or disable it or that the equipment might malfunction and result in interference to broadcasters.[101] WISPA argues that use of a database isn't appropriate because it wouldn't take into account attenuation of the signal from the TV band device due to vegetation, buildings, or terrain.[102]

65. Other comments express support for use of the spectrum sensing method to determine available channels.[103] Supporters of spectrum sensing submit that signal detectors in the TV band are capable of high degrees of detection sensitivity and can detect and avoid broadcast signals that have undergone high attenuation in a hidden node situation.[104] They further state that spectrum sensing can protect incumbent licensees and facilitate spectrum sharing with other low power devices in the TV white spaces and would be more cost effective and efficient than the geo-location/database approach.[105] Several parties argue that spectrum sensing alone is adequate to determine when a TV channel is available. In statements representative of these parties' positions, the White Space Coalition argues that spectrum sensing does not depend on third party assisting technologies such as databases of available channels and would better facilitate the creation of a mass market for devices. It claims that spectrum sensing is a proven, well understood technique and that the concern raised by incumbent licensees that this approach is unproven is simply not the case.[106] NAF argues that spectrum sensing shows great promise, would be cost effective to implement, and that detectors in TV band devices are capable of high degrees of sensitivity and can detect and avoid signals that have undergone 37 dB of attenuation due to the hidden node problem.[107] Tropos Networks states that spectrum sensing could be used in both fixed and personal/portable devices.[108] WISPA believes that a distributed sensing model, whereby interconnected devices would share sensing information, would be far superior to geo-location, especially over time as the number of sensors in an area increases.[109]

66. The White Space Coalition argues that the Commission should allow personal/portable devices that rely on spectrum sensing alone to determine when a channel is vacant. It argues that spectrum sensing will protect incumbent licensees and facilitate spectrum sharing with other low power devices in the white spaces, while avoiding the operational difficulties and economic burdens associated with the other interference avoidance mechanisms identified in this proceeding. The White Space Coalition states that because spectrum sensing does not depend on third-party assisting technologies such as databases of available channels or broadcast beacons to implement, a spectrum sensing approach would better facilitate the creation of a mass market for devices, resulting in more affordable consumer

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[101] *See* Advanced Broadband *Notice* comments at 4.

[102] *See* WISPA *Notice* comments at 2.

[103] The spectrum sensing method is supported by CEA (*Further Notice* comments at 3-5), the White Space Coalition (*Further Notice* comments at 5-7), NAF, *et al.* (*Further Notice* comments at 63-67), and Tropos Networks (*Further Notice* comments at 10).

[104] *See* for example, NAF, *et al. Notice* comments at 63-64. A "hidden node" is a location where an obstruction is present between the sensing receiver and the signal to be detected. In this case, the sensing receiver may fail to detect that a channel is occupied and begin transmitting, thus causing interference to other nearby parties attempting to receive that channel along an unobstructed path.

[105] *See* for example, NAF, *et al. Notice* comments at 65 and White Space Coalition *Notice* comments at 3.

[106] *See* White Space Coalition *Further Notice* comments at 3-4.

[107] *See* NAF *Further Notice* comments at 65-66.

[108] *See* Tropos Networks *Further Notice* comments at 10.

[109] *See* WISPA *Further Notice* comments at 3.

products and more attractive prospects for wireless broadband, including in rural areas.[110] The NAF and a number of consumer and public interest groups believe that the Commission should authorize personal/portable devices, arguing that mobile applications will provide a key driver for economies of scale, and that fixed applications promoted by IEEE and others offer little hope for the economies of scale needed to produce genuinely affordable equipment.[111] The NAF also argues in separate technical comments that sensing can provide adequate interference protection to DTV receivers.[112]

67. Parties representing TV broadcast and other licensed service interests argue that spectrum sensing alone is insufficient to adequately protect licensed services.[113] They contend that sensing alone would be ineffective for preventing devices from operating within the protected contours of co-channel and adjacent channel TV stations and that any sensing capability must be combined with geo-location.[114] MSTV/NAB state that the current sensing proposals are inadequate to protect against co-channel interference and that a -116 dBm minimum threshold for sensing licensed signals would not guarantee that an unlicensed device would be outside a protected TV station's service area rather than in an area of weak signal strength within its service area.[115] They further argue that the White Space Coalition's recommended detection threshold level of -114 dBm fails to account for important differences in antenna height between outdoor TV antennas and TV band devices, disregards real world propagation and building attenuation, and ignores the potential interference distance of a TV band device over which protection is actually required.[116] MSTV/NAB also submitted a report on a signal measurement study in the Washington, D.C.-Baltimore, MD area (MSTV Study) that it states found signal levels below the -114 dBm and -116 dBm levels that have been discussed in this proceeding. The MSTV reports that it measured signal levels below -120 dBm.[117] In its reply comments, the NAF argues that the measurements in the MSTV Study are unreliable due to issues with the way that the measurements were taken and systematic methodological errors.[118]

68. Motorola, McGraw Hill Broadcasting, and Media General also argue that spectrum sensing by itself would not provide adequate protection to users and devices that warrant protection.[119] Motorola is also concerned that the sensing capabilities in devices would need to adapt to detect waveforms that may be devised in the future. The Grand Ole Opry and the Microphone Interests Coalition, the Professional Audio Manufacturers Alliance, and Shure submit that spectrum sensing is promising, but as yet unproven with respect to how it would work in the TV bands to protect incumbents,

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[110] *See* White Space Coalition *Further Notice* comments at 3.

[111] *See* NAF, et al. *Further Notice* comments at 83.

[112] *See* NAF *Further Notice* technical comments at 17.

[113] *See* for example, Grand Ole Opry and Microphone Interests Coalition *Further Notice* reply comments at 4, IEEE 802.18 *Further* Notice comments at 6-7, and MSTV/NAB *Further Notice* comments at 9-10.

[114] *See* MSTV and NAB *Further Notice* reply comments at 11.

[115] *See* MSTV/NAB *Further* Notice comments at 11-13.

[116] *See* MSTV and NAB *Further Notice* reply comments at 14.

[117] *See* "DTV Signal Measurements in the Washington-Baltimore Area" MSTV, attachment to the MSTV/NAB comments on Commission's Initial Prototype Devices Report, August 15, 2007 (MSTV Field Study).

[118] *See* NAF reply comments to the Commission's Initial Prototype Devices Report, September 4, 2007 at 12-17.

[119] *See* Motorola *Further Notice* reply comments at 5, McGraw Hill Broadcasting *Further Notice* comments at 3, and Media General *Further Notice* comments at 2.

including wireless microphones.[120] These parties believe that the Commission should carefully study any use of spectrum sensing.[121] GE Healthcare is not confident that spectrum sensing technology would provide adequate protection to medical telemetry equipment that operates in the TV bands.[122] Shure initially recommended a detection threshold of -107 dBm for detection of wireless microphones, but in a subsequent *ex parte* submission stated that it now supports the White Space Coalition's lower recommended threshold of -114 dBm.[123]

69. Several parties submit that spectrum sensing should be used as an adjunct to the geo-location method. For example, MSTV/NAB and IEEE 802.18 state that spectrum sensing is needed, but is insufficient on its own to adequately and completely protect licensed services. These parties argue that the geo-location and database approach are essential to ensure that unlicensed TVBDs operate outside the protected contours of both co-channel and adjacent channel TV stations and that sensing could be used to detect the presence of wireless microphones, which operate intermittently.[124] NCTA states that cable headends located outside a TV station's protected contour may receive signals that are undetectable at ground level using regular receiver technology. It believes that sensing alone is highly imprecise and will not ensure interference protection, so that sensing must be combined with some type of geo-location/database approach.[125]

70. With the exception of the Community Broadcasters Association (CBA), there is very little support in the record for adopting a plan that would rely on control signals to provide unlicensed devices with a list of channels on which they could operate. The parties that addressed the control signal option generally submit that this approach would require the establishment of an expensive infrastructure.[126] The White Space Coalition and others are further concerned that potential control signal providers might not offer service unless they believe that the number of unlicensed devices would make it profitable to do so.[127] Opponents of the control signal approach also argue that there would be an inherent conflict of interest for TV licensees responsible for a database and signaling information that controls access to the band.[128] CBA supports the control signal approach and offers to have its member stations transmit control information.[129]

71. *Discussion.* We find that the geo-location/database and spectrum sensing methods offer the most practical solutions for identifying unused TV channels and are therefore incorporating both of these methods into the rules for unlicensed TVBDs. Both of these approaches can be implemented using relatively cost effective technologies, although we do recognize that the database/system could involve an

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[120] *See* Shure *Further Notice* reply comments at 5.

[121] *See* Professional Audio Manufacturers Alliance *Further Notice* reply comments at 4.

[122] *See* GE Healthcare *Further Notice* comments at 6.

[123] *See* Shure *Notice* comments at 14 *Notice Reply* comments at 7.

[124] *See* IEEE 802.18 *Further Notice* comments at 6, NAB and MSTV *Further Notice* reply comments at 11, and Shure *Further Notice* comments at 14-16.

[125] *See* NCTA *Further Notice* reply comments at 12-13.

[126] *See* for example, White Space Coalition *Notice* comments at 9-10.

[127] *Id.*

[128] *See* NAF, *et* al, *Notice* comments at 68-69, Tropos Networks *Notice* comments at 12-13, and White Space Coalition *Notice* comments at 9-10.

[129] *See* CBA *Further Notice* comments at 4.

ongoing cost for users of unlicensed TVBDs. We also find that spectrum sensing, as currently presented in our measurement studies of prototype devices, is not sufficient by itself to enable unlicensed devices to reliably determine the TV channels that are available for use at a location. However, we believe that spectrum sensing offers significant potential for use in detecting the signals of protected services and therefore should be included as part of the required means for identifying available channels.

72. At this time, the geolocation/database approach appears best able to reliably identify unoccupied TV channels. Geolocation methods such as GPS can accurately determine the location of an unlicensed device and a database system can compare that information to the location and service areas of fixed transmitters used by broadcast television and other licensed services. Once the distances between an unlicensed device and protected transmitters/service contours are established, adequate and reliable protection can be provided by applying standardized protection criteria.[130]

73. We recognize the significant and pioneering work of those parties who developed and submitted devices for testing as part of our investigation of spectrum sensing in this proceeding. Their efforts and that process has contributed greatly to our understanding of the challenges involved in use of spectrum sensing to determine occupied channels in the TV bands. From our examination of the prototype devices we conclude that while signal detection can and should be used in identifying vacant spectrum for use by TVBDs, spectrum sensing with capabilities as presented in the record of this proceeding would not, by itself, be sufficient to adequately protect from interference television and other licensed services that use the TV bands. In this regard, we observe that sensing the signals of transmitters operated in the licensed services that use the TV bands is a challenging task, as reception of those signals is often limited by shielding from terrain and structures and by multipath and other fading phenomena. This task is especially difficult in the case of personal/portable unlicensed devices, which can be expected to be used indoors and at ground level.

74. As we observed in the *First R&O/Further Notice*, the facts that personal/portable devices have antennas that are less efficient for sensing and may be in a less advantageous position for sensing incumbent signals (*e.g.*, a short, non-directional antenna located in an interior room rather than a high gain antenna on a 10 meter mast) increases the difficulty of reliably detecting incumbent transmissions. With devices operating in such situations, the signal strength that appears at the receive antenna of a sensing device can be very weak, and in particular below the -114 dBm and -116 dBm minimum sensing levels suggested by the proponents and on which we requested comment in the *First R&O/Further Notice*.

75. Our conclusions on this issue are based on the following information and analysis for digital television service, the principal service that will operate in the TV bands on an ongoing basis. The basic principles and results of this analysis are also valid for the signals of wireless microphones and other services that use these bands. While we recognize that the DTV, analog TV, and wireless microphones each operate at minimum received signal levels, we are not specifying separate minimum sensing threshold levels for detection of their signals.[131] Rather, we are adopting a single minimum required sensing detection threshold value for all TV band services at the minimum sensing level that appears to be technically feasible at this time that is adequate to protect authorized services operating in the TV band. We note that the commenting parties did not specifically address detection of analog TV signals. The rules will, however, require that the sensing feature of unlicensed TV band device detect and

[130] The specific protection criteria for licensed services are discussed in the section below on protection of broadcast television and other services.

[131] The service threshold values for signals in the UHF TV band are: DTV signals -84 dBm, analog TV -63 dBm, and wireless microphones -87 dBm.

protect analog TV services because low power analog TV stations will continue to operate after the end of the DTV transition.

76. As discussed above, the threshold signal level for digital TV service in the UHF band is -84 dBm/6 MHz at the terminal of a DTV receiver.[132] The DTV service model assumes that signals are received off-the-air by an antenna with 10 dBd gain that is mounted at 10 meters above ground (about 33 feet).[133] To model an unlicensed personal/portable device, we assume that the device will be used indoors on a first floor location and receive signals with an omnidirectional (0 dBi gain) antenna. Several models for assessing the difference in TV signal levels between an outdoor TV and an indoor personal/portable device were presented in the record. For example, NAB/MSTV submit that signals received by a personal/portable device will be 27-32 dB below those received with an outdoor TV antenna (10 dB antenna gain + 7 dB antenna height + 10-15 dB for building penetration = 27-32 dB).[134] The White Space Coalition bases its proposal for a sensing threshold of -114 dBm/6 MHz on the assumption of up to 30 dB difference between the location of a TV antenna and an unlicensed device.[135] The NAF appears to indicate, based on an engineering assessment submitted with its technical comments, that this difference is 26-31 dB.[136] Motorola submits that the received signal level at an indoor white space device would be 18-39.5 dB lower than that received by an outdoor TV antenna (10-16.5 dB antenna height + 3 dB polarization mismatch + 5-20 dB or more building penetration = 18-39.5 dB).[137] As reflected in these different models and empirical studies, there will plainly be significant variation in the signal attenuation from rooftop to indoor locations across different sites (and even at different locations indoors at the same residential site). To simplify our analysis here, we will begin by assuming a moderate level of attenuation as represented by these models, or 30 dB (we do recognize that in many cases this difference can be significantly higher). Thus, the -84 dBm DTV minimum service threshold less the 30 dB difference between an outdoor TV antenna and an indoor white space device antenna yields a signal level that corresponds to the -114 dBm/6 MHz minimum sensing threshold suggested by some parties in the record.

77. If a TV station's signal were always at or above 41 dBμV/m (-84 dBm) within its service area and the difference in received signal level between an outdoor antenna and an indoor white space device antenna were always 30 dB or less, it could be anticipated that a white space device with a

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[132] Most DTV stations operate on UHF frequencies. Other analytical values are appropriate for use in evaluating a minimum sensing threshold for the high VHF and low VHF bands (see below), but our conclusion on the issue of whether sensing should be permitted to be used as the only means of determining the availability of channels for use by white space devices can be adequately explained by only examining signals in the UHF band.

[133] *See Sixth Report and Order* in MM Docket No. 87-268, 12 FCC Rcd 14558 (1997) at ¶¶ 183-195 and Appendix B; *see also* "OET Bulletin No. 69, Longley-Rice Methodology for Evaluating TV Coverage and Interference," FCC Office of Engineering and Technology, February 6, 2004 at Table 4 (OET-69 is available at http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet69/oet69.pdf. Using this receive system model, the -84 dBm signal strength (in milliwatts) needed for UHF service at the receiver terminal means that the minimum field strength (in microvolts) needed to receive a signal is 41 dBu. The formula for this model and the conversion of received field strength into signal strength is provided in OET-69, page 4.

[134] *See* MSTV *Further Notice* comments at footnote 29 and written *ex parte* submission, May 21, 2007.

[135] *See* White Space Coalition *Further Notice* comments at 6

[136] *See* NAF *Further Notice* technical comments at 17. The NAF specifically states that it "believes a sensitivity level in the range of -110 to -115 dBm should be adequate to protect TV receivers given mobile powers of 100 mW." We subtracted -84 dBm from these figures to obtain the values indicated above, but recognize that the NAF may have considered other factors in their suggestion for a minimum sensing threshold.

[137] *See* Motorola written *ex parte* presentation of October 18, 2007 at 17-20.

minimum sensing level of -114 dBm would be able to reliably detect the presence of a TV station's signal within the station's service area. However, in practice there will be cases where 1) a station's signal is below 41 dBu within its service area, and 2) the difference in received signal level between an outdoor and indoor antenna at the same structure/location will exceed 30 dB. In either case, if the deficiency in signal level is not offset by an equal or greater signal level in the other component, then the signal level of the TV station received at the white space device will be below -114 dBm. For example, a signal as received at an outdoor antenna is 35 dBμV/m (6 dB less than the service threshold), then the signal could still be detected at -114 dBm if the signal attenuation between the outdoor and indoor receive antenna positions were 24 dB rather than 30 dB.

78. With regard to the variability of signal levels across different sites, it is well established that there are locations within DTV stations' F(50,90) noise-limited service contours where their signals are below the level needed for service such that service is not available. Such locations are likely to occur in more distant portions of TV station service areas and certain other locations within a station's service area where, due to shielding by terrain or structures ("hidden nodes"), the station's signal will not be strong enough to be received under the standard TV service model. The definition of the service area of a DTV station in Section 73.622(e) of the rules specifically recognizes that a TV station's signal will not be available everywhere within its service area. That definition provides that "[t]he service area of a DTV station is the geographic area within the station's F(50,90) contour where its signal strength is predicted to exceed the noise-limited service level."[138] Congress also recognized that TV signal levels will be below the service threshold at individual locations in the Satellite Home Viewer Extension and Reauthorization Act of 2004 (SHVERA).[139] Section 204 of the SHVERA directed the Commission to conduct an inquiry on whether the Commission should revise its digital TV signal strength standards and signal measurement procedures used to identify if a household is "unserved" for purposes of the satellite copyright license for distant signals.[140] In response to this statutory charge, the Commission issued a *Notice of Proposed Rulemaking* proposing to amend its rules to include procedures for measuring the field strength of digital television signals at individual locations.[141] The variability of TV signal strengths across different nearby locations recognized in these established regulatory and statutory provisions is also apparent from the field studies in the record of this proceeding.[142]

79. Further, as demonstrated by the various field measurement studies in the record of this proceeding, the signals of TV stations in particular vary substantially over short distances within the

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[138] 47 C.F.R. § 73.682(e). Section 73.622(e) further provides that "[w]ithin this contour, service is considered available at locations where the station's signal strength, as predicted by the Longley-Rice propagation model, exceeds [the noise-limited service levels."

[139] The Satellite Home Viewer Extension and Reauthorization Act of 2004, Pub. L. No. 108-447, § 204, 118 Stat 2809, 3393 3423-24, (2004), codified at 47 U.S.C. §339(c)(1). The SHVERA was enacted as title IX of the "Consolidated Appropriations Act, 2005."

[140] On December 9, 2005, as required by Section 204(b) of the SHVERA, the Commission issued a *Report to Congress, "Study of Digital Television Field Strength Standards and Testing Procedures"* (*SHVERA Report*), ET Docket No. 05-182, 20 FCC Rcd. 19504 (rel. Dec. 9, 2005).

[141] *See Notice of Proposed Rulemaking* in ET Docket No. 06-94, 21 FCC Rcd 4735 (2006) at ¶ 5. Therein, the Commission indicated that while these measurement procedures would be generally applicable for measuring digital TV signal strengths, they would specifically be used in determining if a household is served by a digital television signal as part of an evaluation of the household's eligibility to receive a distant digital network signal from a satellite television provider.

[142] *See* The White Space Coalition's written *ex parte* presentation "Microsoft/Philips Field Tests" Report of September 20, 2007; *see also* MSTV Field Study.

station service areas. These studies provide empirical indication that there is considerable variability in the difference in signal levels received with an outdoor antenna at about 9 meters and with an indoor antenna at differing positions within a structure. For example, the MSTV Study (notwithstanding the concerns expressed with respect to certain aspects of its methodology), a study of DTV signals at residences submitted by the NAF, and White Space Coalition's Microsoft/Philips Field Tests report consistently show that there is substantial variation in the DTV signal levels outdoors and indoors at a residence that are consistent with the models discussed above.[143] These studies also show variation within residences of as much as 20 dB and in a few cases more. If we take the middle of this range of variation to be the signal level as that which would be determined using the 30 dB difference between an indoor and an outdoor antenna, then some locations would receive signals 10 dB higher and some would see signals 10 dB lower.[144] At those positions within a structure where the signal level is below the middle level (up to 10 dB lower, taking half the 20 dB range), the signal level in our model would be lower than -114 dBm and as low as -124 dBm or less. At any of these levels, the signal would plainly not be detectable by a device that can only sense down to -114 dBm; a device that could sense as low as the -116 dBm level we suggested in the *First R&O/Further Notice* would also not be adequate to reliably detect TV signals. As discussed below, it is also possible that the station's signal at a nearby location would be strong enough to provide service, in which case interference could occur if an unlicensed device were to transmit.

80. The White Space Coalition contends that interference protection should not be afforded at locations where a TV signal is too weak to be received.[145] It argues that the touchstone of a claim of interference is whether that interference negatively impacts a signal that would otherwise produce a viewable picture. We generally agree that interference protection should not be afforded where service is unavailable and our rule defining DTV service areas does not include areas within a station's noise-limited contour where its signal is predicted to be below the threshold of service.[146] However, we also recognize that the signals of a low power unlicensed device operating at a location within a TV station's noise-limited contour where the station's service is not available also could reach areas where service is in fact available and thereby cause interference. The information above establishes that the distances between locations where service can be received and those where service cannot be received can be short. We therefore conclude that a device operating within a TV station's noise-limited contour at a location

[143] With respect to its indoor measurements, the MSTV Study showed significant variations in the field strength of local TV stations in different rooms and outdoors at ground level at residential locations within the stations' service areas, while at the same time reception was generally available on the homes' DTV receiving system. *See also* Attachment to NAF Technical comments, "White Spaces Engineering Study: Can Cognitive Radio Technology Operating in the TV White Spaces Completely Protect Licensed TV Broadcasting?" Working Paper #16, (NAF Study) Mark Sturza and Farzad Ghazvinian, January 2007. The NAF conducted field tests at three residences located 25-26 miles from local DTV station transmitters (these sites would be expected to be moderate field strength locations) and found variations in DTV field strengths within individual residences of 39.1 dB, 35.3 dB, and 22.4 dB. The White Space Coalition's "Microsoft/Philips Field Tests", Report of September 20, 2007 indicated a number of instances in which DTV signal strengths varied by more than 20 dB at different locations within a building/residence and one site where the DTV signal variation within a room was more than 30 dB. *See* "Microsoft/Philips Field Tests," presented to OET September 20, 2007 (PowerPoint presentation).

[144] We understand that an argument could be made for using the highest level of the 20 dB range in indoor measurements as the signal level that would be determined using the 30 dB difference between an indoor and an outdoor antenna. However, use of the middle of this range provides a conservative analysis and does not change the basic conclusion of our analysis in any case.

[145] White Space Coalition *Further Notice* reply comments at 9-10.

[146] 47 C.F.R. § 73.622(e).

where the station's service is not available could nonetheless cause interference at locations where the station's service is available.

81. The variability of propagation over short distances also makes it impractical to evaluate the likelihood that a device located at any given location would cause interference. There will also be cases where, due to the approximate nature of predictive models, service will be available and received at locations within a station's noise-limited contour where service is not predicted to be available. We find that service to these viewers should be protected the same as viewers in locations where service is predicted to be available. Therefore, to ensure that TV service is properly protected, we will assume that a device operating on the same channel as a TV station could cause interference if it were located anywhere within a station's noise-limited contour.

82. In considering the role of spectrum sensing in detecting licensed signals in the TV bands, we are aware that sensing technology for consumer products, including the minimum threshold level needed to detect licensed signals in these bands and algorithms for reliably detecting DTV, analog TV, and wireless microphone signals at any sensing level, is still in its nascent stage. The performance of the white space development devices that we tested showed significant potential but also demonstrated the need for additional work on solutions for handling the significant dynamic range of signal field strengths that characterize the service in the TV bands. The devices examined in our Laboratory's measurement program were not able to sense with a high degree of accuracy both TV and wireless microphone performance in different real world environments where signals are subject to different levels and forms of fading, multipath, and other degradations. In particular, our measurement studies found that while the prototype devices were generally able to detect "clean" TV and wireless microphone signals on a channel with no other signals present, their ability to reliably detect unoccupied channels degraded to levels we consider unsatisfactory when the test signals included multipath and other fading effects and when signals were present on other channels. The performance of the devices was observed to degrade substantially and at increasing levels as the level of the signals on adjacent channels was raised. Both fading and relatively stronger signals on adjacent channels are a normal part of the signal conditions in the environment of the TV bands and any device that uses spectrum sensing to determine whether a channel is occupied will have to be able to perform reliably when such conditions are present.

83. We also find unconstructive sensing performance that incorrectly determines all or nearly all unoccupied channels to be occupied, that is the device finds all occupied channels and all or nearly unoccupied channels to be occupied. While a device that returns such results could be seen as minimizing the potential for interference to authorized services, it would not be practically viable because it would allow its transmitter to operate on very few channels or perhaps none.

84. In view of these results, we believe that much more developmental work needs to be accomplished before the spectrum sensing technique can be implemented as the principal means of identifying unoccupied channels in the TV bands, even in the case of fixed unlicensed devices that use outdoor antennas. Thus, we are not convinced that spectrum sensing as currently presented could adequately serve as the only means to protect TV services and other fixed protected contour services from interference by unlicensed TVBDs operating at the power levels proposed in the *Notice*. Coupled with this concern, we also observe that the significant distances at which interference could occur from an unlicensed TVBD operating at greater than 100 mW would make it very difficult to identify the TVBD as the source of the interference.[147]

[147] Using the TM90 propagation model (this model is for short distances and low antennas), for the situation in which an indoor unlicensed TV band device would impact an outdoor DTV antenna at 30 feet, our staff calculates that a 100 mW signal could cause interference at a distance of 1400 meters in locations where the DTV co-channel D/U ratio is 23 dB and at a distance of 900 meters in locations where the DTV co-channel D/U ratio is 15 dB. *See* (continued....)

85. In view of these concerns, we will rely principally on the geo-location/database method to protect incumbent fixed services from interference from TVBDs. The service areas of fixed transmitter TV and low power TV stations, PLMRS/CMRS operations, production locations that use wireless microphones, and other operations with defined operating areas do not change often and their channel numbers, transmitter geographic coordinates, and other operating parameters can be stored in a database. The protected service contours of these fixed transmitter services are clearly defined and can be calculated from information in the database. Therefore, it is a relatively straightforward for an unlicensed TVBD with geo-location capability to access a database system which would determine whether the TVBD is sufficiently far outside the protected service areas of licensed TV band services to ensure that it will not cause interference to those services. Accordingly, we will require that all TV band devices use a geo-location and database approach to determine unused TV channels in their area on which to operate or to operate as a client to a device that has obtained a list of the unused channels using that method.

86. As the location of a fixed device does not change, it is only necessary to determine the device's location once, at the time of installation and first activation, after which the device's coordinates can be stored internally. We will therefore allow the geo-location function for fixed devices to be performed by either an incorporated geo-location capability or a professional installer. In the case that the stored coordinates in a fixed device become corrupted, it will be necessary for the operator to re-activate the devices internal geo-location function or for a professional installer to re-enter those coordinates in the device. Personal/portable devices operating on an independent basis (which will require use of a geo-location capability) will be required to re-establish their position each time they are activated and to re-verify their position with the database on a regular basis. Personal/ portable devices operating on a client basis (which will not require use of an internal geo-location capability) will also be required to receive the list of available channels in their area from a fixed device or personal/portable device operating in Mode II that has determined the available channels in the area through the geo-location and database method and controls the frequencies on which the personal/portable device operates.

87. We also recognize that a personal/portable device operating independently and on battery power could be relocated from its activation point to a different location where the available channels are different without being deactivated in the period before it re-verifies its location with the database. In such cases, the device could operate on a channel in use by a licensed service and cause interference. We will therefore require that personal/portable devices operating in Mode II access the database each time their geolocation feature detects that the device has been moved. In addition, to ensure that personal/portable devices operating in Mode II are always under control of geolocation, we will require that they cease transmitting at anytime they are not able to determine their location.

88. We recognize that requiring access of and, in the case of fixed devices, registration with a database will increase the costs of unlicensed TV band devices, both from the increased complexity of the devices and the potential for the database administrator to charge fees necessary to support its operations and will also reduce the manufacturer's flexibility in designing these devices. However, we believe that given the available alternatives, requiring use of geo-location and a database for fixed TV band devices is necessary to ensure protection of the licensed television and other services that operate in the TV bands. We will also permit parties to petition us to review any fees that appear to be excessive.

89. As discussed below in the Database Requirements section, we will require that the database administrator include in the database records on the fixed incumbent licensed users of the television band,

(Continued from previous page)
"Propagation in Suburban Areas at Distances less than Ten Miles," William Daniel and Harry Wong, January 25, 1991. We also note that the anecdotal transmitter tests at out Laboratory showed co-channel interference at 360 meters (1180 feet), which was the maximum possible separation that could be achieved at the Laboratory.

including full service and low power television stations, PLMRS/CMRS, BAS links, and Offshore Radiotelephone Service stations. We also understand that there are many facilities that use low power auxiliary devices such as wireless microphones on a regular basis. In addition, cable headends and low power TV receive sites located outside of TV station protected service contours often use high gain antennas mounted on towers and/or at high elevation to receive TV signals and then distribute them to large numbers of subscribers and viewers. We believe that it would be appropriate to extend the protection afforded by the database system to cable headends and will therefore provide for registration of such facilities in the database. In addition, we will allow the operators of event and production facilities where low power auxiliary devices such as wireless microphones are regularly used to register those sites in the database.

90. Fixed and Mode II personal portable unlicensed TV band devices will access the database over the Internet and provide it with their location. The database system will then calculate which television channels are available for use by TV band devices at their location based on the information in the database and return a list of those channels to the TV band device. The database will register unlicensed fixed devices and record appropriate information, including the devices' location and user contact information. Personal/portable devices operating on either a client or independent basis will not need to be registered in the database. The registration information for fixed stations will be available to entities recognized by the Commission to assist TV band device users in coordinating efficient use of the available television channels at a particular location. In addition, the registration information could be used to assist the Commission or its designated agents in the identification of the source of any interference to licensed services from TV band devices. We are not specifically requiring professional installation of fixed unlicensed TVBDs or the use of GPS or any particular location technology in a fixed station. Our concern is with the accuracy and reliability of the location information, rather than the method used to obtain the information, and we believe that the requirement that a device not operate until and unless the geo-location/database process has been completed will be sufficient to ensure that devices are provided a reliable list of the channels used by TV and other licensed fixed transmitters in their area.

91. In order to ensure that fixed unlicensed TV band devices with radio-based geolocation capabilities are able to receive GPS or other location signals, we are requiring that the receive antenna for the geo-location function be located outdoors and at the same location as its subject TVBD transmitter. Personal/portable devices operating in Mode II with radio-based geolocation capabilities in most cases will also need to be located outdoors to receive geolocation signals; we will allow these devices to receive such signals through a separate antenna that is located outdoors.[148] We also find that the 10 meter accuracy we proposed to specify for the geo-location capability, while well within the capabilities of the GPS system, would be more accurate than is needed for purposes of identifying the locations of unlicensed TVBDs. We are also concerned that requiring accuracy to 10 meters might preclude the use of other options for geo-location that are less accurate than GPS but would still provide an adequate degree of accuracy. We believe that 50 meters is a reasonable degree of accuracy for the geo-location capability used to determine the coordinates of unlicensed TV band devices. The effectiveness of the separation distances we are providing for TV and other services are adequate to provide protection in an environment where location errors of up to 50 meters may occur. Also, an accuracy of 50 meters is readily achievable using commonly available methods such as GPS and will also provide flexibility for use of alternative geo-location methods. In the case of professional installation, the party who registers the fixed station in the database will be responsible for assuring the accuracy of the entered coordinates.

[148] If the separate antenna became detached such that the Mode II personal/portable device is no longer able to determine its location it will be required to cease transmitting.

92. We will require that unlicensed TVBDs incorporate spectrum sensing capabilities to complement their geolocation/database access capabilities in determining channel availability. TVBDs that sense wireless microphone operations on a TV channel will not be allowed to transmit on that channel. We will also require that devices that detect a TV signal on a channel must cross-check with the channel availability report from the database to verify that the device is within the service area of a TV station on that channel at the device's location. If the channel is reported by the database as available at that location, *i.e.*, the device is not within the service areas of any TV stations that use that channel, then the device will be required to notify the user that the channel appears to be occupied.

93. We also recognize the position of IEEE 802.18, Shure, and others that the geo-location/database method is not suitable for identifying channel occupancy by devices such as wireless microphones that operate on an intermittent, occasional, or one-time basis at locations not identified in the database. Wireless microphones are licensed on an area basis, rather than specific geographic coordinates. A wireless microphone user may operate anywhere in that area and choose a frequency from multiple vacant channels available for operation. It is not practical to require that the locations of wireless microphones that are used in this manner be included in the database. There may also be TV stations and other regularly operating TV band licensed stations on the air in an area that for some reason are not in the database. We agree with Shure and others that spectrum sensing is the most reasonable and appropriate approach for detecting the presence of TV band services that operate on an intermittent basis or are not in the database. The prototype devices developed by the White Space Coalition, Motorola, Google and others indicate that work is under way to improve the performance of this technology in sensing wireless microphones and we believe that, at this time, it is satisfactory as a complement to the database system and for providing a capability for the detection of unregistered wireless microphone operations. Accordingly, we will require that all unlicensed TV band devices incorporate a spectrum sensing capability to detect wireless microphones and to use that capability in determining the available channels in their area.

94. Television signals and wireless microphone signals use different amounts of bandwidth and modulation methods and TVBDs can thus differentiate between them.[149] In cases where a TVBD detects a wireless microphone operation on a TV channel, the device will not be allowed to operate on that channel. In cases where a TVBD detects the signal of a digital or analog TV station, we recognize that it is possible that the signal is being detected outside of the station's service area. In such cases we will not protect the TV service; rather, we will only require TVBDs to protect TV signals within a station's service areas, except relative to cable head-ends and translator sites as indicated below. Thus, if a device detects a TV signal we will require the device to avoid operation on that channel only if the database also provides information that the device is within the protected range of a TV station. Where a TVBD detects a TV signal outside of the protected range of any TV station, we will require that the device notify the user and provide a capability for the user to manually, at his or her discretion, set the device to avoid operating on that channel. This feature will allow users to avoid operating their TVBDs on channels where out-of-service area TV signals are being received locally. Thus, the geo-location/database process will control the list of available channels at a location within a TV station's service area and device users will have the option of avoiding additional channels detected outside of any station's service area.

[149] A TV signal occupies essentially all of a 6 MHz TV channel whereas a wireless microphone occupies only a 200 kHz segment of a TV channel (multiple wireless microphones can use a single TV channel). In addition, wireless microphones use different analog and digital modulation methods than the analog and digital modulation methods used for television transmissions.

95. Based on the submissions of Shure and IEEE.802.18 on the minimum sensing thresholds needed, our testing of the prototype devices, and the practical limits of sensing indicated in *ex parte* discussions with representatives of the White Space Coalition and other prototype developers, we conclude that sensing at a -114 dBm minimum detection threshold is appropriate and feasible to protect wireless microphones and the signals of other services that operate in the TV bands on an intermittent basis and for detecting TV stations that do not appear in the database for whatever reason.[150] This minimum sensing threshold will provide the maximum likelihood of detecting the signals of licensed services, and particularly wireless microphones, in the area of an unlicensed TVBD that is consistent with manufacturing economics. In this regard, we believe that it is best to require use of the most sensitive level of detection capability that is economically feasible for sensing the signals of all services. Given that wireless microphones operate in relatively narrow bandwidths and that both wireless microphones and analog TV signals have distinctive signal characteristics, we also believe that the -114 dBm level we are adopting will provide the same or better protection in detecting wireless microphones and analog TV signals as digital television signals. Additional discussion of our decision on the minimum spectrum sensing threshold is provided in the section below on technical requirements.

96. We also anticipate that use of sensing under both the client and independent mode approaches for personal/portable devices will allow manufacturers to gain experience with sensing that could be used to develop improvements in such capabilities that could then perhaps justify greater reliance on spectrum sensing for determining whether TV channels are occupied. Personal/portable devices operating in the client mode will also be required to pass information on any signals that they sense back to the master device and the master device will then take appropriate steps with respect to its list of available channels to avoid the channel sensed by client devices. That is, if the client device senses a wireless microphone on an otherwise available channel the master device will be required to remove that channel from its list of available channels. If the client device senses a TV station on a channel outside the service areas of any TV stations, the master will be required to notify the operator and provide the option to remove that channel from the devices list of available channels. In the sections below, we present the specific provisions of our rules for operating under the above plans for determining whether TV channels are occupied or unoccupied, including the minimum required distances that devices using the geo-location/database method must be from the protected contours of licensed services and the requirements for spectrum sensing of wireless microphones.

97. While we continue to believe that the control signal approach has merit as a means to communicate available channels to unlicensed TVBDs, we also recognize the practical constraints that lead the commenting parties to oppose this approach and will not include a control signal element in the rules we are adopting.[151] We would, however, revisit this option if the economics or other circumstances develop in a manner that would favor the viable operation of a control signal system.

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[150] *See* Shure *Notice* comments at 14 and IEEE 802.18 *Further Notice* comments at 9. We also note that the White Space Coalition recommended a minimum sensing threshold level of -114 dBm in their comments responding to the *Further Notice*, at 7. While a sensing threshold of -114 dBm may not identify a TV station not in the database at every location within the station's service area, the station's signal will be above that level at enough locations that its presence will be identified and reported to the database administrator so that the database can be corrected. We note that a -114 dBm detection threshold in 6 MHz is equivalent to -132 dBm in a 100 kHz bandwidth.

[151] Although we appreciate the CBA's offer that its member stations could serve as control signal transmitters, its member stations could not provide the near ubiquitous coverage that would be needed to support a viable control signal system for unlicensed TVBD devices.

98. We also do not believe it is necessary to require that unlicensed devices recognize and respond to beacon signals that would carry information on channels to avoid at events using wireless microphones, as requested by Shure and others representing wireless microphone interests. We believe that other actions we are taking in this matter, including restricting unlicensed personal/portable devices from operation on channels 2-20 and adjacent channels used by TV and providing for registration of sites that use wireless microphones in the database, will ensure that wireless microphones are able to operate without receiving interference from unlicensed TV band devices. We are concerned that such beacon signals would occupy spectrum that could better be used for radio service operations themselves and would impose an additional and unnecessary cost on licensees.

2. Fixed Devices

99. In the *Notice*, the Commission anticipated that fixed unlicensed TVBDs would, in general, be used by WISPs and others as base stations to provide Internet access and other broadband data services to homes and businesses, including service to both fixed and personal/portable services. It therefore proposed to allow fixed TVBDs to operate under the same technical provisions as digital transmission systems that operate under Section 15.247 of the rules.[152] Under those provisions, fixed unlicensed TV band devices would be permitted to operate with transmitter output power up to 1 watt and to employ higher gain directional antennas, with requirements for transmitter output reductions for antennas with gains above 6 dBi. This would allow fixed devices to operate with the equivalent to an EIRP of 4 watts. The Commission further proposed to require that such devices automatically and periodically transmit a unique identification so that any harmful interference situation, should one occur, could be quickly identified and remedied. It also sought comment on whether these devices should be subject to routine evaluation for RF exposure.[153] The Commission requested comment on whether additional requirements would be appropriate for fixed unlicensed TVBD operations. In particular, it asked whether it should require that all fixed devices be registered with an industry-accepted entity, such as a frequency coordinator, that maintains a registration database of all fixed transmitters along with their operating frequencies.

100. As indicated above, in the *First Report and Order* the Commission decided to allow fixed low power devices to operate in the TV bands, subject to final technical rules to be adopted in this subsequent action to ensure that they do not cause interference to authorized services within the TV bands.[154] It gave several reasons for reaching this decision. First, there will be significant unused spectrum available in many parts of the country after the DTV transition, either because of the minimum separations required between authorized stations to avoid interference or because available TV channels have not been assigned (due to lack of demand) and other services are not using those vacant channels. The Commission also found it reasonable to expect that existing technology can be adapted to allow devices to identify unused spectrum in a given geographic area, and noted that the IEEE 802.22 Working Group was in the process of developing a standard to enable fixed devices to successfully share spectrum with authorized services in the TV bands.

101. With respect to transmit power, Shure believes that fixed devices should be limited to 1 watt conducted power and 4 watts EIRP.[155] IEEE 802 supports the proposed power limits and states that

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[152] *See Notice* at ¶ 25; *see also* 47 C.F.R. § 15.247(b)(3).

[153] *See* 47 C.F.R. §§ 1.1307(b) and 2.1091.

[154] *See First Report and Order* at ¶ 17.

[155] *See* Shure *Notice* reply comments at 20.

it may be possible to increase them in the future.[156] CWLab believes that a fixed system using an antenna with a beamwidth of less than 120 degrees should be allowed an EIRP of 25 watts, while Shared Spectrum Company believes that fixed network systems should be permitted peak power levels of 10 watts.[157] The Society of Broadcast Engineers, on the other hand, argues that 4 watt EIRP devices are not low power products and that they would not be suitable for unlicensed Part 15 operation because they would inevitably cause interference to broadcast TV and other stations operating in the TV bands. It believes that the proposed power limit should be reduced by a factor of 100 (20 dB) for TV band devices to be rightfully characterized as Part 15 products.[158] A number of parties express support for the IEEE 802.22 model for fixed operation.

102. MSTV/NAB believe that the Commission should develop rules for fixed operation based on IEEE 802.22's draft plan for fixed access, including its prohibition on co-channel and first adjacent channel operation and use of a combination of geo-location and spectrum sensing to determine channel availability. In that plan, spectrum sensing would be employed as an added rather than sole protection. MSTV/NAB state that this approach would enable a broadband plan without endangering television reception.[159] Cox Broadcasting, ION Media Networks, McGraw-Hill Broadcasting and Media General also believe that if the Commission allows fixed operation, then it should follow the IEEE 802.22's recommendations.[160]

103. Microsoft believes these devices should be exempt from routine evaluation for radiofrequency (RF) exposure. It states that the proper RF exposure context for unlicensed TV band fixed devices is a device with 1 W transmit power and a $5\lambda/8$ vertical antenna in an occupational/controlled environment and mounted on a tower or roof. Microsoft states that to reach the maximum permissible exposure (MPE) limit, an individual would have to remain within one inch (six inches for a high power device) of the antenna of a device operating at maximum transmit power and at 100% duty cycle for a period of 6 minutes. It states that this is not likely to happen in the real world.

104. *Discussion.* We are adopting rules for fixed TV band devices that are based on a system architecture model that is generally similar to the model being developed in the IEEE 802.22 Working Group. Under the plan we are adopting, unlicensed TVBDs will be allowed to provide wireless broadband services, *e.g.,* wireless Internet access, and other services using multiple vacant TV channels and will be permitted to operate on a fixed, point-to-point or point-to-multipoint basis. A fixed system will consist of a permanently located base station transmitting to one or more fixed devices or to personal/portable end user devices.

105. As proposed, we will generally limit fixed unlicensed TV band devices to a peak transmitter output power of one watt with a maximum antenna gain of 6 dBi and require that transmitter power be reduced by the same amount in dB that the maximum antenna gain exceeds 6 dBi. This will allow fixed unlicensed TVBDs to operate with the equivalent of 4 watts EIRP. If the maximum antenna gain exceeds 6 dBi, the transmitter power will be required to be reduced by the amount in dB that the antenna gain exceeds 6 dBi so that the EIRP does not exceed 4 watts. Transmitter power will be

[156] *See* IEEE 802.18 *Notice* comments at 6.

[157] *See* CWLab *Notice* comments at 3 and Shared Spectrum Company *Notice* reply comments at 5.

[158] *See* Society of Broadcast Engineers *Notice* comments at 1.

[159] *See* MSTV/NAB *Further Notice* comments at 33.

[160] *See* Cox Broadcasting *Further Notice* comments at 4, ION Media Networks *Further Notice* comments at 3, McGraw-Hill Broadcasting *Further Notice* comments at 3, and Media General *Further Notice* comments at 2.

measured at the antenna input to account for any cable losses between the transmitter and the antenna. We continue to believe that 4 watts EIRP is sufficient to allow fixed devices to communicate at ranges that will serve community and rural users while minimizing the potential for interference to broadcast television and other authorized services in the TV bands. These power/antenna limits are the same as those permitted for spread spectrum transmitters operating in the 915 MHz band under Section 15.247 of the rules and have proven sufficient for WISPs to provide broadband services in that higher frequency band. Because the TV band frequencies are below 915 MHz and have better propagation characteristics than higher frequencies, operation at the power levels we are adopting will allow improved coverage for wireless broadband service providers.

106. We also recognize that there are advantages, such as reduced infrastructure costs and increased service range, to operation of unlicensed TVBDs at even higher power levels. We will not, however, generally allow operation of these devices at power levels greater than 4 watts EIRP for two reasons. First, operation at higher power levels would increase the risk of interference in congested areas and thus could make sharing spectrum between TV band device users more difficult. This concern extends to higher EIRP levels using high gain antennas with narrow beamwidths, as such effective power levels would pose greater interference potential in the direction of the antenna's main beam. Second, inasmuch as we do not have experience with unlicensed wireless broadband operations in the TV bands, we find it prudent to take a more cautious approach in setting power limits to minimize the risk of interference to authorized users of the TV bands. Nevertheless, the Commission will further explore in a separate Notice of Inquiry whether higher powered unlicensed operation might be accommodated in the TV white spaces in rural areas.

107. With respect to SBE's concern that 4 watts EIRP is too high for an unlicensed device and could possibly result in interference to broadcast and auxiliary stations, we believe that other aspects of the plan we are adopting adequately address this concern. In particular and as discussed below, we are requiring TV band devices to incorporate specific interference avoidance features to prevent interference to authorized users in the TV bands and the technical parameters for those features were developed based on the 4 watt EIRP power level. We also believe that the requirement for fixed devices to operate at outdoor locations will provide sufficient separation from consumer TV receivers to avoid direct pick-up interference from their operations to cable service.

108. In order to ensure that unlicensed TV band fixed devices can be identified if interference occurs, we are requiring that all such devices transmit identifying information and be registered with the database system. The identification signal will be required to conform to a standard established by a recognized industry standards setting organization. We will expect the identification signal to carry sufficient information to identify the device and its location.

109. Devices must be designed so that they will not transmit (beyond the brief messaging necessary to complete the registration process in the case of a device connecting to the internet through another fixed device) unless they are currently registered and have received an authorizing response from the database system. To register a fixed device, the party responsible for the device will be required to provide the database system the device's FCC identifier (FCC ID) and serial number, the geographic coordinates of the device's location (from the geo-location capability), the responsible party's name, the name of a contact person, and the contact's address, e-mail address and telephone number. The required registration can be accomplished the first time the device accesses the database to determine the available channels in its area. While registration in the database system will pose some additional burden, we observe that manufacturers of internet access equipment and computing software now typically request that users register their equipment or software purchase with its manufacturer/producer. Thus, systems with registration capability are already widely in use and both manufacturers and users are familiar with registration procedures. The process to be implemented by the database operator for registering unlicensed TV band fixed base stations is expected to be similar to these existing registration procedures.

We therefore do not believe that it will be unduly burdensome to develop or comply with this registration procedure.

110. We note that the IEEE 802.22 draft standard does not provide for fixed devices to communicate with personal/portable devices. However, under the rules we are adopting, fixed TVBDs will be allowed to communicate with personal/portable devices operating independently or using a master/client model. We believe that allowing communications between fixed and personal/portable devices will significantly enhance the service benefits of both types of TV white space devices. In this regard, a fixed base will be able to provide direct internet access and other services that may be developed to a large number of personal/portable devices within its service range.

111. For purposes of these devices, we are defining the terms "master" and "client" as we have for other types of Part 15 devices.[161] That is, a master device is one that operates in a mode in which it has the capability to transmit without receiving an enabling signal, to select a channel, and to initiate a network by sending enabling signals to other devices. A client device is one whose transmissions are under the control of the master and is not able to initiate a network. A network always has at least one device operating in master mode and also some devices that may be capable of operating only in client mode and some devices that may be capable of operating in either mode. All fixed TVBDs will be allowed to operate in master mode. Those personal/portable devices communicating on a master/client basis with a fixed device will be required to use channels/frequencies as directed by the fixed device. Thus, a personal/portable device operating under this arrangement will pose no more risk of interference to a licensed service than the fixed device, and because it will use less power will generally pose less risk of causing such interference. We note that, because the fixed master device will not transmit if its service area would cause harmful interference to a licensed user in the database, the client devices would by definition be within that service area and would likewise not cause harmful interference.

112. If a fixed unlicensed TV band device that does not have a direct connection to the internet (that is a connection provided by a source other than another TV band fixed device) has not yet been initialized and registered with the database system and can receive the transmissions of another fixed TV band device, we will allow the device needing initialization to transmit on either a channel that the other TV band device has transmitted on or on a channel which the other TV band device indicates is available for use.[162] The TV band device needing initialization must then immediately use its communications link with the other TV band device to access the database to register its location and receive a list of channels that are available for it to use. From that point on, the newly registered TV band device must only use the television channels that the database indicates are available for it to use and not the channels indicated or used by the other TV band device.[163]

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[161] *See Report and Order* in ET Docket No. 03-133, 18 FCC Rcd 24484 (2003) at Appendix C; *see also* 47 C.F.R. § 15.202.

[162] In this context, "not initialized" means that the TV band device has not yet registered with and accessed the database to determine a list of available channels.

[163] Because of the relatively low power that TV band devices will be permitted to use, both of the TV band devices will be located fairly close to one another. The lists of television channels available for use by the two devices are therefore likely to be the same in most cases. There will, however, be cases where a fixed device that obtains its internet connection through another fixed device may be located in the service area of a different group of licensed stations. This is particularly likely to occur if a fixed device obtains service from another fixed device that itself does not have a direct connection to the internet.

113. Unlicensed TV band fixed devices must also comply with the Commission's RF exposure guidelines.[164] As Microsoft observes, we recognize that it is likely that the radiating antennas of these devices will generally be the same as their receive antennas and therefore be located outdoors and at some height above ground. However, there are no requirements that those locations be in areas where they are restricted from persons who do not understand that a radiating structure is present and the need to avoid that area or minimize the time spent there. Accordingly, we will apply to these devices our exposure guidelines for publicly accessible/uncontrolled locations. The maximum permissible exposure (MPE) for a 4 W EIRP transmitter operating in the frequency range from channels 5-51 (76 MHz to 698 MHz) varies from an exposure level of 0.2 to 0.47 mW/cm^2. The required separation distance from people for safe exposure when the exposure limit is 0.2 mW/cm^2 (the most restrictive limit over the 76 MHz to 698 MHz range) is about 40 cm, or 15.7". We believe that RF exposure from devices operating at 4 W EIRP in this band can be effectively controlled by measures that can be taken by the party installing the device to ensure that persons maintain a distance of at least 40 cm from a device's the radiating antenna. We therefore will not require that unlicensed TV band fixed devices be subject to our requirements for routine evaluation for compliance with our RF exposure guidelines. Rather, we will require that new units of such devices be accompanied by instructions on measures to take to ensure that persons maintain a distance of at least 40 cm from the device, as well as any necessary hardware that may be needed to implement that protection.

114. As indicated above, we are requiring that all unlicensed fixed TVBDs register with the database system. This registration will provide a means of identifying devices in investigations of any cases of interference that may arise. We believe that registration with the database system using the on-line method presented in the section below on Database System Requirements will minimize the impact of this requirement on operators of fixed unlicensed TV band devices.

115. The rules we are adopting will allow TVBDs to communicate with each other in various network configurations. For example, multiple fixed TVBDs could be organized into a service network comprised of a base station and associated customer premises equipment that communicate through the base station, as described in the IEEE draft standard. Alternatively, a fixed TVBD could initiate communication directly with any other fixed TVBD, without designating any one fixed TVBD as a central relay point. The specific technical requirements and standards for fixed devices are discussed in the Technical Standards section below.

3. Personal/Portable Devices

116. In the *Notice* and *First R&O/Further Notice*, the Commission observed that non-fixed personal/portable devices generally pose a greater risk of harmful interference to authorized operations than fixed devices because the locations where non-fixed devices are used change, making identification of both unused TV frequencies and the devices themselves, if they cause interference, substantially more difficult.[165] It also noted that such devices may not be able to sense transmissions of licensed services as well as fixed devices because they will have antennas that are less efficient and may be located in less advantageous positions.[166] In view of these concerns, the expected ubiquitous use of such devices, and the importance of protecting television service, the Commission proposed to limit personal/portable unlicensed TVBDs to 100 mW and to require that that they have a permanently attached antenna with a maximum gain of 6 dBi, for a maximum EIRP of 400 mW. The Commission also requested comment on

[164] *See* 47 C.F.R. § 1.1307(b).

[165] *Id.*

[166] *See Further Notice* at ¶ 18.

whether personal/portable devices should be required to transmit an identifying signal and the information to be carried on that signal.[167]

117. In the *First R&O/Further Notice*, the Commission further noted that the IEEE 802.22 standard under development is limited to fixed point-to-point and point-to-multipoint operations and does not address the non-fixed personal/portable class of devices the Commission proposed to allow in the *Notice*. The Commission therefore sought comment on how non-fixed unlicensed devices could operate in the TV bands under the different sharing schemes under consideration in this proceeding.[168] It further requested comment on whether such devices should be subject to routine evaluation for RF exposure.

118. Harris Corporation (Harris) supports the Commission's proposal to allow personal/portable devices to operate with a maximum power of 100 mW and to incorporate a permanently attached 6 dBi gain antenna.[169] The White Space Coalition also supports a maximum power of 100 mW for personal/portable devices, but with a maximum antenna gain of 0 dBi, which is 6 dB less than proposed by the Commission.[170] The Consumer Electronics Association believes that the maximum power for personal/portable devices should be 20 mW with a 0 dBi gain antenna to minimize direct pick-up interference to TV receivers, while NCTA believes the maximum power should be in the range of 10-20 mW to avoid that type of interference.[171] Wireless microphone manufacturers recommend reducing the proposed power level for personal/portable devices to minimize the possibility of interference to wireless microphones. In this regard, ATK Audiotech suggests 50 mW, Telex suggests 20 mW, and Shure suggests 10 mW with a maximum antenna gain of 0 dBi.[172] These parties did not provide an analytical basis for their suggested parameters.

119. TV broadcasters argue that unlicensed personal/portable devices should not be allowed to operate in the TV bands. MSTV/NAB claim that personal/portable devices are not compatible with existing operations in the broadcast TV spectrum because no method exists today or the foreseeable future for preventing interference from such devices to the reception of DTV services.[173] Other broadcast interests, including Cox Broadcasting, McGraw-Hill, and Media General, also state that the Commission should not allow personal/portable TV band devices at this time due to the potential for interference to DTV reception.[174]

120. Manufacturers and users of wireless microphones also express concerns about permitting personal/portable devices to operate in the TV bands due to the potential for interference to wireless microphones. Shure believes that it would be premature to consider allowing personal/portable devices in the TV bands because these devices pose a greater risk of harmful interference than fixed devices. It states that personal/portable devices are inherently unpredictable for frequency coordination and sharing

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[167] *See Notice* at ¶ 22.

[168] *See Further Notice* at ¶ 18.

[169] *See* Harris *Notice* comments at 6.

[170] *See* White Space Coalition *Further Notice* comments at 5.

[171] *See* Consumer Electronics Association *Notice* comments at 5 and NCTA *Further Notice* comments at 12.

[172] *See* Telex *Notice* comments 4 and Shure *Notice* reply comments at 7.

[173] *See* MSTV and NAB *Further Notice* comments at 34.

[174] *See* Cox Broadcasting *Further Notice* comments at 4, McGraw-Hill *Further Notice* comments at 3, and Media General *Further Notice* comments at 3.

purposes, may be in a less advantageous position for sensing transmission, change locations randomly, and are impossible for incumbent users to identify as a source of interference.[175] It further notes that neither the IEEE nor any other technical group has offered any comprehensive analysis and proposal for protecting incumbent operations from interference caused by personal/portable devices.[176] The Professional Audio Manufacturers' Alliance and Audio Technica believe that the Commission should not allow personal/portable devices in the TV bands until after it has experience with fixed devices, while Grand Ole Opry and Microphone Interests Coalition believe that personal/portable devices are unsuitable for the white spaces and should be prohibited.[177]

121. Microsoft submits that personal/portable unlicensed TV band devices should be exempt from routine evaluation for RF exposure. It states that the appropriate RF exposure context for personal/portable devices is for public/uncontrolled exposure from a device with 100 mW transmit power and a $\lambda/4$ vertical antenna. Microsoft indicates that to reach the MPE limit set forth in our rules, an individual would have to remain within 1 inch (7 inches for a high power device) of the device antenna when the device is operating at full power and 100% duty cycle for a period of 30 minutes.[178] It contends that the likelihood of that happening in the real world approaches zero. Microsoft further observes that the Commission routinely exempts mobile devices in bands below 1.5 GHz that radiate less than 1.76 dBW ERP (3.9 dBW EIRP) from environmental evaluation for RF exposure.[179]

122. *Discussion.* We understand the concerns of parties representing broadcast TV and other TV band licensees with respect to the potential for interference to their operations from unlicensed personal/ portable broadband devices, and are adopting technical requirements for personal/portable devices to control interference which are accordingly rigorous. We believe that with the safeguards we are adopting, these types of devices can operate successfully on TV white spaces without causing interference to licensed services. As we observed previously in this proceeding, personal/portable devices pose a greater risk of interference to licensed TV band service because the locations where these non-fixed devices are used will change, making the task of determining unused TV frequencies by the devices more complicated. In addition, the transitory nature of such devices makes it difficult for others to identity the devices if they cause interference. As a number of the commenting parties observe, the fact that a non-fixed personal/portable broadband device (*e.g.*, a device installed in laptop computer) is likely to be moved around with some frequency is likely to make it difficult for TV and other users to locate the device if it causes interference. For example, a device operating indoors for a short period of time in a neighborhood might cause interference that disrupts TV service for the households in that neighborhood while it operates. Because personal/portable devices will generally operate intermittently and their antennas will generally not be located where they are visible, the interference from such operations would be very difficult to identify and control.

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[175] *See* Shure *Further Notice* comments at 6.

[176] *See* Shure *Further Notice* comments at 8.

[177] *See* Professional Audio Manufacturers' Alliance *Further Notice* comments at 8, Audio Technica *Further Notice* comments at 9 and Grand Ole Opry and Microphone Interests Coalition *Further Notice* comments at 2.

[178] The standards for RF exposure are contained in Section 1.1310 of the rules. *See* 47 C.F.R. § 1.1310.

[179] For the purpose of radiofrequency radiation exposure evaluation, mobile devices are defined as a transmitting device designed to be used in other than fixed locations and to generally be use in such a way that a separation distance of at least 20 centimeters (7.9 inches) is normally maintained between the transmitter's radiating structure(s) and the body of the user or nearby persons. *See* 47 C.F.R. §2.1091(b). The Commission routinely exempts mobile devices in bands below 1.5 GHz that radiate less than 1.5 watts ERP (3.9 dBW EIRP) from environmental evaluation for RF exposure. *See* 47 C.F.R §2.1091(c).

123. At the same time, we recognize the significant benefits that unlicensed wireless communications in other bands have brought to both businesses and consumers using personal/portable digital devices and believe that propagation advantages of the TV bands would further enhance the capabilities of those products. Accordingly, we have developed a plan that will allow operation of unlicensed personal/portable devices in the TV bands in a manner that provides manufacturers and users considerable flexibility in design and use of products, subject to conservative controls on their operation to protect TV and other licensed services. As discussed below, this plan provides for use of spectrum sensing, but at the present time not as the sole means of determining whether channels are occupied or unoccupied. We have sought to make the controls and technical requirements of this as simple and as reliable as possible to encourage the development of new products and assure the operators of licensed services that they will be protected. We are also providing for certification of devices that rely on spectrum sensing alone to determine available channels under a separate plan, as discussed in a subsequent section.

124. As discussed above, we will allow personal/portable devices to operate under two alternative approaches: Mode I client and Mode II independent. 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. In Mode II, devices operating independently will use their own internal geo-location/database access capabilities to determine the channels available for location in the area. In either mode, the list of available channels that can be used by a device will be determined though the geo-location/database method. For the reasons indicated above, we are not requiring that personal/portable devices register with the database system.

125. Personal/portable devices operating in either mode will also be required to perform spectrum sensing that can detect wireless microphone, TV and other authorized signals at levels as low as -114 dBm over the 6-MHz channel bandwidth to determine whether channels are vacant. We believe several purposes are served by requiring spectrum sensing. Although spectrum sensing did not perform consistently in our testing, we expect it will continue to develop and improve. While the principal means of protecting TV service will be through the geo-location and database requirements, sensing can serve as a back-up for detecting TV signals inside the protected service areas where there may be errors in the database. As such and as further explained below, this function will advise the user of the presence of a signal so that they can take appropriate action. We are aware that TV signals are often present at levels below -114 dBm within a station's service area and that sensing at this level may not reliably detect TV signals in such cases. However, given that the geo-location and database access approach provides a reliable means for protecting TV service, we believe that it is not critical that the sensing function be capable of detecting signals below the -114 dBm level. Further, while we are establishing provisions to ensure that channels are available for operation of wireless microphones, a sensing capability provides at least some means to detect such devices that may be operating on an itinerant basis on virtually any channel. We find that detection at a level as low as -114 dBm is appropriate for detection of wireless microphone signals in a 200 kHz bandwidth. We believe that this level of sensitivity is also acceptable detection of ATSC digital signals in a 6 MHz bandwidth and NTSC analog television signals in a 100 kHz bandwidth as a complement to the geolocation and database requirement.

126. We will permit personal/portable devices operating in either mode to transmit with up to 100 mW EIRP. We recognize the concerns of the cable interests that there is a potential for direct-pick-up interference and their position that power levels should therefore be limited to a lesser value. We appreciate that the tests described on our report on direct pick-up interference to three digital cable ready receivers and the anecdotal tests performed by our engineers in the laboratory and field in our second series of tests of white space developmental devices indicated that there is some potential for direct pick-up (DPU) interference to cable service from TV white space transmitters. We also note, however, that this occurred at relatively close spacings within the user's premises and could be corrected by removing

consumer-installed splitters and wiring that effectively reduce the shielding to interfering signals as well as reduce the desired signal levels available at the TV receiver. Further, when just the cable converter box was used to connect directly to the TV receiver, interference declined dramatically and was virtually non-existent on the digital tier of channels. Cables systems are rapidly moving to digital technology which should further alleviate the potential for interference. Consumers generally should be able to correct any interference to their own devices by increasing the separation, re-orienting the devices, or using wiring with improved shielding. We also note that, in our tests, with a 10 meter separation between devices on separate sides of a wall, such as in a townhouse, the interference did not occur at signals below 100 mW for two receivers and a bit under 50 mW for a third. The interference was also a function of the physical relationship between the devices, such as whether the interfering signal was located towards the front or rear of the TV receiver. In addition, as discussed below, we are requiring that TVBDs use dynamic power reduction, and in locations in townhouses and apartments where the operating distances are apt to be relatively short, the power level would typically be adjusted automatically to less than the maximum permitted power of 100 mW. In contrast, reducing the permitted power of the device could make it unviable in locations where the separations are greater. Accordingly, we are not persuaded at this time that the risk of DPU interference is sufficiently great to warrant a reduction in power that could impede the viability of certain TVBD applications. Nevertheless, we will closely monitor for any reports of this type of interference and will expect the equipment suppliers to cooperate in helping consumers to rectify any such interference.

127. We are adopting the White Space Coalition's recommendation to limit the EIRP of personal/portable devices with antenna gain to a maximum of 0 dBi in either case in order to further reduce the potential for interference. That is, if the gain of a device's antenna exceeds 0 dBi, we will require a reduction in the maximum transmitter power to below 100 mW by the same amount in dB that the antenna gain exceeds 0 dBi. We will further require the antenna to be permanently attached to prevent user substitution of higher gain antennas.

128. We will not require that unlicensed TV band personal/portable devices transmit basic identifying information when they are operating. We find that an identifying signal will not be of significant value in identifying the source of or, more importantly, resolving any interference that these devices might cause. In this regard, the identifying code will not serve to identify a device, its operator, or its location as that information will not be recorded in the database system. We also believe that the range of potential interference from personal/portable devices will be sufficiently short that any persistent interference that might occur from a device that is regularly used at the same location could be resolved by traditional methods of local knowledge from those TV viewers receiving the interference and/or direction finding. In addition, these devices will operate on a transient basis such that a device could be relocated and its interference resolved before steps could be taken to identify and locate the device using information transmitted in its signal.

129. The plan for Mode I client operation by personal/portable devices will protect licensed services in a manner similar to the master/client provisions the Commission adopted for unlicensed U-NII devices operating in the 5 GHz band and is supported by the various parties, including broadcasters.[180] This approach will allow personal/portable TV band devices to be built into laptop computers and other portable devices and operate whenever they are in close proximity to a fixed or Mode II personal/portable device or are able to independently perform geo-location and contact the database. Personal/portable devices will be allowed to communicate with other personal/portable devices on a master/client basis,

[180] *See* 47 C.F.R. § 15.407(h)(2)(i). Master and client modes are defined in the U-NII compliance measurement procedure found in the appendix of the *Memorandum Opinion and Order* in ET Docket No. 03-122, 21 FCC Rcd 7672, 7682 (2006).

with a device that incorporates geo-location/database access and sensing to determine the available channels serving as the master unit. Personal/portable devices operating as client devices in such cases will again be required to use channels/frequencies as directed by the master device. Devices that both make use of geo-location/database access and sensing may, of course, also (and preferably) communicate *with one another and share their sensing information.*

130. If the user of a personal/portable unlicensed TV band device that does not have a geo-location capability intends to operate the device in Mode I as a client to another unlicensed TV band device (either a fixed device or a personal/portable device that uses a geo-location/database access capability) and the personal/portable device can receive the transmissions of such other TV band device, we will allow the personal/portable device to initiate contact by transmitting on either a channel that the TV band device with a geo-location/database access capability has transmitted on or on a channel which the other device indicates is available for use. The personal/portable TV band device will be required to immediately use its communications link with the other TV band device to obtain a list of channels that are available for it to use.

131. Personal/portable devices operating in a Mode II independent basis will protect licensed services using the same geo-location/spectrum sensing and database access/registration plan as fixed devices. Such devices will be required to obtain a list of available channels at its location from the database.

132. The rules we are adopting will allow personal/portable devices to communicate with each other in network configurations over short distances. For example, a Mode II independent device could communicate directly with other Mode II independent devices or with several Mode I client devices. We will permit personal/portable TVBDs to be used in the operation of "mesh" networks, only where a means is provided to ensure that each device is operating consistent with the channels available at its particular location. That is, we will not permit personal/portable devices operating on a client basis to relay information from one client device to another unless some means is used to ensure that each device is operating within the parameters for its particular location. This will allow use of personal/portable devices in that manner and such operation could facilitate the expansion of broadband service in a community. Nonetheless, we are concerned and need to ensure that that the range of a mesh network of client devices does not extend out to distances where the available channels would change, with the result that some licensed services would be subject to interference.

133. We envision that both the Mode I and Mode II approaches will often be incorporated into the same personal/portable device. That is, a personal/portable device could function as a master device when it is able to use geo-location/sensing and database access to identify unused TV channels in its area. If it cannot rely on these techniques but is near a fixed device or another personal/portable device that can act as a master, it could operate in client mode if it makes contact with a master station.

134. With respect to RF exposure, we first observe that personal/portable TV band devices could operate as either "mobile" or "portable" devices as defined in Sections 2.1091 and 2.1093 of the rules, respectively.[181] Under Section 2.1091, a mobile device is a transmitter designed to be used in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimeters is normally maintained between the transmitter's radiating structure(s) and the body of the user or other nearby persons. Such devices that operate on frequencies below 1.5 GHz are subject to routine environmental evaluation for compliance with the RF exposure guidelines only if their effective radiated power (ERP) is 1.5 watts or more. The 100 mW EIRP limit for personal/portable TV band

[181] 47 C.F.R. §§ 2.1091 and 2.1093

devices is equivalent to 61 mW ERP; therefore personal/portable devices that are designed for operation in mobile exposure conditions such that the radiating structure(s) are maintained at distance of at least 20 centimeters from the body of the user or other persons will not be subject to our requirements for routine evaluation for RFE.[182]

135. Section 2.1091 provides that a portable device is a transmitter designed to be used so that the radiating structure(s) of the device is/are within 20 cm of the user. The MPE standards for such devices are specified in terms of the Specific Absorption Rate (SAR) of RF energy by the body as specified in Section 2.1093(d). Inasmuch as users of unlicensed TV band devices cannot generally be expected to be aware of the potential effects of RFE, we believe it is appropriate to apply the standards for general population/ uncontrolled exposure in Section 2.1093(d)(2). Under those standards, the SAR limits are 0.08 W/kg as averaged over the whole body, with spatial peak SAR not exceeding 1.6 W/kg as averaged over any 1 gram of tissue, except for the hands, feet, wrist, and ankles, where the spatial peak SAR shall not exceed 4 W/kg as averaged over any 10 grams of tissue. In order to avoid unnecessary SAR testing for low output power personal/portable devices, we find it is desirable to establish an average power threshold whereby devices operating below that threshold will not be subject to such testing. In developing a threshold, we first observe that SAR is proportional to the average power absorbed in tissues and does not generally have clear and direct relationships with either the average or peak power of a TVBD. However, the energy absorption characteristics of tissues for energy on frequencies in the 76 - 698 MHz range, are relatively flat, as compared to higher frequencies (above 1 GHz); therefore, a single conservative average power threshold can be sufficient as a threshold for all TVBD frequencies.

136. Based on the absorption characteristics of tissues in the 76 - 698 MHz range, we are applying a source-based time-average output power threshold of 20 mW as the triggering point for routine SAR evaluation for personal/portable TVBDs. This standard also allows margin to account for simultaneous transmissions by transmitters in the device operating in other frequency bands that may increase exposure potentials. Accordingly, personal/portable TVBDs that meet the definition of portable devices under Section 2.1093 and operate with time-averaged output of less than 20 mW will not be subject to routine evaluation for compliance with the RFE guidelines; such devices that operate with time-average output power greater than that level will be subject to the routine evaluation requirements. The specific technical requirements and standards for personal/portable devices are discussed in the Technical Standards section below.

C. Permissible Channels For Unlicensed Operation

137. In the *Notice*, the Commission stated its belief that unlicensed TV band devices should be allowed access to the largest practicable number of the 68 television channels. It also indicated that certain channels did not appear suitable or appropriate for use by unlicensed devices. In this regard, the Commission proposed to exclude unlicensed devices from operating on TV channels 2-4 to avoid possible interference to TV interface devices such as VCRs, DVDs, DVRs, satellite and cable boxes that operate on or adjacent to those channels.[183] It further proposed to exclude unlicensed devices from channel 37, which is used for radio astronomy and the wireless medical telemetry service (WMTS), and from channels 52-69, which have been reallocated for new non-broadcast, uses. In addition, it tentatively concluded that channels 14-20 are not suitable for use by unlicensed devices in markets where they are

[182] EIRP is referenced to a theoretical point source radiator, whereas ERP is referenced to a dipole radiator. Power measurements of EIRP are 1.64 (2.15 dB) times higher than measurements of ERP for the same transmit output power level. Therefore, 400 mW EIRP is equivalent to 244 mW ERP (400 mW/1.64).

[183] *Notice* at ¶¶ 33-37.

used for PLMRS and CMRS operations.[184] Using the same criteria specified in the rules for protection of land mobile operations from low power TV, TV translator, TV booster, and Class A TV (LPTV) stations, the Commission therefore proposed not to allow unlicensed devices to operate within 134 km or 131 km from the center coordinates of metropolitan areas where PLMRS/CMRS services operate on co- and adjacent channels, respectively.[185] With the exception of these channels, the Commission proposed to allow unlicensed TV band devices to operate on any unused TV channel. Thus, it proposed to make TV channels 5-36 and 38-51 generally available for unlicensed operation and channels 14-20 available in locations where they are not used by the PLMRS or CMRS. In the *Notice*, the Commission also sought comment on the possibility of designating one or two locally vacant channels for use only by wireless microphones.[186]

138. In the *First Report and Order and Further Notice*, the Commission adopted its proposals to exclude unlicensed TV band devices from channel 37 in order to protect radio astronomy and medical telemetry, and from channels 52-69 as those channels have been reallocated to new uses.[187] With respect to channels 14-20, it decided to prohibit personal/portable TV band devices on these channels everywhere in order to protect public safety and other PLMRS/CMRS operations, as such devices could be easily transported and used anywhere, including within the service areas of PLMRS/CMRS and other licensed operations. The Commission did, however, not make a decision on whether to allow fixed unlicensed devices to operate on channels 14-20 in areas of the country where those channels are not being used for PLMRS/CMRS or other authorized services. It noted that prohibiting operation of fixed TV band devices on channels 14-20 everywhere would preclude operation of such devices in many areas where these channels are not used since PLMRS/CMRS operations only use one to three channels in 13 metropolitan areas and other services on those channels, such as the Offshore Radiotelephone Service, similarly operate only in a few areas. The Commission therefore sought additional comment on whether fixed unlicensed TV band devices should be allowed to operate on channels 14-20 in areas where those channels are not used by PLMRS/CMRS and other operations.[188]

139. The Commission sought further comment on whether it should exclude channels 2-4 from use by TV band devices because of possible interference to TV interface devices such as VCRs, DVRs and MVPD terminal devices that typically use those channels in output connections to TV receivers.[189] In particular, it sought comment on whether TV interface devices would be more susceptible

[184] *See* 47 C.F.R. § 90.305 and 47 C.F.R. § 22.625. PLMRS/CMRS base stations must be located within 80 kilometers (50 miles) of the center of the cities where they are permitted to operate on channels 14-20 (470-512 MHz), and mobile units may be operated within 48 kilometers (30 miles) of their associated base station or stations. Thus, mobile stations may be operated at up to 128 kilometers (80 miles) from the city center. We also note that there are numerous licensed land mobile operators, including public safety entities that currently operate, pursuant to waiver, on defined channels in channels 14-20 at specified locations outside those markets specifically designated in the Part 90 rules. *See, e.g.*, Goosetown Enterprises Inc., 16 FCC Rcd 12792 (2001).

[185] Under this approach, PLMRS/CMRS operations would be protected within a circle of radius 130 kilometers from the city center coordinates. This is the area in which such operations are permitted under the rules. As is the case for LPTV stations, the field strength from an unlicensed device on a co- or adjacent channel would not be permitted to exceed 52 dBu or 76 dBu, respectively, at the 130 km protected contour of the PLMS/CMRS metropolitan area. *See* 47 C.F.R. § 74.709(d).

[186] *Id.* at ¶ 38.

[187] *First Report and Order and Further Notice of Proposed Rulemaking* at ¶¶ 19-21.

[188] *Id.* at ¶ 56.

[189] *Id.* at ¶ 57.

to interference from low power TV band devices than other TV receivers; on whether the cabling between a TV interface device and a TV receiver typically provides adequate shielding from unwanted signals on channels 2-4; and the extent to which such signals may be picked-up directly within the TV receiver. It also sought comment on how much longer consumers can be expected to use TV interface devices that connect to a TV through the tuner (antenna or cable television input) rather than an alternative interface connection. A number of parties commented on these issues. In addition, several parties submitted comments regarding additional channels on which the operation of TV band devices should be restricted.

140. In their Petition for Reconsideration, NAF/CUWN ask the Commission to reconsider its decision to prohibit personal/portable TV band device operation in channels 14-20.[190] They argue that the Commission should defer a decision on this issue until it is more familiar with the available technologies for mobility. NAF/CUWN is concerned that no parties will develop the necessary technologies to permit use of channels 14-20 for mobile devices if the Commission forecloses this possibility now. They contend that the Commission's decision to exclude personal/portable devices from channels 14-20 is imposing unnecessary costs on the public through an overabundance of caution.

141. The NAF and the CEA submit that fixed unlicensed TV band devices can operate on channels 14-20 without interfering with PLRMS/CMRS operations through the use of geo-location capabilities and a database containing the markets where these channels are used.[191] These parties submit that not allowing use of these channels in other areas would needlessly remove a large amount of white space since PLRMS/CMRS operations only make use of one to three channels in a small portion of the United States. Motorola suggests that channels 14-20 be reserved for TV band devices used by public safety agencies.[192] It believed that this would prevent interfering uses and satisfy a great need in the public safety community.

142. The Land Mobile Communications Council (LMCC) argues that unlicensed TV band devices should not be allowed to operate on channels 14-20 anywhere in the country.[193] The LMCC believes that even if these devices are banned from an "exclusion zone" around the area used for PLMRS/CMRS operations, some users of the devices will not adhere to the restrictions. It states that there would be no way to identify nonconforming unlicensed devices in the dense urban areas where these channels are used. LMCC furthermore submits that spectrum sensing would not be effective in identifying PLMRS/CMRS channels because radios in those services are used only intermittently. Los Angeles County adds that fixed devices can always be moved to areas where they would interfere with PLMRS/CMRS operations.[194] Comm Enterprises claims that PLMRS/CMRS use of these channels may expand after the end of the digital transition and that such growth warrants prohibiting unlicensed devices from operating on them.[195]

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[190] *See* NAF/CUWN Petition for Reconsideration at 7-8.

[191] *See* NAF et al. comments at 78; CEA comments at 6.

[192] *See* Motorola comments at 10-11.

[193] *See* LMCC comments at 9.

[194] *See* The County of Los Angeles *Further Notice* comments at 2.

[195] *See* Comm Enterprises, LLC *Further Notice* comments at 6.

143. Most of the commenting parties that address this issue continue to oppose the use of channels 2-4 for TV band devices in order to avoid interference with TV interface devices.[196] For example, CEA states that there is potential to cause interference to the installed base of analog receivers which might be connected to digital-to-analog converter boxes or receiving their content from a terminal device of a multichannel video program distributor such as cable or satellite that uses channels 3 or 4.[197] However, the NAF appears to suggest that channels 2-4 could be used by TV band devices if shielded cables are used to connect the interface device to the TV.[198] The National Cable Television Association (NCTA) counters that the interference to TV interface devices in fact generally results from leakage into the television receiver, so that use of shielded cables would not prevent interference.[199] NCTA submits that leakage into television receivers will occur on all VHF channels and that TV band devices should therefore be limited to only UHF frequencies.

144. GE Healthcare (GE) requests that TV band devices not be allowed on channels 33-36 until February 18, 2010 in order to allow medical facilities time to replace grandfathered medical telemetry systems that operate on those channels.[200] GE and The American Society of Healthcare Engineering note that medical telemetry devices that operate on channels 33-36 are currently being sold in areas where those channels are vacant.[201] GE also argues that stricter spurious emissions limits are needed to protect WMTS devices that operate on channel 37. In addition, GE asks that the Commission restrict operations of TV band devices on channels 36 and 38 or require that professional installation and coordination with WMTS systems to ensure that the emissions in channel 37 are kept below 50 microvolts/meter at WMTS facilities. GE further requests that we require fixed TV band device operators to notify nearby hospitals before beginning operation.[202] The White Space Coalition responds that granting GE's request to protect channels 33-36 would only serve to encourage more grandfathered devices on those channels.[203] GE subsequently submitted an emissions mask for TVBDs that it states would address its concerns about adjacent channel overload and spurious emissions interference from TVBDs to WMTS devices on channel 37.[204]

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[196] *See* CEA *Further Notice* comments at 6; NCTA *Further Notice* comments at 13-15; Echostar *Further Notice* comments at 2; IEEE 802.18 *Further Notice* comments at 23-24.

[197] *See* CEA *Further Notice* comments at 6.

[198] *See* NAF et al. *Further Notice* comments at 83. The NAF notes that the use of channels 2-4 would result in significantly more whitespace because these channels are considered undesirable for DTV. *Id.*

[199] *See* NCTA *Further Notice* comments at 13-15.

[200] *See* GE Healthcare *Further Notice* comments at 5. As indicated above, wireless medical telemetry devices operate on channels 7-13 (174-216 MHz) and channels 14-46 (470-668) MHz on an unlicensed basis under Sections 15.241 and 15.242 of the rules; WMTS devices operate on channel 37 (608-614 MHz) on a licensed basis under Sections 95.1101-1113 of the rules. WMTS devices are also authorized to use the frequency bands as 1395-1400 MHz and 1427-1429.5 MHz. *See* 47 C.F.R. § 15.241-.242 and 47 C.F.R. § 95.1101-.1113. Section 15.37(i) also provides that new equipment approvals may no longer be obtained for medical telemetry devices operating under Sections 15.241 or 15.242 after October 22, 2002. *See* 47 C.F.R. § 15.37(i).

[201] *See* GE Healthcare comments at 3; American Society of Healthcare Engineering *Further Notice* comments at 4.

[202] *See* GE Healthcare *Further Notice* comments at 6, 8-9.

[203] *See* White Space Coalition *Further Notice* reply comments at 34.

[204] *See* GE Healthcare *ex parte* submission of May 6, 2008.