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FEDERAL COMMUNICATIONS COMMISSION

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[ET Docket No. 18-295 and GN Docket No. 17-183; FCC 20-51; FRS 16729]

Unlicensed Use of the 6 GHz Band

AGENCY: Federal Communications Commission.

ACTION: Final rule.

SUMMARY: In this document, the Commission adopts rules designed to optimize unlicensed access by authorizing two types of unlicensed operations in the 6 GHz band while also protecting incumbent services so that they continue to thrive in the band. The Commission is authorizing unlicensed standard-power access points that will operate under the control of an automated frequency coordination system in portions of the 6 GHz band. The Commission is also opening the entire 6 GHz band for unlicensed indoor low power access points. In addition, the Commission will permit unlicensed client devices to communicate with both the standard-power and low-power access points. These rules will provide opportunities for unlicensed operations to use up to 320-megahertz channels to expand capacity and increase performance. This forward-looking action anticipates the next generation of the unlicensed devices and advances the U.S.'s role as an innovator and global spectrum policy leader

DATES: Effective **[INSERT DATE 60 DAYS AFTER DATE OF PUBLICATION IN THE FEDERAL REGISTER.**

ADDRESSES: Federal Communications Commission, 445 12th Street, SW, Washington, DC 20554.

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SUPPLEMENTARY INFORMATION: This is a summary of the Commission's Report and Order, ET Docket No. 18-295 and GN Docket No. 17-183, FCC 20-51, adopted April 23, 2020 and released April 24, 2020. The full text of this document is available for public inspection and copying during normal business hours in the FCC Reference Center (Room CY-A257), 445 12th Street, SW, Washington, DC 20554, or by downloading the text from the Commission's web site at <https://www.fcc.gov/document/fcc-opens-6-ghz-band-wi-fi-and-other-unlicensed-uses-0>.

Alternative formats are available for people with disabilities (Braille, large print, electronic files, audio format) by sending an email to fcc504@fcc.gov or calling the Commission's Consumer and Governmental Affairs Bureau at (202) 418-0530 (voice), (202) 418-0432 (TTY).

SYNOPSIS

Unlicensed Use of the 6 GHz Band

1. The Commission adopts rules designed to optimize unlicensed access to the 6 GHz band while also protecting incumbent services so that they continue to thrive in the band. In doing so, the Commission accounts for the concerns raised by parties representing the various incumbent services that operate in the 6 GHz band, weighs the various technical studies presented by proponents of unlicensed operations as well as representatives of incumbent services, and addresses how the rules the Commission adopts will enable unlicensed operations to operate in the 6 GHz band and protect the various incumbent services that operate in the band.

Standard-Power Operations in U-NII-5 and U-NII-7 Bands

2. The Commission adopts rules to permit standard power unlicensed operations in the U-NII-5 (5.925-6.425 GHz) and U-NII-7 (6.525-6.875 GHz) bands to operate outdoors or indoors with similar power levels as permitted for unlicensed portions of the 5 GHz band through use of an automated frequency coordination (AFC) system to protect incumbent fixed microwave operations from harmful interference. Specifically, the Commission authorizes standard-power access points to operate in these bands at power levels up to 36 dBm EIRP (PSD of 23 dBm

/MHz EIRP), and client devices to operate at up to 30 dBm EIRP (PSD of 17 dBm/MHz EIRP). The rules the Commission adopts for these unlicensed device operations will protect incumbent fixed microwave, radio astronomy, and fixed-satellite operations, add much needed capacity to meet the rapidly increasing demands of the wireless industry, and promote innovation and investment in new wireless unlicensed technologies. To protect incumbent fixed microwave operations from harmful interference, unlicensed access to these bands is only permitted on frequencies and locations determined by an AFC system based on the exclusion zones that it establishes. The Commission also protects certain radio astronomy observatories through the AFC system. Finally, in affirming the Commission's tentative conclusion that the AFC system is not necessary to protect incumbent fixed satellite service operations, the Commission also adopts a restriction on unlicensed standard-power access point to prevent them from pointing toward the space station receivers.

AFC-Based Access to Protect Fixed Microwave Services

3. Consistent with the framework proposed in the Notice, the AFC mechanism, combined with the technical and operational rules that the Commission adopts, will protect incumbent fixed microwave operations from the potential of harmful interference from unlicensed standard-power operations in the U-NII-5 and U-NII-7 bands. As noted by the Commission, the use of an automated system to control access to spectrum is not new. The Commission has previously used this approach to protect television reception from unlicensed white space devices in the TV bands and to protect satellite earth stations and government radars from devices of the Citizens Broadband Radio Service in the 3550-3700 MHz band. A properly designed AFC system in the U-NII-5 and U-NII-7 bands will protect incumbent operations, though they often differ on particular design and features of that system.

4. The AFC-based system for permitting unlicensed standard power operations in the 6 GHz bands will consist of several components which, when taken together, will determine the

specific exclusion zones that will protect incumbent operations. These components include (1) the framework, design, and operation of AFC system; (2) the operational requirements that the Commission establishes regarding standard-power access points (e.g., geolocation capabilities, antenna-related restrictions); and (3) the interference protection parameters that protect the incumbent fixed service operations.

The AFC System Framework and Database

5. *Centralized approach.* The Commission requires the AFC to use a centralized model where each standard-power access point remotely accesses an AFC to obtain a list of available frequency ranges in which it is permitted to operate and the maximum permissible power in each frequency range. This is consistent with the centralized model the Commission has employed in other contexts, will facilitate Commission oversight of AFC operations, and reduces design complexity. Because the Commission is concerned that allowing both architectures (centralized and de-centralized) could create problematic or unforeseen complications in operational management of AFC systems and devices and thereby could delay unlicensed deployment in this band, it declines to permit use of a dual AFC architecture as some parties have suggested.

6. *Use of ULS for information on incumbent operations.* the Commission requires that the AFC system rely on the Commission's Universal Licensing System (ULS) for fixed microwave link data when calculating and establishing the exclusion zones to protect those microwave links from harmful interference. The ULS is the official licensing database for microwave links in the U-NII-5 and U-NII-7 bands and contains extensive technical data for site-based licenses including transmitter and receiver locations, frequencies, bandwidths, polarizations, transmitter EIRP, antenna height, and the make and model of the antenna and equipment used. Thus, the ULS contains the information necessary for AFC systems to protect fixed service links. To ensure that AFC systems have the most recent information on fixed service links, the Commission requires AFC systems to download the database on a daily basis.

7. The Commission recognizes the concerns of some parties that information used by the AFC systems must be accurate and up-to-date, and notes that there may currently be some inaccurate or incomplete data in the ULS database. Because ULS is the official Commission compendium of license records, licensees are obligated under the terms of their licenses to keep their information filed with the Commission current and complete. Thus, licensees have the responsibility, as well as significant incentive, to maintain the continued accuracy of data in the ULS to ensure that they are protected from harmful interference not only from new unlicensed devices, but also from new fixed microwave links that may access the band. To the extent licensees determine that their actual operations differ from the Commission's licensing records, they should modify those records to ensure they are properly protected from harmful interference from any other spectrum users, and the Commission directs the Wireless Telecommunications Bureau to issue a public notice reminding such licensees of the importance of maintaining accurate information in that system.

8. Microwave links may begin operation prior to obtaining a license so long as certain criteria are met, such as completing successful frequency coordination and filing an application that appears in the ULS as pending. Because such a filing may indicate that a new station is operational, or soon will be, the Commission requires the AFC system to protect pending as well as granted facilities. In addition, temporary fixed microwave links may be authorized by a blanket authorization, in which case the licensee is not required to obtain approval from the Commission prior to operating at specific locations or report the technical details of their operation to the Commission. Because the AFC system must have knowledge of the location of temporary fixed links in order to protect them from harmful interference, the Commission requires the operators of temporary fixed stations to register the details of their operations (transmitter and receiver location, antenna height, antenna azimuth, antenna make and model, etc.) in the ULS prior to transmission if they desire to be protected from potentially receiving

harmful interference from standard-power access points in the U-NII-5 and U-NII-7 bands. The capability to register temporary fixed links does not currently exist in the ULS. That functionality will be announced by Public Notice once developed. Because temporary fixed links are not mobile and intended to operate at a specified location for up to a year, the Commission does not believe this registration requirement poses a significant burden on licensees.

9. *Information on microwave operations in border areas near Canada and Mexico.* As required by international agreements, and consistent with actions regarding white spaces and the CBRS, the Commission requires the AFC to protect microwave operations in Canada and Mexico near the United States border. The Commission recognizes that the ULS does not contain information on microwave operations in these countries. The Commission therefore intends to work with the governments of Canada and Mexico to obtain information on microwave systems in those countries and a method for providing it to AFC operators for incorporation into their systems.

10. *Information on location and antenna height of standard-power access points.* The AFC system also will make use of data concerning the location and antenna height of standard-power access points when calculating the availability of frequencies and channels of operations. The Commission establishes particular operational requirements for access points that ensure the accuracy of this data.

11. *Use of specified interference protection parameters.* The AFC system will apply the specified interference protection parameters established in this Order to protect fixed microwave operations from harmful interference. These include use of specified propagation models and a conservative interference protection criterion when calculating exclusion zones, and the methodology for addressing adjacent channel operations.

12. *Determining frequency and channel availability based on unlicensed device power levels.* The Commission requires that the AFC have the capability to determine frequency

availability at the maximum permissible power of 36 dBm for standard-power access points, as well as at lower power levels. Because the minimum required separation distance from a fixed service receiver, among other factors, is a function of the access point power, lower power devices do not have to meet as large a separation distance to provide the same level of protection as higher power devices. This means that more spectrum may be available for access points that operate with power levels below the maximum, especially in congested areas where spectrum is more heavily used by the fixed microwave services. This action is consistent with the Commission's white space rules in which white space devices operating at power levels less than the maximum have shorter required separation distances from protected services, and the white space database provides devices with a list of available frequencies and the maximum permissible power on each.

13. The Commission requires that the AFC system be capable of determining frequency availability in steps of no greater than 3 dB below the maximum 36 dBm permissible EIRP, down to a minimum level of 21 dBm. The Commission believes 3 dB is an appropriate step size because it is large enough to be significant (i.e. a factor of two) and will allow the AFC to determine frequency availability at multiple power levels so a device can select its optimum frequency and power level combination. The Commission's requirement that an AFC only consider power levels as low as 21 dBm is predicated on the expectation that outdoor access points will generally operate at the higher power levels to maximize coverage area or throughput or both. However, because certain situations or applications may not need that much power, there may be a need for AFCs to evaluate additional power levels. The Commission will not preclude AFC operators from determining frequency availability at additional power levels, e.g., below 21 dBm or in smaller step sizes; it simply establishes minimum AFC performance requirements. Consistent with the white space rules, the AFC will provide a list of available frequencies and power levels to standard-power access points but will not select the frequency or control the

power level of a device. Rather, each access point will select its operating frequency and power level from the list provided by the AFC.

Operational Requirements for Access Points

14. The AFC system requires a device's geographic coordinates—along with the accuracy of those coordinates—and the device's antenna height above ground, in order to determine which frequencies are available for use at its location.

15. *Incorporated geo-location.* The Commission requires all standard-power access points to include a geo-location capability to determine their geographic coordinates, rather than relying on a professional installer to determine them. Additionally, an incorporated geo-location capability provides a means for a device to automatically re-establish its coordinates if they are lost or altered due to a power outage or equipment reboot.

16. The Commission requires a device's geo-location capability to determine its location uncertainty and report it to the AFC system, which will use this information to determine the minimum required separation distances from fixed service receivers. The Commission also requires that it be determined, in meters, with 95% confidence level, which is consistent with the rules for white space devices which operate with similar geo-location requirements to those the Commission adopts for AFC controlled standard-power access points. The Commission's experiences with this rule confirms that it reliably ensures protection against harmful interference, at reasonable cost.

17. The Commission recognizes that geo-location technologies such as GPS do not work at locations where satellite signals are blocked by obstructions such as tall buildings and trees, or deep within buildings. To ensure that standard power access points can accurately determine their coordinates and provide them to the AFC in these situations, without the need for professional installation, the Commission provides additional flexibility for manufacturers and

device operators by making provisions for standard-power access points that operate in locations where an incorporated geo-location capability may not work.. The Commission allows standard-power access points to obtain their geographic coordinates through an external geo-location source when they are used at locations where an internal geo-location capability does not function. The Commission also allows an external geo-location source to be connected to an access point through either a wired or a wireless connection and will allow a single geo-location source to provide location information to multiple access points. The Commission requires that an external geo-location source be connected to an access point using a secure connection to ensure that only an external geo-location source approved for use with a device provides geographic coordinates to that device. Additionally, the Commission allows the use of extender cables to connect a remote receive antenna to a geo-location receiver within a fixed device. In cases where equipment uses a remote geo-location source, the separation distance between the access point transmit antenna and geo-location source must be included in the location uncertainty reported to the AFC system. This requirement will be enforced through the equipment certification process. Based on the Commission's experience, it believes these provisions will increase the manufacturers' flexibility to develop devices that can be used in a wide variety of locations while ensuring that devices accurately determine their location and report it to the AFC to prevent harmful interference to protected services.

18. Considering the geo-location requirements, the Commission is not requiring professional installation. It is not necessary because manufacturers can incorporate a variety of location technologies into their devices; many of these, such as GPS, are widely available at low cost. Further, requiring professional installation of all standard-power access points would be burdensome and that requiring devices to incorporate automatic geo-location will ensure that the information provided to the AFC system is accurate.

19. *Antenna height above ground.* For the AFC to accurately calculate exclusion zones to protect fixed service receivers, it requires the antenna height above ground of a standard-power access point. Consistent with the rules for white space devices, the Commission permits this information to be provided to the AFC either automatically by the device, or manually by the installer or operator of the device but does not require it to be determined by a professional installer.

20. Because automated geo-location methods such as GPS may not accurately provide height information in all cases, the Commission allows a device installer to manually determine the antenna height above ground and provide it to the AFC. As the Commission notes with respect to white space devices, installers with simple measuring equipment should be able to accurately determine antenna height above ground. However, because improvements in technology in the future could enable devices to automatically determine their antenna height above ground with more precision, there is also the option for standard-power access points to automatically do so. Industry groups are expected to work on developing methods for automatic height determination that could be used for standard-power access points or other applications where the antenna height above ground must be known.

21. *Frequency availability re-check interval.* The Commission requires a standard-power access point to contact an AFC system at least once per day to obtain the latest list of available frequencies at its location. Once per day is an appropriate re-check interval because the ULS, from which the AFC system will obtain data, is updated on a daily basis. The Commission disagrees with suggestions that of a 30-day re-check interval be instituted. While the likelihood is low that a new microwave link will become operational on any given day at a given location, when 6 GHz devices are widely deployed there will be situations where new microwave links are licensed in the vicinity of co-channel standard-power access points. To ensure that an unlicensed device quickly ceases operation on a frequency that becomes licensed for a microwave link near

its location, standard-power access points are required to re-check their frequency availability on a daily basis, i.e., the same as the ULS update interval.

22. The Commission recognizes that there may be situations when an AFC system is temporarily unavailable due to a sustained power loss, an Internet outage, or other circumstances that disrupt a device's ability to contact an AFC system. Consistent with the Commission's actions in other proceedings, an access point that cannot contact the AFC system during any given day is permitted to continue operating until 11:59 p.m. of the following day at which time it must cease operations until it re-establishes contact with the AFC system and re-verifies its list of available frequencies. The Commission does not believe that a one-day grace period is not likely to result in harmful interference to fixed service links because an access point being unable to contact the AFC system for a day is likely to be a relatively infrequent occurrence, and the probability that it will occur at the same time in the same place where a new microwave link commences operation is low.

Designating AFC Operators

23. *Operator approval and system certification process.* Consistent with the Commission's actions regarding white spaces and the CBRN, the Commission directs the Chief of the Office of Engineering and Technology (OET) to designate AFC system operators and oversee operation of their systems.

24. OET will designate AFC operators using a multi-stage review process similar to that it used for designating white space database and SAS administrators. As the first step, OET will issue a public notice inviting prospective AFC system operators to submit proposals describing how their systems would comply with all Commission AFC rules. The public will have an opportunity to review and comment on these AFC system proposals. OET will conditionally approve applicants that demonstrate that their proposed systems would comply with all AFC requirements. Applicants that receive a conditional approval will then be required to provide a

test system that will be subject to a public trial period to provide interested parties an opportunity to check that it provides accurate results. This trial period will include thorough testing, both in a controlled environment (e.g., lab testing) and through demonstration projects (e.g., field testing).

25. The Commission encourages formation of a multi-stakeholder group that will address issues specific to technical and operational issues associated with the AFC system, and intends to work with industry stakeholder groups as necessary to develop appropriate procedures for thoroughly testing AFC systems prior to use. The Commission will not grant final approval for an AFC system operator to begin providing service until after the operator satisfactorily demonstrates that standard-power access points can operate under the control of its system without causing harmful interference to fixed wireless services.

26. *Multiple AFC Operators.* As proposed in the Notice and consistent with commenters' support and existing rules for white spaces and CBRS multiple AFC operators may be designated. As the Commission previously noted in regard to white spaces databases, this would prevent a single party from obtaining monopoly control over the AFC systems, could provide an incentive for AFC system operators to provide additional services beyond those required by the rules, and is more likely to result in lower costs to consumers.

27. The Commission permits AFC functions, such as a data repository, registration, and query services, to be split among multiple entities, as is done for white spaces and the CBRS. No parties commented on this specific issue. This approach will allow greater flexibility in AFC system design and potential cost savings by allowing multiple operators to share the costs of running parts of an AFC systems. However, to ensure that the Commission can effectively oversee the AFC system operation, it requires that entities designated as AFC system operators be held accountable for all aspects of system administration, including any functions performed by third parties.

28. *Term of AFC Designation.* To ensure a stable operating environment for standard-power access points and consistent with both the white space and CBRS rules, the Commission adopts a five-year term which, at the Commission's discretion, may be renewed. Similar to the requirements for the white space database and SAS administrators, in the event an AFC system operator does not wish to continue to provide services, or if its term is not renewed, the system operator will be required to transfer its database along with the information necessary to access the database to another designated AFC system and will be permitted to charge a reasonable fee for the transfer of this information. Transferring this information assures operational continuity for existing devices; otherwise in the event an AFC discontinues service, devices would be denied operating frequencies and cut-off from providing services until it established a connection to a new database. This action allows that new connection to occur automatically.

29. The Commission disagrees that it would be burdensome for an AFC operator to transfer its registration data to another AFC system operator since the data that must be transferred (e.g., location, antenna height, device FCC ID and serial number) is relatively simple. The Commission also adopts the proposal that an AFC system operator must provide a minimum of 30 days' notice to the Commission when it plans to cease operation. Because standard-power access points must be able to access an AFC in order to operate, the Commission does not believe that the it should designate AFC system operators that could cease operation at any time with no notice as that could leave users with equipment that ceases operating unexpectedly.

30. *Fees.* Consistent with the rules for white space database and CBRS SAS administrators and as supported in the record, the Commission permits AFC operators to charge fees for the provision of service. Because the Commission is allowing multiple AFC operators to be designated, the Commission believes that competition among them will serve to keep fees reasonable and will allow for multiple business models that could benefit consumers, e.g., device manufacturers or a trade association could fund an AFC system as part of its business and no

individual transaction fees would be charged. However, as with white space databases and the CBRS SAS, the Commission permits parties to petition the Commission to review fees and require changes to the fees if they are found to be excessive.

31. *AFC to AFC synchronization requirements.* The Commission concludes that, under the AFC system, there is no need to require AFC systems to synchronize their data with each other. Unlike white space database systems that must accept and share registration information from protected entities, e.g., cable headends and licensed wireless microphone operators, that cannot be obtained from Commission databases, AFC systems will obtain their data on protected entities from a single source (the ULS). Therefore, there will be no need for AFC operators to synchronize protected entity information between different systems as NAB suggests. Additionally, because the Commission is not requiring AFC systems to consider aggregate interference from multiple standard-power access points when determining frequency availability, there is no need for the AFC systems to share information about registered standard-power access points.

Interference Protection Analyses and Parameters

32. The Commission protects fixed microwave operations from harmful interference by using an AFC system that establishes location and frequency-based exclusion zones for standard-power unlicensed devices around fixed microwave receivers operating in the U-NII-5 and U-NII-7 bands. Under this AFC system, individual unlicensed devices will not be permitted to operate on certain frequencies within the exclusion zone. Below, the Commission discusses technical parameters that the AFC system will use to calculate these exclusion zones.

33. *Propagation models.* Evaluating potential harmful interference from U-NII-5 and U-NII-7 unlicensed standard-power access point devices depend on the propagation models assumed for both fixed microwave signals and unlicensed devices. The propagation model that

the Commission adopts will, in turn, be used by the AFC system as one of the factors when determining the exclusion zones.

34. The Commission believes an approach which combines different propagation models is most appropriate for evaluating necessary separation distances of 6 GHz unlicensed devices from fixed microwave links. More specifically, because propagation models have been developed to accommodate a variety of environments and over various distances, the Commission finds that using a combination of models optimized for the varying propagation conditions that will be encountered is the best way to balance unlicensed device access and incumbent protection in the 6 GHz band. That is, it is most appropriate to use a set of propagation models keyed to specific separation distances between an unlicensed device and a fixed service receiver to determine appropriate exclusion zone size. Under this approach, the Commission uses the free-space model for short distances, where it accurately predicts signal path loss, the WINNER II for medium distances, and the Irregular Terrain Model (ITM) for longer distances to more realistically account for terrain and clutter losses.

35. Under our general approach, the Commission finds that for separation distances of 30 meters or less, the free space pathloss model is the appropriate model. Commenters generally assumed that 6 GHz unlicensed devices would not be placed within 30 meters of a microwave receiver and thus, did not suggest a propagation model for such short distances. Because, the potential for a direct line-of-sight between an unlicensed device and a microwave receiver is greatest at short distances, the Commission adopts the free space pathloss model for distances less than 30 meters. This model generates the greatest possible path loss to account for the possibility of direct line-of-sight from a standard-power access point to a microwave receiver. The free space pathloss model though theoretically simple, has a limited range of applicability because it ignores environmental clutter and over long distances can result in extremely conservative calculations that under predict the amount of actual path loss.

36. Incumbents generally recommend use of free space propagation model for all separation distances regardless of environment, while proponents of unlicensed operations advocate use of a combination of propagation models that specifically consider the propagation environment. Beyond 30 meters and up to one kilometer from an unlicensed device to a microwave receiver, the Commission finds that the most appropriate propagation model is the Wireless World Initiative New Radio phase II (WINNER II) model for urban, suburban, and rural environments. At these distances, the WINNER II model accounts for obstructions by urban and suburban clutter, which the free space model does not. The Commission makes this decision recognizing that the WINNER II model is one of the most widely used and well-known channel models in the world and was developed from measurements conducted by the WINNER organization, as well as results from academic literature and used by several commenters for analyses submitted to the record. The Commission requires the use of site-specific information, including buildings and terrain data, for determining the line-of-sight/non-line-of-sight path component in the WINNER II model where this information is available. For evaluating paths where this data is not available, the Commission requires probabilistic combining of the line-of-sight and non-line-of-sight path into a single path-loss. When site-specific information regarding line-of-sight/non-line-of-sight is not available then path losses of line-of-sight(LOS) and non-line-of-sight(NLOS) paths can be combined into a single loss using the following formula: Path-loss (L) = $\sum_i P(i) * L_i = P_{LOS} * L_{LOS} + P_{NLOS} * L_{NLOS}$, where P_{LOS} is the probability of line-of-sight, L_{LOS} is the line-of-sight path loss, P_{NLOS} is the probability of non-line-of sight, L_{NLOS} is the non-line-of-sight path loss, and L is the combined path loss. The WINNER II path loss models include a formula to determine P_{LOS} as a function of antenna heights and distance. P_{NLOS} is equal to $(1-P_{LOS})$. Using the WINNER II propagation model for these separation distances will provide the best prediction of actual pathloss between unlicensed devices and fixed service receivers as it accounts for environmental information not considered in the free space model.

37. The Irregular Terrain Model is a propagation model that specifically takes into account the effects of terrain on radio propagation but does not include clutter losses. The model accounts for transmission loss relative to free space loss for distances between 1 km and 2000 km. For separation distances greater than one kilometer, commenters suggest that the Irregular Terrain Model combined with a clutter model depending on the environment is the most appropriate model. The Commission agrees. Consistent with Commission use of propagation models in other proceedings, the Commission requires use of 1 arc-second digital elevation terrain data and, for locations where such data is not available, the Commission requires use of the most granular digital elevation terrain data available. To account for the effects of clutter, such as from buildings and foliage, the Commission requires that the Irregular Terrain Model be combined with a statistical clutter model ITU-R P.2108 for urban and suburban environments, and ITU-R P.452-16 clutter model for rural environments. The appropriate clutter category that most closely represents the local morphology should be selected when using ITU-R P.452-16. However, if detailed local information is not available, the Commission believes the “Village Centre” clutter category should be used as a default because access points will generally be installed in or on buildings (i.e., in a village) and this category most closely represents that morphology. The Commission specifies the Irregular Terrain Model because it has been widely available and accepted since the early 1980s, has been used by the Commission for interference prediction in other proceedings, is supported by the record, and in its experience has served reliably as a propagation model. The Irregular Terrain Model is the propagation model currently used to determine spectrum availability in the spectrum access systems (SAS) used to manage access to the 3550-3700 MHz band in the Citizens Broadband Radio Service.

38. *Interference protection criterion.* The Commission requires the prescribed AFC system to use an I/N metric rather than C/I for determining the exclusion zones. The I/N ratio was used by most commenters in their analyses as the interference protection metric and is more

straightforward to implement, and thus is more consistent with one of our major goals for the AFC system—simplicity of implementation. Use of a C/I ratio would entail additional implementation complexities. In particular, calculating the C/I ratio would require calculating the power arriving at the microwave receiver from its corresponding transmitter in addition to estimating the signal level from the access point. This would require knowledge of the microwave link characteristics including the instantaneous transmitted power as well as the modulation and coding scheme used, which is information that is not available in ULS.

39. As for the specific interference protection criterion, the Commission specifies a I/N of -6 dB I/N. By specifying that AFC exclusion zone calculations will be based on this particular interference protection criterion, the Commission is taking a conservative approach to ensure that the potential for harmful interference is minimized and important fixed microwave services in the 6 GHz band are protected. The Commission is not, however making a determination that any signal received with an I/N greater than -6 dB would constitute “harmful interference.” No commenter provides technical justification for using a particular I/N level as the actual level necessary to protect fixed microwave receivers against harmful interference. In determining to apply -6 dB I/N as the interference protection criterion, the Commission does not find the need to establish a specific industry multi-stakeholder group to establish the appropriate metric on this issue, as some have suggested.

40. *Aggregate interference.* The Commission did not propose nor find that there is any need to consider the effect of aggregate interference from multiple access points to point-to-point microwave links. The risk of interference from large numbers of standard power access points would not be due to signal aggregation from multiple unlicensed devices, but from a single standard-power access point in or near the main beam of a microwave link receive antenna with little or no intervening clutter. In the event that two or more access points could cause interference to the same microwave receiver, the signal from the nearest would dominate over the

others and make the others irrelevant to the analysis. The Commission does not require the AFC to consider aggregate interference when determining exclusion zones.

41. *Adjacent channel protection.* Although the Commission believes that the risk of adjacent channel interference to fixed service microwave receivers is low, the Commission takes a conservative approach to enabling new unlicensed devices in the 6 GHz band. Thus, in addition to the AFC calculating a co-channel exclusion zone, the Commission also requires it to determine an adjacent channel exclusion zone. The adjacent channel exclusion zone defines a zone under which any standard power access point is prevented from operating adjacent to an FS receiver within one-half channel bandwidth of the access point. The Commission expects these adjacent channel zones will be small and not significantly impact the amount of spectrum available to unlicensed devices at any given location. Also, because the AFC will need to calculate co-channel exclusion zones for all nearby fixed service stations, the incremental burden to also calculate adjacent channel exclusion zones should be minimal. To this end, the Commission requires the AFC to determine an adjacent channel exclusion zone based on the out-of-band emission mask the Commission adopts for unlicensed devices which is designed to keep energy outside an unlicensed device's operating channel to low levels and the same protection criterion used to determine co-channel exclusion zones; that is the I/N ratio must be calculated to be -6 dB or less. This requirement will protect fixed microwave receivers from harmful interference due to unlicensed devices out-of-band emissions.

Other AFC System Issues

42. *Security Issues.* The Commission requires that AFC systems and standard-power access points employ protocols and procedures to ensure that all communications and interactions between the AFC and standard-power access points are accurate and secure and that unauthorized parties cannot access or alter the database or the list of available frequencies and power levels

sent to an access point. These requirements are similar to those adopted for the white space database and the Citizens Broadband Radio Service spectrum access system.

43. The Commission is not mandating specific security models. Instead, the Commission requires AFC system operators to use advanced security standards and demonstrate that their systems contain communication and information security features during the AFC system certification process. These security protocols will be subject to the Commission's review and approval. The Commission anticipates that an industry-wide multi-stakeholder group will take the lead on this process and develop security protocols that AFC administrators may consider for their operation, subject to Commission review and approval. The Commission also expects that security models will be updated as needed to reflect state-of-the-art protection against new security threats. The Commission will review any modifications or updates in the security protocols AFC system operators or a multi-stakeholder group proposes to implement.

44. *AFC device registration.* To further ensure the AFC ecosystem integrity, the Commission requires standard-power access points to register with the AFC system when requesting a list of available operating frequencies and power levels. Although the Commission recognizes that the AFC system would be simpler without a registration requirement, device registration provides another layer of protection by ensuring only authorized devices access the spectrum and by easing the process of mitigating harmful interference if it occurs. Because the registration information would be automatically provided by the access point or network proxy to the AFC system, the registration process will require little effort by the access point user.

45. To register, a standard-power access point will be required to provide the AFC system—in addition to the technical information described above with the device's FCC identifier (FCC ID), and its serial number. Although the FCC ID or the access point's serial number are not required to calculate frequency availability, the AFC will use the information for two purposes. First, the information will be used to authenticate the device, to ensure that no rogue devices are

operating in the band. The AFC will verify the device's FCC ID by accessing the Commission's Equipment Authorization System. The AFC can retrieve the FCC IDs of certified standard-power access points from the Commission's equipment authorization database using an Application Program Interface (API) or another method and determine whether the FCC ID provided by a device during registration is valid. Access to the equipment authorization database and extracting FCC IDs is a process that is used by the CBRS SAS and white space data administrators.

Second, the information will be used for interference mitigation and enforcement purposes to identify the source if harmful interference were to occur. In addition, the Commission requires that AFC systems have the capacity to deny spectrum access to a particular registered standard-power access point upon requests by the Commission, in the event of harmful interference caused by a particular device or type of device. The Commission also requires that AFC operators implement procedures to respond to requests from Commission personnel for information stored or maintained by the AFC, and that they establish and follow protocols to comply with enforcement instructions from the Commission, including discontinuance of access point operations in designated geographic areas. These requirements ensure that the Commission is able to ascertain the accuracy of information stored in the AFC, obtain information necessary to enforce the Commission's rules, and ensure that access points that do not comply with the rules are shut down in a timely manner.

46. The Commission encourages formation of a multi-stakeholder group that would include representatives of unlicensed equipment manufacturers, equipment users and point-to-point microwave providers to develop additional procedures to resolve interference concerns. Regardless of the processes that stakeholders may develop for addressing interference, consistent with statute the Commission is the final arbiter regarding cases of harmful interference.

47. Individual standard-power access points will not be required to interface with the AFC system if the required registration data is communicated by a proxy device or network

control device. The network management device may be the point of interface with the AFC system for multiple access points. In other words, the registration information can be provided directly and individually by a single standard-power access point or by a network proxy representing multiple devices operating on the same network. The access point or its proxy must register with the AFC system via any communication link, wired or wireless, outside the U-NII-5 and U-NII-7 bands. The AFC system will then communicate back a list of permissible frequency range(s) and the maximum power in each range for standard-power access point operation. In the case of a proxy, each access point must still provide its exact location and will obtain a set of available frequencies for that location.

48. The Commission requires the AFC system to store registered information in a secure database until an access point ceases operation at a location, which the Commission defines as a device not contacting the AFC to verify frequency availability information for more than three months. This requirement will ensure that the AFC database does not become cluttered with entries for devices that are no longer being used. To ensure the users' privacy, the AFC system will use the registered data and any other access point operational information only to protect incumbents and for potential interference mitigation.

Radio Astronomy Observatories

49. Incumbent operations in the U-NII-7 band include several radio astronomy observatories, located in remote areas, that observe methanol spectral lines between 6.6500-6.675.2 GHz. The Commission recognizes the importance of these observations to the scientific community and will adopt exclusion zones to protect them from interference over the specified frequencies. In so doing, the Commission notes that there is no radio astronomy allocation for these observations requiring that they be protected from interference; the radio astronomy allocation table footnote merely provides that "all practicable steps shall be taken to protect the radio astronomy service" in this band from harmful interference). As these observatories are

located in remote areas the Commission does not believe excluding standard-power access points from this 25.2 megahertz of spectrum in these areas will be a significant burden on unlicensed operations. The AFC system will determine the size of the exclusion zones by the radio line-of-sight distance between the radio astronomy antenna and the unlicensed access point. The radio line-of-sight should be determined using 4/3 earth curvature using the following formula $dkm_{los} = 4.12 * (\sqrt{H_{tx}} + \sqrt{H_{rx}})$, where H_{tx} and H_{rx} are the heights of the unlicensed access point and radio astronomy antenna in meters above ground level, respectively.

Fixed-Satellite Services

50. The Commission adopts rules supporting the Commission's tentative conclusion that the AFC system is not needed to protect incumbent fixed-satellite operations from standard power access point operations in the U-NII-5 and U-NII-7 bands. Considering that the satellites receiving in these sub-bands are limited to geostationary orbits, approximately 35,800 kilometers above the equator, the Commission believes it unlikely that relatively low-power unlicensed devices would cause harmful interference to the space station receivers.

51. The Commission declines to adopt Intelsat and SES Americom's suggestion for an aggregate power limit from unlicensed devices to be enforced through the use of the AFC systems. As a precautionary measure, the Commission adopts a rule requiring outdoor standard-power access points to limit the maximum EIRP above a 30 degree elevation angle to 21 dBm, which is similar to what the Commission requires in the U-NII-1 band to protect fixed satellite services. The Commission adopts this restriction rather than an aggregate power limit for two reasons. First, outdoor access points have no reason to radiate significant power skyward, and so the Commission does not believe this requirement will impose a burden on standard-power access point manufacturers and users. Second, designing an AFC system to undertake aggregate power limit monitoring would be very complex, requiring the AFC to know how much energy is being emitted to each portion of the geostationary arc for each unlicensed device. That in turn would

require the AFC to have knowledge of each outdoor access point's antenna pattern, orientation, actual transmit power levels, and percent of the time it transmits as well as similar information for unlicensed client devices operating outdoors. Given the skyward EIRP restrictions the Commission is placing on the AFC controlled outdoor unlicensed devices, the Commission see no reason to require this level of complexity in the AFC systems.

Additional Issues

52. *Authorizing standard-power access points to operate in the U-NII-8 band.* The Commission does not authorize standard-power access points to operate in the lower 100-megahertz portion of the U-NII-8 band, which had been requested by some unlicensed proponent. The Commission declines to do so for a number of reasons. The U-NII-8 band is used by both fixed and mobile broadcast auxiliary service services and the lower 25-megahertz portion of the band is available for Low Power Auxiliary Stations operations such as licensed wireless microphones. The geographic areas for these types of licensed operations are specified in a variety of fashions, including point/radius, countywide, statewide and nationwide. The AFC system would not be able to allow standard-power access points to operate in the band while protecting licensed operations without additional information on their exact operating locations and times, and information on mobile operations can change frequently. Even if licensees were to provide additional operational information, this would increase the complexity of the AFC system and its interactions with unlicensed devices, and still may not adequately protect mobile operations. Accordingly, the Commission is not authorizing standard-power access points to operate in the lower 100 megahertz of the U-NII-8 band.

53. *Adopting an "inclusion zone" approach.* The Commission also declines to adopt the suggested alternative to an AFC system. to permit unlicensed devices to operate in an "inclusion zone" around microwave transmitters. Under this approach, an applicant for a microwave license would conduct coordination for both the licensed link and unlicensed devices within the inclusion

zone. In declining to adopt this approach, the Commission notes that its proposal is nearly identical to the concept of auxiliary stations, which the Commission considered as part of the Wireless Backhaul proceeding. The auxiliary station proposal contemplated placement of multiple lower power transmitters within the signal pattern of a microwave link. These auxiliary stations would be coordinated in advance of deployment and have secondary status. The Commission rejects this proposal, one of the reasons being that the proposal would create an incentive for microwave license applicants to propose excessive power or use more diffuse antenna patterns for their primary transmitters thereby precluding use of the spectrum by other microwave operators.

Low-Power Indoor Operations Across the Entire 6 GHz Band

54. The Commission opens the entire 6 GHz band for unlicensed indoor operations without the need for AFC-controlled access. By doing so, the Commission creates new unlicensed use opportunities in these bands—including optimizing the potential for deployment of next generation Wi-Fi that makes use of 160 MHz channels—while protecting the various incumbent licensed services in the band, including fixed microwave services, various other fixed and mobile services, and fixed-satellite services.

55. Because there will be no AFC system to prevent interference to licensed services from occurring, the rules the Commission adopts three restrictions designed to prevent harmful interference. Devices are: (1) limited to indoor operation; (2) required to use a contention-based protocol; and (3) subject to low-power operation.

56. *First*, these low-power access points must operate only indoors. The signals transmitted by these unlicensed devices will be significantly attenuated when passing through the walls of buildings. The median signal loss from a traditionally constructed building is 17 dB and newer, highly efficient buildings provide even higher signal attenuation. No commenters disagreed with the ITU median signal loss value for traditional construction. This attenuation is

key to providing the necessary signal reduction to prevent harmful interference from occurring to incumbents.

57. *Second*, the Commission requires that the indoor low-power devices, both access points and their associated client devices, employ a contention-based protocol. A contention-based protocol allows multiple users to share spectrum by providing a reasonable opportunity for the different users to transmit. Because the weighted average airtime utilization of Wi-Fi networks today is 0.4%, Wi-Fi devices share spectrum using a contention-based protocol. For IEEE's 802.11, a "listen-before talk" medium access scheme based on the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol functions as a contention-based algorithm to provide access to all traffic. Before initiating any packet delivery, a station listens to the wireless medium and if the medium is idle, the station may transmit; otherwise the station must wait until the current transmission is complete before transmitting. To ensure efficient and cooperative shared use of the spectrum, the Commission requires all unlicensed indoor low power operations use technology that includes a contention-based protocol.

58. In addition to providing equal access to the spectrum for unlicensed devices, a contention-based protocol can also be used to avoid co-frequency interference with other services sharing the band. Thus, this requirement can be leveraged to facilitate spectrum sharing with incumbent fixed and mobile services in the band. In addition, requiring a contention-based protocol will limit the amount of time that the low-power unlicensed device will transmit because of the need to share the spectrum with other devices. This will limit the time periods during which interference could potentially occur.

59. *Third*, the Commission limits the low-power indoor access points to lower power levels than the standard-power access points that operate under the control of an AFC. Consistent with the Commission's approach for the existing U-NII bands, the Commission specifies both a maximum power spectral density and an absolute maximum transmit power, both in terms of

EIRP. Specifically, the Commission allows a maximum radiated power spectral density of 5 dBm per 1 megahertz and an absolute maximum radiated channel power of 30 dBm for the maximum permitted 320-megahertz channel (or 27 dBm for a 160-megahertz channel). In addition, to ensure that client devices remain in close proximity to the indoor access points, the Commission limits their PSD and maximum transmit power to 6 dB below the power permitted for the access points. In adopting these power levels in our rules, the Commission authorizes indoor unlicensed devices with adequate power to be useful to the public while also protecting the licensed services in the 6 GHz band from harmful interference. In accordance with the record developed in this proceeding, the Commission finds that this power level meets these twin goals.

60. In the sections below, the Commission first discusses the provisions adopting to keep these low-power access points indoors. The Commission then discusses the technical parameters for indoor unlicensed operations in this band—the power levels different parties request, the rationale behind the power levels the Commission adopts today, and how the technical filings in this proceeding support our conclusion that the potential for harmful interference to incumbent services operating in the 6 GHz band is insignificant. The Commission then evaluates the probability of unlicensed devices causing harmful interference to the incumbent services in the 6 GHz band—fixed services, mobile services, FSS, and radio astronomy. The Commission discusses the technical studies submitted to the record, most of which employ different analysis methodologies with widely varying input assumptions leading to divergent conclusions. Certain studies are based on statistical simulations while others are based on worst-case scenarios. In evaluating these studies, the Commission discusses the methodologies and the underlying assumptions regarding propagation models, building entry loss, antenna patterns, height of unlicensed devices, activity factor and the bandwidth overlap of incumbent and unlicensed services and the associated consequences and conclusions.

Indoor Operations

61. The Commission first addresses measures designed to restrict these operations to indoor use. Because building attenuation is a key factor in minimizing the potential for harmful interference from indoor low-power access points to licensees' receivers, the Commission adopts reasonable and practical measures that will restrict low power access points to indoor operations. Specifically, the Commission adopts three equipment-related hardware requirements that are designed to keep these low-power access points indoors. *First*, as suggested by Boeing, the Commission requires that the access point devices cannot be weather resistant. *Second*, the Commission requires that the low-power access points have integrated antennas and prohibit the capability of connecting other antennas to the devices, which will prevent substituting higher gain directional antennas and make the devices less capable or suitable for outdoor use. *Third*, the Commission prohibits these low-power access points from operating on battery power. Furthermore, the Commission requires that the access points be marketed as "for indoor use only" and include a label attached to the equipment stating that "FCC regulations restrict to indoor use only." The Commission also requires that this statement be placed in the device's user manual. This statement along with existing Commission requirements for Part 15 equipment will inform consumers of the appropriate use.

62. The Commission finds that these requirements will make outdoor operations impractical and unsuitable, and disagree with those commenters that suggest either that no requirements are needed or that any requirements would be ineffective. The Commission declines to adopt a suggestion to use GPS to determine whether a device is indoors. Furthermore, the Commission is hesitant to require all devices to incur the cost of incorporating a GPS capability given that the effectiveness of this idea has not been demonstrated.

Power Spectral Density Limit

63. In determining the appropriate power spectral density for low power indoor unlicensed devices in this band, the Commission has carefully reviewed the studies submitted into the record by all parties. Various analysis methodologies are used which fall into two main categories: (i) Monte Carlo simulations, which take into account probabilistic factors such as building entry loss, activity factor, and co-channel probability, and (ii) static link budgets with limited considerations of probabilistic dependencies. The studies submitted to the record result in widely varying conclusions. While the studies performed by the incumbents tend to assume worst case conditions and ignore the very low probabilities associated with such worst-case scenarios, the proponents of unlicensed usage tend to assume very low probabilities for the activity factor and high building entry losses. Other assumptions that vary between the models are building entry loss and propagation loss, with incumbents generally assuming line of sight free space propagation and unlicensed device proponents applying industry standard models that either inherently include clutter loss or treat such loss as an additive factor determined by a separate statistical clutter model appropriate for the environment.

64. The Commission adopts a 5 dBm/MHz PSD. Based on our experience with unlicensed operations and interference analyses as well as our engineering judgment, the Commission finds that 5 dBm/MHz PSD will both adequately protect all incumbents in the band from harmful interference as well as offer enough power to unlicensed devices, commensurate with the levels in the other U-NII bands, to sustain meaningful applications especially when using wider bandwidths. At this power limit and with the other constraints imposed on these operations, the risk of harmful interference to incumbent operations is insignificant.

65. With respect to unlicensed client devices, the Commission adopts the proposal and does not permit client devices to operate with the same power spectral density as access points. The Commission finds that client devices does not need the same power level due to the

asymmetrical nature of traffic. An additional margin of 6 dB will provide protection to incumbents as client devices operate in the vicinity of access points. Accordingly, the Commission concludes that the appropriate maximum power spectral density for low power indoor client devices in this band is 6 dB below the limit for access points (or -1 dBm/MHz based on the adopted PSD limit).

Protecting Incumbent Operations

66. *Fixed Microwave Service.* The Commission finds that fixed microwave receivers will be protected from harmful interference from unlicensed indoor low power devices operating at the power levels the Commission is authorizing. The Commission reaches this conclusion based on the examination of two representative technical studies submitted to the record. First, a Monte Carlo simulation submitted by CableLabs provides a strong basis for reaching this conclusion. This study assumes realistic operating conditions for both licensed incumbent services and unlicensed operations. Second, a link budget analysis for six particular cases submitted by AT&T illustrates that interference is not likely to occur with the proposed power levels when realistic assumptions are made regarding propagation losses and taking into account the probabilistic nature of unlicensed transmissions. Because these six cases represent microwave receiver/unlicensed device geometries that are challenging from an interference perspective, the results give us confidence that interference is unlikely to occur. The Commission explains in more detail the numerous other technical filings submitted and why they are not significant to the conclusion.

67. Among several technical studies submitted by advocates of indoor low-power operations showing that the likelihood of interference to fixed microwave receivers is extremely low, the Commission finds the CableLabs study the most significant. These studies generally perform Monte Carlo computer simulations that model a random deployment of low-power unlicensed devices and calculate statistics on the likelihood of interference occurring to

microwave receivers. Advocates of indoor low-power operations claim that fixed microwave links will not experience harmful interference from the unlicensed devices.

68. In general, any technical study pertaining to spectrum sharing should take into consideration the specific behavior of services involved and the complexity of the propagation environment where the services operate. Studies that focus on static link budgets, for example, neglect the effects of the sporadic nature of most unlicensed transmissions (activity factor) and the probability of co-channel operation of the unlicensed device and the licensed service (e.g., an 80-megahertz unlicensed channel covers less than 7% of the 6 GHz band). These factors reduce the probability of interference to the licensed service.

69. CableLabs submitted a technical study that models the interference potential of low-power indoor unlicensed devices to microwave receivers. This Monte Carlo simulation explores the potential for interference to fixed links in the New York City area. The simulation uses the WINNER II urban propagation model, the propagation model the Commission adopts in this Report and Order for intermediate distances for AFC systems (By intermediate distances the Commission is referring to distances between 30 meters and 1 kilometer.). The CableLabs study selects a building entry loss between 10dB and 30 dB, which is consistent with ITU recommendation P.2109. Furthermore, the simulation uses a distribution of airtime utilization based on data taken from 500,000 Wi-Fi access points to model how often each access point in the simulation transmits. The simulations showed that the I/N ratio is far below the conservative -6 dB I/N threshold. This is the same -6 dB threshold that the Fixed Wireless Communications Coalition, which represents the interest of the fixed microwave licensees, uses as a threshold for protecting against harmful interference to fixed microwave links.

70. The Commission finds the CableLabs' study persuasive because it uses actual airtime utilization data for hundreds of thousands of Wi-Fi access points along with a statistical model for building entry loss. Rather than using a single average or median value to represent building

entry loss the CableLabs' study uses attenuation values drawn from a probability distribution for each access point in the simulation. In this way the simulation more accurately models the variability of the building loss than using a single number for building loss such as the median or average.

71. Wi-Fi is the predominant use of the U-NII bands, and is ubiquitous in both residences and businesses. The Commission expects that the majority of indoor unlicensed operations in the 6 GHz band will be for Wi-Fi as well. Additionally, while the adopted rules do not limit the activity factor, the Commission requires devices to use a contention-based protocol which will prevent devices from transmitting at extremely high duty cycles. For these reasons, the Commission finds that the CableLabs study is the best evidence in the record of the impact that unlicensed low-power indoor devices will have on incumbent operations—and it demonstrates that such operations will not cause harmful interference.

72. AT&T offered six scenarios where an unlicensed device operates in close proximity to a fixed microwave receiver or where an unlicensed device operates relatively far from the microwave receiver but the terrain causes the unlicensed device to be in or close to the main receiver beam.

73. AT&T's technical study attempts to overcome the limitation of simple deterministic interference calculations by introducing a probability distribution around building entry loss. AT&T claims that their examples properly apply building entry loss by treating it as a probabilistic quantity using the distribution from ITU-recommendation P.2109 and that prior analyses have oversimplified building entry loss into a single value. The Commission concludes that this step does not fully remedy the limitation of a static link budget analysis limitations. Some of the most significant elements of the AT&T link budgets are also probabilistic quantities. AT&T's link budget makes the following assumptions: (a) an EIRP of 30 dBm in an 80 MHz channel (11 dBm/MHz); (b) the maximum unlicensed device EIRP is in the direction of the

microwave antenna; (c) free-space propagation for the interfering signal; (d) zero clutter loss; (e) that an unlicensed device at the specified location is capable of 6 GHz band operation and is operating co-frequency with the microwave receiver; and (f) the unlicensed device has a 100% duty cycle. Clearly, all of these parameters except for the EIRP have an associated probability distributions that are missing from AT&T's link budgets. For example, AT&T's use of a free-space propagation model ignores clutter that often surrounds the transmitter and receiver sites (and that may significantly reduce the risk of harmful interference). Recognizing that each of these factors can take on a range of values and that it is unlikely that each will be worst case at the same time and location, the Commission finds that AT&T overstates the potential for harmful interference.

74. The Commission presents a detailed comparison in Table 1 for one of AT&T's examples (Example 2) The Commission does this because it gives a more useful indication of unlicensed device signal levels than only treating one factor in the calculation as a probabilistic quantity as AT&T has done in their examples. By treating only the building entry loss as a probabilistic quantity while not considering all the other statistical quantities, AT&T's examples exaggerate the likelihood of interference occurring.

Table 1: AT&T Example 2

	AT&T	Apple, Broadcom et al.	FCC
EIRP/BW	30 dBm/ 80 MHz	30 dBm/160 MHz	24 dBm/80 MHz
PSD	11 dBm/MHz	8 dBm/MHz	5 dBm/MHz
Antenna Gain	37.9 dB	37.9 dB	37.9 dB
Antenna	-1.5 dB	-2.538 dB	-1.5 dB

Discrimination			
RLAN/FS Antenna Mismatch	0 dB	-5 dB	-5 dB
Clutter	0 dB	-25.00 dB	-18.4 dB (using ITU-R P.452 clutter model)
Path Loss	-118.96 dB (free space)	-118.92 dB (free space)	-120.12 dB (ITM P2P model)
Bandwidth Mismatch	- 3 dB (assuming 80 MHz channels)	-7.27 dB (assuming 160 MHz channels)	-4.26 (assuming 80 MHz channels)
Noise Figure	-3.0 dB	-3.0 dB	-3.0 dB
Polarization Loss	-3.0 dB	-3.0 dB	-3.0 dB
Feeder Loss	0 dB	0 dB	0 dB
Building Entry Loss (50%)	-17.00 dB	- 17.00 dB	-20.62 dB (70/30 mix)
Interference (I)	-78.76 dBm	-113.83 dBm	-114 dBm
Noise Floor (N)	-99 dBm	-99 dBm	-99 dBm
I/N	20.44 dB	- 14.83 dB	-15.0 dB

75. The parameters in the above table were adjusted as follows:

(i) *EIRP/BW*: The analysis assumes a nominal channel bandwidth of 80 MHz, which results in a 5 dBm/MHz PSD limit.

(ii) *RLAN/FS Antenna mismatch*: The Commission agrees with Apple, Broadcom et al. that there will be an antenna pattern mismatch between the unlicensed devices and the microwave antenna and that 5 dB is a reasonable assumed loss.

(iii) *Clutter*: The Commission uses a standard clutter model (ITU-R P.452) to derive an 18.4 dB clutter loss.

(iv) *Path loss*: The Commission believes that the ITM P2P path loss model is most appropriate for this scenario

(v) *Bandwidth mismatch*: The mismatch is based on an 80-megahertz bandwidth unlicensed channel. However, The Commission assumes that the mismatch factor should be -4.26 dB based on the ratio of the passband of AT&T’s receiver and the bandwidth of the unlicensed channel.

(vi) *Building Entry Loss*: The Commission finds that a 70% traditional construction/30% energy efficient construction mix of building types for determining building entry loss is appropriate.

76. Table 2 presents all of AT&T’s six examples but substitutes more realistic technical parameters.

Table 2: FCC Analysis of the AT&T Examples

	Example 1A	Example 1B	Example 2	Example 3	Example 4	Example 5
EIRP Power Spectral Density (dBm/MHz)	5	5	5	5	5	5
Bandwidth (MHz)	80	80	80	80	80	80
EIRP (dBm)	24	24	24	24	24	24
RLAN Antenna	-5	-5	-5	-5	-5	-5

Discrimination (dB)						
BW Mismatch (80 MHz Chan.) (dB)	-4.26	-4.26	-4.26	-4.26	-4.26	-4.26
Polarization Loss (dB)	-3	-3	-3	-3	-3	-3
Propagation Model	Winner II Urban LOS	Winner II Urban LOS	ITM P2P	ITM P2P	Winner II Suburban LOS	Winner II Suburban LOS
Propagation Loss (dB)	-103.6	-99.5	-120.12	-122.7	-96.1	-83.6
Clutter Loss(dB)	0	0	-18.4	-18.4	0	0
MW Antenna Gain (dB)	43.2	43.2	37.9	38.8	41.3	38.8
MW Antenna Discrimination (dB)	-36	-38	-1.5	-0.9	-38	-40
Feeder Loss (dB)	-2	-2	0	0	-2	0
Building Entry Loss (70T/30E) 50 th Percentile (dB)	-21.4	-21.9	-20.6	-20.6	-23.1	-24.0
Noise (dBm)	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0
Noise Figure (dB)	3	3	3	3	3	3
I/N (dB)	-12.06	-10.46	-15	-16.1	-10.1	-1.06

77. Table 2 shows that when more realistic technical parameters than assumed by AT&T are used, the I/N ratio in all but one case now falls below the conservative -6 dB interference protection benchmark—indicating that there is an insignificant risk of harmful interference in five of these cases, when considering a static link budget analysis. Significantly, because these examples represent cases where the unlicensed devices are close to the microwave receivers or have terrain features that place the unlicensed device squarely in the main beam, they are representative of the worst cases that are likely to occur. Accordingly, they do not serve to rebut the persuasive showing by CableLabs based on a reliable probabilistic assessment derived from measurements associated with hundreds of thousands of actual Wi-Fi APs.

78. In only one case does a static link budget analysis suggest a nontrivial possibility of harmful interference (Case 5), and the Commission does not believe this one case poses a significant potential for actual harmful interference. That is in part because a -6 dB I/N interference protection criterion is a conservative approach to ensuring that the potential for harmful interference is minimized and in part because many statistical factors unaccounted for in this link budget analysis further make the potential for harmful interference much less likely. Combining the low probability of co-channel operation and low activity factor, the Commission concludes that based on a 5 dBm/MHz EIRP, the low power indoor operation will have an insignificant chance of causing harmful interference to the microwave links for any of these six examples (or fixed microwave links more generally). If the EIRP were increased to 8 dBm/MHz, the I/N ratios for examples 1B, 4, and 5 in Table 5 would recalculate to -7.46 dB, -7.1 dB, and 1.94 dB respectively, which would create a higher risk of harmful interference (although still very low). As the Commission cannot conduct an analysis for every fixed station and each of their associated link paths, it chooses to adopt a conservative 5 dBm/MHz EIRP at this time to enable low-power indoor operations throughout the 6 GHz band with insignificant risk of harmful interference.

79. CITA, Southern Company, the Critical Infrastructure Industry, and Apple, Broadcom et al. also submitted technical studies exploring the potential for harmful interference to fixed microwave receivers. The Commission examined these technical studies. These technical studies did not change the Commission's conclusion that unlicensed low-power indoor operations would present an insignificant risk of harmful interference.

80. *Additional Considerations.* The Commission is convinced, that as the Monte Carlo simulations involving extensive use of unlicensed devices in the band and examination of the link budget studies show, fixed microwave links will have an insignificant chance of experiencing harmful interference from indoor low-power unlicensed operations. Further, the non-continuous nature of the transmissions of the most widely used unlicensed systems today, like Wi-Fi makes the occurrence of harmful interference even less likely. And the Commission's rule requiring that low-power indoor access points employ a contention-based protocol ensures that none of these unlicensed devices will employ continuous transmissions. The data that CableLabs submitted collected from 500,000 Wi-Fi access points shows that 95% of access points have an activity factor of less than 2% and only 1% of access points are active more than 7% of the time. This illustrates that most of the time a particular access point will not be transmitting.

81. The sporadic and bursty nature of Wi-Fi transmissions is significant for two reasons. First, it illustrates why discussions of aggregate interference from Wi-Fi devices cannot simply add the power received from the individual access points to calculate the received interference. Instead, to more accurately estimate aggregate interference a Monte Carlo simulation which accounts for the intermittent nature of the transmissions should be undertaken.

82. Second, potential degradation of a microwave link will only occur if a deep atmospheric multipath fade occurs at the same time the microwave receiver receives an excessively high powered transmission from an unlicensed device, such that natural losses due to

separation distance, clutter, and terrain do not sufficiently diminish the power received from the unlicensed device.

83. The Commission disagrees with the Fixed Wireless Communications Coalition to the extent that it implies that our obligation regarding harmful interference from unlicensed devices goes beyond what is enumerated in our rules. While as general matter harmful interference is defined as “[a]ny emission, radiation or induction that endangers the functioning of a radio navigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radiocommunications service operating in accordance with this chapter,” the Part 15 rules apply this criteria on a case by case basis for different bands after careful consideration of the incumbent services in each band that ensures such harmful interference is unlikely to occur. The technical and operational limits the Commission adopts in this proceeding ensures that unlicensed devices will not have a significant potential for causing harmful interference to the users authorized to operate in the 6 GHz band.

84. The Commission, however, is not required to refrain from authorizing services or unlicensed operations whenever there is any possibility of harmful interference. Indeed, such a prohibition would rule out virtually all services and unlicensed operations, given that there is virtually no type of RF-emitting device that does not have the potential for causing such interference if used incorrectly. NCTA notes that the Commission may promulgate rules for unlicensed operations in bands occupied by other users so long as unlicensed devices do not “transmit[] enough energy to have a significant potential for causing harmful interference.” In rulemakings, the Commission may authorize operations in a manner that reduces the possibility of harmful interference to the minimum that the public interest requires, and it will then authorize the service or unlicensed use to the extent that such authorization is otherwise in the public interest. The Commission determines that the restrictions and requirements that it is establishing

for indoor use of low power access points eliminates any significant risk of causing harmful interference.

85. AT&T, CTIA, and others express concern that harmful interference nonetheless may occur, and the rules do not go far enough to ensuring that the interfering devices can be identified and the operation cease. Both AT&T and CTIA advocate use of an AFC system to address these concerns. While in certain bands the Commission has required database use, for other bands the Part 15 rules have no such requirement. Of particular relevance here, there is no spectrum management system in the 2400-2483.5 MHz band, where unlicensed devices share spectrum with the incumbent broadcast auxiliary service licensees and operate at higher powers than the indoor low-power access points authorized here. Nor are there such requirements in the 5 GHz band, which includes sensitive incumbent operations and where the unlicensed operations are similar to the kinds of low-power operations anticipated in the 6 GHz band. Wi-Fi devices have been deployed in these bands in abundance for well over 20 years, and the Commission expects that the deployment of 6 GHz devices will resemble the deployment of devices in these other bands, where instances of harmful interference have been effectively identified and addressed.

86. The Commission disagrees with CTIA's contention that our rules will be ineffective in keeping the low-power indoor devices from being used outdoors. The Commission's Part 15 rules prohibited outdoor operation in the U-NII-1 band from 1997 until 2014 and currently prohibit outdoor operation for unlicensed devices in the 92-95 GHz band and many ultra-wideband devices. As outdoor operation of these indoor devices has not been a problem, the Commission's rules restricting devices to indoors cannot be categorized as ineffective. None of these existing and previous rules contain all of the restrictions the Commission adopts here to discourage outdoor use. As in the rules for those operations, the Commission concludes that the technical and operational rules will be sufficient to protect incumbent operations.

87. In the unlikely event that harmful interference does occur, the Commission's Part 15 rules in section 15.5 (b)-(c) require that such operations cease, and the Commission's Enforcement Bureau has the ability to investigate reports of such interference and take appropriate enforcement action as necessary. Also, once interference to a protected service crosses the relevant threshold specified in section 15.3(m) for harmful interference, it is immediately actionable for enforcement purposes. Any user causing interference may be required to cease operating the U-NII device, even if the device in use was properly certified and configured and will not be permitted to resume operation until the condition causing the harmful interference has been corrected.

88. Here, as always, the Commission focuses on identifying and protecting against actual-use cases; were the Commission to act on every unrealistic or contrived situation that purports to show the potential for harmful interference, the Commission's rules would allow for few or no opportunities for sharing between unlicensed devices and licensed services; sharing that has allowed Wi-Fi to prosper along with continued licensed spectrum use. The Commission emphasizes, however, that under our long-established rules, Part 15 devices are not permitted to cause harmful interference. This fundamental principle stands regardless of the particular band- and application-specific rules adopted.

Mobile Services

89. The 6 GHz band Mobile service allocation is limited to the U-NII-6 (6.425-6.525 GHz) and U-NII-8 (6.875-7.125 GHz) bands. In these bands, the mobile service incumbents operate electronic news gathering and other Part 74 broadcast auxiliary services, as well as Part 78 Cable Television Relay Service, and Part 101 Local Television Transmission Service. Incumbents operate portable camera relays to "jumbotron" screens for major sporting events at stadiums and arenas, and at musical concerts at large venues, indoors and outdoors; use the spectrum bands for video relay to production trucks at news events; and for video signal multi-

hop mobile relay from newsworthy events to either a satellite news truck, a fixed receive site or a temporary relay site. Low Power Auxiliary Stations, also licensed in the U-NII-8 band, operate on an itinerant basis and transmit over distances of approximately 100 meters for uses such as wireless microphones, cue and control communications, and TV camera synchronization signals. Additional terrestrial uses of the band include short range video relay for video production at automobile and sailboat racing event, political conventions and golf tournaments. Because of the nature of their use—breaking news, event coverage, etc.—the use of particular portions of this band by these auxiliary services is unpredictable.

90. NAB opposes allowing indoor unlicensed operations in the bands where there are broadcast auxiliary service operations (U-NII-6 and U-NII-8), unless a “robust, reliable mechanism is developed to coordinate” the unlicensed operations with the licensed uses. To support of its position, NAB submitted a study which evaluates the impact of indoor and outdoor unlicensed operations in the U-NII-6 and U-NII-8 bands in three different use scenarios: (i) an electronic news gathering truck transmitting to a central receive site; (ii) portable cameras transmitting to an outdoor electronic news gathering truck receive site; and (iii) portable cameras transmitting to an indoor receive site.

91. Though the NAB study provides some valuable information about the potential risk of harmful interference to electronic news gathering receive sites, the Commission disagrees with certain of its assumptions. The Commission disagrees with NAB’s use of free-space path loss for all paths based on a predicted percentage of area that is line-of-sight when in fact unlicensed devices will be randomly located and could very well be in areas of buildings without line-of-sight to the electronic news gathering receiver. Under more realistic conditions, the Commission notes that NAB’s use of a -10 dB I/N benchmark is rarely exceeded in the electronic news gathering truck receiver case. The Commission notes that the use of a conservative but more reasonable -6 dB would show much less likelihood of any potential for harmful interference. And

taking into account the power-level and contention-based protocol limitations would show even less likelihood of harmful interference.

92. NAB's study includes co-channel operation probability in its statistical study but bases this probability on unlicensed devices being restricted to the U-NII-6 and U-NII-8 bands. NAB's assumption increases the probability of co-channel operations and thus, over predicts the potential for harmful interference to electronic news gathering operations.

93. Finally, NAB requests that the Commission authorize low power indoor operations in the U-NII-6 band altogether or alternatively to reserve 80 megahertz in the upper U-NII-8 band for ENG use only. As discussed below, low-power indoor operations will have little potential of causing harmful interference to ENG operations and decline to take this action. Moreover, eliminating the spectrum available for 6 GHz unlicensed devices could have the unintended effect of actually increasing the potential interference to other users as more unlicensed devices would have access to fewer channels.

94. *Outdoor electronic news gathering central receive sites.* For the reasons outlined above, the Commission believes NAB's study overstates the potential of exceeding its chosen I/N criterion of -10 dB and therefore also overstates the likelihood of exceeding the conservative and sufficiently protective I/N value of -6 dB. Apple, Broadcom et al. submitted a statistical study of the same scenarios but based on a combination of WINNER II and Irregular Terrain Model with the P.2108 propagation models. The Apple, Broadcom et al. study considers two activity factors and a 70/30 mix of building entry loss based on ITU Recommendation P.2109. The Apple, Broadcom et al. results indicate that aggregate signal level from indoor unlicensed devices will exceed a level 6 dB below the electronic news gathering central site receiver noise floor only 0.1% of the time. Thus, concluding that there is a negligible risk of harmful interference. The Commission finds that the Apple, Broadcom et al. study uses more appropriate propagation models and therefore more accurately represents the risk of harmful interference from indoor

unlicensed devices to electronic news gathering central receive sites and find that risk to be insignificant.

95. *Interference to electronic news gathering truck receivers.* Results of NAB's own study show that at the lower activity factor of 0.44% indoor unlicensed devices are unlikely to cause the I/N to exceed -10 dB. At the 10% activity factor, the electronic news gathering truck receiver results showed that between 0.2 and 49.8% of the time the aggregate I/N exceeds the -10 dB I/N threshold. CableLabs' empirical activity factor data show a weighted distribution of 0.4%. The Commission concludes that it is highly unrealistic to assume that every unlicensed device in an area surrounding an electronic news gathering truck will be transmitting at the high 10% activity factor.

96. The NAB study also concludes that the level of unwanted signal seen by the electronic news gathering truck receiver is dependent on the relationship between the height of the unlicensed device, the height of the electronic news gathering antenna and the height of the surrounding environment. The same relationship between local environment and antenna heights will exist for the desired link between the electronic news gathering transmitter and truck mounted receiver, except the electronic news gathering link can be planned and the electronic news gathering truck can be positioned to achieve the best possible signal between transmitter and receiver. Given the sensitivity of potential interference to geometry coupled with NAB's unrealistic assumption that every unlicensed device in an area surrounding an electronic news gathering truck will be transmitting at the high activity factor, the Commission concludes that the potential for harmful interference (using a more appropriate -6 dB threshold) is again insignificant for the scenario indicated.

97. CableLabs and Apple, Broadcom et al. both submitted studies indicating that potential for harmful interference from indoor unlicensed devices to outdoor electronic news gathering truck receivers will be unlikely. The Commission agrees with CableLabs' and Apple,

Broadcom et al.'s findings, that the risk of harmful interference to outdoor electronic news gathering receivers from indoor unlicensed devices is negligible. The Commission notes that the same conditions that cause signal variations in the electronic news gathering signal will also act upon a signal from an unlicensed device. CableLabs states that a 10 dB signal-to-interference-plus-noise provides an accurate basis for determining the impact of unlicensed indoor devices on broadcast auxiliary service signals. Apple, Broadcom et al. asserts “[n]ews truck operators will be able to improve their link budgets by slightly adjusting the positions of their trucks or shooting locations.” The Commission also notes that both Apple, Broadcom et al. and CableLabs’ studies assume a maximum of 30 dBm EIRP with at least an 8 dBm/MHz PSD, and that it is permitting indoor unlicensed devices to transmit with only a maximum 5 dBm/MHz PSD. This 3 dB variance further reduces the probability of harmful interference to electronic news gathering trucks from unlicensed devices.

98. *Interference to indoor electronic news gathering receivers.* The final scenario studied by NAB is communication between indoor electronic news gathering transmitters, such as microphones and camera-back transmitters, and indoor electronic news gathering receivers. The Commission is not permitting client devices to be used as hotspots and requires 6 GHz unlicensed devices to use a contention-based protocol. The Commission concludes that such a protocol will allow unlicensed devices to sense the energy from nearby indoor licensed operations and avoid using that channel. Apple, Broadcom et al. points out that the 802.11 specification dictates that devices sense the energy in the channel and not transmit if they detect energy at a level greater than -62 dBm. To confirm that energy sensing could be used to mitigate interference to indoor electronic news gathering receivers, Apple, Broadcom et al. simulated the receive power level from electronic news gathering transmitters at 20 unlicensed access points operating within the US House of Representatives chamber. The results of this simulation demonstrate that, even at the lowest electronic news gathering transmit power level, all unlicensed access points would

detect the electronic news gathering signal at greater than -62 dBm and therefore not transmit co-channel. While it is not requiring a specific technology protocol or contention method, the Commission concludes that the results of the Apple, Broadcom et al. study shows the likely potential of contention-based protocols to protect indoor mobile links, including electronic news gathering and Low Power Auxiliary Stations. Thus, the Commission concludes that the risk of harmful interference to indoor electronic news gathering receivers from indoor unlicensed devices is insignificant.

Fixed-Satellite Services

99. The entire 6 GHz band is also home to a FSS allocation (Earth-to-space), while U-NII-8 has a few space-to-Earth MSS feeder downlinks. The Commission agrees with Sirius XM, Intelsat, and SES that there will be negligible interference to satellite receivers from low-power indoor unlicensed devices. The low power levels of these devices as well as building attenuation will prevent harmful interference. With regard to earth station receivers, the Commission disagrees with Globalstar's analysis. As Apple, Broadcom et al. point out Globalstar's analysis represents an impossible worst-case scenario because it assumes that the earth station antenna is pointing at its minimum usable elevation angle in each of the interfering indoor access points resulting in the assumption that earth station antennas will simultaneously receive unlicensed device transmissions from all directions with the same antenna gain. Globalstar also assumes all unlicensed devices are operating at the same location where the incidence angle at the building wall is always zero, yielding the least building entry loss. Globalstar, uses a conservative 10% activity factor with all unlicensed activity concentrated at a small number of sites resulting in an unrealistic assumption that unlicensed transmission will always be subject to 7 dBi of earth station gain. However, it is unlikely that all indoor unlicensed devices will be operating at the same location and orientation with respect to the path between the device and the earth station receiver. Instead, the elevation angle at the building façade should be considered to be variable,

resulting in incidence angles greater than zero, which would increase the building entry loss value and minimize the probability of interference. Globalstar assumes line-of-sight and free-space propagation for all paths. The Commission disagrees that line of sight and free-space propagation loss is appropriate in all cases between a randomly placed unlicensed device and Globalstar's earth station.

100. Finally, Globalstar's analysis assumes all unlicensed devices are operating at the proposed maximum permissible power with the peak antenna gain directed toward its earth stations. The Commission is allowing unlicensed indoor devices to operate at a maximum 5 dBm/MHz PSD which represents at least a 3 dB/MHz reduction over the power levels assumed in the Globalstar analysis. Additionally, when considering random placement of unlicensed devices and variations in the unlicensed device antenna pattern, it is unlikely that the unlicensed device EIRP in the direction of the earth station will always be at maximum power, thus the risk of harmful interference is further reduced. For the reasons outlined here, the Commission finds that Globalstar's link budget analysis fails to fully consider all the probability factors that must align in order for interference to occur. The Commission therefore finds that the risk of harmful interference occurring to Globalstar's earth stations to be low.

Radio Astronomy

101. The National Academy of Sciences Committee on Radio Frequencies requests that the Commission use the AFC system to protect four radio astronomy observatories located in remote areas. The Commission is not adopting any AFC-based requirements for unlicensed low-power indoor operations generally, and declines to adopt such a requirement here. The four radio observatories that receive in the 6 GHz band are in remote locations and it is unlikely that indoor low-power unlicensed devices will be operating nearby. Furthermore, these observatories can restrict installation of such devices at their facilities. The Commission believes that indoor unlicensed devices do not pose any risk of harmful interference to radio astronomy operations.

Multi-Stakeholder Group

102. The Commission notes that many of the companies and organizations with interest in the 6 GHz band may not have previously participated in multi-stakeholder groups on matters related to specific Commission proceedings. Therefore, while the Commission takes no position on whether an existing organization could or should serve as host of the 6 GHz multi-stakeholder group, the Commission believes that any such multi-stakeholder group should be newly formed (not an offshoot of an existing group) and focus solely on issues relevant to the 6 GHz band. To ensure that all viewpoints are considered, the Commission encourages stakeholders comprising all sectors of the 6 GHz ecosystem to participate, including: wireless service providers with interest in providing service through standard-power and indoor low power devices, RLAN and network equipment manufacturers, potential AFC operators, fixed service vendors and operators, existing 6 GHz band incumbent licensees, ultrawideband equipment manufacturers, academic experts, testing organizations, and other 6 GHz band stakeholders. The Commission does not, however, take a position on the exact makeup or organizational structure of any such stakeholder group.

103. The Commission encourages the multi-stakeholder group to address any issues it deems appropriate regarding interference detection and mitigation in the event that an incumbent licensee believes it may be experiencing harmful interference from standard-power or indoor low-power operations. These issues would include procedures and processes that could be followed if an incumbent licensee has, or potentially has, an interference complaint. For example, network operators of standard-power or indoor low-power operations could decide to make points of contact publicly available or to create a website to facilitate addressing concerns or for reporting complaints. The Commission also believes that the group should set a goal of creating a process through which the industry can effectively address and resolve interference claims without necessitating involvement of the Commission's Enforcement Bureau.

104. While the Commission is not requiring general device testing as a gating criterion for devices before they begin operating in the 6 GHz band, the Commission recognizes that it will take some time before devices can be designed, manufactured and made available to consumers. During this interim period, members of the multi-stakeholder group could work cooperatively to develop and test devices to aid in the goal of developing processes for introducing and operating devices across the 6 GHz band. As the Commission does not require the multi-stakeholder group to conduct testing, the Commission also declines to set any timelines if any testing is conducted. Because the Commission does not expect widespread availability of 6 GHz unlicensed devices immediately, the Commission encourages the multi-stakeholder group, if conducting any testing related to developing procedures and processes regarding interference detection and mitigation, to set a goal of implementing any agreed-upon device-related features before unlicensed 6 GHz devices reach consumers.

105. The Commission also encourages the multi-stakeholder group to address any other issues that may be specific to standard-power operations or indoor low-power operations. In particular, the Commission encourages the group to address, as proposed in the Notice, AFC system development for standard power access points. Related tasks are expected to include any standards that are necessary for AFC operators, such as how to implement the required propagation models or whether common communications protocols are needed between standard power unlicensed devices and the AFC(s). Additionally, the Commission expects that the multi-stakeholder group will develop AFC system testing and certification procedures and processes for ensuring that AFC systems contain complete and up-to-date incumbent data.

106. Finally, the Commission expects that the multi-stakeholder group will develop best practices and standards concerning standard-power operations (and use of the AFC system) and for indoor low-power operations—practices that the Commission expects will benefit all users of the 6 GHz band, both incumbents that desire additional protection and new unlicensed

users that want to use the spectrum more intensely. The Commission expects that these best practices will include such concerns as device and communication link security. These activities should be viewed as a starting point; participants of the multi-stakeholder group should tackle any issues they deem appropriate.

107. The Commission's Office of Engineering and Technology (OET) will act as a liaison for the Commission with any such multi-stakeholder group so formed. In particular, the Commission expects the Office to observe the functioning of any such group and the technical concerns that it is considering to ensure that the group's activities are useful and pertinent. OET will provide guidance to any such group on the topics on which it would be most helpful for the Commission to receive input and a sense of the time frames in which such input would be helpful.

Equipment Issues

108. *LAntenna Requirements.* The Commission requires that all low power devices incorporate permanently attached integrated antennas. Requiring an integrated antenna makes it significantly more difficult for a party to replace a device's antenna with a higher gain antenna, which could increase a device's EIRP above the limit and therefore increase the potential for a device to cause harmful interference.

109. The Commission does not, however, require a permanently attached antenna for standard-power access points. The Commission finds that a requirement to use a permanently attached antenna on standard power access points could be overly restrictive. These types of devices are typically used outdoors by parties such as schools, businesses and WISPs and are configured in a manner where the antenna is mounted on a mast or building and connected through a cable to a separately located transmitter. Such a requirement could be difficult to implement for these configurations. In addition, permitting such devices a choice of appropriate antennas will provide options for meeting the antenna pointing restrictions which limit outdoor devices to antenna elevation angles less than 30 degrees for devices transmitting more than 21

dBm EIRP to protect satellite operations in the band. Further, the Commission notes that devices in other U-NII bands do not have a requirement for permanently attached antennas, so adding a requirement for equipment in the 6 GHz bands could make it more difficult for manufacturers to develop devices that are capable of operating across multiple bands. Consistent with the existing Part 15 rules, applicants for standard-power access point equipment authorizations will be required to list all types of antennas that will be used with a device and demonstrate that the equipment complies with the EIRP limits with all types of antennas with which it is authorized.

110. *Maximum Channel Bandwidth.* Because the Commission is setting a power spectral density limit of 5 dBm/MHz for low power indoor devices to limit their potential for causing interference to incumbent services, the Commission permits these devices to operate with a maximum channel bandwidth to 320 megahertz to permit a maximum power of up to 30 dBm. For consistency the Commission also specifies a maximum bandwidth of 320 megahertz for AFC controlled standard-power access points.

111. The Commission finds that this bandwidth requirement is appropriate for several reasons. It will permit manufacturers to develop equipment under current standards with bandwidths of up to 160 megahertz as a number of parties suggest. In addition, the Commission's understanding is that industry standards under consideration such as IEEE 802.11be will specify channel bandwidths of up to 320 megahertz. Thus, a 320 megahertz bandwidth limit will permit future equipment development under anticipated standards without a need for additional rule changes. However, the Commission is placing a 320-megahertz upper limit on bandwidth so as not to supplant the rules for wideband and ultrawideband operations in the 6 GHz band. These rules permit operation with bandwidths greater than 500 megahertz, but with a lower - 41 dBm/MHz power spectral density. The Commission notes that unlicensed proponents have not requested channels bandwidths greater than 320 megahertz and that the

Commission did not provide notice of any proposed changes to the wideband or ultrawideband rules

112. *Standard power transmitted power levels in rural areas.* The Commission does not at this time permit higher power limits in rural areas, nor make any specific provisions for higher power point-to-point or point-to-multipoint operations in the U-NII-5 and U-NII-7 bands as suggested by some commenters. While the Commission recognizes that establishing a single power limit of 36 dBm for standard-power access points differs from the rules for the U-NII-1 and U-NII-3 bands that permit higher power for fixed point-to-point devices, and from the white space rules that permit higher power for fixed devices in “less congested” (e.g., rural) areas, the Commission is not adopting higher power limits for several reasons. The Commission first notes that the rules adopted does not place an upper limit on antenna gain; the transmit limits are based solely on EIRP, and manufacturers can use any combination of transmitter power and antenna gain to reach that limit. The Commission interprets parties’ requests for higher antenna gain limits as requests for higher EIRP limits. While allowing higher power could encourage the provision of additional services in rural and other areas, it also increases the range at which harmful interference to incumbent users in the bands could potentially occur. Therefore, the Commission is taking a conservative approach at this time and not permitting power levels greater than 36 dBm for standard-power access points. In addition, permitting higher power in only certain areas would make the AFC implementation more complex because criteria for where to allow higher power operation would have to be defined and incorporated into the AFC. Also, taking into account the directivity of standard-power access point transmit antennas as some parties suggest would make AFC calculations more complex.

113. *Client Device Transmit Power Levels.* The Commission is adopting rules that limit client devices to power levels 6 dB below the power limits for access points. The Commission concludes that this 6 dB reduction is necessary because when the client device is

operating under the control of the access point, the client device may have a slightly different propagation path and interference potential to a victim receiver.

114. The Commission generally declines to increase client device power levels to the same power levels as access points, as suggested by some commenters. The Commission recognizes commenters concerns regarding the power differential between access points and client devices. However, because a client device may be portable (e.g., a cell phone) and operate at different locations around its serving access point, the propagation path of its emissions could vary. This could, in turn, slightly change the potential for interference from any particular client device to incumbent operations within the area. Thus, the Commission declines to adopt power limits for client devices commensurate with access points. However, the Commission makes two limited exceptions to this requirement.

115. First, to the extent that an access point and a client device are both permanently fixed and operate under the control of an AFC system that provides a list of available frequencies to each device, each may operate at up to the maximum 36 dBm level. In such cases, the Commission does treat the client device as another access point with respect to operational rules, provided it complies with all of the requirements for access points, including using an AFC to obtain a list of available channels, having a geolocation capability and complying with the limit on upward antenna radiation from outdoor devices (no greater than 21 dBm at more than 30 degrees above the horizon). To distinguish these devices from actual access points for equipment certification purposes (as they differ in not having a direct connection to the internet), the Commission defines them as fixed client devices.

116. The Commission also adopts an exception to accommodate devices such as Wi-Fi extenders and mesh networking equipment intended to work in conjunction with an indoor access point and share the same propagation path and thus the same power requirements. The Commission also permits other devices under certain conditions to operate at the full 5 dBm/MHz

power spectral density. The Commission permits such devices to operate at the same power levels as an access point provided that they comply with all the requirements set out for low power indoor access points (i.e., the device cannot be weather resistant, must have an integrated antenna and cannot have capability of connecting other antennas, cannot be capable of operating on battery power, and must include a label regarding proper usage) and the end unit obtains its own equipment certification. Under these requirements modules do not qualify for higher power. Further, such devices may only be used within a single structure and not to connect separate buildings or structures. The Commission believes such relief is a reasonable accommodation to keep most popular consumer devices less complex and more affordable without increasing the potential of harmful interference to incumbent licensees as these devices will be installed and used in a manner analogous to an access point.

117. The Commission does not find it necessary to restrict the power radiated upward from client devices as required for standard-power access points. The Commission believes it is unlikely that relatively low-power unlicensed devices will cause harmful interference to receivers on geostationary satellites approximately 36,000 km above the equator. The Commission is limiting upward power from standard-power access points merely as a precautionary measure as they are more likely to operate outdoors and with higher power. The Commission notes that client devices can operate with EIRP as high as 30 dBm, but finds that they are less likely to cause interference to satellite receivers than similarly powered outdoor access points due to the nature of their operation. The Commission first notes that client devices are limited to a power level 6 dB lower than access points, but the Commission expects them to generally operate at much lower power levels to maximize battery life and comply with RF exposure limits. In addition, client devices communicate with access points in an asymmetric nature, in that relatively little data is transmitted in the uplink direction (i.e. from the client device) as compared to the downlink direction where any single access point may be serving many client devices.

Moreover, client devices typically operate with omnidirectional antennas at low antenna heights and in a mobile or portable mode (i.e., not installed in permanent outdoor locations). Thus, the Commission expects that upwardly directed client device emissions will often be at low power levels and shielded to some extent by buildings, foliage, or other obstructions.

118. *Emission Mask and Out-of-Band Emission Limits.* The Commission concludes that the emission mask suggested by RKF Engineering, with certain modifications, protects incumbent microwave links and other services operating in the adjacent channel to unlicensed devices within the U-NII-5 through U-NII-8 bands. Accordingly, the Commission requires emissions from standard power access points and low power indoor devices within the U-NII-5 through U-NII-8 bands to comply with the transmit emission mask proposed in the Notice. Specifically, the Commission is requiring 20 dB suppression of power spectral density at one megahertz outside of an unlicensed device's channel edge, 28 dB suppression of power spectral density at one channel bandwidth from an unlicensed device's channel center, and 40 dB suppression of power spectral density at one and one-half times the channel bandwidth away from an unlicensed device's channel center. At frequencies between one megahertz outside an unlicensed device's channel edge and one channel bandwidth from the center of the channel, the limits must be linearly interpolated between 20 dB and 28 dB suppression, and at frequencies between one and one and one-half times an unlicensed device's channel bandwidth from the center of the channel, the limits must be linearly interpolated between 28 dB and 40 dB suppression. Emissions removed from the channel center by more than one and one-half times the channel bandwidth, but within the U-NII-5 and U-NII-8 bands, must be suppressed by at least 40 dB.

119. The Commission adopts a -27 dBm/MHz limit for emissions from all 6 GHz unlicensed devices at frequencies below the bottom of the U-NII-5 band (5.925 GHz) and above the upper edge of the U-NII-8 band (7.125 GHz), but will not require it between the sub-bands, i.e. between the U-NII-5 and U-NII-6, the U-NII-6 and U-NII-7, and the U-NII-7 and U-NII-8

bands. The Commission believes that a limit of -27 dBm/MHz is necessary to protect services outside the U-NII-5 and U-NII-8 bands, including the Intelligent Transportation Service below the U-NII-5 band and federal government operations above the U-NII-8 band. The Commission is not requiring devices to meet this emission limit between the sub-bands as suggested by Sony because it is seeking to maximize spectrum use and it would stifle innovation by precluding the use of wide bandwidth channels (up to 320 megahertz) that straddle sub-bands. Standards bodies have generally developed channeling plans for unlicensed devices based on technical characteristics, including devices' out-of-band emissions. Manufacturers will have the freedom to determine how they will meet this limit either by reducing power levels, through filtering or through other means, such as not enabling channels closest to the U-NII-5 and U-NII-8 band edges.

120. Finally, the Commission addresses the measurement procedures for 6 GHz unlicensed devices. To protect Intelligent Transportation Services in the band below 6 GHz, 5GAA states that the -27 dBm/MHz standard the Commission is adopting, when based on a root-mean-square (RMS) measurement, is sufficient to protect those services from indoor device OOB. RLAN proponents agree that the OOB should be verified using an RMS detector or other appropriate techniques for measuring average power. The Commission agrees and will provide guidance to the test labs and telecommunications certification bodies which conduct equipment approval measurements and oversight that 6 GHz unlicensed device measurements may be conducted based on using an RMS detector. Because RMS measurements represent the continuous power being generated from a device as opposed to peak power which may only be reached occasionally and for short periods of time, the Commission believes an RMS measurement is more appropriate. The Commission notes that this is a departure from the Commission's measurement guidance for similar devices in the 5 GHz band where the Commission specifies a peak measurement. However, that procedure was instituted to mitigate a

known interference issue with federal radars in the 5 GHz band. No such situation exists in the 6 GHz band. The Commission will update its Knowledge Database guidance consistent with this decision.

121. *Client Device Restrictions.* The Commission adopts a requirement that client devices operate either under the control of a standard-power access point or a low-power access point. The purpose of this requirement is to prevent client devices from transmitting outdoors at locations where they may cause interference to a microwave receiver or other incumbent. When client devices are under the control of a standard-power access point, they will be in close proximity to the access point and may transmit only on frequencies that the AFC system has determined will not cause interference to fixed microwave links. When a client device is under the control of a low-power indoor access point, it should also be indoors and in close proximity to the access point, and therefore avoid presenting an interference risk to licensed services. However, the Commission also adopts an exception to this general requirement to allow a client device to transmit brief messages (“probe requests”) to an access point when attempting to join its network as discussed below.

122. The Commission recognizes the utility of permitting probe requests to enable client devices to join an access point’s network. However, these probe requests have the potential to cause harmful interference to licensed operations. The Commission therefore only permits a client device to send a probe request to an access point after it has detected a transmission from the access point. The client device will be required to send the probe request on the same frequency as the access point’s transmission. This is consistent with the white space rules that permit a fixed white space device establishing a network to make brief transmissions on a frequency that it detects is in use by another fixed device prior to receiving a list of available channels from a database. Under this exception, because the client device will have to detect an access point transmission, the client device will only transmit when it is close enough to an access

point to be under its control and on a frequency on which the access point has permission to transmit. This will prevent harmful interference from occurring.

123. The Commission prohibits the use of client devices as mobile hotspots that could authorize the operation of other client devices. The rules the Commission adopts for AFC controlled operation of unlicensed access points are designed to prevent harmful interference to licensed stations by only allowing operation at locations where an access point and client devices directly communicating with it would not cause interference to licensed stations. Permitting a client device operating under the control of an access point to authorize the operation of additional client devices could potentially increase the distance between these additional client devices and the access point and increase the potential for harmful interference to fixed service receivers or electronic news gathering operations. For standard-power devices in the U-NII-5 and U-NII-7 bands hotspot operation could allow the additional client devices to transmit in locations where the AFC otherwise would prevent operation to protect incumbent service operations. With regard to low-power indoor access points, our rules are designed to prevent the low-power access points from being used outdoors which should also keep the client devices indoors. In addition, as APCO states, allowing such portable access points could make identifying and resolving interference difficult.

Making Portions of the 6 GHz Band Available for New Licensed Services

124. The Commission declines the requests to repurpose substantial portions of the 6 GHz band for new licensed services in place of new unlicensed operations and existing incumbents. Most importantly, the Commission believes that providing new opportunities for unlicensed operations across the entire 6 GHz band can help address the critical need for providing additional spectrum resources for unlicensed operations. Making the entire band available for these unlicensed operations enables use of wide swaths of spectrum, including several 160-megahertz channels as well as 320-megahertz channels, which promotes more

efficient and productive use of the spectrum, and would also help create a larger ecosystem in the 5 GHz and 6 GHz bands for U-NII devices. Repurposing large portions of the 6 GHz band for new licensed services would diminish the benefits of such use to the American public. Accordingly, the Commission agrees with the unlicensed proponents to reject these requests. Similarly, repurposing substantial portions of the band, as CTIA and Ericsson request substantially affects existing licensed services in the band. This is contrary to the Commission's goal in this proceeding to ensure that existing incumbents can continue to thrive in the 6 GHz band. Representatives of the incumbent fixed microwave services also raise concerns about the reasonableness and practicality of relocation, and question whether other appropriate spectrum can be found. The fixed satellite service commenters also strongly reject the contention of CTIA and Ericsson that satellite services would not need to be relocated because new licensed services would not cause harmful interference to the satellite services. Further, there is no certain or clear path for achieving what CTIA and Ericsson propose, and it would take years. For all of these reasons, the Commission will not take the approach suggested by CTIA and Ericsson to repurpose this band. By the actions the Commission takes today to open the entire 6 GHz band for new unlicensed operations, the American public will begin to see the benefits in the near term.

125. The Commission also declines to reconsider the approach it is taking to authorize unlicensed low-power operations in the U-NII-6 band. Ericsson asked to make the U-NII-6 band available for licensed indoor use rather than permitting unlicensed indoor use as proposed in the Notice. The Commission has made the entire 6 GHz band available for indoor low-power operations under rules that will protect incumbent operations across the band while also enabling use of wide channels that promote efficient use of the entire band. These unlicensed devices can provide the IoT applications envisioned by Ericsson in the entire 6 GHz band while protecting incumbent operators from harmful interference.

Mobile Operations and Use in Moving Vehicles

126. *General prohibition on mobile operations.* The Commission does not at this time permit standard-power and low-power indoor access points in the 6 GHz band to operate while in motion, with one exception in the U-NII-5 band with respect to large passenger aircraft operating over 10,000 feet. The Commission declines to permit operation in vehicles because of the potential for increasing interference to incumbent services. As a result, the use of unlicensed access points shall not be permitted in moving vehicles such as cars, trains, ships, or small aircraft. Also, the Commission is prohibiting unlicensed devices in the 6 GHz band to be installed on unmanned aircraft systems.

127. As commenters note, the white space rules do provide a method that could enable personal/portable devices to operate while in motion by obtaining channel availability information for multiple locations and using this information to define a geographic area of operation. However, no personal/portable white space devices have yet been certified and such devices are limited to a lower power level than other white space devices. The Commission is concerned that allowing standard-power access points to operate while in motion would add complexity to the AFC system as it would need to continuously update available frequency lists for such devices, and that this could add substantial congestion to links connecting devices to the AFC, potentially degrading the quality of service for the expected predominant fixed access point use. Given the lack of a record as to the power levels and operational requirements that would be needed to permit mobile operation, the Commission will not permit mobile standard-power access point operation at this time.

128. Similarly, the Commission rejects the Wi-Fi Alliance's position that it should consider the signal attenuation provided by the vehicle or the user's body to establish appropriate power levels to enable mobile and transportable operations. Unlicensed devices will have no way

to determine whether they are within a car, train, or plane and therefore would not be able to adjust their output power accordingly.

129. While the Commission is prohibiting the use of 6 GHz access points while in motion, the Commission is not prohibiting transportable devices, which the rules define as devices that “are not intended to be used in motion, but rather at stationary locations.” However transportable access points will have to otherwise comply with the rules the Commission adopting. That is, they will either operate under the control of an AFC system or they will have to operate only indoors. Indoor transportable access points will have to comply with all of the restrictions the Commission is adopting to prevent outdoor use.

130. The Commission is prohibiting use of access points in cars, trains, and small aircraft because of the complications of using an AFC to control frequency access while in motion and because of the uncertain attenuation properties of these vehicles. Use of 6 GHz devices on ships raises the same issues as use in cars, trains, and aircraft regarding use of the AFC systems to protect licensees and lack of building attenuation when access points are used indoors. To address these issues and protect the earth exploration satellite service operations over oceans, the Commission also prohibits standard-power and low-power indoor access points aboard ships and on oil platforms.

131. The Commission prohibits unlicensed devices in the 6 GHz band – whether standard-power or low-power devices – from operating on unmanned aircraft systems. Unmanned aircraft systems pose similar issues as other vehicles with the added complication of operating at significant height, and the Commission has no technical bases in the record to enable an evaluation of the potential harmful interference concerns posed by these systems. For the reasons it is not permitting standard-power and low-power indoor devices generally in vehicles, the Commission is not permitting them in unmanned aircraft systems.

132. *Exception for large aircraft operating above 10,000 feet.* Boeing requests that the Commission permit unlicensed operations aboard large aircraft when flying above 10,000 feet. The Commission agrees with Boeing that the fuselage of large passenger aircraft will provide significant attenuation of signals from unlicensed in-flight entertainment systems. The measured average signal attenuation from the fuselage of a large aircraft at 5 gigahertz is 17 dB, which is comparable to a building of traditional construction. The Commission does not expect the aircraft fuselage signal attenuation at 6 GHz to differ significantly from 5 GHz given the closeness in frequency. In addition, large passenger aircraft normally fly at high altitudes which will provide additional signal attenuation preventing signals from reaching terrestrial fixed and mobile receivers. The only potential area of concern would be if an aircraft flew through the main beam of a microwave link during take-off or landing. To address this concern, the Commission limits the use of low-power access points for in-flight entertainment systems in aircraft to above 10,000 feet. Because the only data on the signal attenuation from aircraft fuselage submitted on the record is for large passenger aircraft, the Commission shall also limit use to this type of aircraft. Finally, to prevent harmful interference to radio astronomy and earth exploration satellite service, the Commission limits airborne use of low-power access points to the U-NII-5 band where such passive scientific operations do not occur.

Microwave Links in the Gulf of Mexico

133. The Commission does not find RigNet's technical study regarding aggregate interference from indoor unlicensed devices convincing for several reasons. RigNet's study presents a link budget analysis of aggregate interference to each of ten microwave receivers located on land. In each of the link budget calculations the study assumes that a number of access points ranging from 2 to 100 are present. For each receiver all the access points are assumed to be at the same distance from the microwave receiver, but this distance varies from 250 m to 5 km for the different receivers. The reason for assuming these distances and number of access points

is not explained. The study assumes that the access points would transmit power at a power spectral density of 23 dBm/MHz and that there would be 11 dB of building loss. Because the Commission is only permitting access points to transmit at 5 dBm/MHz and, as discussed above, an appropriate assumption for building loss is 20.5 dB, the calculated signal from each access point should be 26.5 dB lower than what the study assumes. While the study does not discuss the propagation model used, from the pathloss shown in the link budgets it appears that free space was used for all cases. In addition, the study assumes that every access point was directly in the main beam of the microwave receiver, which is unrealistic considering the height of the microwave receivers compared to the likely height of the indoor access points. Thus, the Commission believes the calculated interference levels should be at least 50 dB lower than what RigNet's study finds. This is consistent with the Commission's conclusion that microwave receivers will not experience harmful interference from indoor access points. With respect to AFC-controlled devices, RigNet's microwave links will be protected by the AFC as would any other microwave link licensed in the 6 GHz band. RigNet's microwave network appears to be no different from any other microwave links, which our new unlicensed rules are designed to protect from harmful interference. Accordingly, the Commission's rules do not exclude the Gulf of Mexico from unlicensed operations.

Ultra-Wideband and Wideband

134. The Commission declines to adopt specific provisions to provide special protections for ultra-wideband and wideband devices. As ultra-wideband and wideband devices operate under Part 15 unlicensed rules, taking such action would effectively provide those devices with a level of interference protection to which they are not entitled. Ultra-wideband and wideband devices are permitted to operate at a variety of power levels, all of which are below -41.3 dBm/MHz. These devices also operate over large bandwidths that are typically allocated to a variety of services.

135. The Commission notes that ultra-wideband and wideband devices, as with all unlicensed devices operating under our Part 15 rules, are subject to the condition that they may receive interference—including interference from other unlicensed devices. Unlicensed Part 15 devices have no vested right in the continued use of any particular block of spectrum. Moreover, ultra-wideband and wideband devices operate across a varied spectrum landscape with different types of licensed services (in this case, microwave links and satellite uplinks) that are governed by differing service and technical rules. Thus, by their nature, wideband and wideband devices must be designed to tolerate varying levels of interference with no assurance of an interference-free operating environment.

136. All of the provisions that the ultra-wideband and wideband advocates request would in effect reserve spectrum in a manner that the Commission has not previously contemplated or proposed for such devices. The Commission declines to let the spectrum provisions applicable to ultra-wideband and wideband devices preclude the provision of other services that the Commission has widely permitted under the unlicensed framework applicable to the U-NII bands. The Commission's experience with the 2.4 GHz and existing U-NII bands has shown that the adoption of technology neutral rules has resulted in an explosion of innovation and the widespread adoption of unlicensed technologies by consumers and businesses. The Commission expects a similar experience to occur in the 6 GHz band. If the Commission were to adopt the suggested limitations on power levels, available spectrum, and duty cycle it would limit the range and data rates of the new unlicensed devices in a way that limits their utility. The Commission finds that it would not be in the public interest to restrict the use of the 6 GHz band unlicensed devices in this way. However, the Commission notes that the contention-based protocol requirement it is adopting for low power indoor devices will limit the unlicensed device duty cycle and that it could also detect the presence of ultra-wideband and wideband devices. The Commission encourages ultra-wideband and wideband interests to work with standards bodies to

explore protocols that may enhance those devices coexistence with new 6 GHz unlicensed devices.

137. Additionally, the record provides compelling evidence of circumstances where unlicensed devices operating under both the existing and new rules will be able to peacefully co-exist. A study submitted by Broadcom indicates that wideband devices may be able to operate outdoors in areas immediately adjacent to locations where unlicensed devices operating indoors under the new rules are deployed and that, where devices are in close proximity, users will likely be able to promote co-existence by adjusting the positioning of UWB and RLAN devices. Thus, for ultra-wideband and wideband devices employed in industrial applications and other indoor locations, the facility owner will be able to exercise control over the use and placement of new unlicensed devices, and if necessary, can choose which devices to deploy to avoid unwanted interference. In addition, according to data submitted by CableLabs, the weighted average of the activity factor for Wi-Fi is 0.4% which is below the 0.5% activity factor suggested by the ultra-wideband and wideband proponents to enable co-existence. Thus, the Commission has reason to believe that in many cases ultra-wideband and wideband devices will be able to operate in the presence of new devices that will operate under the new 6 GHz unlicensed rules.

Synchronized Unlicensed Operation

138. Qualcomm requests that the Commission adopt a rule which it claims will permit access points that use synchronized contention windows to operate without disadvantaging other technologies. The specific rule that Qualcomm requests would establish a synchronized mode for unlicensed devices with contention windows every 6 milliseconds.

139. The Commission has historically adopted rules that are technologically neutral and remains committed to this policy. This is reflected by our U-NII rules which do not require the use of a particular contention method for unlicensed devices to share access to spectrum. The Commission's embrace of technology neutrality has encouraged the development of a vast variety

of unlicensed devices operating under our Part 15 rules. In fact, Qualcomm has endorsed our policy stating that this “approach to both licensed and unlicensed spectrum bands has supported perpetual innovation by the entire wireless industry” and that “[t]here is no question that the FCC should continue its successful tech neutral policy to existing and future spectrum bands.” While there may be ways to increase spectrum efficiency by synchronization as Qualcomm advocates, this would necessarily require restricting the flexibility that Part 15 has permitted to U-NII devices. The Commission does not believe that this would be an acceptable tradeoff and rejects Qualcomm’s request.

140. The Commission also does not find convincing Qualcomm’s contention that granting its request would be in keeping with our technology neutral policy. The Commission agrees with HP Enterprise that “far from being technologically neutral, the stated purpose of [Qualcomm’s] proposal is to advantage one specific type of unlicensed technology over all others.” The Commission also expects that technologies other than IEEE 801.11be (EHT) or 5G NR-U will be used by unlicensed devices in this band and do not see any reason to place limitations on their operation.

Digital Identifying Information

141. The Commission declines to adopt a requirement that 6 GHz unlicensed devices transmit digital identifying information. To impose such a requirement requires the Commission to mandate a modulation format for the transmitted information, which necessarily imposes restrictions on the development of unlicensed technology in the band. Given that the record has provided no details on how this requirement will help resolve interference, the Commission does not believe that imposing this requirement can be justified. The Commission also agrees with those commenters who express concern that this requirement could intrude upon the privacy of device users by facilitating tracking of devices.

Benefits and Costs

142. Making available 1200 megahertz of spectrum in the 6 GHz band for new types of unlicensed use will yield important economic benefits and will allow more extensive use of technologies such as Wi-Fi and Bluetooth by American consumers. Consumers are using more and more data, on average, and this is expected to continue to grow significantly. As demand for data increases, making more spectrum available for two types of unlicensed use — standard-power and low-power indoor — will provide economic benefits by relieving potential congestion, allowing more users to access these new bands, and potentially making new use cases possible. As noted above, the ability of unlicensed devices to use significant portions of this band may also complement new licensed 5G services by allowing providers to offer a full range of services to consumers and will help to secure U.S. leadership in the next generation of wireless services. One report cited by several commenters estimates that in 2018, the economic benefits associated with Wi-Fi in the United States was valued at almost \$500 billion. A further report estimated that these new rules will produce over \$150 billion in economic value. In some ways, unlicensed usage on the new spectrum will be more restricted than for current Wi-Fi usage due to the AFC and lower power limits. However, in the United States, Wi-Fi currently operates in different bands over nearly 700 megahertz of spectrum, none of which enables channels as large as 160 megahertz. Making an additional 1200 megahertz of 6 GHz spectrum available for unlicensed use, including enabling the use of 160-megahertz channels that will lead to expanded throughput, capacity, and performance will have a significant economic benefit.

143. The Commission notes, however, that the new rules for unlicensed spectrum use could impose some economic costs if harmful interference to incumbent services occurs. As explained above, the technical and operational rules are designed to minimize the potential interference to incumbent licensed uses. While under the rules there can be interference with ultra-wideband and wideband applications, these costs will be lower than the total U.S. economic

value for ultra-wideband and wideband products, which in turn, are lower than the total economic value of new unlicensed use. The CableLabs study gives reason to believe that interference with ultra-wideband and wideband will only be intermittent, so that coexistence with new users will be possible. Further, when ultra-wideband and wideband use is specific to an indoor facility, it will be feasible for facility owners to prevent interference by regulating use of unlicensed activity within the facility. Thus, in most cases, the full value of ultra-wideband or wideband will be preserved, with only management costs incurred by facility owners. While the Commission is unable to precisely estimate the value of U.S. ultra-wideband and wideband, one market research firm cited the global value of the ultra-wideband industry will be \$85.4 million in 2022. In addition, the Commission notes that revenues from a non-exhaustive list of U.S. firms producing ultra-wideband products, among others, imply that even if costs are incurred, they will be significantly less than the potential hundreds of billions of dollars of economic value created. Overall, while the Commission identifies some economic costs, the Commission believes that they are limited and do not outweigh the substantial economic benefits of making such a large amount of spectrum available for unlicensed use.

PROCEDURAL MATTERS

144. *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 First Report and Order, which is found in Appendix B of the link provided in the beginning of this SUPPLEMENTARY INFORMATION section. 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.

145. *Paperwork Reduction Act Analysis.* — This document does not contain new or modified information collection requirements subject to the Paperwork Reduction Act of 1995 (PRA), Public Law 104-13. In addition, therefore, it does not contain any new or modified information collection burden for small business concerns with fewer than 25 employees, pursuant to the Small Business Paperwork Relief Act of 2002, Public Law 107-198, *see* 44 U.S.C. 3506(c)(4).

146. *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 major under the Congressional Review Act, 5 U.S.C. § 804(2). The Commission will send a copy of this Report & Order to Congress and the Government Accountability Office pursuant to 5 U.S.C. § 801(a)(1)(A).

Ordering Clauses

147. Accordingly, 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, and Section 1.411 of the Commission's Rules, 47 C.F.R § 1.411; that this *Report and Order and Further Notice of Proposed Rulemaking*, is hereby ADOPTED.

148. IT IS FURTHER ORDERED that the amendments of the Commission's rules as set forth in Appendix A ARE ADOPTED, effective sixty days from the date of publication in the Federal Register.

149. 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 and Further Notice of Proposed Rulemaking*, including the Initial and Final Regulatory Flexibility Analyses, to the Chief Counsel for Advocacy of the Small Business Administration.

150. 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 and Further Notice of Proposed Rulemaking*, including the Initial and Final Regulatory Flexibility Analysis, 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

47 CFR Part 0

Reporting and recordkeeping requirements, Telecommunications.

47 CFR Part 15

Communications equipment, Radio.

FEDERAL COMMUNICATIONS COMMISSION

Cecilia Sigmund,
Federal Register Liaison Officer.

Final Rules

For the reasons discussed in the preamble, the Federal Communications Commission amends 47 parts 0 and 15 as follows:

PART 0 – COMMISSION ORGANIZATION

1. The authority citation for Part 0 continues to read as follows:

AUTHORITY: Secs. 5, 48 Stat. 1068, as amended; 47 U.S.C. 155.

2. Section 0.241 is amended by adding paragraph (k) to read as follows:

§ 0.241 Authority delegated.

* * * * *

(k) The Chief of the Office of Engineering and Technology is delegated authority to administer the Automated Frequency Coordination (AFC) system and AFC system operator functions set forth in subpart E of part 15 of this chapter. The Chief is delegated authority to develop specific methods that will be used to designate AFC system operators; to designate AFC system operators; to develop procedures that these AFC system operators will use to ensure compliance with the requirements for AFC system operations; to make determinations regarding the continued acceptability of individual AFC system operators; and to perform other functions as needed for the administration of the AFC systems.

PART 15 – RADIO FREQUENCY DEVICES

3. 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.

4. Section 15.401 is revised to read as follows:

§ 15.401 Scope.

This subpart sets out the regulations for unlicensed National Information Infrastructure (U-NII) devices operating in the 5.15-5.35 GHz, 5.47-5.725 GHz, 5.725-5.85 GHz, and 5.925-7.125 GHz bands.

5. Section 15.403 is revised to read as follows:

§ 15.403 Definitions.

Access Point (AP). A U-NII transceiver that operates either as a bridge in a peer-to-peer connection or as a connector between the wired and wireless segments of the network or as a relay between wireless network segments.

Automated Frequency Coordination (AFC) System. A system that automatically determines and provides lists of which frequencies are available for use by standard power access points operating in the 5.925-6.425 GHz and 6.525-6.875 GHz bands.

Available Channel. A radio channel on which a *Channel Availability Check* has not identified the presence of a radar.

Average Symbol Envelope Power. The average symbol envelope power is the average, taken over all symbols in the signaling alphabet, of the envelope power for each symbol.

Channel Availability Check. A check during which the U-NII device listens on a particular radio channel to identify whether there is a radar operating on that radio channel.

Channel Move Time. The time needed by a U-NII device to cease all transmissions on the current channel upon detection of a radar signal above the DFS detection threshold.

Client Device. A U-NII device whose transmissions are generally under the control of an access point and is not capable of initiating a network

Contention-based protocol. A protocol that allows multiple users to share the same spectrum by defining the events that must occur when two or more transmitters attempt to simultaneously access the same channel and establishing rules by which a transmitter provides reasonable opportunities for other transmitters to operate. Such a protocol may consist of procedures for initiating new transmissions, procedures for determining the state of the channel (available or unavailable), and procedures for managing retransmissions in the event of a busy channel.

Digital modulation. The process by which the characteristics of a carrier wave are varied among a set of predetermined discrete values in accordance with a digital modulating function as specified in document ANSI C63.17-1998.

Dynamic Frequency Selection (DFS) is a mechanism that dynamically detects signals from other systems and avoids co-channel operation with these systems, notably radar systems.

DFS Detection Threshold. The required detection level defined by detecting a received signal strength (RSS) that is greater than a threshold specified, within the U-NII device channel bandwidth.

Emission bandwidth. For purposes of this subpart the emission bandwidth is determined by measuring the width of the signal between two points, one below the carrier center frequency and one above the carrier center frequency, that are 26 dB down relative to the maximum level of the modulated carrier.

Fixed client device. For the purpose of this subpart, a client device intended as customer premise equipment that is permanently attached to a structure, operates only on channels provided by an AFC, has a geolocation capability, and complies with antenna pointing angle requirements.

Indoor Access Point. For the purpose of this subpart, an access point that operates in the 5.925-7.125 GHz band, is supplied power from a wired connection, has an integrated antenna, is not battery powered, and does not have a weatherized enclosure.

In-Service Monitoring. A mechanism to check a channel in use by the U-NII device for the presence of a radar.

Non-Occupancy Period. The required period in which, once a channel has been recognized as containing a radar signal by a U-NII device, the channel will not be selected as an available channel.

Operating Channel. Once a U-NII device starts to operate on an Available Channel then that channel becomes the Operating Channel.

Maximum Power Spectral Density. The maximum power spectral density is the maximum power spectral density, within the specified measurement bandwidth, within the U-NII device operating band.

Maximum Conducted Output Power. The total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g.,

alternative modulation methods), the *maximum conducted output power* is the highest total transmit power occurring in any mode.

Power Spectral Density. The power spectral density is the total energy output per unit bandwidth from a pulse or sequence of pulses for which the transmit power is at its maximum level, divided by the total duration of the pulses. This total time does not include the time between pulses during which the transmit power is off or below its maximum level.

Pulse. A pulse is a continuous transmission of a sequence of modulation symbols, during which the average symbol envelope power is constant.

RLAN. Radio Local Area Network.

Standard Power Access Point. An access point that operates in the 5.925-6.425 GHz and 6.525-6.875 GHz bands pursuant to direction from an Automated Frequency Coordination System.

Subordinate Device. For the purpose of this subpart, a device that operates in the 5.925-7.125 GHz band under the control of an Indoor Access Point, is supplied power from a wired connection, has an integrated antenna, is not battery powered, does not have a weatherized enclosure, and does not have a direct connection to the internet. Subordinate devices must not be used to connect devices between separate buildings or structures. Subordinate devices must be authorized under certification procedures in part 2 of this chapter. Modules may not be certified as subordinate devices.

Transmit Power Control (TPC). A feature that enables a U-NII device to dynamically switch between several transmission power levels in the data transmission process.

U-NII devices. Intentional radiators operating in the frequency bands 5.15-5.35 GHz, 5.470-5.85 GHz, 5.925-7.125 GHz that use wideband digital modulation techniques and provide a wide array of high data rate mobile and fixed communications for individuals, businesses, and institutions.

6. Section 15.407 is amended by:

- A. Redesignating paragraphs (a)(4) and (5) as (a)(11) and (12);
- B. Adding paragraphs (a)(4) through (10);
- C. Revising newly redesignated paragraph (a)(12);
- D. Redesignating paragraphs (b)(5) through (8) as (b)(7) through (10);
- E. Adding paragraphs (b)(5) and (6), (d) and (k) through (n).

The additions and revisions read as follows.

§ 15.407 General technical requirements.

(a) * * *

(4) For a standard power access point and fixed client device operating in the 5.925-6.425 GHz and 6.525-6.875 GHz bands, the maximum power spectral density must not exceed 23 dBm e.i.r.p in any 1-megahertz band. In addition, the maximum e.i.r.p. over the frequency band of operation must not exceed 36 dBm. For outdoor devices, the maximum e.i.r.p. at any elevation angle above 30 degrees as measured from the horizon must not exceed 125 mW (21 dBm).

(5) For an indoor access point operating in the 5.925-7.125 GHz band, the maximum power spectral density must not exceed 5 dBm e.i.r.p. in any 1-megahertz band. In addition, the maximum e.i.r.p. over the frequency band of operation must not exceed 30 dBm.

(6) For a subordinate device operating under the control of an indoor access point in the 5.925-7.125 GHz band, the maximum power spectral density must not exceed 5 dBm e.i.r.p in

any 1-megahertz band, and the maximum e.i.r.p. over the frequency band of operation must not exceed 30 dBm.

(7) For client devices, except for fixed client devices as defined in this subpart, operating under the control of a standard power access point in 5.925-6.425 GHz and 6.525-6.875 GHz bands, the maximum power spectral density must not exceed 17 dBm e.i.r.p. in any 1-megahertz band, and the maximum e.i.r.p. over the frequency band of operation must not exceed 30 dBm and the device must limit its power to no more than 6 dB below its associated standard power access point's authorized transmit power.

(8) For client devices operating under the control of an indoor access point in the 5.925 - 7.125 GHz bands, the maximum power spectral density must not exceed -1 dBm e.i.r.p. in any 1-megahertz band, and the maximum e.i.r.p. over the frequency band of operation must not exceed 24 dBm.

(9) Access points operating under the provisions of paragraphs (a)(5) and(a)(6) of this section must employ a permanently attached integrated antenna.

(10) The maximum transmitter channel bandwidth for U-NII devices in the 5.925 – 7.125 GHz band is 320 megahertz

* * * * *

(12) Power spectral density measurement. The maximum power spectral density is measured as either a conducted emission by direct connection of a calibrated test instrument to the equipment under test or a radiated measurement. Measurements in the 5.725-5.85 GHz band are made over a reference bandwidth of 500 kHz or the 26 dB emission bandwidth of the device, whichever is less. Measurements in all other bands are made over a bandwidth of 1 MHz or the 26 dB emission bandwidth of the device, whichever is less. A narrower resolution bandwidth can be used, provided that the measured power is integrated over the full reference bandwidth.

(b) * * *

(5) For transmitters operating within the 5.925-7.125 GHz band: Any emissions outside of the 5.925-7.125 GHz band must not exceed an e.i.r.p. of -27 dBm/MHz.

(6) For transmitters operating within the 5.925-7.125 GHz bands: power spectral density must be suppressed by 20 dB at 1 MHz outside of channel edge, by 28 dB at one channel bandwidth from the channel center, and by 40 dB at one- and one-half times the channel bandwidth away from channel center. At frequencies between one megahertz outside an unlicensed device's channel edge and one channel bandwidth from the center of the channel, the limits must be linearly interpolated between 20 dB and 28 dB suppression, and at frequencies between one and one- and one-half times an unlicensed device's channel bandwidth, the limits must be linearly interpolated between 28 dB and 40 dB suppression. Emissions removed from the channel center by more than one- and one-half times the channel bandwidth must be suppressed by at least 40 dB.

* * * * *

(d) *Operational restrictions for 6 GHz U-NII devices.* (1) Operation of standard access points, fixed client devices and indoor access points in the 5.925-7.125 GHz band is prohibited on oil platforms, cars, trains, boats, and aircraft, except that indoor access points are permitted to operate in the 5.925-6.425 GHz bands in large aircraft while flying above 10,000 feet.

(2) Operation of transmitters in the 5.925-7.125 GHz band is prohibited for control of or communications with unmanned aircraft systems.

(3) Transmitters operating under the provisions of paragraphs (a)(5), (a)(6), and (a)(8) of this section are limited to indoor locations.

(4) In the 5.925-7.125 GHz band, indoor access points and subordinate devices must bear the following statement in a conspicuous location on the device and in the user's manual: FCC regulations restrict operation of this device to indoor use only. The operation of this device is prohibited on oil platforms, cars, trains, boats, and aircraft, except that operation of this device is permitted in large aircraft while flying above 10,000 feet.

(5) In the 5.925-7.125 GHz band, client devices, except fixed client devices, must operate under the control of a standard power access point, indoor access point or subordinate devices; Subordinate devices must operate under the control of an indoor access point. In all cases, an exception exists for transmitting brief messages to an access point when attempting to join its network after detecting a signal that confirms that an access point is operating on a particular channel. Access points and subordinate devices may connect to other access points or subordinate devices. Client devices are prohibited from connecting directly to another client device.

(6) Indoor access points, subordinate devices and client devices operating in the 5.925-7.125 GHz band must employ a contention-based protocol.

(7) Fixed client devices may only connect to a standard power access point.

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(k) *Automated frequency coordination (AFC) system.* (1) Standard power access points and fixed client devices operating under paragraph (a)(4) of this section must access an AFC system to determine the available frequencies and the maximum permissible power in each frequency range at their geographic coordinates prior to transmitting. Standard power access points and fixed client devices may transmit only on frequencies and at power levels that an AFC system indicates as available.

(2) An AFC system must be capable of determining the available frequencies in steps of no greater than 3 dB below the maximum permissible e.i.r.p of 36 dBm, and down to at least a minimum level of 21 dBm.

(3) An AFC system must obtain information on protected services within the 5.925-6.425 GHz and 6.525-6.875 GHz bands from Commission databases and use that information to determine frequency availability for standard power access points and fixed client devices based on protection criteria specified in paragraph (l)(2) of this section.

(4) An AFC system must use the information supplied by standard power access points and fixed client devices during registration, as set forth in this section, to determine available frequencies and the maximum permissible power in each frequency range for a standard power access point at any given location. All such determinations and assignments must be made in a non-discriminatory manner, consistent with this part.

(5) An AFC system must store registered information in a secure database until a standard power access point or fixed client device ceases operation at a location. For the purpose of this paragraph, a standard power access point or fixed client device is considered to have ceased operation when that device has not contacted the AFC system for more than three months to verify frequency availability information.

(6) An AFC system must verify the validity of the FCC identifier (FCC ID) of any standard power access point and fixed client device seeking access to its services prior to authorizing the access point to begin operation. A list of standard power access points with valid FCC IDs and the FCC IDs of those devices must be obtained from the Commission's Equipment Authorization System.

(7) The general purposes of AFC system include:

(i) Enacting all policies and procedures developed by the AFC system operators pursuant to this section.

(ii) Registering, authenticating, and authorizing standard power access point and fixed client device operations, individually or through a network element device representing multiple standard power access points from the same operating network.

(iii) Providing standard power access points and fixed client devices with the permissible frequencies and the maximum permissible power in each frequency range at their locations using propagation models and interference protection criteria defined in paragraph (1) of this section.

(iv) Obtaining updated protected sites information from Commission databases.

(8) Standard power access points and fixed client devices:

(i) Must register with and be authorized by an AFC system prior to the standard power access point and fixed client device's initial service transmission, or after a standard power access point or fixed client device changes location, and must obtain a list of available frequencies and the maximum permissible power in each frequency range at the standard power access point and fixed client device's location.

(ii) Must register with the AFC system by providing the following parameters: geographic coordinates (latitude and longitude referenced to North American Datum 1983 (NAD 83)), antenna height above ground level, FCC identification number, and unique manufacturer's serial number. If any of these parameters change, the standard power access point or fixed client device must provide updated parameters to the AFC system. All information provided by the standard power access point and the fixed client device to the AFC system must be true, complete, correct, and made in good faith.

(iii) Must provide the registration information to the AFC system either directly and individually or by a network element representing multiple standard power access points or fixed client devices from the same operating network. The standard power access point, fixed client device or its network element must register with the AFC system via any communication link, wired or wireless, outside 5.925-6.425 GHz and 6.525-6.875 GHz bands.

(iv) Must contact an AFC system at least once per day to obtain the latest list of available frequencies and the maximum permissible power the standard power access point or fixed client device may operate with on each frequency at the standard power access point and fixed client device's location. If the standard power access point or fixed client device fails to successfully contact the AFC system during any given day, the standard power access point or fixed client device may continue to operate until 11:59 p.m. of the following day at which time it must cease operations until it re-establishes contact with the AFC system and re-verifies its list of available frequencies and associated power levels.

(v) Must incorporate adequate security measures to prevent it from accessing AFC systems not approved by the FCC and to ensure that unauthorized parties cannot modify the device to operate in a manner inconsistent with the rules and protection criteria set forth in this section and to ensure that communications between standard power access points, fixed client devices and AFC systems are secure to prevent corruption or unauthorized interception of data. Additionally, the AFC system must incorporate security measures to protect against unauthorized data input or alteration of stored data, including establishing communications authentication procedures between client devices and standard power access points.

(9) Standard power access point and fixed client device geo-location capability:

(i) A standard power access point and a fixed client device must include either an internal geo-location capability or an integrated capability to securely connect to an external geolocation devices or service, to automatically determine the standard power access point's geographic coordinates and location uncertainty (in meters), with a confidence level of 95%. The standard power access point and fixed client device must report such coordinates and location uncertainty to an AFC system at the time of activation from a power-off condition.

(ii) An external geo-location source may be connected to a standard power access point or fixed client device through either a wired or a wireless connection. A single geo-location source may provide location information to multiple standard power access points or fixed client devices.

(iii) An external geo-location source must be connected to a standard power access point or fixed client device using a secure connection that ensures that only an external geo-location source approved for use with a standard power access point or fixed client device provides geographic coordinates to that standard power access point or fixed client device. Alternatively, an extender cable may be used to connect a remote receive antenna to a geo-location receiver within a standard power access point or fixed client device.

(iv) The applicant for certification of a standard power access point or fixed client device must demonstrate the accuracy of the geo-location method used and the location uncertainty. For standard power access points and fixed client devices that may not use 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 standard power access point or fixed client device.

(10) An AFC system operator will be designated for a five-year term which can be renewed by the Commission based on the operator's performance during the term. If an AFC system ceases operation, it must provide at least 30-days' notice to the Commission and transfer any registration data to another AFC system operator.

(11) The Commission will designate one or more AFC system operators to provide service in the 5.925-6.425 GHz and 6.525-6.875 GHz bands.

(12) The Commission may permit the functions of an AFC system, such as a data repository, registration, and query services, to be divided among multiple entities; however, entities designated as AFC system operators will be held accountable for the overall functioning and system administration of the AFC system.

(13) The AFC system must ensure that all communications and interactions between the AFC system and standard power access points and fixed client devices are accurate and secure and that unauthorized parties cannot access or alter the database, or the list of available frequencies and associated powers sent to a standard power access point.

(14) An AFC system must implement the terms of international agreements with Mexico and Canada.

(15) Each AFC system operator designated by the Commission must:

(i) Maintain a regularly updated AFC system database that contains the information described in this section, including incumbent's information and standard power access points and fixed client devices registration parameters.

(ii) Establish and follow protocols and procedures to ensure compliance with the rules set forth in this part.

(iii) Establish and follow protocols and procedures sufficient to ensure that all communications and interactions between the AFC system and standard power access points and fixed client devices are accurate and secure and that unauthorized parties cannot access or alter the AFC system, or the information transmitted from the AFC system to standard power access points or fixed client devices.

(iv) Provide service for a five-year term. This term may be renewed at the Commission's discretion.

(v) Respond in a timely manner to verify, correct, or remove, as appropriate, data in the event that the Commission or a party presents to the AFC system Operator a claim of inaccuracies in the AFC system. This requirement applies only to information that the Commission requires to be stored in the AFC system.

(vi) Establish and follow protocols to comply with enforcement instructions from the Commission, including discontinuance of standard power access point operations in designated geographic areas.

(16) An AFC system operator may charge fees for providing service in registration and channel availability functions. The Commission may, upon request, review the fees and can require changes to those fees if the Commission finds them unreasonable.

(l) *Incumbent Protection by AFC system: Fixed Microwave Services.* A standard power access point or fixed client device must not cause harmful interference to fixed microwave services authorized to operate in the 5.925-6.425 GHz and 6.525-6.875 GHz bands. Based on the criteria set forth below, an AFC system must establish location and frequency-based exclusion zones (both co-channel and adjacent channel) around fixed microwave receivers operating in the 5.925-6.425 GHz and 6.525-6.875 GHz bands. Individual standard power access points and fixed client devices must not operate co-channel to fixed microwave system frequencies within co-

channel exclusion zones, or on adjacent channel frequencies within adjacent channel exclusion zones.

(1) Propagation Models: Propagation models to determine the appropriate separation distance between a standard power access point or a fixed client device and an incumbent fixed microwave service receiver. For a separation distance:

(i) Up to 30 meters, the AFC system must use the free space path-loss model.

(ii) More than 30 meters and up to and including one kilometer, the AFC system must use the Wireless World Initiative New Radio phase II (WINNER II) model. The AFC system must use site-specific information, including buildings and terrain data, for determining the line-of-sight/non-line-of-sight path component in the WINNER II model, where such data is available. For evaluating paths where such data is not available, the AFC system must use a probabilistic model combining the line-of-sight path and non-line-of-sight path into a single path-loss as follows: $\text{Path-loss (L)} = \sum_i P(i) * L_i = P_{\text{LOS}} * L_{\text{LOS}} + P_{\text{NLOS}} * L_{\text{NLOS}}$, where P_{LOS} is the probability of line-of-sight, L_{LOS} is the line-of-sight path loss, P_{NLOS} is the probability of non-line-of sight, L_{NLOS} is the non-line-of-sight path loss, and L is the combined path loss. The WINNER II path loss models include a formula to determine P_{LOS} as a function of antenna heights and distance. P_{NLOS} is equal to $(1-P_{\text{LOS}})$. In all cases, the AFC system will use the correct WINNER II parameters to match the morphology of the path between a standard power access point and a fixed microwave receiver (i.e., Urban, Suburban, or Rural).

(iii) More than one kilometer, the AFC system must use Irregular Terrain Model (ITM) combined with the appropriate clutter model. To account for the effects of clutter, such as buildings and foliage, that the AFC system must combine the ITM with the ITU-R P.2108-0 (06/2017) clutter model for urban and suburban environments and the ITU-R P.452-16 (07/2015) clutter model for rural environments. The AFC system should use the most appropriate clutter category for the local morphology when using ITU-R P.452-16. However, if detailed local information is not available, the “Village Centre” clutter category should be used. The AFC

system must use 1 arc-second digital elevation terrain data and, for locations where such data is not available, the most granular available digital elevation terrain data.

(2) Interference Protection Criteria:

(i) The AFC system must use -6 dB I/N as the interference protection criteria in determining the size of the co-channel exclusion zone where I (interference) is the co-channel signal from the standard power access point or fixed client device at the fixed microwave service receiver, and N (noise) is background noise level at the fixed microwave service receiver.

(ii) The AFC system must use -6 dB I/N as the interference protection criteria in determining the size of the adjacent channel exclusion zone, where I (interference) is the signal from the standard power access point or fixed client device's out of channel emissions at the fixed microwave service receiver and N (noise) is background noise level at the fixed microwave service receiver. The adjacent channel exclusion zone must be calculated based on the emissions requirements of paragraph (b)(6) of this section.

(m) *Incumbent Protection by AFC system: Radio Astronomy Services.* The AFC system must enforce an exclusion zones to the following radio observatories that observe between 6650-6675.2 MHz: Arecibo Observatory, the Green Bank Observatory, the Very Large Array (VLA), the 10 Stations of the Very Long Baseline Array (VLBA), the Owens Valley Radio Observatory, and the Allen Telescope Array. The exclusion zone sizes are based on the radio line-of-sight and determined using 4/3 earth curvature and the following formula: $d_{km_los} = 4.12 * (\sqrt{H_{tx}} + \sqrt{H_{rx}})$, where H_{tx} is the height of the unlicensed standard power access point or fixed client device and H_{rx} is the height of the radio astronomy antenna in meters above ground level. Coordinate locations of the radio observatories are listed in section 2.106, notes US 131 and US 385 of this part.

(n) *Incumbent Protection by AFC system: Fixed-Satellite Services.* Standard power access points and fixed client devices located outdoors must limit their maximum e.i.r.p. at any

elevation angle above 30 degrees as measured from the horizon to 21 dBm (125 mW) to protect fixed satellite services.

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