NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

6 GHz Microwave Link Interference Preparedness

NERC 6 GHz Task Force

November 2023

RELIABILITY | RESILIENCE | SECURITY




3353 Peachtree Road NE
Suite 600, North Tower
Atlanta, GA 30326
404-446-2560 | www.nerc.com

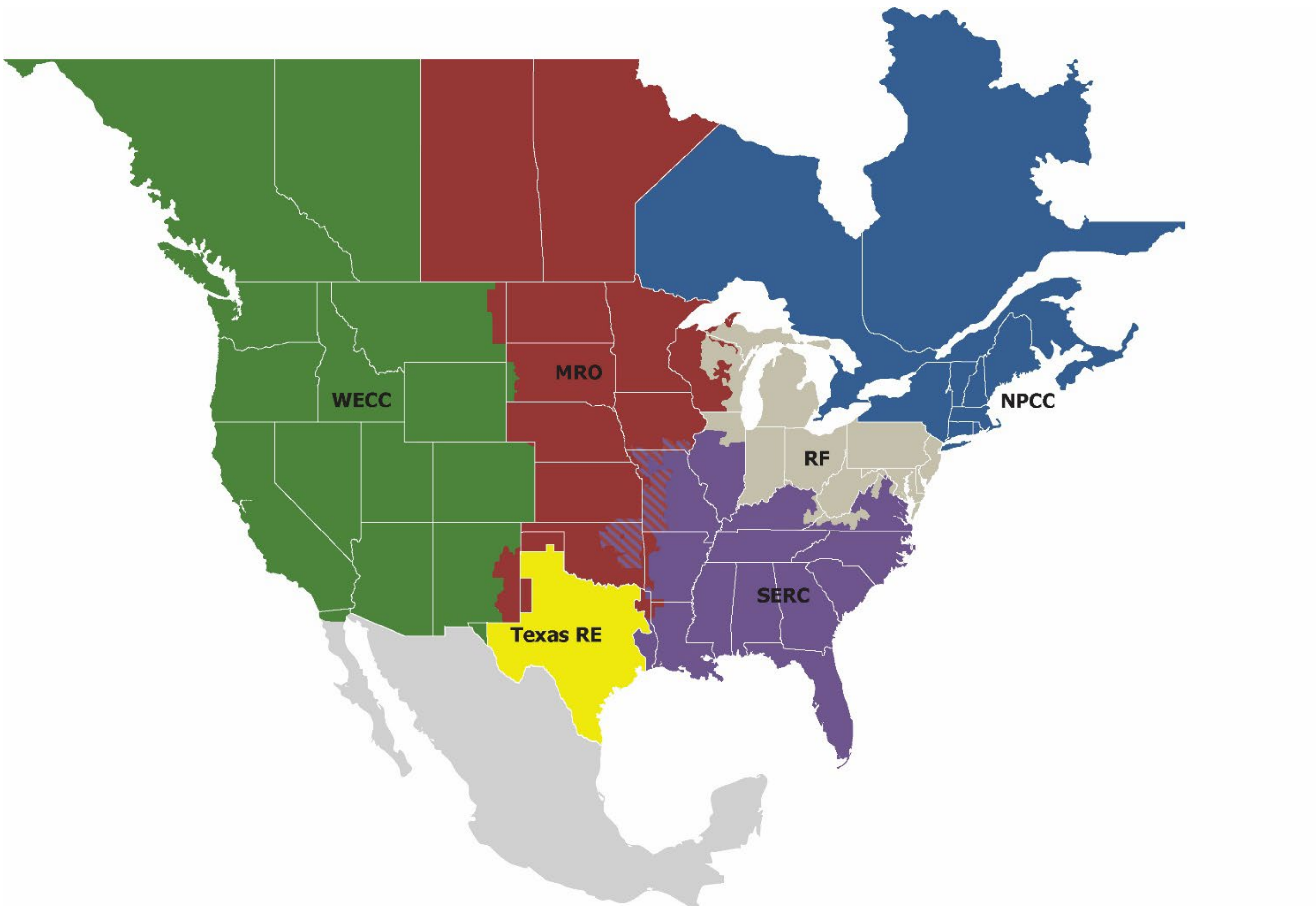
Table of Contents

Preface

Electricity is a key component of the fabric of modern society and the Electric Reliability Organization (ERO) Enterprise serves to strengthen that fabric. The vision for the ERO Enterprise, which is comprised of NERC and the six Regional Entities, is a highly reliable, resilient, and secure North American bulk power system (BPS). Our mission is to assure the effective and efficient reduction of risks to the reliability and security of the grid.

Reliability | Resilience | Security
Because nearly 400 million citizens in North America are counting on us

The North American BPS is made up of six Regional Entities as shown on the map and in the corresponding table below. The multicolored area denotes overlap as some load-serving entities participate in one Regional Entity while associated Transmission Owners/Operators participate in another.



MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst
SERC	SERC Reliability Corporation
Texas RE	Texas Reliability Entity
WECC	WECC

Executive Summary

In April 2020, the Federal Communications Commission (FCC) opened usage of the 6 GHz spectrum[1] to new users to promote spectrum sharing. The report and order (R&O) issued in April 2020 represented a partial opening of the 6 GHz band of radio spectrum to unlicensed users. Sharing this spectrum will likely impact the energy industry—specifically critical infrastructure—and the reliable operation of the BPS. At the same time, it also published a further notice of proposed rulemaking (FNPRM) that would represent additional spectrum sharing that could increase the possibility for potential harmful interference. The original FCC R&O published in April 2020 became effective on July 27, 2020.[2]

The industry and incumbent users continue to conduct testing on potential harmful interference for BPS communications. Numerous efforts are in progress to accomplish the following objectives:

- Establishing a baseline for observation and performance understanding.
- Developing the ability to identify harmful interference.
- Using reporting tools to share confirmed harmful interference.
- Creating a process to evaluate communication interference.
- Quantifying the reliable communication impact to BPS operations.
- Building industry awareness and readiness for spectrum sharing impacts.

With respect to the objectives above, the directives to industry that they consider the types of equipment, scenario evaluations, and remediation actions should be generic enough to allow each company to assess and correct appropriately. When these interference issues occur or increase in occurrence, there will be a quick solution set, and arguably scenarios where service degradation is experienced will not be easily identifiable to an unlicensed 6 GHz device.

In support of industry awareness and strengthening reliability, this whitepaper provides valuable background information on the current state of the FCC processes, current spectrum usage, and recommendations for the industry to assist with baseline understanding, the identification of potential harmful interference, and mitigation options to offset impacts from harmful interference.

The recommendations are summarized as follows:

- Identifying critical circuits for the individual utilities.
- Performing and recording baseline testing for communication links / critical circuits.
- Considering predictive events increasing likelihood for interference in communications.
- Monitoring design versus actual performance of communication links.

As spectrum sharing continues to increase across all bands, the electric industry will need to be proactive with solutions to ensure reliable communication networks are available to underpin grid operations. While the 6 GHz R&O has presented the current challenges and need for risk mitigation, with the national / international strategy committed to spectrum sharing it represents the harbinger for challenges to come highlighting the importance of coordination between critical infrastructure sectors and accommodation for the interdependencies.

[1] https://www.fcc.gov/document/fcc-opens-6-ghz-band-wi-fi-and-other-unlicensed-uses-0
[2] https://docs.fcc.gov/public/attachments/FCC-20-51A1_Rcd.pdf

Introduction

Background

Noting the explosive demand for unlicensed radio spectrums, primarily driven by Wi-Fi, the FCC embarked on a process to investigate the possible use of the 6 GHz band for unlicensed services.

The FCC regulates interstate and international communications by radio, television, wire, and satellite across the US. It is also responsible for implementing and enforcing communications law and regulations. When considering changes to regulations, the FCC employs a process known as “notice and comment” rulemaking. Under this process, the FCC first provides notice to the public about its intention to modify existing rules. Each of these notices is followed by a period of public comment where interested parties can submit feedback on the tentative proposals. This feedback is considered by the FCC before it issues its final rules on the subject.

As part of the process, the FCC can publish several different documents (like the FERC processes):

- **Notice of Inquiry (NOI):** This is an initial invitation to the public to allow the FCC to gather information on a broad subject. An NOI about the use of 6 GHz by unlicensed users was issued by the FCC in July 2017.[3]
- **Notice of Proposed Rulemaking (NPRM):** The NPRM contains more detail on the proposed changes to the Commission’s rules. It may follow an NOI. Each NPRM is followed by a period of at least 30 days where comments can be submitted to the FCC. The FCC issued its NPRM on unlicensed use of the 6 GHz band in October 2018.[4]
- **Future Notice of Proposed Rulemaking (FNPRM):** An FNPRM may be issued after review of comments on NPRM and provides an opportunity to comment further on a related or specific proposal.
- **R&O:** An R&O is issued after considering comments to a NPRM or FNPRM and specifies new rules, amends existing rules, or decides not to do so. After the approval of the R&O, the new or amended rules will become effective 30 days after publication in the federal register.

What the FCC Has Done Pertaining to the 6 GHz Band

In April 2020, the FCC issued an R&O that partially opened the radio spectrum 6 GHz band to unlicensed users. At the same time, it also published an FNPRM to solicit input on additional topics that were not part of the original NPRM. The 6 GHz NPRM generated significant interest from both proponents of unlicensed operations and representatives of incumbent services. Over 100 companies or organizations commented on the NPRM as part of the rulemaking process. During the subsequent post-rulemaking period, over 100 technical studies were submitted to the FCC to address specific issues, simulate performance impacts, investigate technical claims, etc. Submission of technical studies representing both the incumbent services and proponents of unlicensed operations continue even today. In addition, as previously mentioned, there is a pending FNPRM with the FCC to fully open the 6 GHz band to unlicensed use and cause additional harmful interference to proliferate through this radio spectrum band. The original FCC R&O published in April 2020 became effective on July 27, 2020, providing for unlicensed use of the 6 GHz band proposed mitigation efforts (Automated Frequency Coordination) to protect incumbent users of the band from interference.

Since 2020, there have been numerous filings from electric industry trade associations, new participant users and incumbent utilities filed into the FCC record about the impacts of proposed Wi-Fi operations on microwave links in the 6 GHz band. The 6 GHz band of the radio spectrum is widely used by a broad array of industries responsible for critical infrastructure, such as electric, natural gas and water utilities, railroads, and wireless carriers, and public safety and law enforcement officials. These groups rely on the 6 GHz band to operate their equipment, and this band is the main source of primary communications for voice and data and back-up communications in many cases during

[3] https://www.fcc.gov/document/fcc-opens-inquiry-new-opportunities-mid-band-spectrum
[4] https://docs.fcc.gov/public/attachments/DOC-354364A1.pdf

emergencies and disasters. The report identifies impacts on electric power operations. Additional follow-on work by the Electric Power Research Institute and various affected stakeholders have shown—through testing—impacts on their critical electric infrastructure communications due to increased congestion and interference on the 6 GHz wireless communication band. As adoption of the innovative technology increases, the risk to BPS operations will increase.

Prior to the FCC ruling, the 6 GHz licensees had exclusive use of the assigned frequency, so communication interference was not much of a concern as it could easily be identified due to licensing requirements.

Chapter 1: 6 GHz Networks

Identifying the 6 GHz Radio Spectrum

The 6 GHz spectrum is characterized as a band of radio frequencies (also referred to as bandwidth) that is allocated for use to industries and sectors for communications over the airwaves. Telecommunications work by broadcasting over these allocated airwaves. Use of spectrum has significant ability and potential to generate economic value and social benefit. Additional frequencies/new bandwidths, including both coverage and capacity bands, means mobile operators can connect more people and offer faster speeds. For this reason, pressure has increased on the FCC and international telecommunications regulators to release additional spectrums due to greatly increasing mobile usage. In this case, sharing an already-used spectrum from one industry to another is also an option.

However, not all spectrums are considered equal. Spectrum bands have distinctive characteristics that make them suitable for different purposes. In general, low-frequency transmissions can travel greater distances before losing their integrity and can pass through dense objects more easily. That said, less data can be transmitted over these radio waves. Higher-frequency transmissions carry more data but are poorer for penetrating obstacles.

Prior to the April 23, 2020, announcement from the FCC, the 6 GHz band was designated as an exclusive non-federal spectrum and licensed to several radio services. The 6 GHz bands were used primarily–but not exclusively–by the electric sector and first responders, now identified as the incumbent services or users. Fixed service and fixed-satellite service (FSS) operations are spread throughout most of the 6 GHz band (See **Figure 1.1**)[5]. Fixed service provides for reliable point-to-point microwave links. These links support a variety of services, such as public safety, management of electric grids, long-distance telephone service, and backhaul. FSS allows for Earth-to-space communication in all but the upper 150 MHz of the 6 GHz band. FSS uses these frequencies for content distribution, live news and sports events, cable television, and a backhaul of telephone and data traffic. See **Figure 1.1** as an example.

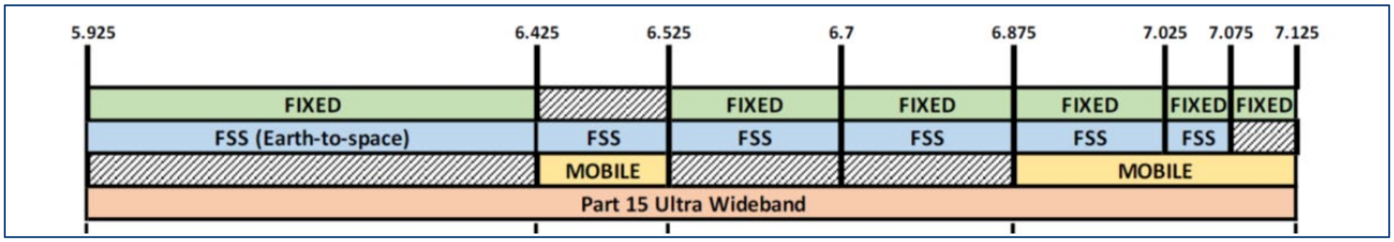


Figure 1.1: Incumbent Services in 6 GHz

Reasons to Use the 6 GHz Spectrum

Prior to the 2020 FCC Order, most Wi-Fi router activity likely transmitted on the 2.4 GHz or 5 GHz frequency. Anyone could use or broadcast on these two bands without much administration, interference, or impendence. However, as the bands increased in traffic, the speed or latency of data transfer increased as well. As an analogy, consider if every vehicle on a large interstate highway were routed in the same two lane; there would be obvious disruption, congestion, and interference. This spectrum works in the same manner.

To alleviate congestion and interference, the FCC looked to spectrum sharing with the FCC order to open 6 GHz. Ironically, 6 GHz does not transmit faster than 5 GHz, but it does add more channels and less overlap to alleviate the challenge of congestion and interference.

[5] https://www.5gtechnologyworld.com/new-regulations-for-unlicensed-6-ghz-operation-explained/

Spectrum Sharing

The National Institute for Standards and Technology has this to say about spectrum sharing[6]:

"Spectrum sharing is a way to optimize the use of the airwaves, or wireless communications channels, by enabling multiple categories of users to safely share the same frequency bands. Spectrum can be helpful sharing and is necessary because growing demand is crowding the airwaves. Smartphones, the Internet of Things (IOT), military and public safety radios, wearable devices, smart vehicles, and countless other devices all depend on the same wireless bands of the electromagnetic spectrum to share data, voice, and images."

Spectrum sharing to minimize latency and interference for unlicensed Wi-Fi with use of 6 GHz was the solution proposed with the April 2020 FCC R&O. As the shared spectrum would include incumbents (electric utilities, first responders, etc.) and new entrants (unlicensed Wi-Fi), the FCC proposed the creation of a new automated frequency coordination (AFC) function to mitigate harmful interference. AFC will be discussed in more detail later in **Chapter 2** of this white paper.

Electricity Subsector Usage

Grid telecommunications systems work to protect critical infrastructure. Many electric sector participants use 6 GHz for critical infrastructure communications and grid reliability. The FCC rulemaking(s) for unlicensed use raises substantive concerns over impact to mission-critical communications systems that are used to monitor and support the reliable delivery of electricity. Examples of this are as follows:

- Automatic Generation Control
- SCADA
- System Protection
- Voice over IP
- Two Way Radios
- Smart Grid Applications

These systems serve as the backbone to the electric grid and their impairment could undermine its reliability.

International Coordination and Regulation

To understand why spectrum sharing is a high priority and why the utilization of bandwidth is so controversial, it is important to understand some broader concepts around spectrum use. Spectrums are considered sovereign assets and are finite, meaning that use of the airwaves in each country is overseen by the government or the designated national regulatory authority that manages it and issues the needed licenses. For the United States, this is the FCC.

At the international level, the International Telecommunication Union and regional bodies are deeply involved in assigning spectrum bands for mobile use and are bound by international treaty[7]. National regulatory authorities are concerned with interference that could arise from incompatible spectrum use across borders, so they must negotiate with neighboring countries concerning spectrum use.

Nations need to migrate incumbent users, such as broadcasters or defense programs, out of bands in a practical, managed way or put in place a function to block the use of the shared bandwidth in the proximity of the incumbent users' facilities. Additionally, equipment manufacturers need to develop affordable devices that work seamlessly within new frequency bands. Each of these steps can take years to achieve before new spectrums can be licensed

[6] https://www.nist.gov/advanced-communications/spectrum-sharing
[7] https://en.wikipedia.org/wiki/International_Telecommunication_Union

and used for mobile services. The implications to the reliability and security of critical infrastructure must be a part of the equation as the United States and international peers consider allocation of spectrum use.

Chapter 2: Automated Frequency Coordination

The FCC R&O has supported the development of an AFC system to protect the incumbent license holder's microwave radios. The basic construct of AFC, although still in process of implementation, is that licensed user registration databases would validate new devices to confirm that there is no impact on licensed and/or registered users. AFC service providers will manage their AFC systems and processes.

The AFC provider will contain a database of existing 6 GHz operators, including geolocation, frequencies, and power levels among other pertinent information. The AFC database can be built from the existing FCC database in which users are required to register their transmitters. This is where the FCC's existing systems come in. It is important to note that most unlicensed devices are low-power indoor Wi-Fi routers that do not require AFC under the FCC R&O.

The FCC Universal Licensing System (ULS) database[8] will provide the key data needed for the AFC system to function. Currently, the ULS database struggles with accuracy due to incorrect location data. Each utility should verify that all the 6 GHz licenses have the correct information, especially location data.

NOTE: To correct any discrepancies, contact a certified Frequency Coordinator to facilitate any changes.

Figure 3.1-Figure 3.4 demonstrate the ULS process and how to execute reviews of the data as well as verification needs.

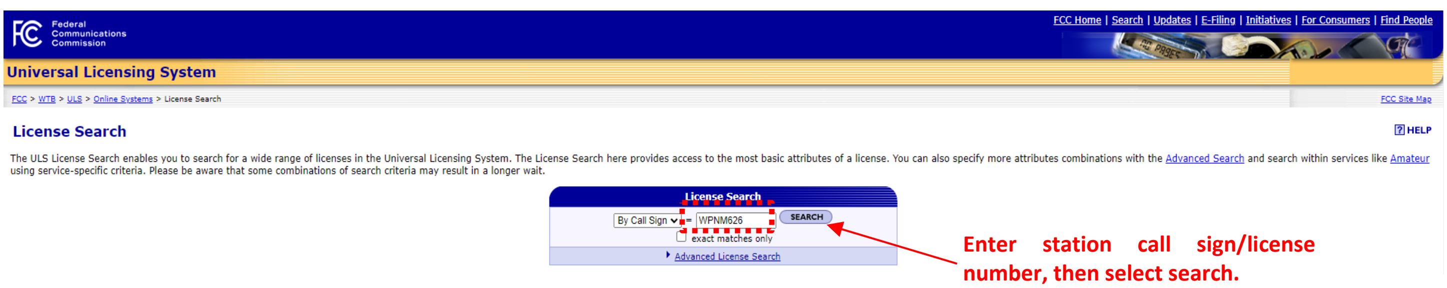


Figure 3.1: Step 1—License Search

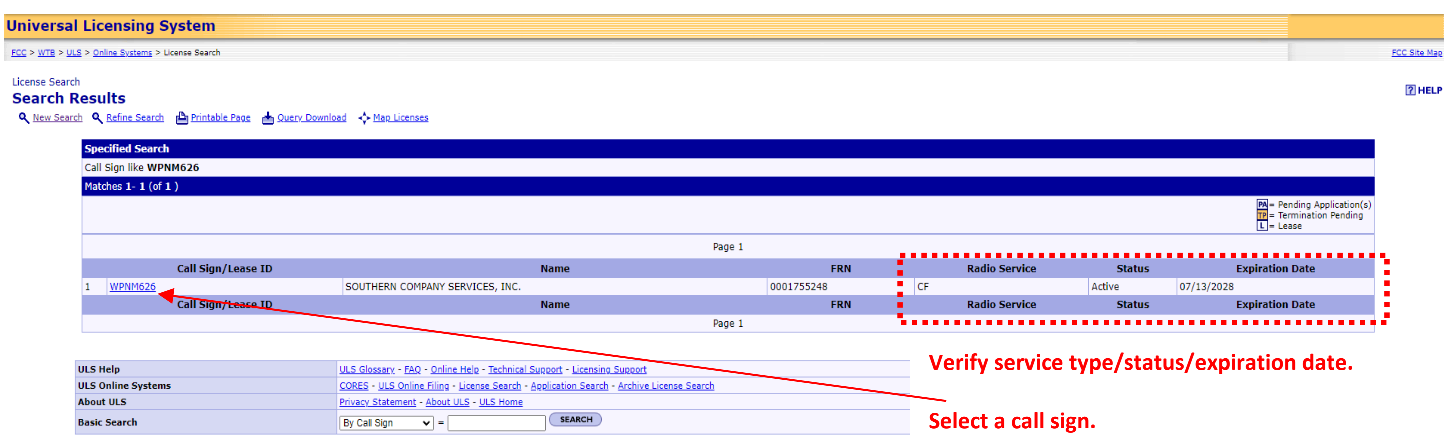


Figure 3.2: Step 2—Select Call Sign and Verify Service Type

8 https://wireless2.fcc.gov/UlsApp/UlsSearch/searchLicense.jsp

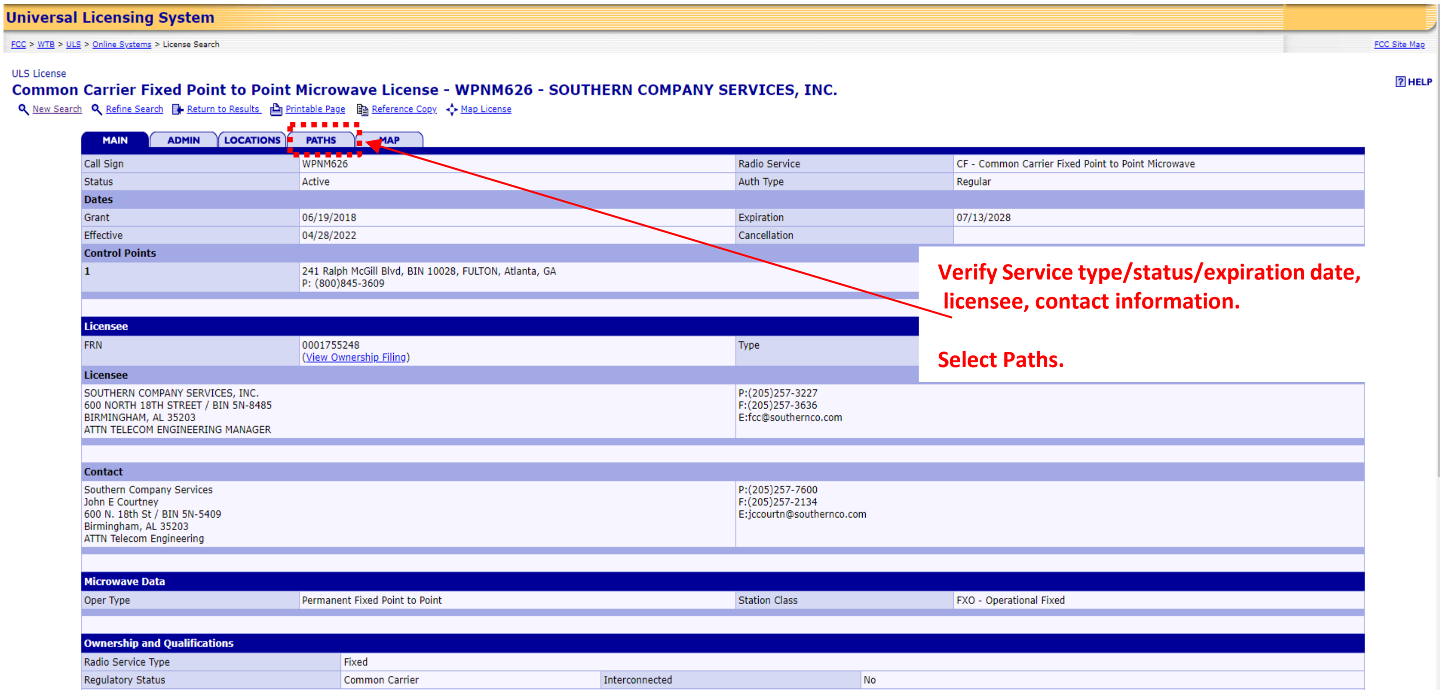


Figure 3.3: Step 3—Verify Licensee and Contact Information

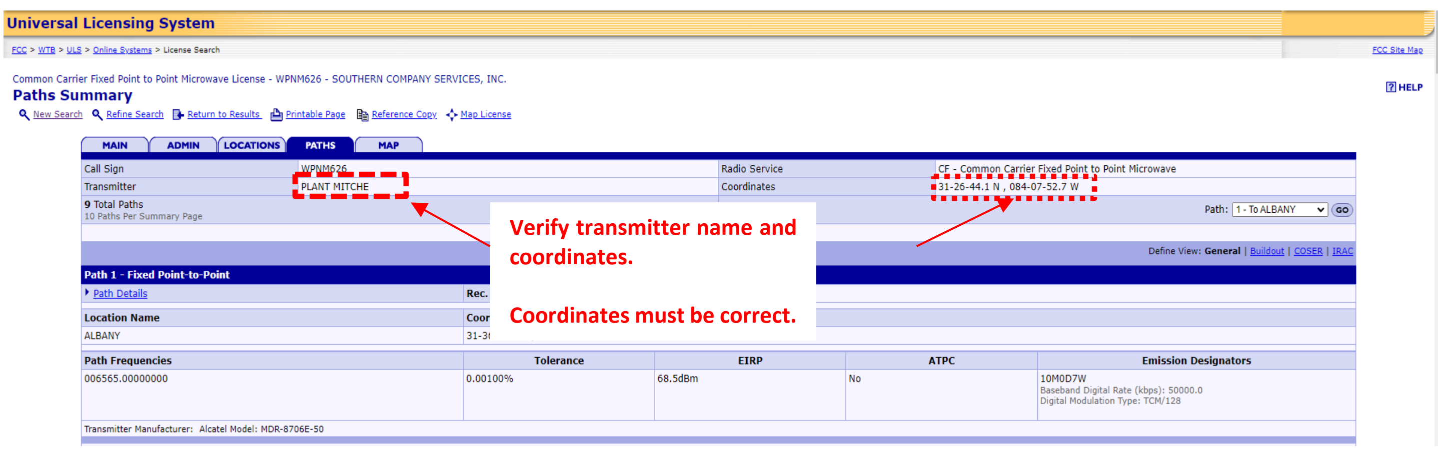


Figure 3.4: Step 4—Verify Transmitter Name and Coordinates

Chapter 3: Harmful Interference Identification

Importance of a Baseline

Monitoring spectrum performance is the foundation upon which evaluation and impact assessments are based and is critical for ensuring the integrity of operations to preserve BPS reliability. The most critical element of this monitoring, especially for impact assessments, is the establishment of baselines against which changes can be measured. As a model that can be easily replicated to perform this baseline establishment, the industry currently performs baseline definition and monitoring for many existing Reliability Standards (e.g., change management, patching). Baselines are a set of factors or indicators that are used to describe the current state of communication networks (or the aggregated use of spectrum in support of BPS communications). The collected data and definition of the baseline function acts as a reference point against which progress can be assessed or comparisons made. In the instance of the 6 GHz spectrum and users, the baseline data will be critical to ensure the ability to identify and assess potential harmful interference.

Reliability Implications

As the electric industry is still studying the implications of spectrum sharing broadly as well as the ability for AFC to effectively help mitigate the risk of frequency disturbance, BPS owners and operators must be aware of potential interference and have tools to respond to mitigate communications disruption and reporting channels so they can alert fellow owners and operators of the reliability implications of experienced harmful interference. Assessing spectrum baseline performance is key to each owner and operator’s ability to identify and remedy harmful interference to reliability communications in 6 GHz or any frequency where this could apply prospectively.

When interference issues arise, it can take significant effort to pinpoint the cause and negotiate with the unlicensed interferer to implement a solution to mitigate the issue (or turn off their transmission). In the case of additive interference from multiple sources that dynamically change their frequencies, mitigating interference will be impossible.

Noise Floor

“Noise” refers to any signal other than the one being monitored. At the most general level, the noise floor is the measure of the signal created from the sum of all unwanted signals in the frequency or channel of communication. Consider people speaking in a restaurant as an analogy. Two people sitting at the same table in a restaurant when no other parties are present can communicate easily across the table. As the restaurant starts to fill up with other parties, the noise level of the restaurant increases, and these two people may have difficulty hearing each other; this is the noise floor increasing. This same concept applies to the communication links that are sending signals for protection systems, supervisory control, and data acquisition, etc. and recognize that it is critical to reliable operations that those communications are not disrupted. The ability for owners and operators to ensure communications without disruption of reliability signals and to identify when harmful interference is occurring becomes paramount to BPS reliability.

Fade Margin

The fade margin is the amount a received signal level can be reduced without causing communication issues. The introduction of even minor interference creates a reduction to the baseline fade margin, directly impacting reliability. Reliability is a paramount construct to serving critical infrastructure. Historically, communications infrastructure has been expected to service the “Five 9’s of Reliability,” meaning that communications should function 99.999% of the time. The noise floor can lower the buffer or value of the margins built in to accommodate interference, impacting effective and reliable communications.

When it comes to the communication links, the fade margin essentially provides a design allowance that affords for sufficient headroom or a sensitivity to accommodate expected signal fading for the purpose of ensuring that the required quality of service is maintained. The introduction of even minor interference creates a reduction to the baseline fade margin, directly impacting path reliability. To reiterate, like the noise floor concept, the ability for owners and operators to ensure communications without disruption to reliability signals as well as identify when harmful interference is occurring becomes paramount to reliability of the BPS.

Chapter 4: Recommendations

Recommendations for industry preparedness are outlined below:

- Entities should identify and record critical circuits (individual company view) and be cognizant of the origination and destination of each circuit. If the circuit(s) traverse multiple microwave hops or links, there will be multiple points of possible interference (see **Figure 5.1**).

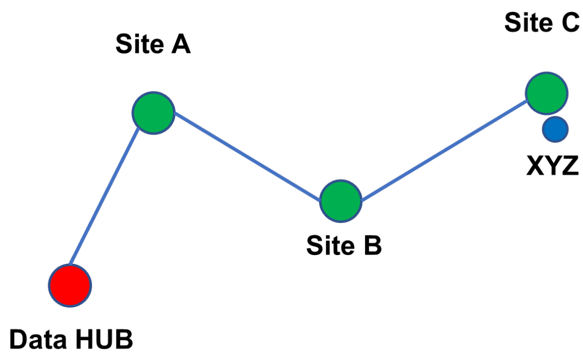


Figure 5.1: Example of Microwave Links and Possible Interference Points

- Each utility should perform baseline performance tests on all their microwave radios and record. Test results will prove invaluable when assessing problems and suspecting interference issues. Utilities should perform the following actions:
  - Verify that radio configuration parameters are set to deliver payloads as expected (e.g., modulation, adaptive modulation, ATPC, QOS, matching OS software revisions).
  - Verify that transmitter power is within specified limits of licensed Effective Isotropic Radiated Power (EIRP).
  - Verify that the receiving signal level is within specified limits of path design.
  - Record errors accumulated over a specified period with the radio network management system (24 hours, 48 hours, 72 hours, etc.).
  - Select or configure a test circuit to perform various payload tests over a specified period.
  - Verify the link's fade margin.

    This is an "out-of-service" test that requires the reduction of "far-end" transmitter power and then measuring the receiver threshold on the "near-end." The entity should correct any issues found for each circuit periodically. There are tools that will do this automatically in the background (e.g., FAS Interference Monitoring, Aviat Networks).[9]
- Consider predictive events on critical circuits for planning and proactive mitigation options where possible (concert venues, sporting events, etc.).
- Monitor mobile subscriber equipment.
- Continued monitoring of design vs. actual performance

[9] https://aviatnetworks.com/hosted-software/interference-monitoring-fas/

Chapter 5: Risk Mitigation

Interference Remediation

There are many factors to consider as companies take steps to mitigate interference that from spectrum sharing. These steps must be considered to protect the communication that BPS reliability depends on. Currently, supply chain challenges, the availability of commercially available devices to be used in the 6 GHz band, and the timeline and cost to mitigate potential impacts of interference to existing spectrum use represent substantive concerns for the electricity subsector companies that rely on the 6 GHz band for reliable communications. There may be limitations to any solution, so companies should analyze all options before selecting mitigation actions. The following are several options for remediation steps.

Private Long-Term Evolution (LTE)

A private LTE refers to a mobile network that is a public network that allows a company to provide priority access or licensing for its wireless spectrum. This can be beneficial when deploying private wireless networks at facilities where coverage, speed, and security capabilities are needed beyond those offered by Wi-Fi and other network technologies. A private LTE can offer the private operator greater control to access and isolation (if desired) with lower latency and higher connectivity throughput.

Additional 6 GHz Investment

Redundancy has long been a key tenet of grid operations and can apply to using radio spectrum bands. Building additional access points in the same 6 GHz band with different channels or frequencies could provide options to reduce harmful interference. This option may represent a riskier approach to mitigation given the penetration in the 6 GHz band will eventually be so dense that reliance on its use in any way deem it unreliable. However, redundant use of the 6 GHz spectrum may offer a delay in the interference and accommodate more time to build out longer-term solutions.

Different Microwave Band Use

Moving communications to a different frequency or band is a consideration but is complex and expensive to implement. Spectrum bands are not equitable in properties of use, so all bands will not represent practical and reliable options for the communications that underpin the BPS. Long-distance communications are necessary, and access to remote areas can complicate them. Furthermore, it is important to recognize that there are distance limitations with higher frequencies, eliminating the ability to upgrade many paths based on this principle. Additionally, Today, there may be options that represent a solution for the near term or long term. However, as spectrum sharing remains a key strategic priority for the FCC, moving to a new band does not fundamentally reduce the risk of interference to critical infrastructure spectrum use; it merely relocates it.

Fiber

Using a fiber network may be a good solution when high bandwidth, long distance, or immunity to electromagnetic interference is required. This type of communication can transmit data through local area networks or across long distances. Infrastructure development within cities can be difficult and time-consuming, and fiber-optic systems can be complex and expensive to install and operate. Supply chain challenges are reducing the viability of fiber optics as a near-term solution. In addition, the cost multiplier of fiber use is another reason that this mitigation option is less practical in the near-term solution set.

Chapter 6: Conclusion

As spectrum sharing continues to increase across all bands, the electric industry will need to be proactive with solutions to ensure reliable communication networks are available to underpin grid operations. Effective operation of the BPS relies on these critical networks, systems, and tools. The emergence of the issues related to the 6 GHz FCC R&O are simply indicative of the spectrum sharing challenges to come serving as a harbinger of the importance of critical infrastructure dependency requiring coordination of efforts. The evolving grid, electrification demands, and emerging technologies will tax the BPS and require more communication through the spectrum bands. Consequently, the behavior of all resources—including communication networks—must be understood and protected to support reliable operations. This often-overlooked aspect of grid operations and planning is vital to and a foundational activity for maintaining BPS reliability and resiliency.