



FEDERAL COMMUNICATIONS COMMISSION

47 CFR Part 15

[ET Docket No. 20-36; FCC 20-156; FRS 17258]

Unlicensed White Space Device Operations in the Television Bands

AGENCY: Federal Communications Commission.

ACTION: Final rule.

SUMMARY: In this document, the Commission revises its rules to expand the ability of unlicensed white space devices to deliver wireless broadband services in rural areas and areas where fewer broadcast television stations are on the air. The Commission also modifies its rules to facilitate the development of new and innovative narrowband Internet of Things (IoT) devices in TV white spaces. Unlicensed white space devices operate in the VHF and UHF broadcast TV bands, a spectral region that has excellent propagation characteristics that are particularly attractive for delivering wireless communications services over long distances, varying terrain, and into and within buildings. The Commission adopts a number of changes to the white space device rules to spur continued growth of the white space ecosystem, especially for providing affordable broadband service to rural and unserved communities that can help close the digital divide, while at the same time protecting broadcast television stations in the band from harmful interference.

DATES: Effective [INSERT DATE 30 DAYS AFTER DATE OF PUBLICATION IN THE FEDERAL REGISTER], except for amendatory instruction 4.f. for § 15.709(g)(1)(ii), which is delayed. The Commission will publish a document in the Federal Register announcing the effective date.

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SUPPLEMENTARY INFORMATION: This is a summary of the Commission's document, *Report and Order*, FCC 20-156, ET Docket No. 20-36, adopted October 27, 2020 and released

October 28, 2020. The full text of this document is available for public inspection and can be downloaded at: <https://www.fcc.gov/document/fcc-increases-unlicensed-wireless-operations-tv-white-spaces-0> or by using the search function for ET Docket No. 20-36 on the Commission's ECFS web page at www.fcc.gov/ecfs.

SYNOPSIS

1. The Commission adopts targeted changes to the part 15 unlicensed device rules for white space devices in the TV bands to provide improved broadband coverage that will benefit American consumers in rural and underserved areas as well as to provide improved access to narrowband IoT applications that will benefit consumers and businesses while still protecting broadcast television stations from harmful interference. Specifically, the Commission permits higher EIRP ("equivalent isotropically radiated power") and higher antenna HAAT ("height above average terrain") for fixed white space devices in "less congested" geographic areas. In addition, the Commission permits higher power mobile operation within "geo-fenced" areas in "less congested" areas. The Commission also adopts rule changes designed to facilitate the development of new and innovative narrowband IoT services.

2. The Commission declines at this time to allow higher power operation by white space devices operating within the service contour of an adjacent channel TV station or to change the methodology it uses to protect authorized services within the TV bands. The changes the Commission adopts apply only to white space devices operating on TV channels 2-35. The Commission excludes channel 36 from these changes based on the need to protect Wireless Medical Telemetry Service and Radio Astronomy Service operations on channel 37 (608-614 MHz).

Fixed white space devices in rural areas in the TV bands

3. The Commission adopts rule changes for fixed white space devices that operate in the TV bands to enable improved broadband service in rural areas and underserved areas. Specifically, in "less congested" areas the Commission increases the maximum permissible radiated power from 10 to 16 watts EIRP, and increases the maximum permissible antenna HAAT from 250 meters to 500 meters. Because the higher power and increased antenna limits

will expand the maximum transmission range of white space devices, they will be able to provide broadband service over larger areas. Given these revisions, the Commission is commensurately increasing the minimum required separation distances between white space devices operating at higher power/HAAT and protected services in the TV bands.

Higher power limits

4. Current rules permit fixed white space devices to operate on channels 2-36 with a 4 watts EIRP maximum in any area, provided the device meets minimum separation distances from co-channel and adjacent channel users in the band. In addition, a fixed white space device may operate with up to 10 watts EIRP on channels 2-35 in “less congested” areas, defined as those areas where at least half the television channels in the band of operation are not in use, provided the fixed device complies with larger separation distances from other users in the band. Fixed white space devices are limited to one-watt maximum conducted transmitter power, requiring devices with radiated power levels above one-watt EIRP to use an antenna with directional gain, e.g., 6 dBi to produce 4 watts EIRP, and 10 dBi to produce 10 watts EIRP.

5. In the notice of proposed rulemaking (85 FR 18901, April 3, 2020), the Commission proposed to permit fixed devices to operate in the TV bands, up to channel 35, with a maximum 16 watts EIRP (42 dBm) in “less congested” areas. The Commission proposed this change to permit fixed devices to reach users at greater distances in rural and other less congested areas, and thus enable improved broadband coverage at lower cost. The Commission proposed to maintain the one-watt transmitter conducted power limit for fixed devices and require instead that the higher power be achieved by using higher gain, more highly directional antennas to improve spectrum efficiency. The Commission proposed that in cases where an antenna with a gain higher than 12 dBi is used, the transmitter power must be reduced below one watt by the amount in dB that the antenna gain exceeds 12 dBi, in order to ensure that the EIRP from a fixed device does not exceed 16 watts EIRP.

6. The Commission adopts its proposal to permit fixed white space devices to operate in the TV bands on channels 2-35 with a maximum 16 watts EIRP (42 dBm) in “less congested” areas. The record generally supports this action, and as the Commission noted in the

NPRM, this change will permit fixed devices used in “less congested” areas (including rural areas) to reach users at greater distances, thus enabling improved broadband coverage at less cost in these hard-to-reach areas. In addition, higher power will enable signals to better penetrate foliage, buildings, and other obstacles, thus providing improved coverage at locations where there is not a direct line-of-sight to the transmitter. The Commission also adopts its related proposals to maintain the transmitter conducted power limit of one watt, and to require that when an antenna with a directional gain of greater than 12 dB is used, the transmitter power must be reduced by the amount in dB that the antenna gain exceeds 12 dBi, thus ensuring that the maximum EIRP does not exceed 16 watts (42 dBm).

7. The Commission limits higher power operation to “less congested” areas as proposed in the NPRM. This is consistent with the Commission’s actions in other white spaces proceedings in which it initially took a cautious approach when adopting white space rules. This limitation will also minimize the likelihood of any potential harmful interference to authorized services in the TV bands since there are fewer authorized services in “less congested,” typically rural, areas. The Commission therefore declines requests by Broadband Connects America Coalition and Public Interest Spectrum Coalition to allow higher power in all areas, not just “less congested” ones.

8. Restricting higher power operations only to “less congested” areas will also limit the potential impact on users of unlicensed wireless microphones (which share use of unused TV channels but are not entitled to any interference protection from unlicensed white space devices). Higher power operation will be permitted only at locations where multiple vacant channels are available for use by varying types of unlicensed users. The Commission’s decision to limit the areas where higher power operations may occur should alleviate the concerns of wireless microphone operators about the potential impact that higher power white space devices would have on wireless microphone operations.

9. The Commission is not increasing the maximum permissible conducted transmitter power as requested by some parties. NAB opposes this request, arguing that greater conducted power levels will inevitably lead to inadvertent or intentional overpowered operation

and increased potential for interference. The Commission finds that increasing conducted transmitter power limits could encourage the use of lower gain (i.e., less directional) antennas, resulting in less efficient spectrum use and also increasing the potential for causing harmful interference to licensees and protected users. Requiring the use of more highly directional antennas will ensure that less white space device energy is directed outside the main antenna beam than would be the case if higher radiated power were achieved using lower gain, less directional antennas.

Higher antenna height above average terrain limits

10. *HAAT limit.* The rules currently permit fixed white space devices to operate with a maximum 250-meter antenna HAAT. A white space database will not provide a list of available channels to a fixed white space device with an antenna HAAT that exceeds 250 meters, and such devices are not permitted to operate. The Commission adopted this requirement to limit the distance over which the fixed white space devices would transmit and thus limit the distance at which harmful interference to other TV band users could occur. The antenna HAAT limit also precludes white space devices from operating at certain locations, e.g., those where the ground HAAT exceeds 250 meters. In the *White Spaces Order on Reconsideration*, the Commission upheld its previous decision to maintain a 250-meter antenna HAAT limit but stated that it might consider increasing the limit in the future if there were a more complete record addressing whether higher HAAT could be permitted without causing harmful interference.

11. In the NPRM, the Commission proposed to increase the maximum permissible antenna HAAT for fixed white space devices operating on channels 2-35 from 250 meters to 500 meters and sought comment on appropriate procedures that may be necessary to ensure that broadcast operations and other entities in the TV bands are protected from harmful interference. The Commission noted that increasing permissible antenna HAAT would improve broadband coverage in rural areas by enabling signals to reach greater distances and enable fixed white space devices to operate at locations where they are not currently permitted due to the 250-meter HAAT limit, such as existing towers located at higher ground elevations. To protect Wireless Medical

Telemetry Service and radio astronomy operations on channel 37, the Commission did not propose to permit operation with a higher HAAT in the adjacent channel 36.

12. Several commenters—including Adaptrum, Broadband Connects America Coalition, Consumer Technology Association, Dynamic Spectrum Alliance, Microsoft, Public Interest Spectrum Coalition, RADWIN, RED Technologies, RTO Wireless, and the Wireless Internet Service Providers Association (WISPA)—support the proposal to increase the maximum HAAT for fixed devices to 500 meters as a way of promoting expanded coverage. Broadband Connects America Coalition, Microsoft, Public Interest Spectrum Coalition, and Dynamic Spectrum Alliance also recommend allowing higher HAAT in all areas, not just “less congested” ones.

13. As proposed, the Commission increases the HAAT limit for fixed white space devices that operate in the TV bands on channels 2-35 from 250 to 500 meters in “less congested” areas. As with the Commission decision to increase the maximum power allowed for fixed white space devices, this change will permit fixed devices used in “less congested,” including rural, areas to reach users at greater distances, thus enabling improved broadband coverage at less cost in these hard-to-reach areas. This change will also increase the number of locations where fixed white space devices can operate since it will permit white space device operators to use sites where the HAAT of the ground exceeds 250 meters, which would have been precluded under the current rules. Many parties support this change.

14. While the Commission recognizes that some parties request that it not limit this higher HAAT to “less congested” areas, the Commission believes that a more cautious approach is appropriate at this time due to the significant increase in HAAT it is allowing and the potential for harmful interference at greater distances, as noted by Smith and Fisher. Therefore, consistent with the Commission’s actions increasing the maximum power limit for fixed white space devices, the Commission is restricting operation of white space devices with an HAAT of greater than 250 meters to “less congested” areas where fewer authorized services and protected entities are expected to be operating in the TV bands. Relatedly, because there are expected to be fewer authorized services and protected entities operating in “less congested” areas, the Commission

expects that the separation distances between white space devices and authorized services and protected entities to generally be greater. This combination of fewer potential interactions between white space devices and authorized services and protected entities and greater distance separation minimizes the potential for harmful interference to such services. Moreover, these white space devices are still required to operate pursuant to the channel availability and power levels provided by a white space database which is designed to ensure that harmful interference does not occur. While wireless microphone interests express concerns about the impact of increased HAAT on unlicensed wireless microphone operations, restricting higher HAAT operations to “less congested” areas will serve to limit any impact on users of unlicensed wireless microphones since by definition these areas have multiple vacant TV channels (i.e., at least half) available for use by other types of unlicensed operations. The Commission also notes that the rules do not provide harmful interference protection between unlicensed devices. However, because fixed white space device locations are registered in a database, unlicensed wireless microphone users have the ability to check the database and avoid using channels where a higher probability of harmful interference is predicted. In addition to limiting the use of high HAAT to “less congested” areas, as discussed in more detail below, the Commission is increasing the required separation distances between white space devices operating with higher HAAT and co-channel and adjacent channel TV contours to further minimize the likelihood of harmful interference.

15. *Coordination procedure with licensees.* The Commission sought comment on whether to require a coordination procedure between white space device operators and broadcast licensees when fixed white space devices operate with an HAAT exceeding 250 meters. In particular, the Commission requested comment on Microsoft’s suggested coordination procedure comprised of several steps, including notifying a white space database administrator, notifying broadcast licensees, operating on a test basis on a 30-day trial authorization, as well as a process to submit claims of harmful interference, investigate such claims, and upon satisfactorily addressing any such claims, permit authorization on a permanent basis. The Commission expressed concern about the complexity of Microsoft’s suggested coordination procedure and

whether such a procedure is even warranted given the existing obligations of unlicensed devices to protect authorized radio services and other protected users. The Commission also sought comment on a simpler alternative to this procedure. Specifically, the Commission sought comment on whether a party wishing to operate a fixed white space device at an HAAT greater than 250 meters should be required to notify potentially affected, protected entities of their intended operation at least 48 hours in advance. The notification would include the prospective white space device operator's contact information, geographic coordinates of the antenna, antenna height above ground and average terrain, EIRP and channel(s) of operation. For notification purposes, a potentially affected TV station would be defined consistent with Microsoft's proposal, i.e., a station would receive notification if its broadcast contour was within the separation distance corresponding to an assumed HAAT 50 meters higher than the actual deployment.

16. Adaptrum, Microsoft, and WISPA support the more streamlined coordination procedure with broadcasters that the Commission proposed in the NPRM. RADWIN, RED Technologies, and Dynamic Spectrum Alliance assert that no coordination procedure is necessary since unlicensed device operators already have an obligation to not interfere with authorized services, although RED Technologies states that it supports the Commission's proposed coordination procedure if one is required.

17. The Commission adopts the simpler procedures proposed in the NPRM, except it will require that notifications be made four calendar days in advance of operating at an increased HAAT, in response to concerns raised by some parties that 48 hours is not sufficient notice. The Commission requires this coordination procedure because white space devices operating at high HAAT have the potential to interfere with TV reception at large distances. Several parties support this simpler procedure, which will ensure that TV broadcasters are aware of new white space device operations with high HAAT that have the potential to affect broadcast operations at greater distances. This procedure provides an opportunity for TV broadcasters to work with white space system operators to address any concerns regarding potential harmful interference situations.

18. Parties operating white space devices on an unlicensed basis have an ongoing obligation under the rules to cease operation if harmful interference occurs to any authorized service. The complex multi-step procedure, including a 30-day trial period, initially suggested by Microsoft and supported by NAB is therefore unnecessary. For example, requiring a 30-day trial period appears unnecessary since the unlicensed device operating parameters (location, channel, power, and antenna height) during a trial period would be no different than those planned for normal operation of the device. In addition, parties who believe that an unlicensed device is causing harmful interference may report this occurrence to the Commission and unlicensed device operator at any time, so there appears to be no need to require a specific time period for reporting and investigating interference complaints. An unlicensed device that causes harmful interference to an authorized service must cease operation regardless of whether the interference was found during the first 30 days of operation or sometime later.

19. As proposed in the NPRM, the Commission requires that when a party plans to operate a fixed white space device with an HAAT greater than 250 meters, it must contact a white space database and identify all TV broadcast station contours that would be potentially affected by operation at the planned HAAT and EIRP. The Commission will define a potentially affected TV station as one where the protected service contour would be within the applicable separation distance if the white space device were operating at an HAAT of 50 meters above the planned HAAT at the proposed power level. The Commission will also require that the installing party notify each of these broadcast licensees and provide the geographic coordinates of the white space device, relevant technical parameters of the proposed deployment, and contact information. The Commission will permit this process to be automated through the white space database, with notifications sent to a TV station licensee's address of record with the Commission. The white space device may commence operations no earlier than four days after the notification.

20. The Commission believes that increasing the notification period from two to four days balances broadcasters' concerns regarding having sufficient time to review proposed white space device operations when operating at high HAATs and the need for white space device operators to begin providing service. Because these white space devices are restricted to "less

congested” areas, the Commission does not expect broadcasters to be overloaded with notification requests. Also, because device installation must generally be planned in advance, the four-day requirement should not unduly delay new broadband service to rural and underserved areas.

21. The Commission also adopts the other elements of the coordination procedure proposed in the NPRM. Specifically, the Commission will require that, upon request, the installing party must provide each potentially affected licensee with information on the time periods of operations. This will help licensees investigate alleged harmful interference from white space devices. The Commission will also require that if the installing party seeks to modify its fixed operations by (i) increasing its power level, (ii) moving more than 100 meters horizontally from its location, or (iii) making an increase in the HAAT or EIRP of the white space device that results in an increase in the minimum required separation distances from co-channel or adjacent channel TV station contours, then it must conduct a new coordination. This requirement will ensure that TV broadcast licensees have the most current information on white space device operations. The Commission selects 100 meters as the minimum change in location for which a new coordination is required since the tables of separation distances from TV station contours are rounded to the nearest 0.1 kilometer (100 meters). The Commission see no benefits in requiring a new coordination for changes less than 100 meters.

22. The Commission declines to require parties planning to operate white space devices with an HAAT above 250 meters to notify public safety or wireless microphone licensees prior to commencing operation, as requested by NPSTC, Sennheiser, and Shure. Their services are very different from broadcast TV. In the case of broadcast TV, white space devices must protect a consumer receive-only service with very weak signal levels at long distances from the transmitter. By contrast, public safety licensees operate two-way voice and data systems, generally operate with much higher signal levels than those a consumer receives at the edge of a TV contour and could increase power if necessary. Wireless microphones also operate at significantly higher signal levels than those at the edge of a TV contour. In addition, the required separation distances from licensed wireless microphones are much shorter than those for

broadcast TV and are in fact shorter than the distances over which HAAT is calculated (3 to 16 kilometers). Therefore, the Commission believes it is unnecessary to notify wireless microphone licensees of nearby white space devices operating at high HAAT since the HAAT is undefined at the wireless microphone's location.

23. *Antenna height above ground.* The Commission previously increased the maximum permissible antenna height above ground from 30 meters to 100 meters in “less congested” areas in the *White Spaces Order on Reconsideration* (84 FR 34792, July 19, 2019). It took this action to improve wireless broadband service to Americans in rural and other underserved areas, and stated that a 100-meter antenna height above ground limit will benefit wireless broadband providers and users by permitting antennas to be mounted on towers or other structures at heights sufficient to clear intervening obstacles such as trees and hills that would attenuate the transmitted signal, thereby increasing the range at which the signal can be received.

24. In the NPRM, the Commission sought comment on whether to increase the antenna height above ground limit in addition to the HAAT limit, noting that antenna heights above ground and average terrain are directly related, in that any change to a device's antenna height above ground changes its HAAT by the same amount. The Commission further noted that limiting the antenna height above ground may also limit the maximum achievable HAAT in areas where the terrain is flat since in those areas the HAAT will be approximately the same as, or not significantly higher than, the antenna height above ground. This means that the antenna height above ground limit (30 or 100 meters) may preclude white space device operators from taking advantage of a higher HAAT limit, or even the current 250-meter limit. The Commission sought comment on whether it should increase the antenna height above ground limit or remove it completely and rely only on HAAT since the separation distances from protected services are based on HAAT. The Commission also sought comment on whether modified rules should apply across the entire U.S. or only in certain areas, such as “less congested” areas.

25. The Commission eliminates the requirement that a fixed device's antenna height above ground may not exceed 30 meters generally or 100 meters in “less congested” areas. Several parties support eliminating this requirement opining that it is unnecessary. As the

Commission noted in the NPRM, the separation distances from protected services are based on the antenna HAAT, and the HAAT already takes into account the antenna height above ground. Therefore, there does not appear to be a need for a separate antenna height above ground limit, and limiting the height above ground can unnecessarily limit the maximum achievable HAAT. CP Communications and Sennheiser assert that the Commission has previously concluded that there is no general need to mount an antenna higher than the current limit to avoid shadowing by trees or other obstructions and that the current limit should therefore not be changed. The Commission acknowledges that it did decide in the 2015 *White Spaces Order* (80 FR 73044, Nov. 23, 2015) that there was no need for a higher antenna height above ground limit. However, upon further consideration the Commission reversed its decision and decided that there was a need to increase this limit in “less congested” areas in the 2019 *White Spaces Order on Reconsideration*. In that proceeding, the Commission stated “that real world experience has sufficiently demonstrated that increasing the allowable height above ground would be beneficial for operators in less congested areas” and that such a change would not increase the potential to cause harmful interference to other users. In that same *White Spaces Order on Reconsideration*, the Commission noted Sennheiser’s concern about potential interference to wireless microphones from a higher height limit, but concluded that limiting higher antenna height to less congested areas, where there are many vacant channels, ensures there will be sufficient spectrum resources in these areas for multiple spectrum users. Finally, the Commission notes that no party provided specific information or analysis in response to the NPRM showing that there is actually a need to retain an antenna height above ground limit.

26. However, the Commission is not removing the 10-meter height above ground limit that applies to fixed white space devices operating within the protected contours of adjacent channel TV stations since the NPRM did not seek comment on changing that limit and no party indicated a need to do so. That height limit could be addressed at a future date.

Separation distances

27. The Commission increases the minimum required separation distances between white space devices operating at higher power and HAAT and the following services in the TV

bands: (1) broadcast television services, including low power; (2) receive sites of TV translators, low power TV stations, Class A TV stations, Multichannel Video Programming Distributors (MVPDs), and Broadcast Auxiliary Service (BAS) facilities; (3) private land mobile radio services and commercial mobile radio services (PLMRS/CMRS), and (4) licensed low power auxiliary service (LPAS) stations, including licensed wireless microphones. The increases the Commission adopts will protect these services from potentially receiving harmful interference as a result of expanded white space device operating parameters.

28. *Broadcast television services, including low power.* In the NPRM, the Commission proposed to expand the existing tables of minimum separation distances from broadcast television protected contours (both co-channel and adjacent channel) to include additional entries for fixed white space device operation at up to 500 meters HAAT and 42 dBm EIRP. No party argued that the proposed separation distances from co-channel and adjacent channel TV station protected contours are inadequate to prevent interference to TV reception. However, several parties request that the Commission significantly change the methodology used to protect services in the TV bands. Dynamic Spectrum Alliance, WISPA, and Public Interest Spectrum Coalition argue that the Commission should determine white space channel availability using a terrain-based model, such as the Longley-Rice Irregular Terrain Model, which they assert will determine channel availability more accurately than the overly conservative current contour-based model. NAB and Sennheiser, however, oppose using the Longley-Rice model due to concerns about its accuracy in protecting TV receivers and because it may slow operation of the white space database.

29. The Commission adopts the updated tables of separation distances from TV contours proposed in the NPRM. As noted, NAB supported these proposed separation distances in its comments to Microsoft's petition. In addition, the Commission adds a row at the end of each table (co-channel and adjacent channel) to include separation distances for white space devices with HAAT values over 500 meters and up to 550 meters, which will be used only for the purpose of determining which TV broadcast stations must be notified when a white space device operates with an HAAT of more than 450 meters and up to 500 meters.

Fixed White Space Devices

Antenna height above average terrain of unlicensed devices (meters)	Required separation in kilometers from co-channel digital or analog TV (full service or low power) protected contour*							
	16 dBm (40 mW)	20 dBm (100 mW)	24 dBm (250 mW)	28 dBm (625 mW)	32 dBm (1600 mW)	36 dBm (4 W)	40 dBm (10 W)	42 dBm (16 W)
Less than 3	1.3	1.7	2.1	2.7	3.3	4.0	4.5	5.0
3 - 10	2.4	3.1	3.8	4.8	6.1	7.3	8.5	9.4
10 - 30	4.2	5.1	6.0	7.1	8.9	11.1	13.9	15.3
30 - 50	5.4	6.5	7.7	9.2	11.5	14.3	19.1	20.9
50 - 75	6.6	7.9	9.4	11.1	13.9	18.0	23.8	26.2
75 - 100	7.7	9.2	10.9	12.8	17.2	21.1	27.2	30.1
100 - 150	9.4	11.1	13.2	16.5	21.4	25.3	32.3	35.5
150 - 200	10.9	12.7	15.8	19.5	24.7	28.5	36.4	39.5
200 - 250	12.1	14.3	18.2	22.0	27.3	31.2	39.5	42.5
250 - 300	13.9	16.4	20.0	23.9	29.4	35.4	42.1	45.9
300 - 350	15.3	17.9	21.7	25.7	31.4	37.6	44.5	48.4
350 - 400	16.6	19.3	23.2	27.3	33.3	39.7	46.9	51.0
400 - 450	17.6	20.4	24.4	28.7	35.1	41.9	49.4	53.8
450 - 500	18.3	21.4	25.5	30.1	36.7	43.7	51.4	55.9
500 - 550	18.9	21.8	26.3	31.0	37.9	45.3	53.3	57.5

Fixed White Space Devices							
Antenna height above average terrain of unlicensed devices (meters)	Required separation in kilometers from adjacent channel digital or analog TV (full service or low power) protected contour*						
	20 dBm (100 mW)	24 dBm (250 mW)	28 dBm (625 mW)	32 dBm (1600 mW)	36 dBm (4 W)	40 dBm (10 W)	42 dBm (16 W)
Less than 3	0.1	0.1	0.1	0.1	0.2	0.2	0.3
3 - 10	0.1	0.2	0.2	0.2	0.3	0.4	0.5
10 - 30	0.2	0.3	0.3	0.4	0.5	0.6	0.7
30 - 50	0.3	0.3	0.4	0.5	0.7	0.8	1.0
50 - 75	0.3	0.4	0.5	0.7	0.8	0.9	1.0
75 - 100	0.4	0.5	0.6	0.8	1.0	1.1	1.3
100 - 150	0.5	0.6	0.8	0.9	1.2	1.3	1.5
150 - 200	0.5	0.7	0.9	1.1	1.4	1.5	1.7
200 - 250	0.6	0.8	1.0	1.2	1.5	1.7	1.9
250 - 300	0.7	0.8	1.0	1.3	1.6	2.1	2.3
300 - 350	0.7	0.9	1.1	1.4	1.8	2.2	2.4
350 - 400	0.8	1.0	1.2	1.5	1.9	2.4	2.7
400 - 450	0.8	1.0	1.3	1.6	2.1	2.6	2.9
450 - 500	0.8	1.1	1.4	1.7	2.1	2.7	2.9
500 - 550	0.9	1.2	1.5	1.8	2.2	2.8	3.0

30. The Commission declines at this time to alter the current method of protecting TV stations (i.e., minimum separation distances outside of defined protected contours) by changing to a terrain-based model as requested by some parties. The Commission did not propose to make this change in the NPRM. However, it recognizes parties' arguments that more sophisticated propagation models could possibly identify unused TV spectrum more accurately than the current contour-based model while still protecting TV service from harmful interference.

31. *Receive sites of TV translators, low power TV stations, Class A TV stations, MVPDs, and BAS facilities.* In the NPRM, the Commission proposed to modify the keyhole-shaped exclusion zone around receive sites where white space devices may not operate. For fixed devices operating with an EIRP of greater than 10 watts, the Commission proposed to increase the minimum required separation distance from the receive site from 10.2 kilometers to 16.6 kilometers co-channel, and from 2.5 kilometers to 3.5 kilometers adjacent channel, over an arc of more than ± 30 degrees outside the main lobe of the receive antenna. The Commission proposed

no changes to the minimum required separation distances from a receive site (80 kilometers co-channel and 20 kilometers adjacent channel) within a ± 30 degrees arc in the main lobe of the receive antenna. No party argued that the proposed changes are insufficient to protect these receive sites from higher power white space device operation. As such, the Commission adopts its proposal.

32. *Private land mobile radio services and commercial mobile radio services (PLMRS/CMRS)*. The Commission proposed to increase the minimum required separation distances between fixed white space devices operating at greater than 10 watts EIRP and PLMRS/CMRS operations, which include public safety operations, on TV channels 14-20 (the T-Band) in 11 major markets and in some additional areas under rule waivers. In the 11 markets where PLMRS/CMRS stations are permitted to operate in the TV bands, the Commission proposed to increase the minimum required separation distance beyond the defined city center coordinates from 136 kilometers to 139.2 kilometers co-channel, and from 131.5 kilometers to 132.2 kilometers adjacent channel. The Commission also proposed to increase the minimum separation distance from PLMRS/CMRS base stations operating under a waiver outside the 11 markets from 56 kilometers to 59.2 kilometers co-channel and from 51.3 kilometers to 52.2 kilometers adjacent channel. NPSTC argues that these proposed separation distances need to be increased to reflect both the higher power and the higher HAAT proposed and provided a table of recommended separation distances.

33. The Commission will increase the proposed separation distances between PLMRS/CMRS operations and fixed white space devices operating with an HAAT of greater than 250 meters to properly reflect the increase in HAAT of up to 500 meters the Commission is permitting in “less congested” areas. No party objected to NPSTC’s suggested separation distances, and the Commission believes that they will adequately protect PLMRS/CMRS operations from white space device operations at the higher power and HAAT levels the Commission is permitting. However, the Commission also recognizes Microsoft’s suggestion that if the separation distances to protect PLMRS/CMRS are increased, they should be provided on a stepped basis, rather than based on the assumption that all white space devices operate at a

maximum HAAT of 500 meters, to avoid needlessly making areas off limits to white space devices. The Commission agrees that this approach will maximize the amount of spectrum available for white space devices while protecting the PLMRS/CMRS from white space devices operating at higher power and antenna heights. The Commission will therefore specify protection distances for the PLMRS/CMRS for three power level ranges (i.e., up to 4 watts EIRP, greater than 4 and up to 10 watts EIRP, and greater than 10 watts and up to 16 watts EIRP), and for two ranges of HAAT (i.e., up to 250 meters, and greater than 250 meters and up to 500 meters). The Commission adopts the proposed separation distances for the lower HAAT range, and NPSTC’s suggested separation distances for the higher HAAT range.

34. In the *T-Band NPRM* (85 FR 46047, July 31, 2020), the Commission sought comment on reallocating T-Band spectrum, assigning new licenses by auction for that spectrum in each of the 11 markets areas where the PLMRS/CMRS currently operates, and relocating “public safety eligibles” from this band. The Commission proposed rules that would allow for flexible use in the auctioned T-Band, including wireless use, and also proposed to permit broadcast operations. If the Commission adopts rules to allow new types of licensed services in the T-Band, white space devices would operate on a non-interference basis to them as they do with the current PLMRS/CMRS services in the bands. To the extent that any future services in the T-Band have a different potential for receiving interference than the PLMRS/CMRS, the Commission may need to adjust the minimum separation distances that white space devices must meet.

35. The following two tables show the minimum required separation distances from the 11 metropolitan areas where the PLMRS/CMRS can operate in the TV bands, and from PLMRS/CMRS operations authorized under waivers of the rules.

White space device transmitter power	Required separation in kilometers from the areas specified in §90.303(a) of this chapter			
	Co-channel operation		Adjacent channel operation	
	Up to 250 meters HAAT	Greater than 250 meters HAAT	Up to 250 meters HAAT	Greater than 250 meters HAAT

Up to 4 watts EIRP	134.0	158.0	131.0	155.4
Greater than 4 watts and up to 10 watts EIRP	136.0	169.8	131.5	166.0
Greater than 10 watts and up to 16 watts EIRP	139.2	171.1	132.2	166.2

White space device transmitter power	Required separation in kilometers from operations authorized by waiver outside of the areas specified in §90.303(a) of this chapter			
	Co-channel operation		Adjacent channel operation	
	Up to 250 meters HAAT	Greater than 250 meters HAAT	Up to 250 meters HAAT	Greater than 250 meters HAAT
Up to 4 watts EIRP	54.0	78.0	51.0	75.4
Greater than 4 watts and up to 10 watts EIRP	56.0	89.8	51.5	86.0
Greater than 10 watts and up to 16 watts EIRP	59.2	91.1	52.2	86.2

36. *LPAS stations, including licensed wireless microphones.* The Commission proposed an increase from one kilometer to 1.3 kilometers in the minimum required separation distance between fixed white space devices operating with greater than 10 watts EIRP and registered licensed wireless microphones. Sennheiser and Shure argue that the proposed separation distances to protect licensed wireless microphones should be increased, and they provided a table of recommended distances. Microsoft, however, argues that there is no need to increase the separation distances in the manner Sennheiser and Shure proposes.

37. The Commission increases the minimum required separation distance between fixed white space devices operating with a power level greater than 10 watts EIRP and licensed wireless microphones as proposed in the NPRM. This will provide the same level of protection to wireless microphones as the current rules based on a conservative free space propagation model.

38. The Commission declines to require even greater separation distances from wireless microphones as suggested by Sennheiser and Shure. The Commission first notes that no party challenged its 2015 decision to increase the maximum power for fixed white space devices to 10 watts in “less congested” areas without also increasing the one-kilometer separation

distance from wireless microphones. The Commission also notes that it did not propose to increase the existing one-kilometer separation distance in the NPRM, and it believes that it would be inappropriate in these circumstances to take such an action based on this record. As a separate and independent basis for its decision, the Commission does not believe that Sennheiser's suggested increased separation distances for higher HAAT operations are appropriate. HAAT is defined and calculated along radials at a distance of three to 16 kilometers from a transmitter site, i.e., HAAT is not defined for distances less than three kilometers. The majority of Sennheiser's suggested separation distances are at distances of less than three kilometers, which is shorter than the distance (3-16 kilometers) over which HAAT is defined. Moreover, because higher HAAT operations are expected to be coupled with higher power operations to reach greater distances, the rules require use of a directional antenna which will both direct energy towards the horizon (rather than downward) and minimize the energy outside the main beam. This, in effect, will minimize white space signal strength at nearby wireless microphones. Thus, the Commission does not believe there would be any benefit to wireless microphones by increasing the separation distance requirements. In fact, the directional antenna requirement may actually provide a better operating environment for wireless microphones in such situations.

Definition of "less congested" area

39. In the NPRM, the Commission sought comment on whether any changes are necessary to the definition of "less congested" area given that many of the proposals were limited to those areas. "Less congested" locations are typically rural or semi-rural areas and are defined as those where at least half of the TV channels within a device's particular TV sub-band of operation (i.e., the low VHF (channels 2-6), the high VHF (channels 7-13), or the UHF (channels 14-36) band) are unused for broadcast and other protected services and are available for white space device use. The Commission sought comment on whether the current definition is still appropriate, and if not, what the appropriate metric for defining "less congested" area would be. In addition, because the number of vacant channels at a location can vary based on the EIRP and HAAT of a white space device, the Commission sought comment on whether it should define vacant channels depending on particular antenna height and power level.

40. The Commission will continue to define “less congested” areas as those where at least half of the TV channels in the bands that will continue to be allocated and assigned only for broadcast service are unused for broadcast and other protected services and available for white space device use. Areas where the spectrum is less congested generally correspond to rural and unserved areas that will benefit from improved broadband coverage, and the current definition provides a simple way for the white space database to identify these areas where the Commission permits higher power and antenna heights to improve broadband coverage. In addition, in areas where the spectrum is less congested, there is less likelihood that white space devices operating at higher power and antenna heights will cause interference to protected services in the TV band. The Commission agrees with wireless microphone operators that the current definition should be retained because spectrum is a scarce resource and it is therefore appropriate to base the definition on how much spectrum is available at a given location rather than population density.

41. Shure states that to the extent there are concerns about accounting for the number of vacant channels with variations in white space device EIRP and HAAT, the Commission can address this by defining vacant channels at a particular antenna height and power level. While no party suggested a specific white space device EIRP and HAAT that should be used in determining TV channel availability, the Commission notes that it stated in the 2015 *White Spaces Order* that vacant channels would be defined as those available for fixed white space devices operating with an EIRP of 40 milliwatts and an HAAT of 3 meters, although it did not codify this decision. Since no party suggested specific criteria for determining channel availability in response to the NPRM, the Commission retains and codifies its 2015 decision by specifying the power and antenna heights used to determine TV channel availability in the definition of “less congested” area in § 15.703.

42. In addition, the Commission clarifies the definition of “less congested” area by codifying its decision in the 2015 *White Spaces Order* that “less congested” areas are calculated by the white space database in the three TV bands separately: the low VHF band (channels 2-6), the high VHF band (channels 7-13) and the UHF band (channels 14-36). The Commission declines to significantly modify the definition of “less congested” areas as suggested by some

parties. For the reasons described above, the Commission finds that the current definition, with certain modifications, is the appropriate metric for determining which areas are “less congested”. The Commission also declines Dynamic Spectrum Alliance’s request to modify the definition of “less congested” area to consider all TV bands together (low VHF, high VHF and UHF) in determining vacant channel availability and whether an area qualifies as less congested. The higher frequency UHF TV band (470-608 MHz) is more heavily used by TV stations, white space devices, and wireless microphones than the lower frequency VHF TV bands (54-72 MHz, 76-88 MHz and 174-216 MHz) due to factors such as the shorter radio wavelengths and smaller required antennas. Moreover, because the TV bands are not contiguous, determining “less congested” areas based on considering all TV bands together may not produce a result that is representative of the actual spectrum congestion in the specific band where a white space device will operate. Thus, the Commission believes it is appropriate to continue determining “less congested” areas on a band-by-band approach, rather than by considering all TV bands together.

Higher power mobile operation within “geo-fenced” areas

43. The white space rules permit two general classes of devices: fixed and personal/portable, with personal/portable devices further subdivided into two types: Mode I and Mode II. Fixed and Mode II personal/portable devices must incorporate a geo-location capability to determine their coordinates and access a database to determine the available channels at those specific coordinates. The current rules permit fixed white space devices to operate with up to 4 watts EIRP generally, and up to 10 watts in “less congested” areas, which the Commission is increasing to 16 watts as discussed above. Personal/portable devices may operate with a maximum EIRP of 100 milliwatts. A Mode II personal/portable device must re-check its coordinates every 60 seconds and contact the database for an updated list of available channels if it changes location by more than 100 meters. Additionally, Mode II personal/portable devices may load channel availability information for multiple locations from the white space database and use that information to define a geographic area within which it can operate on a mobile basis (on the same available channels at all locations within that geographic area); the device must contact the database again, however, if it moves beyond the boundary of the area where the

channel availability information is valid. No device manufacturers or database systems have yet implemented this provision.

44. In the NPRM, the Commission proposed to allow white space devices to operate on TV channels 2-35 on mobile platforms within geo-fenced areas at higher power levels than the rules currently permit for personal/portable devices, and proposed to limit such operations to “less congested” areas to limit their potential for causing harmful interference. The Commission proposed to permit a higher power Mode II white space device installed on a movable platform to load channel availability information for multiple locations in the vicinity of its current location and to use that information to define a geo-fenced area within which it can operate on the same available channels at all locations. The Commission also proposed to require that the white space device’s location be checked at least once every 60 seconds while in operation (unless in “sleep” mode). The Commission further proposed that a device may not use channel availability information for multiple locations if or when it moves closer than 1.6 kilometers to the boundary of the geo-fenced area in which the device operates, or at any point outside that boundary; this requirement would ensure that a device moving at 60 miles per hour (1.6 kilometers per minute) does not cross outside the boundary between device re-checks of its location. Additionally, the Commission proposed to prohibit operation on board aircraft or satellites to limit the range at which harmful interference could occur.

45. The Commission sought comment on a number of equipment issues for higher power geo-fenced mobile operations, including whether to permit fixed devices to operate on mobile platforms, the antenna and equipment authorization requirements that should apply, and whether the Commission should establish a new class of higher power mobile device to distinguish such devices from personal/portable white space devices. The Commission also sought comment on other requirements for higher power mobile white space devices, including whether to place limitations on the size of the area over which a geo-fenced mobile device could operate, the appropriate maximum power, whether there is a need to specify how information on an area will be provided to the white space database, and any other safeguards needed to ensure that higher power mobile devices do not cause harmful interference to protected operations. The

Commission further sought comment on whether there is a need to prohibit operation on other mobile platforms such as trains and boats.

46. The Commission permits the operation of higher power mobile devices within defined geo-fenced areas in “less congested” areas, as proposed in the NPRM. A number of parties support this change, stating that it will benefit Americans in rural and underserved areas by permitting new agricultural applications and enabling broadband communications with moving vehicles such as school buses. The Commission implements this change by establishing a new class of higher power mobile white space device, rather than by modifying the Mode II personal/portable device rules as proposed in the NPRM and supported by Shure and Sennheiser, or by allowing fixed devices to operate on mobile platforms as suggested by Microsoft in its petition and supported by RED Technologies. The Commission agrees with commenters that establishing a new class of mobile white space device would be simpler than modifying the Mode II personal/portable device rules to permit higher power operation, and that this approach is more congruous than an approach providing for a fixed device on mobile platform as initially suggested by Microsoft. The Commission uses the term “mobile device” to refer to this class of white space devices to distinguish them from personal/portable white space devices. As suggested by Shure, the Commission is clearly indicating in the rules that mobile devices may operate only in “less congested” areas by adding this requirement to the definition of “mobile white space device”.

47. The Commission permits mobile devices to operate at the same radiated power level permitted for fixed devices in “less congested” areas, i.e., up to 16 watts EIRP. This power level will enable the provision of new types of mobile broadband services in rural and other unserved areas. Because the Commission is permitting power levels that are the same as fixed devices, it believes that many of the technical requirements that apply to fixed devices are also appropriate for the new class of mobile white space devices. Accordingly, the Commission requires mobile devices to comply with the same transmitter power limits as fixed devices, including maximum in-band power, adjacent channel emissions, power spectral density, and out-of-band emissions, as well as require them to meet the same antenna gain requirements as fixed devices. Under these requirements, a mobile device will be permitted to operate with a maximum

transmitter power output of one watt, and can use an antenna with a gain of up to 12 dBi to achieve an EIRP of 16 watts. If the maximum gain of the antenna exceeds 12 dBi, then the transmitter power must be reduced by the same amount in dB that the antenna gain exceeds 12 dBi. Because mobile devices change direction as they travel, the Commission permits the use of electrically steerable directional antennas to help enable mobile devices to remain in contact with their associated base unit or another mobile device.

48. The white space database will determine channel availability over a defined geo-fenced area where a mobile device will operate. In order to provide flexibility for manufacturers and mobile device operators, the Commission does not specify how the boundaries of an area are entered into and stored within the white space database or a mobile device. The Commission does, however, require that both the white space database and mobile device contain the same boundary information. This requirement will ensure that mobile devices operate only where the database has determined available channels. Because mobile devices will operate at the same maximum power level as fixed devices, the Commission requires that the database use the same minimum required separation distances from protected services in the TV bands as fixed devices in determining available channels. This includes all protected services, including the PLMRS/CMRS, as noted by NPSTC. For simplicity of operation, the Commission requires that any channel identified by the database as available within the geo-fenced area must be available at the same power level over an entire geo-fenced area.

49. The Commission recognizes that there are some complexities in determining the available channels over a contiguous geo-fenced area. The current white space database system determines channel availability at discrete locations since it was designed to implement rules that require devices to determine their geographic coordinates at a single location and submit those coordinates to the database when requesting a list of available channels. The database system would have to use a modified methodology for determining available channels over a geo-fenced area. For example, it could divide the area into cells, e.g., 100 by 100-meters, and determine channel availability within each cell. The Commission will not prescribe the exact method that database administrators must use to determine channel availability within geo-fenced areas, but

mobile white space devices must comply with the minimum required separation distances from protected services at any point within a geo-fenced area. The white space database will have to consider a mobile device's HAAT in determining available channels and consider any variation in HAAT over a geo-fenced area to determine whether a channel is available over the entire area. To simplify calculations, the Commission permits the database to use only the highest, i.e., worst case, HAAT within a geo-fenced area in determining channel availability rather than having to calculate the HAAT at each location. The Commission sees no reason to limit the size of the geo-fenced area since mobile devices will only be permitted to operate in areas where the spectrum is "less congested." The requirement that a channel must be available over an entire geo-fenced area will tend to preclude extremely large areas since there is less likelihood that the same TV channel will be vacant over a very large contiguous area.

50. Because a mobile device must be able to accurately determine its location, the Commission requires that a mobile device comply with similar geo-location requirements to fixed devices. Specifically, the Commission requires that a mobile device incorporate a geo-location capability that is capable of determining its location and geo-location uncertainty (expressed in meters), with a confidence level of 95%. To provide flexibility in the design of mobile devices, the Commission permits the use of a remote geo-location unit as the rules permit for fixed devices, provided the remote unit is located on the same moveable platform as the mobile device, e.g., bus or tractor. To ensure that a mobile device is capable of determining whether it is within a geo-fenced area, the Commission requires that a mobile device have the ability to store information on the boundaries of a geo-fenced area in which it will operate.

51. While the Commission proposed in the NPRM to require a mobile white space device operating within a geo-fenced area to re-check its geographic coordinates at least once every 60 seconds and to cease operation if it travels closer than 1.6 kilometers to the edge of the geo-fenced area or is outside the boundary of the area, the Commission agrees with Shure that this proposed distance should be slightly increased to account for vehicles traveling at allowable highway speed limits. The proposed buffer requirement was intended to ensure that a mobile white space device traveling at 60 miles per hour (1.6 kilometers per minute) does not cross

outside the geo-fenced area between location checks. However, the Commission recognizes Shure's argument that many vehicles travel faster than this speed. The Commission disagrees with Shure's contention that a 2.7-kilometer buffer is necessary because that corresponds to an atypical vehicle speed of more than 100 miles per hour, but note that Shure believes an increase in the buffer zone size to 1.9 kilometers (corresponding to a vehicle speed of just over 70 miles per hour) would be an improvement over the Commission's proposal of 1.6 kilometers. Accordingly, the Commission adopts the proposed location re-check interval of 60 seconds, but increases the size of the geo-fenced area buffer from the proposed 1.6 kilometers to 1.9 kilometers.

52. The Commission limits operation of mobile devices to "less congested" areas as proposed in the NPRM. The Commission believes that the primary applications for mobile devices will be in more rural areas, and limiting the new class of higher power mobile device to areas with more available spectrum will limit the likelihood of interference to authorized services in the TV bands as well as enable all unlicensed devices, including other white space devices and unlicensed wireless microphones, to have an opportunity to access spectrum in the TV bands. To limit the distance at which mobile devices could cause interference to authorized services, the Commission prohibits their operation on satellites and aircraft as proposed in the NPRM. This prohibition of operation on aircraft will include unmanned aerial vehicles (e.g., drones).

53. The Commission sees no reason to specially limit the maximum height above ground level for mobile devices or to preclude operation on cranes or bucket trucks as suggested by NAB and others. The Commission requires a mobile device to report its height above ground to the white space database as is required for fixed devices, and the database will take the antenna height above ground into consideration when calculating a mobile device's HAAT and the available channels within a geo-fenced area. Thus, a higher antenna height above ground will not increase the likelihood of interference to authorized services as parties suggest. The Commission also sees no reason to make any special requirements regarding the directivity of mobile device antennas, i.e., larger buffer zones, as suggested by Shure. The required size of the

buffer zone is a function of a mobile device's speed and re-check interval and is independent of the power level used.

Narrowband IoT operations

54. Under current rules, fixed white space devices operating with 4 watts or greater EIRP must comply with a power spectral density (PSD) limit of 12.6 dBm per 100 kilohertz, which limits total conducted power within any 6-megahertz television channel to 30 dBm. The PSD limit is proportionally lower for devices operating at lower EIRP levels. The Commission established PSD limits to prevent multiple white space devices from simultaneously operating at the maximum allowable power with transmit bandwidths of less than six megahertz within a single television channel, which would result in a total transmitted power within that channel significantly greater than the limit. The PSD limits were calculated based upon a single white space device spreading its energy uniformly across a 6-megahertz television channel bandwidth, excluding 250 kilohertz near each channel edge for roll-off, and serve to limit the maximum power of white space devices with bandwidths of less than 6-megahertz.

55. In the NPRM, the Commission proposed changes to the white space rules to facilitate narrowband (e.g., 100 kilohertz) IoT device deployment on TV channels 2-35. The proposed rules would permit white space devices to operate with narrowband carriers rather than having to spread all of their energy across a six megahertz channel, and are designed to ensure that narrowband white space devices have no greater interference potential than wider bandwidth devices operating under the current rules. Specifically, the Commission proposed to define a "narrowband white space device" as a type of fixed or personal/portable white space device operating in a bandwidth of no greater than 100 kilohertz. The Commission also proposed that narrowband white space devices be client devices that communicate with a fixed or Mode II master device that contacts the white space database to obtain a list of available channels and operating powers at its location. In this connection, the Commission also sought comment on whether the proposed definition for narrowband white space device is appropriate for the intended IoT applications.

56. The Commission proposed to permit narrowband white space devices to operate with the same conducted PSD limit, adjacent channel emission limits, and antenna gain requirements as 4-watt fixed devices. To ensure that the total energy in a single TV channel does not cause harmful interference, the Commission proposed to limit each transmitter to transmissions totaling no more than 10 seconds per hour. The Commission further proposed to require narrowband devices to use a channel plan that limits total transmitted power in a six-megahertz channel to no higher than the existing limits for a four-watt EIRP broadband white space device. Although the Commission declined to propose requiring narrowband devices to use a listen-before-talk mechanism, it nonetheless sought comment on whether one would be necessary to prevent harmful interference to protected services in the TV bands. The Commission also sought comment on whether there is a need to increase the minimum separation distances from co-channel and adjacent channel TV station contours as the rules require for personal/portable devices operating as clients.

57. The Commission modifies the rules to facilitate the development of new and innovative narrowband IoT devices in the TV bands. Specifically, the Commission establishes a new class of “narrowband white space device,” which it defines as a type of fixed or personal/portable white space device operating in a bandwidth of no greater than 100 kilohertz. A number of parties support the proposals to modify the white space rules to permit narrowband IoT operations. In response to specific comment sought on the definition of a narrowband white space device, the Commission expands that definition to include master devices as well as clients. This change is suggested by Dynamic Spectrum Alliance and Microsoft to enable greater flexibility in the design of IoT networks. No party opposed this change. A narrowband device that operates as a client must communicate with a master device that contacts the white space database to obtain a list of available channels and operating powers at its location, while a narrowband device that acts as a master must incorporate a geo-location mechanism and be capable of obtaining lists of available channels and operating powers from the white space database. The Commission permits all types of white space devices that incorporate geo-location and have database access (fixed, Mode II, mobile, and narrowband) to act as a master device to a

narrowband client device. TV band frequencies are better able to penetrate foliage and other obstacles than higher frequencies, so this action will permit the development of IoT devices with improved transmission range.

58. As proposed in the NPRM, the Commission permits narrowband white space devices to operate with a conducted PSD of up to 12.6 dBm/100 kilohertz, which is the same maximum level permitted for fixed devices, and require narrowband devices to comply with the same maximum antenna gain requirements as fixed devices, i.e., a maximum antenna gain of 6 dBi with no reduction in transmitter conducted power, or higher antenna gain if the conducted power is proportionally reduced. The Commission also requires narrowband white space devices to comply with an emission limit of -42.8 dBm into adjacent channels, i.e., outside of the 6-megahertz channel in which they operate. These requirements will permit a white space device to operate with a single or several narrowband carriers rather than having to spread all of its energy across a six megahertz channel while ensuring that narrowband white space devices have no greater interference potential than wider bandwidth devices operating under the current rules. To prevent narrowband devices from being used for data intensive applications and to limit the potential for these devices to cause harmful interference, the Commission limits transmissions on each narrowband channel to a total of 36 seconds per hour, as suggested by Dynamic Spectrum Alliance and Microsoft, i.e., a 1% duty cycle.

59. The Commission will not, however, increase this transmission time limit for narrowband devices to allow for signaling overhead as suggested by Microsoft. Microsoft has not indicated how much additional transmission time would be necessary for this overhead. Further, to the extent that a narrowband device needs additional transmission time for functions such as contacting a white space database to obtain a list of available channels, there appear to be ways to perform these functions while still complying with the 36 second per hour per narrowband channel limit. For example, under the rules the Commission is adopting there will be up to 55 narrowband channels within one six-megahertz TV channel, and a device could use one or more of these narrowband channels for signaling purposes. In addition, any overhead

associated with contacting the database could be accomplished by other means, such as a non-narrowband white space channel, Wi-Fi, a fixed link, or a fiber connection.

60. The Commission also requires narrowband devices to use the proposed channel plan that limits total transmitted power in a six-megahertz channel to no higher than the existing limits for a four-watt EIRP broadband white space device. This channel plan requires narrowband white space devices to operate at least 250 kilohertz from the edge of a six-megahertz TV channel, unless the adjacent channel is also vacant, and requires narrowband white space devices to operate only on channels centered at integral multiples of 100 kilohertz between the 250 kilohertz guard bands. The net effect of these requirements is that narrowband devices will be permitted to operate within 55 possible 100-kilohertz channels in the center 5.5 megahertz of each six-megahertz channel. Even in the event that all 55 narrowband channels within a six-megahertz channel were occupied simultaneously by devices transmitting at maximum power, the total conducted and radiated power within that six-megahertz channel would be no greater than for a fixed device operating with one-watt conducted power and 4 watts EIRP. Because of the transmission time limit of thirty-six seconds per hour (a one-percent duty cycle), the interference potential of these narrowband white space devices will actually be significantly less than four-watt EIRP fixed devices in most cases since it is extremely unlikely that devices would transmit at maximum power on all 55 narrowband channels simultaneously, and even if they did, that would occur for no more than 36 seconds per hour.

61. The Commission is not limiting operation of narrowband devices to “less congested” areas as suggested by wireless microphone interests. Since narrowband devices will operate under control of a master device that accesses a white space database to determine available channels at its location, narrowband devices will not be permitted to operate on the channels at locations where registered licensed wireless microphones operate. Additionally, unlicensed wireless microphones and white space devices must already share spectrum with fixed white space devices operating at up to 4 watts EIRP in areas that do not meet the definition of “less congested.” Even under worst-case conditions, narrowband devices will have no greater interference potential than four-watt fixed devices and will have a significantly lower interference

potential in the vast majority of cases. For these reasons, the Commission does not agree with RADWIN that a proliferation of narrowband devices will prevent spectrum use for Internet access.

62. The Commission declines to allow a greater transmission duty cycle for narrowband devices used only by public safety entities as requested by NPSTC. While NPSTC does not indicate how much it wants the limit increased, the higher transmit duty cycle the Commission is permitting will benefit all narrowband device applications, including those used by public safety entities. Allowing different technical requirements for public safety entities would complicate equipment certification and would be difficult to enforce since there could be multiple versions of the same device, some of which could be legally used only by specific types of entities. It is not clear how the Commission could ensure that devices approved for use only by public safety entities would be marketed to, and operated by, only those entities.

Higher power on adjacent channels

63. White space devices must generally operate outside the protected contours of adjacent channel TV stations because a strong signal on an adjacent channel can cause interference to the reception of a channel being viewed. The general requirement that white space devices avoid operation within the protected contours of a station operating on an adjacent channel means that, as a practical matter, a white space device may operate only at locations where there are three contiguous vacant channels, i.e., the channel used by the white space device plus both adjacent channels. The Commission's rules do, however, provide two exceptions that permit white space device operations at lower power levels when adjacent channels are occupied, based upon the shorter distances at which interference to adjacent channel TV stations could occur. First, both fixed and personal/portable white space devices may operate at up to 40 milliwatts EIRP at locations where both adjacent channels are occupied. Second, fixed white space devices may operate within the protected contour of adjacent channel TV stations with a power level of 100 milliwatts EIRP when the white space device operates in a six-megahertz band centered on the boundary of two contiguous vacant channels, i.e., 50 milliwatts EIRP within a three-megahertz band in each channel.

64. In the NPRM, the Commission sought comment on whether it could permit white space devices to operate at higher power levels than the rules currently permit when adjacent TV channels are occupied. In particular, the Commission sought comment on methods that could be used to determine the locations where it could permit higher power unlicensed operations on adjacent channels, and if so, what specific technical parameters would need to be considered or specified in such calculations. The Commission also sought comment on whether there is any information available on adjacent channel selectivity and interference rejection capabilities of next-generation TV receivers, such as manufacturers' specifications or actual measurement results, and whether there is any indication that next-generation TV receivers will have better adjacent channel interference rejection than current receivers.

65. The Commission does not increase the maximum permissible power for white space devices operating inside the protected contour of adjacent channel TV stations at this time. As an initial matter, the Commission does not at this time have sufficient evidence in the record on which to change the manner of protecting broadcast services to a terrain-based model, as Microsoft and others suggest. Microsoft argues that the Commission should permit white space device operation within the protected contour of adjacent channel TV stations at higher power levels than the rules currently permit. In so doing, Microsoft supplied a test report on the results of laboratory measurements of current model ATSC 1.0 TV receivers and next generation ATSC 3.0 TV receivers that it claims shows higher power adjacent channel operation is possible because these TV receivers have better selectivity than the Commission assumed in developing the current power limits and because the use of terrain-based propagation models (e.g., Longley-Rice) can provide a more accurate determination of where higher power adjacent channel white space device operation can be permitted without causing harmful interference. Microsoft also supplied a test report on field measurements conducted with Ark Multicasting, a lower power TV network operator, that it claims validates its laboratory measurements and demonstrates that for the given parameters (e.g., fixed white space device EIRP and antenna pattern, DTV transmitter characteristics, adjacent channel selectivity of the newer model TV receivers with integral display tested, and distance between the DTV transmitter and the TV receiver) a white space device can

operate within the protected contour on a first adjacent channel at higher powers than currently allowed.

66. But while data supplied by Microsoft shows that some newer model TV receivers have better adjacent channel selectivity than the -33 dB D/U ratio the Commission assumed when it adopted the power limits for white space devices operating inside the protected contour of adjacent channel TV stations, NAB disputes Microsoft's analysis, arguing that the TV receivers it used are not representative of the currently installed consumer base. Microsoft's report shows that the average adjacent channel selectivity of tested ATSC 1.0 receivers is better than the value the Commission assumed, and that ATSC 3.0 receivers have a selectivity 10 dB better than that of ATSC 1.0 receivers at lower order modulations and similar to ATSC 1.0 receivers at higher order modulations. In addition, the report shows that receiver adjacent channel selectivity improves by 5.7 dB on average when a white space device operates at a 3 megahertz offset from a TV channel edge.

67. The improved receiver selectivity shown in Microsoft's testing could allow white space devices to operate within adjacent channel protected contours at higher power levels than the rules currently permit without increasing the potential for interference to TV reception. The Commission recognizes, however, NAB's concern that Microsoft's testing was performed with a limited number of TV receivers which may not be representative of the currently installed base. The Commission encourages Microsoft and other parties to continue studies and white space device and TV receiver testing to determine whether or how the Commission can permit higher power for white space devices without causing harmful interference to TV reception. The Commission welcomes interested parties to file a petition in the future when this work has been done.

Other matters

68. *Directional antennas.* Broadband Connects America Coalition, Public Interest Spectrum Coalition, and WISPA request that the white space database be allowed to consider the directivity of white space device transmit antennas in determining channel availability for white space devices. NAB opposes this request, arguing that there is no way of determining whether a

directional antenna has been installed properly without hiring a licensed land-surveyor, which it believes is unlikely to occur. The Commission previously considered and rejected requests to consider white space device transmit antenna directivity in the *White Spaces Order on Reconsideration* and did not make any proposals on this issue in the NPRM. The Commission declines to take any action on these requests.

69. *Wireless microphone issues.* Wireless microphone interests request that the Commission not take action to change the rules for white space devices until it acts on the outstanding proceeding (GN Docket No. 14-166) that proposed to expand the eligibility for obtaining a part 74 license for wireless microphones and until the Commission addresses difficulties with the white space database in registering licensed wireless microphones.

70. The Commission declines to defer action in this proceeding pending a decision in GN Docket No. 14-166 on expanding part 74 licensing eligibility. The Commission actions in this proceeding will benefit Americans in rural and underserved areas by enabling improved broadband access. The Commission does not wish to delay these public benefits until some unspecified point in the future. Further, the Commission decision here will not adversely impact either licensed or unlicensed wireless microphone operations. For example, the Commission is limiting higher power and antenna height operations, as well as higher power geo-fenced operations, to areas where the spectrum is less congested, which will limit the impact on wireless microphones that operate in the TV bands. Moreover, because white space devices operate on an unlicensed basis, they are obligated by the rules to protect licensed wireless microphone operations; unlicensed wireless microphones operate on a co-equal basis with white space devices. However, if the Commission decides to expand wireless microphone licensing eligibility in GN Docket No. 14-166, any newly licensed wireless microphone operation would receive the same protection from harmful interference, even if white space device operators need to adjust their systems. Thus, the actions the Commission takes in this *Report and Order* do not alter the relationship between wireless microphones and white space devices, including the obligation for unlicensed devices to protect licensed wireless microphones.

71. The Commission appreciates parties bringing concerns about the white space database to its attention, and is working with the database administrators to address them. The Commission notes that a new administrator, RED Technologies, has taken over operation of the Nominet white space database. However, the Commission believes that the concerns parties raised, e.g., improvements to the licensed wireless microphone registration procedure, can be addressed without a need to delay action in this proceeding.

PROCEDURAL MATTERS

72. *Paperwork Reduction Act Analysis.* This document contains new or modified information collection requirements subject to the Paperwork Reduction Act of 1995 (PRA), Public Law 104-13. It will be submitted to the Office of Management and Budget (OMB) for review under section 3507(d) of the PRA. OMB, the general public, and other Federal agencies will be invited to comment on the new or modified information collection requirements contained in this proceeding. In addition, we note that pursuant to the Small Business Paperwork Relief Act of 2002, Public Law 107-198, *see* 44 U.S.C. 3506(c)(4), we previously sought specific comment on how the Commission might further reduce the information collection burden for small business concerns with fewer than 25 employees.

73. *Final Regulatory Flexibility Analysis.* As required by the Regulatory Flexibility Act of 1980 (RFA), as amended, the Commission has prepared a Final Regulatory Flexibility Analysis (FRFA) regarding the possible significant economic impact on small entities of the policies and rules adopted in this *Report and Order*, which the full FRFA is found in Appendix C at <https://www.fcc.gov/document/fcc-increases-unlicensed-wireless-operations-tv-white-spaces-0>. The Commission's Consumer and Governmental Affairs Bureau, Reference Information Center, will send a copy of the *Report and Order*, including the FRFA, to the Chief Counsel for Advocacy of the Small Business Administration.

74. *Congressional Review Act.* The Commission has determined, and the Administrator of the Office of Information and Regulatory Affairs, Office of Management and Budget, concurs that this rule is non-major under the Congressional Review Act, 5 U.S.C. 804(2).

The Commission will send a copy of this *Report and Order* to Congress and the Government Accountability Office pursuant to 5 U.S.C. 801(a)(1)(A).

ORDERING CLAUSES

75. IT IS ORDERED, pursuant to sections 4(i), 201, 302, and 303 of the Communications Act of 1934, as amended, 47 U.S.C. 154(i), 201, 302a, 303, that this *Report and Order* is hereby ADOPTED.

76. IT IS FURTHER ORDERED that the amendments of the Commission's rules as set forth below ARE ADOPTED, effective thirty days from the date of publication in the Federal Register, except for the amendment to § 15.709(g)(1)(ii), which contains new or modified information collection requirements that require approval by the OMB under the PRA and WILL BECOME EFFECTIVE after the Commission publishes a document in the *Federal Register* announcing such approval and the relevant effective date.

77. IT IS FURTHER ORDERED that the Commission's Consumer and Governmental Affairs Bureau, Reference Information Center, SHALL SEND a copy of this *Report and Order*, including the Final Regulatory Flexibility Analyses, to the Chief Counsel for Advocacy of the Small Business Administration.

78. IT IS FURTHER ORDERED that the Commission's Consumer and Governmental Affairs Bureau, Reference Information Center, SHALL SEND a copy of this *Report and Order*, including the Final Regulatory Flexibility Analyses, to Congress and the Government Accountability Office pursuant to the Congressional Review Act, *see* 5 U.S.C. 801(a)(1)(A).

List of Subjects in 47 CFR Part 15

Communications equipment, Radio, Reporting and recordkeeping requirement.

FEDERAL COMMUNICATIONS COMMISSION

Marlene Dortch,
Secretary.

Final Rules

For the reasons discussed in the preamble, the Federal Communications Commission amends 47 CFR part 15 as follows:

PART 15 – RADIO FREQUENCY DEVICES

1. The authority citation for part 15 continues to read as follows:

AUTHORITY: 47 U.S.C. 154, 302a, 303, 304, 307, 336, 544a, and 549.

2. Amend § 15.703 by:

- a. Removing the paragraph designations;
- b. Adding a definition for “Geo-fenced area” in alphabetical order;
- c. Revising the definition of “Less congested area”;
- d. Adding definitions for “Mobile white space device” and “Narrowband white space device in alphabetical order.

The additions and revision read as follows:

§ 15.703 Definitions.

* * * * *

Geo-fenced area. A defined geographic area over which the white space database has determined the set of available channels.

* * * * *

Less congested area. Geographic areas where at least half of the TV channels within a specific TV band are unused for broadcast and other protected services and available for white space device use. Less congested areas are determined separately for each TV band -- the low VHF band (channels 2-6), the high VHF band (channels 7-13) and the UHF band (channels 14-36); i.e., one, two or all three bands or any combination could qualify as less congested. White space devices may only operate at the levels permitted for less congested areas within the area and the specific TV band(s) that qualify as a less congested area. For the purpose of this definition, a channel is considered available for white space device use if it is available for fixed devices operating with 40 milliwatts EIRP at 3 meters HAAT. Less congested areas in the UHF TV band are also considered to be less congested areas in the 600 MHz service band.

Mobile white space device. A white space device that transmits and/or receives radiocommunication signals on available channels within a defined geo-fenced area. A mobile white space device uses an incorporated geo-location capability to determine its location with respect to the boundaries of the defined area. A mobile white space device may operate only in less congested areas.

* * * * *

Narrowband white space device. A fixed or personal/portable white space device operating in a bandwidth of no greater than 100 kilohertz.

* * * * *

3. Revise § 15.707 to read as follows:

§ 15.707 Permissible channels of operation.

(a)(1) *470-614 MHz band.* Fixed and personal/portable white space devices are permitted to operate on available channels in the frequency bands 470-614 MHz (TV channels 14-37), subject to the interference protection requirements in §§15.711 and 15.712.

(2) *600 MHz duplex gap.* Fixed and personal/portable white space devices may operate in the 657-663 MHz segment of the 600 MHz duplex gap.

(3) *600 MHz service band.* Fixed and personal/portable white space devices may operate on frequencies in the bands 617-652 MHz and 663-698 MHz in areas where 600 MHz band licensees have not commenced operations, as defined in §27.4 of this chapter.

(4) *Channel 37 guard band.* White space devices are not permitted to operate in the band 614-617 MHz.

(b) Only mobile white space devices and fixed white space devices that communicate only with other fixed or mobile white space devices may operate on available channels in the bands 54-72 MHz (TV channels 2-4), 76-88 MHz (TV channels 5 and 6), and 174-216 MHz (TV channels 7-13), subject to the interference protection requirements in §§ 15.711 and 15.712.

(c) Narrowband and mobile white space devices may only operate on frequencies below 602 MHz.

4. Amend § 15.709 by:

- a. Revising paragraphs (a)(2)(i);
- b. Adding paragraph (a)(5);
- c. Revising paragraph (b)(1);
- d. Adding paragraph (b)(4);
- e. Revising paragraphs (c)(2) and (g)(1)(i); and
- f. Delayed indefinitely, revising paragraph (g)(1)(ii).

The additions and revisions read as follows:

§ 15.709 General technical requirements.

(a) * * *

(2) * * *

(i)(A) Fixed devices in the TV bands below 602 MHz: Up to 4 W (36 dBm) EIRP, and up to 16 W (42 dBm) EIRP in less congested areas. Fixed devices in the 602-608 MHz band may operate with up to 4 W (36 dBm) EIRP.

(B) Fixed devices in the 600 MHz service bands above 620 MHz: Up to 4 W (36 dBm) EIRP, and up to 10 W (40 dBm) EIRP in less congested areas. Fixed devices that operate in any portion of the 614-620 MHz band may operate with up to 4 W (36 dBm) EIRP.

* * * * *

(5) *Mobile devices in the TV bands below 602 MHz.* Up to 16 W (42 dBm) EIRP in less congested areas. Mobile device operation is not permitted above 602 MHz. Mobile devices may operate only in less congested areas.

(b) * * *

(1) *Fixed and mobile white space devices.* (i) Technical limits for fixed and mobile white space devices are shown in the table in paragraph (b)(1)(iii) of this section and subject to the requirements of this section.

(ii) For operation at EIRP levels of 36 dBm (4,000 mW) or less, fixed and mobile white space devices may operate at EIRP levels between the values shown in the table in paragraph (b)(1)(iii) of this section provided that the conducted power and the conducted power spectral density (PSD) limits are linearly interpolated between the values shown and the adjacent channel emission limit

of the higher value shown in the table is met. Operation at EIRP levels above 36 dBm (4000 mW) but not greater than 40 dBm (10,000 mW) shall follow the requirements for 40 dBm (10,000 mW). Operation at EIRP levels above 40 dBm (10,000 mW) shall follow the requirements for 42 dBm (16,000 mW).

(iii) The conducted power spectral density from a fixed or mobile white space device shall not be greater than the values shown in the table in this paragraph (b)(1)(iii) when measured in any 100 kilohertz band during any time interval of continuous transmission.

Table 1 to Paragraph (b)(1)(iii)

EIRP (6 MHz)	Conducted power limit (6 MHz)	Conducted PSD limit¹ (100 kHz)	Conducted adjacent channel emission limit (100 kHz)
16 dBm (40 mW)	10 dBm (10 mW)	-7.4 dBm	-62.8 dBm
20 dBm (100 mW)	14 dBm (25 mW)	-3.4 dBm	-58.8 dBm
24 dBm (250 mW)	18 dBm (63 mW)	0.6 dBm	-54.8 dBm
28 dBm (625 mW)	22 dBm (158 mW)	4.6 dBm	-50.8 dBm
32 dBm (1600 mW)	26 dBm (400 mW)	8.6 dBm	-46.8 dBm
36 dBm (4000 mW)	30 dBm (1000 mW)	12.6 dBm	-42.8 dBm
40 dBm (10000 mW)	30 dBm (1000 mW)	12.6 dBm	-42.8 dBm
42 dBm (16000 mW)	30 dBm (1000 mW)	12.6 dBm	-42.8 dBm

* * * * *

(4) *Narrowband white space devices.* (i) A narrowband white space device that operates as a client must communicate with a master device (fixed, Mode II, mobile or narrowband) that contacts the white space database to obtain a list of available channels and operating powers at its location. A narrowband white space device that acts as a master must incorporate a geo-location mechanism and be capable of obtaining lists of available channels and operating powers from the white space database.

(ii) Narrowband white space devices shall operate on channel sizes that are no more than 100 kilohertz. The edge of a narrowband channel shall be offset from the upper and lower edge of the 6 megahertz channel in which it operates by at least 250 kilohertz, except in the case where bonded 6 megahertz channels share a common band edge. Narrowband operating channels shall be at integral multiples of 100 kilohertz beginning at a 250 kilohertz offset from a 6 megahertz channel's edge, or with no offset at the common band edge of two bonded 6 megahertz channels.

(iii) The conducted power limit is 12.6 dBm in a 100 kilohertz segment. The EIRP limit is 18.6 dBm in a 100 kilohertz segment. The conducted power spectral density limit is 12.6 dBm in any 100 kilohertz band during any time interval of continuous transmission.

(iv) Conducted adjacent channel emissions shall be limited to -42.8 dBm in 100 kilohertz in a first adjacent 6 megahertz channel, starting at the edge of the 6 megahertz channel within which the narrowband device is operating. This limit shall not apply between the edge of the narrowband channel and the edge of the 6 megahertz channel that contains it.

(v) If transmitting antennas of directional gain greater than 6 dBi are used, the maximum conducted power output shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

(vi) Total occupancy for each narrowband channel shall be limited to 36 seconds per hour.

(c) * * *

(2) The conducted power, PSD, and adjacent channel limits for fixed and mobile white space devices operating at greater than 36 dBm (4000 milliwatts) EIRP shown in the table in paragraph (b)(1)(iii) of this section are based on a maximum transmitting antenna gain of 12 dBi. If transmitting antennas of directional gain greater than 12 dBi are used, the maximum conducted output power shall be reduced by the amount in dB that the directional gain of the antenna exceeds 12 dBi.

* * * * *

(g) * * *

(1) * * *

(i) *Above ground level.* The transmit antenna height shall not exceed 10 meters above ground level in any area for fixed white space devices operating in the TV bands at 40 mW EIRP or less or operating across multiple contiguous TV channels at 100 mW EIRP or less.

(ii) *Height above average terrain (HAAT).* For devices operating in the TV bands below 602 MHz, the transmit antenna shall not be located where its height above average terrain exceeds 250 meters generally, or 500 meters in less congested areas. For devices operating in all other bands the transmit antenna shall not be located where its height above average terrain exceeds

250 meters. The HAAT is to be calculated by the white space database using the methodology in § 73.684(d) of this chapter. For HAAT greater than 250 meters the following procedures are required:

(A) The installing party must contact a white space database and identify all TV broadcast station contours that would be potentially affected by operation at the planned HAAT and EIRP. A potentially affected TV station is one where the protected service contour is within the applicable separation distance for the white space device operating at an assumed HAAT of 50 meters above the planned height at the proposed power level.

(B) The installing party must notify each of these licensees and provide the geographic coordinates of the white space device, relevant technical parameters of the proposed deployment, and contact information.

(C) No earlier than four calendar days after the notification in paragraph (g)(1)(ii)(B) of this section, the installing party may commence operations.

(D) Upon request, the installing party must provide each potentially affected licensee with information on the time periods of operations.

(E) If the installing party seeks to modify its operations by increasing its power level, by moving more than 100 meters horizontally from its location, or by making an increase in the HAAT or EIRP of the white space device that results in an increase in the minimum required separation distances from co-channel or adjacent channel TV station contours, it must conduct a new notification.

(F) All notifications required by this section must be in written form (including e-mail). In all cases, the names of persons contacted, and dates of contact should be kept by the white space device operator for its records and supplied to the Commission upon request.

* * * * *

5. Amend § 15.711 by revising paragraphs (j)(3) and (4) and adding paragraph (k) to read as follows:

§ 15.711 Interference avoidance methods.

* * * * *

(j) * * *

(3) A white space database shall be protected from unauthorized data input or alteration of stored data. To provide this protection, the white space database administrator shall establish communications authentication procedures that allow fixed, mobile, and Mode II white space devices to be assured that the data they receive is from an authorized source.

(4) Applications for certification of white space devices shall include a high level operational description of the technologies and measures that are incorporated in the device to comply with the security requirements of this section. In addition, applications for certification of fixed, mobile, and Mode II white space devices shall identify at least one of the white space databases operated by a designated white space database administrator that the device will access for channel availability and affirm that the device will conform to the communications security methods used by that database.

(k) *Requirements for mobile white space devices.* (1) Mobile white space devices shall operate within geo-fenced areas over which the white space database has determined channel availability. A mobile white space device shall have the capability to internally store the boundaries of a geo-fenced area and determine its location with respect to those boundaries. The area boundaries stored within a mobile white space device must be the same as those used by the white space database to determine channel availability.

(2) A mobile white space device shall incorporate a geo-location capability to determine its geographic coordinates. A mobile white space device may obtain its geographic coordinates through an external geo-location source, provided that source is on the same vehicle or other mobile platform as the mobile device. An external geo-location source may be connected to a mobile device through either a wired or a wireless connection, and a single geo-location source may provide location information to multiple mobile devices on the same mobile platform. An external geo-location source must be connected to a mobile device using a secure connection that ensures that only an external geo-location source that has been approved with a particular mobile

device can provide geographic coordinates to that device. The geographic coordinates must be provided automatically by the external geo-location source to the mobile device; users may not manually enter them. Alternatively, an extender cable may be used to connect a remote receive antenna to a geo-location receiver within a mobile device.

(3) The applicant for certification of a mobile device must demonstrate the accuracy of the geo-location method used and the location uncertainty as defined in paragraph (b) of this section. For mobile devices that are not using an internal geo-location capability, this uncertainty must account for the accuracy of the geo-location source and the separation distance between such source and the white space device.

(4) The antenna height above ground shall be determined by the operator of the device, or by an automatic means. The mobile device shall provide this information to the white space database when it requests a list of available channels for the geo-fenced area in which it will operate.

(5) Each mobile device must access a white space database over the Internet to determine the available channels and the maximum permitted power for each available channel within the geo-fenced area in which it will operate. The white space database must take into consideration the mobile device's antenna height above ground level and geo-location uncertainty in determining the list of available channels. It must also take into consideration any variation in mobile device HAAT throughout the geo-fenced area and must use the highest HAAT within the geo-fenced area in determining channel availability. Operation is permitted only on channels that are indicated by the database as being available at the same power level throughout the entire geo-fenced area in which the mobile device will operate.

(6) Mobile devices must comply with the same separation distances from protected services in § 15.712 as fixed devices.

(7) Mobile devices may use electrically steerable directional antennas, but a device's maximum EIRP in any direction must be used by the white space database in determining channel availability.

(8) A mobile device must re-check its coordinates at least once every 60 seconds while in operation except while in sleep mode, i.e., in a mode in which the device is inactive but is not

powered down. It must cease operation if its location is within 1.9 kilometers of the boundary, or outside the boundary, of the geo-fenced area over which the white space database has determined the available channels.

(9) Each mobile white space device shall access the white space database at least once a day to verify that the operating channels within the geo-fenced area continue to remain available. Each mobile white space device must adjust its use of channels in accordance with channel availability schedule information provided by its database for the 48-hour period beginning at the time the device last accessed the database for a list of available channels.

(10) Operation of mobile white space devices on satellites and aircraft, including unmanned aerial vehicles, is prohibited.

6. Amend § 15.712 by:

- a. Revising the introductory text and paragraphs (a)(2) and (3) and (b)(3)(ii) and (iii);
- b. Adding paragraph (b)(3)(iv);
- c. Revising paragraph (c)(2)(ii);
- d. Adding paragraph (c)(2)(iii); and
- e. Revising paragraphs (d), (f), (g), (h)(1), and (i)(1).

The revisions and additions read as follows:

§ 15.712 Interference protection requirements.

The separation distances in this section apply to fixed, mobile, and personal/portable white space devices with a location accuracy of ± 50 meters. These distances must be increased by the amount that the location uncertainty of a white space device exceeds ± 50 meters. Narrowband white space devices shall comply with the separation distances applicable to a fixed white space device operating with 30 dBm conducted power and 36 dBm EIRP across a 6 megahertz channel.

(a) * * *

(2) *Required separation distance.* White space devices must be located outside the contours indicated in paragraph (a)(1) of this section of co-channel and adjacent channel stations by at least the minimum distances specified in the tables in paragraph (a)(2)(v) of this section.

- (i) If a device operates between two defined power levels, it must comply with the separation distances for the higher power level.
- (ii) White space devices operating at 40 mW EIRP or less are not required to meet the adjacent channel separation distances.
- (iii) Fixed white space devices operating at 100 mW EIRP or less per 6 megahertz across multiple contiguous TV channels with at least 3-megahertz separation between the frequency band occupied by the white space device and adjacent TV channels are not required to meet the adjacent channel separation distances.
- (iv) Fixed white space devices may only operate above 4 W EIRP in less congested areas as defined in § 15.703.
- (v) The following are the tables of minimum required separation distances outside the contours of co-channel and adjacent channel stations that white space devices must meet.

Table 2 to Paragraph (a)(2)(v)

Mode II Personal/Portable White Space Devices		
	Required separation in kilometers from co-channel digital or analog TV (full service or low power) protected contour	
	16 dBm (40 mW)	20 dBm (100 mW)
Communicating with Mode II or Fixed device	1.3	1.7
Communicating with Mode I device	2.6	3.4

Table 3 to Paragraph (a)(2)(v)

Fixed White Space Devices								
Antenna height above average terrain of unlicensed devices (meters)	Required separation in kilometers from co-channel digital or analog TV (full service or low power) protected contour¹							
	16 dBm (40 mW)	20 dBm (100 mW)	24 dBm (250 mW)	28 dBm (625 mW)	32 dBm (1600 mW)	36 dBm (4 W)	40 dBm (10 W)	42 dBm (16 W)
Less than 3	1.3	1.7	2.1	2.7	3.3	4.0	4.5	5.0
3 - 10	2.4	3.1	3.8	4.8	6.1	7.3	8.5	9.4
10 - 30	4.2	5.1	6.0	7.1	8.9	11.1	13.9	15.3
30 - 50	5.4	6.5	7.7	9.2	11.5	14.3	19.1	20.9

50 - 75	6.6	7.9	9.4	11.1	13.9	18.0	23.8	26.2
75 - 100	7.7	9.2	10.9	12.8	17.2	21.1	27.2	30.1
100 - 150	9.4	11.1	13.2	16.5	21.4	25.3	32.3	35.5
150 - 200	10.9	12.7	15.8	19.5	24.7	28.5	36.4	39.5
200 - 250	12.1	14.3	18.2	22.0	27.3	31.2	39.5	42.5
250 - 300	13.9	16.4	20.0	23.9	29.4	35.4	42.1	45.9
300 - 350	15.3	17.9	21.7	25.7	31.4	37.6	44.5	48.4
350 - 400	16.6	19.3	23.2	27.3	33.3	39.7	46.9	51.0
400 - 450	17.6	20.4	24.4	28.7	35.1	41.9	49.4	53.8
450 - 500	18.3	21.4	25.5	30.1	36.7	43.7	51.4	55.9
500 - 550	18.9	21.8	26.3	31.0	37.9	45.3	53.3	57.5

¹When communicating with Mode I personal/portable white space devices, the required separation distances must be increased beyond the specified distances by 1.3 kilometers if the Mode I device operates at power levels no more than 40 mW EIRP or 1.7 kilometers if the Mode I device operates at power levels above 40 mW EIRP.

Table 4 to Paragraph (a)(2)(v)

Personal/Portable White Space Devices	
	Required separation in kilometers from adjacent channel digital or analog TV (full service or low power) protected contour
	20 dBm (100 mW)
Communicating with Mode II or Fixed device	0.1
Communicating with Mode I device	0.2

Table 5 to Paragraph (a)(2)(v)

Fixed White Space Devices							
Antenna height above average terrain of unlicensed devices (meters)	Required separation in kilometers from adjacent channel digital or analog TV (full service or low power) protected contour¹						
	20 dBm (100 mW)	24 dBm (250 mW)	28 dBm (625 mW)	32 dBm (1600 mW)	36 dBm (4 W)	40 dBm (10 W)	42 dBm (16 W)
Less than 3	0.1	0.1	0.1	0.1	0.2	0.2	0.3
3 - 10	0.1	0.2	0.2	0.2	0.3	0.4	0.5
10 - 30	0.2	0.3	0.3	0.4	0.5	0.6	0.7
30 - 50	0.3	0.3	0.4	0.5	0.7	0.8	1.0
50 - 75	0.3	0.4	0.5	0.7	0.8	0.9	1.0
75 - 100	0.4	0.5	0.6	0.8	1.0	1.1	1.3

100 - 150	0.5	0.6	0.8	0.9	1.2	1.3	1.5
150 - 200	0.5	0.7	0.9	1.1	1.4	1.5	1.7
200 - 250	0.6	0.8	1.0	1.2	1.5	1.7	1.9
250 - 300	0.7	0.8	1.0	1.3	1.6	2.1	2.3
300 - 350	0.7	0.9	1.1	1.4	1.8	2.2	2.4
350 - 400	0.8	1.0	1.2	1.5	1.9	2.4	2.7
400 - 450	0.8	1.0	1.3	1.6	2.1	2.6	2.9
450 - 500	0.8	1.1	1.4	1.7	2.1	2.7	2.9
500 - 550	0.9	1.2	1.5	1.8	2.2	2.8	3.0

¹When communicating with a Mode I personal/portable white space device that operates at power levels above 40 mW EIRP, the required separation distances must be increased beyond the specified distances by 0.1 kilometers.

(3) *Fixed white space device antenna height.* Fixed white space devices must comply with the requirements of §15.709(g).

(b) * * *

(3) * * *

(ii) White space devices operating with more than 4 watts EIRP and up to 10 watts EIRP may not operate within 10.2 kilometers from the receive site for co-channel operation and 2.5 kilometers from the receive site for adjacent channel operation.

(iii) White space devices operating with more than 10 watts EIRP may not operate within 16.6 kilometers from the receive site for co-channel operation and 3.5 kilometers from the receive site for adjacent channel operation.

(iv) For purposes of this section, a TV station being received may include a full power TV station, TV translator station or low power TV/Class A TV station.

(c) * * *

(2) * * *

(ii) White space devices operating with more than 4 watts EIRP and up to 10 watts EIRP may not operate within 10.2 km from the receive site for co-channel operation and 2.5 km from the receive site for adjacent channel operation.

(iii) White space devices operating with more than 10 watts EIRP may not operate within 16.6 kilometers from the receive site for co-channel operation and 3.5 kilometers from the receive site for adjacent channel operation.

(d) *PLMRS/CMRS operations.* (1) White space devices may not operate at distances less than those specified in the table in this paragraph (d)(1) from the coordinates of the metropolitan areas and on the channels listed in §90.303(a) of this chapter.

Table 6 to Paragraph (d)(1)

White space device transmitter power	Required separation in kilometers from the areas specified in §90.303(a) of this chapter			
	Co-channel operation		Adjacent channel operation	
	Up to 250 meters HAAT	Greater than 250 meters HAAT	Up to 250 meters HAAT	Greater than 250 meters HAAT
Up to 4 watts EIRP	134.0	158.0	131.0	155.4
Greater than 4 watts and up to 10 watts EIRP	136.0	169.8	131.5	166.0
Greater than 10 watts and up to 16 watts EIRP	139.2	171.1	132.2	166.2

(2) White space devices may not operate at distances less than those specified in the table in this paragraph (d)(2) from PLMRS/CMRS operations authorized by waiver outside of the metropolitan areas listed in §90.303(a) of this chapter.

Table 7 to Paragraph (d)(2)

White space device transmitter power	Required separation in kilometers from operations authorized by waiver outside of the areas specified in §90.303(a) of this chapter			
	Co-channel operation		Adjacent channel operation	
	Up to 250 meters HAAT	Greater than 250 meters HAAT	Up to 250 meters HAAT	Greater than 250 meters HAAT
Up to 4 watts EIRP	54.0	78.0	51.0	75.4
Greater than 4 watts and up to 10 watts EIRP	56.0	89.8	51.5	86.0
Greater than 10 watts and up to 16 watts EIRP	59.2	91.1	52.2	86.2

* * * * *

(f) *Low power auxiliary services, including wireless microphones.* White space devices are not permitted to operate within the following distances of the coordinates of registered low power auxiliary station sites on the registered channels during the designated times they are used by low power auxiliary stations.

- (1) Fixed white space devices with 10 watts EIRP or less: 1 kilometer.
- (2) Fixed white space devices with greater than 10 watts EIRP: 1.3 kilometers.
- (3) Personal/portable white space devices: 400 meters.

(g) *Border areas near Canada and Mexico.* Fixed, mobile, and personal/portable white space devices shall comply with the required separation distances in paragraph (a)(2) of this section from the protected contours of TV stations in Canada and Mexico. White space devices are not required to comply with the separation distances in paragraph (a)(2) from portions of the protected contours of Canadian or Mexican TV stations that fall within the United States.

(h) * * *

(1) Operation of fixed, mobile, and personal/portable white space devices is prohibited on all channels within 2.4 kilometers at the following locations.

* * * * *

(i) * * *

(1) Fixed white space devices may only operate above 4 W EIRP in less congested areas as defined in §15.703.

* * * * *

7. Amend § 15.713 by revising paragraphs (a)(1), (e)(1), (2), (3), and (6), (h), and (l)(2) to read as follows:

§ 15.713 White space database.

(a) * * *

(1) To determine and provide to a white space device, upon request, the available channels at the white space device's location in the TV bands, the 600 MHz duplex gap, the 600 MHz service band, and 608-614 MHz (channel 37). Available channels are determined based on the interference protection requirements in §15.712. A database must provide fixed, mobile, and Mode II personal portable white space devices with channel availability information that includes scheduled changes in channel availability over the course of the 48-hour period beginning at the time the white space devices make a recheck contact. In making lists of available channels available to a white space device, the white space database shall ensure that all communications and interactions between the white space database and the white space device include adequate security measures such that unauthorized parties cannot access or alter the white space database or the list of available channels sent to white space devices or otherwise affect the database

system or white space devices in performing their intended functions or in providing adequate interference protections to authorized services operating in the TV bands, the 600 MHz duplex gap, the 600 MHz service band, and 608-614 MHz (channel 37). In addition, a white space database must also verify that the FCC identifier (FCC ID) of a device seeking access to its services is valid; under the requirement in this paragraph (a)(1) the white space database must also verify that the FCC ID of a Mode I device provided by a fixed or Mode II device is valid. A list of devices with valid FCC IDs and the FCC IDs of those devices is to be obtained from the Commission's Equipment Authorization System.

* * * * *

(e) * * *

(1) Fixed, mobile, and Mode II white space devices must provide their location and required identifying information to the white space database in accordance with the provisions of this subpart.

(2) Fixed, mobile, and Mode II white space devices shall not transmit unless they receive, from the white space database, a list of available channels and may only transmit on the available channels on the list provided by the database.

(3) Fixed and mobile white space devices register and receive a list of available channels from the database by connecting to the Internet, either directly or through another fixed white space device that has a direct connection to the Internet. Fixed devices must also register with the database in accordance with paragraph (g) of this section.

* * * * *

(6) A fixed device with an antenna height above ground that exceeds 30 meters or an antenna height above average terrain (HAAT) that exceeds 250 meters generally, or 500 meters in less congested areas shall not be provided a list of available channels. The HAAT is to be calculated using computational software employing the methodology in §73.684(d) of this chapter.

* * * * *

(h) *Mode II personal/portable and mobile device information to database.* (1) A mobile device and a personal/portable device operating in Mode II shall provide the database its FCC Identifier

(as required by §2.926 of this chapter) and serial number as assigned by the manufacturer.

(2) A personal/portable device operating in Mode II shall provide the database the device's geographic coordinates (latitude and longitude (NAD 83)).

(3) A mobile device shall provide the database with the boundaries of the geo-fenced area in which it will operate. Alternatively, the boundaries of the geo-fenced area may be loaded from the database into the mobile device.

* * * * *

(1) * * *

(2) A white space database shall verify that the FCC identification number supplied by a fixed, mobile, or personal/portable white space device is for a certified device and may not provide service to an uncertified device.

* * * * *

8. Amend § 15.714 by revising paragraph (a) to read as follows:

§ 15.714 White space database administration fees.

(a) A white space database administrator may charge a fee for provision of lists of available channels to fixed, mobile, and personal/portable devices and for registering fixed devices. This paragraph (a) applies to devices that operate in the TV bands, the 600 MHz service band, the 600 MHz duplex gap, and 608-614 MHz (channel 37).

* * * * *

9. Amend § 15.715 by revising paragraph (e) to read as follows:

§ 15.715 White space database administrator.

* * * * *

(e) Provide accurate lists of available channels and the corresponding maximum permitted power for each available channel to fixed, mobile, and personal/portable white space devices that submit to it the information required under §15.713(e), (g), and (h) based on their geographic location and provide accurate lists of available channels and the corresponding maximum permitted power for each available channel to fixed, mobile, and Mode II devices requesting lists of available channels for Mode I devices. Database administrators may allow prospective operators of white

space devices to query the database and determine whether there are vacant channels at a particular location.

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