COMMENTS OF THE WIRELESS INNOVATION FORUM ON THE INSTITUTO FEDERAL DE TELECOMUNICACIONES (IFT) MEXICO CONSULTATION ON THE 6GHZ BAND[1]

The Wireless Innovation Forum (WInnForum) is a U.S. based international non-profit organization driving technology innovation in commercial, civil, and defense communications around the world. Forum members bring a broad base of experience in Software Defined Radio (SDR), Cognitive Radio (CR) and Dynamic Spectrum Access (DSA) technologies in diverse markets and at all levels of the wireless value chain to address emerging wireless communications requirements through enhanced value, reduced total life cost of ownership, and accelerated deployment of standardized families of products, technologies, and services. In 2014, the WInnForum created a Spectrum Sharing Committee focused on implementing the U.S. Federal Communications Commission's regulations for three-tiered spectrum sharing in the 3550-3700 MHz (CBRS) band.

In 2019, the 6 GHz Committee (6GHzC) was formed by the WInnForum to serve as an industry body to study and specify sharing arrangements in spectrum designated for unlicensed operation within all or part of the 6 GHz band (5925-7125 MHz). The Committee is providing technical input to inform the FCC's 6 GHz Notice of Proposed Rulemaking (NPRM)[2] and facilitate the interpretation and implementation of the rulemaking that allows industry and regulators to collaborate on implementation of a common, efficient and well-functioning 6 GHz ecosystem. The Committee Charter can be found here. The initial activities being conducted by the Committee include:

- Defining:

[1] "Consulta Pública de Integración del "Cuestionario sobre la banda de frecuencias 5925-7125 MHz", 5 November 2020

[2] FCC, "In the Matter of Unlicensed Use of the 6 GHz Band Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz; ET Docket No. 18-295 and GN Docket No. 17-183," FCC 18-147, October 2018.

    - Propagation Modeling
    - Interference Protection Criteria
    - Spectrum Occupancy Determination
- Developing a Security Threat Assessment
- Identifying Automated Frequency Coordination (AFC) Requirements for Incumbent Protection

WInnForum notes that IFT is seeking comments on the 5925-7125 MHz frequency band (referred to as the 6 GHz band). While the WInnForum does not have detailed comments, we want to bring to the attention of IFT the following 6GHz Technical Reports developed by the WInnForum that can be useful to IFT. These WInnForum reports are also attached.

- WINNF-TR-1002-V1.0.0 Propagation and IPC for 6 GHz Sharing

The purpose of this Technical Report is to provide stakeholders, including the regulatory authorities, with relevant information regarding the operation of unlicensed mobile equipment within the 6 GHz band under terms to be detailed by the FCC under 47 CFR Part 15 rules. In addition, it provides a summary of viewpoints regarding some of the important criteria (e.g., propagation modelling approaches and interference protection criteria) that need to be considered when sharing that spectrum with one primary assignee to the band, namely the Fixed Service (FS), which is composed of point-to-point microwave links. A secondary purpose of this report is to provide relevant information to regulators and stakeholders outside the United States, who may be interested in adopting similar sharing rules between the fixed service and unlicensed users in the band.

- WINNF-TR-1003-V0.0.0-r5.1 (IR1) Requirements for 6 GHz Incumbent Protection

The scope of this document is to identify for 6 GHz stakeholders (e.g., incumbents, proposed unlicensed interests, FCC, etc.) the requirements for the protection of incumbents to support unlicensed operation of Universal National Information Infrastructure (U-NII) devices in the 6 GHz band (5925-7125 MHz) in the U.S.

- WINNF-TR-1008-V1.0.0 6 GHz Incumbent Data Technical Report

With the FCC 6 GHz Report and Order (R&O)[3], the FCC requires that the Automated Frequency Coordination (AFC) system rely on the Universal Licensing System (ULS) for fixed microwave link data when calculating and establishing the exclusion zones to protect those microwave links from harmful interference in the 5.925-6.425 GHz and 6.525-6.875 GHz bands. This document provides information on general data quality issues with the ULS and identifies some of the missing data that will be pertinent to future discussion on AFC system implementation.

The WInnForum welcomes the opportunity to provide these inputs to IFT as they seek information on the 6 GHz band and looks forward to continuing the discussion with IFT.

Respectfully submitted,

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The Wireless Innovation Forum
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Dated: 19 January, 2021

[3] https://ecfsapi fcc.gov/file/0424167164769/FCC-20-51A1.pdf

Requirements
for
Protection of Incumbents in the 6 GHz Band

Working Document WINNF-TR-1003

Version V0.0.0 (IR1) -r5.1
8 April, 2020

TERMS, CONDITIONS & NOTICES

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Interim Release Status

This is the first of several planned interim releases in the development of this report. Interim releases are approved at the Committee level, but do not go through final Forum ballot. Accordingly, the contents of this document are not final and are subject to change as the project progresses.

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Requirements for Protection of Incumbents in the 6 GHz Band

1 Scope

The scope of this document is to identify for 6 GHz stakeholders (e.g., incumbents, proposed unlicensed interests, FCC, etc.) the requirements for the protection of incumbents to support unlicensed operation of Universal National Information Infrastructure (U-NII) devices in the 6 GHz band (5925-7125 MHz) in the U.S. These requirements are identified based on the FCC NPRM. [1]

This document presumes there will be an Automatic Frequency Coordination (AFC) system as described in the NPRM, "To determine whether an individual unlicensed device can transmit at a particular location on a given frequency…".[2]

This document is provided from the perspective of incumbent protection. For the purposes of this document, "incumbents" refers to any system authorized to operate in parts or the entirety of the four U-NII sub-bands comprising the 6 GHz band.[1][1] and "U-NII devices" refers to, unless otherwise specified, Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) which will operate on an unlicensed basis in the sub-bands which would require AFC system. The document specifically concerns itself with protection of the fixed microwave services that occupy large parts of 5925-7125 MHz.

2 References

[1] FCC, "In the Matter of Unlicensed Use of the 6 GHz Band Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz; ET Docket No. 18-295 and GN Docket No. 17-183," FCC 18-147, October 2018. ("NPRM")

[2] *Id*, Sec III A. 2., para 25

[3] *Id*, para 41

[4] WINNF-TR-1002, Version V0.0.0-r6.0, "Propagation Models and Interference Protection Criteria for Sharing between the Fixed Service and Unlicensed Devices in the 6 GHz Band"

[5] NPRM, Sec II B.

3 Definitions and Abbreviations

This document uses the following definitions and abbreviations:

[1] See section II B. "Incumbent Services in the 6 GHz Band"

3.1 Abbreviations

Abbreviation	**Description**
3DEP	3D Elevation Program (USGS)
6MSC	6 GHz Band Multi-stakeholder Committee
AFC	Automated Frequency Coordination
APO	Availability Performance Objective
ATPC	Automated Transmit Power Control
BEL	Building Entry Loss
CBRS	Citizens Broadband Radio Service
CFR	Code of Federal Regulations
EAS	Equipment Authorization System
ECC	European Communications Committee
ECO	European Communications Office
EIRP	Equivalent Isotropic Radiated Power
eHata	Extended Hata
EPO	Error Performance Objective
FCC	Federal Communications Commission
FS	Fixed Service
IPC	Interference Protection Criteria
ISM	Industrial, Scientific, and Medical
ITM	Irregular Terrain Model
ITS	Institute of Telecommunications Studies
ITU-R	International Telecommunications Union, Radio Communications Bureau
LA	Link Adaptation
NLoS	Non-line of Sight
LoS	Lone of Sight
LPI	Low Power Indoor
NLCD	National Land Cover Database
NPO	Network Performance Objective

Abbreviation	Description
NPRM	Notice of Public Rule-Making
NSMA	National Spectrum Management Association
NTIA	National Telecommunications and Information Administration
P2P	Point-to-Point
R&O	Report and Order
RLAN	Radio Local Area Network
SAS	Spectrum Access System
SDR	Software Defined Radio
ULS	Universal Licensing System
U-NII	Unlicensed National Information Infrastructure
USGS	United States Geological Survey
VLP	Very Low Power
WInnForum	Wireless Innovation Forum

3.2 Definitions

4 Requirements

Below is an outline of areas that requirements must address regarding protection of incumbents in the 6 GHz bands (5925-7125 MHz). These will be more developed in future releases.

4.1 Data

Requirements must describe the data on incumbent operations needed to protect incumbents and identify data sources. Requirements must also describe how to address data accuracy issues and how data are corrected.

4.1.1 Data Required

The data needed to perform effective determination of harmful interference from U-NII devices into incumbents.

Information on incumbent deployments should include details about assigned frequencies, the location of the installation, the height of any receiving structures relative to a suitable reference (e.g. ground level or mean sea level), antenna characteristics that include, at a minimum, gain and half-power beamwidths of the receiving antenna in the horizontal and vertical directions, and the front-to-side-lobe ratio and front-to-back ratio. It would be preferable to get the antenna directivity in azimuthal and elevation profiles and the peak gain of the antenna. The absence of such a database will require the FCC to actively solicit the corresponding information from incumbent users as a condition of receiving protection from U-NII devices.[2]

4.1.2 Data Sources

The sources of the data detailed above including FCC databases (ULS, EAS, others) or other data sources. [3]

4.1.3 Update Interval

How frequently the data should be updated from the data sources considering the dynamic nature of licensing or frequency coordination.

4.1.4 Accuracy & Corrections

Mechanism to ensure data are accurate and there is a way to apply corrections.

4.1.5 Public Availability

Should any of this data be made public if it is not already so?

4.2 Spectrum Availability Determination

Requirements must detail how spectrum availability will be determined for operation of U-NII devices. The requirements should also include the factors that should be considered and how are they used to determine spectrum availability.

[2] The FCC could issue Public Notices inviting incumbents to update their information in the various FCC databases.

4.2.1 U-NII Device-specific Information

Radio transmission characteristics of U-NII devices need to be considered under some circumstances when determining the allowable transmit power and frequency ranges on which the U-NII devices may operate. Specific implementation details of these characteristics may be guided by regulations, but the precise definitions should be left to industry. For example, how these characteristics are considered, when and how they are shared between entities (e.g., AFC, U-NII device, etc.) and which operational entities might take actions based on these characteristics can be addressed under the appropriate multi-stakeholder groups.

Examples of radio transmission characteristic that might affect radio operational parameters include:

- Total transmit power (conducted plus antenna gain or EIRP), power density
- Occupied bandwidth
- Activity factor (i.e., fraction of time actual transmission occurs)
- Location
- Whether or not it's talking to an AFC and what kind
- Antenna characteristics

4.2.2 Accounting for Multiple U-NII Devices

Methods to account for combination of received interference at the incumbent's antenna from multiple U-NII devices operating from multiple locations.

UNII device aggregation, if used by AFC, should be subject to a statistical distribution of multiple UNII devices with mapping to associated characteristics of the incumbent antenna.

4.2.3 Propagation Modeling (or measurements, possibly per U-NII device)

Describe propagation models appropriate for varied situations. Should address the following (note this has also been addressed in [4]):

- Clutter Loss
- Building Entry Loss (BEL) (optionally, the AP can report measured BEL)
  - BEL is suggested for structures with various construction materials such as conventional low-loss building materials (e.g. plain glass windows) and new construction e.g. using foil-backed insulation and low-emissivity windows.
  - For BEL evaluation, a minimum distance, e.g. 1-3 meters, may be considered for the distance of a UNII device from a window.
- Visual inspection to determine potential blockages
- Interference Protection Criteria
- Probability of crossing the I/N threshold at the FS receiver

For clutter loss, in addition or as a replacement of analytical models, clutter evaluation using mapping software, e.g. Google Earth, may be considered.

4.2.4 Incumbent Receiver Characteristics

How the above information is used to determine potential for interference and describe additional data required to perform calculations. Industry solutions need to consider:

Antenna & cabling/waveguide characteristics

Near-field considerations

Polarization decoupling

Blocking

Rx filter selectivity

4.2.5 Quiet Zones

Identify and describe any Quiet Zones and the method for protecting (e.g., exclusion zone). These will likely be provided by the FCC.

Quiet zones may be subject to a time limit, and occurrence limit per incumbent station per unit time interval.

4.2.6 U-NII Device Location and Accuracy

This will be used to calculate an ellipsoid of location uncertainty around each U-NII device roughly equal to the device's location accuracy in three axes. The uncertainty ellipsoid will be used to determine proximity of the device to a given incumbent.

4.2.7 Periodic Spectrum Availability Re-check

The circumstances and how often devices need reverify available spectrum due to the following:

U-NII device relocation (max distance device can be moved and not have to recheck)

Frequency of recheck: How often should the device recheck considering dynamic nature of incumbent activity (e.g., new ULS filings, frequency coordinations, etc.)

Power off/on: Device powers off then back on.

4.3 Testing and Certification

AFCs and U-NII devices operating under AFC management will likely need to be tested and certified. This section describes the potential requirements for the testing and certification process for AFCs associated U-NII devices to ensure they meet minimum requirements and have appropriate certifications.

4.3.1 Development of Test Plans

How test plans will be developed to ensure sufficient testing of device's compliance with FCC rules.

4.3.2 Testing Agency

Identify criteria for testing agencies to instantiate test plans into a certification testing program.

4.3.3 Minimum Requirements for Certification

Describes the minimum testing requirements for devices to be certified by the FCC.

4.3.4 Reporting & feedback requirements

How to address bug fixes, changes, enhancements, etc. that would require additional testing and certification.

4.4 Performance requirements

Incumbents need assurance that AFCs are duly certified and operating pursuant to that certification.[3] This section describes the potential requirements for AFC system operator.

4.4.1 Term

The duration of the AFCs' certification

4.4.2 Termination

Circumstances that would cause an AFC to lose certification

4.4.3 Change of AFC Ownership or Transfer of Responsibility

This may be provided by the FCC, but requirements should dictate how to handle changing who manages an AFC (AFC system operator).

4.5 Interference Reporting, Identification and Mitigation

Incumbents need assurance there is a means to report interference and ensure it is promptly and correctly mitigated.[4] This section describes the potential requirements for interference reporting, identification and mitigation. The section also includes the relevant analysis.

4.5.1 Description of Interference

Describe and characterize what is interference and what AFC can manage. Need to consider whether devices are managed or not managed by the AFC.

LPI (Low Power Indoor) and VLP (Very Low Power) devices are not coexisting with Standard Power Access Points in the band.

LPI and VLP devices are coexisting with Standard Power Access Points in the band.

4.5.2 U-NII Device Registration

Registering on an AFC and providing location information will help identify potential interferers. As an alternative, AFC might poll device behavior but need to balance complexities of this approach and pending privacy verification/checks.

[3] See for example UTC NPRM Reply Comments at Sec. 6.
[4] See FWCC NPRM Reply Comments at Sec 10.

4.5.3 Interference Mitigation

The steps to mitigate interference once it is verified.

4.5.4 Enforcement Actions

Actions by the FCC to enforce incumbent interference protection. (Note, the FCC may likely engage AFC system operator in the enforcement process. Would be worthwhile to discuss and suggest a process.)

4.5.5 Considerations on Unmanaged U-NII Devices

What are the steps (if any) to identify and mitigate interference from U-NII devices not managed by an AFC.

4.5.6 Aggregative Effects

How to accommodate aggregate interference when the interferer is not a single source. Also need to consider interference with incumbents that may be transportable such as Broadcast Auxiliary.

4.6 Security

This section assesses the potential for security breaches that could put incumbents at risk and identifies mitigations.

4.6.1 Threat Assessment

Comprehensive assessment of all potential security threats.

4.6.2 Verification and Validation

How threats are verified and validated.

4.6.3 Blacklisting

What are conditions and circumstances for blacklisting and de-blacklisting devices if needed.

4.6.4 Device Integrity

How to ensure device is resistant to hacking, tampering, software trust, etc.

4.6.5 Privacy

How to ensure end-user privacy.
AFC should be designed and enabled to protect the information of the U-NII devices that have been authorized or considered for authorization by the AFC.

4.7 Ongoing ecosystem management

Need process to ensure ecosystem evolves as needed and there is a means to capture lessons learned and feedback to requirements as needed.

4.7.1 Management of Operational Feedback

How to gather operational feedback to ensure capture of lessons learned and improvements to processes and procedures.

4.7.2 Requirements Review

Process to review, update and reissue requirements as needed given the above.

4.7.3 Management of Future Releases

How to manage the above in the context of future releases, what are the requirements and responsibilities and who manages.

5 Recommendations and Conclusions

6 Future work

Incumbent Fixed Service Data in the U.S. U-NII 5 & 7 Bands

Document WINNF-TR-1008

Version V1.0.0
January 5, 2021

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Incumbent Fixed Service Data in the U.S. U-NII 5 & 7 Bands

1 Background

With the FCC 6 GHz Report and Order (R&O), FCC 20-51[1], the FCC requires that the Automated Frequency Coordination (AFC) system rely on the Universal Licensing System (ULS) for fixed microwave link data when calculating and establishing the exclusion zones to protect those microwave links from harmful interference in the 5.925-6.425 GHz and 6.525-6.875 GHz bands. This document provides information on general data quality issues with the ULS and identifies some of the missing data that will be pertinent to future discussion on AFC system implementation.

1.1 FCC Report and Order FCC 20-51

The R&O establishes ULS as the data source for incumbent fixed microwave link data. From paragraph 30 (underlining added):

"Use of ULS for information on incumbent operations. As proposed in the Notice, we will require that the AFC system rely on the Commission's Universal Licensing System (ULS) for fixed microwave link data when calculating and establishing the exclusion zones to protect those microwave links from harmful interference. The Universal Licensing System is the official licensing database for microwave links in the U-NII-5 and U-NII-7 bands and contains extensive technical data for site-based licenses including transmitter and receiver locations, frequencies, bandwidths, polarizations, transmitter EIRP, antenna height, and the make and model of the antenna and equipment used. Thus, the Universal Licensing System contains the information necessary for AFC systems to protect fixed service links. Several commenters, including APCO, the Dynamic Spectrum Alliance, the Open Technology Institute et al., Apple, Broadcom et al., and Wi-Fi Alliance support using the ULS system for this purpose. To ensure that AFC systems have the most recent information on fixed service links, we will require AFC systems to download the database on a daily basis."

Paragraph 32 goes on to clarify that licensed, pending, and temporary fixed stations should all be protected by the AFC system (underlining added):

"Microwave links may begin operation prior to obtaining a license so long as certain criteria are met, such as completing successful frequency coordination and filing an application that appears in the Universal Licensing System as pending. Because such a filing may indicate that a new station is operational, or soon will be, we will require the AFC system to protect pending as well as granted facilities. In addition, temporary fixed microwave links may be authorized by a blanket authorization, in which case the licensee is not required to obtain approval from the Commission prior to operating at specific locations or report the technical details of their operation to the Commission. Because the AFC system must have knowledge of the location of temporary fixed

[1] https://ecfsapi.fcc.gov/file/0424167164769/FCC-20-51A1.pdf

links in order to protect them from harmful interference, we will require the operators of temporary fixed stations to register the details of their operations (transmitter and receiver location, antenna height, antenna azimuth, antenna make and model, etc.) in the Universal Licensing System prior to transmission if they desire to be protected from potentially receiving harmful interference from standard-power access points in the U-NII5 and U-NII-7 bands. Because temporary fixed links are not mobile and intended to operate at a specified location for up to a year, we do not believe this registration requirement poses a significant burden on licensees."

2 The ULS and how to Access it

2.1 The ULS

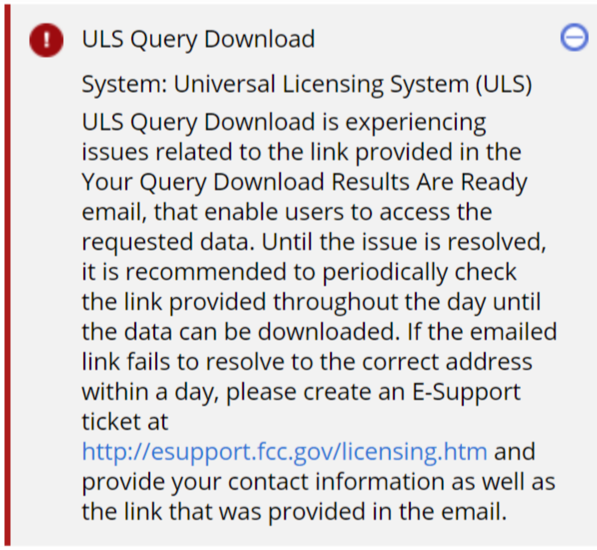
The ULS is used by the FCC to authorize licensed incumbent fixed microwave transmitters in the 6 GHz bands in which unlicensed devices are subject to direction by an AFC system: 5.925-6.425 GHz and 6.525-6.875 GHz. The ULS contains data on several other bands and several radio services under the FCC's Wireless Telecommunications Bureau. The AFC system discussion is concerned with the Microwave Service (47 CFR Parts 74 and 101).

The ULS is primarily a regulatory database and lacks comprehensive technical data required to perform accurate interference analyses by an AFC system. Data on microwave systems is typically entered into the ULS by filing an application after the successful completion of the Part 101 Frequency Coordination Process. The user interface for ULS can be found at https://www.fcc.gov/wireless/systems-utilities/universal-licensing-system.

2.2 Accessing ULS Data

ULS data is freely available to anyone via three mechanisms:

1. A user web interface at https://www.fcc.gov/wireless/systems-utilities/universal-licensing-system. From this page, there is a License Search and an Application Search link. The Advanced search can be used to limit the frequency range, and any other criteria. The licenses and applications will be displayed on an easy-to-read web page.
2. Email request for data (text file). On the query results of the user web interface, there is a Query Download link where an e-mail address can be provided. A link to the download, once it is prepared, will be sent in the e-mail.
    a. This method often has issues, especially with zipped files over 5 MB.
    b. While an e-mail with the subject, License Search Query Download Confirmation is provided, the download file is frequently not created.
    c. The main ULS page, https://www.fcc.gov/wireless/systems-utilities/universal-licensing-system, provides system alerts, like that shown in Figure 1 below:


ULS Query Download

System: Universal Licensing System (ULS)

ULS Query Download is experiencing issues related to the link provided in the Your Query Download Results Are Ready email, that enable users to access the requested data. Until the issue is resolved, it is recommended to periodically check the link provided throughout the day until the data can be downloaded. If the emailed link fails to resolve to the correct address within a day, please create an E-Support ticket at http://esupport.fcc.gov/licensing.htm and provide your contact information as well as the link that was provided in the email.

Figure 1: Example ULS Query Download Error Message

3. Weekly and daily files containing all fixed microwave bands is posted via FTP at:
    a. ftp://wirelessftp.fcc.gov/pub/uls/complete/
    b. ftp://wirelessftp.fcc.gov/pub/uls/daily/
    c. The FCC provides more information about the downloads at https://www.fcc.gov/wireless/data/public-access-files-database-downloads
    d. Note that these downloads will need to be filtered to just the U-NII-5 and U-NII-7 bands.

ULS data is arranged in a series of over 80 different tables, none of which contains header information. In addition, when the data is made available through the e-mail/download process, it is provided as a single delimited file. An example of a typical microwave data record is provided in Figure 2.

The ULS data that is relevant to 6 GHz fixed service incumbents is the "Microwave – 47 CFR Parts 74 and 101, and 3650-3700 MHz (NN)" database.

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HD|||MW000CF001|||CF|||||C|N|N|N|N|N|N|N|N|N|N|N|Y|Y|Y|N|N|N|N|Robert|L|Smith|Sr|President|||||||||||
AD|||MW000CF001|NE||N|N||||||||Y|1|N|||||Y||||
EN|||MW000CF001||CL||MW Law LLC|||||2024184563|2024187799||2100 M Street|Washington|DC|20004||||
EN|||MW000CF001||O|L00065142|||||||||||||||
MW|||MW000CF001||N|||F||FX0|N
EN|||MW000CF001||L|456789122|EBF Inc.|||||2027287100|2027287722||1720 K Street|Washington |DC|20006||000||
PS|||MW000CF001|2||Arlington
CP|||MW000CF001||A|1|800 North Ave|New York|NY|2125554646|Queens
LO|||MW000CF001||A|F|T|1|||601 Cleveland St|Clearwater|Pinellas|FL||||10.7|27|57|54.9|N|82|47|54.3|W||||||||
N|||36.6|38.8|B||Tamp003|||||
LO|||MW000CF001||A|F|R|2|||||||||9.1|27|57|57.9|N|82|47|54.3|W||||||||||||||Tam0014024|||||
LO|||MW000CF001||A|F|R|3|||||||||22.6|27|57|40|N|82|46|33.3|W||||||||||||||Tam0013938|||||
LO|||MW000CF001||A|F|R|4|||||||||11.3|27|57|57.9|N|82|47|27.9|W||||||||||||||Tam0013861|||||
AN|||MW000CF001||A|1|1||T||38.1|Radio Waves Inc|HPLP1.5-23|3.8|V|2.1|37.8|0||||||||||1|||1|
AN|||MW000CF001||A|1|2||R||51.5|Radio Waves Inc|HPLP1.5-23||||37.8|||||||||||2|||1|
AN|||MW000CF001||A|2|1||T||38.1|Radio Waves Inc|HPLP1.5-23|0|V|2.1|37.8|101.7||||||||||1|||2|
AN|||MW000CF001||A|1|3||R||25.6|Radio Waves Inc|HPLP1.5-23||||37.8|||||||||||3|||2|
AN|||MW000CF001||A|3|1||T||38.1|Radio Waves Inc|HPLP1.5-23|1.5|V|2.1|37.8|82.7||||||||||1|||3|
AN|||MW000CF001||A|1|4||R||55.8|Radio Waves Inc|HPLP1.5-23||||37.8|||||||||||4|||3|
FR|||MW000CF001||A|1|1|FX0||22725||||||0.001|||29.8|Digital Microwave Corp||N||||||1
FR|||MW000CF001||A|1|2|FX0||22525||||||0.001|||54.8|Digital Microwave Corp||N||||||2
FR|||MW000CF001||A|1|3|FX0||22925||||||0.001|||37.8|Digital Microwave Corp||N||||||3
EM|||MW000CF001||1|1|22725|A|10M0F7W|12352|4FSK||1
EM|||MW000CF001||1|2|22525|A|10M0F7W|12352|4FSK||2
EM|||MW000CF001||1|3|22925|A|10M0F7W|12352|4FSK||3
PA|||MW000CF001||A|1|1|1|2|1||PP|N||N|
PA|||MW000CF001||A|2|1|2|3|1||PP|N||N|
PA|||MW000CF001||A|3|1|3|4|1||PP|N||N|
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Figure 2: Example of ULS ASCII Batch File

3 Problems with ULS Data

The AFC system will need to interface with the ULS to obtain data on technical configurations of incumbents' microwave systems. This retrieval must occur at least daily and it must include data on granted licenses as well as pending applications. [2] Granted licenses and pending applications are stored as two separate sets of data with different table structures.

The following sections outline typical ULS data issues that will need to be addressed to ensure operational effectiveness of the AFC system.

The ULS data is maintained by and the responsibility of incumbent licensees.[3] As indicated in the R&O, the FCC is expected to issue a Public Notice reminding licensees of the importance of maintaining accurate information in the ULS.

[2] See 47 CFR 15.407 (k)(8)(iv).

[3] See the R&O at ¶ 31.

3.1 Administrative Issues

An AFC system must have accurate, up to date data to sufficiently protect incumbents and make accurate calculations. If FTP data downloads are moved, changed, or delayed, AFC systems could be out of compliance with the 24-hour data accuracy rule stated in the R&O. The FCC routinely has the following administrative challenges with their FTP posting.

3.1.1 Changes to the Location of the Data Download

In April of 2019, and again in March 2020, the FCC changed the location where the ULS data was posted. This caused automated data-retrieval tools to stop functioning. While adequate notice was provided in April of 2019, no noticed was received for the March 2020 change and old data files still existed in the locations for months after the change.

3.1.2 Field Definition Changes

The FCC routinely makes changes to data definitions due to regulatory changes. In September 2015, and March 2018, the FCC made changes to the ULS data definitions with no notice. In July 2020, the FCC announced an upcoming change to the data definitions with 30 days' notice, tentatively scheduled for August 2020.
Without a header row in each file, there is no easy way to detect new definitions or implement a "fail-operate" approach to the data.

3.1.3 Data Posting Times Inconsistent

Full data downloads are typically posted on Sunday. Daily change downloads for activity on the prior day post the next day, usually late in the morning, but posting times vary frequently and times late in the afternoon have been observed.

The FCC used to provide alerts on their website when there were delays in posting the data, but there have been no alerts lately.

3.2 General notes on data quality

The nature of the ULS gives rise to the probability of data accuracy issues. First, ULS data can be entered manually with remedial error checking. This increases the likelihood of introducing errors. For example, there is a license record that shows a 500 MHz emission bandwidth, which is clearly incorrect. Cross-checking against Comsearch's frequency coordination database found that it should have been entered as 5 MHz.[4] It is also possible to find antenna models that are clearly the names of radio models.[5] There is little validation or control on critical fields and data in key fields is sometimes missing entirely.

Furthermore, by design, the FCC uses the ULS to authorize transmitters. To a much lesser extent, the FCC collects receiver information, but some key data required to protect receivers is not collected as described below. Given that interference manifests at the receiver, comprehensive and accurate receiver information will be critical for the AFC system.

[4] Comsearch is a well-known Part 101 microwave frequency coordinator who maintains a proprietary database microwave systems and configurations.
[5] For example, a cursory glance revealed 36 receivers starting with MDR, which is a radio model nomenclature.

We note that incumbent licensees are responsible for the completeness and accuracy of their license record information in the ULS. However, data inaccuracies present an inaccurate picture of spectrum usage, which can affect both incumbents and new entrants alike. Some specific examples are outlined in the following sections.

3.3 "Zombie" Paths

An example of a situation where data errors might over-protect incumbents is the concept of a "zombie path".

A "zombie path" occurs under the following scenario:

- A single call sign (unique identifier of a site license) represents a single site per licensee, but it may have multiple paths emanating from that site.
- In the case where a duplex (two-way) path is decommissioned, a licensee must remember to delete or modify both licenses for each direction of the path. That includes the receive end of the path.
- The FCC charges fees to licensees as they manage the data related to their license records. There is no fee to delete an entire call sign, but the FCC charges a fee to delete one path on a call sign that has other licensed paths. This is considered a license modification.
- Consequently, there are paths where one call sign is deleted but the call sign on the other end of the path is licensed and still shows the path to the original receive site. Since that receiver still appears on its formerly associated transmitter's license, the license record for that call sign shows a receiver that likely no longer exists.

Note that these zombie paths are generally indistinguishable from legitimate simplex (one-way) paths.

About 1200 zombie paths were found in the ULS data by using Comsearch's frequency coordination database to identify them. A call for incumbents to clean up their license data could mitigate the zombie path issue, though the underlying reason they exist would remain.

3.4 ULS Antenna Data Problems

Correct and comprehensive data on antennas is critical for the AFC system analysis and will influence spectrum availability, but ULS antenna data has many issues as discussed below.

3.4.1 Null and Missing ULS Antenna Data

Several ULS data queries were performed and the following null or missing data were found in the FCC's licensed data sets as of August 4, 2020. Note that "null" data refers to fields that exist in the ULS but are not populated, while "missing" data is information that is important for the interference calculations (e.g., antenna patterns), but the necessary field is not available in the ULS at all.

Figure 3 shows that for over 6000 data records, the information for the main receive antenna is null and that for over 200 records, the gain is null.

If the FCC prompts licensees to update their license data, this information could be largely corrected. It should be noted that there could still be nulls to deal with even if the Commission prompts licensees to update their data.

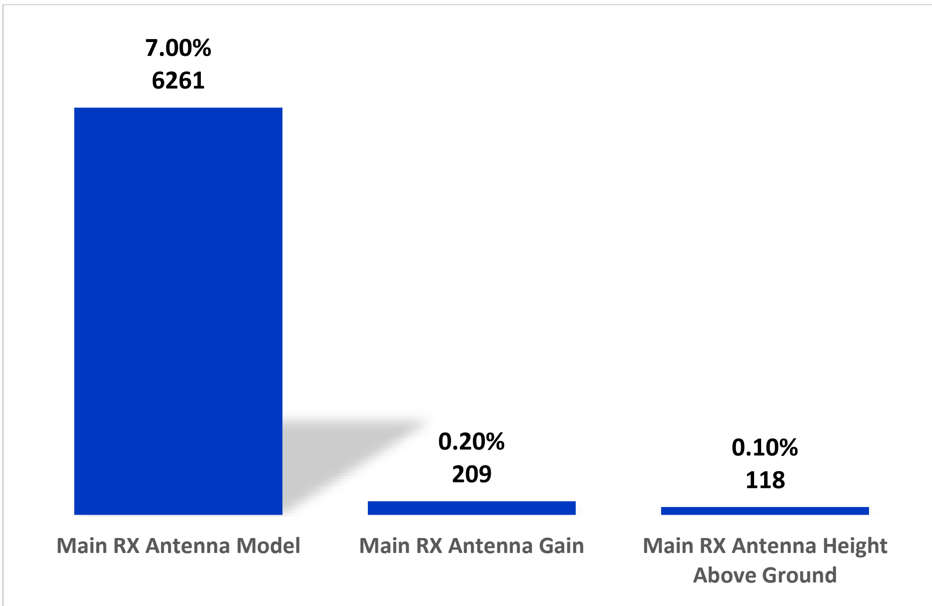

Figure 3: Null Antenna Data

Figure 4 shows that receive-only losses, diversity RX antenna models, and antenna patterns are completely missing from the ULS. From other data it has been determined that nearly a third of licenses have diversity antennas, so that is how many records are affected by the missing diversity RX antenna model data. These missing data items are discussed further in the following sections.

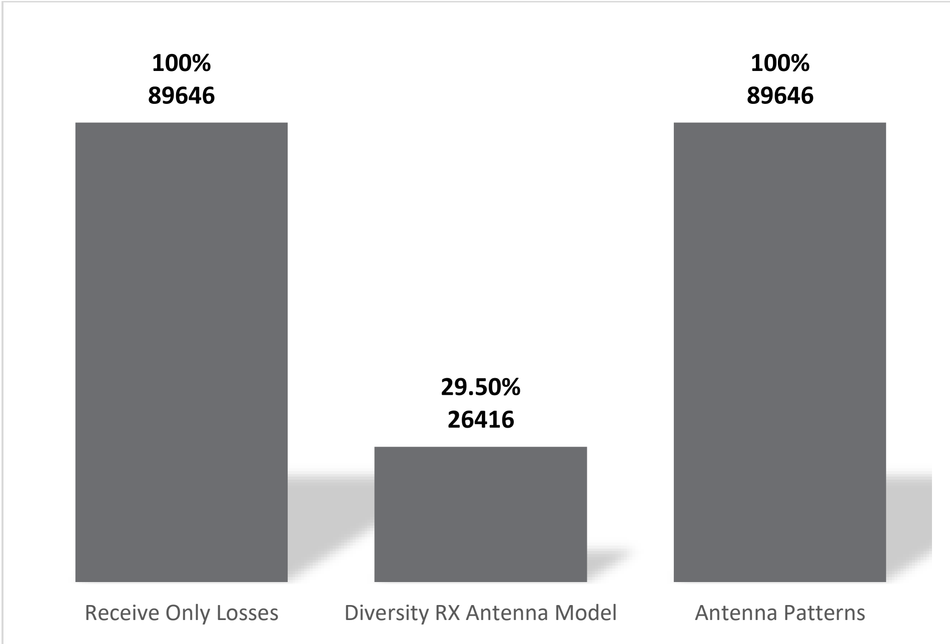

Figure 4: Missing Antenna Data[6]

3.4.1.1 Receive Only Losses

The ULS does not record receive losses (i.e., line and connector losses) between radio and antenna at all, but it is an important value for interference calculations. Without receive losses, incumbent receivers may be over-protected. It should be noted that 0 dB is typical for ODU (outdoor unit) type systems that are being deployed widely today.

3.4.1.2 Diversity RX Antenna Models

The ULS data does not record a diversity antenna model, only a gain. Given that the AFC system must protect all receivers, the question of how to address diversity antenna models is important.

Diversity antennas are relatively common in the 6 GHz bands, with almost a third of receivers having one. Diversity antennas are typically used to mitigate against multi-path fading. In an interference analysis, it could be reasonable to assume that the diversity antenna model matches the main receive antenna when the gains match. However, Table 1 shows that more than half of diversity gains do not match the main antenna gain.

Treatment of diversity antennas should be a topic of further discussion. Simply using the main receive gain as the diversity gain when the antenna models are missing is likely not a sufficient substitute.

[6] Receive-only losses are included in this chart since these losses are typically considered as part of the antenna system.

Table 1: Diversity Antenna Counts

	Count of Antenna/Polarizations	% of Total Receivers
Diversity Antenna Exists	26,416	29.5%
Diversity Gain = Main Gain	12,205	13.6%
Diversity Gain ≠ Main Gain	14,211	15.9%

3.4.1.3 Antenna Patterns and Passive Repeaters

The discussion of antenna patterns must include the treatment of passive repeaters, particularly billboard style passive repeaters.

A passive repeater is used when the two endpoints do not have line-of-sight to each other. Instead, the signal is relayed through a site that has line-of-site to both end points. There are two types of passive repeaters shown in Figures 5 and 6, billboard and back-to-back antennas. ULS data indicates that there are 1748 paths with passive repeaters (1.3% of all paths). The locations have been mapped with colors corresponding to population density in Figure 7.

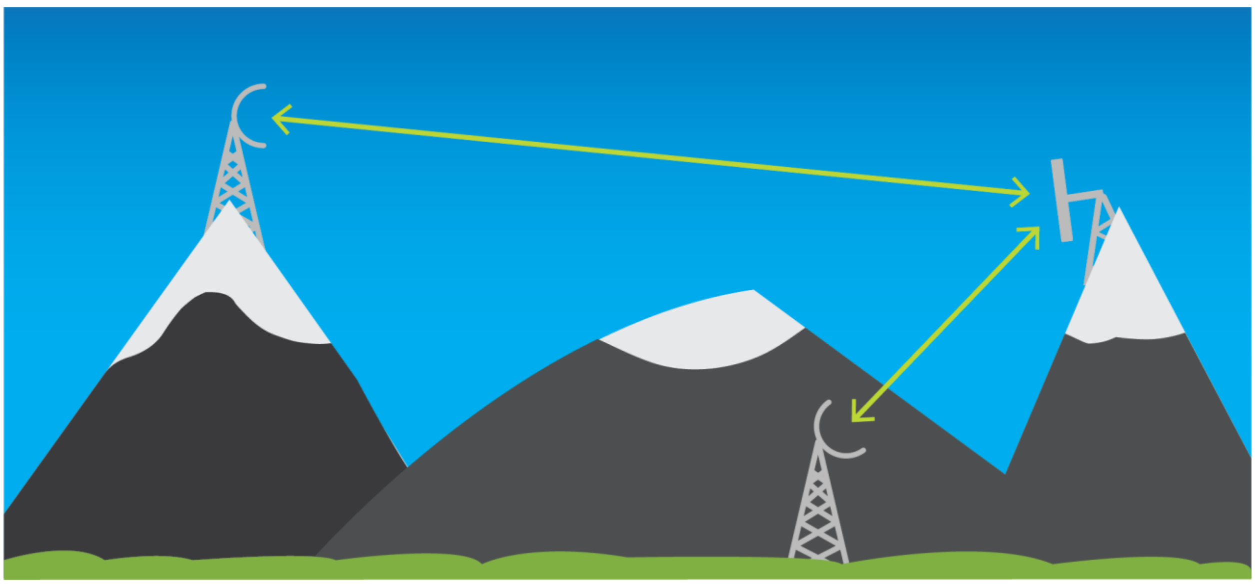

Figure 5: Billboard repeater

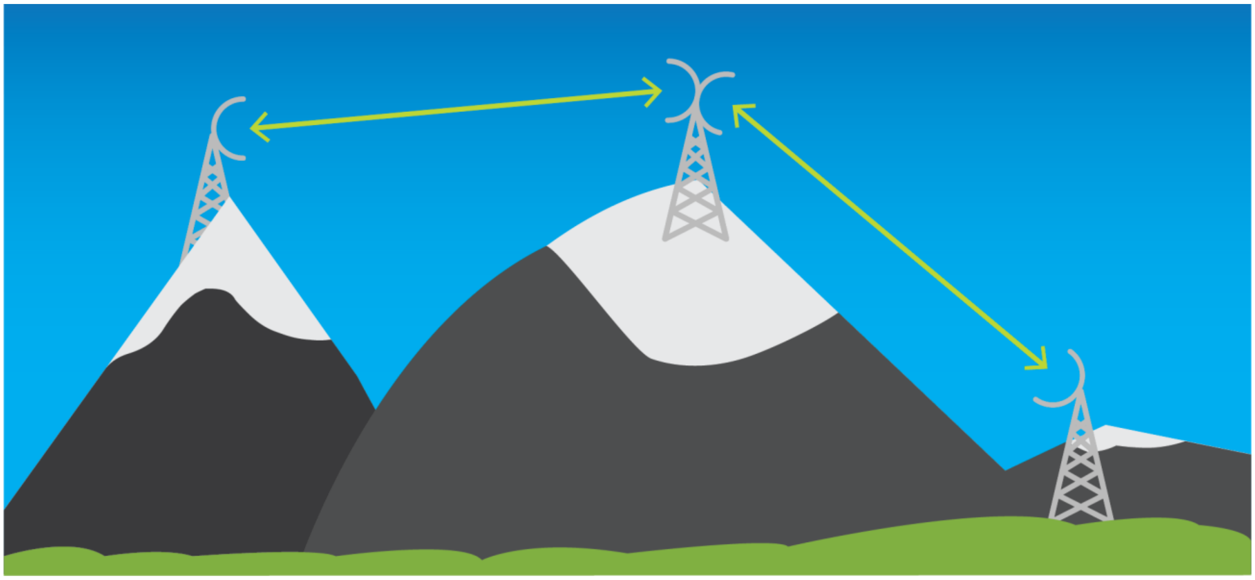

Figure 6: Back-to-Back Passive

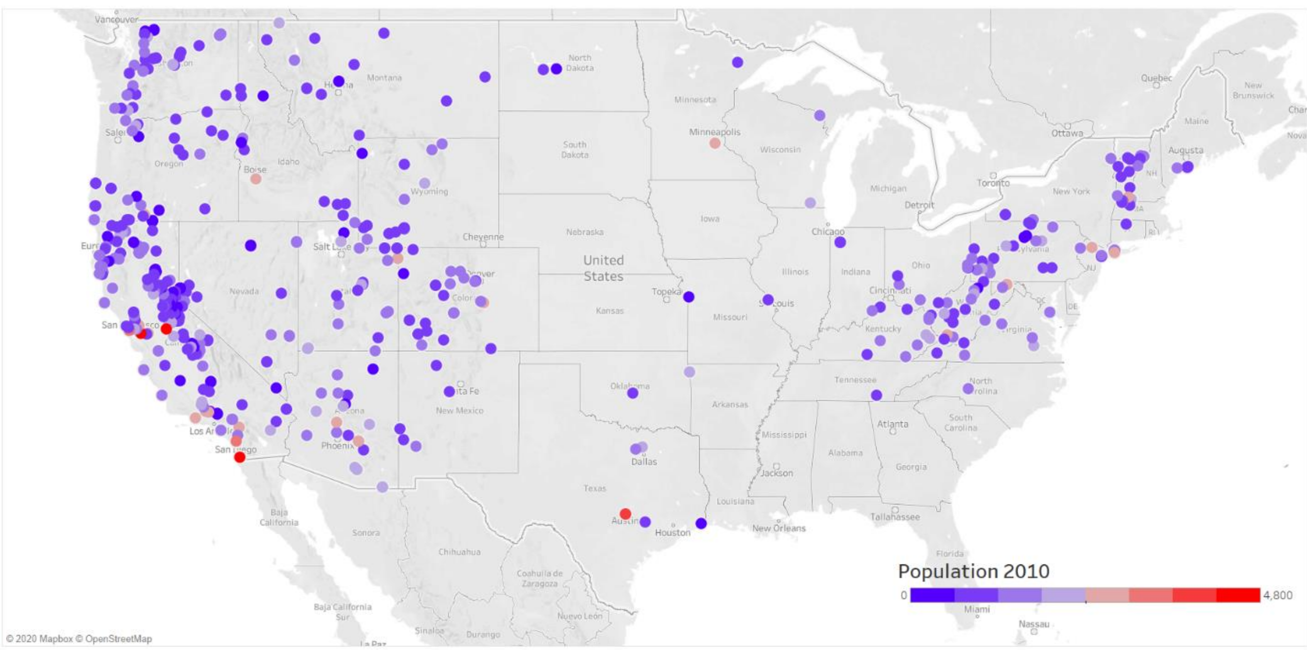

Figure 7: Passive Repeater Locations with Population

Figure 7 shows that there are significant numbers of passive repeater locations in the ULS data and a few are in highly populated areas. Going forward, discussions on addressing antenna patterns should consider how to address passive repeaters. Interference calculations will also likely need to consider these passive repeater paths.

3.4.2 Data Conflicts Within Antenna Data

In addition to null and missing data, it should be noted that some data is self-conflicting within the ULS as described below. Any treatment of antenna data in the AFC system may need to consider how to address these conflicts.

3.4.2.1 Conflicting Antenna Gains per Antenna Model

There is no data-verification in the ULS data enforcing the following:

1. The data in the Antenna Model field corresponds to an actual antenna model.
2. The data in the Antenna Gain field has any relation to the real gain for the antenna model.

Using Comsearch's antenna data and information, 2222 discrete antenna models were consolidated into 914 by simply scrubbing the data manually. A cursory glance also revealed some antenna model fields that clearly contain radio model data[7]. These types of discrepancies could likely be addressed by a cleanup of data by incumbents.

There were 55 antenna models in ULS where the gains across all licenses varied by *over 3dB* (excluding models that were clearly radios). Some varied by up to 43.9 dB.
Even if incumbents are required to correct their data, variance in gain by antenna model across the data will likely persist within the ULS, due partially to real differences in gain specifications over different antenna model versions. Discussions so far of antenna treatment in an AFC system have depended largely on antenna model, but this variance in gain per model should also be considered.

3.4.2.2 Main Antenna Gain Below FCC minimum or Unreasonably High

The spread of gain values within the ULS licensed data was investigated to see if the gains appear reasonable. Largely, gain values overall are within the expected range for FCC compliant antennas. The ULS data shows several cases where the listed gain does not meet the FCC minimum gain of 32 dBi. In all but 10 of these, an antenna model is listed, so the gain can be derived. The remaining 10 have gains between 3 and 31.9 dBi.

In addition, there are cases with very high gain which are obviously incorrect. For example, the highest gain value is 449 dBi.

A cleanup of incumbent data would help eliminate these types of gain problems. However, it should be noted that some of these data problems may persist even after a cleanup effort.

[7] For example, a cursory glance revealed 36 receivers starting with "MDR", which is a radio model nomenclature.

3.5 ULS Microwave Receiver Data Problems

Since the interference protection criteria (IPC) for microwave receivers is related only to the receiver emission bandwidth and noise floor, this is the only radio-related data required for interference analysis in an AFC system.

3.5.1 Emission Designators

The emission bandwidth of the receiver can be derived using the first 4 characters of the emission designator, which is a ULS data field.[8] For example, "28M5D7W" is a 28.5 MHz emission bandwidth.

Emission designators in the ULS data appear to be accurate to the extent they correspond to the bandwidth of the existing FCC channel plan. There is currently one with a designation of "0M00D7W" (indicating a 0 MHz bandwidth) and one has a 500 MHz bandwidth (as mentioned above).

Since there are minimal inconsistencies, emission designator seems like a relatively high-quality, trustworthy field to use in the AFC system.

3.5.2 Discrete Radio Models with Conflicting Emission Designators

The relationship between emission designators and radio models were also investigated in a similar way that gain should match to antenna models.

Out of 6108 distinct radio models, only 249 show any variation in emission bandwidth. Of those, 160 have a standard deviation in the emission bandwidth greater than 1 MHz. Upon further investigation, however, these varying emission bandwidths appear to be tied to simple matters of mistyped or incomplete radio model information, further reinforcing that emission designator is overall a high-quality field in the ULS data.

3.5.3 Missing Noise Figures

The AFC system will need to calculate the IPC as the interference-to-noise ratio (I/N). One of the components needed to calculate I/N is the Noise Level (N). As shown below, the Noise Level is determined by the combination of the receiver filter bandwidth, the atmospheric temperature and the amount of noise introduced by the receiver itself. The noise introduced by the receiver is called the Noise Figure.

The noise figure of the radio is not contained in the ULS data. Thus, the AFC system will need to establish a methodology to determine the noise figure of any given radio. Some suggestions are provided below.

3.5.3.1 Noise Figure Method

One method to calculate the Noise Level is to use the following equation:

$$N\ (\text{dBm}) = -114\ \text{dBm} + 10 * \log 10\ (B_{MHz}) + NF(\text{dB})$$

In this equation, the Bandwidth (B_{MHz}) can be determined using the emission designator in the FCC Database. As mentioned above, the radio's Noise Figure (NF) is not defined in the ULS.

[8] See 47 CFR 2.201 & 2.202

This can sometimes be determined from the radio manufacturer and model, with additional information from the manufacturer.

3.5.3.2 Threshold to Interference Method

The defined protection criteria of I/N = -6 dB correlates to a 1 dB threshold degradation of the receiver. The Threshold-to-Interference (T/I) method, defined in TIA Standard 10[9], is the power level that causes 1 dB of threshold degradation. Therefore, we can develop an equation to calculate the Noise Level from the T/I data for the radio.

$$N\ (\text{dBm}) = \text{Threshold}\ (\text{dBm}) - T/I\ (0\ \text{MHz}) + 6\ \text{dB}$$

As with the Noise Figure, T/I data is typically available from radio manufacturers in the U.S. but is not defined in the ULS.

3.5.3.3 Noise Figure Histogram

Using the T/I method to calculate Noise Figure for radios in the Comsearch database, the distribution of Noise Figures by frequency assignment and by distinct radio is shown in Figures 8 and 9. When weighted by frequency assignment, the average Noise Figure is 2.7 dB, and when looking at distinct radio models and not weighting by frequency assignment, the average Noise Figure is 3.3 dB.

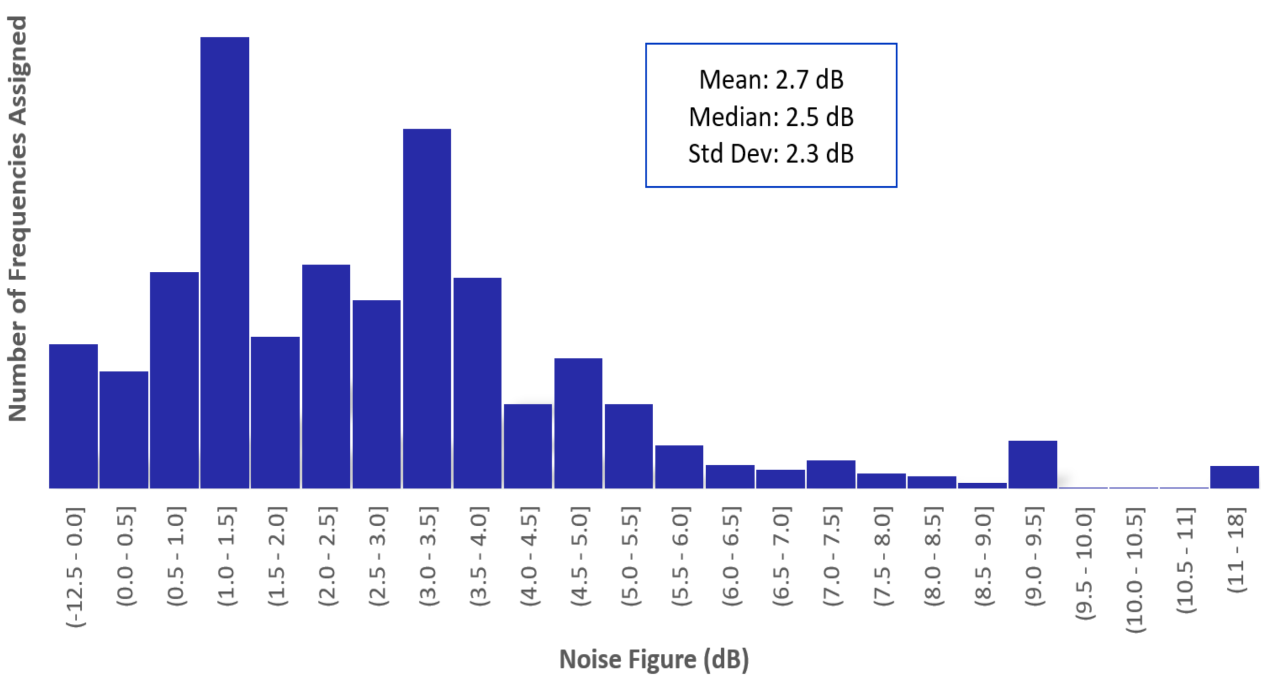

Figure 8: Noise Figure by frequency assignment using Comsearch path and radio data

[9] TIA, "Interference Criteria For Microwave Systems", TIA-10, May 2019.

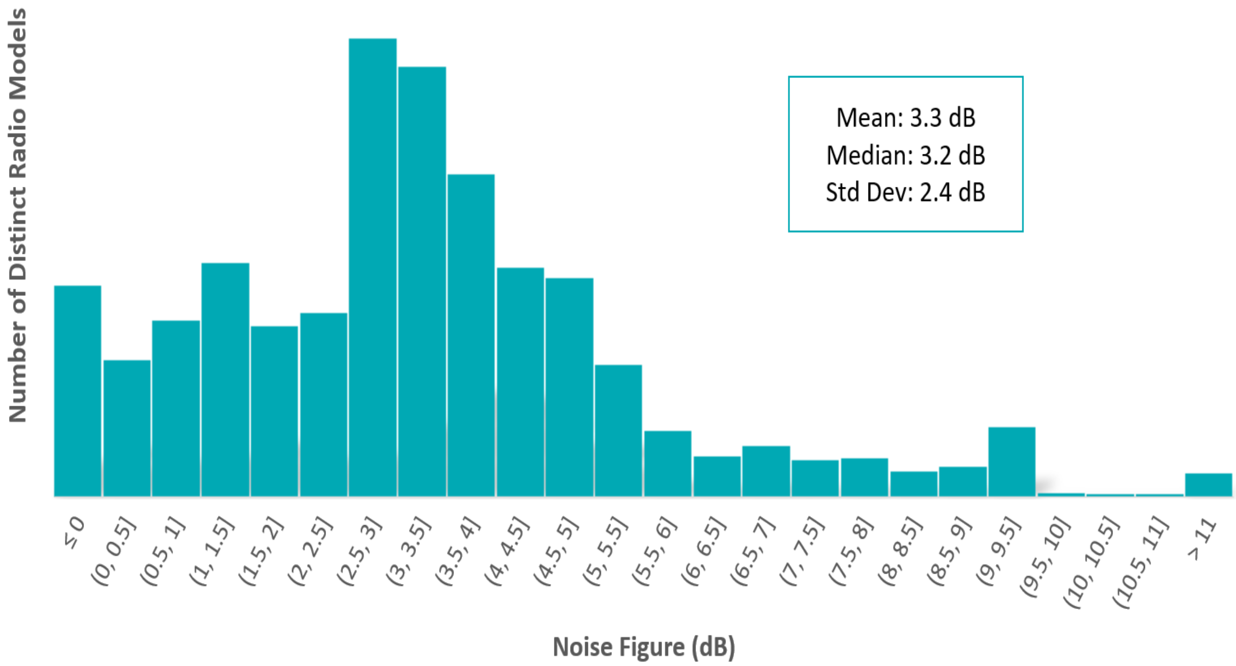

Figure 9: Noise Figure by distinct radio model using Comsearch radio data only

Using either the Threshold-to-Interference method or a default Noise Figure may be appropriate for calculating the noise floor. These histograms represent the statistical distribution of Noise Figure and can be used to inform discussion.

Appendix A
Using ULS Data

Data Access

Complete files are posted weekly at https://www.fcc.gov/uls/transactions/daily-weekly. The file is in the "Weekly Databases" section under the heading "Microwave - 47 CFR Parts 74 and 101, and 3650 - 3700 MHz". Licensed links are normally posted on Monday morning and are in the file l_micro.zip (l = licensed, micro = microwave). Applications are in a_micro.zip (a = applications), and are normally posted Sunday morning.

Differential files are posted in-between weekly files and are available in the "Daily Databases" section under the heading "Microwave - 47 CFR Parts 74 and 101, and 3650 - 3700 MHz". Newly-licensed links for the prior day's data are in the l_mw_<day>.zip file (e.g., "l_mw_mon.zip" for Monday's file). New applications from the previous day are in a_mw_<day>.zip.

Documentation

Documentation about the ULS database is available at the following links:

- FCC Documentation
  - https://www.fcc.gov/wireless/data/public-access-files-database-downloads
- Introduction to the data
  - https://www.fcc.gov/sites/default/files/pubacc_intro_11122014.pdf
- Sybase SQL to create tables:
  - https://www.fcc.gov/sites/default/files/public_access_database_definitions_sql_v2.txt
- Table Definitions in PDF Format:
  - https://www.fcc.gov/sites/default/files/public_access_database_definitions_v3.pdf
- Code definitions (provides a lookup for various field codes to plain English):
  - https://www.fcc.gov/sites/default/files/pubacc_uls_code_def_02162017.txt

ULS Tables

Two sets of data are necessary: microwave applications, and microwave licenses (see above). The specific tables that are needed are highlighted in the figure below. "R" and "O" mark whether a specific table is required or optional for the microwave database.

Tables	Table Contents	Microwave		Tables	Table Contents	Microwave	
Hierarchy		App	Lic	Hierarchy		App	Lic
HD	Main Form 601 data that carries over to license	R	R	LO	Location data	O	R
AD	Main Form 601 data that does not carry over to license	R		L2	Additional Location data	O	O
A2	Additional Application data that does not carry over to the license	R		LS	Location Level Canned Special Conditions	O	O
RE	Application return or dismissal reasons	O		LF	Location Level Free Form Special Conditions	O	O
EN	Names and addresses	R	R	AN	Antenna data	O	R
CO	FCC Comments	O	O	RC	Receiver data	O	O
HS	Application and License history	R	R	FR	Frequency data	O	R
IR	IRAC status	O	O	F2	Additional frequency data	O	O
CS	COSER status	O	O	TP	Transmission Method or Protocol	R	R
MW	Microwave administrative data	O	R	FS	Frequency Level Canned Special Conditions	O	O
BC	Broadcast Call Signs	O	O	FF	Frequency Level Free Form Special Conditions	O	O
FC	Frequency Coordination	O		BF	Frequency build out data		R
SC	License Level Canned Special Conditions	O	O	EM	Emission data	O	R
SF	License Level Free Form Special Conditions	O	O	PA	Paths	O	R
CP	Control point data	O	O	SG	Segments	O	R
CF	Multiple call signs or file numbers affected by this application	O		AT	Attachment information	O	

The HD table is the top-level data table. The “Unique System Identifier” (USI) field in each table is used to join tables together for the same filing or call sign. Note however that the USI is different between application and license tables for the same call sign.

Data can be joined whenever the column name is the same in both tables. The primary column for joining license data is the call sign. The primary column for joining application data is ULS file number. In addition to the call sign or ULS file number, each application and license has been assigned a unique, 9-digit system identifier. This system identifier is useful in cases where a call sign has been reassigned, insofar as it allows you to differentiate between the active call sign and the call sign that has expired or been cancelled or terminated. (This situation occurs commonly with Amateur vanity licenses.)

Site-based services (such as fixed microwave links) can be joined by the following combination of columns:

- call_sign or unique_system_identifier
- call_sign or unique_system_identifier and location_number
- call_sign or unique_system_identifier, location_number and antenna_number
- call_sign or unique_system_identifier, location_number, antenna_number and frequency_number
- call_sign or unique_system_identifier, path number, location_number and antenna_number
- call_sign or unique_system_identifier, path_number and segment_number

Header Data

Header table (HD.dat) contains key license information. The License Status indicates whether the license is active, but the Cancellation date, when populated indicates whether the record should not be protected. The required fields from the header table are highlighted in the figure below.

Application / License Header

Position	Data Element	Definition
1	Record Type **[HD]**	char(2)
2	Unique System Identifier	numeric(9,0)
3	ULS File Number	char(14)
4	EBF Number	varchar(30)
5	Call Sign	char(10)
6	License Status	char(1)
7	Radio Service Code	char(2)
8	Grant Date	mm/dd/yyyy
9	Expired Date	mm/dd/yyyy
10	Cancellation Date	mm/dd/yyyy
11	Eligibility Rule Num	char(10)
12	Reserved	char(1)
13	Alien	char(1)
14	Alien Government	char(1)
15	Alien Corporation	char(1)
16	Alien Officer	char(1)
17	Alien Control	char(1)
18	Revoked	char(1)
19	Convicted	char(1)
20	Adjudged	char(1)
21	Reserved	char(1)
22	Common Carrier	char(1)
23	Non Common Carrier	char(1)
24	Private Comm	char(1)
25	Fixed	char(1)
26	Mobile	char(1)

(additional fields not shown).

Path Data

The path table (PA.dat) contains key information that links locations (transmit and receive, and also antennas). The necessary fields are highlighted below.

Microwave Path

Position	Data Element	Definition
1	Record Type **[PA]**	char(2)
2	Unique System Identifier	numeric(9,0)
3	ULS File Number	char(14)
4	EBF Number	varchar(30)
5	Call Sign	char(10)
6	Action Performed	char(1)
7	Path Number / Link Number	integer
8	Transmit Location Number	integer
9	Transmit Antenna Number	integer
10	Receiver Location Number	integer
11	Receiver Antenna Number	integer
12	MAS/DEMS SubType of Operation	char(2)
13	Path Type Code	char(20)
14	Passive Receiver Indicator	char(1)
15	Country Code	char(3)
16	Interference to GSO?	char(1)
17	Receiver Call Sign	varchar(10)
18	Angular Separation	numeric(3,2)
19	Cert No Alternative	char(1)
20	Cert No Interference	char(1)
21	Status Code	char(1)
22	Status Date	mm/dd/yyyy

Segment Data

The segment table (SG.dat) contains key information that orders segments, and is required for passive repeater sequencing. Segments are individual point-to-point links that make up a potentially longer (multi-segment) microwave path.

Microwave Segments

Position	Data Element	Definition
1	Record Type [SG]	char(2)
2	Unique System Identifier	numeric(9,0)
3	ULS File Number	char(14)
4	EBF Number	varchar(30)
5	Call Sign	char(10)
6	Action Performed	char(1)
7	Path Number	integer
8	Transmit Location Number	integer
9	Transmit Antenna Number	integer
10	Receiver Location Number	integer
11	Receiver Antenna Number	integer
12	Segment Number	integer
13	Segment Length	numeric(12,6)
14	Status Code	char(1)
15	Status Date	mm/dd/yyyy

Location Data

The location table (LO.dat) contains technical site information, where Location Number 1 is the Transmit site, all other numbers are the receive sites.

Location

Position	Data Element	Definition
1	Record Type **[LO]**	char(2)
2	Unique System Identifier	numeric(9,0)
3	ULS File Number	char(14)
4	EBF Number	varchar(30)
5	Call Sign	char(10)
6	Location Action Performed	char(1)
7	Location Type Code	char(1)
8	Location Class Code	char(1)
9	Location Number	integer
10	Site Status	char(1)
11	Corresponding Fixed Location	integer
12	Location Address	varchar(80)
13	Location City	char(20)
14	Location County/Borough/Parish	varchar(60)
15	Location State	char(2)
16	Radius of Operation	numeric(5,1)
17	Area of Operation Code	char(1)
18	Clearance Indicator	char(1)
19	Ground Elevation	numeric(7,1)
20	Latitude Degrees	integer
21	Latitude Minutes	integer
22	Latitude Seconds	numeric(3,1)
23	Latitude Direction	char(1)
24	Longitude Degrees	integer
25	Longitude Minutes	integer
26	Longitude Seconds	numeric(3,1)

27	Longitude Direction	char(1)
28	Max Latitude Degrees	integer
29	Max Latitude Minutes	integer
30	Max Latitude Seconds	numeric(3,1)
31	Max Latitude Direction	char(1)
32	Max Longitude Degrees	integer
33	Max Longitude Minutes	integer
34	Max Longitude Seconds	numeric(3,1)
35	Max Longitude Direction	char(1)
36	Nepa	char(1)
37	Quiet Zone Notification Date	mm/dd/yyyy
38	Tower Registration Number	char(10)
39	Height of Support Structure	numeric(7,1)
40	Overall Height of Structure	numeric(7,1)
41	Structure Type	char(7)
42	Airport ID	char(4)
43	Location Name	char(20)
44	Units Hand Held	integer

(not all fields shown).

Antenna Data

The antenna table (AN.dat) contains antenna details, including primary and diversity antenna information and polarization. For passive repeaters, additional details are also included. Note that Line Loss appears in this table, but this information is not collected for the fixed microwave service.

Antenna

Position	Data Element	Definition
1	Record Type **[AN]**	char(2)
2	Unique System Identifier	numeric(9,0)
3	ULS File Number	char(14)
4	EBF Number	varchar(30)
5	Call Sign	char(10)
6	Antenna Action Performed	char(1)
7	Antenna Number	integer
8	Location Number	integer
9	Receive Zone Code	char(6)
10	Antenna Type Code	char(1)
11	Height to Tip	numeric(5,1)
12	Height to Center RAAT	numeric(5,1)
13	Antenna Make	varchar(25)
14	Antenna Model	varchar(25)
15	Tilt	numeric(3,1)
16	Polarization Code	char(5)
17	Beamwidth	numeric(4,1)
18	Gain	numeric(4,1)
19	Azimuth	numeric(4,1)

20	Height Above Avg Terrain	numeric(5,1)
21	Diversity Height	numeric(5,1)
22	Diversity Gain	numeric(4,1)
23	Diversity Beam	numeric(4,1)
24	Reflector Height	numeric(5,1)
25	Reflector Width	numeric(4,1)
26	Reflector Separation	numeric(5,1)
27	Passive Repeater Number	integer
28	Back-to-Back Tx Dish Gain	numeric(4,1)
29	Back-to-Back Rx Dish Gain	numeric(4,1)
30	Location Name	varchar(20)
31	Passive Repeater Sequence ID	integer
32	Alternative CGSA Method	char(1)
33	Path Number	integer
34	Line loss	numeric(3,1)
35	Status Code	char(1)
36	Status Date	mm/dd/yyyy
37	PSD/Non-PSD Methodology	varchar(10)
38	Maximum ERP	numeric(15,3)

Frequency Data

The frequency table (FR.dat) contains the frequency and radio information for each antenna.

Frequency

Position	Data Element	Definition
1	Record Type **[FR]**	char(2)
2	Unique System Identifier	numeric(9,0)
3	ULS File Number	char(14)
4	EBF Number	varchar(30)
5	Call Sign	char(10)
6	Frequency Action Performed	char(1)
7	Location Number	integer
8	Antenna Number	integer
9	Class Station Code	char(4)
10	Op Altitude Code	char(2)
11	Frequency Assigned	numeric(16,8)
12	Frequency Upper Band	numeric(16,8)
13	Frequency Carrier	numeric(16,8)
14	Time Begin Operations	integer
15	Time End Operations	integer

16	Power Output	numeric(15,3)
17	Power ERP	numeric(15,3)
18	Tolerance	numeric(6,5)
19	Frequency Indicator	char(1)
20	Status	char(1)
21	EIRP	numeric(7,1)
22	Transmitter Make	varchar(25)
23	Transmitter Model	varchar(25)
24	Auto Transmitter Power Control	char(1)
25	Number of Units	integer
26	Number of Paging Receivers	integer
27	Frequency Number	integer
28	Status Code	char(1)
29	Status Date	mm/dd/yyyy
30	Date First Used	mm/dd/yyyy

Emission Data

The emission table (EM.dat) contains the emission bandwidth information for each frequency.

Emission

Position	Data Element	Definition
1	Record Type **[EM]**	char(2)
2	Unique System Identifier	numeric(9,0)
3	ULS File Number	char(14)
4	EBF Number	varchar(30)
5	Call Sign	char(10)
6	Location Number	integer
7	Antenna Number	integer
8	Frequency Assigned/Channel Center	numeric(16,8)
9	Emission Action Performed	char(1)
10	Emission Code	char(10)
11	Digital Mod Rate	numeric(8,1)
12	Digital Mod Type	char(255)
13	Frequency Number	integer
14	Status Code	char(1)
15	Status Date	mm/dd/yyyy
16	Emission Sequence Id	integer

ULS Sample

The following sample shows a set of data that would appear for a single license in each .dat file for the applicable table, HD, PA, LO, AN, FR, and EM. The data have been joined by the Unique System Identifier (the second field in each record).

HD|4082800|0008669102||WRCF240|A|CF|09/14/2018|09/14/2028||||N|N|N|N|N|N|N|N|
|Y||Y|Y|N|N|N|N|N|Sean|R|Middleton||Manager of
Engineering||||||||10/04/2019|06/28/2020||||N|||

PA|4082800|||WRCF240||2|1|2|2|2||Fixed Point-to-Point|N||N||||||

SG|4082800|||WRCF240||2|1|2|2|2|1|17.385819||

LO|4082800|||WRCF240||F|T|1|||Rearl Hill
Top|Pearl|PIKE|IL||||196.0|39|27|0.0|N|90|37|26.0|W||||||||||||51.8|53.3|LTOW
ER||PEARL HILLTOP||||||||

LO|4082800|||WRCF240||F|R|2||||||||||220.3|39|17|46.0|N|90|39|40.5|W|||||||||
|||||||KAMPSVILLE TOWER||||||||

AN|4082800|||WRCF240||2|1||T||47.2|RADIO WAVES INC.|HPD3-
11|0.1|V|2.1|38.5|190.7|||||||||||PEARL HILLTOP|||2|||||

AN|4082800|||WRCF240||2|2||R||54.9|RADIO WAVES INC.|HPD3-
11|||2.1|38.5||||||||||||KAMPSVILLE TOWER|||2|||||

FR|4082800|||WRCF240||1|2|FXO||10755.00000000|||||||0.00040|||59.5|CERAGON
NETWORKS|FibeAir-IP-20C|N|||1|||07/30/2019

FR|4082800|||WRCF240||1|2|FXO||10755.00000000|||||||0.00040|||61.5|CERAGON
NETWORKS|FibeAir-IP-20C|N|||2|||07/30/2019

FR|4082800|||WRCF240||1|2|FXO||10755.00000000|||||||0.00040|||61.5|CERAGON
NETWORKS|FibeAir-IP-20C|N|||3|||07/30/2019

EM|4082800|||WRCF240|1|2|10755.00000000||60M0D7W|530000.0|2048QA|1|||1

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EM|4082800|||WRCF240|1|2|10755.00000000||60M0D7W|460000.0|1024QA|3|||1

Propagation Models and Interference Protection Criteria for Sharing between the Fixed Service and Unlicensed Devices in the 6 GHz Band

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TERMS, CONDITIONS & NOTICES

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Propagation Models and Interference Protection Criteria for Sharing between the Fixed Service and Unlicensed Devices in the 6 GHz Band

1 Introduction

The 6 GHz Band Multi-stakeholder Committee (6MSC) is a committee of The Wireless Innovation Forum that will serve as an industry body to study and specify sharing arrangements in spectrum designated for unlicensed operation within all or part of the 6 GHz band (5925-7125 MHz). The Committee will provide technical input to inform the FCC's 6 GHz rulemaking and will facilitate the interpretation and implementation of the rulemaking that allows industry and regulators to collaborate on implementation of a common, efficient and well-functioning 6 GHz ecosystem.

The initial activities to be conducted by the Committee include:

- Defining:
    - Propagation Modeling
    - Interference Protection Criteria
    - Spectrum Occupancy Determination
- Developing a Security Threat Assessment
- Identifying Automated Frequency Coordination (AFC) Requirements for Incumbent Protection

The approach to the committee's work will emphasize the technical aspects of sharing while simplifying interfaces and requirements. This is done to advance innovative and competitive sharing approaches and to increase deployment speed of AFC systems.

The Committee is ultimately a standards and technical implementation forum for industry stakeholders and developers of the spectrum-sharing technologies. The Committee will not address policy-making or liability management but may occasionally make formal technical recommendations to the FCC or other regulatory bodies following the Forum's standard policies and procedures.

The participants of this Committee include, but are not be limited to, the following:

- Developers and operators of wireless equipment and devices
- Developers and operators of spectrum sharing systems
- Operators and service providers interested in deploying in the spectrum
- Suppliers of systems and components operating in this spectrum
- General users of spectrum outside of main providers
- Policy makers, academics, and researchers
- Liaisons from other standards groups with which joint work is desired or necessary

The FCC issued a Notice of Proposed Rule Making (NPRM) in Oct. 2018, proposing unlicensed use of the 5925-7125 MHz band in combination with protection for incumbent licensed services in the band [1]. The Commission has, within the NPRM, extended the Unlicensed National Information Infrastructure (U-NII) regime in the 5GHz band into four new parts, labeled U-NII-5 through U-NII-8. Specifically, the FCC introduces the NPRM with the suggestion that users in the 850 MHz comprised by U-NII-5 and U-NII-7 and corresponding to 5925-6425 MHz and 6525-6875 MHz respectively, be required to use an AFC "that would prevent the unlicensed devices from transmitting on frequencies where such transmissions could cause harmful interference to incumbent services." The NPRM then asks respondents to offer answers to questions about the nature of the AFC, including whether the AFC database should have device registration requirements, the level of control on power and frequency allocation to devices under control by the AFC, periodic verification of continued frequency availability etc. The NPRM also raises questions about AFC security requirements, certification of the system, operator obligations and competition between operators. Many of these questions directly suggest that the FCC is not certain about the architecture of the system; clearly, industry guidance is sought and needed. Importantly, the NPRM also asks about preferences for interference protection of fixed services and other technical matters such as propagation models, adjacent channel protection, and fading margins.

In general, the NPRM is not uniformly accepted in its current form by all stakeholders in the band, and various petitions on suggested policy directions are still under review, including objections regarding the band plan as proposed. Some respondents to the NPRM have proposed that incumbents in U-NII-6 and U-NII-8 should also be protected using an AFC. Concerns have been raised regarding the architecture of the AFC and on which use cases and environments the AFC is applicable. Some organizations have raised questions around the aggregate accuracy of the information available, the integrity and conformance of devices, and the question of whether AFC mechanisms should be centralized, distributed within equipment, or could effectively be a hybrid between centralized resources and distributed control mechanisms (as has been suggested by the FCC or assumed by the WiFi industry).

This document interprets U-NII devices as being included within the classification of Radio Local Area Networks (RLAN) as defined by the ITU-R. Indeed, the FCC describes U-NII devices as unlicensed intentional radiators, which use wideband digital modulation techniques to provide a wide array of high-data-rate mobile and fixed communications used by individuals, businesses, and institutions, particularly for wireless local area networking – including Wi-Fi – and broadband access [2]. While RLANs are not restricted to unlicensed operation, they are

a) widely used for fixed, semi fixed (transportable) and portable computer equipment for a variety of broadband applications;
b) that broadband RLANs are used for fixed, nomadic and mobile wireless access applications;
c) that broadband RLAN standards currently being developed are compatible with current wired LAN standards;

as detailed in Recommendation ITU-R M.1450 [3]. This document therefore freely references requirements for RLANs and applies them to U-NII devices.

It has been suggested by some members that the Citizens Broadband Radio Service (CBRS) approach of direct control by a centralized Spectrum Access System (SAS) has proven to be complex and prone to unnecessarily prolonged standardization and testing processes [4][5].[1] At the same time, the benefits of affirmitive control and strong validation mechanisms (e.g. by an AFC) might prove to be beneficial to verifiable protection for some use cases in the band.[2] One advantage of an affirmative approach to frequency authorization is its compatibility with widespread outdoor deployment of unlicensed radios, that employ higher power levels for many important use cases. Another point of contention is whether low-power indoor devices need to be controlled by an AFC; indeed, it is possible to create several scenarios where indoor devices could significantly impact aggregate interference levels. This topic clearly requires further investigation to achieve a consensus among stakeholders.

This document does not concern itself with policy issues such as whether changes to the band plan or the organization of band into four sub-bands of the U-NII radio band will be adopted within any final Report and Order (R&O) that is issued.

The purpose of this report is to provide stakeholders, including the regulatory authorities, with relevant information regarding the operation of unlicensed mobile equipment within the 6 GHz band under terms to be detailed by the Federal Communications Commission under 47 CFR Part 15 rules. In addition, it provides a summary of viewpoints regarding some of the important criteria (e.g., propagation modelling approaches and interference protection criteria) that need to be considered when sharing that spectrum with one primary assignee to the band, namely the Fixed Service (FS), which is composed of point-to-point microwave links. The presented methodologies are meant to be extendable for AFC protection of other 6 GHz incumbents such as TV Pickup, Passive Sensor, and Broadcast Auxiliary services; specific attention to these will need to await further revisions. A secondary purpose of this report is to provide relevant information to regulators and stakeholders outside the United States, who may be interested in adopting similar sharing rules between the fixed service and unlicensed users in the band.

2 References

[1] FCC, "In the Matter of Unlicensed Use of the 6 GHz Band Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz; ET Docket No. 18-295 and GN Docket No. 17-183," FCC 18-147, October 2018.

[2] FCC, "In the Matter of Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band," FCC 14-30, ET Docket No. 13-49, April, 2014.

[3] ITU-R M.1450, "Characteristics of broadband radio local area networks," 2014.

[1] The CBRS is a novel authorized sharing regime between three tiers of users in the 3550-3700 MHz band that is introduced by the FCC rules in 47 CFR Part 96 and allows tier 1 incumbents such as military radar and commercial Fixed Satellite Service (FSS) users to share the band with secondary mobile broadband users constituted by Priority Access Licensees forming the second tier, and Generally Authorized Access (GAA) use of the spectrum for the third tier.

[2] Although the proposed regulations do not explicitly identify incumbent licensed use of the 6 GHz band as worthy of primary status or that unlicensed users would be secondary users, it is inconceivable that RLAN use of the band under unlicensed rules within 47 CFR Part 15 would be considered on an equal footing.

[4] FCC, "Part 96 – Citizens Broadband Radio Service," Code of Federal Regulations, Title 47, Chapter I, Subchapter D, Part 96, Oct. 2019; available at https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&mc=true&r=PART&n=pt47.5.96

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[17] P. L. McQuate, J.M. Harman, M.E. Johnson and A.P. Barsis, Tabulations of Propagation Data Over Irregular Terrain in the 230-to 9200-MHz Frequency Range Part 2: Fritz Peak Receiver Site, NTIA Technical Report ERL 65-ITS 58-2, December 1968. <https://www.its.bldrdoc.gov/publications/2042.aspx>

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[19] https://nationalmap.gov/3dep_prodserv.html (1 arc second 3DEP Seamless DEM).

[20] https://github.com/Wireless-Innovation-Forum/Spectrum-Access-System

[21] ITU-R P.2108, "Prediction of clutter loss," June 2017.

[22] ITU-R P.2109, "Prediction of building entry loss," June 2017.

[23] NLCD 2011 data available at https://github.com/Wireless-Innovation-Forum/Spectrum-Access-System.

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3 Abbreviations

Abbreviation	Description
3DEP	3D Elevation Program (USGS)
6MSC	6 GHz Band Multi-stakeholder Committee
AFC	Automated Frequency Coordination
AP	Access Point
APO	Availability Performance Objective
ATPC	Automated Transmit Power Control
BAS	Broadcast Auxiliary Service
BEL	Building Entry Loss
CARS	Cable Television Relay Service

Abbreviation	Description
CBRS	Citizens Broadband Radio Service
CFR	Code of Federal Regulations
ECC	European Communications Committee
ECO	European Communications Office
eHata	Extended Hata
EPO	Error Performance Objective
FCC	Federal Communications Commission
FS	Fixed Service
FSS	Fixed Satellite Service
FWS	Fixed Wireless Systems (alternative name for FS)
IPC	Interference Protection Criteria
ISM	Industrial, Scientific, and Medical
ITM	Irregular Terrain Model
ITS	Institute of Telecommunications Studies
ITU-R	International Telecommunications Union, Radio Communications Bureau
LA	Link Adaptation (also known as Adaptive Modulation)
MCL	Minimum Coupling Loss
MIMO	Multiple-Input Multiple-Output
NLoS	Non-line of Sight
LoS	Lone of Sight
NLCD	National Land Cover Database
NPO	Network Performance Objective
NPRM	Notice of Public Rule-Making

Abbreviation	Description
NSMA	National Spectrum Management Association
NTIA	National Telecommunications and Information Administration
P2P	Point-to-Point
R&O	Report and Order
RLAN	Radio Local Area Network
SAS	Spectrum Access System
SDR	Software Defined Radio
UE	User Equipment
U-NII	Unlicensed National Information Infrastructure
USGS	United States Geological Survey
UWB	Ultra-Wide-Band
WAS	Wireless Access Systems
WiFi	Class of unlicensed RLAN devices conforming to IEEE 802.11
WInnForum	Wireless Innovation Forum

4 Characteristics of the Fixed Service in the 6 GHz band

A number of licensed users occupy this spectrum, prominent occupants being users of fixed point-to-point links[1]. The 5925-6425 MHz and 6525-6875 MHz bands are the most heavily used by the common carrier fixed point-to-point microwave service and private operational fixed point-to-point microwave service. The NPRM lists 17,580 common carrier fixed point-to-point microwave links, 15,011 microwave links in the industrial/business pool, and 13,664 microwave links in the public safety pool that are listed in FCC databases. A large fraction of these links serves critical functions that must maintain a high level of availability, very often designed for five- or six-nines of availability on an annual basis; designed outage targets may range from less than 1 minute to 5 minutes per year.

Many FS systems in the industrial/business pool are associated with process control of pipelines and serve critical control functions for railroad switches, synchronization of train movement, control of the electric grid including monitoring and control of distribution networks and utility circuit breakers, control of pumps and valves in petroleum and natural gas pipelines etc.

In addition, the band provides backhaul to dispatch public safety and emergency vehicles (first responders, emergency repair crews, etc.), Internet and telephone carriage, backhaul for cellular systems, including voice and 3G/4G/5G data, connecting commercial centers with real-time financial and market information, other business data etc.

Microwave links are designed for adequate margin, but the amount of available margin is dependent on path length and modulation. As modulation levels increase, receiver thresholds are higher and margins decrease. While some legacy links may have margins in the 40-50 dB range, state-of-the-art radios in use today typically implement higher-order modulations and typically have lower margins of the order of 30 dB at the primary modulation level. Modern radios have the option of Link Adaptation (LA) or Adaptive Modulation, but not every installation uses it. For long paths, the highest order modulations can rarely provide the required availability, so they are often unused. The allowable modulation levels are therefore limited to fewer states, or relegated to be a single static modulation order.

Automatic Transmit Power Control (ATPC) is used to avoid interference with incumbent links by keeping output power low until required during times of decreased received signal strength. All current radios have the feature, but as shown in the FCC database, its use is infrequent. Use of this feature on radios coordinated at the lower power levels cannot exceed time limits established by ANSI/TIA Standard 10 [6].

Some FS links have spatial diversity, used to increase availability during multipath conditions.

Multiple Input Multiple Output (MIMO) antenna systems are designed to increase the throughput of an FS link and the layers of a MIMO antenna system are equivalent in function to the use of higher-order modulations.

5 Propagation Overview

For fixed point-to-point microwave paths, the paths are designed to have approximately 0.6 first Fresnel zone clearance above the terrain or obstacles. For this condition, the received signal level is accurately predicted using the familiar free space attenuation formula in Section 2.2 of ITU-R P.525[7]. For the more general case corresponding to interfering signals, where the transmitter and receiver may be located anywhere, the received signal level is typically the resultant of a mix of direct, reflected, scattered and/or diffracted signals. Most frequency management procedures require a short term (0.01% probability) and long-term (greater than 80% probability) received signal estimate. In the analysis of compatibility between unlicensed stations in the 6 GHz band and the fixed microwave service, the long-term estimate may be especially consequential, although short-term variations must also be considered in relation to the assessment of bit-error rates to a victim receiver and the frequency of exercise of LA mechanisms designed to handle events like weather and wind shear as opposed to interference.

There is no consensus in the 6MSC whether the propagation models proposed within this document should be mandated by the FCC for inclusion as part of the rules. The material in the preceding section has been offered as a demonstration of good faith and diligence regarding the possible models that may be used by the AFC. Additional study is needed to resolve the actual choice of model for a particular environment and further determine the parameters that will configure that chosen model.

5.1 Average Point to Point Signal Prediction

When an interfering transmitter and victim receiver are moved away from each other (distance between interference and receiver = d), initially the interfering radio signal propagation is line of sight (LoS) (essentially free space, path attenuation ≅ 20 Log d). Eventually as intervening clutter starts to obstruct the propagation path, propagation becomes non-line of sight (NLoS). The interfering signal is attenuated at a faster rate with distance [8].

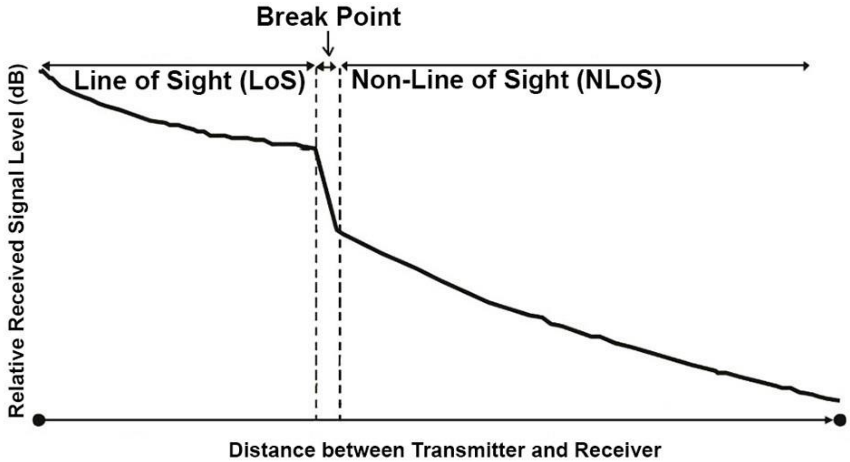


Figure 1 Measurements corroborate empirical models of median path loss that show a rapid transition at the break point between LoS and NLoS properties; e.g. the ITM and ITU-R P.452 models are designed to capture the effect of such real-world observations.

6 Propagation Models for Interference Analysis[3]

When modeling interference into FS stations from a deployment of a large number of RLANs across a large geographical area, any RF propagation must model the variations in interference path morphologies that exist. In particular, the model must allow the following requirements:

1. Applicability from low distances, e.g. at least 10 m to the order of 100-150 km.
2. Applicability in the band of interest, namely 5925-7125 MHz.
3. Modeling of terrain over long-distance propagation paths, with additional consideration of clutter beyond the break-point between LoS and NLoS propagation
4. Modeling of clutter and environmental effects over short distances

[3] The treatment of propagation models specifically addresses the protection of 6 GHz incumbent receivers and does not pertain to the protection of earth-to-space links in the Fixed Satellite Service (FSS).

5. Consideration of the effect of propagation paths where one of the end-points (e.g. RLAN station) is within the clutter and the FS receiver is above the clutter.

6. Modeling of building entry loss where applicable to RLAN stations that are placed indoor

7. Applicability to typical FS antenna heights of up to 20m above ground level.

When applying a propagation model to statistical analysis of the impact of many RLAN stations to a single FS receiver, the effect of building entry loss may be accounted for in a probabilistic manner, i.e., the BEL can be applied to some fraction of the links in the process of estimating aggregate interference. When a propagation model is applied to the case of a single RLAN station desiring operation in the band, it is unclear whether BEL is directly applicable without clear validation of the conditions of deployment. Indeed, a declaration of indoor installation can only be taken at faith without the authority of enforcement of regulations.

Interference paths and their corresponding morphologies may be modeled using one of the following choices for propagation models of pathloss:

1. WINNER II [9] for near-in distances, out to 1 km for suburban and urban areas, followed by ITU-R P.452 [10] for propagation paths beyond 1 km in urban, suburban, and rural area. This approach has been used by ECC report 302 [11] for analyzing interference from RLANs into FS stations at 6 GHz.

2. CBRS Hybrid propagation (eHata/ITM) [12][13][14][15][16][17][18].

3. WINNER II [9] for near-in, out to 1 km for suburban/urban areas and P2P ITM for rural; then P2P ITM [15] for propagation pathloss beyond 1 km.

When using either ITU-R P.452 or ITM, we recommend the use of CBRS 3DEP DEM as the elevation profile [19] available from the Github repository hosted by the WInnForum [20]. The 6MSC favors Option 3 with further agreement needed on an appropriate clutter model for urban, suburban, and rural environments.

6.1 Clutter Loss

"Clutter" is described here in the context of ITU-R P-Series Recommendations.

Clutter refers to objects, such as buildings or vegetation, which are on the surface of the Earth but not actually terrain[21]. Clutter around a radio transmitter/receiver terminal can have a significant effect on the overall propagation. It is normally the clutter closest to the terminal that has most effect on the propagation, but the actual distance will depend on the nature of the clutter and the radio parameters.

The effects of clutter in the environment may be captured using the recommendations in ITU-R P.2108 [21] for urban and suburban environment,[4] while the clutter model in section 4.5 of ITU-R P.452 [1] may continue to be used for the rural environment. It should be noted that the model

[4] The model in Section 3.2 of ITU-R P.2108 [21] will replace the Section 4.5 of ITU-R P.452 [10].

in ITU-R P.452 is applicable from 50 m in coniferous and deciduous forests and from 100 m over open fields or sparse vegetation. The clutter model in ITU-R P.2108 is applicable from a distance of 250 m. ITU-R P.452 is itself valid beyond 1 km making the clutter loss model applicable without restriction. Moreover, the WINNER II and eHata model incorporate clutter loss in their design and Recommendation ITU-R P.2108 will not be applied when those models are used.

Recommendation ITU-R P.2108 (Equations 3-5 in [21]) provides a statistical distribution of clutter loss. The clutter loss is given as a cumulative distribution function where the loss is not exceeded for p% of locations.

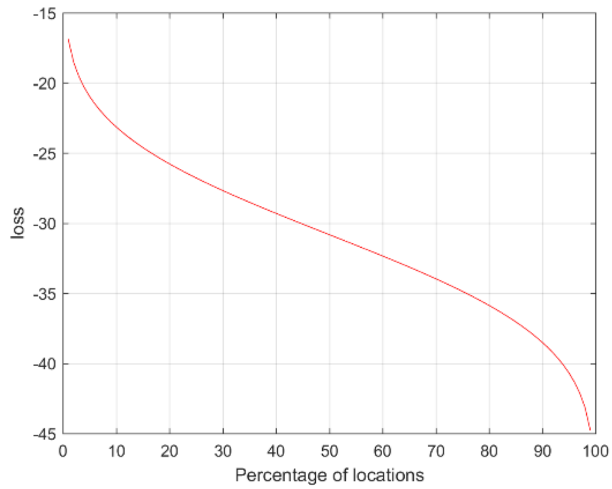


Figure 2 Inverse Cumulative Distribution of clutter loss.

It is important to understand the proper application of the above distribution in a way that is considerate of the need to be conservative when protecting microwave links. For example, the choice of the median clutter loss, suggested by some interested parties, is not conservative enough to account for worst case effects. While some would compromise at mean estimates of the loss function, arguments can be made for more conservative estimates such as the 20th percentile loss. The appropriate loss percentile to use to properly protect the incumbent users while permitting new unlicensed users into the band is an important issue that still needs to be resolved by this committee.

It is also important to understand that the loss in ITU-R P.2108 must be applied under the assumption of the interferer being within the clutter and the FS receiver being above it. Table 1 lists some default clutter heights with representative clutter height *R* (where local information is not available). NLCD is used to determine clutter type and appropriate R(m).

Table 1 Clutter height R for various local clutter environments

Clutter Type	*R* (m)
Water/sea	10

Clutter Type	*R* (m)
Open/Rural	10
Suburban	10
Urban/trees/forest	15
Dense urban	20

The application of the recommended model is meant to be in a statistical manner. Clutter is already designed into the WINNER II and eHata models in a statistical manner. It is to be noted that, for short path lengths, the eHata model emulates free-space behavior.

6.2 Building Entry Loss (BEL)

ITU-R P.2109 [22] provides a well-documented model for BEL. This model is directly applicable to and is designed to be added to the effect of a long-distance propagation path represented by ITU-R P.452 and the ITM propagation pathloss models. BEL may be applied using ad hoc estimates (e.g 15 dB as is used in CBRS) for statistical considerations or by use of the ITU-R P.2109 model in the case of low distances where the WINNER II or eHata model are employed.

There are certain assumptions for the model that need to be noted:

- The statistical output of the model represents the generality of building orientations with respect to the outdoor terminal
- The model assumes that the indoor antenna is omnidirectional; the building entry loss will therefore take account of all energy arriving at the terminal location.
- The model makes the implicit assumption that terminals have an equal probability of location at any point within a building.

The implication of these assumptions indicates that the model is more suitable to the case where the receiving station in an outdoor-to-indoor path is within the building. In the case where the RLAN station has directional antennas, there may be a discrepancy in the ability of the model to account for the orientation of the antenna in relation to exterior walls or windows. It is still expected that the proposed model is a relevant statistical characterization of BEL.

Further study is recommended on the proper application of BEL.

6.3 Land-cover Data

The National Land Cover Database (NLCD) is an effort by the Multi-Resolution Land Characteristics (MRLC) consortium to coordinate and generate consistent and relevant land cover information at the national scale for a wide variety of environmental, land management, and modeling applications. The NLCD2011 for land-cover data is hosted in the github repository in reference [23] by the WinnForum and is being used for CBRS, viz. NLCD Land Cover Class - 23 or 24 for urban and Class 22 for suburban.

6.4 Summary of available propagation models

Table 2 The various propagation models of interest to FS protection are listed.

Model	Purpose	Frequency Range	Distance	Constraints
ITU-R P.525	Propagation FS-to-FS	All EM waves	Straight-path distances	None
ITU-R P.452	Propagation RLAN-to-FS	0.1 to 50 GHz	Unspecified	Clutter losses are not applicable over short distances; rule of thumb is to use P.452 past 1 km
ITM	Propagation RLAN-to-FS	20 MHz to 20 GHz	1-2000 km	Elevation angle not to exceed 12 degrees
WINNER II	Propagation RLAN-to-FS	2 to 6 GHz	Metropolitan area or wide area short distances	Various models available. Weighted combinations of appropriate models as per [9]
eHata	Propagation RLAN-to-FS	100 MHz to 3 GHz	1 to 100 km	NTIA extension to 3.5 GHz in [24].
ITU-R P.2108	Clutter Loss	2 to 67 GHz	≥ 250 m	If clutter loss to be applied at both ends of the link, then minimum distance is 1 km
ITU-R P.2109	Building-entry loss	80 MHz to 100 GHz	N/A	model assumes that the indoor antenna is omnidirectional and applicability to an indoor transmitter with directional or sectorized antennas may be questionable.

7 Interference Protection Criteria

7.1 Sources of impairments to fixed links

It may be tempting to assume that advances in state-of-the-art microwave systems, such as those described in Section 4, e.g. adaptive modulation, spatial diversity, MIMO, can be harnessed to combat short-term interference effects and thereby mitigate such interference:

1. Adaptive Modulation: Interference from RLANs may cause a radio to switch to a lower modulation if it is capable of doing so, or it may just cause increased errors in critical systems. Members belonging to the microwave industry maintain that both conditions result in decreased availability.

2. ATPC: Use of this feature on radios coordinated at the lower power levels cannot exceed time limits established by ANSI Standard 10. It is felt by some that there is no ability to use this feature to combat interference from RLANs as it would increase interference from the FS link into all other FS links in range during the time of RLAN interference by increasing the output power of the FS link. This would then more quickly use up the allowable time above coordinated power level eventually rendering the feature unusable, and the FS link would be vulnerable to all future events.

3. Spatial diversity: Space diversity techniques can reduce the effects of multipath fading on line-of-sight systems to insignificance [25]. While spatial diversity is not used for interference mitigation in microwave deployments, its use for interference mitigation with RLAN devices requires further study. While space diversity does reduce the intensity and depth of fading events, the use of space diversity by microwave systems is usually limited to installations that are frequently subject to greater depletion of available margin due to the prevailing conditions.

4. Antenna gain: Antenna beamwidth generally decreases as antenna size increases, but the trend is to deploy smaller, lighter, and cheaper antennas. The side effect of their size is wider beamwidths meaning that the angle over which the RLAN handset can cause maximum interference is increasing. Although the gain of the smaller antenna is less, mobile stations or terminals in its larger half-power beamwidth area will likely contribute to the composite interference level at a much higher level than mobile stations or terminals outside of the smaller half-power beamwidth of a higher gain antenna.

5. MIMO: As detailed in Section 4, MIMO antenna systems are designed to increase the throughput of an FS link and not to increase the link's resistance to increased interference. Consequently, FS industry members of the 6MSC feel that RLANs cannot reasonably expect to use this feature to mitigate the interference they create.

Many of our members feel that the above features are already being used to maintain the availability of the existing systems and are not designed for use as a coexistence or interference mitigation mechanism for sharing spectrum with RLANs. Especially in the case of ATPC, it is felt that increased RLAN interference could use up the time limits for increased power and cause the feature to be unusable, resulting in repeated outages throughout the year. While this is not a consensus view, the arguments above are made from a factual basis and are worthy of consideration.

7.2 ITU-R Recommendations on compatibility

The protection of FS is a well-studied problem in practice and the ITU-R has several recommendations on the performance characteristics of microwave links as well as considerations that must go into the protection of such services under various scenarios, among which are 1) intra-service (microwave) co-primary users, 2) interference from co-primary users that operate in other primary services (e.g. FSS earth-to-space), 3) unwanted and spurious emissions from other systems, 4) emissions from secondary radiators that are out-of-band or co-channel 5) emissions from secondary services authorized to operate in the band.

ITU-R recommendations are given for both long- and short-term interfering signal criteria. Excess long-term interference to FS receivers reduces the margin available to protect the FS system against fading, causing a reduction in the link availability. Short-term interference requires separate consideration because the interference power may be high enough to produce degradation even when the desired signal is unfaded, e.g., due to demodulator impairments such as synchronization and automatic gain control processing. Long-term interference is usually characterized as the interference power that is exceeded 20% of the time at the victim receiver input.

It is understood that some RLAN devices may not cause sustained long-term interference, e.g., some industry groups have sponsored studies that claim that the median duty cycle of Wi-Fi access points, operating across a wide range of environments and activities (e.g., file transfer, video streaming, audio, surfing on the internet), is on the order of 1% [26]. Further studies are needed on applicability of these models for RLAN device use cases to the 6 GHz band. For example, low individual duty cycles can still lead to significance in activity levels on an aggregate basis. The unlicensed spectrum is moreover not only limited to one class of devices, and new applications such as surveillance cameras can change the traffic characteristics significantly. Moreover, it must be recognized that the short-term peak activity by potential interferers can severely impact the performance of an FS receiver over periods spanning tens of minutes. Therefore, we cannot discount the impact of short-term interference effects, from individual radiators or populations of interferers during periods of high traffic, on the availability of a fixed microwave link. Furthermore, many other RLAN devices may operate at a much higher duty cycle, causing long-term interference. Specifically, the 6 GHz band is of importance to the commercial wireless industry and it is expected that the impending introduction of Licensed Assisted Access (LAA) or NR-U into the band will bring a host of new use cases into the band that do not conform to the prevailing wisdom regarding traffic characteristics. WiFi, LTE, and NR use of the band must reckon with the technology-neutral approach to RLAN use of the band on equal terms for access to spectrum and channel. Further study is needed to fully characterize the range of RLAN transmit duty cycles and, as a result, whether FS receivers should be protected from RLAN interference using long- or short-term interference models or whether a combination of these models should be applied.

7.2.1 Protection Criteria Based on Long-Term Interference Models

While not directly pertinent to the introduction of RLAN devices, Recommendation ITU-R P.758 offers one potentially applicable treatment of the system parameters and considerations in the development of criteria for sharing or compatibility between fixed wireless systems and other services [27] given long-term interference. This recommendation could influence the sharing between RLANs and FS receivers. Additional considerations based on short term performance variations may also be applicable if the conditions for their application are met. There is significant disagreement on the relevance of short-term effects.

The document draws a distinction between two kinds of objectives that must enter into any such sharing or compatibility analysis: a) Availability Performance Objective (APO) and b) Error Performance Objective (EPO).

The difference between the two objectives is in the time basis of the evaluation. Availability evaluation occurs on an annual basis whereas error performance evaluation is typically done over the duration of a month. These objectives are independent of the measurement of the impact of short-term or long-term interference effects. In general, our concern is with long term interference effects that impact both the availability and error performance of a fixed service receiver (section 4.1 of [27]):

a. Degradation in the error performance or the availability performance resulting from interference from the co-primary service, which is clearly specified as 10% in Recommendation ITU-R F.1094 (and also in Recommendation ITU-R F.1565).

b. Degradation in fade margin due to the interference, which is directly calculated from (I/N) value, as 10 log ((N + I)/N) = 10 log ((1 + (I/N))) (dB).

ITU-R F.758 characterizes the objectives thus:

> *In particular, when the interference into FS victim is constantly present (e.g. from a GSO space station), it is generally assumed that the acceptable level of interference should be sufficiently low for not affecting the FS system availability threshold, on a yearly basis. In this case, ensuring the suitable FS availability degradation, it is generally assumed that any related "error performance" degradation would be within the acceptable limits (in any month) and no specific study is required.*
>
> *On the contrary, when the interference into the FS victim is relatively fast varying (e.g. from a non GSO space station), it is generally assumed that, due to uncorrelated wanted and unwanted paths, the acceptable interference level may be higher, so that the "error performance" degradation would predominate over the possible "availability" degradation. In this case, the "error performance" degradation study should be carried out on the "worst month" basis (see example in Recommendations ITU-R F.1108 and ITU R F.1495).*

For prediction purposes, conversion of annual statistics to worst-month statistics is addressed in ITU-R P.841[28].

The impact of RLAN interference into an FS receiver spans both these objectives, as the impact of interference from a single RLAN device may affect the expected availability of a FS receiver adversely, whereas the aggregate interference emitted by hundreds or thousands of RLAN devices with varying traffic characteristics that operate in the vicinity of an FS receiver may affect its EPO adversely. Thus, we submit that the introduction of unlicensed devices into the 6 GHz band may need to be evaluated from an availability as well as an error performance perspective.

The understanding of the difference is further illustrated by the following:

1. Automated Frequency Coordination from the perspective of a single RLAN transmitter seeking to operate in the 6 GHz band should consider the impact of that transmitter on the availability of FS receivers that would be impacted by the presence of the RLAN transmitter as a cochannel or in-band interferer. This impact may be assessed by means of a minimum coupling loss analysis of the link.

2. The criteria used to establish exclusion or coordination regions around an FS receiver must consider the impact of aggregate interference. This can be done using a number of ways:

    i. Estimate the number of interferers and perform a Monte-Carlo analysis of the error performance impact

    ii. Assess the number of interferers present and either simulate or sense the impact at the FS receiver

    iii. Use the Minimum Coupling Loss (MCL) analysis corresponding to the availability evaluation of a median interferer and add a margin corresponding to the expected impact of aggregate effects.

    Of the above methods, (iii) is practical, while (i) deserves further study allowing that there is precedent from CBRS, while (ii) is dependent on a significant amount of diligence and system knowledge to make it suitable for unlicensed devices in the band.

7.2.1.1 Network Performance Objective (NPO)

The performance requirements that pertain to assessing the ability to meet the APO or EPO are defined in Recommendation ITU-R F.1094 in the form of maximum allowable degradations to error performance and availability [29]. The assessment of the NPO which in turn comprises the EPO and the APO is conducted in five parts based on:

a) Emissions from FS links operating in the same band

b) Emissions from other radio services which share frequency allocations on a primary basis

c) Emissions from radio services which use frequency allocations on a non-primary basis;

d) Unwanted emissions (i.e. out-of-band and spurious emission domains such as energy spread from radio systems, etc.) in non-shared bands ;

e) Unwanted radiations (e.g. among others, UWB applications)

Clearly, unlicensed communication devices such as RLAN/WAS should be classified as in category (c) above.

Of the above categories of emissions that may cause degradation to a Fixed Service or microwave receiver, the maximum allowable value of error performance and availability degradation defined by the NPO should be divided into:

I. an element X% for the fixed service portion, including equipment imperfections and degradations due to propagation effects (intraservice sharing as in (a) above),

II. Y% for frequency sharing on a primary basis (interservice sharing as in (b) above), and

III. Z% for all other sources of interference (encompassing the sum of contributions from (c), (d), and (e) in the preceding list).

The sum of X% + Y% + Z% is not to exceed the EPO or the unavailability objectives from ITU-R F.1668 and ITU-R F.1703 respectively [30][31]. Both documents provide identical values of X=89, Y=10, and Z=1.

7.2.1.2 Interference Protection Criteria for FS

Table 3 Relevant interference protection criteria for FS links assuming Long-Term Interference Objective

Impairment category from Section 7.2.1.1	I/N[5]	Frequency range	Sharing/compatibility conditions	Comments and relevant ITU-R Recommendations
(a)	–6 dB	30 MHz to 3 GHz	Co-primary intra-service sharing	Generally applicable value for the aggregate interference corresponds to
	–10 dB	Above 3 GHz		
(b)	≤ –6 dB	30 MHz to 3 GHz	Sharing with more than one co-primary service e.g. FSS earth to space	–6 dB or –10 dB, as appropriate, may be applicable where the risk of simultaneous interference from the stations of the other co-primary allocations is negligible. In other cases, a more stringent criterion may be required to account for aggregate interference from all interfering co-primary services (i.e. –6 dB or –10 dB should be intended as maximum aggregate I/N from all other co-primary services).
	≤ –10 dB	Above 3 GHz		
(e)	–20 dB	3-8.5 GHz	Compatibility with UWB	SM.1757
(c)	–20 dB	All	Compatibility studies	F.1094

ITU-R recommendations for 6 GHz microwave protection from long-term interference are summarized:

1. Aggregate interference protection levels corresponding to an I/N level better than -10 dB for intra-service co-primary protection for a FS receiver; this corresponds to 89% of the allowable error performance or availability degradations;

2. Aggregate interference protection levels corresponding to an I/N level better than -10 dB for intra-service co-primary protection for a FS receiver, corresponding to 10% of allowable error performance or availability degradations;

3. All other services and extraneous sources of interference are accorded an interference protection threshold equivalent to an I/N level of -20 dB, corresponding to the remaining 1% of the allowable error performance or unavailability levels.

[5] All values in the table pertain to aggregate interference.

7.2.2 Protection Criteria Based on Short-Term Interference Models

ITU-R Recommendations SF.1650 and F.1108 provide examples of studies of short-term interference objectives [32][33]. Recommendation ITU-R SF.1650 is based on a treatment of Earth Stations in Motion (E-SIM) that are based on vessels off-shore; acceptability criteria result in distances 293-404 km from the coast and a scaling down of coupling loss will allow casual understanding of expectations for RLANs. While the equivalence of the study to the sharing between FS and RLANs must be drawn with care, the methodologies used to derive the results bear examination and are relevant for future consideration. Table 4 is a reproduction of interference objectives suggested by ITU-R SF.1650.

Table 4 Relevant interference protection criteria for FS links Assuming Short-Term Interference Objective

Short-term interference objective		
Interference criteria, I/N_{th} (dB)	– $I/N = 23$ dB, not to be exceeded for more than 1.2×10^{-5}% of the time for the severely errored second (SES) level. – $I/N = 19$ dB, not to be exceeded for more than 4.5×10^{-4}% of the time for the errored second (ES) level	These figures are based on a net fade margin of 24 dB referenced to the 1×10^{-3} BER level. Note that the interference criterion associated with the ES level is the more stringent criterion and hence this is used to determine the required distance

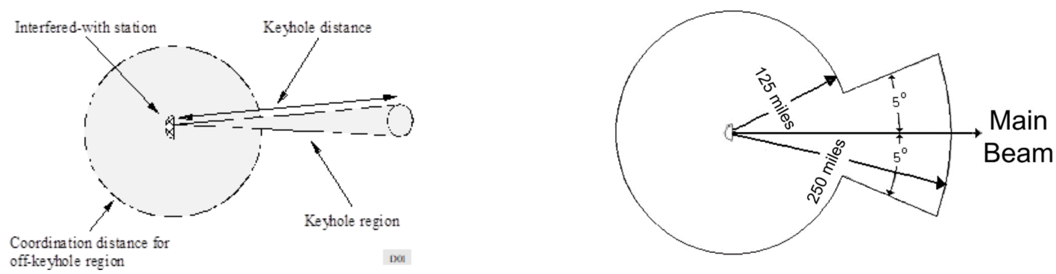
Recommendation ITU-R F.1108 addresses the short-term interference criteria for protection of FS receivers from space stations in non-geostationary orbits. The document offers two methods for characterization of performance: (1) a translation of the estimate of fractional degradation in performance, due to short-term interference, into a fade margin loss, and (2) a relation between the fractional degradation in performance and I/N. Clearly, the propagation models used to analyze space stations are not directly applicable here and the methodology is alone of importance.

RLAN duty cycles may potentially exceed those in Table 4 [11]. However, the table shows that there exist certain situations with duty cycle less than 20%, where higher levels of I/N could be tolerated for brief periods of time. The open question is whether these levels are considerate of the APO and EPO objectives in Table 7.2. As mentioned before, low duty cycles do not automatically translate to a change of protection regime to that in Table 4. Interference can still be of such duration as to impact the availability of a critical service. Under these circumstances, the typical FS user would justifiably resist alteration of long-term requirements to short-term interference protection objectives.

7.3 US Considerations

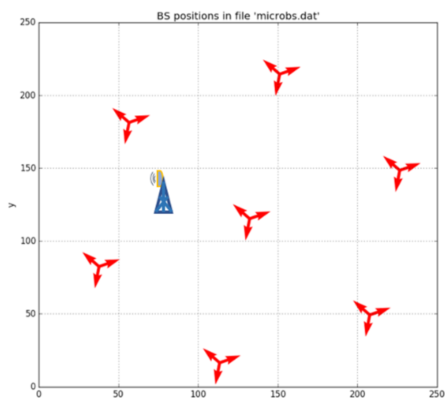
Lastly, the question of over what area must frequency management be imposed must be addressed. ITU-R addresses this with their recommendation F.1095 [34]. In the United States a different area definition is used as defined by the NSMA [35].

In both cases, there is a distinction between coordination distances in the proximity of the receiver antenna boresight as opposed to an off-axis location of the interfering station.

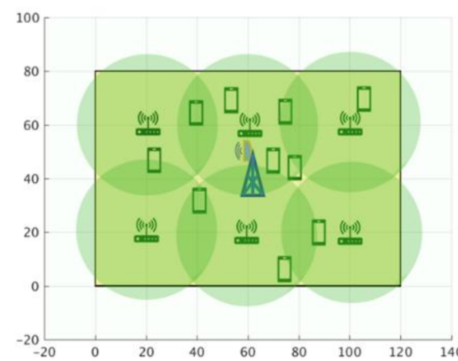


(a) (b)

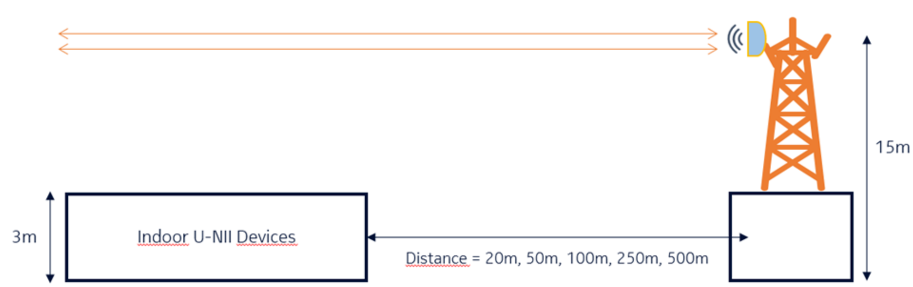
Figure 3 Coordination of fixed service operation in (a) ITU-R F.1095, (b) NSMA recommendation for 6 GHz from WG3.90.026.



(A) Outdoor Deployment of RLAN devices in proximity of an FS receiver



(B) Indoor RLAN devices in the same building as the rooftop FS receiver



(C) Indoor RLAN devices in an adjacent building to the rooftop FS receiver

Figure 4 Scenarios simulated in [36]; as a reminder, U-NII devices are identical to RLAN devices.

7.4 Protection Considerations

7.4.1 Aggregate Interference Effects

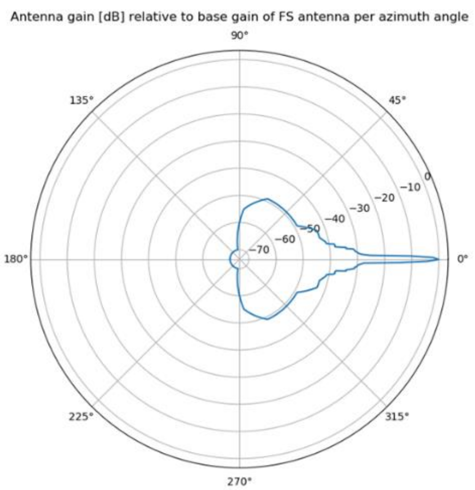
Some studies of compatibility between RLANs and the Fixed Service (FS) are described in reference [36]. The referenced annex to Nokia's *ex parte* filing to the FCC reports on Monte Carlo simulations of three scenarios:

A. Outdoor macro/micro deployments of RLAN/WAS in the same area as an FS receiver;

B. Indoor RLAN deployments in a building with the FS receiver installation on its rooftop; and

C. Indoor RLAN deployments buildings that neighbor a building with an FS receiver.

Adjacent Carrier Interference (ACI) and Co-channel Carrier Interference effects were considered. The traffic model used was full-buffer. Under the assumptions and deployment scenarios considered, the study's results demonstrated that co-channel aggregate interference can be an issue in all the cases simulated. Figure 5 provides some details for context with results in Figure 6 and the reader is referred to the submission [36] for further details.



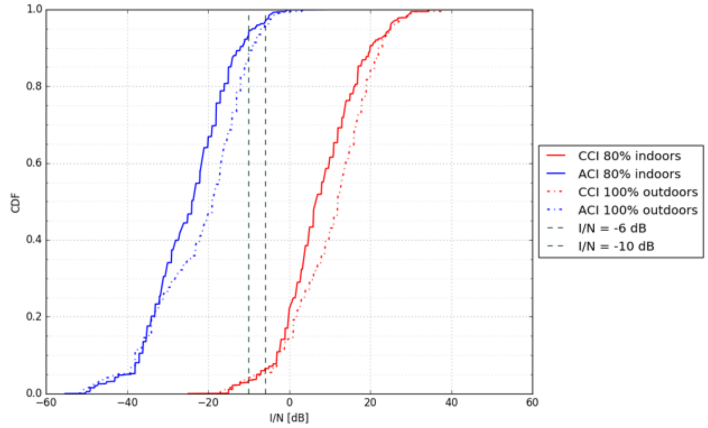
FS channel bandwidth	10 MHz
FS antenna pattern	12.0 ft / 3.6 m dish antenna with 45.1 dBi max gain -3 dB beam width 0.9 degrees -25 dBi Gain at ≥ +/-100 degrees from main beam 0-degree downtilt
FS adjacent channel selectivity	Not modeled (assumed better than 50 dB and TX ACLR dominates)

(A) FS modeling

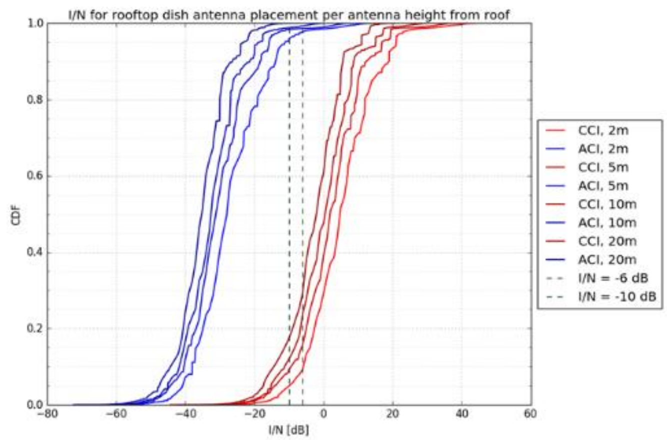
Parameter	Value
RLAN channel bandwidth	20 MHz
RLAN device transmit output power (conducted)	Outdoor access point: 30 dBm Indoor access point: 24 dBm Client device: 18 dBm
RLAN antenna pattern	Outdoor access point: 6 dBi max gain, 120-degree sectors, Indoor access point: 0 dBi isotropic Client device: 0 dBi isotropic
RLAN device Adjacent Channel Leakage Ratio (ACLR) (Note 1)	Access point : 35 dB Client device : 30 dB
Outdoor configuration	Hexagonal grid, 7 sites with 3 cells per site (ISD = 100m), RLAN access point at 10 m height, 5 UEs, 100% outdoor or 80% indoor.
Indoor configuration	office model, 120x80 m, 6 access points, RLAN access point height at 3 m, 30 UEs, all indoor
RLAN traffic model	Full buffer
Propagation model	3GPP TR 38.901 UMi [37] LOS and NLOS
Wall penetration loss	3GPP TR 38.901 [37] 13.4 dB for low-loss model (50% probability) 30.7 dB for high-loss model (50% probability).

(B) RLAN modeling

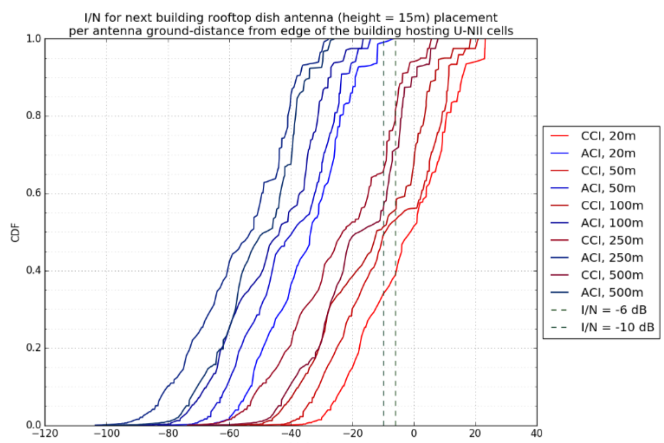
Figure 5 Simulation conditions for a sample aggregate interference study.



(A) CDF of aggregate I/N for FS with Outdoor Deployment of RLAN devices



(B) Indoor RLAN devices in the same building as the rooftop FS receiver



(C) Indoor RLAN devices in an adjacent building to the rooftop FS receiver

Figure 6 Results on I/N under ACI and CCI conditions for scenarios in Figure 4; here, RLAN is identical to U-NII.

7.4.2 Interference characterization

There is a temptation among some proponents to treat microwave links on terms equivalent to the way mobile wireless systems coordinate between themselves, namely by using geometry measures based on C/I. This is not advisable. Apart from requiring a dependency of the AFC on very detailed knowledge of the equipment characteristics, it will place an additional burden on the AFC function to be aware of the environmental conditions under which the FS receiver is deployed. In the case of microwave applications that span hundreds of kilometers, where the end-to-end system is composed of several Path Elements (PE), this is particularly problematic.

There is a very clear recommendation in ITU-R F.758 to relate error performance and availability objectives to an I/N threshold for the FS receiver. The choice of I/N allows the characterization of error performance and objective in a device-independent manner. Thus, evaluations of equipment need not be tied into a minimum performance objective dependent on the transmission characteristics of the microwave links. In other words, higher complexity equipment can be used to improve the performance of a link with some degree of flexibility in being able to retain high availability constraints.

Based on the above considerations, the WInnForum 6 GHz Multi-stakeholder Committee strongly recommends that FS protection be based on an I/N requirement.

7.5 Important considerations regarding fixed service protection

We raise the following questions and proffer answers as noted below:

1. To what extent should fixed microwave services be protected?

   The stakeholders represented in the WInnForum 6MSC currently analyzing a sharing regime for the band that primarily protects fixed service incumbents, keeps the band viable for new entrants, and makes the band available for RLAN use, in a manner where the primary status of incumbents is not violated.

2. Does microwave deserve to be in the 6 GHz band?

   The lower segment of the 6 GHz band corresponding to the U-NII-5 designation for RLAN users as well as the upper segment U-NII-7 is heavily used by microwave links as detailed in Section 4, many of which are for critical purposes; the U-NII-7 segment is relatively less utilized [1]. Furthermore, the band is assigned to the fixed service throughout much of the world and is an important resource for long-haul carrier-grade links and many critical services. A sharing regime that is not considerate to the performance requirements of critical use of the band for high availability applications will cause users to exit the band. The US benefits from the economies of scale of the supply chain. It must be noted that other segments have BAS and CARS systems that deserve their own assessment in addition to the treatment of FS protection in this report.

3. What is the interference objective (I/N) for co-primary protection of fixed services on an intra-service manner?

The 6MSC accepts that there is reasonable consensus around an I/N threshold of -6 dB for a single exposure of interference between one FS interferer and a victim FS receiver. This is based on an assumption of a 1 dB threshold on noise rise. The FS industry does not formally consider requirements on Multiple Exposure Allowance (MEA) for FS-to-FS coordination because "simultaneous [approximately equal] interfering signals from multiple FS transmitters [are] considered rare" (see TIA-10 [6]).

4. What is the level for I/N for completely uncoordinated unlicensed services relative to the above?

   There does not exist consensus among stakeholders regarding whether the ITU-R recommendations are or are not appropriate or applicable for the purpose of U.S. rules. Indeed, there are strong indications that the relevant protection level for FS protection from intra-service sharing may be raised to as high as a nominal level of I/N = -6 dB on aggregate interference allowance assumptions. This would be 4 dB higher than the ratio I/N recommended by the ITU-R at 6 GHz for long-term interference. If such a relaxation is warranted, and the long-term interference model is deemed most appropriate, the logical conclusion may well be to raise the other levels in Table 2 by an equivalent amount of 4 dB.

5. It may also be argued that the interference levels in Table 3 corresponding to non co-primary services are based on an assumption of no interference coordination capabilities in relation to compatibility between co-primary use of the band. Under those circumstances, would the availability of an AFC to protect a victim FS receiver with more relevant information accord a further relaxation of the I/N thresholds?

   The 6MSC will need to study this further. It is a majority opinion that the ITU-R recommendation of -20 dB is untenable. The rationale in this document would tend to place the fixed service industry at some level of I/N that accounts for the relaxation of the co-primary number somewhere in the range of -10 dB to -6 dB and additionally adds a suitable relaxation for RLAN devices based on the characteristics of the AFC mechanism that is chosen..

6. What are the further relaxations that may be possible to the above level given that an automated frequency coordination is envisaged for the band?

   Although no consensus exists in the 6MSC, some incumbent stakeholders have suggested that an I/N level of -12 dB may be considered as a nominal threshold for the portion of interference contributed by RLAN users.Further study of the overall effectiveness of the AFC mechanisms that are adopted must be conducted before this level is validated.

   This level may be amenable to further relaxation given the following two considerations:

   - *Interference from 6 GHz RLAN devices may have radio characteristics and use cases (e.g. a duty cycle well less than 20%) under which circumstances the long-term protection criteria may be substantially conservative and short-term interference protection criteria involving much higher I/N levels than those* *provided for long-term interference. As discussed before, there are doubts about whether characterizations of low duty cycle for some kinds of RLAN use cases do not cause any impact to FS receiver performance.*

- *Long-term interference recommendations do not take into account FS link features such as spatial diversity and link improvements due to adaptive modulation, forward error correction, and more directive transmit and receive antennas. Such features are commonly available in FS and RLAN products. As mentioned earlier, spatial diversity is usually employed in specific situations where availability or error performance is compromised by prevailing environmental conditions for the link. It must further be recognized that the use of such margins to compensate for short-term interference from RLAN devices will impact the error performance objectives and the overall throughput objectives of an FS link beyond what was dimensioned at initial planning prior to deployment.*

The answers to the preceding questions depend on a number of interdependent factors:

1. Trust in the AFC: The architecture, design, and certification of an decentralized AFC must assure that it works, sufficiently protects incumbents, is secure and not prone to faults or tampering etc.

2. Trust in the devices and their ability to declare their location: Whereas CBRS has an elaborate operational diligence around installation and registration of the devices (based largely on the need to protect extremely sensitive Tier 1 DoD incumbents, which may not be applicable in 6 GHz), the proposed applications in the 6 GHz unlicensed band cannot reasonably be expected to conform to the same level of operational control. Indoor U-NII devices that originate from diverse, global supply chains will not have any way of validating their declared location. Such processes can be subverted by malicious or uninformed users (e.g., as is the case for some existing regulations concerning WiFi APs).

3. Validation of AFC operation and certification of devices: A centralized AFC can be validated and certified. Distributed implementation of the AFC function in U-NII devices should likewise be subject to certification and the level of trust in industry compliance needs to be assured.

4. Effect of aggregate interference: Further study is needed to characterize the level of isolation needed between U-NII devices and the FS receiver, accounting e.g. the relative duty cycle of individual U-NII devices, using a standard set of models acceptable to all industry members etc. Previous studies have shown that under certain conditions, allowing outdoor or indoor RLAN use in the same channel used by an FS link can cause unacceptable noise rise in an incumbent receiver [36]. This revelation, although interesting, must still be reconciled with the recommendations of this report leading towards a common understanding of modeling and analysis principles. The ability of the AFC to retain state of U-NII use of the band will significantly improve the coordination of interference towards fixed service receivers.

5. Vulnerabilities to critical infrastructure from U-NII devices: The fact that many critical services in the utility industry and public safety users depend on the 6 GHz band should be assessed and taken into account when devising the AFC architecture.

8 Recommendations and Conclusions

Propagation models chosen must protect incumbents. Several suggestions have been provided, specifically WINNER II [4] for near-in distances, out to 1 km for suburban and urban areas, followed by ITM [15] for propagation paths beyond 1 km, and ITM alone for rural areas for all distances. Further study is needed regarding the application of clutter models, which are potentially favored to be consistent with ITU-R P.2108 and Section 6.1 for urban and suburban cases and with ITU-R P.452, Section 4.5, for the rural case. Clutter loss will be applied consistent with ITU-R P.2108 and Section 6.1. Further study is needed on BEL, but ITU-R P.2109 is promising. Use of the elevation profile 3DEP DEM is recommended [19]. Land cover modeling should be according to NLCD2011 [23].

Currently, incumbents have offered technical arguments in favor of an interference protection level of I/N=-12 dB. It has also been pointed out that FSS receivers are accorded protection of I/N=-12 dB for e.g. AWS-3 in the 1695-1710 MHz band. Given the nature of use of the 6 GHz band by many critical services, it is therefore reasonable to expect some sort of a support for I/N less than or equal to -6 dB, pending further studies to establish a better assessment of the right I/N value based on analysis such as an MCL calculation.

9 Future work

The following studies bear future consideration:

1. Aggregate interference effects have to be analyzed either with Monte Carlo simulations or an MCL analysis followed by a reasonable accounting of user density. This is an analysis that could be carried out by the 6MSC.

2. Effective duty cycle values for different classes of indoor and outdoor users are worth studying in order to get a better idea of the impact of multiple exposure situations.

3. More work needs to be done on sharing studies with the other incumbents in the band.

4. Contributions have been received in the area of BEL values and measurement approaches. These include using either fixed values or building loss measurements with systems such as GPS/GNSS.

5. Additional Studies are required on clutter loss considering the preference for the ITM model.

6. The impact of advanced antenna technologies on incumbents and U-NII operation may also be studied further.

One final objective of the 6MSC is a more detailed analysis of the requirements of the AFC and study of AFC architecture given the FS industry’s desire for affirmative control of spectrum authorization.