Technical Appendix

Coexistence of Unlicensed National Information Infrastructure (U-NII) Devices

with Fixed Links at 6 GHz

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1 Introduction

This document presents initial results for compatibility between U-NII Devices and Fixed Service (FS) Links for the 6 GHz band. We use the term "U-NII devices" for 6 GHz unlicensed devices generally. The transmit power assumed for the U-NII devices are as per the Commission's NPRM for indoor and outdoor cases [1]. Interference caused by the new U-NII networks to FS receivers is simulated using a dynamic system simulator, which models the U-NII radio access at a detailed level with realistic traffic loads, medium access protocols, transmit output power levels, and transceiver impairments. The deployment models, propagation models and device antenna patterns are described.

Both co-channel and adjacent channel interference scenarios are considered, and the study focuses on three different deployment scenarios that include outdoor to outdoor and indoor to outdoor interference cases.

2 System simulation models and parameters

2.1 Simulator description

The system simulator models the cellular system using stationary base stations or access points with configurable antenna patterns including downtilt, and user equipment or client devices at randomly dropped positions within the simulation area. The client devices are connected to the access points. Propagation models are used to compute the path loss from transmitting nodes to the receiving ones (including nodes which consider interference). Scheduling and power control algorithms are used and at the receiving nodes the simulator calculates the signal to interference and noise ratio (SINR) and uses statistical methods to determine whether data was successfully received or not.

In the context of this study, the interfering system is parameterized according to the proposed U-NII device limits. In this first stage, we have evaluated interference performance using the standard emission masks [2] and maximum output power, without power control. As we do more studies, we intend to provide our inputs to the Commission to help augment the record on this important issue.

The interference to the FS receivers is calculated at each time instance, and cumulative distribution functions of the interference probability are presented.

2.2 Simulation scenarios

Three different deployment scenarios have been studied.

Scenario 1: The first deployment is outdoor and is based on 3GPP Urban Micro scenario [3]. In this scenario, the U-NII access points / base stations are arranged in a hexagonal grid with 3 sectors each covering 120 degrees, with wrap-around across the map edges. The inter-site distance is relatively small due to the restricted client device transmit power limit, 100 meters in this case. A single FS receiver is randomly placed within the simulation area, and the aggregate interference is simulated. The location of the FS receiver and the client devices are randomized for each simulation drop.

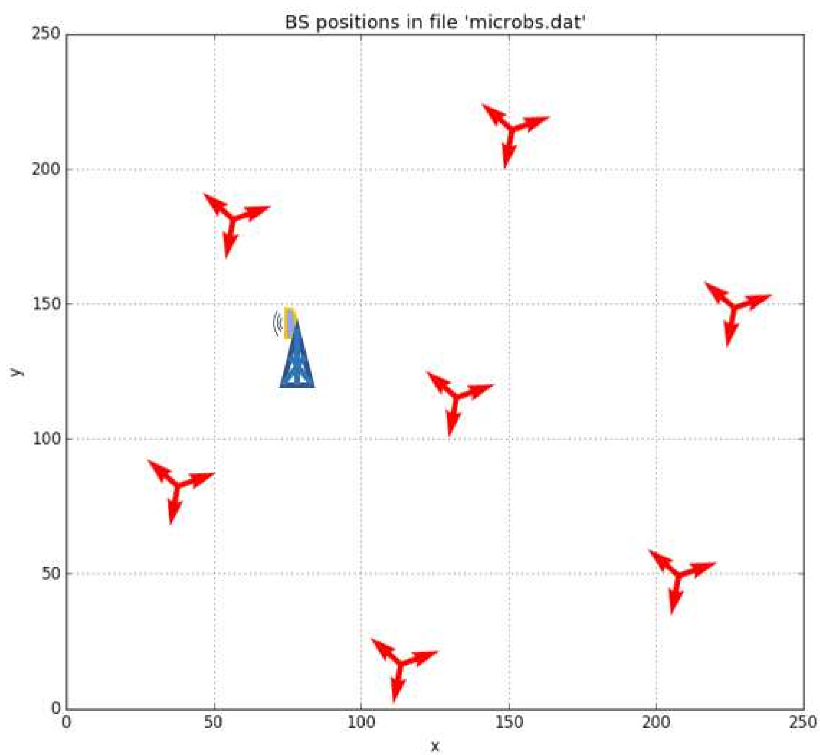


Figure 1: Outdoor scenario based on Urban Micro (Scenario 1)

Scenario 2: The second deployment is indoor, with an FS receiver placed on the roof of the building. The building can be considered a single-story or multi-story office building, and the U-NII devices are deployed on the top floor. In a multi-story building, the lower floors will have significantly larger penetration loss to the rooftop FS antenna, compared to the top floor, hence the contribution to interference can be considered negligible. The building layout is similar to the scenarios presented in [3].

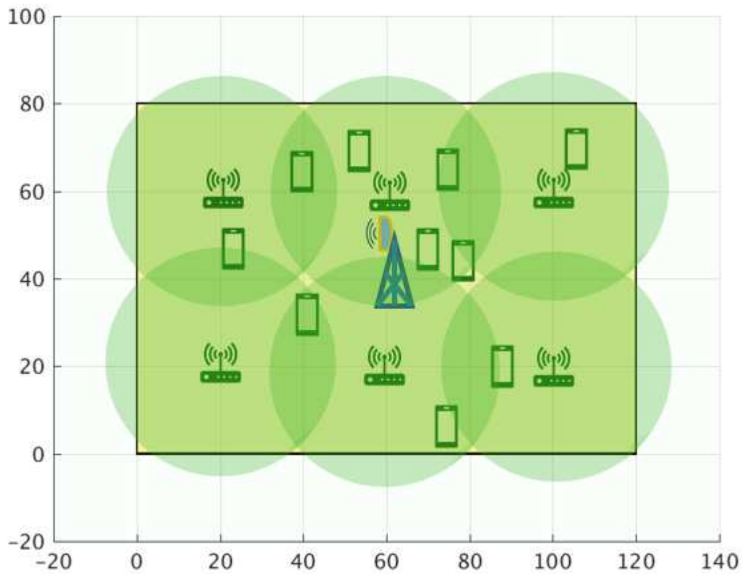
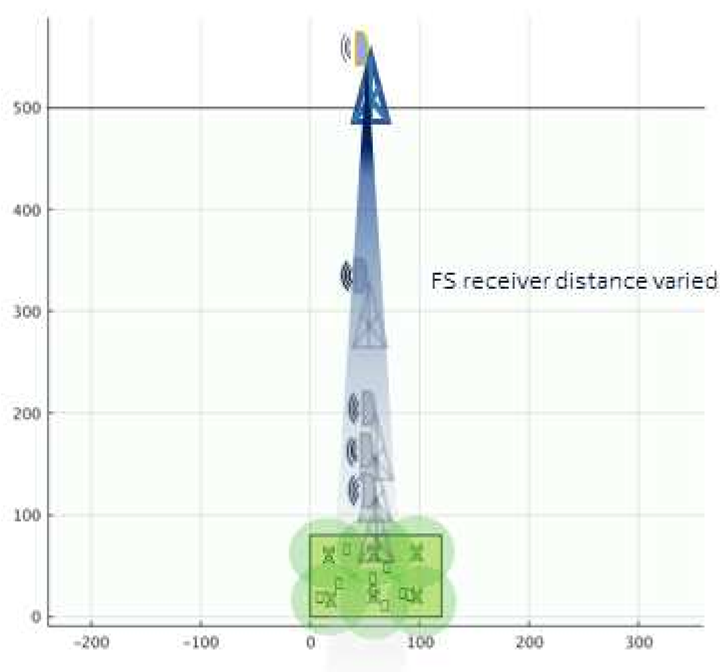


Figure 2: FS on rooftop of the same building with indoor U-NII devices (Scenario 2)

Scenario 3: The third deployment uses the same office building as the second deployment, but instead of the FS receiver being on the rooftop of the same building as the U-NII devices, it is moved horizontally away from the building (e.g. on the rooftop of the adjacent building), with the azimuth pointed towards the building where the FS receiver is. Again, only one floor of U-NII devices is modeled.



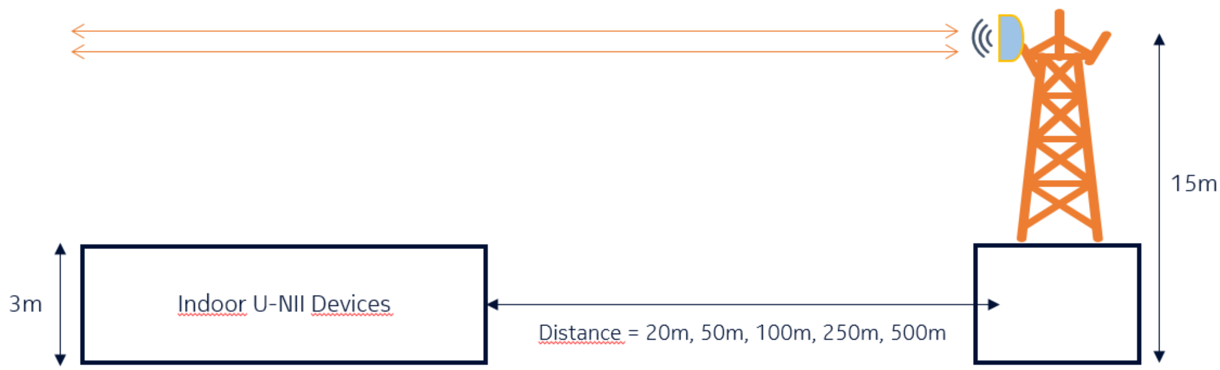


Figure 3: FS on rooftop of an adjacent building to the one which has indoor U-NII devices (Scenario 3)

In all scenarios, the U-NII devices form a network which is simulated using the dynamic system simulator, and the aggregate interference to the FS receiver is calculated. Both Co-Channel Interference (CCI) and Adjacent Channel Interference (ACI) cases are calculated.

2.3 Simulation parameters

Tables 1 to 3 list the relevant parameters for U-NII and FS devices as well as for the simulated scenarios.

Table 1: Simulation parameters for U-NII devices

Parameter	Value
U-NII channel bandwidth	20 MHz
U-NII device transmit output power (conducted)	Outdoor access point: 30 dBm Indoor access point: 24 dBm Client device: 18 dBm
U-NII antenna pattern	Outdoor access point: 6 dBi max gain, 120 degree sectors, Indoor access point: 0 dBi isotropic Client device: 0 dBi isotrotpic
U-NII device emission mask	Emission mask according to [2]
U-NII device Adjacent Channel Leakage Ratio (ACLR) (Note 1)	Access point: 35 dB Client device: 30 dB
U-NII TDD configuration	Frame structure with 50% DL and 50% UL
U-NII device scheduling	Single user multiplexing in DL and UL
U-NII transmit power control	Not used; maximum output power used
U-NII receiver noise figure	Access point: 5 dB Client device: 9 dB
Note 1: The ACLR is based on 3GPP specification for unlicensed 5 GHz band operations and is stricter than the emission mask that was used.	

Table 2: Simulation parameters for FS receivers

Parameter	Value
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 Gain per angle relative to max. gain illustrated in Figure 4
FS adjacent channel selectivity	Not modeled (assumed better than 50 dB and TX ACLR dominates)
FS receiver noise figure	4 dB
FS receiver duty cycle	100% (FDD)

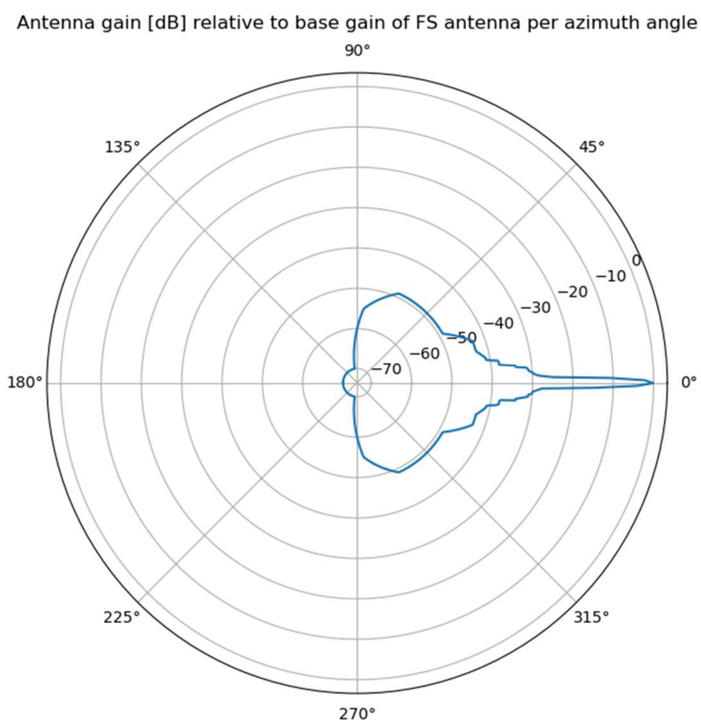


Figure 4: FS antenna gain relative to maximum gain per azimuth angle

Table 3: Scenario parameters

Parameter	Value
Scenario 1: Outdoor based on Urban Micro	
U-NII network topology	Hexagonal grid, 7 sites with 3 cells per site (ISD = 100m)
U-NII access point height	10 m
U-NII client device location	5 UEs per cell a) 20% outdoor, 80% indoor b) 100% outdoor Uniformly distributed
U-NII traffic model	Full buffer

FS receiver location	Uniformly distributed
FS receiver height	Uniformly distributed between 15 m and 115 m
Carrier frequency	6 GHz
Propagation model	3GPP TR 38.901 UMi LOS and NLOS
Wall penetration loss	3GPP TR 38.901 13.4 dB for low-loss model (50% probability) 30.7 dB for high-loss model (50% probability)
Scenario 2: Rooftop FS on the same building	
U-NII network topology	Indoor office model, 120x80 m, 6 access points
U-NII access point height	3 m (ceiling mounted)
U-NII client device location	30 UEs 100% indoor Uniformly distributed
U-NII traffic model	Full buffer
FS receiver location	Rooftop, middle of the building
FS receiver height	Different mast heights between 2 m and 20 m (in addition to the rooftop at 3 m)
Carrier frequency	6 GHz
Propagation model	Combined 3GPP TR 38.900 UMa/InH propagation models NLOS
Roof penetration loss	3GPP TR 38.901 13.4 dB for low-loss model (50% probability) 30.7 dB for high-loss model (50% probability)
Scenario 3: Rooftop FS on the adjacent building	
U-NII network topology	Indoor office model, 120x80 m, 6 access points
U-NII access point height	3 m (ceiling mounted)
U-NII client device location	30 UEs 100% indoor Uniformly distributed
U-NII traffic model	Full buffer
FS receiver location	Adjacent to the building, horizontal distance between 20 m and 500 m
FS receiver height	15 m
Carrier frequency	6 GHz
Propagation model	Combined 3GPP TR 38.900 UMa/InH propagation models NLOS
Wall penetration loss	3GPP TR 38.901 13.4 dB for low-loss model (50% probability) 30.7 dB for high-loss model (50% probability)

3 Initial simulation results

3.1 General

The results as documented are from initial simulations which used the parameters listed in Tables 1 to 3.

3.2 Scenario 1: Outdoor based on Urban Micro

The results for this scenario are presented in Figure 4. The figure shows a cumulative distribution function of the aggregate interference to noise ratio (I/N) at the FS receiver node.

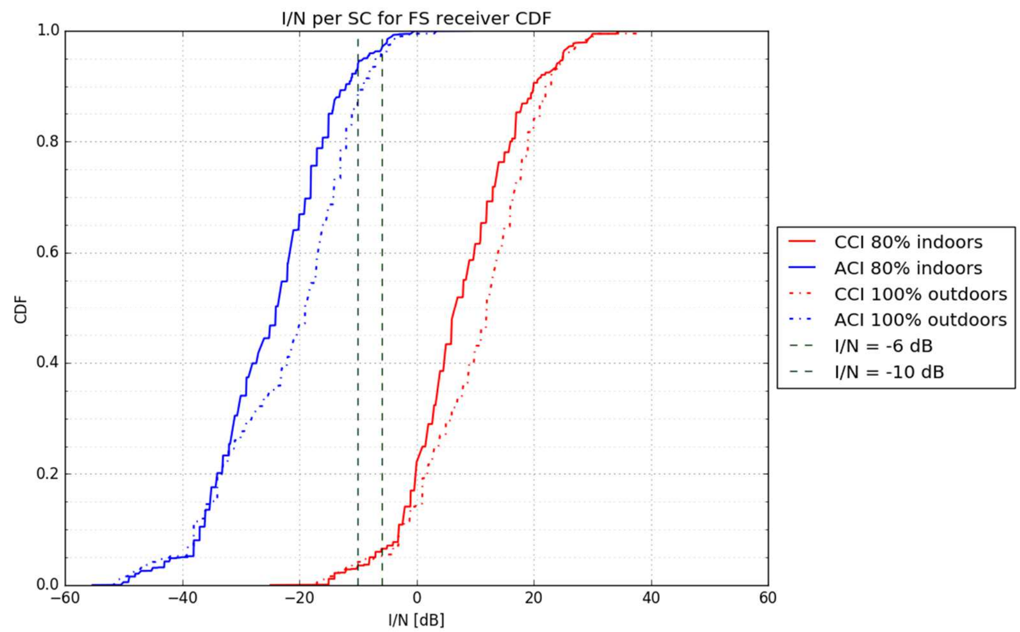


Figure 5: FS receiver I/N probability in scenario 1

The results indicate that for co-channel U-NII outdoor deployment when 80% of the users are located indoors, the I/N levels are above -6 dB in approximately 94% of the simulated cases, with 50% probability of approximately 6 dB. If all users are located outdoors, the -6dB limit is exceeded 95% of the time and the median is at approximately 12dB. This level of interference is certainly not tolerable for the fixed service, indicating that the AFC (Automatic Frequency Coordination) system is required to avoid co-channel use of U-NII outdoor devices.

For adjacent channel interference, I/N exceeds -10 dB in about 5% and -6 dB in about 3% of the cases with 80% of the users indoors. The respective percentages for cases with all of the users outdoor are 11% and 4%. These results suggest than under the scenarios considered, adjacent channel interference should be acceptable. It should however be noted that the ACLR used in simulation is somewhat better than the spectrum mask in [2], which is typical behaviour for real devices. With ACLR derived exactly according to the spectrum mask in [2], higher interference to FS is likely to occur.

3.3 Scenario 2: FS on the rooftop of building with indoor U-NII devices

The results for this scenario are presented in Figure 5. The figure shows a CDF of the aggregate I/N at the FS receiver node.

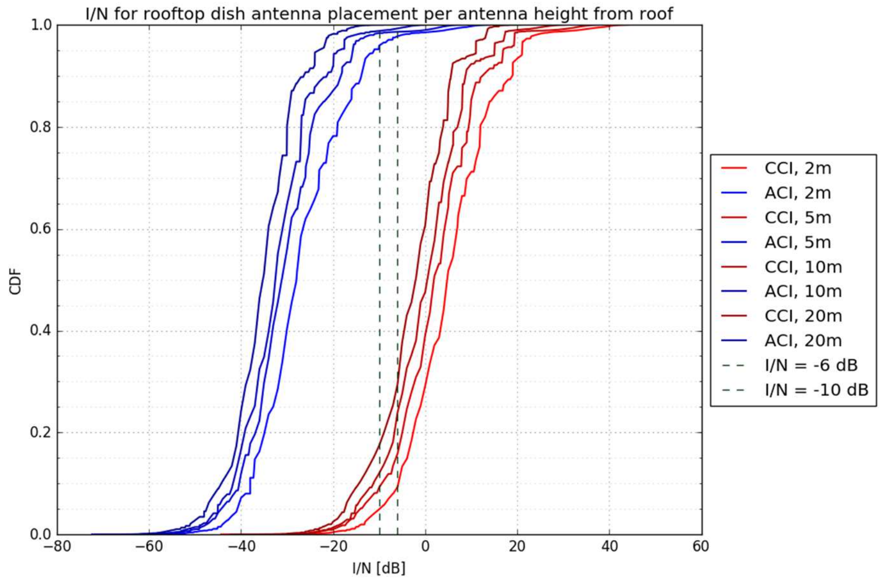


Figure 6: FS receiver I/N probability in scenario 2

According to the results, co-channel interference can be very challenging, with majority of cases of I/N exceeding -6 dB. The mast height on top of the roof has some effect, but even at 20 meters the results do not look encouraging.

The adjacent channel I/N is in vast majority of cases below -6 dB, indicating possible U-NII compatibility.

The results for the rooftop scenario are mostly impacted by the roof penetrating loss. In the initial simulations, the same model as for wall penetration loss was used. This may provide too small loss values e.g. for metal roof materials. Another significant contributor is the dish antenna radiation pattern at large offset from the main beam. The antenna pattern also impacts the results obtained.

3.4 Scenario 3: FS on rooftop of the building adjacent to the one with indoor U-NII devices

The results for this scenario are presented in Figure 6. The figure shows a CDF of the aggregate I/N at the FS receiver node.

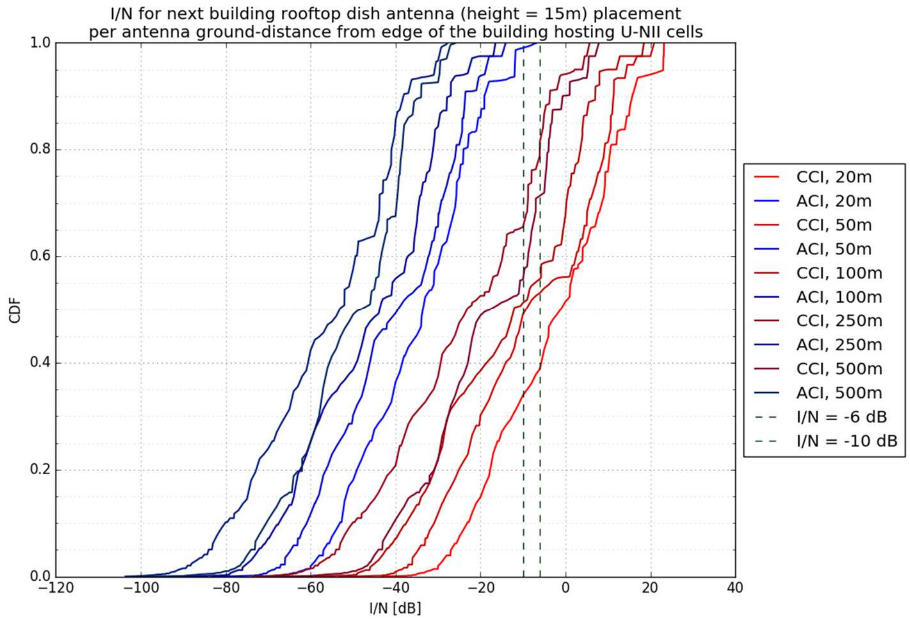


Figure 7: FS receiver I/N probability in scenario 3

Again, in this scenario, the co-channel case looks challenging, with about 30% to 60% of the cases exceeding I/N of -6 dB. In adjacent channel cases, the -6 dB I/N is not exceeded, even if the FS receiver is very close to the building with U-NII deployment.

The two main contributors to this scenario are the wall penetration losses, and the FS beam width and radiation pattern at relatively small offset from the main beam. The FS mast height could also be increased to improve the compatibility.

4 Conclusion

The results show that co-channel interference can be an issue for the case of outdoor U-NII devices but also for indoor cases.

- For the sub-bands most heavily used by fixed links, i.e., 5.925-6.425 GHz (U-NII-5) and 6.525-6.875 GHz (U-NII-7), the Commission should indeed allow indoor and outdoor access point operations under the control of an Automated Frequency Coordination (AFC) system to mitigate potential interference from the U-NII devices to the fixed links. In particular, the AFC system should avoid any co-channel operation of U-NII devices with the fixed links in situations where interference could occur as depicted in this study.
- For the 6.425-6.525 GHz (U-NII-6) and 6.875-7.125 GHz (U-NII-8) sub-bands which have no or very limited number of fixed links but have mobile services such as the Broadcast Auxiliary Service and Cable Television Relay Service, restricting the U-NII devices to indoor low power use without an AFC system is acceptable. However, it is worth studying if high power operation in U-NII-6 and U-NII-8 is also feasible via an AFC system without interfering with these mobile systems.

In addition, for the scenarios studied, the fixed links operating on adjacent channels to U-NII devices do not seem to require an AFC system or any other measure for protection. The standard Adjacent Channel Leakage Ratio specification of U-NII devices seemed to be enough to not cause harmful interference to the fixed links on adjacent channels in the considered scenarios. However, there could be other scenarios where adjacent channel interference is also an issue and this issue warrants careful consideration.

Based on these initial simulations, we recommend that the Commission consider the use of an AFC system for both outdoor and indoor U-NII devices in 5.925-6.425 GHz (U-NII-5) and 6.525-6.875 GHz (U-NII-7) to protect the fixed links in these two sub-bands and further study if an AFC system could also allow outdoor high power U-NII devices in 6.425-6.525 GHz (U-NII-6) and 6.875-7.125 GHz (U-NII-8). If an AFC system is not viable because of the itinerant nature of the incumbent mobile systems in U-NII-6 and U-NII-8, the U-NII devices could be restricted in these two sub-bands to indoor low power operation without an AFC system.

5 References

[1] Unlicensed Use of the 6 GHz Band, Notice of Proposed Rulemaking, GN docket No. 18-295, et al., FCC 18-147 (rel. Oct. 24, 2018) (“NPRM”).

[2] Recommendation ITU-R M.1450-4 (04/2010), Characteristics of broadband radio local area networks

[3] 3GPP TR 38.901, Study on channel model for frequencies from 0.5 to 100 GHz (Release 15)