6 GHz Unlicensed Device Policy Overview

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Note: The views expressed in this presentation are those of the author and may not necessarily represent the views of the Federal Communications Commission

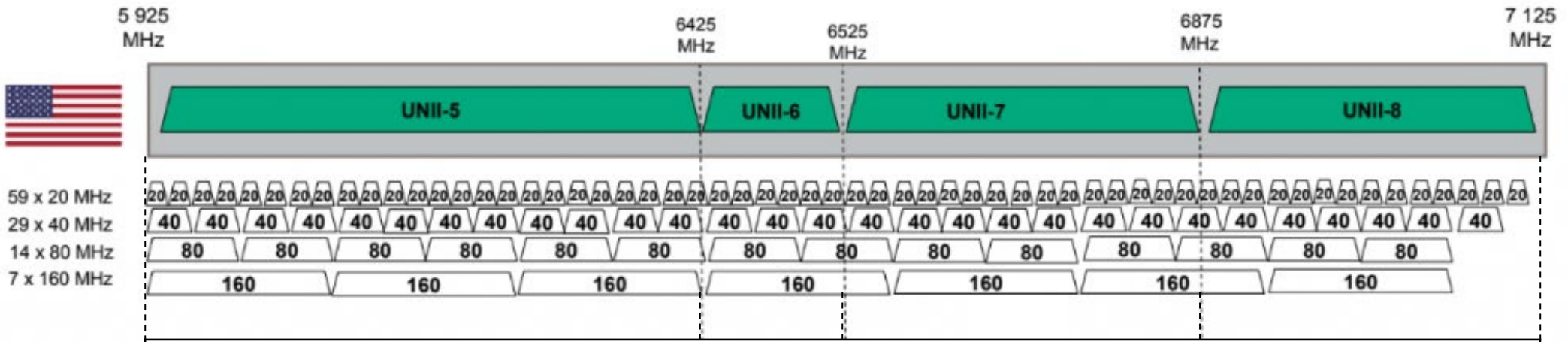
6 GHz U-NII – Major Decisions and Actions

- Report & Order adopted April 2020
  - Unlicensed device access to 5925-7125 MHz
    - Provided expanded access for unlicensed devices to 1200 megahertz
  - Devices with access to the full 1200 megahertz
    - Low-power indoor (LPI) devices
    - Low-power client devices
    - Subordinate devices
  - Devices with access only to U-NII-5 and U-NII-8
    - Standard-power devices
    - Standard-power client devices
    - Fixed client devices
- Further Notice of Proposed Rulemaking adopted April 2020
  - Proposed permitting very low power (VLP) unlicensed devices
- Second Report & Order adopted November 2023
  - Permits VLP devices in U-NII-5 and U-NII-7
- Second Further Notice of Proposed Rulemaking adopted November 2023
  - Proposes expanding VLP to U-NII-6 and U-NII-8
  - Seeks comment on permitting direct client-to-client communications
- Seven automated frequency coordination systems certified for full commercial use – February 2024

Why 1200 MHz For Unlicensed Devices?

- Balanced approach to spectrum
  - Commission recently made/is pursuing licensed spectrum available for mid-band
    - 530 MHz available for mobile broadband (3.45-3.55 GHz, 3.55-3.7 GHz, 3.7-3.98 GHz)
    - 3.1-3.45 GHz currently under study
- Economic Impact
  - Consumer Technology Association – permitting unlicensed use would add over $95.8 billion to the economy (retail hardware sales)
  - The Economic Value of Wi-Fi: A Global View (2018 and 2023)
    - 2025 forecast predicts 6 GHz band addition will add additional $200B in economic value to U.S.; value will continue to grow over time
    - Job creation by 2025 will reach 720,000
    - https://www.wi-fi.org/download.php?file=/sites/default/files/private/The_Economic_Value_of_Wi-Fi-A_Global_View_2021-2025_202109.pdf
- Most data traffic already carrier over Wi-Fi
  - Carriers rely on Wi-Fi to keep their networks from capacity overload
- Future-proof for Wi-Fi 7
  - Three 320-megahertz channels available vs. only one in lower 500 megahertz
- IMT use of upper 6 GHz band will cause harmful IX to FSS operations

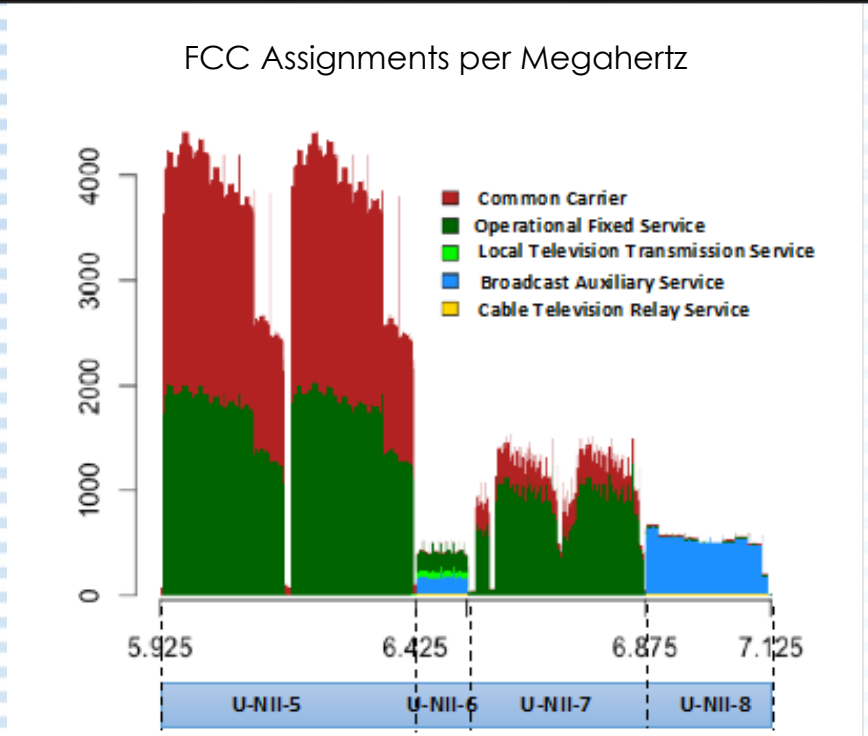
6 GHz Band Overview

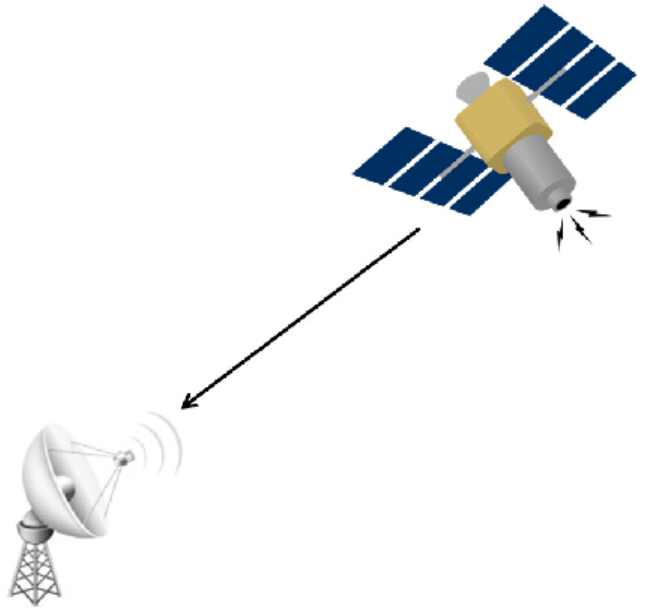


Low-Power Indoor Access Point			
Low-Power Indoor Client			
Subordinate Device			
Standard-Power AP		Standard-Power AP	
Standard-Power Client		Std. Pwr. Client	
Fixed Client		Fixed Client	
Very Low Power Device		VLP Device	

6 GHz Band Incumbents

47,695 unique call signs



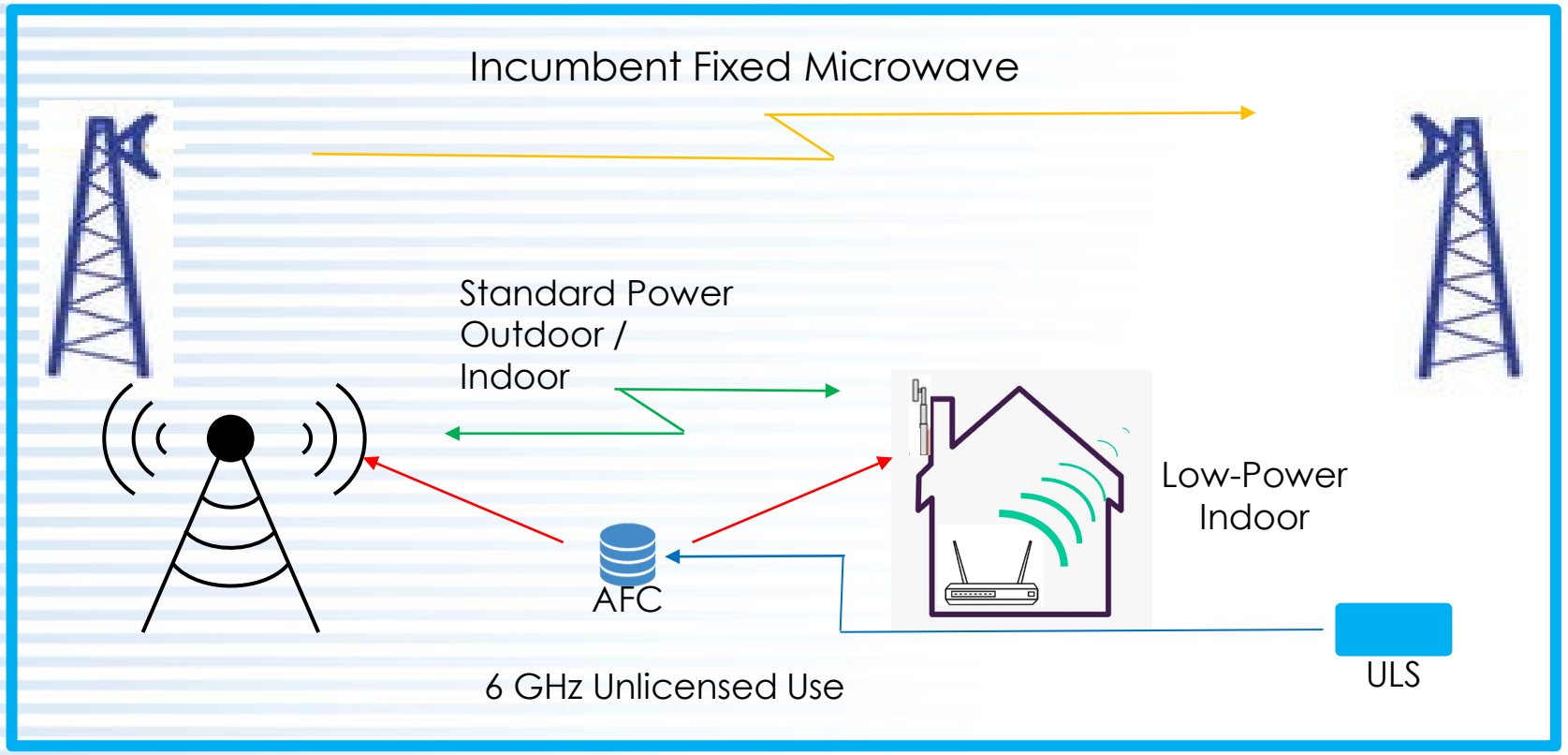


Microwave links (including public safety, utilities, cellular backhaul), Broadcast Auxiliary Services

Fixed Satellite Service
1,517 Downlinks
21 Uplinks

*Licensing data as of June 2020

6 GHz Band Basic Concept



Standard-Power Access Point is limited to U-NII-5 & 7 (avoids operation in bands with mobile services), can operate outdoors and must be under the control of an Automated Frequency Coordination system (i.e., database)

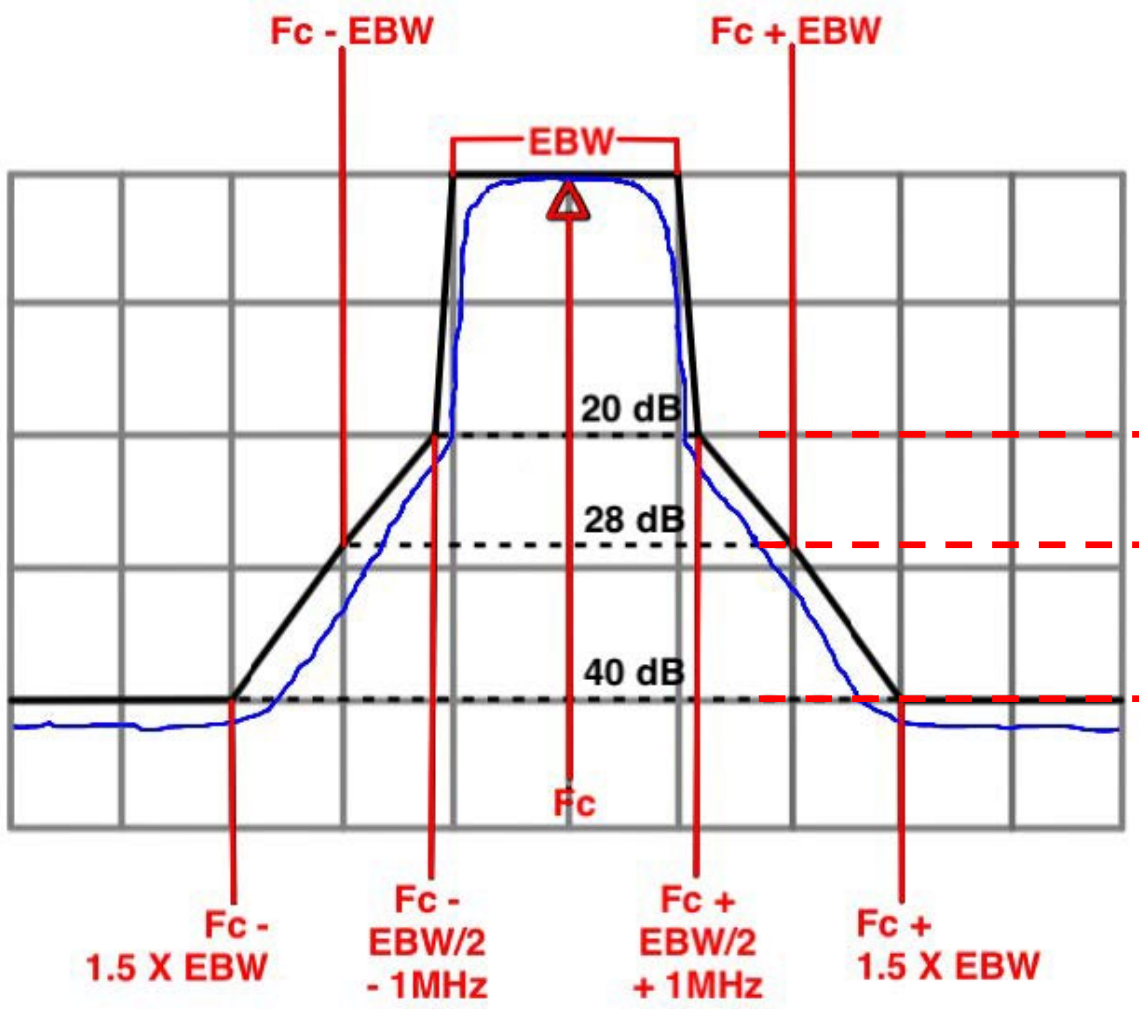
Low-Power Indoor Access Point can operate throughout entire 1200 megahertz, but is limited to indoor usage (takes advantage of building attenuation to enable co-existence)

Technical & Operational Rules Overview

Device Class	Operating Bands	Maximum EIRP	Maximum EIRP Power Spectral Density	Out-of-Band Emissions at Band Edges (Below 5.925 GHz) (Above 7.125 GHz)
Standard-Power Access Point and Fixed-Client Devices (AFC Controlled)	U-NII-5 (5.925-6.425 GHz) U-NII-7 (6.525-6.875 GHz)	36 dBm	23 dBm/MHz	-27 dBm/MHz EIRP
Client Connected to Standard-Power Access Point		30 dBm	17 dBm/MHz	
Low-Power Access Point (indoor only) and Subordinate Devices	U-NII-5 (5.925-6.425 GHz) U-NII-6 (6.425-6.525 GHz) U-NII-7 (6.525-6.875 GHz) U-NII-8 (6.875-7.125 GHz)	30 dBm	5 dBm/MHz	
Client Connected to Low-Power Access Point		24 dBm	-1 dBm/MHz	
Very Low Power Device	U-NII-5 (5.925-6.425 GHz) U-NII-7 (6.525-6.875 GHz)	14 dBm	-5 dBm/MHz	

Maximum EIRP is based on a 320-megahertz wide channel; power density limits EIRP for other channel bandwidths

Out-of-Band Emissions Per Operational Channel



For Maximum Power Operation

LPI	LPI Client	Std Pwr	Std Client
30 dBm	24 dBm	36 dBm	30 dBm
10 dBm	4 dBm	16 dBm	10 dBm
2 dBm	-4 dBm	8 dBm	2 dBm
-10 dBm	-16 dBm	-4 dBm	-10 dBm

-27 dBm/MHz required below 5.925 GHz and above 7.125 GHz

Out-of-Band Emissions

- Band edge limits protect:
  - Lower adjacent Intelligent Transportation Services
  - Upper adjacent federal services – fixed and mobile

- Per channel limits protect:
  - Adjacent incumbent operations
    - Fixed point-to-point systems
    - Broadcast auxiliary systems

Technical & Operational Rules
Low-Power Indoor & Subordinate Devices

- Contention-based protocol required
- Form factor
  - Integrated antenna
  - Non-weatherized enclosure
  - Not battery-powered (back-up for power outage is permitted)
- Location restrictions – No operation on:
  - Oil platforms
  - Cars, Trains, Boats and aircraft
    - Except, permitted in large aircraft when flying above 10,000 feet
- Client and Subordinate devices must operate under the control of a low–power indoor access point
  - Limited to maximum power 6 dB lower than LPI access point limit (i.e., 26 dBm)
- Direct client-to-client communications prohibited

Technical & Operational Rules
Standard Power and Fixed Client Devices

- Limited to U-NII-5 and U-NII-7 bands
- Must incorporate geolocation capability
  - Must determine location uncertainty with 95% confidence level
- Must operate under the control of a standard power access point
- Outdoor devices limited to 21 dBm (125 mW) maximum EIRP above 30° elevation angles to protect fixed satellite services
- Location restrictions – No operation on:
  - Oil platforms
  - Land vehicles (e.g., cars, trains), boats and aircraft
    - Except, permitted in large aircraft when flying above 10,000 feet
  - Unmanned aerial systems
- Client and Fixed Client devices must operate under the control of a standard power access point
  - Client devices are limited to maximum power 6 dB below associated standard power access point maximum permitted power
- Direct client-to-client communications prohibited

Technical & Operational Rules
Very Low Power Devices

- Must prioritize operations on frequencies above 6.105 GHz prior to operating on lower frequencies
  - To protect lower adjacent band Intelligent Transportation Systems (e.g., VLP devices and on-board ITS devices could operate in the same vehicle at the same time)
- Must incorporate transmit power control with capability to operate at least 6 dB below permitted maximum power (i.e., -11 dBm/MHz *vis-à-vis* -5 dBm/MHz)
- Contention-based protocol required
- Location restrictions – No operation on:
  - Oil platforms
  - Aircraft
    - Except, permitted in large aircraft when flying above 10,000 feet
  - Unmanned aerial systems
- Installation in fixed outdoor infrastructure is not permitted
- Direct client-to-client communications **IS** permitted

Automated Frequency Coordination Systems

- Determines available channels and maximum power for each channel for standard power access points and fixed client devices
  - To protect fixed point-to-point systems
    - System information (transmitter & receiver locations) obtained from ULS
  - Power granularity no greater than 3 dB steps from 36 dBm to 21 dBm
  - Must verify validity of FCC ID for each device requesting service
  - FCC specified propagation models
    - 0 – 30 m: Free Space
    - 30m – 1 km: Winner II
    - > 1 km: ITM
- First seven AFCs approved for commercial service – February 2024
  - Extensive lab testing against Wi-Fi Alliance / WinnForum test vectors
  - Extensive public testing by any interested party
  - Required by April 23, 2024 to implement a system for receiving and processing potential interference complaints

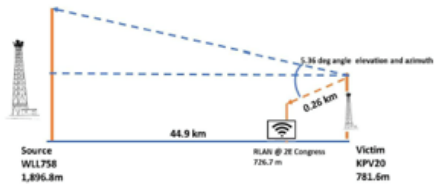
Analytic Basis for Commission Decision

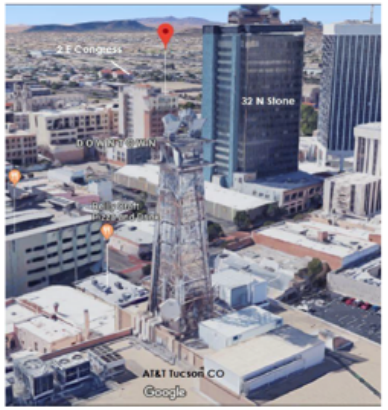
- Majority of analysis was focused on protecting fixed point-to-point systems from harmful interference
  - Building entry loss (20.5 dB median based on 70/30 traditional/thermally efficient construction split) - ITU-R P.2109 (2017)
- Much work also focused on preventing broadcast auxiliary service from harmful interference
- Commission determined I/N ≤ -6 dB was an appropriate evaluation metric
  - But did not equate a higher I/N with harmful interfernce
- Considered deterministic link budget analysis
- Considered probabilistic Monte Carlo analysis
  - Low-power Indoor devices
  - Very low power devices

Deterministic Link Budget Analysis

Example 1A: WLL758 > KPV20, RLAN at 2 E. Congress

- FS link to AT&T's CO in Tucson, AZ
  - Low Path loss – 0.26 km between RLAN and victim FS receiver
  - High FS antenna discrimination factor (36 dB) between RLAN and victim FS receiver
- RLAN at 36m AGL with transmit power of 30 dBm





	AT&T Value	RLAN Value	FCC Value
EIRP/BW	**30 dBm/ 80 MHz**	**30 dBm/160 MHz**	**24 dBm/80 MHz**
PSD	**11 dBm/MHz**	**8 dBm/MHz**	**5 dBm/MHz**
Antenna Gain	43.2 dB	43.2 dB	43.2 dB
Antenna Discrimination	-36 dB	-37.22 dB	-36 dB
RLAN/FS Antenna Mismatch	**0 dB**	**-5 dB**	**-5 dB**
Clutter	0 dB	0 dB	0 dB
Path Loss	**-96.45 dB (free space)**	**-96.14 dB (free space)**	**-103.60 dB (WINNER II Urban model**
Bandwidth Mismatch	**- 3 dB (assuming 80 MHz channels)**	**-7.27 dB (assuming 160 MHz channels)**	**-4.26 (assuming 80 MHz channels)**
Noise Figure	-3.0 dB	-5.0 dB	-3.0 dB
Polarization Loss	-3.0 dB	-3.0 dB	-3.0 dB
Feeder Loss	-2.0 dB	-2.0 dB	-2.0 dB
BEL (50%)	**-19.00 dB**	**- 32.75 dB**	**-21.44 dB (70/30 mix)**
Interference (I)	**-89.25 dBm**	**-115.18 dBm**	**-111.1 dBm**
Noise Floor (N)	-99 dBm	-99 dBm	-99 dBm
I/N	**9.75 dB**	**- 16.18 dB**	**-12.1 dB**

Example 4: WPTX494 > WLU230, RLAN at Vet Clinic

- FS link in Lynnwood, WA
  - Low Path loss – 0.17 km between RLAN and victim FS receiver
  - High FS antenna discrimination factor (38 dB) between RLAN and victim FS receiver
- RLAN at 2m AGL with transmit power of 30 dBm

	AT&T Value	RLAN Value	FCC Value
EIRP/BW	**30 dBm/ 80 MHz**	**30 dBm/160 MHz**	**24 dBm/80 MHz**
PSD	**11 dBm/MHz**	**8 dBm/MHz**	**5 dBm/MHz**
Antenna Gain	41.30 dB	41.30 dB	41.30 dB
Antenna Discrimination	**-38.00 dB**	**-47.165 dB**	**- 38 dB**
RLAN/FS Antenna Mismatch	**0 dB**	**-5 dB**	**-5 dB**
Clutter	0 dB	0 dB	0 dB
Path Loss	**-92.84 dB (free space)**	**-92.9 dB (free space)**	**-96.1 dB (WINNER II Suburban model)**
Bandwidth Mismatch	**- 3 dB (assuming 80 MHz channels)**	**-7.27 dB (assuming 160 MHz channels)**	**-4.26 (assuming 80 MHz channels)**
Noise Figure	**-3.0 dB**	**-5.0 dB**	**-3.0 dB**
Polarization Loss	-3.0 dB	-3.0 dB	-3.0 dB
Feeder Loss	**0 dB**	**-2 dB**	**-2 dB**
BEL (50%)	**-18.46 dB**	**- 18.46 dB**	**-23.08 dB (70/30 mix)**
Interference (I)	**-87 dBm**	**-109.5 dBm**	**-109.14 dBm**
Noise Floor (N)	-99 dBm	-99 dBm	-99 dBm
I/N	**12.0 dB**	**- 10.5 dB**	**-10.14 dB**

Probabilistic Monte Carlo Analysis

Simulated Area	Houston, TX
Losses Due to the Human Body	Gaussian distribution with a mean of 4 dB with a standard deviation of 4 dB, truncated to +/- 1 standard deviation. (The real-world loss will be significantly higher and the FCC should use higher values in its analysis).
Bandwidth distribution	20 MHz: 10% 40 MHz: 10% 80 MHz: 45% 160 MHz: 30% 320 MHz: 5%
VLP EIRP	10 dBm/MHz, no total EIRP limit 1 dBm/MHz, 14 dBm total EIRP limit -5 dBm/MHz, 14 dBm total EIRP limit -8 dBm/MHz, 14 dBm total EIRP limit -18 dBm/MHz, no total EIRP limit Each VLP EIRP is modeled in a separate simulation. TPC is applied to these power levels as detailed below.
6 GHz-Capable VLP Devices	1,285,376 *(50% adoption factor)*
Number of Iterations	10 million
Propagation Model	d >= 30m — Free Space 30m < d <= 1 km — WINNER II (statistical d > 1 km — ITM

RLAN Height	90% at ground level (1.5 m) 10% above ground level (>= 1.5 m). (The real-world percentage will be significantly smaller). Devices above ground level assigned heights according to actual Houston building height distribution. (See slide XX)
Antenna Pattern Loss / EIRP	ECC Report 302 “client” antenna pattern
TPC	Gaussian truncated distribution with 7 discrete steps (0-6 dB reduction)
Polarization mismatch	Random value according to CEPT algorithm min(-10log(cos²θ),35) * (0,2-0,1* [azimuth offset]/360+0,8*(EXP(-0,1*[azimuth offset]))
FS Feeder loss	1.3 dB
FS Noise Figure	5 dB
VLP Device locations	Uniform
FS Elevation Angle	+/- 2 degrees
Min. Separation Distance	10 m
FS Antenna Gain	44 dBi (conservative)
FS Height	35 m (the 10th percentile value in Houston)
FS BW	30 MHz

2nd Further Notice of Proposed Rulemaking

- Comments were due March 27,2024; Reply comments due April 26, 2024
- Expand rules for very low power devices
  - Increase power to 1 dBm/MHz and 14 dBm EIRP maximum
    - Based on implementing a geo-fencing system to protect fixed point-to-point systems
    - Seeks comment on additional power (e.g., up to 21 dBm EIRP)
    - Proposes rules consistent with existing rules
      - Transmit power control
      - Out-of-band emissions
      - Propagation models
  - Geofencing
    - Centralized model or decentralized architecture (e.g., determined by the device)
  - Expand VLP devices to U-NII-6 and U-NII-8 bands
    - Seeks comment on how to protect fixed receive sites
    - Seeks comment on conducting information collection for fixed receive sites
- Seek comment on emission limits below U-NII-5 to protect Intelligent Transportation Services

6 GHz – Ongoing Work

- AFC Waiver request to use building entry loss for indoor standard power devices
  - Composite low-power indoor / standard power device with low-power indoor device form factor
- Extreme networks waiver request to use a weatherized enclosure with Petitions for Reconsideration
  - For use in sports arenas; protect from abuse, spilled drinks, power washing

Questions?