
-80
-100
-120
dBm
6.6e+08
6.62e+08
6.64e+08
6.66e+08
6.68e+08
6.7e+0
Frequency

E. Place of worship in South Barrington, IL – parking lot

Suburban location, with multiple active WMs at the facility (more than 30 at the time of rehearsals), 4:30 to 5:30 pm (rehearsal time.)

UHF Channel		Channel Pin, dBm		Narrow peaks found	Peak frequency, MHz	Peak power, dBm	Narrow peaks Pdet %	Notes
#	Center MHz	min	max					
17	491	-81	-80	2	488.313	-93	100.0	DTV pilot (56.1 Gary PBS)
					493.975	-81	100.0	Shure WM (100 mW) – Auditorium
21	515			-				Excluded (20.1 Chicago PBS DTV)
22	521			-				Weak NTSC 22 Arlington Heights TBN
					524.200	-69	100.0	Shure WM (100 mW) - Auditorium
					525.250	-51	100.0	NTSC Video (23 Chicago IND WWME-CA); AGC Att 30 dB
23	527	-51	-50	5	526.825	-80	100.0	Shure WM (100 mW) - Auditorium (far side)
					527.975	-92	12.0	Shure WM (100 mW) - Lakeside (far remote)
					529.750	-61	100.0	NTSC Audio
					530.375	-81	100.0	Shure WM (100 mW) - Auditorium (far side)
					531.000	-71	100.0	Shure WM (100 mW) - Auditorium
					531.250	-101	1.0	Weak NTSC (24 Milwaukee MNT); not sensed due to AGC Att 10 dB
24	533	-67	-67	9	532.060	-101	89.0	IM
					533.300	-69	100.0	Shure WM (100 mW) - Auditorium
					534.550	-101	99.0	IM
					535.170	-112	24.0	IM
					535.610	-105	100.0	IM
					535.790	-109	34.0	IM
25	539			-				Weak NTSC/DTV (W25DW/24.1 Milwaukee MNT)
26	545			-				Excluded (26 Chicago IND NTSC)
27	551			-				Excluded (26.1 Chicago IND DTV)
28	557			-				Weak DTV (4.1 Milwaukee NBC)
29	563			-				Excluded (5.1 Chicago NBC DTV)
30	569			-				Weak DTV (57.1 Elgin W57DN)
31	575			-				Excluded (32.1 Chicago FOX DTV)
32	581			-				Excluded (32 Chicago FOX NTSC)
					586.625	-100	100.0	Shure WM (10mW) - Auditorium
33	587	-95	-92	3	588.025	-102	100.0	Shure WM (10mW beltpack) - Auditorium
					588.970	-96	100.0	?
34	593			-				Weak NTSC/DTV (34 Arling. Hts REL WEDE-CA)
35	599			-				Weak DTV (36.1 Milwaukee PBS)
36	605			-				Excluded (62.1 Hammond IND DTV)
37	611	-107	-105	2	608.320	-115	99.0	IM
					608.820	-116	97.0	IM
38	617			-				Excluded (38 Chicago ION NTSC)
39	623			-				Excluded (39.1Chicago MeTV DTV)
40	629			-				Weak NTSC/DTV (Palatine W40BY)
41	635			-				Weak NTSC (41 WOCH-CA)
42	641			-				Weak NTSC/DTV (42 W64CQ/39.1 Rockford FOX)
43	647			-				Excluded (38.1 Chicago ION DTV)
44	653			-				Excluded (44 Chicago TEL NTSC)
45	659			-				Excluded (44.1 Chicago TEL DTV)
46	665	-94	-88	2	662.800	-89	100.0	Shure WM (10mW) - Lakeside (far remote); DTV (WMEU-LD)
					663.800	-103	99.0	Shure WM (10mW) - Lakeside (far remote)
47	671			-				Excluded (11.1 Chicago PBS DTV)
48	677			-				NTSC (48 WMEU-CA)
49	683			-				Weak DTV (41.1 WOCH-CA)
50	689			-				Excluded (50 Gary MNT NTSC)
51	695			-				Excluded (50.1 Gary MNT DTV)
candidates		Max	-50					

At this location, several channels (17, 23, 24, 33 and 46) with known location/power pattern of WMs in the building were sensed. Some of the WMs are co-located with NTSC or DTV signals on channels 17, 23 and 46 of modest power levels. The low power DTV station on channel 46 is within the protection contour.

All the active WMs on the sensed channels were successfully detected. Channel 37 was observed and two very weak peaks were detected, most probably the result of intermodulation. This seems to be the most expressed case of the vulnerability of the -114 dBm sensitivity limit,

seen in our testing. Several IM peaks are also seen on channel 24 with strong lower adjacent signal.

F. Residential area

Location (42.098N, 88.135W) – close (~0.8 km) to the place of worship location above. At the sensing time (6-7 pm), many WMs at that location were active, including ones sensed earlier.

UHF Channel		Channel Pin, dBm		Narrow peaks found	Peak frequency, MHz	Peak power, dBm	Narrow peaks Pdet %	Notes
#	Center MHz	min	max					
					488.313	-96	100.0	DTV pilot (56.1 Gary PBS)
17	491	-85	-84	3	489.265	-90	95.0	Weak NTSC Video (17 Rockford ABC)
					493.765	-111	78.0	Weak NTSC Audio
					493.975	-		No Microphone detected - high noise floor (co-channel NTSC/DTV)
21	515			-				Excluded (20.1 Chicago PBS DTV)
22	521			-				Weak NTSC 22 Arlington Heights TBN
					524.200	-		No Microphone detected - AGC Att 30 dB (strong co-channel NTSC)
					525.250	-52	100.0	NTSC Video (23 Chicago IND WWME-CA); AGC Att 30 dB
23	527	-51	-50	3	526.825	-		No Microphone detected - AGC Att 30 dB
					527.975	-99	2.0	Shure WM (100 mW) - Lakeside - No Detect - AGC Att 30 dB
					529.750	-57	100.0	NTSC Audio
					530.375	-		No Microphone detected - strong adjacent
					531.000	-96	100.0	Shure WM (100 mW) - Auditorium
					531.250	-103	4.0	Weak NTSC Video (24 Milwaukee MNT)
24	533	-90	-87	5	533.300	-97	100.0	Shure WM (100 mW) – Auditorium
					534.260	-115	30.0	IM
					535.760	-113	100.0	Weak NTSC Audio (24 Milwaukee MNT)
					536.340	-109	100.0	Weak DTV pilot (24.1 Milwaukee MNT)
					537.325	-79	100.0	Shure WM (100 mW) - Lakeside
25	539	-79	-79	4	538.150	-99	100.0	Shure WM (100 mW) - Auditorium
					540.675	-97	99.0	Shure WM (100 mW) - Lakeside
26	545			-				Excluded (26 Chicago IND NTSC)
27	551			-				Excluded (26.1 Chicago IND DTV)
					554.313	-111	86.0	Weak DTV pilot (4.1 Milwaukee NBC)
28	557	-100	-99	3	555.263	-109	16.0	IM
					556.376	-111	10.0	IM
29	563			-				Excluded (5.1 Chicago NBC DTV)
30	569	-70	-70	0	-			Weak DTV (57.1 Elgin W57DN CP)
31	575			-				Excluded (32.1 Chicago FOX DTV)
32	581			-				Excluded (32 Chicago FOX NTSC)
					586.625	-111	90.0	Shure WM (10mW) - Auditorium
33	587	-102	-100	2	588.025	-106	99.0	Shure WM (10mW beltpack) - Auditorium
34	593			-				Weak NTSC/DTV (34 Arling. Hts REL WEDE-CA)
35	599			-				Weak DTV (36.1 Milwaukee PBS)
36	605			-				Excluded (62.1 Hammond IND DTV)
37	611	-109	-107	1	610.733	-115	76.0	IM
38	617			-				Excluded (38 Chicago ION NTSC)
39	623			-				Excluded (39.1Chicago MeTV DTV)
40	629			-				Weak NTSC/DTV (Palatine W40BY)
41	635			-				Weak NTSC (41 WOCH-CA)
42	641	-96	-94	1	643.350	-99	100.0	Sennheiser WM (100 mW) - Auditorium
43	647			-				Excluded (38.1 Chicago ION DTV)
					650.875	-		No Microphone detected - high noise floor (strong co-channel NTSC)
					651.250	-76	52.0	NTSC Video (44 Chicago TEL NTSC)
					652.675	-		No Microphone detected - high noise floor (strong co-channel NTSC)
44	653	-85	-75	3	653.375	-111	30.0	Shure WM (10mW) - Activity Center
					655.200	-		No Microphone detected - high noise floor (strong co-channel NTSC)
					655.750	-109	30.0	NTSC Audio
45	659			-				Excluded (44.1 Chicago TEL DTV)
					662.800	-103	69.0	Shure WM (10mW) - Lakeside (far remote); DTV (WMEU-LD)
46	665	-90	-88	2	663.800	-92	99.0	Shure WM (10mW) - Lakeside (far remote)
47	671			-				Excluded (11.1 Chicago PBS DTV)
					675.250	-77	100.0	NTSC Video (48 WMEU-CA)
48	677	-77	-76	2	679.750	-84	68.0	NTSC Audio
49	683	-80	-78	0	-			Weak DTV (41.1 WOCH-CA)
50	689			-				Excluded (50 Gary MNT NTSC)
51	695			-				Excluded (50.1 Gary MNT DTV)
candidates		Max	-50					

Out of 10 candidate channels from the TV Database, 2 channels were open after WM sensing. At least 1 of the 8 channels rejected by sensing appear to be due to the problems with detection at this low level, not from actual WM operations or required protection of TV.

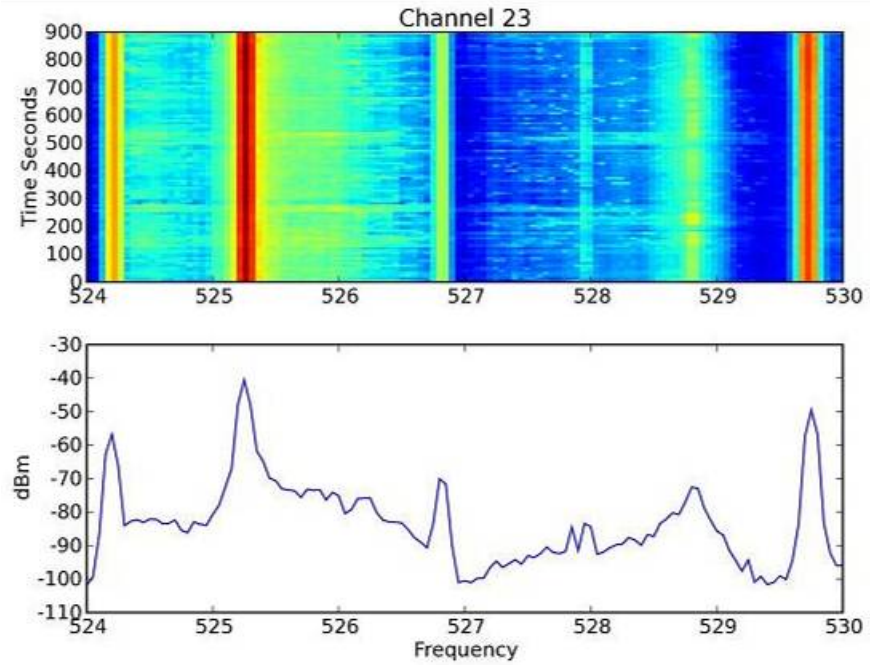
The same channels as before (17, 23, 24, 33 and 46) were sensed to verify if the WMs are still detected. And, as time allowed, more channels (25, 28, 30, 42, 44, 48 and 49) were investigated for sensing active WMs and finding channels available for WSD use.

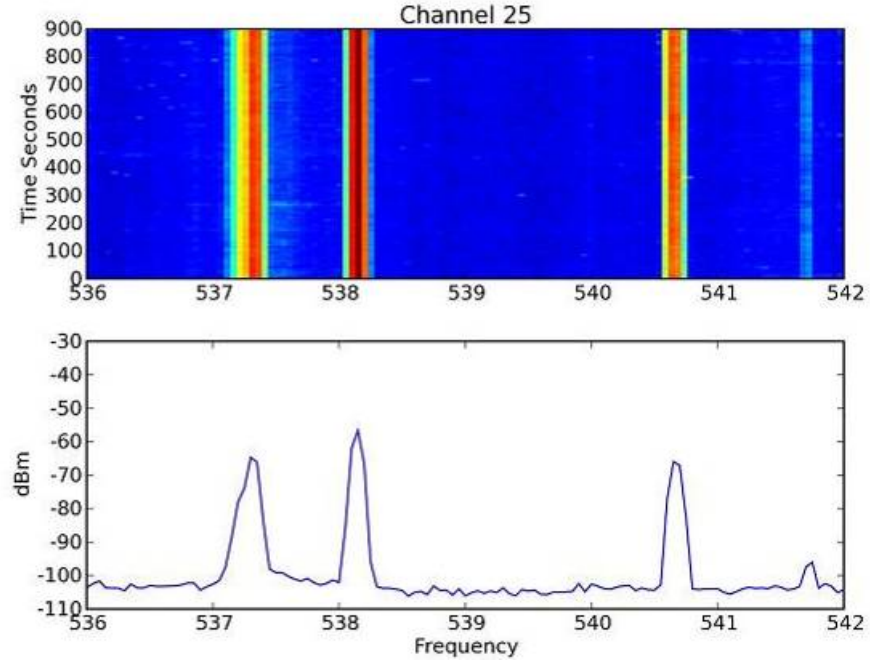
Again, some WMs were observed on two channels (44 and 46) with TV signals within protected contours. And similar to the previous case, one IM induced peak was detected on channel 37, and peaks on channels 24 and 28.

Except for the channels with significant co-located TV signals (17, 23 and 44), the active WMs were successfully detected on channels 24, 25, 33, 42, and 46. An exception – one channel 24 WM, allocated close to the strong lower adjacent NTSC signal. As such sensor desensitization due to strong adjacent signals and false detection on IM components should be considered the norm rather than the exception.

Three channels were identified as potentially usable for a WSD device, subject to additional considerations. Channel 28 has two low probability IM peaks, and a detected weak DTV pilot, but after verifying with the database that this station is out of contour, it might be considered a low priority candidate. Similar database verification would also verify usage of two other candidate channels 30 and 49, with no NB or WM signals detected. However, a WSD would likely provide a false detection on the weak DTV pilot on channel 28 given a -114 dBm threshold requirement.

The RF spectrum graphs below illustrate cases of channel 23 as a function of time. Three WMs co-located with a strong NTSC station (NTSC video, audio components and one of the WMs detected – see the Table above), and channel 25 with three active WMs in absence of other strong sources. The graphs below don’t show the 9.5 dB offset for the effective LNA gain.


Channel 23
Time Seconds
900
800
700
600
500
400
300
200
100
0
524
525
526
527
528
529
530
dBm
-30
-40
-50
-60
-70
-80
-90
-100
-110
Frequency


Channel 25
Time Seconds
900
800
700
600
500
400
300
200
100
0
536
537
538
539
540
541
542
dBm
-30
-40
-50
-60
-70
-80
-90
-100
-110
Frequency

VI. Conclusions

The overall conclusions can be summarized as:

- Depending on the location, from 50 to 90% of candidate WSD channels are unavailable due to narrow band peaks which were not the result of WM operation or required TV protection.
- Reliable sensing for low level WM signals in real world conditions with strong adjacent signals is difficult.

VII. Acronyms used in the Notes.

AGC	Automatic Gain Control
CR	Cognitive Radio
DTV	Digital Television
ESG	Agilent ESG Series Signal Generator
FE	Front End
IM	Intermodulation
LNA	Low Noise Amplifier – first stage of RF Receivers
NB	Narrow Band
NTSC	National Television System Committee
P_d	Detection Probability
P_{fa}	False Alarm Probability
PSA	Agilent PSA Series Spectrum Analyzer
PSD	Power Spectral Density
RF	Radio Frequency
ROC	Receiver Operating Characteristic
UHF	Ultra High Frequency
WM	Wireless Microphone
WSD	White Space Device