Functional Requirements for the U.S. 6 GHz Band under the Control of an AFC System

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Functional Requirements for the U.S. 6 GHz Band under the Control of an AFC System

1 Scope

The scope of this technical specification is to define the functional requirements for the AFC System, AFC System Operator, Standard Power Access Points, Fixed Client Devices and Proxies and to specify the necessary standards to enable test and certification procedures for a properly functioning environment in the 6 GHz band. The functional requirements specified in this specification are based on Federal Communications Commission (FCC) rules governing the use of 6 GHz band subject to the control of an AFC System, which are codified in Part 15 Subpart E of Title 47 the U.S. Code of Federal Regulations [n.1] adopted in the 2021.

The requirements captured in this specification, outside of the normative annexes, are described in a technology neutral manner and applicable for any unlicensed wireless communication technology operating in the 6 GHz band under the Part 15 Subpart E rules in the 6 GHz band. This specification will be further extended to include the following topics in different normative annexes.

- Technology-neutral optional features and the requirements for those features that are not required to be tested for FCC certification;
- Technology-specific optional features and the requirements for those features that are required to be tested for FCC certification if implemented by an AFC System, a Proxy, a Standard Power Access Point or a Fixed Client Device; and,
- Technology-specific optional features and the requirements for those features that are not required to be tested for the FCC certification.

The FCC's Part 15 Subpart E rules will hereafter be referred to as "the FCC Rules", "the Rules" or "Part 15" and reference to specific items in the rules will be given in the form of, for example, 15.407(k)(16) if from Part 15.

NOTE 1: Not all the 6 GHz-specific rules are captured in this specification as this document is not a comprehensive list of requirements for the implementation or operation of an AFC System, Proxy, Standard Power Access Point or Fixed Client Device. AFC System operation, components and/or devices, as applicable, are expected to comply with the rules that are not considered in this specification.

NOTE 2: Unless otherwise specified, "Standard Power Access Point" and "Fixed Client Device" are collectively referred to as "Standard Power Device" in this document.

2 References

2.1 Normative References

The following referenced documents are necessary for the application of the present document.

[n.1] Title 47, Code of Federal Regulations, Part 15 Subpart E - Unlicensed National Information Infrastructure Devices, available at: https://ecfr.federalregister.gov/current/title-47/chapter-I/subchapter-A/part-15/subpart-E

[n.2] RFC-2119, "Key words for use in RFCs to Indicate Requirement Levels", March 1997. Available at: https://tools.ietf.org/html/rfc2119

[n.3] Federal Communications Commission, Unlicensed Use of the 6 GHz Band Report and Order and Further Notice of Proposed Rulemaking ET Docket No. 18-295; GN Docket No. 17-183, available at: https://docs.fcc.gov/public/attachments/FCC-20-51A1_Rcd.pdf

[n.4] P. Kyösti et al., "WINNER II channel models", IST-4-027756 WINNER II Deliverable D1.1.2, 2008, available at: https://www.cept.org/files/8339/winner2%20-%20final%20report.pdf

[n.5] NTIA – ITS Irregular Terrain Model (ITM) (Longley-Rice) (20MHz-20 GHz), available at: http://www.its.bldrdoc.gov/resources/radio-propagation-software/itm/itm.aspx

[n.6] ITU-R P.2108: Prediction of clutter loss (P.2108-0 (06/2017)), available at https://www.itu.int/rec/R-REC-P.2108/en

[n.7] ITU-R P.452: Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz (P.452-16 (07/2015)), available at https://www.itu.int/rec/R-REC-P.452-16-201507-I/en

[n.8] Federal Communications Commission, "Unlicensed Use of the 6 GHz Band; Review of the Commission's Rules Governing the 896-901/935-940 MHz Band", Federal Register / Vol. 86, No. 32, available at: https://www.federalregister.gov/documents/2021/02/19/2021-00782/unlicensed-use-of-the-6-ghz-band-review-of-the-commissions-rules-governing-the-896-901935-940-mhz

[n.9] RFC-2616, "Hypertext Transfer Protocol -- HTTP/1.1", Fielding, Gettys, Mogul, Frystyk, Masinter, Leach and Berners-Lee, June 1999.

[n.10] RFC-5246, "The Transport Layer Security (TLS) Protocol Version 1.2", Dierks and Rescorla, August 2008.

[n.11] RFC-8446, "The Transport Layer Security (TLS) Protocol Version 1.3", E. Rescorla and Mozilla, August 2018

[n.12] 3GPP TS 38.101-1, "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone", available at: https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3283

[n.13] 3GPP TS 38.104, "NR; Base Station (BS) radio transmission and reception", available at: https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3202

[n.14] Wi-Fi Alliance AFC System to AFC Device Interface Specification, available at: https://www.wi-fi.org/file/afc-system-to-afc-device-interface-specification

[n.15] ITU Recommendation ITU-R F.699-8, "Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to 86 GHz", available at https://www.itu.int/rec/R-REC-F.699/en

[n.16] 47 C.F.R. §101.115(b)(2), available at https://www.ecfr.gov/current/title-47/chapter-I/subchapter-D/part-101#101.115

[n.17] WINNF-TS-5008, "6 GHz Supplementary Data Repository Technical Specification", Wireless Innovation Forum

[n.18] National Land Cover Database (NLCD) data for CONUS, Alaska, Hawaii and Puerto Rico, available at https://www.mrlc.gov/data

[n.19] ULS Data File Format, available at, https://www.fcc.gov/sites/default/files/public_access_database_definitions_v6.pdf

[n.20] 47 C.F.R. §101.147(i), available at: https://www.ecfr.gov/current/title-47/chapter-I/subchapter-D/part-101/subpart-C/section-101.147#p-101.147(i)

[n.21] 47 C.F.R. §101.147(k), available at: https://www.ecfr.gov/current/title-47/chapter-I/subchapter-D/part-101/subpart-C/section-101.147#p-101.147(k)

[n.22] KDB 987594 D05 AFC DUT Test Harness Testing v01 (August 7, 2023), available at: https://apps.fcc.gov/kdb/GetAttachment.html?id=bTx5S2dBrBUu%2F%2F1kuciwtw%3D%3D&desc=987594%20D05%20AFC%20DUT%20Test%20Harness%20Testing%20v01&tracking_number=277034

2.2 Informative References

The following referenced documents are not necessary for the application of the present document, but they assist the reader with regard to a particular subject area.

[i.1] RFC-8996, "Deprecating TLS 1.0 and TLS 1.1", K. Moriarty, CIS, S. Farrell, Trinity College Dublin, March 2021

[i.2] NIST Special Publication 800-52 Revision 2, "Guidelines for the Selection, Configuration, and Use of Transport Layer Security (TLS) Implementations", August 2019, available at: https://doi.org/10.6028/NIST.SP.800-52r2

[i.3] RFC-7525, "Recommendations for Secure Use of Transport Layer Security (TLS) and Datagram Transport Layer Security (DTLS)", Y. Sheffer, Intuit, R. Holz, NICTA, P. Saint-Andre, &yet, May 2015

[i.4] IEEE Std 802.11ax™-2021, "IEEE Standard for Information Technology--Telecommunications and Information Exchange between Systems Local and Metropolitan Area Networks--Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 1: Enhancements for High-Efficiency WLAN", May 2021.

[i.5] TIA-10 (2019 Edition), "Interference Criteria for Microwave Systems", The Telecommunications Industry Association

[i.6] ITU Recommendation ITU-R F.758-7, "System parameters and considerations in the development of criteria for sharing or compatibility between digital fixed wireless systems in the fixed service and systems in other services and other sources of interference".

[i.7] Federal Communications Commission, "The Commission Begins The Process For Authorizing 6 GHz Band Automated Frequency Coordination Systems", FCC 21-100, available at: https://ecfsapi.fcc.gov/file/09281454120568/FCC-21-100A1.pdf

[i.8] R. C. Hansen, "A One-Parameter Circular Aperture Distribution with Narrow Beamwidth and Low Sidelobes", Trans. IEEE, vol. AP-24 no.4, pp. 477-480, July 1976.

[i.9] ETSI EN 319 403-1 V2.3.1 (2020-06), "Electronic Signatures and Infrastructures (ESI); Trust Service Provider Conformity Assessment; Part 1: Requirements for conformity assessment bodies assessing Trust Service Providers", available at: https://www.etsi.org/deliver/etsi_en/319400_319499/31940301/02.03.01_60/en_31940301v020301p.pdf

[i.10] CA/Browser Forum Baseline Requirements, available at: https://cabforum.org/baseline-requirements-documents

[i.11] WINNF-TS-0022, "WInnForum CBRS Certificate Policy", available at: https://winnf.memberclicks.net/assets/CBRS/WINNF-TS-0022.pdf

[i.12] Passive Repeater Engineering, Microflect Co. Inc. 1989, Catalog 161A; available at: http://www.qrp.gr/passivereptitan/Passive_repeaters.pdf

3 Definitions, Abbreviations and Symbols

3.1 Definitions

3.1.1 FCC Definitions

The Wireless Innovation Forum 6 GHz Committee leverages the definitions provided by the FCC from 47 CFR 15.403. These definitions and others are also available at reference [n.1].

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.

> NOTE: Although not explicitly stated in the definition, the AFC System provides lists of which frequencies are available for use by Fixed Client Devices in the same way as to Standard Power Access Points operating in the 5.925-6.425 GHz and 6.525-6.875 GHz bands. (See the definition of Fixed Client Device)

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.

Fixed Client Device: A Client Device intended as customer premise equipment that is permanently attached to a structure, operates only on channels provided by an AFC System, has a geolocation capability, and complies with antenna pointing angle requirements.

> NOTE: WInnForum believes that the FCC allows a Fixed Client Device to operate as a Client Device in accordance with 15.407(a)(7), 15.407(d)(5) and 15.407(d)(7), and, while doing so, to communicate with an AFC System.

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.

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.

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.

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.

3.1.2 WInnForum Definitions

AFC System Operator: An entity designated by the Commission to operate an AFC System in accordance with the rules and procedures set forth in the Part 15 Subpart E.

Available Channel: A Channel, determined by an AFC System, on which a Standard Power Device is allowed to operate at its geographic coordinates.

> NOTE: For the purpose of this document, the WInnForum definition of *Available Channel* takes precedence over the definition in the 47 CFR Part 15 Subpart E [n.1] since the FCC-defined *Available Channel* applies only in the context of its DFS rules.

Channel: A contiguous frequency range between lower and upper frequency limits.

FS Link Path: A sequence of Segments between a fixed service transmitter and a fixed service receiver.

Passive Sites: A terminology collectively referring to 1) a passive repeater consisting of back-to-back antennas connected to each other by waveguide or cable, 2) a single billboard reflector, or 3) a double passive reflector consisting of two billboard reflectors typically less than 120 meters from each other.

NOTE: Double passive reflectors are treated as two single billboard reflectors as per R2-AIP-31.

Proxy: A network entity engaging in communications with an AFC System on behalf of one or more Standard Power Devices, or networks of such devices.

NOTE: The WInnForum has defined this terminology such that it becomes equivalent to the term "network element representing multiple Standard Power Access Points or Fixed Client Devices" or "network element device representing multiple Standard Power Access Points or Fixed Client Devices" used by the FCC in some of the rules. For R0 requirements using these terms, "[Proxy]" is inserted for clarification purposes.

Segment: A path within an FS Link between a fixed service transmitter and a fixed service receiver (when there are no Passive Sites), between a fixed service transmitter and a Passive Site, between two Passive Sites, or between a Passive Site and a fixed service receiver.

NOTE: For an FS Link Path without any Passive Site, the FS Link Path has a single segment between the fixed service transmitter and receiver. For an FS Link Path containing *n* Passive Sites, it has *n*+1 Segments between the transmitter and receiver, where the first Segment is from the fixed service transmitter to the first Passive Site, the next Segment is from the first Passive Site to the second Passive Site and so on. The final Segment ends at the fixed service receiver.

Server Certificate: A digital certificate issued to a server for the purpose of authenticating its identity and creating secure communication channels to its clients.

Standard Power Device: A terminology collectively referring to Standard Power Access Point and Fixed Client Device.

NOTE: In this document, this terminology is used for R1, R2 and R3 requirements.

Trusted CA: A certificate authority (CA) which has been proven to be secure by an external WebTrust audit or equivalent (e.g., ETSI EN 319 403 [i.9]).

NOTE: Example policies against which such audit would occur are CA/Browser Forum Baseline Requirements [i.10] and WINNF-TS-0022 [i.11].

Virtual Receiver: A term referring to a Passive Site as fixed service receiver virtually.

3.2 Abbreviations

3GPP	3rd Generation Partnership Project

AFC	Automated Frequency Coordination
AGL	Above Ground Level
BER	Bit Error Rate
DFS	Dynamic Frequency Selection
e.i.r.p.	Equivalent Isotropically Radiated Power
FCC	Federal Communications Commission
FS	Fixed Service
HH	The response of a horizontally polarized antenna port to a horizontally polarized signal
HV	The response of a horizontally polarized antenna port to a vertically polarized signal
IEEE	Institute of Electrical and Electronic Engineers
ITM	Irregular Terrain Model
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication Sector
NAD	North American Datum
NIST	National Institute of Standards and Technology
NLCD	National Land Cover Database
OET	Office of Engineering and Technology
RPE	Radiation Pattern Envelope
TIA	Telecommunications Industry Association
ULS	Universal Licensing System
U-NII	Unlicensed National Information Infrastructure
VH	The response of a vertically polarized antenna port to a horizontally polarized signal
VV	The response of a vertically polarized antenna port to a vertically polarized signal
WINNER II	Wireless World Initiative New Radio phase II

3.3 Symbols

$[a : b]$	from a to b inclusive (where a and b are numerical values)

A_{R}	Area of receiving reflector (in m^2)
A_{T}	Area of transmitting reflector (in m^2)
BW_{FS}	Channel bandwidth of the fixed microwave service receiver
c	The speed of light
D_{DRx}	Fixed service diversity receive antenna diameter
$d_{\mathrm{FSRx\text{-}Eval}}$	Distance between the FS receiver antenna and the evaluation point
$d_{\mathrm{FSTx\text{-}FSRx}}$	Distance between fixed service transmit and receive antennas
d_{Limit}	Near field distance limit
$d_{\mathrm{PathSegLength}}$	Path segment length (in meters)
D_{Rx}	Fixed service primary receive antenna diameter
$D_{\mathrm{Rx,\ B\text{-}B}}$	Diameter of receiving back-to-back antenna (in meters)
$D_{\mathrm{Rx,\ Next}}$	Diameter of the antenna at the next site towards the actual FS receiver
$D_{\mathrm{Rx,\ NFA}}$	Fixed service primary receive antenna diameter for near field adjustment
$D_{\mathrm{Tx,\ B\text{-}B}}$	Diameter of transmitting back-to-back antenna (in meters)
dkm_los	Size of the exclusion zone to protect the radio astronomy antenna
$F_{\mathrm{c,\ FS\text{-}Rx,\ ULS}}$	Center frequency of fixed service receiver recorded in the ULS
$F_{\mathrm{c,\ U\text{-}NII\text{-}band}}$	Center frequency of a U-NII band (i.e., 5925-6425 MHz or 6525-6875 MHz)
G_0	The boresight gain of the fixed service receiver antenna
G_{CDisc}	The effective antenna discrimination of the fixed service receiver co-polarization RPE
G_{Common}	The most common antenna gain for the antenna model
G_{Disc}	The effective discrimination of the antenna RPE
G_{DRx}	Fixed service diversity receive antenna gain
$\mathrm{G}_{\mathrm{VRx}\text{-}j\mathrm{,\ Effective}}$	Effective gain of the j-th Virtual Receiver
G_{MB}	The mid-band antenna gain
G_{Rx}	Fixed service primary receive antenna gain
$G_{\mathrm{Rx,\ AZ\text{-}RPE}}$	Fixed service receive antenna azimuthal RPE
$G_{\mathrm{Rx,\ B\text{-}B}}$	Receiving back-to-back antenna gain
$G_{\mathrm{Rx,\ B\text{-}B,\ ULS}}$	Fixed service receive back-to-back antenna gain recorded in the ULS
$G_{\mathrm{Rx,\ C\text{-}RPE}}$	The co-polarization RPE of the fixed service receiver antenna
$G_{\mathrm{Rx,\ Effective}}$	The effective antenna gain of the fixed service receiver antenna
$G_{\mathrm{Rx,\ EL\text{-}RPE}}$	Fixed service receive antenna elevation RPE
$G_{\mathrm{Rx,\ HH\text{-}RPE}}$	HH RPE of the fixed service receiver antenna

$G_{\text{Rx, HV-RPE}}$	HV RPE of the fixed service receiver antenna
$G_{\text{Rx, ULS}}$	Fixed service primary receive antenna gain recorded in the ULS
$G_{\text{Rx, VH-RPE}}$	VH RPE of the fixed service receiver antenna
$G_{\text{Rx, VV-RPE}}$	VV RPE of the fixed service receiver antenna
$G_{\text{Rx, XX-RPE}}$	Discrimination value for an unspecified polarization
G_{Typical}	The typical antenna gain for a given antenna of diameter of a fixed service microwave receiver
$G_{\text{Tx, B-B}}$	Transmitting back-to-back antenna gain
$G_{\text{Tx, B-B, ULS}}$	Fixed service transmit back-to-back antenna gain recorded in the ULS
$G_{\text{Tx, ULS}}$	Fixed service transmit antenna gain recorded in the ULS
$G_{\text{VRx-}j\text{, Disc}}$	The antenna discrimination of the *j*-th Virtual Receiver antenna
G_{XDisc}	The effective antenna discrimination of the fixed service receiver cross-polarization RPE
$H_{\text{EP (AMSL)}}$	Height above mean sea level of an evaluation point in km
$H_{\text{FS, DRx (AGL)}}$	Fixed service diversity receive antenna height above ground level
$H_{\text{FS, Rx (AMSL)}}$	Fixed service receive antenna height above mean sea level
$H_{\text{FS, Rx (AGL)}}$	Fixed service receive antenna height above ground level
$H_{\text{FS, Tx (AMSL)}}$	height of fixed service transmit site (AMSL) in km.
$H_{\text{Ref-AntennaModel}}$	Reflector Height associated with the antenna model recorded in the ULS
$H_{\text{Ref-ULS}}$	Reflector Height recorded in the ULS
$H_{\text{SPD (AGL)}}$	Height above ground level reported by the Standard Power Device (in meters)
Hrx	Height of the radio astronomy antenna above ground level
Htx	Height of the unlicensed Standard Power Device above ground level
I	Interference from the Standard Power Device at the fixed microwave service receiver
$I/N_{\text{Rx, Est}}$	Estimated interference-to-noise ratio at the fixed service receiver or diversity receiver
$I/N_{\text{VRx-}j\text{, Est}}$	Estimated interference-to-noise ratio at the *j*-th Virtual Receiver
I/N_{Thres}	Interference-to-noise ratio as the interference protection criteria
k_{B}	Boltzmann's constant
L	Combined path loss
L_{BEL}	Building Entry Loss
$L_{\text{FS, Feeder}}$	Fixed service receiver feeder loss, which is the total loss between the fixed service receive antenna port and the transceiver receive port.

L_{LOS}	Line-of-sight path loss
$L_{Propagation, Rx}$	Propagation loss between the Standard Power Device and FS receiver antenna
$L_{Propagation, VRx\text{-}j}$	Propagation loss between the Standard Power Device and the *j*-th Virtual Receiver
L_{WG}	Connecting waveguide/cable loss
N	Background noise level at the fixed microwave service receiver
NF	Noise figure
P_{LOS}	Probability of line-of-sight
P_{NLOS}	Probability of non-line-of-sight
$P_{SPD, Tx}$	The Standard Power Device transmission power across the frequency range I/N_{Est} calculations are performed.
r_{Earth}	Effective radius of the Earth (= 8500 km)
T	Threshold level
T/I	Threshold-to-interference
T_0	Standard temperature
u	FS antenna discrimination parameter
$W_{Ref\text{-}AntennaModel}$	Reflector Width associated with the antenna model recorded in the ULS
$W_{Ref\text{-}ULS}$	Reflector Width recorded in the ULS
x_{dB}	Normalized separation distance
ΔH_{SPD}	Vertical uncertainty reported by the Standard Power Device (in meters)
η_{Rx}	Antenna aperture efficiency
$\eta_{Rx, B\text{-}B}$	Antenna aperture efficiency for back-to-back passive receiver
$\eta_{Rx, NFA}$	Antenna aperture efficiency for near field adjustment
$\theta_{AZ\text{-}Bearing\text{-}To\text{-}Eval}$	The bearing angle of the azimuth plane to the evaluation point with respect to the fixed service receive antenna
$\theta_{AZ\text{-}Boresight}$	The fixed service receive antenna boresight direction of the azimuth plane with respect to true north
θ_{DDisc}	The angle-off-boresight between vectors from Standard Power Device to fixed service diversity receive antenna and from segment transmitter (e.g., fixed service transmitter, passive reflector) to fixed service diversity receive antenna, and reflects both the horizontal azimuth and vertical elevation
θ_{Disc}	The angle-off-boresight between vectors from Standard Power Device to fixed service primary receive antenna and from segment transmitter (e.g., fixed service transmitter, passive reflector) to fixed service primary receive antenna, and reflects both the horizontal azimuth and vertical elevation

$\varphi_{FSRx\text{-}Eval}$	Off-boresight axis angle in a direction from the FS receiver antenna towards the evaluation point
λ	Wavelength (= $c/F_{c,\ U\text{-}NII\text{-}band}$) (in meters)
$\sigma_{CPL\ (dB)}$	Standard deviation in dB of combined path loss
$\sigma_{LOS\ (dB)}$	Standard deviation of LOS path loss (i.e., L_{LOS}) in dB
$\sigma_{NLOS\ (dB)}$	Standard deviation of NLOS path loss (i.e., L_{NLOS}) in dB

4 Requirement Organization

Requirements shall be uniquely identified by: R#-<FEATURE>-<CATEGORY>-<XX>-<Y>, where R<#> is defined by:

- R0-: Requirements directly from FCC rules
  R1-: Requirements derived from FCC rules or from the text of an applicable FCC order
  R2-: Requirements imposed by WInnForum to meet FCC rules
  R3-: Requirements imposed by WInnForum to meet industry needs.

  NOTE: Support of R3 requirements for some optional features specified in normative annexes will need to be considered in the protection of fixed service receivers and radio astronomy service facilities in accordance with the technology neutral requirements specified in the main body of this technical specification. See details in each normative annex.

- <FEATURE>: Unique feature identifier for which the requirements are applicable.

  NOTE: If this tag is not present, the requirement is not feature specific.

- <CATEGORY>: Categorization of the requirement by using a code from the table below:

Table 1: Requirements Categorization

Code	Category
DGR	Standard Power Device General Requirements
DSQ	Standard Power Device Security Requirements
AGR	AFC System General Requirements
ASQ	AFC System Security Requirements
AIP	AFC System Incumbent Protection

- <XX>: Unique number to identify the requirement

- <Y>: Optional and used to identify subordinate requirements, typically captured in an alphabetical list following the main requirement number <XX> (e.g., R0-DTR-06-a).

Requirements taken from the FCC Rules are included as “R0” and we attempted to use the FCC Rules without change. In some instances, the FCC uses “must”, “should” or “will” for the rules, which we have included below as “R0” requirements; however, [shall] is inserted to indicate this is considered as a mandatory requirement. In addition, the FCC uses the term "network element" or "network element device" in some of the rules which have been adopted for "R0" requirements in this specification; for these cases the term [Proxy] is inserted for clarification purposes. Furthermore, citations used in the FCC rule are converted into the corresponding requirement numbers in this specification.

The following terms are used within this document and should be interpreted as described in RFC-2119 [n.2]:

- SHALL is a mandatory requirement (negative is SHALL NOT)
- SHOULD is recommended requirement/best practice (negative is SHOULD NOT)
- MAY is an optional requirement, i.e. something that is allowed (negative is NEED NOT)

5 Standard Power Device General Requirements (DGR)

5.1 Device Registration and Spectrum Inquiry

R0-DGR-01 Device registration requirements:

a. Standard Power Access Points and Fixed Client Devices must [shall] 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. (15.407(k)(8)(i))

b. Standard Power Access Points and Fixed Client Devices must [shall] 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. (15.407(k)(8)(ii))

   i. If any of these parameters change, the Standard Power Access Point or Fixed Client Device must [shall] provide updated parameters to the AFC System.

c. Standard Power Access Points and Fixed Client Devices must [shall] provide the registration information to the AFC System either directly and individually or by a network element [Proxy] representing multiple Standard Power Access Points or Fixed Client Devices from the same operating network. (15.407(k)(8)(iii))

R2-DGR-07 In addition to registration parameters required by R0-DGR-01-b, Standard Power Device may notify the AFC System whether it is located indoors.

R0-DGR-02 Standard Power Access Points and Fixed Client Devices may transmit only on frequencies and at power levels that an AFC System indicates as available. (15.407(k)(1))

R0-DGR-06 Standard Power Access Points and Fixed Client Devices operating under CFR 15.407(a)(4) must [shall] 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. (15.407(k)(1))

R0-DGR-03 Standard Power Access Points and Fixed Client Devices must [shall] 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. (15.407(k)(8)(iv))

R0-DGR-04 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 [shall] cease operations until it re-establishes contact with the AFC System and re-verifies its list of available frequencies and associated power levels. (15.407(k)(8)(iv))

R2-DGR-02 When contacting the AFC System in accordance with R0-DGR-03, the Standard Power Device shall query the AFC System for the frequency availability using one of the following methods:

a. Query the AFC System for a frequency range(s) without specifying a Channel size across which it will operate.

b. Query the AFC System for Channel(s) identified in a manner specific to an air interface that defines its upper and lower frequency boundaries and bandwidth.

R2-DGR-05 The frequency range(s) queried by the Standard Power Device following R2-DGR-02-a shall include up to one and one-half times the device's intended operating Channel bandwidth away from the Channel's center frequency to the extent that such frequencies are within the U-NII-5 and U-NII-7 bands.

R2-DGR-06 In R0-DGR-04, the Standard Power Device shall use the time zone of its geographic coordinates (i.e., local time).

R3-DGR-01 Deprecated.

5.2 Geolocation Capability

R0-DGR-05 Geolocation capability:

a. A Standard Power Access Point and a Fixed Client Device must [shall] report such coordinates [its geographic coordinates] and location uncertainty to an AFC System at the time of activation from a power-off condition. (15.407(k)(9)(i))

b. An external geolocation source may be connected to a Standard Power Access Point or Fixed Client Device through either a wired or a wireless connection. A single geolocation source may provide location information to multiple Standard Power Access Points or Fixed Client Devices. (15.407(k)(9)(ii))

c. The applicant for certification of a Standard Power Access Point or Fixed Client Device must [shall] demonstrate the accuracy of the geolocation method used and the location uncertainty. (15.407(k)(9)(iv))

d. For Standard Power Access Points and Fixed Client Devices that may not use an internal geo-location capability, this uncertainty must [shall] account for the accuracy of the geolocation source and the separation distance between such source and the Standard Power Access Point or Fixed Client Device. (15.407(k)(9)(iv))

R1-DGR-01 A Standard Power Device must [shall] include either an internal geolocation capability or an integrated capability to securely connect to an external geolocation devices or service, to automatically determine the Standard Power Device's geographic coordinates and location uncertainty (in meters), with a confidence level of 95 %. (15.407(k)(9)(i))

5.3 Use of Proxy

R2-DGR-01 The obligations of one or more Standard Power Devices to communicate with the AFC System may be met in combination with a Proxy.

5.4 Device Power and Emission Limits

R0-DGR-07 Power Limits (15.407(a)(4))

a. The maximum power spectral density must [shall] not exceed 23 dBm e.i.r.p in any 1-megahertz band.

b. The maximum e.i.r.p. over the frequency band of operation must [shall] not exceed 36 dBm.

R2-DGR-03 A Standard Power Device that follows the available frequencies and the maximum permissible power provided by the AFC System in accordance with R2-AGR-03-a shall ensure that its emissions outside of its intended Channel of operation do not exceed the allowable level on any frequency, on either the upper or lower adjacent Channels, by applying the relative out of Channel emission maxima specified in 15.407(b)(7), or an alternative set of relative emission levels as authorized for the specific device.

R2-DGR-04 Channel emission limits in multiple channel operation:

The Standard Power Device that follows the available frequencies and the maximum permissible power provided by the AFC System in accordance with R2-AGR-03-b, and which operates on more than one Channel simultaneously, shall reduce out of Channel emissions by 3 dB for overlapping frequencies of the out of Channel emission masks corresponding to any of the transmission Channels.

6 Standard Power Device Security Requirements (DSQ)

6.1 Communication Security

R1-DSQ-01 Standard Power Device Security (15.407(k)(8)(v)):

a. Standard Power Devices must [shall] incorporate adequate security measures to prevent it from accessing AFC Systems not approved by the FCC.

b. Standard Power Devices must [shall] incorporate adequate security measures to ensure that communications between Standard Power Devices and AFC Systems are secure to prevent corruption or unauthorized interception of data.

R1-DSQ-02 The Proxy shall implement security mechanisms to prevent any third party to control, authorize or allow Standard Power Devices to radiate emissions in the 6 GHz band any other way than permitted by an AFC System ([n.22], Section 2).

R2-DSQ-05 Standard Power Device shall address R1-DSQ-01-a by verifying the AFC System's Server Certificate.

R2-DSQ-01 A Standard Power Device or Proxy if applicable shall use, for the purpose of communications with an AFC System, the following protocols: HTTP 1.1 [n.9] or higher and TLS 1.2 [n.10] or higher, or an alternative method of communication which provides a similar or higher level of security.

NOTE: Useful information related to this requirement is available in RFC-8996 [i.1], NIST Special Publication 800-52 Revision 2 [i.2], and RFC-7525 [i.3].

R2-DSQ-02 A Standard Power Device or Proxy shall support at least the following cipher suites when utilizing TLS 1.2 [n.10]:

- TLS_ECDHE_ECDSA_WITH_AES_128_GCM_SHA256
- TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256

R2-DSQ-03 Cipher suites that offer equivalent or higher levels of protection as those cited in R2-DSQ-02 may also be supported and used.

R2-DSQ-04 All cipher suites supported in TLS 1.3 [n.11] or higher may also be supported and used.

7 AFC System General Requirements (AGR)

7.1 Device Registration

R1-AGR-01 An AFC System must [shall] verify the validity of the FCC identifier (FCC ID) of any Standard Power Device seeking access to its services prior to authorizing the Standard Power Device to begin operation. (15.407(k)(6))

a. A list of Standard Power Devices with valid FCC IDs and the FCC IDs of those devices must [shall] be obtained from the Commission's Equipment Authorization System.

R1-AGR-02 The AFC System shall register, authenticate and authorize Standard Power Device operations, individually or through a network element device [Proxy] representing multiple Standard Power Devices from the same operating network. (15.407(k)(7)(ii))

R2-AGR-06 If the Standard Power Device does not notify whether it is located indoors as per R2-DGR-07, the AFC System shall assume the Standard Power Device is located outdoors.

7.2 Determination of Available Frequencies and the Maximum Permissible Power

R0-AGR-01 An AFC System must [shall] 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. (15.407(k)(2))

R1-AGR-03 An AFC System must [shall] use the information supplied by Standard Power Devices during registration to determine available frequencies and the maximum permissible power in each frequency range for a Standard Power Device at any given location using propagation models and interference protection criteria defined in 47 CFR 15.407(l). (15.407(k)(4), 15.407(k)(7)(iii), 15.407(l))

a. All such determinations and assignments must [shall] be made in a non-discriminatory manner.

R2-AGR-01 An AFC System shall use location uncertainty reported by a Standard Power Device to determine maximum acceptable power levels to protect fixed service receivers. ([n.3], Paragraph 41)

R2-AGR-02 The AFC System shall support one or more query methods specified in R2-DGR-02 for providing frequency availability to the Standard Power Devices.

R2-AGR-03 Available Frequencies and the Maximum Permissible Power:

a. The AFC System responding to the Standard Power Device using the method a in R2-DGR-02 shall identify the maximum allowed Power Spectral Density for each 1 MHz interval across the queried frequency range.

b. The AFC System responding to the Standard Power Device using the method b in R2-DGR-02 shall identify the maximum allowed e.i.r.p for each specified Channel bandwidth.

R2-AGR-04 Limits of Maximum Permissible Power determined by the AFC System:

a. Maximum PSD returned by the AFC System as per R2-AGR-03-a shall not exceed the maximum PSD limit specified in R0-DGR-07-a.

b. When calculating the maximum e.i.r.p of a queried Channel, the AFC System shall assume the Standard Power Device will operate on only the queried Channel over the frequency band of operation.

R2-AGR-05 Standard Power Device Height Above Ground Level

The AFC System shall assume a height above ground level of 1.5 meters for the Standard Power Device height if the corresponding height reported by the device, $H_{SPD\ (AGL)}$, is less than 1.5 meters.

R3-AGR-01 Deprecated.

R3-AGR-02 Deprecated.

7.3 Storage of Information

R0-AGR-02 An AFC System shall obtain updated protected sites information from Commission databases. (15.407(k)(7)(iv))

R0-AGR-03 Each AFC System Operator designated by the Commission must [shall] maintain a regularly updated AFC System database, including incumbent's information and Standard Power Access Points and Fixed Client Devices registration parameters. (15.407(k)(15)(i))

R1-AGR-04 Storage of registered information (15.407(k)(5)):

a. An AFC System shall store Standard Power Device registration information in a secure database.

b. The stored registration information shall be available for more than three months after the Standard Power Devices last contacted with the AFC System.

7.4 Enforcement Instructions from the Commission

R1-AGR-05 AFC Systems shall have the capability to deny spectrum access to a particular Standard Power Device upon requests by the Commission, in the event of harmful interference caused by a particular device or type of device. ([n.3], Paragraph 83)

R1-AGR-06 Each AFC System Operator designated by the Commission must [shall] comply with enforcement instructions from the Commission, including discontinuance of Standard Power Device operations in designated geographic areas. (15.407(k)(15)(vi))

8 AFC System Security Requirements (ASQ)

8.1 Communication Security

R0-ASQ-01 The AFC System must [shall] ensure that:

a. all communications and interactions between the AFC System and Standard Power Devices are accurate and secure. (15.407(k)(13))

b. unauthorized parties cannot access or alter the database, or alter the list of available frequencies and associated powers sent to a Standard Power Device. (15.407(k)(13))

R1-ASQ-01 The AFC System shall incorporate security measures to protect against unauthorized data input or alteration of stored data, including establishing communications authentication procedures between the AFC System and Standard Power Devices. (15.407(k)(8)(v))

R2-ASQ-05 The AFC System shall identify itself via a Server Certificate issued by a Trusted CA.

a. Server Certificates shall be OV (Organization Validated) certificates that include vetted company information.

b. Server Certificates with only domain name shall not be accepted.

R2-ASQ-01 An AFC System shall use the following protocols for the purpose of communications between itself and a Standard Power Device or Proxy: HTTP 1.1 [n.9] or higher and TLS 1.2 [n.10] or higher, or an alternative method of communication which provides a similar or higher level of security.

NOTE: Useful information related to this requirement is available in RFC-8996 [i.1], NIST Special Publication 800-52 Revision 2 [i.2], and RFC-7525 [i.3].

R2-ASQ-02 An AFC System shall support at least the following cypher suites when utilizing TLS 1.2 [n.10]:

- TLS_ECDHE_ECDSA_WITH_AES_128_GCM_SHA256
- TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256

R2-ASQ-03 Cypher suites that offer equivalent or higher levels of protection as those cited in R2-ASQ-02 may also be supported and used.

R2-ASQ-04 All cipher suites supported in TLS 1.3 [n.11] or higher may also be supported and used.

9 AFC System Incumbent Protection (AIP)

9.1 Fixed Service Receiver Protection

9.1.1 Interference Protection Criteria and Evaluation Point

R0-AIP-07 Based on the criteria set forth in R0-AIP-03 and R0-AIP-04, an AFC System must [shall] 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. (15.407(l))

R0-AIP-03 The AFC System must [shall] 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 (15.407(l)(2)(i))

R0-AIP-04 The AFC System must [shall] 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. (15.407(l)(2)(ii))

a. The adjacent channel exclusion zone must [shall] be calculated based on the emissions requirements specified in 47 CFR 15.407(b)(7).

R2-AIP-03 When calculating an adjacent channel exclusion zone in accordance with R0-AIP-04-a, the AFC system following R2-AGR-03-b shall take into account out of channel emission limits (specified in 47 CFR 15.407(b)(7)) up to one and a half times the device's channel bandwidth away from its channel center, where the device's Channel bandwidth refers to Channel bandwidth provided by the device using the method b in R2-DGR-02.

R2-AIP-01 AFC Systems shall protect temporary fixed links from harmful interference during the term defined by "start date" and "end date" in the ULS database. ([n.3], Paragraph 32, and [n.8])

R2-AIP-16 In determining frequency availability and maximum permissible power as per R2-AGR-03, the AFC System shall determine the maximum permissible power so that the following condition is met for protection of fixed service receivers and diversity receivers:

$$\mathrm{I/N_{Thres}} \geq \max\left(\mathrm{I/N_{Rx,\,Est}},\ \mathrm{I/N_{VRx\text{-}1,\,Est}}, \cdots, \mathrm{I/N}_{\mathrm{VRx}\text{-}j,\,\mathrm{Est}}, \cdots, \mathrm{I/N}_{\mathrm{VRx}\text{-}X_{\mathrm{NumOfVRx}},\,\mathrm{Est}}\right)$$

$$\mathrm{I/N_{Rx,\,Est}} = P_{\mathrm{SPD,\,Tx}} - L_{\mathrm{Propagation,\,Rx}} - L_{\mathrm{BEL}} + G_{\mathrm{Rx,\,Effective}} - N - L_{\mathrm{FS,\,Feeder}}$$

$$\mathrm{I/N}_{\mathrm{VRx}\text{-}j,\,\mathrm{Est}} = P_{\mathrm{SPD,\,Tx}} - L_{\mathrm{Propagation,\,VRx}\text{-}j} - L_{\mathrm{BEL}} + G_{\mathrm{VRx}\text{-}j,\,\mathrm{Effective}} - G_{\mathrm{VRx}\text{-}j,\,\mathrm{Disc}} - N - L_{\mathrm{FS,\,Feeder}}$$

where:

- $\mathrm{I/N_{Thres}}$ (dB): interference-to-noise ratio as the interference protection criteria as per R0-AIP-03 and R0-AIP-04
- $\mathrm{I/N_{Rx,\,Est}}$ (dB): estimated interference-to-noise ratio at the fixed service receiver or diversity receiver[1]
- $\mathrm{I/N}_{\mathrm{VRx}\text{-}j,\,\mathrm{Est}}$ (dB): estimated interference-to-noise ratio at the *j*-th Virtual Receiver (if present)
- $P_{\mathrm{SPD,\,Tx}}$ (dBm): the Standard Power Device transmission power across the frequency range $\mathrm{I/N_{Est}}$ calculations are performed.
- $L_{\mathrm{Propagation,\,Rx}}$ (dB): propagation losses as per R0-AIP-02 between the Standard Power Device and FS receiver antenna. In addition, R2-AIP-34 provides additional information for WINNER II path loss.

[1] Fixed Service site can be protected as long as maximum permissible power is determined based on higher value of $\mathrm{I/N_{Rx,\,Est}}$ between primary and diversity receivers.

- $L_{\text{Propagation, VRx-}j}$ (dB): propagation losses as per R2-AIP-38 between the Standard Power Device and the *j*-th Virtual Receiver. In addition, R2-AIP-34 provides additional information for WINNER II path loss.
- L_{BEL} (dB) (OPTIONAL): the Building Entry Loss (BEL) applicable to Standard Power Devices located indoors.
- $G_{\text{Rx, Effective}}$ (dBi): the FS receiver effective antenna gain determined in the direction of the Standard Power Device (R2-AIP-05, R2-AIP-07, R2-AIP-08, R2-AIP-09 and R2-AIP-23)
- $\text{G}_{\text{VRx-}j\text{, Effective}}$: Effective gain of the *j*-th Virtual Receiver as per R2-AIP-31-b
- $\text{G}_{\text{VRx-}j\text{, Disc}}$: The *j*-th Virtual Receiver gain determined in the direction of the Standard Power Device as per R2-AIP-31-c
- *N* (dBm): the actual FS receiver noise level as per R2-AIP-02 scaled to the frequency range $\text{I/N}_{\text{Rx, Est}}$ and $\text{I/N}_{\text{VRx-}j\text{, Est}}$ calculations are performed.
- $L_{\text{FS, Feeder}}$ (dB): the FS feeder loss of the actual FS receiver antenna as per R2-AIP-10

R2-AIP-26 Building Entry Loss (BEL):

a. When BEL is applicable to the propagation loss of a Standard Power Device, the default value of L_{BEL} in R2-AIP-16 shall be set to 20.5 dB.

b. An AFC System Operator may modify the BEL value for specific locations based on site-specific information, such as measured values of BEL, to ensure required protection of incumbents as per R0-AIP-03 and R0-AIP-04 and efficient access for unlicensed users. The methods for modification are for further study.

R2-AIP-22 Use of Location Uncertainty in Fixed Service Receiver Protection:

a. The AFC System shall determine the available frequencies and maximum radiated PSD per frequency or maximum allowed e.i.r.p. for each specified channel bandwidth consistent with the most restrictive radiated PSD or e.i.r.p. for each point and frequency or channel evaluated within the uncertainty volume.

b. The evaluation points within this uncertainty volume shall be determined based on a grid superimposed on the Standard Power Device's horizontal area of location uncertainty as reported in the request, along with the reported height $\text{H}_{\text{SPD (AGL)}}$ and associated vertical uncertainty $\Delta\text{H}_{\text{SPD}}$, sampled at intervals no greater than 1 arc second of latitude and longitude and no greater than 5 meters of elevation.

c. The minimum and maximum Standard Power Device heights (i.e., $\text{H}_{\text{SPD (AGL)}}$ +/- $\Delta\text{H}_{\text{SPD}}$) shall always be included in the range covered by the set of evaluation points, where the minimum height is set in accordance with R2-AGR-05.

d. The morphology shall be determined as per R2-AIP-11 and R2-AIP-12 at each evaluation point within the horizontal area of location uncertainty.

R2-AIP-40 FS in Standard Power Device's Horizontal Area of Location Uncertainty

If the FS Rx is inside the Standard Power Device's horizonal area of location uncertainty or if the FS Rx is outside the Standard Power Device's horizonal area of location uncertainty but within a 1-arcsec by 1-arcsec evaluation point that overlaps with the Standard Power Device's horizonal area of location uncertainty,

a. if the FS Rx height is inside the Standard Power Device's vertical uncertainty, AFC System reports an allowable PSD[2] level of -40 dBm/MHz for the frequencies co-channel with that FS Rx

b. else if the FS Rx height is outside the Standard Power Device's vertical uncertainty,

    i. Compute the minimum angle-off-boresight from that FS Rx to the Standard Power Device's uncertainty volume, and use this angle to compute FS Rx antenna gain towards the Standard Power Device for all evaluation points.

    ii. Use free space path loss for path loss calculation at all evaluation points.

    iii. In all cases if the calculation of PSD is below -40 dBm/MHz in any MHz co-channel with FS Rx, report an allowable PSD level of -40 dBm/MHz for the frequencies co-channel with that FS Rx.

R2-AIP-41 Evaluation Point Ground Elevation

Each USGS 1-arcsec 3DEP ground elevation data point represents a uniform height over a 1-arcsec by 1-arcsec region, and is used for all calculations requiring the ground elevation above mean sea level (AMSL).

R3-AIP-01 Deprecated.

9.1.2 Fixed Service Transmitter and Receiver Parameters

9.1.2.1 Retrieval of Fixed Service Data

R0-AIP-01 An AFC System must [shall] 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 R0-AIP-03 and R0-AIP-04. (15.407(k)(3))

NOTE: The ULS data element corresponding to fixed service parameters referred in this section can be found in Annex C.

R1-AIP-02 The AFC System shall download the ULS databases on a daily basis to obtain information on protected services within the 5.925-6.425 GHz and 6.525-6.875 GHz bands. (Paragraph 30, [n.3])

[2] Note that for the channel response, the EIRP is calculated by multiplying the PSD by the channel bandwidth. The EIRP is set such that both in-band and adjacent channel interference are met across SPD's channel +/- first adjacent channel.

R2-AIP-18 Missing Center Frequency in the ULS:

If the center frequency, $F_{c,\ FS\text{-}Rx,\ ULS}$ (MHz), is not available in the ULS, the AFC System need not perform any protection for the fixed service receiver primary and diversity path.

R2-AIP-13 Use of Supplementary Data Repository:

a. The AFC System shall obtain the following data from the Supplementary Data Repository [n.17].

- Category B1 Antenna data (if supporting the procedure specified in R2-AIP-07-b)
- High Performance Antenna data (if supporting the procedure specified in R2-AIP-07-b)
- Transmit Radio Unit Architecture data (as per R2-AIP-10)
- Billboard Reflector data (as per R2-AIP-29)
- Antenna Model, Diameter and Gain data (as per R2-AIP-06 and R2-AIP-29)

b. The AFC System may additionally obtain the following data from the Supplementary Data Repository [n.17].

- FCC Frequency Assignment data (as per R2-AIP-19)

9.1.2.2 Determination of Fixed Service Antenna Parameters

R2-AIP-05 Fixed Service Receiver Antenna Gain, Diameter and Aperture Efficiency:

In determining a fixed service receiver antenna gain G_{Rx} (dBi), diameter D_{Rx} (m) and aperture efficiency η_{Rx} for I/N estimation in R2-AIP-16, the AFC System shall use one of the following methods in order of precedence:

a. If the receiver antenna gain $G_{Rx,\ ULS}$ (dBi), receive antenna model and receive antenna make are available in the ULS, and if D_{Rx} (m) is available for the receive antenna model in the Antenna Model, Diameter, and Gain data, the AFC System shall determine G_{Rx} (dBi), D_{Rx} (m) and η_{Rx} by using $G_{Rx,\ ULS}$ (dBi), receive antenna model, receive antenna make and the center frequency $F_{c,\ FS\text{-}Rx,\ ULS}$ (MHz) in the method specified by R2-AIP-06.

b. If $G_{Rx,\ ULS}$ (dBi) is available in the ULS and receive or passive end antenna model is not available, but the antenna model of the transmitter of the FS Path Link is available in the ULS, D_{Tx} (m) is available for the transmit antenna model in the Antenna Model, Diameter, and Gain data and $G_{Rx,\ ULS}$ (dBi) is equal to the transmit antenna gain $G_{Tx,\ ULS}$ (dBi), the AFC System shall determine G_{Rx} (dBi) and η_{Rx} by using $G_{Rx,\ ULS}$ (dBi), transmit antenna model, transmit antenna make, and $F_{c,\ FS\text{-}Rx,\ ULS}$ (MHz) in the method specified by R2-AIP-06 and shall set D_{Rx} (m) to D_{Tx} (m).

c. If $G_{Rx,\ ULS}$ (dBi) is available in the ULS, receive or passive antenna model and make are not available, but the return path is known and the transmitter antenna gain for that return path, $G_{\text{Tx, ULS}}$ (dBi), transmit antenna model, transmit antenna make of the return path are available in the ULS, D_{Tx} (m) is available for the transmit antenna model of the return path in the Antenna Model, Diameter, and Gain data and $G_{\text{Rx, ULS}}$ (dBi) is equal to $G_{\text{Tx, ULS}}$ (dBi), the AFC System shall determine G_{Rx} (dBi) and η_{Rx} by using $G_{\text{Tx, ULS}}$ (dBi), return path transmit antenna model, return path transmit antenna make and $F_{c,\text{ FS-Rx, ULS}}$ (MHz) in the method specified by R2-AIP-06 and shall set D_{Rx} (m) to D_{Tx} (m).

NOTE: A return path is available in the ULS if the same licensee has a path within the same frequency band with transmit, receive and all Passive Site location coordinates that match the receive, transmit and all Passive Site location coordinates respectively.

d. If $G_{\text{Rx, ULS}}$ (dBi) is available in the ULS but the methods in a-to-c above are not applicable, the AFC System shall determine G_{Rx} (dBi), D_{Rx} (m) and η_{Rx} by using the following formula:

$$G_{\text{Rx}} = \begin{cases} 32 \text{ dBi} & \text{for } G_{\text{Rx, ULS}} < 32 \text{ dBi} \\ G_{\text{Rx, ULS}} \text{ dBi} & \text{for } 32 \le G_{\text{Rx, ULS}} \le 48 \text{ dBi} \\ 48 \text{ dBi} & \text{Otherwise} \end{cases}$$

$$D_{\text{Rx}} = \frac{c}{\pi \cdot F_{\text{c, U-NII-band}}} \cdot \sqrt{\frac{10^{G_{\text{Rx}}/10}}{\eta_{\text{Rx}}}} \text{ (m)}$$

- c: The speed of light (= 299,792,458 m/s)
- $F_{\text{c, U-NII-band}} = \begin{cases} 6{,}175{,}000{,}000 \text{ Hz (if } F_{c,\text{ FS-Rx, ULS}} \text{ is within the U-NII-5 band)} \\ 6{,}700{,}000{,}000 \text{ Hz (if } F_{c,\text{ FS-}Rx\text{, ULS}} \text{ is within the U-NII-7 band)} \end{cases}$
- η_{Rx}: 55% typical antenna aperture efficiency (0.55)

e. If $G_{\text{Rx, ULS}}$ (dBi) is not available in the ULS, the AFC System shall determine G_{Rx} (dBi), D_{Rx} (m) and η_{Rx} as follows:

$$G_{\text{Rx}} \text{ (dBi)} = \begin{cases} 38.8 \text{ dBi (if } F_{c,\text{ FS-Rx, ULS}} \text{ is within the U-NII-5 band)} \\ 39.5 \text{ dBi (if } F_{c,\text{ FS-Rx, ULS}} \text{ is within the U-NII-7 band)} \end{cases}$$

$$D_{\text{Rx}} \text{ (m)} = 1.83 \text{ meters (= 6 feet)}$$

$$\eta_{\text{Rx}} = 0.55$$

R2-AIP-06 Determination of Fixed Service Receiver Antenna Gain, Diameter and Aperture Efficiency using ULS information:

a. In the methods a-to-c in R2-AIP-05, the AFC System shall determine the fixed service receiver antenna gain G_{Rx} (dBi), D_{Rx} (m) and η_{Rx} as follows:

- D_{Rx} (m) = Antenna diameter identified by the antenna model according to Antenna Model, Diameter, and Gain data as per R2-AIP-13, where the antenna model to be used for identification of diameter depends on which method is selected in R2-AIP-05.

- $$G_{\text{Rx}}\ (\text{dBi}) = \begin{cases} G_{\text{ULS}} & \text{if } G_{\text{Typical}} - 0.7 \leq G_{\text{ULS}} \leq G_{\text{Typical}} + 0.7 \\ G_{\text{MB}} & \text{else if } G_{\text{MB}} \text{ is available} \\ G_{\text{Typical}} & \text{otherwise} \end{cases}$$

- η_{Rx} = 55% typical antenna aperture efficiency (0.55)

where:

- G_{ULS} (dBi): $G_{\text{Rx, ULS}}$ or $G_{\text{Tx, ULS}}$, depending on which method is selected in R2-AIP-05

- G_{MB} (dBi): The licensed mid-band antenna gain identified by the antenna model according to Antenna Model, Diameter, and Gain data as per R2-AIP-13, where the antenna model to be used for identification of the mid-band gain depends on which method is selected in R2-AIP-05. from the specifications of receive antenna model produced by receive antenna make is used in most circumstances.

  NOTE: The exception to using the licensed gain is in the situation where it does not fall within reasonable tolerance of the typical gain for the antenna diameter.

- G_{Typical} (dBi): The typical antenna gain for an antenna of diameter D_{Rx} (m), determined by using the following formula:

$$G_{\text{Typical}} = 10\log_{10}\left[\eta_{\text{Rx}} \cdot \left(\frac{\pi \cdot F_{\text{c, U-NII-band}} \cdot D_{\text{Rx}}}{c}\right)^2\right]\ (\text{dBi})$$

  - c: The speed of light (= 299,792,458 m/s)
  - $F_{\text{c, U-NII-band}}$ = $\begin{cases} 6{,}175{,}000{,}000 \text{ Hz (if } F_{c,\text{ FS-Rx, ULS}} \text{ is within the U-NII-5 band)} \\ 6{,}700{,}000{,}000 \text{ Hz (if } F_{c,\text{ FS-Rx, ULS}} \text{ is within the U-NII-7 band)} \end{cases}$
  - D_{Rx}: Antenna diameter specified for the antenna model (depending on which method is selected in R2-AIP-05)

b. The AFC system shall then adjust the value of η_{Rx} as follows:

$$\eta_{\text{Rx}} = \begin{cases} 0.55 & \text{if } \left|G_{\text{ULS}} - G_{\text{Typical}}\right| \leq 0.7 \\ 10^{0.1\left[G_{\text{Rx}} + 159.593 - 20\log_{10}(F_{\text{c, U-NII-band}}) - 20\log_{10}(D_{\text{Rx}})\right]} & \text{Otherwise} \end{cases}$$

R2-AIP-07 Fixed Service Receiver and Diversity Receiver Antenna Radiation Pattern Envelope:

a. For the purpose of fixed service receiver protection, the AFC System shall use the FS antenna radiation pattern envelope (RPE).

b. The AFC System shall support at least one of the following methods to determine the FS antenna RPE:

i. To use actual RPE provided by the manufacturer.

ii. To use default RPE defined by the following procedures:

1. The AFC System shall use $|\theta_{\text{Disc}}|$ (and $|\theta_{\text{DDisc}}|$) calculated from the receiver antenna (and the diversity receiver antenna) with boresight in the direction of the Segment transmitter (i.e., fixed service transmitter or Passive Site).

2. For primary receive antennas with $G_{\text{Rx}} < 38$ dBi:

   - Use the formulas in ITU-R F.699-8 [n.15] by using D_{Rx} and G_{Rx} determined in accordance with R2-AIP-05 if $|\theta_{\text{Disc}}| < 5$ degrees.

   - Use the minimum radiation suppression in Table 3 for the $F_{c,\text{ FS-Rx, ULS}}$ (MHz) and Category B2 if $|\theta_{\text{Disc}}| \geq 5$ degrees.

3. For primary receive antennas with $G_{\text{Rx}} \geq 38$ dBi:

   - Use the formulas in ITU-R F.699-8 [n.15] by using D_{Rx} and G_{Rx} determined in accordance with R2-AIP-05 if $|\theta_{\text{Disc}}| < 5$ degrees.

   - If $|\theta_{\text{Disc}}| \geq 5$ degrees:

     - Use the minimum radiation suppression in Table 2 for the $F_{c,\text{ FS-Rx, ULS}}$ (MHz) and Category B1 if antenna model is blank in the ULS or is identified as a Category B1 antenna according to Category B1 Antenna data obtained as per R2-AIP-13.

     - Use the greater discrimination value of:

       - the minimum radiation suppression in Table 2 for the $F_{c,\text{ FS-Rx, ULS}}$ (MHz) and Category A and

       - $G_{\text{Rx}} - G_{\text{Rx}}(\theta_{\text{Disc}})$, where $G_{\text{Rx}}(\theta_{\text{Disc}})$ is determined using the formulas in ITU-R F.699-8 [n.15] by using D_{Rx} and G_{Rx} determined in accordance with R2-AIP-05 and $F_{c,\text{ FS-Rx, ULS}}$

if antenna model is identified as a high-performance antenna according to High Performance Antenna data obtained as per R2-AIP-13.

- Use the minimum radiation suppression in Table 2 for the $F_{c,\text{ FS-Rx, ULS}}$ (MHz) and Category A otherwise.

4. For diversity receive antennas with $G_{\text{DRx}} < 38$ dBi:
   - Use the formulas in ITU-R F.699-8 [n.15] by using D_{DRx} and G_{DRx} determined in accordance with R2-AIP-08 if $|\theta_{\text{DDisc}}| < 5$ degrees.
   - Use the minimum radiation suppression in Table 2 for the $F_{c,\text{ FS-Rx, ULS}}$ (MHz) and Category B1 if $|\theta_{\text{DDisc}}| \geq 5$ degrees.

5. For diversity receive antennas with $G_{\text{DRx}} \geq 38$ dBi:
   - Use the formulas in ITU-R F.699-8 [n.15] by using D_{DRx} and G_{DRx} determined in accordance with R2-AIP-08 if $|\theta_{\text{DDisc}}| < 5$ degrees.
   - If $|\theta_{\text{DDisc}}| \geq 5$ degrees:
     - Use the minimum radiation suppression in Table 2 for the $F_{c,\text{ FS-Rx, ULS}}$ (MHz) and Category B1 if antenna model is blank in the ULS or is identified as a Category B1 antenna according to Category B1 Antenna data obtained as per R2-AIP-13.
     - Use the greater discrimination value of
       - the minimum radiation suppression in Table 2 for the $F_{c,\text{ FS-Rx, ULS}}$ (MHz) and Category A and
       - $G_{\text{DRx}} - G_{\text{DRx}}(\theta_{\text{DDisc}})$, where $G_{\text{DRx}}(\theta_{\text{DDisc}})$ is determined using the formulas in ITU-R F.699-8 [n.15] by using D_{DRx} and G_{DRx} as specified in R2-AIP-08 and $F_{c,\text{ FS-Rx, ULS}}$.

       if antenna model is identified as a high-performance antenna according to High Performance Antenna data obtained as per R2-AIP-13.
     - Use the minimum radiation suppression in Table 2 for the $F_{c,\text{ FS-Rx, ULS}}$ (MHz) and Category A otherwise.

Table 2: Minimum radiation suppression defined in FCC Rules Part 101.115 [n.16]

Frequency (MHz)	Category	Maximum beamwidth to 3 dB point (included angle in degrees)	Minimum antenna gain (dBi)	Minimum radiation suppression to angle in degrees from centerline of main beam in decibels						
				5° to 10°	10° to 15°	15° to 20°	20° to 30°	30° to 100°	100° to 140°	140° to 180°
5,925 to 6,425	A	2.2	38	25	29	33	36	42	55	55
	B1	2.2	38	21	25	29	32	35	39	45
	B2	4.1	32	15	20	23	28	29	60	60
6,525 to 6,875	A	2.2	38	25	29	33	36	42	55	55
	B1	2.2	38	21	25	29	32	35	39	45
	B2	4.1	32	15	20	23	28	29	60	60

R2-AIP-08 Fixed Service Diversity Receive Antenna Gain and Diameter:

In determining a fixed service diversity receive antenna gain G_{DRx} (dBi) and diameter D_{DRx} (m), the AFC System shall use one of the following methods in order of precedence:

a. If the receive antenna gain $G_{\text{Rx, ULS}}$ (dBi), receive antenna model, receive antenna make in the ULS are not blank, the value of $G_{\text{Rx, ULS}}$ (dBi) is not 0, and the value of diversity receiver antenna gain $G_{\text{DRx, ULS}}$ (dBi) is not blank, the value of $G_{\text{DRx, ULS}}$ (dBi) is not 0, and $G_{\text{Rx, ULS}}$ (dBi) = $G_{\text{DRx, ULS}}$ (dBi), the AFC System shall determine G_{DRx} (dBi) and D_{DRx} (m) by using $G_{\text{Rx, ULS}}$ (dBi), receive antenna model, receive antenna make and $F_{c,\text{ FS-Rx, ULS}}$ (MHz) in the method specified by R2-AIP-05.

b. If the value of $G_{\text{DRx, ULS}}$ (dBi) is not blank, and the value of $G_{\text{DRx, ULS}}$ (dBi) is not 0, but the method a above is not applicable, the AFC System shall determine G_{DRx} (dBi) and D_{DRx} (m) by using the following formula:

$$G_{\text{DRx}} = \begin{cases} G_{\text{DRx, ULS}} \text{ dBi} & \text{for } 28 \le G_{\text{DRx, ULS}} \le 48 \text{ dBi} \\ G_{\text{Rx, ULS}} \text{ dBi} & \text{Otherwise} \end{cases}$$

$$D_{\text{DRx}} = \frac{c}{\pi \cdot F_{\text{c, U-NII-band}}} \cdot \sqrt{\frac{10^{G_{\text{DRx}}/10}}{\eta_{\text{Rx}}}} \text{ (m)}$$

- c: The speed of light (= 299,792,458 m/s)
- $F_{\text{c, U-NII-band}} = \begin{cases} 6{,}175{,}000{,}000 \text{ Hz (if } F_{c,\text{ FS-Rx, ULS}} \text{ is within the U-NII-5 band)} \\ 6{,}700{,}000{,}000 \text{ Hz (if } F_{c,\text{ FS-Rx, ULS}} \text{ is within the U-NII-7 band)} \end{cases}$
- η_{Rx}: 55% typical antenna efficiency (0.55)

c. If the value of $G_{\text{DRx, ULS}}$ (dBi) is blank, or the value of $G_{\text{DRx, ULS}}$ (dBi) is 0, the AFC System need not perform any protection for the fixed service receiver diversity path.

R2-AIP-23 Consideration of Antenna Discrimination in Determining Fixed Service Receiver Effective Antenna Gain:

a. The AFC System shall use at least one of the following methods to determine Fixed Service receiver effective antenna gain, $G_{\text{Rx, Effective}}$ (in dBi), in R2-AIP-16:

   i. Fixed Service receiver effective antenna gain determined as per R2-AIP-37, which is based on the off-boresight antenna discrimination angle.

   ii. Fixed Service receiver effective antenna gain determined as per R2-AIP-36, which is based on both azimuthal and elevation antenna discrimination angles.

b. The AFC System shall then make any required near field adjustment to the determined antenna discrimination as specified in R2-AIP-17.

R2-AIP-09 Determination of Fixed Service Receiver Effective Antenna Gain:

a. If the AFC System uses R2-AIP-23-a to determine the effective antenna gain $G_{\text{Rx, Effective}}$ (in dBi) in R2-AIP-16, the AFC System shall set $G_{\text{Rx, Effective}}$ (in dBi) to the value calculated by using the following equations:

$$G_{\text{Rx, Effective}} = G_0 + G_{\text{Disc}}$$

where:

- G_0: the boresight gain of the fixed service receiver antenna in dBi,

$$G_0 = \begin{cases} G_{\text{Rx}} & \text{for primary receive antenna} \\ G_{\text{DRx}} & \text{for diversity receive antenna} \end{cases}$$

- G_{Disc} (≤ 0): the effective discrimination of the antenna RPE in dB

$$G_{\text{Disc}} = G_{\text{Rx, RPE}}(\theta_{\text{Disc}})$$

b. Instead of the effective antenna gain $G_{\text{Rx, Effective}}$ (in dBi) above, the AFC System may use the effective antenna gain considering polarization mismatch calculated by using the following equations:

$$G_{\text{Rx, Effective}} = G_0 + G_{\text{Disc}} - 3\text{ dB}$$

where:

- G_{Disc} (≤ 0): the effective discrimination of the antenna RPE in dB,

$$G_{\text{Disc}} = \begin{cases} G_{\text{Rx, RPE}}(\theta_{\text{Disc}}) & \text{for default RPE} \\ G_{\text{Rx, C-RPE}}(\theta_{\text{Disc}}) & \text{for actual RPE without cross-polarization data} \\ 10\log_{10}\left(10^{0.1 G_{\text{CDisc}}} + 10^{0.1 G_{\text{XDisc}}}\right) & \text{for actual RPE with cross-polarization data} \end{cases}$$

- $G_{\text{Rx, C-RPE}}(\theta)$: the co-polarization RPE of the fixed service receiver antenna which is computed using the procedure specified in R2-AIP-23.

- G_{CDisc} (≤ 0): the effective antenna discrimination of the fixed service receiver co-polarization RPE in dB.

- G_{XDisc} (≤ 0): the effective antenna discrimination of the fixed service receiver cross-polarization RPE in dB.

NOTE 1: -3 dB is the polarization mismatch factor.

NOTE 2: Actual RPE and default RPE refer to RPEs determined by using the Method A and Method B in R2-AIP-07, respectively.

i. For actual RPE with cross-polarization data, the AFC System shall set G_{CDisc} and G_{XDisc} as follows:

- For vertically-polarized receive antenna (i.e., "V"):

$$G_{\text{CDisc}} = G_{\text{Rx, VV-RPE}}(\theta_{\text{Disc}})$$

$$G_{\text{XDisc}} = G_{\text{Rx, VH-RPE}}(\theta_{\text{Disc}})$$

- For horizontally-polarized receive antenna (i.e., "H"):

$$G_{\text{CDisc}} = G_{\text{Rx, HH-RPE}}(\theta_{\text{Disc}})$$

$$G_{\text{XDisc}} = G_{\text{Rx, HV-RPE}}(\theta_{\text{Disc}})$$

- For other cases (i.e., "S", blank or anything else):

$$G_{\text{CDisc}} = \begin{cases} \max\left[G_{\text{Rx, HH-RPE}}(\theta_{\text{Disc}}), G_{\text{Rx, VV-RPE}}(\theta_{\text{Disc}})\right] & \text{if } G_{\text{Rx, HH-RPE}}(\theta) \text{ and } G_{\text{Rx, VV-RPE}}(\theta) \text{ are available} \\ G_{\text{Rx, HH-RPE}}(\theta_{\text{Disc}}) & \text{if only } G_{\text{Rx, HH-RPE}}(\theta) \text{ is available} \\ G_{\text{Rx, VV-RPE}}(\theta_{\text{Disc}}) & \text{if only } G_{\text{Rx, VV-RPE}}(\theta) \text{ is available} \end{cases}$$

$$G_{\text{XDisc}} = \begin{cases} \max\left[G_{\text{Rx, HV-RPE}}(\theta_{\text{Disc}}), G_{\text{Rx, VH-RPE}}(\theta_{\text{Disc}})\right] & \text{if } G_{\text{Rx, HV-RPE}}(\theta) \text{ and } G_{\text{Rx, VH-RPE}}(\theta) \text{ are available} \\ G_{\text{Rx, VH-RPE}}(\theta_{\text{Disc}}) & \text{if only } G_{\text{Rx, VH-RPE}}(\theta) \text{ is available} \\ G_{\text{Rx, HV-RPE}}(\theta_{\text{Disc}}) & \text{if only } G_{\text{Rx, HV-RPE}}(\theta) \text{ is available} \end{cases}$$

where the following quantities are computed using the procedure specified in R2-AIP-23:

- $G_{\text{Rx, HH-RPE}}(\theta)$: HH RPE of the fixed service receiver antenna
- $G_{\text{Rx, VV-RPE}}(\theta)$: VV RPE of the fixed service receiver antenna
- $G_{\text{Rx, HV-RPE}}(\theta)$: HV RPE of the fixed service receiver antenna
- $G_{\text{Rx, VH-RPE}}(\theta)$: VH RPE of the fixed service receiver antenna

c. In R2-AIP-09-b, if the fixed service antenna receive polarization is not available but the transmit polarization is available in the ULS, the AFC System shall assume that the receive polarization is the same as the transmit polarization specified in the ULS.

R2-AIP-37 Antenna Discrimination Based on Off-Boresight Discrimination Angle:

a. If the actual RPE provided by the manufacturer is used, the AFC System shall use the following procedure to determine the antenna discrimination based on off-boresight angle:

i. If the AFC System uses R2-AIP-09-a and R2-AIP-23-a-i to determine the effective antenna gain $G_{\text{Rx, Effective}}$ (in dBi) in R2-AIP-16, the AFC System shall use the following procedure to determine $G_{\text{Rx, RPE}}(\theta_{\text{Disc}})$ using the off-boresight discrimination angle and the co-polarization RPE for the antenna's polarization.

1. The off-boresight, or overall, discrimination angle, γ, may be computed using the relations in R2-AIP-36-a and R2-AIP-36-b or by other essentially equivalent methods such as the directional vector inner product method.

2. If no elevation antenna pattern data is available at angles $\pm\gamma$, the antenna discrimination value $G_{\text{Rx, ZZ-RPE}}$ is taken as the more conservative value of the appropriate polarization azimuthal pattern at the angles $+\gamma$ and $-\gamma$.

$$G_{\text{Rx, ZZ-RPE}} = \max[G_{\text{Rx, AZ-RPE}}(+\gamma), G_{\text{Rx, AZ-RPE}}(-\gamma)]$$

where $G_{\text{Rx, AZ-RPE}}$ (≤ 0) is the azimuthal RPE data provided by the manufacturer.

3. If elevation antenna pattern data is available at angles $\pm\gamma$, the antenna discrimination value $G_{\text{Rx, ZZ-RPE}}$ is taken as the most conservative value of the appropriate polarization azimuthal pattern and elevation pattern data at the angles $+\gamma$ and $-\gamma$.

$$G_{\text{Rx, ZZ-RPE}} = \max[G_{\text{Rx, AZ-RPE}}(+\gamma), G_{\text{Rx, AZ-RPE}}(-\gamma), G_{\text{Rx, EL-RPE}}(+\gamma), G_{\text{Rx, EL-RPE}}(-\gamma)]$$

where $G_{\text{Rx, EL-RPE}}$ (≤ 0) is the elevation RPE data provided by the manufacturer.

NOTE: Since RPE discrimination values are negative, the maximum (least negative) is the more conservative value.

ii. If the AFC System uses R2-AIP-09-b and R2-AIP-23-a-i to determine the effective antenna gain $G_{\text{Rx, Effective}}$ (in dBi) in R2-AIP-16, the AFC System shall use the above procedure to determine any of $G_{\text{Rx, HH-RPE}}(\theta)$, $G_{\text{Rx, VV-RPE}}(\theta)$, $G_{\text{Rx, HV-RPE}}(\theta)$, or $G_{\text{Rx, VH-RPE}}(\theta)$ using the off-boresight angle and appropriate polarization RPE.

b. Else, if the default RPE as specified per R2-AIP-07 is used, the antenna discrimination based on off-boresight angle shall be determined per R2-AIP-07 and R2-AIP-09.

R2-AIP-36 Determination of Fixed Service Receiver Effective Antenna Gain Using Two-Dimensional Discrimination:

If the AFC System uses R2-AIP-23-b to determine the effective antenna gain $G_{\text{Rx, Effective}}$ (in dBi) in R2-AIP-16, the AFC System shall use the following procedure to determine $G_{\text{Rx, Effective}}$ (in dBi) using both azimuthal and elevation.

a. The following three types of angles shall be computed:

i. The azimuthal discrimination angle, $\theta_{\text{AZ-Disc}}$, as follows:

$$\theta_{\text{AZ-Disc}} = \begin{cases} \theta_{\text{AZ-Bearing-To-Eval}} - \theta_{\text{AZ-Boresight}} & -180 \leq \theta_{\text{AZ-Bearing-To-Eval}} - \theta_{\text{AZ-Boresight}} \leq 180 \\ \theta_{\text{AZ-Bearing-To-Eval}} - \theta_{\text{AZ-Boresight}} - 360 & 180 < \theta_{\text{AZ-Bearing-To-Eval}} - \theta_{\text{AZ-Boresight}} \\ \theta_{\text{AZ-Bearing-To-Eval}} - \theta_{\text{AZ-Boresight}} + 360 & \theta_{\text{AZ-Bearing-To-Eval}} - \theta_{\text{AZ-Boresight}} < -180 \end{cases}$$

where:

- $\theta_{\text{AZ-Bearing-To-Eval}}$: the bearing angle of the azimuth plane to the evaluation point with respect to the fixed service receive antenna
- $\theta_{\text{AZ-Boresight}}$: the fixed service receive antenna boresight direction of the azimuth plane with respect to true north

ii. The fixed service receive antenna boresight elevation angle, $\theta_{\text{EL-Disc}}$, as follows:

$$\theta_{\text{EL-Disc}} = \tan^{-1}\left(\frac{H_{\text{FS, Tx(AMSL)}} - H_{\text{FS, Rx(AMSL)}}}{d_{\text{FSTx-FSRx}}} - \frac{d_{\text{FSTx-FSRx}}}{2r_{\text{Earth}}}\right)$$

where:

- $H_{\text{FS, Tx (AMSL)}}$: height of fixed service transmit site (AMSL) in km. The transmit site is the location of equipment directing signals to the fixed service receive antenna. This equipment may be the fixed service transmit antenna or a passive repeater/reflector.
- $H_{\text{FS, Rx (AMSL)}}$: height of fixed service receive antenna (AMSL) in km
- $d_{\text{FSTx-FSRx}}$: Distance between fixed service transmit and receive antennas in km
- r_{Earth}: Effective radius of the Earth (= 8500 km)

iii. The elevation angle from the fixed service receive antenna to the evaluation point, φ', as follows: (see details of "evaluation point" in R2-AIP-22)

$$\varphi' = \tan^{-1}\left(\frac{H_{\text{EP(AMSL)}} - H_{\text{FS, Rx(AMSL)}}}{d_{\text{EP-FSRx}}} - \frac{d_{\text{EP-FSRx}}}{2r_{\text{Earth}}}\right)$$

where:

- $H_{\text{EP (AMSL)}}$: height of an evaluation point (AMSL) in km
- $d_{\text{EP-FSRx}}$: Distance between an evaluation point and the fixed service receive antenna in km

b. Overall discrimination angle, γ, shall be computed as follows:

$$\gamma = \cos^{-1}(\cos\varphi' \cos\theta_{\text{AZ-Disc}} \cos\theta_{\text{EL-Disc}} + \sin\varphi' \sin\theta_{\text{EL-Disc}})$$

c. The azimuthal discrimination contribution $G_{\text{AZ-Disc}}$ in dB shall be computed as follows:

$$G_{\text{AZ-Disc}} = \begin{cases} G_{\text{Rx, AZ-RPE}}(\gamma) & \text{if } \theta_{\text{AZ-Disc}} \geq 0 \\ G_{\text{Rx, AZ-RPE}}(-\gamma) & \text{otherwise} \end{cases}$$

where:

- $G_{\text{Rx, AZ-RPE}}$: Fixed service receive antenna azimuthal RPE determined as per R2-AIP-07-b (RPE provided by the manufacturer or RPE computed as per the defined procedure)

NOTE 1: These two values will be different only when antenna manufacturer pattern data is selected in R2-AIP-07 and it is asymmetric.

NOTE 2: $G_{\text{AZ-Disc}}$ is a negative value.

d. The elevation discrimination contribution $G_{\text{EL-Disc}}$ in dB shall be computed as follows:

$$G_{\text{EL-Disc}} = \begin{cases} G_{\text{Rx, EL-RPE}}(\gamma) & \text{if } G_{\text{Rx, EL-RPE}} \text{ is available at } \gamma, \text{ and } \beta \geq 0 \\ G_{\text{Rx, EL-RPE}}(-\gamma) & \text{if } G_{\text{Rx, EL-RPE}} \text{ is available at } -\gamma, \text{ and } \beta < 0 \\ \max\left(G_{\text{Rx, AZ-RPE}}(\gamma), G_{\text{Rx, AZ-RPE}}(-\gamma)\right) & \text{otherwise} \end{cases}$$

where:

- $G_{\text{Rx, EL-RPE}}$: Fixed service receive antenna elevation RPE provided by the manufacturer
- $\beta = \sin\varphi' \cos\theta_{\text{EL-Disc}} - \cos\varphi' \cos\theta_{\text{AZ-Disc}} \sin\theta_{\text{EL-Disc}}$

NOTE: $G_{\text{EL-Disc}}$ is a negative value.

e. $G_{\text{Rx, Effective}}$ (in dBi) shall be computed as follows:

$$G_{\text{Rx, Effective}} = G_0 + w_A \cdot G_{\text{AZ-Disc}} + w_E \cdot G_{\text{EL-Disc}}$$

where:

$$w_A = \frac{\cos^2\varphi' \sin^2\theta_{\text{AZ-Disc}}}{\beta^2 + \cos^2\varphi' \sin^2\theta_{\text{AZ-Disc}}}$$

$$w_E = \frac{\beta^2}{\beta^2 + \cos^2\varphi' \sin^2\theta_{\text{AZ-Disc}}}$$

i. If both $\cos\varphi' \sin\theta_{\text{AZ-Disc}} = 0$ and $\beta = 0$, so that the weights are indeterminate, then w_A shall be taken as one and w_E as zero.

NOTE: This procedure is consistent with that described in TIA Standard 10 section 4.16 [i.5]. It consists of computing various angles, then an azimuthal and elevation discrimination contribution and finally weights to use in combining these contributions into an estimated discrimination value.

R2-AIP-17 Near Field Adjustment of the Fixed Service Receiver Antenna RPE:

a. When determining the maximum permissible power at the evaluation point as per R2-AIP-16, the AFC System shall perform near field adjustment to the fixed service antenna RPE as per the item b of this requirement if the following inequalities are met.

$$\begin{cases} d_{\text{FSRx-Eval}} < d_{\text{Limit}} \\ \varphi_{\text{FSRx-Eval}} < 90 \text{ (deg)} \end{cases}$$

where:

- $d_{\text{FSRx-Eval}}$: Distance (in meters) between the FS receiver antenna and the evaluation point (see R2-AIP-22)
- d_{Limit}: Near field distance limit (in meters) computed by the following formula:

$$d_{\text{Limit}} = \frac{0.185806 \cdot F_{\text{c, U-NII-band}} \cdot D^2_{\text{Rx, NFA}}}{c}$$

- $\varphi_{\text{FSRx-Eval}}$: Off-boresight axis angle (in degrees) in a direction from the FS receiver antenna towards the evaluation point (see R2-AIP-22), having a value between 0 (deg) and 180 (deg) inclusive.
- $F_{\text{c, U-NII-band}} = \begin{cases} 6{,}175{,}000{,}000 \text{ Hz (if } F_{c,\text{ FS-Rx, ULS}} \text{ is within the U-NII-5 band)} \\ 6{,}700{,}000{,}000 \text{ Hz (if } F_{c,\text{ FS-Rx, ULS}} \text{ is within the U-NII-7 band)} \end{cases}$
- $D_{\text{Rx, NFA}}$: Antenna diameter (in feet) used for near field adjustment. See the item i below.

i. $D_{\text{Rx, NFA}}$ shall be determined by using one of the following methods in order of precedence:

- Set $D_{\text{Rx, NFA}}$ to the antenna diameter specified for the receive antenna make and the receive antenna model.
- Determine $D_{\text{Rx, NFA}}$ by using the ULS antenna gain data $G_{\text{Rx, ULS}}$ according to Table 3 (if $F_{c,\text{ FS-Rx, ULS}}$ is within 5,925 – 6,425 MHz band) or Table 4 (if $F_{c,\text{ FS-Rx, ULS}}$ is within 6,525 – 6,875 MHz band).
- Set $D_{\text{Rx, NFA}}$ to 6 feet.

Table 3: U-NII-5 Antenna Size versus Gain

Range of ULS Antenna Gain Data $G_{\text{Rx, ULS}}$ [dBi]		Antenna Diameter for Near Field Adjustment $D_{\text{Rx, NFA}}$ [ft]
Min	**Max**	
32.0	34.3	3
34.4	37.5	4
37.6	40.3	6
40.4	42.5	8
42.6	44.5	10
44.6	46.1	12
46.2	48.0	15

Table 4: U-NII-7 Antenna Size versus Gain

Range of ULS Antenna Gain Data $G_{Rx,\ ULS}$ [dBi]		Antenna Diameter for Near Field Adjustment $D_{Rx,\ NFA}$ [ft]
Min	**Max**	
32.0	34.5	3
34.6	37.6	4
37.7	40.5	6
40.6	42.7	8
42.8	44.5	10
44.6	46.2	12
46.3	48.0	15

b. The near field adjustment shall be performed by adding the near field adjustment factor to the FS antenna RPE, where the near field adjustment factor is computed by linear interpolation of the data in the Appendix[3] using the normalized separation distance x_{dB} in dB, fixed service antenna discrimination parameter, u, and the antenna aperture efficiency $\eta_{Rx,\ NFA}$.

i. The normalized separation distance x_{dB} in dB shall be computed as follows:

$$x_{dB} = 10\log_{10}\left(\frac{c \cdot d_{FSRx\text{-}Eval}}{2F_{c,\ U\text{-}NII\text{-}band} \cdot D^2_{Rx,\ NFA}}\right) + 10.32$$

ii. The FS antenna discrimination parameter u shall be computed as follows:

$$u = \frac{0.3048 \cdot F_{c,\ U\text{-}NII\text{-}band} \cdot D_{Rx,\ NFA}}{c} \sin\varphi_{FSRx\text{-}Eval}$$

iii. The antenna aperture efficiency $\eta_{Rx,\ NFA}$ for near field adjustment shall be determined as follows:

$$\begin{cases} 0.4 & \text{if } \eta_{Rx,\ NFA} < 0.4 \\ 0.7 & \text{if } \eta_{Rx,\ NFA} > 0.7 \\ \eta_{Rx,\ NFA} & \text{otherwise} \end{cases}$$

where:

- $\eta_{Rx,\ NFA} = 10^{\frac{\eta_{Rx,\ NFA\ (dB)}}{10}}$
- $\eta_{Rx,\ NFA(dB)}$: If the ULS antenna gain data $G_{Rx,\ ULS}$ is more than 0.3 dB outside the range from Table 3 or Table 4 for the antenna diameter $D_{Rx,\ NFA}$ determined as per the first method of the R2-AIP-17-a-i, or if the ULS antenna gain data $G_{Rx,\ ULS}$ is not available or if the diameter $D_{Rx,\ NFA}$ is determined as 6 feet as per the third method of the R2-AIP-17-a-i, the value is set to -2.6 dB. Otherwise, the value is set according to the following formula:

[3] The Appendix (App01) is available at https://6ghz.wirelessinnovation.org/work-group-products. See also Annex E (Informative) for the information about the Appendix.

$\eta_{\text{Rx, NFA (dB)}} =$

$$\begin{cases} G_{\text{Rx, ULS}} - 25.90 - 20\log_{10}(D_{\text{Rx, NFA}}) & \text{(if } F_{c,\text{ FS-Rx, ULS}} \text{ is within 5,925 – 6,425 MHz)} \\ G_{\text{Rx, ULS}} - 26.61 - 20\log_{10}(D_{\text{Rx, NFA}}) & \text{(if } F_{c,\text{ FS-Rx, ULS}} \text{ is within 6,525 – 6,875 MHz)} \end{cases}$$

NOTE: The theoretical dBi gain of a 100 % efficient dish antenna is $25.90 + 20\log_{10}(D)$ at 6.175 GHz and is $26.61 + 20\log_{10}(D)$ at 6.700 GHz, and these values can be used in the computation of actual antenna efficiency.

9.1.2.3 Determination of other Fixed Service Parameters

R2-AIP-02 Fixed Service Receiver Noise Level:

In determining the noise level N of a fixed service receiver, if the AFC System has the needed radio manufacturer data, technique b, technique c or technique d shall be used. Otherwise, technique a shall be used.

a. Use of the typical noise level N determined as follows:

$$N = \begin{cases} -110.0 \text{ dBm/MHz (if } F_{c,\text{ FS-Rx, ULS}} \leq 6425 \text{ MHz)} \\ -109.5 \text{ dBm/MHz (if } F_{c,\text{ FS-Rx, ULS}} > 6425 \text{ MHz)'} \end{cases}$$

where:

- $F_{c,\text{ FS-Rx, ULS}}$: Center frequency of the FS receiver recorded in the ULS

NOTE: These noise levels are computed by the formula in c below with a noise figure value of 4 dB below or equal to 6425 MHz and 4.5 dB above 6425 MHz. These values are provided as default FS parameters in ITU-R F.758-7 [i.6]. See Table 7 of ITU-R F.758-7 [i.6] for more information.

b. Use of the noise level N (with proper consideration for the occupied bandwidth) specified by the manufacturer's specification for the given receiver model identified by the corresponding data element in the ULS.

NOTE: For example, if the receiver model is listed as "ACME XYZ" in ULS, an AFC System can use N available in the specification for XYZ receiver model published by the Acme receiver company.

c. Use of the noise level N determined by the following equation:

$$N = -114 \text{ dBm/MHz} + NF,$$

where:

- NF: Noise figure specified by the manufacturer's specification for the receiver model identified by the corresponding data element in the ULS

NOTE: –114 dBm/MHz equals $10\log_{10}(k_B \cdot T_0) + 10\log_{10}(10^6 \text{ Hz/MHz}) + 10\log_{10}(10^3 \text{ mW/W})$, where k_B is Boltzmann's constant of $1.38064852 \times 10^{-23}$ $m^2 \cdot kg \cdot s^{-2} \cdot K^{-1}$ and T_0 is the standard reference temperature of 290 K.

d. Use of the noise level N determined by the following equation:

$$N\text{ (dBm/MHz)} = T\text{ (dBm)} - T/I\text{ (dB)} - 10\log_{10}[BW_{FS}\text{ (MHz)}] + 6\text{ dB},$$

where:

- BW_{FS}: Channel bandwidth of the FS receiver (as per R2-AIP-19)
- T: Threshold for 10^{-6} bit error rate (BER) for the channel bandwidth BW_{FS}
- T/I: Threshold-to-Interference (T/I) specified by the manufacturer's specification for the given receiver model identified by the corresponding data element in the ULS.

NOTE: The T/I specification is defined to apply for 10^{-6} BER in TIA-10, 2019 Edition [i.5].

R2-AIP-10 Feeder Loss:

a. In R2-AIP-16, the AFC System shall use the fixed service receiver feeder loss, $L_{FS,\text{ Feeder}}$, determined by using one of the following methods in order of precedence:

i. The receive feeder loss as provided in the ULS, if it is not null.

ii. A feeder loss of 3 dB shall be used if the transmit radio, make and model is available in the ULS and it is identified as IDU (Indoor Unit) according to Transmit Radio Unit Architecture data obtained as per R2-AIP-13.

iii. Deprecated.

iv. A feeder loss of 0 dB shall be used if the transmit radio, make and model is available in the ULS and it is identified as ODU (Outdoor Unit) according to Transmit Radio Unit Architecture data obtained as per R2-AIP-13.

v. Otherwise, the AFC System shall set the feeder loss to any value in the range $0\text{ dB} \leq L_{FS,\text{ Feeder}} \leq 3\text{ dB}$.

NOTE These fallback feeder loss values are computed by calculating the average feeder/multiplexer loss values provided in ITU-R F.758-7 [i.6]. See Table 7 of ITU-R F.758-7 [i.6] for more information.

R2-AIP-14 Fixed Service Receive Antenna Height:

a. In determining a fixed service receive antenna height $H_{FS,\text{ Rx (AGL)}}$ (m), the AFC System shall use one of the following methods in order of precedence:

i. The receive antenna height as provided in ULS, if it is not blank.

ii. If the return path's segment is known, the return path's transmit antenna height, if it is not blank.

NOTE: A return path is available in the ULS if the same licensee has a path within the same frequency band with transmit and receive location coordinates that match the receive and transmit location coordinates respectively.

iii. A receive antenna height of 42.5 meters.

b. If the receive antenna height is equal to or less than 1.5 meter above ground level, the AFC System shall use 1.5 meters for the receive antenna height.

R2-AIP-15 Fixed Service Diversity Antenna Height:

a. In determining a fixed service diversity antenna height $H_{\text{FS, DRx (AGL)}}$ (m) in cases where it is determined that a diversity receiver is in use, the AFC System shall use one of the following methods in order of precedence:

i. The diversity antenna height as provided in ULS, if it is not blank.

ii. The following formula:

$$H_{\text{FS, DRx (AGL)}} = \begin{cases} H_{\text{FS, Rx (AGL)}} + 11 \text{ (m)} & \text{for } H_{\text{FS, Rx (AGL)}} < 14 \text{ m} \\ H_{\text{FS, Rx (AGL)}} - 11 \text{ (m)} & \text{for } H_{\text{FS, Rx (AGL)}} \geq 14 \text{ m} \end{cases}$$

b. If the fixed service diversity antenna height is equal to or less than 1.5 meter above ground level, the AFC System shall use 1.5 meters for the fixed service diversity antenna height

R2-AIP-19 Fixed Service Receiver Bandwidth

In determining a fixed service receiver bandwidth BW_{FS} (MHz), the AFC System shall use one of the following methods in order of precedence:

a. If the associated transmitter's emissions designator as provided in the ULS is not blank, not 0 and not greater than 60 MHz, the AFC System shall determine BW_{FS} (MHz) by following the following steps.

Step 1: Compute the bandwidth using transmitter's emissions designator from the ULS ($BW_{\text{EmissionsDesignator}}$)

Step 2: Set BW_{FS} to $BW_{\text{EmissionsDesignator}}$ if $F_{\text{c, FS-Rx, ULS}}$ is not in U-NII-5 nor U-NII-7. Otherwise, determine BW_{FS} as follows:

Step 2.1: Find the smallest value ($BW_{\text{SmallestFCC}}$) of the FCC-authorized bandwidths that is greater than or equal to the $BW_{\text{EmissionsDesignator}}$, where the FCC-defined authorized bandwidths are defined in FCC Rule Parts 101.147(i) [n.20] and 101.147(k) [n.21] as shown in the table below:

Table 5: FCC-Authorized Bandwidths

Frequency Band of $F_{\text{c, FS-Rx, ULS}}$	**FCC-authorized bandwidths**
In 5925 – 6425 MHz	400 kHz, 800 kHz, 1.25 MHz, 2.5 MHz, 3.75 MHz, 5 MHz, 10 MHz, 30 MHz and 60 MHz
In 6525 – 6875 MHz	400 kHz, 800 kHz, 1.25 MHz, 2.5 MHz, 3.75 MHz, 5 MHz, 10 MHz, 30 MHz

Step 2.2: Set BW_{FS} as follows:

$$BW_{FS}(\text{MHz}) = \begin{cases} BW_{\text{EmissionsDesignator}} & \text{if } F_{\text{c, FS-Rx, ULS}} \text{ is in U-NII-7 and } BW_{\text{EmissionsDesignator}} > 30 \text{ MHz} \\ \min\left(BW_{\text{SmallestFCC}}, 1.1 \cdot BW_{\text{EmissionDesignator}}\right) & \text{otherwise} \end{cases}$$

NOTE: $1.1 \cdot BW_{\text{EmissionsDesignator}}$ refers to the value 10 % greater than $BW_{\text{EmissionsDesignator}}$, and 30 MHz is the maximum FCC-authorized bandwidth in 6525 – 6875 MHz.

b. The maximum FCC-authorized bandwidth for the assigned frequency, $F_{\text{c, FS-Rx, ULS}}$ with a 0.5 MHz tolerance as determined according to either of the followings.

- The FCC Rule Parts 101.147(i) [n.20] and 101.147(k) [n.21]
- The FCC Frequency Assignment data obtained as per R2-AIP-13.

NOTE: Both sources provide exactly the same data, and the item ii provides the data in machine-readable format. Table 5 can also be referenced for the purpose of this method.

c. The bandwidth for the assigned frequency, $F_{\text{c, FS-Rx, ULS}}$, as follows:

Table 6: FS Assigned Frequency vs. Bandwidth

Assigned frequency $F_{\text{c, FS-Rx, ULS}}$ (MHz)	Bandwidth BW_{FS} (MHz)
5967.4375	30
6056.3875	30
6189.8275	30
6219.4775	30
6308.4275	30

d. The bandwidth as determined by the following formula:

$$BW_{FS}(\text{MHz}) = \begin{cases} 2\left(F_{\text{c, FS-Rx, ULS}} - 5925\right) & 5925 \text{ MHz} \le F_{\text{c, FS-Rx, ULS}} < 5955 \text{ MHz} \\ 60 & 5955 \text{ MHz} \le F_{\text{c, FS-Rx, ULS}} < 6395 \text{ MHz} \\ 2\left(6425 - F_{\text{c, FS-Rx, ULS}}\right) & 6395 \text{ MHz} \le F_{\text{c, FS-Rx, ULS}} < 6425 \text{ MHz} \\ 2\left(F_{\text{c, FS-Rx, ULS}} - 6525\right) & 6525 \text{ MHz} \le F_{\text{c, FS-Rx, ULS}} < 6540 \text{ MHz} \\ 30 & 6540 \text{ MHz} \le F_{\text{c, FS-Rx, ULS}} < 6860 \text{ MHz} \\ 2\left(6875 - F_{\text{c, FS-Rx, ULS}}\right) & 6860 \text{ MHz} \le F_{\text{c, FS-Rx, ULS}} < 6875 \text{ MHz} \end{cases}$$

9.1.3 Propagation Models

9.1.3.1 Common Requirements

R0-AIP-02 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:

a. Up to 30 meters, the AFC System must [shall] use the free space path-loss model. (15.407(l)(1)(i))

b. More than 30 meters and up to and including one kilometer, the AFC System must [shall] use the Wireless World Initiative New Radio phase II (WINNER II) model [n.4]. (15.407(l)(1)(ii))

i. The AFC System must [shall] 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 [n.4], where such data is available.

ii. For evaluating paths where such data is not available, the AFC System must [shall] use a probabilistic model combining the line-of-sight path and non-line-of-sight path into a single path-loss as follows:

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 $(1 - P_{LOS})$.

iii. In all cases, the AFC System will [shall] 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).

c. More than one kilometer, the AFC System must [shall] use Irregular Terrain Model (ITM) [n.5] combined with the appropriate clutter model. (15.407(l)(1)(iii))

i. To account for the effects of clutter, such as buildings and foliage, that the AFC System must [shall] combine the ITM [n.5] with the ITU-R P.2108-0 (06/2017) [n.6] clutter model for urban and suburban environments and the ITU-R P.452-16 (07/2015) [n.7] clutter model for rural environments.

ii. The AFC System should use the most appropriate clutter category for the local morphology when using ITU-R P.452-16 [n.7].

iii. If detailed local information is not available, the “Village Centre” clutter category should be used.

iv. The AFC System must [shall] 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.

R2-AIP-24 Use of National Land Cover Database (NLCD):

For R2-AIP-11 and R2-AIP-12, the AFC System shall employ the National Land Cover Database (NLCD) data[4] [n.18].

9.1.3.2 WINNER II Model

R2-AIP-04 WINNER II Parameters:

a. For urban, suburban, and rural morphologies, scenarios C2 (Typical urban macro-cell), C1 (Suburban), and D1 (Rural macro-cell) of WINNER II model as defined in Table 4-4 of IST-4-027756 [n.4] shall respectively be used by the AFC System.

b. For propagation loss calculations between 30 meters and 50 meters distances, only LOS component of the model shall be used by the AFC System, i.e., Path-loss (L) = L_{LOS}.

c. The AFC System shall set h_{BS} to the height above ground level of fixed service receiver antenna (i.e., $H_{FS,\ Rx\ (AGL)}$ or $H_{FS,\ DRx\ (AGL)}$) and h_{MS} to the height above ground level of Standard Power Device.

NOTE: h_{BS} and h_{MS} are the symbols defined in the WINNER II model.

R2-AIP-11 WINNER II Morphology:

The AFC System shall determine morphology for the WINNER II model based on the corresponding NLCD code at the location of Standard Power Device as following:

- Code 23 or 24: Urban
- Code 21 or 22: Suburban
- Else: Rural

R2-AIP-34 WINNER II:

a. In the absence of site-specific information, including buildings and terrain data, to determine the presence of an obstruction in the path between the evaluation point and FS receiver antenna, the AFC System shall set $L_{Propagation,\ Rx}$ (dB) in R2-AIP-16 as follows:

$$L_{Propagation,\ Rx}\ (\mathrm{dB}) = \text{Path-loss (L)} - \sigma_{CPL(dB)}$$

where:

- Path-loss (L): the combined path loss in dB as per R0-AIP-02-b-ii
- $\sigma_{CPL(dB)}$: Standard deviation in dB of combined path loss, which is computed as follows:

$$\sigma_{CPL\ (dB)} = \sqrt{P_{LOS}^2 \cdot \sigma_{LOS(dB)}^2 + P_{NLOS}^2 \cdot \sigma_{NLOS(dB)}^2}$$

[4] Suggested baseline versions of NLCD data are NLCD 2019 Land Cover (CONUS), NLCD 2016 Land Cover (ALASKA), NLCD 2001 Land Cover (HAWAII) and NLCD 2001 Land Cover (PUERTO RICO).

- $\sigma_{LOS(dB)}$: Standard deviation of LOS path loss (i.e., L_{LOS}) in dB, as per Table 4-4 of IST-4-027756 [n.4]
- $\sigma_{NLOS\ (dB)}$: Standard deviation of NLOS path loss (i.e., L_{NLOS}) in dB, as per Table 4-4 of IST-4-027756 [n.4]

b. Where site-specific information is available to determine the presence of an obstruction in the path between the evaluation point and FS receiver antenna, the AFC System shall set $L_{\text{Propagation, Rx}}$ (dB) in R2-AIP-16 as follows:

$$L_{\text{Propagation, Rx}}(\text{dB}) = \begin{cases} L_{NLOS} - \sigma_{NLOS(dB)} & \text{If an obstruction is found} \\ L_{LOS} - \sigma_{LOS(dB)} & \text{otherwise} \end{cases}$$

c. An AFC System Operator may modify the amount of deviation from the median WINNER II path loss for site-specific and combined models to ensure required protection of incumbents as per R0-AIP-03 and R0-AIP-04 and efficient access for unlicensed users. The methods for modification are for future study.

9.1.3.3 Irregular Terrain Model (ITM) with Clutter Models

R2-AIP-27 ITM Parameters:

a. The AFC System shall use the default ITM parameter values listed in Table 7.

Table 7: Default ITM Parameter Values

ITM Parameter Name	**Default Value**
Polarization	Horizontal or Vertical
Climatic Zone	Per ITU-R P.617-3 map using the minimum value of {Standard Power Device location, FS Rx location}. 1: Equatorial 2: Continental sub-tropical 3: Maritime sub-tropical 4: Desert 5: Continental temperate 6: Maritime temperate, overland 0: Maritime temperate, oversea
Surface refractivity (N-units)	Per ITU-R P.452 database using mid-point of the interference path
Ground dielectric constant	25
Ground conductivity (S/m)	0.02
Mode of variability	13
Confidence	5%
Reliability	20%

NOTE: For Climatic Zone, ITU-R P.617-3 uses “0” for “maritime temperate, oversea”, but ITM uses “7” for “maritime temperate, oversea”.

b. An AFC System Operator may modify the ITM reliability and confidence factors for specific locations based on site-specific information, such as buildings and terrain data and/or measured values of components of path loss, to ensure required protection of incumbents as per R0-AIP-03 and R0-AIP-04 and efficient access for unlicensed users. The methods for modification are for further study.

R2-AIP-33 Minimum Path Loss:

If the predicted path loss using the ITM propagation model with the parameters in Table 7 or using the WINNER II propagation model is less than the free space loss, the free space loss value shall be used instead.

R2-AIP-25 Clutter Model:

In determination of clutter loss as per R0-AIP-02:

a. For urban and suburban morphologies:
   i. Clutter loss shall be calculated and applied taking into consideration each morphology separately at the FS receiver antenna and Standard Power Device locations as given in R2-AIP-12.
   ii. Clutter loss may be applied at the FS receiver location only if the FS receive antenna height $H_{FS, Rx (AGL)}$ determined as per R2-AIP-14 is lower than 6 meters above ground level.
b. For morphologies other than urban and suburban, clutter loss shall only be applied to the Standard Power Device location.
c. The frequency of 6400 MHz shall be used.

   NOTE: 6400 MHz is the frequency that corresponds to the center of the lower edge of U-NII-5 band and upper edge of U-NII-7 band, i.e., 6400 MHz = 5925 + (6875 – 5925)/2 MHz.

R2-AIP-12 Clutter Morphology for ITM:

a. The AFC System shall determine the morphology for the clutter model using the corresponding NLCD code at the location of application (Standard Power Device or FS receiver locations). The following classification shall be used:
   - Code 23 or 24: Urban (use ITU-R P.2108)
   - Code 21 or 22: Suburban (use ITU-R P.2108)
   - Else: Rural (use ITU-R P.452)
b. When using P.452 for rural regions, the following model types shall be used:
   - Code 11, 12, 31, 51, 71, 72, 73, 74, 81, 95: No clutter loss is added.
   - Code 52, 82: High Crop fields (use ITU-R P.452-16 Table 4, Row 1)

- Code 41, 43, or 90: Deciduous trees (use ITU-R P.452-16 Table 4, Row 3)
- Code 42: Coniferous (use ITU-R P.452-16 Table 4, Row 4)
- Else: Village Center (use ITU-R P.452-16 Table 4, Row 2)

NOTE: This requirement is mandatory WInnForum requirement which overrides the optionality provided by R0-AIP-02-c-ii and the recommendation provided by R0-AIP-02-c-iii.

R2-AIP-35 Confidence Factor for P.2108-0:

a. The default values of P.2108-0 clutter parameters used by the AFC System to calculate clutter loss shall be based on 0.25 confidence factor, where the result of calculation is as follows:

$$L_{ctt} = -5\log_{10}\left(10^{-0.2L_l} + 10^{-0.2L_s}\right) - 6 \cdot 0.675$$

b. An AFC System Operator may modify the value of the P.2108-0 confidence factor at specific locations to ensure required protection of incumbents as per R0-AIP-03 and R0-AIP-04 and efficient access for unlicensed users. The methods for modification are for future study.

NOTE 1: “Confidence factor” in this requirement refers to “Percentage of Locations” in ITU-R Recommendation P.2108-0 [n.6].

NOTE 2: See definitions of L_{ctt}, L_l and L_s in ITU-R Recommendation P.2108-0 [n.6].

9.1.4 Passive Sites

R2-AIP-38 The AFC System shall use propagation models specified in R0-AIP-02 to determine the propagation loss between a Standard Power Device and a Passive Site.

R2-AIP-28 Consideration of Fixed Service Passive Sites:

a. For protection of fixed service receivers using Passive Sites in their fixed service link, the AFC System shall consider the Passive Sites in determining frequency availability and maximum permissible power as per R2-AIP-16.

b. The AFC System shall obtain fixed service passive repeater data from the ULS.

R2-AIP-29 Determination of Fixed Service Passive Site Antenna Data:

Based on the ULS data obtained as per R2-AIP-28-b, the AFC System shall determine fixed service Passive Site antenna data by using the following procedure:

a. For each ULS record of a Passive Site antenna, the AFC System shall identify whether it is billboard reflector or back-to-back antenna by using the Billboard Reflector data and the Antenna Model, Diameter and Gain data obtained as per R2-AIP-13 and the antenna model recorded in the ULS.

   i. If the antenna model is missing from the ULS record, or if the antenna model is recorded in the ULS but the antenna model in the ULS does not match the antenna model in the Billboard Reflector data and the Antenna Model, Diameter and Gain data obtained as per R2-AIP-13, the type of Passive Site shall be identified by the following method in order of precedence:

1. If at least either a back-to-back Tx gain value or a back-to-back Rx gain value is recorded in the ULS and if either the range of gain value is [32 : 48] (dBi), the AFC System shall assume the Passive Site is back-to-back antenna.
2. For cases not meeting the above, the AFC System shall assume the Passive Site is billboard reflector.

b. If the Passive Site is a billboard reflector, the AFC System shall determine the billboard reflector dimensions by using the following procedure:

NOTE: if $H_{Ref\text{-}ULS}$ or $W_{Ref\text{-}ULS}$ is missing from the ULS record, use R2-AIP-30-a to determine $H_{Ref\text{-}ULS}$ and $W_{Ref\text{-}ULS}$.

i. The AFC System shall identify the billboard reflector dimensions which is associated with the antenna model recorded in the ULS by using the Billboard Reflector data obtained as per R2-AIP-13, $H_{Ref\text{-}AntennaModel} \times W_{Ref\text{-}AntennaModel}$.

ii. The AFC System shall identify the billboard reflector dimensions identified by the combination of the Reflector Height and Reflector Width recorded in the ULS, $H_{Ref\text{-}ULS} \times W_{Ref\text{-}ULS}$.

iii. If the dimension $H_{Ref\text{-}ULS}$ is greater or equal to 1.83 m and $W_{Ref\text{-}ULS}$ is greater or equal to 2.44 m, the AFC System shall determine the billboard reflector dimension as follows, where "identical" is defined as within 0.1 m.

1. If either $H_{Ref\text{-}AntennaModel}$ or $W_{Ref\text{-}AntennaModel}$ is missing from the Billboard Reflector data (per R2-AIP-13), $H_{Ref\text{-}ULS}$ and $W_{Ref\text{-}ULS}$ shall be used.
2. If $H_{Ref\text{-}AntennaModel}$ is identical to $H_{Ref\text{-}ULS}$ and $W_{Ref\text{-}AntennaModel}$ is identical to $W_{Ref\text{-}ULS}$, these dimensions shall be used.
3. If $H_{Ref\text{-}AntennaModel}$ is not identical to $H_{Ref\text{-}ULS}$ or $W_{Ref\text{-}AntennaModel}$ is not identical to $W_{Ref\text{-}ULS}$, and if both $\{H_{Ref\text{-}AntennaModel}, W_{Ref\text{-}AntennaModel}\}$ and $\{H_{Ref\text{-}ULS}, W_{Ref\text{-}ULS}\}$ are listed in Table 8, the dimensions with the greater surface area (Height × Width) shall be used.
4. If $H_{Ref\text{-}AntennaModel}$ is not identical to $H_{Ref\text{-}ULS}$ or $W_{Ref\text{-}AntennaModel}$ is not identical to $W_{Ref\text{-}ULS}$, and if either $\{H_{Ref\text{-}AntennaModel}, W_{Ref\text{-}AntennaModel}\}$ or $\{H_{Ref\text{-}ULS}, W_{Ref\text{-}ULS}\}$ is listed in Table 8, the dimensions listed in Table 8 shall be used.
5. Else, the dimensions with the greater surface area (Height × Width) shall be used.

iv. Else, the billboard reflector dimensions $\{H_{Ref\text{-}AntennaModel}, W_{Ref\text{-}AntennaModel}\}$ shall be used.

Table 8: Typical Billboard Reflector Dimensions

Height (ft)	Width (ft)	Height (m)	Width (m)
6	8	1.83	2.44
8	10	2.44	3.05

8	12	2.44	3.66
10	15	3.05	4.57
10	16	3.05	4.88
10	24	3.05	7.32
12	16	3.66	4.88
14	16	4.27	4.88
16	20	4.88	6.10
16	24	4.88	7.32
20	24	6.10	7.32
20	30	6.10	9.14
20	32	6.10	9.75
24	30	7.32	9.14
30	32	9.14	9.75
30	40	9.14	12.19
30	48	9.14	14.63
40	50	12.19	15.24

c. If the Passive Site is back-to-back antenna, the AFC System shall determine the back-to-back antenna data by using the following procedure:

NOTE: If either the Tx or Rx Back-to-Back Gain is missing in the ULS or is out of range [32 : 48] dBi, they need to be set per R2-AIP-30-b, R2-AIP-30-c or R2-AIP-30-d before going through steps below. In that case, the Back-to-Back Tx or Rx ULS Gain below refers to the Tx or Rx ULS Gains as determined in R2-AIP-30.

i. If the Back-to-Back Tx ULS Gain matches the Back-to-Back Rx ULS Gain, the AFC System shall determine the back-to-back receiver antenna gain, diameter and aperture efficiency as per R2-AIP-39 and the back-to-back receiver antenna RPE as per R2-AIP-07, respectively. Next, the back-to-back transmitter antenna gain shall be set to the back-to-back receiver antenna gain (as set per R2-AIP-39).

ii. If the Back-to-Back Tx ULS Gain does not match the Back-to-Back Rx ULS gain, the AFC System shall determine the back-to-back receiver antenna gain, diameter, aperture efficiency and the back-to-back receiver antenna RPE by using the following procedure:

1. If the antenna model recorded in the ULS is found in the Antenna Model, Diameter and Gain data obtained as per R2-AIP-13, extract G_{MB} for this antenna model from the Antenna Model, Diameter and Gain data (per R2-AIP-13).

(a) The back-to-back receiver antenna gain, diameter and aperture efficiency shall be set as following:

(1) If $|G_{\text{Rx, B-B, ULS}} - G_{\text{MB}}| \leq 0.7$ dB, R2-AIP-39-a shall be used with $G_{\text{Rx, B-B, ULS}}$ set to the Back-to-Back Rx ULS Gain and using the antenna model from the Antenna Model, Diameter and Gain data.

(2) Else, R2-AIP-39-b or R2-AIP-39-c shall be used with $G_{\text{Rx, B-B, ULS}}$ set to the Back-to-Back Rx ULS Gain.

(b) The back-to-back transmitter antenna gain shall be set as following:

(1) If $|G_{\text{Tx, B-B, ULS}} - G_{\text{MB}}| \leq 0.7$ dB, R2-AIP-39-a shall be used with $G_{\text{Rx, B-B, ULS}}$ set to the Back-to-Back Tx ULS Gain and using the antenna model from the Antenna Model, Diameter and Gain data.

(2) Else, R2-AIP-39-b or R2-AIP-39-c shall be used with $G_{\text{Rx, B-B, ULS}}$ set to the Back-to-Back Tx ULS Gain.

NOTE: For determination of the back-to-back transmitter antenna gain, R2-AIP-39-b is applied in reverse, where the receivers are replaced with transmitters and vice versa.

2. Else, R2-AIP-39-b or R2-AIP-39-c shall be used with $G_{\text{Rx, B-B, ULS}}$ set to the Back-to-Back Rx ULS Gain to determine the back-to-back receiver antenna gain, diameter and aperture efficiency. For the back-to-back transmitter gain, R2-AIP-39-b or R2-AIP-39-c shall be used with $G_{\text{Rx, B-B, ULS}}$ set to the Back-to-Back Tx ULS Gain to determine the back-to-back transmitter antenna gain.

NOTE: For determination of the back-to-back transmitter antenna gain, R2-AIP-39-b is applied in reverse, where the receivers are replaced with transmitters and vice versa.

3. The back-to-back receiver antenna RPE shall be determined using R2-AIP-07.

R2-AIP-30 Determination of Fixed Service Passive Site Antenna Data using Missing/Erroneous ULS Data

a. In R2-AIP-29-b, if at least either $H_{\text{Ref-ULS}}$ or $W_{\text{Ref-ULS}}$ is missing from the ULS record, the AFC System shall determine $H_{\text{Ref-ULS}} = 4.88$ m and $W_{\text{Ref-ULS}} = 6.10$ m.

b. In R2-AIP-29-c, if Back-to-Back Tx Gain is missing from the ULS or is in the ULS but not in the range [32 : 48] dBi and the Back-to-Back Rx Gain is recorded and the range is [32 : 48] dBi, the AFC System shall determine that the Back-to-Back Tx Gain is the same as Back-to-Back Rx Gain.

c. In R2-AIP-29-c, if Back-to-Back Rx Gain is missing from the ULS or is in the ULS but not in the range [32 : 48] dBi and the Back-to-Back Tx Gain is provided the range is [32 : 48] dBi, the AFC System shall determine that the Back-to-Back Rx Gain is the same as Back-to-Back Tx Gain.

d. In R2-AIP-29-c, if both Back-to-Back Tx Gain and Back-to-Back Rx Gain are missing from the ULS or both are not in the range [32 : 48] dBi, they shall be determined by R2-AIP-39.

R2-AIP-39 Fixed Service Back-to-Back Receiver Antenna Gain, Diameter and Aperture Efficiency:

In determining a fixed service back-to-back receiver antenna gain $G_{\text{Rx, B-B}}$ (dBi), diameter $D_{\text{Rx, B-B}}$ (m) and aperture efficiency $\eta_{\text{Rx, B-B}}$ for I/N estimation in R2-AIP-16, the AFC System shall use one of the following methods in order of precedence:

a. If the back-to-back receiver antenna gain $G_{\text{Rx, B-B, ULS}}$ (dBi), back-to-back receive antenna model and back-to-back receive antenna make are available in the ULS, and if $D_{\text{Rx, B-B}}$ (m) is available for the back-to-back receive antenna model in the Antenna Model, Diameter, and Gain data, the AFC System shall determine $G_{\text{Rx, B-B}}$ (dBi), $D_{\text{Rx, B-B}}$ (m) and $\eta_{\text{Rx, B-B}}$ by using $G_{\text{Rx, B-B, ULS}}$ (dBi), back-to-back receive antenna model, back-to-back receive antenna make and the center frequency $F_{c,\text{ FS-Rx, ULS}}$ (MHz) in the method specified by R2-AIP-06.

b. If $G_{\text{Rx, B-B ULS}}$ (dBi) is available in the ULS, the back-to-back receive antenna model and make are not available, but the return path is known and the back-to-back transmitter antenna gain for that Passive Site in the return path, $G_{\text{Tx, B-B ULS}}$ (dBi), the Passive Site's antenna model in the return path are available in the ULS, and $D_{\text{Tx, B-B}}$ (m) is available for the passive transmit antenna model of the return path in the Antenna Model, Diameter, and Gain data and $G_{\text{Rx, B-B ULS}}$ (dBi) is equal to $G_{\text{Tx, B-B ULS}}$ (dBi), the AFC System shall determine $G_{\text{Rx, B-B}}$ (dBi) and $\eta_{\text{Rx, B-B}}$ by using $G_{\text{Tx, B-B ULS}}$ (dBi), return path Passive Site's antenna model and $F_{c,\text{ FS-Rx, ULS}}$ (MHz) in the method specified by R2-AIP-06 and shall set $D_{\text{Rx, B-B}}$ (m) to $D_{\text{Tx, B-B}}$ (m).

NOTE: A return path is available in the ULS if the same licensee has a path within the same frequency band with transmit, receive, and all Passive Site location coordinates that match the receive, transmit, and all Passive Site location coordinates respectively.

c. If $G_{\text{Rx, B-B ULS}}$ (dBi) is available in the ULS but the methods in a and b above are not applicable, the AFC System shall determine $G_{\text{Rx, B-B}}$ (dBi), $D_{\text{Rx, B-B}}$ (m) and $\eta_{\text{Rx, B-B}}$ by using the following formula:

$$G_{\text{Rx, B-B}} = \begin{cases} 32\text{ dBi} & \text{for } G_{\text{Rx, B-B, ULS}} < 32\text{ dBi} \\ G_{\text{Rx, B-B, ULS}}\text{ dBi} & \text{for } 32 \le G_{\text{Rx, B-B, ULS}} \le 48\text{ dBi} \\ 48\text{ dBi} & \text{Otherwise} \end{cases}$$

$$D_{\text{Rx, B-B}} = \frac{c}{\pi \cdot F_{\text{c, U-NII-band}}} \cdot \sqrt{\frac{10^{G_{\text{Rx, B-B}}/10}}{\eta_{\text{Rx, B-B}}}}\ \text{(m)}$$

- c: The speed of light (= 299,792,458 m/s)
- $F_{\text{c, U-NII-band}} = \begin{cases} 6{,}175{,}000{,}000\text{ Hz (if } F_{c,\text{ FS-Rx, ULS}} \text{ is within the U-NII-5 band)} \\ 6{,}700{,}000{,}000\text{ Hz (if } F_{c,\text{ FS-}Rx\text{, ULS}} \text{ is within the U-NII-7 band)} \end{cases}$
- $\eta_{\text{Rx, B-B}}$: 55% typical antenna aperture efficiency (0.55)

d. If $G_{\text{Rx, B-B ULS}}$ (dBi) is not available in the ULS, the AFC System shall determine $G_{\text{Rx, B-B}}$ (dBi), $D_{\text{Rx, B-B}}$ (m) and $\eta_{\text{Rx, B-B}}$ as follows:

$$G_{\text{Rx, B-B}}\ (\text{dBi}) = \begin{cases} 38.8\ \text{dBi (if } F_{c,\text{ FS-Rx, ULS}} \text{ is within the U-NII-5 band)} \\ 39.5\ \text{dBi (if } F_{c,\text{ FS-Rx, ULS}} \text{ is within the U-NII-7 band)} \end{cases}$$

$$D_{\text{Rx, B-B}}\ (\text{m}) = 1.83 \text{ meters}$$

$$\eta_{\text{Rx, B-B}} = 0.55$$

R2-AIP-31 Interference Analysis involving Passive Sites:

NOTE: The techniques specified in this requirement are based on [i.12].

a. The AFC System shall treat the Passive Sites as fixed service receivers virtually (hereinafter “Virtual Receivers”) when determining frequency availability and maximum permissible power as per R2-AIP-16.

b. The AFC System shall determine effective gain of the Virtual Receiver according to the following procedure:

i. Given X_{NumOfVRx} Passive Sites from the fixed service transmitter to the receiver, the AFC System shall calculate the effective gain, $G_{\text{VRx-}j,\text{ Effective}}$, of the Virtual Receiver by summing all the path Segment gains from the j-th Passive Site to the actual receiving antenna along with the boresight gain (G_{Rx} as determined per R2-AIP-05) of the actual receiving antenna as follows:

$$G_{\text{VRx-}j,\text{ Effective}} = \left(\sum_{i=j}^{X_{\text{NumOfVRx}}} G_{\text{PathSeg, }i} \right) + G_{\text{Rx}}$$

NOTE: This effective boresight gain does not include any discrimination that could be the result of a Standard Power Device being off of the passive boresight receive direction. That discrimination pattern is discussed in R2-AIP-31-c.

ii. The AFC System shall determine the effective path Segment gain of the Virtual Receiver, G_{PathSeg}, as follows:

1. Back-to-back antennas:

$$G_{\text{PathSeg}} = G_{\text{Rx, B-B}} + G_{\text{Tx, B-B}} - L_{\text{WG}} + 20\log_{10}\left(\frac{\lambda}{4\pi d_{\text{PathSegLength}}}\right)$$

where:

- $G_{\text{Rx, B-B}}$: Receiving back-to-back antenna gain

- $G_{\text{Tx, B-B}}$: Transmitting back-to-back antenna gain
- L_{WG}: Connecting waveguide/cable loss
- λ: Wavelength (= $c/F_{\text{c, U-NII-band}}$) (in meters)

  NOTE: The definition of λ is applicable to R2-AIP-31-b-ii-2 and R2-AIP-31-b-ii-3 as well.

- $d_{\text{PathSegLength}}$: Path Segment length (in meters) calculated using the latitude and longitude coordinates of the path Segment endpoints. $d_{\text{PathSegLength}}$ of zero as determined by the segment (SG) and location (LO) ULS tables indicates an error in the ULS database and no further analysis is necessary for the links with $d_{\text{PathSegLength}} = 0$.

2. Single passive reflector:

$$G_{\text{PathSeg}} = \begin{cases} \min(+3, \alpha_n) & \text{if } 1/K_S \geq 2.5 \text{ or If the next site is a single reflector} \\ \alpha_{NF} & \text{otherwise} \end{cases}$$

where:

- $\alpha_n = 20\log_{10}\left(\frac{\pi}{4} \cdot K_S\right)$

  NOTE: In practice, α_n could be greater than 3 dB when the next site is a passive reflector and close by (< 120 meters), as in the case of a double passive reflector.

- α_{NF}: the near field component of segment gain which is computed by the method for given $1/K_S$ and Q provided in Annex E.2, which uses Appendix (App02) in the calculation.
- $K_S = 4A \cdot \cos\theta_{\text{IN}} / (\pi \cdot \lambda \cdot d_{\text{PathSegLength}})$
- $Q = D_{\text{Rx, Next}} [\pi / (4A \cdot \cos\theta_{\text{IN}})]^{1/2}$
- $D_{\text{Rx, Next}}$: Diameter (meters) of the antenna at the next site towards the actual FS receiver, where the diameter is the back-to-back receive antenna diameter if the next site towards the actual FS receiver is a back-to-back repeater.
- A: Area of the reflector (in m^2)
- $2\theta_{\text{IN}}$: Inclusion angle between incident and reflected waves at the reflector

c. The AFC System shall determine discrimination value, $G_{VRx\text{-}j,\ Disc}$ of the j-th Virtual Receiver according to the following procedure:

i. The AFC System shall determine the discrimination angle $\theta_{VRx\text{-}j,\ Disc}$ by computing as the difference in the Virtual Receiver boresight direction and the bearing to the evaluation point.

1. The bearing to the evaluation point shall be based on the latitude, longitude and height AMSL of the Virtual Receiver and the evaluation point.

ii. The AFC System shall determine boresight direction of the Virtual Receiver as follows:

1. Back-to-back antennas: the boresight direction of the receiving antenna calculated by using latitude, longitude and height AMSL of the receiving antenna and the Segment transmitter (i.e., fixed service transmitter or Passive Site) latitude, longitude and height AMSL.

2. Single passive reflector: the boresight direction calculated by using latitude, longitude and height AMSL of the reflector and the previous Segment transmitter (i.e., fixed service transmitter or Passive Site) latitude, longitude and height AMSL

iii. The AFC System shall determine the discrimination value $G_{VRx\text{-}j,\ Disc}$ as follows:

1. For back-to-back antenna, the discrimination value $G_{VRx\text{-}j,\ Disc}$ shall be computed based on the discrimination angle $\theta_{VRx,\ Disc}$ to the evaluation point and the Rx antenna RPE as per R2-AIP-23.

2. For single passive reflector, the discrimination value $G_{VRx\text{-}j,\ Disc}$ shall be computed based on the discrimination angle $\theta = \theta_{VRx\text{-}j,\ Disc}$ to the evaluation point and the single passive reflector discrimination pattern

$$G_{VRx\text{-}j,\ Disc} = \max(D_0, D_1)$$

$$D_0 = -10\log_{10}[4\pi A\cos\theta_{IN} / \lambda^2]$$

$$D_1(\theta) = \begin{cases} 20\log_{10}\left(\frac{\sin u}{u}\right); & |\theta| \le \theta_1 \text{ [degs]} \\ -20\log_{10}(|u|); & \theta_1 < |\theta| \le \theta_0 \text{ [degs]} \\ D_1(\theta_0) - m(|\theta| - \theta_0); & \theta_0 < |\theta| \text{ [degs]} \end{cases}$$

where:

- The calculation uses the angles θ, θ_0 and θ_1 expressed in degrees and u expressed in radians:

$$u\ [\text{rad}] = \frac{\pi s}{\lambda} \sin\theta$$

$$\frac{\sin u}{u} \approx 1 - \frac{u^2}{6}\left(1 - \frac{u^2}{20}\right);\ \ |u| < 0.1$$

$$m\ [\text{dB/deg}] = 0.4165$$

$$\theta_0\ [\text{deg}] = 20$$

$$\theta_1\ [\text{deg}] = \sin^{-1}\left(\frac{\lambda}{2s}\right)$$

$$s = \max(W, H)\cos\theta_{\text{IN}}$$

- *W*: Reflector width (in meters)
- *H*: Reflector height (in meters)

R2-AIP-32 Back-To-Back Antenna Waveguide Loss

The AFC System shall use 0.5 dB of waveguide loss, L_{WG}, when calculating the back-to-back antenna path segment gain in R2-AIP-31.

9.2 Radio Astronomy Service Protection

R0-AIP-05 Protection of radio observatories:

a. The AFC System must [shall] 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.

b. The exclusion zone sizes are [shall be] based on the radio line-of-sight and determined using 4/3 earth curvature and the following formula:

   dkm_los = 4.12 * (sqrt(Htx) + sqrt(Hrx)),

   where Htx is the height of the unlicensed Standard Power Access Point or Fixed Client Device and Hrx is the height of the radio astronomy antenna in meters above ground level. (15.407(m))

R1-AIP-01 Radio Astronomy Service protection:

For protection of radio astronomy facilities listed in R0-AIP-05-a, the following reference coordinates and receiver antenna heights above ground level (AGL) shall be used.

Table 9: Reference coordinates and receiver heights above ground level (AGL)

Observatory	North latitude	West longitude	AGL (in meters)
Arecibo Observatory, PR	18° 20′ 37″	66° 45′ 11″	142.2
Green Bank Telescope (GBT), WV	38° 25′ 59″	79° 50′ 23″	139.6
Very Large Array (VLA), Socorro, NM	34° 04′ 44″	107° 37′ 06″	25
Very Long Baseline Array (VLBA) Stations:			
Brewster, WA	48° 07′ 52″	119° 41′ 00″	25
Fort Davis, TX	30° 38′ 06″	103° 56′ 41″	25
Hancock, NH	42° 56′ 01″	71° 59′ 12″	25
Kitt Peak, AZ	31° 57′ 23″	111° 36′ 45″	25
Los Alamos, NM	35° 46′ 30″	106° 14′ 44″	25
Mauna Kea, HI	19° 48′ 05″	155° 27′ 20″	25
North Liberty, IA	41° 46′ 17″	91° 34′ 27″	25
Owens Valley, CA	37° 13′ 54″	118° 16′ 37″	25
Pie Town, NM	34° 18′ 04″	108° 07′ 09″	25
St. Croix, VI	17° 45′ 24″	64° 35′ 01″	25
Allen Telescope Array	40° 49' 03"	121° 28' 24"	6.1
Owens Valley Radio Observatory	37° 14' 02"	118° 16' 56"	40

R2-AIP-20 Use of Vertical Location Uncertainty in Radio Astronomy Service Protection:

In determining the size of the exclusion zone using the formula in R0-AIP-05-b, the AFC System shall use the following value of Htx.

$$Htx = H_{SPD\ (AGL)} + \Delta H_{SPD}$$

where:

- $H_{SPD\ (AGL)}$: the height above ground level reported by the Standard Power Device (in meters)
- ΔH_{SPD}: the vertical uncertainty reported by the Standard Power Device (in meters)

R2-AIP-21 Frequency Availability Determination using Horizontal Location Uncertainty in Radio Astronomy Service Protection:

The AFC System shall determine that 6650 – 6675.2 MHz frequency range is unavailable for the Standard Power Device if the horizontal area of location uncertainty reported by the Standard Power Device overlaps with at least one of the exclusion zones determined as per R0-AIP-05, R1-AIP-01 and R2-AIP-20.

9.3 International Border Protection

R0-AIP-06 An AFC System must [shall] implement the terms of international agreements with Mexico and Canada. (15.407(k)(14))

R2-AIP-42 For the purpose of Canadian Border Protection, regardless of the antenna height or the morphology of the Canadian FS receiver, the AFC System operating in the United States shall not apply any clutter at the FS Receiver, in calculating the path loss.

Annex A (Normative): 3GPP Specific Features (Optional)

A.1 Description

This annex provides requirements for 3GPP specific features. In this section, unless otherwise specified, Standard Power Devices refer to those employing 3GPP based radio access technology for operations in the 6 GHz band.

A.1.1 NRU1: 3GPP-defined 6 GHz Channel

An NRU1 feature enables an AFC System and a Standard Power Devices employing the frequency availability query method specified in R2-DGR-02-b and R2-AGR-03-b to support 3GPP-defined 6 GHz Channels (e.g., Channels within the 3GPP-defined n96 band [n.12][n.13]).

The support of this feature is optional for AFC System and Standard Power Devices.

A.2 Use for Operations that could impact Part 15 Subpart E Regulatory Compliance

Requirements for the NRU1 feature in this section need to be considered in the protection of fixed service receivers and radio astronomy service facilities in accordance with the technology neutral requirements specified in the main body of this technical specification.

A.2.1 AFC System General Requirements (AGR)

R2-NRU1-AGR-01 The AFC System shall support the query method specified in R2-DGR-02-b

R2-NRU1-AGR-02 Support of 3GPP-defined 6 GHz channelization [n.12][n.13]:

When an AFC System determines and provides a list of Available Channels and the associated maximum power levels in accordance with R2-AGR-03-b, for a Standard Power Device request based on R2-NRU1-DGR-02, each Channel in the list shall be aligned with 3GPP-defined 6 GHz channelization.

R3-NRU1-AGR-01 Deprecated (Converted into R2-NRU1-AGR-02).

A.2.2 Device General Requirements (DGR)

R2-NRU1-DGR-01 The Standard Power Device shall support the query method specified in R2-DGR-02-b

R2-NRU1-DGR-02 Support of 3GPP-defined 6 GHz channelization [n.12][n.13]:

A Standard Power Device using the method in R2-DGR-02-b shall be able to request from an AFC System that each Channel in the list of Available Channels be aligned with 3GPP-defined 6 GHz channelization.

R3-NRU1-DGR-01 Deprecated (Converted into R2-NRU1-DGR-02).

A.3 Use for Operations not impacting Part 15 Subpart E Regulatory Compliance

Not applicable for this version of this document.

Annex B (Normative): IEEE 802.11ax Specific Features (Optional)

B.1 Feature Description

This annex provides requirements for the support of IEEE 802.11ax specific features [i.4].

In this release of the specification, all mandatory and optional requirements for IEEE 802.11ax-specific features are found in the Wi-Fi Alliance AFC System to AFC Device Interface Specification [n.14].

Annex C (Normative): Reference Table for Fixed Service Receiver Parameters

This annex provides a reference of how to obtain fixed service receiver parameters referenced in this specification from the ULS. For each parameter, the ULS Record Type and ULS Data Element [n.19] are provided.

"Antenna Type Code" element in "AN" type of record specifies whether the antenna identified by the record is receive antenna ("R") or transmit antenna ("T").

Table 10: Relationship between ULS data elements and fixed service receive antenna parameters employed in this specification

ULS		**WINNF-TS-1014**		
ULS Data Element	**Record Type**	**Parameter**	**Symbol**	**Requirement ID(s)**
Gain	AN	receive antenna gain	$G_{\mathrm{Rx,\ ULS}}$	R2-AIP-05, R2-AIP-06, R2-AIP-08,
Antenna Model	AN	receive antenna model	*n/a*	R2-AIP-05, R2-AIP-06, R2-AIP-07, R2-AIP-08,
Antenna Make	AN	receive antenna make	*n/a*	R2-AIP-05, R2-AIP-06, R2-AIP-08,
Height to Center RAAT	AN	receive antenna height	*n/a*	R2-AIP-14
Polarization Code	AN	receive polarization	*n/a*	R2-AIP-09
Latitude Degrees Latitude Minutes Latitude Seconds Latitude Direction Longitude Degrees Longitude Minutes Longitude Seconds Longitude Direction	LO	receive location coordinates	*n/a*	R2-AIP-05, R2-AIP-14

Frequency Assigned	FR	center frequency	$F_{c,\text{ FS-Rx, ULS}}$	R2-AIP-02, R2-AIP-05, R2-AIP-06, R2-AIP-07, R2-AIP-08, R2-AIP-17, R2-AIP-19
Diversity Gain	AN	diversity receive antenna gain	$G_{\text{DRx, ULS}}$	R2-AIP-08,
Diversity Height	AN	diversity antenna height	*n/a*	R2-AIP-15
Line Loss	AN	feeder loss	*n/a*	R2-AIP-10
Transmitter Make	FR	radio make	*n/a*	R2-AIP-10
Transmitter Model	FR	radio model	*n/a*	R2-AIP-10
NOTE: The most convenient way to uniquely determine an FS receiver antenna location is to use Tx call sign plus the path number.				

Table 11: Relationship between ULS data elements and fixed service transmit antenna parameters employed in this specification

ULS		**WINNF-TS-1014**		
ULS Data Element	**Record Type**	**Parameter**	**Symbol**	**Requirement ID(s)**
Gain	AN	transmit antenna gain	$G_{\text{Tx, ULS}}$	R2-AIP-05, R2-AIP-06,
Antenna Make	AN	transmit antenna model	*n/a*	R2-AIP-05,
Antenna Model	AN	transmit antenna make	*n/a*	R2-AIP-05,
Height to Center RAAT	AN	transmit antenna height	*n/a*	R2-AIP-14

Latitude Degrees Latitude Minutes Latitude Seconds Latitude Direction Longitude Degrees Longitude Minutes Longitude Seconds Longitude Direction	LO	transmit location coordinates	*n/a*	R2-AIP-05
Polarization Code	AN	transmit polarization	*n/a*	R2-AIP-09,

Table 12: Relationship between ULS data elements and fixed service passive repeater parameters employed in this specification

ULS		**WINNF-TS-1014**		
ULS Data Element	**Record Type**	**Parameter**	**Symbol**	**Requirement ID(s)**
Antenna Type Code	AN	passive repeater antenna	*n/a*	R2-AIP-29
Antenna Model	AN	antenna model	*n/a*	R2-AIP-29
Back-to-Back Rx Dish Gain	AN	Back-to-back receive antenna gain	*n/a*	R2-AIP-29 R2-AIP-30
Back-to-Back Tx Dish Gain	AN	Back-to-back transmit antenna gain	*n/a*	R2-AIP-29 R2-AIP-30
Reflector Height	AN	reflector height	*n/a*	R2-AIP-29
Reflector Width	AN	reflector width	*n/a*	R2-AIP-29
NOTE: In “AN” record file for Back-to-Back antennas, “Antenna Model” is applied to both Tx and Rx dish antennas.				

Annex D (Informative): AFC System Operator Certification Procedure Information

The FCC has provided the information about the certification procedure for AFC System Operators in its Public Notice [i.7]. The descriptions below can be found in the Public Notice and are shown for informational purpose only.

- As specified in the 6 GHz Report and Order [n.3], OET will follow a multistep process to approve AFC Systems in which each prospective AFC System Operator must demonstrate its ability to perform the required functions pursuant to the Commission's 6 GHz unlicensed rules [n.1]. ([i.7], Paragraph 7)
- We request that parties interested in becoming an AFC System operator as part of the initial evaluation process submit their proposals no later than November 30, 2021. ([i.7], Paragraph 7)
    - The AFC System proposals must describe how the prospective AFC System Operator will comply with the requirements and core functions described in Section 15.407(k) of the Commission's rules [n.1] and the 6 GHz Report and Order [n.3]. ([i.7], Paragraph 9)
    - The public will then have an opportunity to review and comment on these proposals, including on each prospective operator's fitness to operate an AFC System as well as the technical and operational description of each proposed AFC System. Comments on these proposals must be submitted by December 21, 2021. ([i.7], Paragraph 7)
    - OET will review all proposals submitted by November 30, 2021 concurrently and with equal priority. Proposals submitted after this date will be considered by OET, but they may not be considered concurrently with proposals submitted by November 30, 2021. For any proposal received after November 30, 2021, OET will issue a public notice announcing receipt of the proposal and establishing a period for the public to review and comment on the proposal. ([i.7], Paragraph 7)
- Proposals will not be considered mutually exclusive and OET will conditionally approve as many proposals as are found to satisfy all AFC System requirements. ([i.7], Paragraph 7)
- Applicants who receive a conditional approval will then be required to allow access to their AFC System for a public trial period to provide interested parties an opportunity to check that it provides accurate results. ([i.7], Paragraph 8)
    - This trial period shall include thorough testing, both in a controlled environment (e.g., lab testing) and through demonstration projects (e.g., field testing). OET may also require prospective AFC System Operators to attend workshops and meetings as part of the assessment process. ([i.7], Paragraph 8)
- Prospective AFC system operators must comply with all instructions from OET and must provide any requested information in a timely manner. ([i.7], Paragraph 8)

Annex E (Informative): Data Interpolation Methods for Fixed Service Receiver Antenna and Passive Sites

E.1 Linear Interpolation for Fixed Service Antenna RPE

This informative annex provides the information about the Appendix A (App01) (in .xlsx format) of WINNF-TS-1014 which is used for FS receiver near field adjustment specified in R2-AIP-17.

The Appendix lists the difference, in dB, between the near field and far field RPE of a parabolic dish antenna assuming a Hansen single parameter dish illumination. This difference in the near and far field is a function of three parameters: 1) antenna illumination efficiency, 2) normalized distance from the antenna and 3) the discrimination parameter.

The antenna illumination efficiency is defined as the ratio of the far field boresight gain for a given illumination to the gain of the antenna with a uniform illumination [i.8]. This efficiency can be expressed in dB or as a simple ratio. For a Hansen illumination, the efficiency η is a function of its H parameter. The table below lists the H parameter for a number of efficiencies.

Table 13: H parameter vs efficiency η

H parameter	efficiency η	efficiency η [dB]
2.817	0.40	-3.98
2.454	0.45	-3.47
2.161	0.50	-3.01
1.918	0.55	-2.60
1.711	0.60	-2.22
1.532	0.65	-1.87
1.371	0.70	-1.55

The normalized distance x and the discrimination parameter u can be calculated as follows:

$$x = \lambda d/(2D^2),$$

$$u = (D/\lambda)\sin\theta,$$

where:

- D: the diameter of the dish antenna;
- λ: the wavelength of the microwave signal;
- d: the distance from the fixed service microwave antenna;
- θ: the discrimination angle from boresight;
- x can be expressed in dB as $10\log_{10}(x)$; and
- all distances are expressed in the same units.

A different tab is present in the Appendix A for 18 different normalized distances expressed in dB ranging from 0 dB ($x = 1$) to -17 dB ($x = 0.02$). On each tab the near field - far field difference is listed for the seven efficiencies in the table above as a function of the discrimination parameter. A properly interpolated value from these curves can be used to estimate the near field

RPE from the far field RPE given an efficiency, normalized distance and discrimination parameter.

Steps to interpolate the data are as follows:

1. First determine the fixed service antenna efficiency along with the discrimination parameter and the normalized distance in dB to the interference source. Then, find the two worksheets in the workbook that bracket the normalized distance. If the normalized distance is greater than or equal to 0 dB, no near field adjustment is needed, and no further calculations are necessary. If the normalized distance is less than -17 dB, use the -17 dB worksheet.
2. Next find the two column pairs on each worksheet that bracket the antenna efficiency (η). If the efficiency is less than 0.4, use the 0.4 column pair. If the efficiency is greater than 0.7, use the 0.7 column pair.
   - In the left column of each column pair, find the two discrimination parameter (u) values that bracket the discrimination parameter. If the discrimination parameter is greater than the largest value listed in the column, use an adjustment factor value of zero. Otherwise use linear interpolation between the two bracketing values and the desired discrimination parameter for each column pair.
   - If working with two column pairs in a worksheet, use linear interpolation between the two determined column values for the desired antenna efficiency. This is the adjustment factor associated with the worksheet.
   - If working with two worksheets, use linear interpolation between the two adjustment factors for each worksheet and the desired normalized distance in dB. This will result in the final adjustment factor to be added to the far field RPE value at the discrimination angle.

E.2 Linear Interpolation for Passive Sites

In R2-AIP-31, the near field dB value of α_n can be interpolated from the supplementary tabulated data with the following procedure. To determine the value of α_n for particular $1/K_s$ and Q values, the nearest surrounding values of these parameters can be found in column A and row 1 of the Appendix B (App02). Then bilinear interpolation is used to find α_n. Assuming these surrounding values are given by:

$$1/K_{S1} \leq 1/K_S \leq 1/K_{S2}$$

$$Q_1 < Q \leq Q_2$$

Then,

$$\alpha_n(1/K_S, Q) = w_{K1}w_{Q1}\alpha_n(1/K_{S1}, Q_1) + w_{K2}w_{Q1}\alpha_n(1/K_{S2}\ Q_1) + w_{K1}w_{Q2}\alpha_n(1/K_{S1}, Q_2) + w_{K2}w_{Q2}\alpha_n(1/K_{S2}, Q_2)$$

Where the $\alpha_n(1/K_{Si}, Q_j)$ dB values come from the appropriate row and column of the tabulated data and the weights are defined as:

$$w_{K1} = \frac{1/K_{S2} - 1/K_S}{1/K_{S2} - 1/K_{S1}} \qquad w_{Q1} = \frac{Q_2 - Q}{Q_2 - Q_1}$$

$$w_{K2} = \frac{1/K_S - 1/K_{S1}}{1/K_{S2} - 1/K_{S1}} \qquad w_{Q2} = \frac{Q - Q_1}{Q_2 - Q_1}$$

Annex F (Informative): Revision History

Document History		
V1.0.0	15 December, 2021	Initial version.
V1.1.0	25 May, 2022	New revision incorporating the following features: ▪ Formula for I/N determination ▪ Propagation model parameters ▪ Fixed Service receiver primary and diversity antenna RPE, and polarization mismatch ▪ Feeder loss ▪ Use of location uncertainty ▪ Query methods for a list of available frequencies
V1.2.0	31 October, 2022	New revision incorporating the following features: ▪ Technical clarifications to the existing requirements ▪ Determination of fixed service receiver parameters (bandwidth, effective antenna gain, etc.) ▪ Propagation model parameters ▪ Building entry loss ▪ Passive repeaters and reflectors ▪ New structure of section 9.1 for better readability. ▪ Minor editorial changes.
V1.2.1	10 November 2022	Editorial revision to page 54 to address the following: ▪ Item iii) $G_{VRx, Disc}$ to $G_{VRx-j, Disc}$ (Agreed resolution included this, but missing to add “-j”.) ▪ Item iii-1) $G_{VRx, Disc}$ to $G_{VRx-j, Disc}$ (Same as above. Two places in this item.) ▪ Item iii-2) $D_0 = -10\log_{10}[4pAcos(\theta_{IN}/\lambda^2)]$ to $D_0 = -10\log_{10}[4pAcos\theta_{IN}/\lambda^2]$ (Agreed resolution did not include circle brackets, but accidentally added circle brackets before θ_{IN} and after λ^2 .)
V1.3.0	9 March 2023	New revision incorporating the following changes: ▪ Clarification of R2-AIP-29 and R2-AIP-30 ▪ New footnote in R2-AIP-16 for protection of both primary and diversity antennas ▪ Addition of WINNER II model to the scope of R2-AIP-33 ▪ Clarification of the definition of “Proxy” ▪ Clarification of Feeder Loss value for IDU and ODU (R2-AIP-10)
V1.4.0	6 October 2023	New revision incorporating the following changes: ▪ WINNF-22-I-00129 CR for Fixed Service Diversity Receive Antenna Gain and Diameter IITG Approved ▪ WINNF-23-I-00023 Change Request to Bandwidth determination from Emission Designator ▪ WINNF-23-I-00037 CR to TS-1014 V1.2.1 ▪ WINNF-23-I-00065-r1 CR – Addressing Network Element Security