Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of Shortwave Modernization Coalition Petition for Rulemaking to Amend the Commission's Rules to Allow Fixed, Long-Distance, Non-Voice Communications Above 2 MHz and Below 25 MHz	)	RM- ______________________________

PETITION FOR RULEMAKING OF THE SHORTWAVE MODERNIZATION COALITION

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Pursuant to Section 1.401 of the Commission's Rules,[1] the Shortwave Modernization Coalition ("SMC")[2] hereby petitions the Federal Communications Commission ("Commission") to initiate a rulemaking to amend its eligibility and technical rules for licensees in the Industrial/Business Pool to authorize licensed use of frequencies above 2 MHz and below 25 MHz (the "2-25 MHz Band") for fixed, long-distance, non-voice communications.

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[1] 47 C.F.R. § 1.401.

[2] The SMC comprises the following entities: DRW Holdings, LLC, a related entity to experimental licensee Skycast Services LLC; IMC Trading, an affiliate of experimental licensees Toggle Communications LLC and RCA Telecom LLC; Jump Trading Group ("Jump"); Virtu Financial Inc. ("Virtu"); NLN Holdings LLC, a joint venture of Jump and Virtu, and the indirect parent of experimental licensee 10Band LLC; Optiver Services B.V., an affiliated company of experimental licensee County Information Services, LLC; and Tower Research Capital LLC, the parent of experimental licensees m-Wave Networks LLC, Rockland Wireless LLC, and Alpha Bravo Communications, LLC.

INTRODUCTION AND SUMMARY.

Through extensive independent research and technological experimentation over the past several years, the SMC members – firms that, among other activities, serve as market makers and liquidity providers for exchange-traded financial instruments – have confirmed that frequencies in the under-licensed 2-25 MHz Band are the optimal medium for fixed, long-distance transmission of time-sensitive data. The SMC members also have concluded as a result of these activities that it is technologically feasible for their proposed Part 90 2-25 MHz Band operations to coexist with other 2-25 MHz Band licensees and with each other. The technical study detailed in the Coexistence Report submitted herewith supports this conclusion.[3]

The SMC members respectfully request that the Commission promptly initiate a rulemaking to modernize the Part 90 Rules for 2-25 MHz Band licensees in the Industrial/Business Pool to enable commercial licensed use of the 2-25 MHz Band for fixed, long-distance, non-voice communications, as set forth in this Petition.[4] Through their experimental use of 2-25 MHz Band frequencies, the SMC members have developed and refined technologies to, among other things, enhance spectrum sharing in the band without materially increasing the risk of harmful interference to other authorized 2-25 MHz Band users. Enabling use of 2-25 MHz Band frequencies as proposed herein would allow 2-25 MHz Band licensees to rely on these and other innovations that would increase efficient utilization of 2-25 MHz Band spectrum. In making this request, the SMC members acknowledge that the proposed licensed

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[3] Study on 2-25 MHz Band Coexistence, Prepared by Chris Helzer, Chief Engineer, Quadra Partners, LLC (Apr. 28, 2023) ("Coexistence Report") (attached hereto).

[4] "Part 90 Rules" refers herein to those rules under 47 C.F.R. Part 90 that apply to 2-25 MHz Band frequencies, and the corresponding Part 2 Rules, in particular, Sections 2.102 and 2.106. 47 C.F.R. §§ 2.102, 2.106.

use of the 2-25 MHz Band would be non-exclusive, as is the case under the current Part 90 Rules for 2-25 MHz Band licensees in the Industrial/Business Pool.[5] The SMC members do not seek to amend parts of the Commission's Rules that pertain exclusively to, nor do they plan to utilize spectrum allocated exclusively for, amateur, maritime, or aeronautical services. In addition, the proposed changes to the Part 90 Rules are focused on fixed rather than mobile communications wherever the Part 90 Rules make a distinction between the two.

Modernization of the Part 90 Rules to expand non-exclusive commercial licensed access to fixed, long-distance, non-voice communications is consistent with the Commission's duty to make efficient and effective use of spectrum and manifestly is in the public interest. If adopted, the proposed amendments would enhance market makers' ability to quickly access real-time financial data and to continue to act in a manner that provides liquidity and helps to improve asset prices, to the benefit of centralized markets and market participants. The proposed amendments also have the potential to spur additional innovations in the use of 2-25 MHz Band frequencies. The availability of 2-25 MHz Band frequencies for such use also would obviate the need for businesses that require the fixed, long-distance transmission of time-sensitive data to rely on fiber, microwave and millimeter wave wireless, and satellite systems, which are costly, not capable of achieving comparably short transmission delay, and can be less secure than 2-25 MHz Band transmission systems.

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[5] *See id.* § 90.173(a).

I. MODERNIZATION OF THE COMMISSION'S RULES WILL ENABLE EFFICIENT USE OF 2-25 MHZ BAND FREQUENCIES.

A. The 2-25 MHz Band Is the Ideal Medium for the Long-Distance Transmission of Time-Sensitive Data.

As is well known in the radio arts, 2-25 MHz Band transmissions can propagate over distances of thousands of miles. To enable long-distance 2-25 MHz Band communications, transmitters employ sky wave propagation, through which radio waves directed at the sky are refracted by the ionosphere and therefore can travel beyond the horizon and along the curve of the earth. Such propagation makes 2-25 MHz Band frequencies the superior medium for transmission of relatively low-bandwidth data over long distances with minimal delay as compared to other transmission technologies.

Only one transmit site and one receive site is required for 2-25 MHz Band transmissions over entire continents and oceans. In contrast, radio frequency transmissions via microwave and millimeter wave spectrum require multiple transmit and receive links to travel even relatively short distances. Because each hop introduces additional delay, and given other considerations, such as cost and the availability of suitable tower locations, microwave and millimeter wave spectrum offer less desirable solutions for time-sensitive transcontinental and other long-distance transmissions compared to 2-25 MHz Band transmissions. Because radio frequency signals travel faster in air than does light transmitted via fiber optic cable, use of the 2-25 MHz Band enables transmission with a shorter delay than fiber. Geostationary satellite communications are not a competitive alternative because signals must travel, at a minimum, to the geostationary arc (22,236 miles) and back. Moreover, nascent low-earth orbit satellite technology requires the use of ground-based gateway antennas and transmission hand-off among a network of numerous satellites before being transmitted back to another ground station, each step of which increases signal delay and cost. Given the limitations of these communications media, use of the 2-25

MHz Band is ideally suited to entities that seek to reduce delay in the transmission of time-sensitive, mission-critical data over long distances.

These characteristics also mean that 2-25 MHz Band communications systems can support enhanced physical security and entail lower cost to construct and maintain as compared to other long-distance transmission technologies. System architecture in the 2-25 MHz Band utilizes far fewer transmit and receive sites than do fiber, microwave and millimeter wave transmission technologies to cover similar distances, and it is less complicated to preserve the physical security of 2-25 MHz Band transmission systems because they offer hackers and other malign actors fewer points of potential attack. Further, long-distance data transmission via satellite systems and fiber frequently requires reliance on third-party facilities that are outside of the direct control of the transmitting party, whereas 2-25 MHz Band transmission systems readily can be owned and operated end-to-end by the transmitting party. Moreover, because 2-25 MHz Band transmission systems employ fewer transmit and receive sites and do not require launch into geosynchronous orbit, they are less costly to construct and maintain than satellite systems, fiber, and microwave and millimeter wave transmission systems.

The efficient use of 2-25 MHz Band frequencies is not without technical challenges. The approximately 11-year solar cycle causes variations in sunspot activity, resulting in changes to the levels of solar electromagnetic radiation that reach Earth. This, in turn, causes fluctuations in the altitude of the ionosphere at different times of day and from year-to-year. In addition, electromagnetic frequency noise in the 2-25 MHz Band is quite high as compared to other spectrum bands.[6] Maximizing efficient use of the 2-25 MHz Band therefore requires coexistence

[6] Coexistence Report at 1.

so that licensees have the ability to access multiple frequencies, and to choose among those frequencies to account for this variability.[7] As explained further below, the SMC members have used their experimental licenses to develop various technical solutions that enable switching among available 2-25 MHz Band frequencies to overcome these challenges and minimize the likelihood that 2-25 MHz Band transmission technologies will cause or experience harmful interference.

B. Sound Spectrum Policy Requires Modernization of the Part 90 Rules for the 2-25 MHz Band.

Despite the 2-25 MHz Band's promise of near real-time data transmission over long distances, and the public interest benefits that would accompany such use, 2-25 MHz Band frequencies are underutilized in the U.S. This is the case for at least two reasons. *First*, the Commission's Rules currently limit licensed use of 2-25 MHz Band frequencies to public safety, aeronautical, maritime, amateur, and certain narrowly specified Part 90 Industrial/Business Pool uses.[8] *Second*, the rules governing Part 90 Industrial/Business Pool use of 2-25 MHz Band frequencies include technical limitations that do not reflect the current state of 2-25 MHz Band innovation. Given these limitations on use of the 2-25 MHz Band, it comes as no surprise that the introduction of innovative 2-25 MHz Band technologies for private sector use has languished for decades. Indeed, the Commission's Universal Licensing System ("ULS") illustrates the extent to which the 2-25 MHz Band is under-licensed. Of the 21,507 active licenses in ULS for 2-25 MHz Band frequencies, only 61 are licensed for Industrial/Business Pool use pursuant to

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[7] As explained *infra* Section I.C, the Commission's Part 90 Rules for the 2-25 MHz Band require non-exclusive use, thereby facilitating coexistence.

[8] To the extent there is federal use of the 2-25 MHz Band, the techniques described herein also would protect those users.

Part 90.[9] In contrast, of the *215,980* total licenses in the 450 MHz Band (450-512 MHz), there are *163,624* active licenses for Part 90 Industrial/Business Pool use.[10]

The Part 90 Rules for the 2-25 MHz Band are ripe for modernization that reflects the significant advancements that the SMC members and their technology partners have made in the fixed, long-distance transmission of data with minimal delay via sky wave propagation. Amendments to the Part 90 Rules consistent with this Petition would advance the Commission's statutory mandate to maximize spectrum utilization where doing so is efficient and does not impair other Commission objectives.[11] As it has done on numerous occasions, the Commission should weigh the interests of government users, incumbent licensees, and innovators to ensure that Part 90 2-25 MHz Band frequencies are put to their "highest-value and most efficient use."[12]

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[9] *See* FCC Universal Licensing System, License Search, https://wireless2.fcc.gov/UlsApp/UlsSearch/searchLicense.jsp (last visited Apr. 26, 2023).

[10] *Id.*

[11] *See* 47 U.S.C. § 303(g) (the Commission must "[s]tudy new uses for radio, provide for experimental uses of frequencies, and generally encourage the larger and more effective use of radio in the public interest."); *see also Cellco P'ship v. FCC*, 700 F.3d 534, 542 (D.C. Cir. 2012) ("the Supreme Court has emphasized that [the Communication Act] . . . endow[s] the Commission with 'expansive powers' and a 'comprehensive mandate to encourage the larger and more effective use of radio in the public interest.'") (quotation omitted).

[12] *Expanding Flexible Use of the 12.2-12.7 GHz Band et al.*, Notice of Proposed Rulemaking, 36 FCC Rcd. 606, ¶ 1 (2021). *See, e.g.*, *Unlicensed Use of the 6 GHz Band Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz*, Report and Order and Further Notice of Proposed Rulemaking, 35 FCC Rcd. 3852, ¶¶ 1-5, 146 (2020) ("*6 GHz Order*") (adopting rules to facilitate unlicensed use of the band while ensuring the protection of licensed incumbent users from harmful interference); *Amendment of the Commission's Rules With Regard to Commercial Operations in the 3550-3650 MHz Band*, 30 FCC Rcd. 3959, ¶¶ 1-4, 55 (2015) (adopting rules to establish spectrum sharing arrangements to allow for commercial use of portions of the 3.5 GHz Band and recognizing that "[a]dvances in radio and computing technologies provide new tools to facilitate more intensive spectrum sharing," which would serve the public interest by encouraging innovation and spurring investment in the band).

Applying such a balancing of interests, the Commission should conclude that permitting expanded use of 2-25 MHz Band frequencies through more flexible Part 90 Rules will advance the public interest by facilitating more efficient operation of financial markets and encouraging the development of other innovative uses of the 2-25 MHz Band, and technologies to facilitate those uses, to the benefit of businesses and consumers.

C. Modernization of the Part 90 Rules for the 2-25 MHz Band Is Well Within the Commission's Discretion and Expertise.

As the arbiter of commercial spectrum policy, charged with "foster[ing] innovative methods of exploiting . . . spectrum,"[13] there is no doubt that the Commission possesses the authority and expertise to modernize its rules for the 2-25 MHz Band to reflect technological advances that enable efficient and non-interfering use of 2-25 MHz Band frequencies.[14] The D.C. Circuit has explained that "[t]o effectively assign frequency bands, the [Commission] 'must predict the effect and growth rate of technological newcomers on the spectrum, while striking a balance between protecting valuable existing uses and making room for . . . sweeping new technologies.'"[15] This is a highly technical task to which the Commission is uniquely suited. Where, as here, the Commission has both the discretion and the expertise to make technical and policy determinations regarding spectrum allocation and use, the Commission's predictive

[13] *AT&T Servs. v. FCC*, 21 F.4th 841, 846 (D.C. Cir. 2021) (quoting *Mobile Relay Assocs. v. FCC*, 457 F.3d 1, 8 (D.C. Cir. 2006) (quoting *Teledesic LLC v. FCC*, 275 F.3d 75, 84 (D.C. Cir. 2001))).

[14] *Id.* (citing *EarthLink, Inc. v. FCC*, 462 F.3d 1, 12 (D.C. Cir. 2006) ("[T]he Commission's 'predictive judgments about areas' within its 'discretion and expertise are entitled to particularly deferential review, as long as they are reasonable.'") (emphasis omitted) (quoting *In re Core Commc'ns, Inc.*, 455 F.3d 267, 282 (D.C. Cir. 2006))).

[15] *Intelligent Transp. Soc'y of Am. v. FCC*, 45 F.4th 406, 411 (D.C. Cir. 2022) (quoting *Teledesic LLC*, 275 F.3d at 84).

judgments are accorded heightened deference.[16] Thus, the Commission is well-equipped to craft rules to facilitate innovative uses of 2-25 MHz Band frequencies as requested in this Petition.

D. Modernization of the Commission's Part 90 Rules to Enable Efficient Use of 2-25 MHz Band Frequencies Would Be a Straightforward Undertaking and Is Consistent With Commission Precedent.

Together with the Coexistence Report, the SMC members' respective technological developments and the results of their respective experimental activities powerfully demonstrate that Commission action to facilitate the introduction of innovative 2-25 MHz Band communications technologies would be sound spectrum policy. With the amendments proposed here, the Part 90 Rules would provide the ideal regulatory framework for efficient use of 2-25 MHz Band frequencies. To begin with, the Part 90 Rules for licensees in the Industrial/Business Pool already contemplate non-exclusive use of 2-25 MHz Band frequencies and therefore are well-suited to the fixed, long-distance, non-voice communications that the SMC members envision.[17] The proposed amendments are relatively modest and would offer ample flexibility for innovative licensed commercial uses of 2-25 MHz Band Industrial/Business Pool frequencies, including those developed by the SMC members. Furthermore, the SMC members' proposed use case contemplates only private internal communications in support of their commercial activities, operations for which the Part 90 Industrial/Business Pool Rules are

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[16] *See supra* note 14.

[17] *See* 47 C.F.R. § 90.

intended.[18] Accordingly, this Petition does not seek amendment of Part 73, Subpart F of the Commission's Rules for International Broadcast Stations.[19]

The Commission's Rules confirm that modification of the Part 90 Rules for 2-25 MHz Band Industrial/Business Pool frequencies consistent with this Petition would not require international coordination. Section 2.102(h) of the Commission's Rules provides that, except in certain limited circumstances not relevant here,[20] (1) the Commission will not accept responsibility to protect licensed 2-25 MHz Band frequencies licensed under Part 90 from harmful interference caused by foreign operations if used to transmit data to points outside of the U.S.; (2) if the Commission receives a harmful interference complaint from any other nation, the Commission will instruct the offending licensee to cease operation on that frequency; and (3) to ensure that licensees can fulfill these requirements, their "equipment[] shall be capable of transmitting and receiving on any frequency in the bands assigned to the particular operation and capable of immediate change among the frequencies."[21] Section 2.102(h) reflects the conditions

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[18] *See id.* § 90.31 ("The Industrial/Business Radio Pool covers the licensing of the radio communications of entities engaged in commercial activities."); *id.* § 90.35(a) (making persons primarily engaged in "operation of a commercial activity," among other defined activities, eligible to hold authorizations in the Industrial/Business Pool). The SMC members do not seek to amend parts of the Commission's Rules that pertain exclusively to – nor do they plan to utilize spectrum allocated exclusively for – amateur, maritime, or aeronautical services. Amendments to the Part 90 Rules proposed herein are focused on fixed rather than mobile communications where the Part 90 Rules make a distinction between the two.

[19] *See id.* §§ 73.701-.788.

[20] *See id.* § 2.102(h)(3) (carving out transmissions originating from Alaska and the United States Pacific insular areas).

[21] *See id. See also Frequency Allocations and Radio Treaty Matters; General Rules and Regulations; Use of the High Frequency Radio Spectrum*, Report and Order, 87 FCC.2d 1035, ¶ 13 (1981).

under which the SMC members have operated in the 2-25 MHz Band on an experimental basis, and there is no reason to alter these requirements.

Modernization of the Part 90 Rules for 2-25 MHz Band Industrial/Business Pool frequencies would also be consistent with prior Commission action to permit novel licensed use of such frequencies under the Part 90 Industrial/Business Pool Rules where such use is unlikely to cause interference to existing authorized uses. Notably, in 1997 the Commission granted Flash Comm, Inc., later known as Terion, Inc., authority to construct and operate a system for "monitoring and telemetering purposes" using frequencies between 3 and 30 MHz pursuant to waivers of certain Part 2 and Part 90 Rules.[22] The Commission determined that the license would be renewed "only in accordance with final rules regularly permitting [the] operations" arising from Flash Comm's then-pending rulemaking petition.[23] In reaching this decision, the Commission observed that Flash Comm's operation pursuant to the waivers could "yield operational and technical data that could be useful to the Commission in its consideration of proposed rules for regular operations."[24] This precedent demonstrates that a rulemaking

[22] *Flash Comm, Inc. Request for Waiver of the Commission's Rules Regarding Its Application for Authorization in the High Frequency Band*, Order, 12 FCC Rcd. 9877 (1997) ("*Flash Comm Order*").

[23] *Flash Comm, Inc. Request for Waiver of the Commission's Rules Regarding Its Application for Authorization in the High Frequency Band*, Order, 12 FCC Rcd. 12029, ¶¶ 1, 3 (1997); *see also Flash Comm Order* ¶ 25 ("[W]e are granting a 5 year authorization to Flash Comm to construct and operate their system, conditioned on the outcome of any proceeding arising from Flash Comm's pending petition for rule making that establishes rules providing for regular authorization of this type of service.").

[24] *Flash Comm Order* ¶ 24. After the company announced plans to scale back its proposed Digital High Frequency System, the Commission declined to initiate the rulemaking, citing the uncertain future of Terion's system. *Terion, Inc. Application to Modify the Conditions of Its Authorization for Its Nationwide High Frequency Locating, Monitoring and Telemetering System, to Increase Overall System Capacity, and to Allow Application for Renewal Prior to Adoption of Final Rules Governing This Type of Operation*, Order, 17 FCC Rcd. 4382, ¶ 11 (2002). More than twenty-five years after the Commission's initial grant, a successor entity

proceeding to amend the Part 90 Rules for 2-25 MHz Band Industrial/Business Pool use is the Commission's preferred vehicle for enabling long-term licensed use of those frequencies to support a novel use case.[25] Moreover, the results of the SMC members' experimental use of 2-25 MHz Band frequencies, and the results of the technical study detailed in the Coexistence Report, are important sources of information that will assist the Commission in evaluating this Petition.

II. PART 90 RULES THAT PROMOTE EFFICIENT USE OF 2-25 MHZ BAND FREQUENCIES WILL FACILIATE INNOVATION WITHOUT CAUSING MATERIAL RISK OF HARMFUL INTERFERENCE.

Modernization of the Part 90 2-25 MHz Band Rules would promote "effective use of radio in the public interest" by making available a rigorously researched alternative communications technology for the long-distance transmission of time-sensitive data with minimal delay. In addition, based on the SMC member companies' experiences using 2-25 MHz Band frequencies under their respective experimental licenses, and as shown in the Coexistence Report, non-exclusive licensed use of 2-25 MHz Band frequencies for fixed, long-distance, non-

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continues to operate pursuant to the license and associated waivers. *See* HySky ULS File No. 0005210562.

[25] The Commission also has amended the Part 90 Rules to permit terrestrial trunked radio technology, which the Commission found to be a "spectrally efficient digital technology with the potential to provide valuable benefits to land mobile radio users, such as higher security and lower latency than comparable technologies." *Amendment of Part 90 of the Commission's Rules to Permit Terrestrial Trunked Radio (TETRA) Technology*, Report and Order, 27 FCC Rcd. 11569, ¶ 1 (2012). And rules that allow fixed, long-distance commercial use of 2-25 MHz Band frequencies would not be unprecedented. Before 2010, the Commission's Part 23 Rules established licensing requirements for commercial long-distance voice communications in the 2-25 MHz Band. *See Elimination of Part 23 of the Commission's Rules*, Report and Order, 25 FCC Rcd. 541, ¶¶ 1, 6 (2010) (eliminating rules for the International Fixed Public Radiocommunication Services and related frequency allocations).

voice communications, as proposed herein, would not materially increase the risk that other users of 2-25 MHz Band frequencies would experience harmful interference.

A. SMC Members' Extensive Experimentation Confirms That the 2-25 MHz Band Is Optimal for Long-Distance Data Transmissions with Minimal Delay, and Coexistence with Other 2-25 MHz Band Users Can Be Achieved Readily.

Over the past several years, the SMC members individually have engaged in extensive research, development, and testing of proprietary systems designed for fixed, long-distance, non-voice communications in the 2-25 MHz Band. In doing so, each SMC member has relied on experimental licenses issued by the Office of Engineering and Technology, which primarily utilize 2-25 MHz Band frequencies that otherwise are allocated for licensed use under Part 90, to evaluate and improve the performance of their 2-25 MHz Band transmission systems.[26]

The SMC members have confirmed through their respective experiments that the 2-25 MHz Band is the optimal medium for the fixed, long-distance transmission of time-sensitive data.[27] They have also shown that their technological innovations will allow 2-25 MHz Band

[26] *See* Skycast Services LLC, Call Sign WI2XER, File No. 0725-EX-CR-2022 (granted Jan. 4, 2023); Toggle Communications LLC, Call Sign WI2XAJ, File No. 0562-EX-CR-2021 (granted Oct. 12, 2021); RCA Telecom LLC, Call Sign WM2XTS, File No. 0746-EX-CN-2022 (granted Nov. 29, 2022); 10Band LLC, Call Sign WI2XNX, File No. 0277-EX-CM-2022 (granted Dec. 23, 2022); County Information Services, LLC, Call Sign WN2XCR, File No. 1238-EX-CN-2022 (granted Jan. 5, 2023); m-Wave Networks LLC, Call Sign WL2XEE, File No. 0676-EX-CN-2020 (granted Sept. 10, 2020); Rockland Wireless, LLC, Call Sign WK2XJK, File No. 0472-EX-CR-2021 (granted Sept. 3, 2021); Alpha Bravo Communications LLC, Call Sign WM2XZU, File No. 0675-EX-CN-2022 (granted Nov. 29, 2022).

[27] *See* Declaration of Eric Bellerive on Behalf of DRW Holdings, LLC (Mar. 24, 2023) ("Bellerive Decl."); Declaration of Thomas Maxwell on Behalf of IMC Trading (Mar. 24, 2023) ("Maxwell Decl."); Declaration of John P. Madigan on Behalf of NLN Holdings LLC (Mar. 24, 2023) ("Madigan Decl."); Declaration of Kevin Nielsen on Behalf of County Information Services, LLC, an Affiliated Company of the Optiver Services B.V. (Mar. 30, 2023) ("Nielsen Decl."); Declaration of Tom Proudley on Behalf of Tower Research Capital LLC (Mar. 24, 2023) ("Proudley Decl.") (attached hereto).

licensees operating under the proposed rules to detect and avoid harmful interference with other 2-25 MHz Band users.[28] As subject-matter expert employees of the SMC member companies confirm in their declarations submitted herewith, over the course of several years of experimental operations, none of the SMC members, or their respective subsidiaries or affiliates that hold an experimental license, has received a verified complaint of harmful interference attributable to their experimental operations in the 2-25 MHz Band from either the Commission or another 2-25 MHz Band licensee, including other experimental licensees.[29] Thus, the SMC members have significant evidence that regular licensed operation of their 2-25 MHz Band systems as proposed herein would not cause harmful interference to incumbent 2-25 MHz Band licensees.

Although each SMC member's 2-25 MHz Band transmission system is unique to that member, all such systems are designed to avoid interference and are "capable of transmitting and receiving on any frequency in the bands assigned to the particular operation and capable of immediate change among the frequencies."[30] For example:

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[28] *See* Bellerive Decl. ¶ 5; Maxwell Decl. ¶ 5; Madigan Decl. ¶ 5; Nielsen Decl. ¶ 5; Proudley Decl. ¶ 6.

[29] *See* Bellerive Decl. ¶ 6; Maxwell Decl. ¶ 6; Madigan Decl. ¶ 6; Nielsen Decl. ¶ 6; Proudley Decl. ¶ 7. In early 2021, most of the SMC members received a letter from a law firm purporting to represent unnamed members of the public and asserting that unspecified experimental operations appeared to be causing harmful interference to unidentified Commission licensees. None of these letters (1) provided a location at which the transmissions supposedly occurred; (2) referenced the name of any SMC member's experimental licensee subsidiary or affiliate; or (3) provided the call sign of any SMC member's subsidiary or affiliate's experimental license. No SMC member has received follow-up communications concerning these vague and unsupported claims.

[30] 47 C.F.R. § 2.102(h)(3); *see also* Bellerive Decl. ¶ 5; Maxwell Decl. ¶ 5; Madigan Decl. ¶ 3; Nielsen Decl. ¶¶ 3, 5; Proudley Decl. ¶ 3. The SMC members will submit confidential information as necessary when a proceeding resulting from this Petition progresses.

- One SMC member explains that its interference avoidance system utilizes a listen before transmit ("LBT") functionality in addition to monitoring real time signal-to-noise ratio and utilizing station identification capability.[31] In this SMC member's experiments to date, its 2-25 MHz Band transmission system has proven effective on both the transmit and receive sides of the link.[32]
- Another SMC member's interference avoidance system "automatically changes frequency as soon as another signal appears on [its] position."[33] This mechanism has been designed to "give 'right of way' to other users and virtually eliminate service disruption, disturbance and interference to other operators."[34] This SMC member's transmission system can also, in real-time, monitor spectrum occupancy and propagation and space weather data, and thus correctly choose the best transmission path.[35]
- Yet another SMC member uses custom, in-house software tools to monitor and operate its equipment to, among other things, facilitate frequency agility.[36]

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[31] *See* Bellerive Decl. ¶ 5. Other SMC members also rely on LBT functionality. *See* Maxwell Decl. ¶ 5 ("Toggle's and RCA's experimental use of 2-25 MHz Band frequencies avoids interference with licensed users, and with other experimental licensees, primarily by utilizing listen-before-transmit technology."); Nielsen Decl. ¶ 5 ("CIS uses a 'listen-before-speak' system and a continuous channel monitor to detect and mitigate its own interference" with other authorized users in the 2-25 MHz Band.).

[32] *See* Bellerive Decl. ¶ 6.

[33] Proudley Decl. ¶ 3(a).

[34] *Id.*

[35] *See id.* ¶¶ 3(e)-(f).

[36] *See* Madigan Decl. ¶ 3.

- A fourth SMC member's interference avoidance system checks for power-in-band changes in the current center frequency and over the next user configurable set of center frequencies in order to determine interference risk and recommend new channels.[37]

The SMC members remain deeply engaged in efforts to conform their systems to the annual and diurnal fluctuations in the ionosphere and validate system performance in a real-world electromagnetic environment. In addition, they continue to conduct experiments to determine, among other things, the extent to which time-sensitive data can be transmitted reliably using 2-25 MHz Band frequencies with reduced delay as compared to other transmission technologies.[38] For example:

- One SMC member plans to test channel selection methods and processes that would conform to the Part 90 operations proposed herein.[39]
- Another SMC member's experiments include efforts to refine harmonic filter and suppression techniques.[40]
- A different SMC member hopes to test its system with a new long distance link with a higher Doppler shift and increased multipath delay.[41]

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[37] *See* Nielsen Decl. ¶ 3.

[38] *See* Bellerive Decl. ¶ 7; Maxwell Decl. ¶ 7; Madigan Decl. ¶ 7; Nielsen Decl. ¶ 7; Proudley Decl. ¶ 8.

[39] *See* Maxwell Decl. ¶ 7.

[40] *See* Nielsen Decl. ¶ 7.

[41] *See* Bellerive Decl. ¶ 7.

- Another SMC member intends to further develop its system for monitoring 2-25 MHz Band frequencies with regional polling stations and public and privately available software-defined radio systems.[42]
- And yet another SMC member anticipates that further experimentation conducted in consultation with other industry experts and leading academics will lead to advances in both 2-25 MHz Band radio frequency performance and digital signal processing.[43]

B. The Coexistence Report Is Consistent with the Results of the SMC Members' Experiments.

The technical study described in the Coexistence Report demonstrates the feasibility of updating the Part 90 2-25 MHz Band Rules to accommodate sophisticated communications systems without materially increasing the risk of harmful interference to other authorized 2-25 MHz Band users, consistent with the results of the SMC members' experiments. As the Coexistence Report explains, the technical study comprises a robust, comprehensive examination of the potential for co-channel and adjacent/out-of-band interference from 2-25 MHz Band operations that mirror the updated Part 90 Rules proposed herein.

The study relied primarily on the Voice of America Coverage Analysis Program ("VOACAP") propagation prediction tool to examine the likely result of hypothetical transmissions at 20 kW power with a 10 kHz bandwidth from hypothetical transmit locations in Chicago and New York.[44] The study also examined the results of transmissions at four different

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[42] *See* Proudley Decl. ¶ 8(c).

[43] *See* Madigan Decl. ¶ 7.

[44] *See* Coexistence Report at 2-3. The National Telecommunications and Information Administration's Institute for Telecommunication Sciences developed VOACAP, which

azimuths (two different azimuths at each transmit location), covering a range of potential long-distance receive locations and ensuring that a geographically diverse area is covered.[45] Similarly, the study simulated transmissions at each location and azimuth for five different frequencies allocated to the Part 90 Industrial/Business Pool for fixed transmissions.[46] These frequencies, 4.9 MHz, 10.2 MHz, 14.9 MHz, 19.9 MHz, and 24.8 MHz, were selected to ensure that the study examined transmissions at frequencies representing a cross-section of the 2-25 MHz Band.[47] Because 2-25 MHz Band transmissions also vary based on time of day, season of the year, and sunspot activity, the study analyzed each of the hypothetical transmissions under the conditions dictated by 360 scenarios, accounting for three different potential indicators of sunspot activity, five different frequencies, each of the four seasons, and six distinct times of day, for a total of 1,440 different scenarios requiring 5,760 VOACAP runs.[48] Finally, the study incorporated population inputs to account for electromagnetic frequency noise in the 2-25 MHz Band.[49] The Coexistence Report therefore offers a compelling technical basis upon which the Commission should rely to modernize the Part 90 Rules for the 2-25 MHz Band.

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originally was intended for Voice of America's use. *See* Jari Perkiomaki, *VOACAP Quick Guide*, https://www.voacap.com/ (last updated Feb. 14, 2023).

[45] *See* Coexistence Report at 2.

[46] *See id*. at 3.

[47] *See id*.

[48] *See id*. at 15.

[49] *See id*. at 7-8.

Based on the results of the technical study, the Coexistence Report observes that when Part 90 2-25 MHz Band frequencies are used for fixed, long-distance, non-voice communications:

> (1) co-channel interference could occur at some times and places, but is sufficiently limited to enable the prevention of *harmful* interference, provided that licensees are granted multiple Part 90 2-25 MHz Band frequencies throughout the Industrial/Business Pool, and licensees use those diverse 2-25 MHz Band frequencies with frequency-agile techniques, and (2) with an attenuation of 35 dB for out-of-band emissions, harmful interference to spectrally adjacent and out-of-band services is extremely unlikely.[50]

Significantly, the predicted areas of potential increased risk of co-channel interference show a high degree of variability depending on the assumed frequency, time of day, time of year, and sunspot activity.[51] Thus, as the Coexistence Report concludes, "the risk of co-channel interference is sufficiently limited to enable the prevention of harmful interference, provided that licensees are granted multiple Part 90 2-25 MHz Band frequencies throughout the Industrial/Business Pool, and licensees use those diverse 2-25 MHz Band frequencies with frequency agile techniques."[52]

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[50] *Id.* at 17; *see* 47 C.F.R. § 2.1(c) (defining "harmful interference" as "[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [the ITU] Radio Regulations"); *see also id.* § 90.7 (defining "harmful interference" as "any emission, radiation, or induction which specifically degrades, obstructs, or interrupts the service provided by such stations").

[51] *See* Coexistence Report at 18-21.

[52] *Id.* at 24. The Coexistence Report further concludes that "[f]or cases in which 2-25 MHz Band users are not operating on the same channel, if out-of-band emissions are attenuated by 35 dB, adjacent band harmful interference becomes extremely unlikely. Therefore, no special techniques are needed to prevent adjacent channel harmful interference beyond a reasonable out-of-band emissions mask." *Id.*

Under the current Part 90 Rules for the 2-25 MHz Band, licensees can and frequently do change frequencies when they detect impairment of their transmissions. Given the unique propagation characteristics of 2-25 MHz Band spectrum, this practice is both necessary and commonplace. As explained above and in their fact declarations, the SMC members have relied on their experimental licenses to develop various technical solutions that enable switching among available 2-25 MHz Band frequencies.[53] The SMC members also have tested interference avoidance in their experimental operations, and it has allowed them to coexist with each other and with other 2-25 MHz Band licensees.[54] Moreover, as the Coexistence Report explains, "at the transmit bandwidths proposed by the SMC, a large number of potential channels are available for the frequencies allocated to the Part 90 Industrial/Business Pool."[55] The Commission therefore should encourage licensees to employ frequency agility techniques to minimize the potential for harmful interference and should continue to allow prospective licensees to apply for multiple Industrial/Business Pool 2-25 MHz Band frequencies.

III. MODERNIZATION OF THE PART 90 2-25 MHZ BAND RULES WOULD ADVANCE THE PUBLIC INTEREST IN OTHER WAYS AND WOULD MAKE POSSIBLE FURTHER INNOVATION.

A. Use of 2-25 MHz Band Technology Will Enable Market Makers to Operate More Efficiently, to the Benefit of Financial Markets and Other Market Participants.

Licensed use of 2-25 MHz Band frequencies as proposed in this Petition would enable financial firms, including firms like the SMC members that act as market makers, to improve

[53] *See supra* Section II.A.

[54] *See* Bellerive Decl. ¶¶ 3-6; Maxwell Decl. ¶¶ 4-6; Madigan Decl. ¶¶ 4-6; Nielsen Decl. ¶¶ 3-6; Proudley Decl. ¶¶ 3, 5-7.

[55] Coexistence Report at 24.

efficiency, increase liquidity, and reduce transaction costs in the financial markets in which they participate, thereby benefiting all market participants.

A "market maker" is a financial institution or individual that participates in a capital market by buying and selling securities, such as stocks, bonds, and derivatives, and thereby provides liquidity to that market. In most cases, market makers are contractually required or incentivized to quote bid/ask prices for specified financial products in the markets where they operate. Market makers typically maintain an inventory of securities they are willing to buy and sell at publicly quoted prices from and to other traders, investors, and institutions. The buying and selling of such securities ensure that expected price relationships across financial products are maintained and, more generally, that financial markets remain efficient. These activities benefit all market participants.

The SMC members have concluded that the 2-25 MHz Band is the optimal transmission medium for reducing delay in the long-distance transmission of the data essential to their market making activities. As noted, market makers are obligated or incentivized to quote bid/ask prices in the markets where they operate. They therefore are motivated to update their bid/ask prices continuously based on the most up-to-date information available to them. Where the requisite market data originates in a market thousands of miles away, 2-25 MHz Band communications systems meet that need better than other transmission technologies, benefitting all market participants. By quoting, buying, and selling in those markets on the basis of the most accurate bid/ask prices, market makers effectively share the most up-to-date data with all other market participants and incorporate that new information into market prices. This enhances market efficiency by ensuring that prices are more closely aligned across markets, tightening bid/ask spreads and lowering costs for investors.

Market participants would also benefit from licensed use of 2-25 MHz Band frequencies as proposed in this Petition in another way. By facilitating the availability of the most up-to-date market information for all participants in the capital markets in which they operate, market makers enable all market participants to make faster and better-informed decisions. This increased transparency can lead to lower risk, reduced bid/ask spreads, and more active trading, which in turn can further increase liquidity and improve price discovery.

B. Modernization of the Part 90 2-25 MHz Band Rules Would Open The Door to Other Innovative Uses and New Technologies that Encourage Efficient Use of 2-25 MHz Band Frequencies.

As a result of the SMC members' substantial investments and extensive experimentation to develop more efficient transmission technology, the 2-25 MHz Band is now at an inflection point after decades of underutilization. Amendment of the Part 90 Rules for the 2-25 MHz Band would promote the evolution of 2-25 MHz Band technology, not only by enabling the public interest benefits described above, but also by inviting potential new uses that require fixed, long-distance transmission of time sensitive data with reduced delay as compared to other transmission technologies. Furthermore, the amendments proposed in this Petition could encourage innovation in the development of 2-25 MHz Band equipment.

Businesses that require fixed, long-distance, machine-to-machine communications could benefit from the proposed amendments to the Part 90 Rules. For example, multi-national companies could use Part 90 2-25 MHz Band transmission technologies for continuous, centralized, real-time monitoring of their fixed assets throughout the world. Companies could also rely on 2-25 MHz Band communications systems as an important alternative to other long-distance communications media, which have distinct advantages and disadvantages as compared to 2-25 MHz Band communications.[56] In fact, SMC members have tested such strategies and found that 2-25 MHz Band communications systems are a valid back-up for primary communications systems.[57]

Amendment of the Part 90 Rules to permit fixed, long-distance, non-voice communications could also promote the increased availability of innovative new technologies to enable efficient use of 2-25 MHz Band frequencies for a host of purposes. Given the possibility of new licensed uses of 2-25 MHz Band frequencies, some U.S. equipment manufacturers have introduced promising new products, such as advanced remotely tuned antennas.[58] The proposed amendments to Part 90 could bring these burgeoning technological developments to fruition, ushering in a new age of communications in the 2-25 MHz Band. These and other innovations could deliver myriad benefits to businesses and consumers alike.

IV. PROPOSED AMENDMENTS TO THE COMMISSION'S RULES.

For the foregoing reasons, the SMC respectfully requests that the Commission initiate a rulemaking to modernize its rules to authorize non-exclusive licensed use of Part 90 Industrial/Business Pool 2-25 MHz Band frequencies for fixed, long-distance, non-voice communications. The amendments proposed in Sections IV.A and IV.B herein would conform those operations to the Commission's eligibility and technical requirements for

[56] *See* Bellerive Decl. ¶ 4(b) (noting the "increased bandwidth and/or throughput" of other communications technologies as compared to the "reduced latency" of 2-25 MHz transmissions); Nielsen Decl. ¶ 4(b) (same); Proudley Decl. ¶ 5(b) (same); *see also* Maxwell Decl. ¶ 4(c) (observing that "in addition to reduced latency," 2-25 MHz transmissions also provide the benefit of "infrastructure diversity and decreased costs").

[57] *See* Bellerive Decl. ¶ 4(b); *see also* Madigan Decl. ¶ 4(a) (advancements in the reliability of 2-25 MHz Band technology "could lead to wider adoption of 2-25 MHz Band transmission systems. . .by. . .firms that do business in global trouble spots and need or desire to avoid reliance upon vulnerable alternative facilities (e.g., satellite, terrestrial/subsea fiber)").

[58] *See, e.g.*, SteppIR Communications Systems, https://steppir.com/ (last visited Apr. 27, 2023).

Industrial/Business Pool use of 2-25 MHz Band frequencies. As shown in the Coexistence Report, and consistent with the SMC members' experimental operations, fixed, long-distance, non-voice communications that adhere to the technical parameters set forth in Section IV.B would not disrupt authorized operations in the 2-25 MHz Band because (1) co-channel interference could occur at some times and places but would be sufficiently limited to enable the prevention of *harmful* interference, provided that licensees are granted multiple Part 90 2-25 MHz Band frequencies throughout the Industrial/Business Pool, and licensees use those diverse 2-25 MHz Band frequencies with frequency agile techniques, and (2) with an attenuation of 35 dB for out-of-band emissions, harmful interference to spectrally adjacent and out-of-band services is extremely unlikely.[59]

A. Eligibility Rules (47 C.F.R. Parts 2 and 90).

Set forth below are proposed eligibility rule amendments to permit fixed, long-distance, non-voice communications in frequencies above 2 MHz and below 25 MHz allocated for Industrial/Business Pool use pursuant to the Commission's Rules.

1. Part 2 Eligibility Rules.

- ***47 C.F.R. § 2.102(h)(1)(ii).*** Add new subsection (h)(1)(ii)(F) to Section 2.102:

  § 2.102(h)(1)(ii)(F) Provide long-distance, non-voice communications.

2. Part 90 Eligibility Rules.

- ***47 C.F.R. § 90.35(c)(1)(i).*** Add new subsection (c)(1)(i)(E) to Section 90.35:

  § 90.35(c)(1)(i)(E) Fixed, long-distance, non-voice communications.

- ***47 C.F.R. § 90.35(c)(1)(ii).*** Add new subsection (c)(1)(ii)(H) to Section 90.35:

  § 90.35(c)(1)(ii)(H) Fixed, long-distance, non-voice communications.

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[59] *See* Coexistence Report at 17.

- ***47 C.F.R. § 90.264(b).*** Add a new subsection (b)(3) to Section 90.264:

  § 90.264(b)(3) To provide fixed, long-distance, non-voice communications.

- ***47 C.F.R. § 90.264(f).*** Modify Section 90.264(f) as follows (proposed new text is underlined):

  (f) Only 2K80J3E, 100HA1A, 100HA1B, emission types permitted by Section 90.207(h), and those emission types listed in § 90.237(g) are permitted.

- ***47 C.F.R. § 90.264(g).*** Modify Section 90.264(g) as follows (proposed new text is underlined):

  Except in the case of applicants to provide fixed, long-distance, non-voice communications pursuant to § 90.264(b)(3), applicants must fulfill eligibility requirements set out in § 90.20(d)(6) and shall submit disaster communications plans pursuant to § 90.129(m).

- ***47 C.F.R. § 90.266(b).*** Add a new subsection (b)(3) to Section 90.266:

  § 90.266(b)(3) To provide fixed, long-distance, non-voice communications.

- ***47 C.F.R. § 90.266(f).*** Modify Section 90.266(f) as follows (proposed new text is underlined):

  (f) Only 2K80J3E, 100HA1A, 100HA1B, emission types permitted by Section 90.207(h), and those emission types listed in § 90.237(g) are permitted.

B. Technical Rules (47 C.F.R. Part 90).

The proposed amendments to the technical rules set forth below are narrowly tailored to provide the flexibility necessary to permit the proposed fixed, long-distance, non-voice communications in frequencies above 2 MHz and below 25 MHz allocated for Industrial/Business Pool use pursuant to the Commission's Rules.

The ambiguity of three current Part 90 technical Rules necessary to support 2-25 MHz Band fixed, long-distance, non-voice communications suggests the need for additional explanation of corresponding proposed amendments. *First*, the current Part 90 Rules do not set a power limit for non-J3E transmissions in the 2-25 MHz Band.[60] A survey of ULS shows a variety of power levels on non-J3E licenses in the band. This Petition proposes a transmit power limitation of 20 kW because (a) SMC members' experiments have shown this to be an effective power level for 2-25 MHz Band fixed, long-distance, non-voice communications, and (b) the Coexistence Report shows that harmful interference can be avoided at this power level.[61]

Second, the current Part 90 Rules do not include appropriate emissions designators and bandwidths for fixed, long-distance, non-voice communications in the 2-25 MHz Band.[62] Given the variety of technologies that the SMC members have used in their experimental operations and the value in allowing flexibility as technology for the band continues to develop, this Petition proposes that the Part 90 Rules limit bandwidth to no more than 50 kHz, and restrict emission designators to those appropriate for 2-25 MHz Band fixed, long distance non-voice communications, but not further constrain the allowed designators. The technical study described in the Coexistence Report relied on a bandwidth of 10 kHz, and because the total power is fixed, bandwidths wider than 10 kHz, including 50 kHz, present less risk of harmful interference than the assumptions detailed in the Coexistence Report.[63]

Third, the current Part 90 emissions masks applicable to the 2-25 MHz Band, mask B and mask C, are not appropriate for the use proposed in this Petition.[64] Mask B is not appropriate for non-voice communications because it is applicable only to transmitters with an audio low-pass

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[60] *See* 47 C.F.R. § 90.205.

[61] *See* Coexistence Report at 3.

[62] *See* 47 C.F.R. §§ 90.027, 90.209.

[63] *See* Coexistence Report at 17.

[64] *See* 47 C.F.R. § 90.210.

filter. Mask C is not appropriate for 2-25 MHz Band fixed, long-distance, non-voice communications because it is not suitable for transmission bandwidths over 10 kHz, due to the use of 10 kHz and 5 kHz in the formulas in the rules specifying the mask. Therefore, this Petition proposes a new mask for 2-25 MHz Band fixed, long-distance, non-voice communications. The proposed new mask is based on mask C and yields similar results for an authorized bandwidth of 10 kHz while also supporting larger authorized bandwidths. The proposed mask has an attenuation of 36 dB at 150 percent of the authorized bandwidth. As shown in the Coexistence Report, 35 dB of attenuation of out-of-band power makes harmful interference very unlikely.[65] This level of attenuation therefore is both sufficiently protective and consistent with the current emissions mask C. In addition, the proposed mask has an attenuation of 50 dB beyond 250 percent of the authorized bandwidth. The Coexistence Report demonstrates that 50 dB of attenuation prevents harmful interference in 100 percent of the scenarios studied, rendering this level of attenuation more than sufficiently protective.[66]

- ***47 C.F.R. §§ 90.129(a), (h).*** Clarify that Sections 90.129(a) and (h) (referencing Sections 90.417(b) and 90.20(b)) do not prohibit or impede international transmissions outside of certain public safety or police radiocommunications.

- ***47 C.F.R. § 90.129(o).*** Modify Section 90.129(o) as follows (proposed new text is underlined):

  Applicants requesting licenses to operate on frequencies pursuant to § 90.35(c)(1), except those operating pursuant to § 90.35(c)(1)(i)(E), must submit communications plans containing the following information: …

- ***47 C.F.R. § 90.205(a).*** Modify Section 90.205(a) as follows (proposed new text is underlined):

[65] *See* Coexistence Report at 24.

[66] *See id*. at 24.

Below 25 MHz. For single sideband operations (J3E emission), the maximum transmitter peak envelope power is 1000 watts. For fixed, long-distance, non-voice communications, the maximum transmitter power is 20,000 watts RMS.

- ***47 C.F.R. § 90.207.*** Add a new subsection (h) to Section 90.207:

  For fixed, long-distance, non-voice communications below 25 MHz, any emissions designator consistent with non-voice communications will be authorized.

- ***47 C.F.R. § 90.209.*** Renumber current subsection (b)(2) as subsection (b)(2)(i) and add a new subsection (b)(2)(ii) to Section 90.209:

  (b)(2)(ii) For non-voice transmissions below 25 MHz, the bandwidth occupied by the emission shall not exceed 50 kHz.

- ***47 C.F.R. § 90.210.*** To add a new emission mask type, add a new subsection (n) to Section 90.210, moving down the current Section 90.210(n) to (o) and Section 90.210(o) to (p). Table 1 to Section 90.210 should be modified to reflect this addition (proposed deleted text is in ~~strikethrough~~, and proposed new text is underlined).

  (n) **Emission Mask N**. For fixed non-voice transmitters in the 2-25 MHz Band, the power of any emission must be attenuated below the unmodulated carrier output power (P) as follows:

    (1) On any frequency removed from the center of the authorized bandwidth by 50 percent to 100 percent of the authorized bandwidth: At least 83 log ($2*f_d/B$) dB where f_d is the displacement from the center frequency in kHz and B is the authorized bandwidth in kHz;

    (2) On any frequency removed from the center of the authorized bandwidth by 100 percent to 250 percent of the authorized bandwidth: At least 31.5 log ($(2.5*f_d/B)^2$) dB where f_d is the displacement from the center frequency in kHz and B is the authorized bandwidth in kHz;

    (3) On any frequency removed from the assigned frequency by more than 250 percent of the authorized bandwidth: At least 50 dB.

  ~~(n)~~ (o) Other frequency bands. Transmitters designed for operation under this part on frequencies other than listed in this section must meet the emission mask requirements of Emission Mask B. Equipment operating under this part on frequencies allocated to but shared with the Federal Government, must meet the applicable Federal Government technical standards.

  ~~(o)~~ (p) Instrumentation. The reference level for showing compliance with the emission mask shall be established, except as indicated in §§ 90.210(d), (e), and (k), using standard engineering practices for the modulation characteristic used by the equipment under test. When measuring emissions in the 150-174 MHz and 421-512

MHz bands the following procedures will apply. A sufficient number of sweeps must be measured to ensure that the emission profile is developed. If video filtering is used, its bandwidth must not be less than the instrument resolution bandwidth. For frequencies more than 50 kHz removed from the edge of the authorized bandwidth a resolution of at least 100 kHz must be used for frequencies below 1000 MHz. Above 1000 MHz the resolution bandwidth of the instrumentation must be at least 1 MHz. If it can be shown that use of the above instrumentation settings do not accurately represent the true interference potential of the equipment under test, then an alternate procedure may be used provided prior Commission approval is obtained.

Table 1 to § 90.210 - Applicable Emission Masks

Frequency band (MHz)	Mask for equipment with audio low pass filter	Mask for equipment without audio low pass filter
Below 25[1]	A or B	A ~~or~~, C, or N
25-50	B	C
72-76	B	C
150-174[2]	B, D, or E	C, D or E
150 paging only	B	C
220-222	F	F
421-512[2 5]	B, D, or E	C, D, or E
450 paging only	B	G
806-809/851-854[6]	B	H
809-824/854-869[35]	B, D	D, G
896-901/935-940	I	J
902-928	K	K
929-930	B	G
4940-4990 MHz	L or M	L or M
5895-5925[4]		
All other bands	B	C

[1] Equipment using single sideband J3E emission must meet the requirements of Emission Mask A. Equipment using other emissions must meet the requirements of Emission Mask B, ~~or~~ C, or N, as applicable.

- ***47 C.F.R. § 90.213.*** Modify footnote 1 to Section 90.213 as follows (proposed new text is underlined):

  [1] Fixed and base stations with over 200 watts transmitter power must have a frequency stability of 50 ppm except for equipment used in the Public Safety Pool or for fixed, long-distance, non-voice communications where the frequency stability is 100 ppm.

- ***47 C.F.R. § 90.419.*** Add a new subsection (g) to Section 90.419:

  For fixed, long-distance, non-voice communications.

CONCLUSION.

The SMC members' proposal to modernize the Part 90 Rules to permit, on a non-exclusive licensed basis, fixed, long-distance, non-voice communications using frequencies above 2 MHz and below 25 MHz will make efficient use of spectrum that has been underutilized for decades, and it manifestly is in the public interest. The Commission should promptly commence a rulemaking to adopt the amendments set forth herein.

Respectfully submitted,

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APPENDIX A
Coexistence Report

Study on 2-25 MHz Band Coexistence

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April 28, 2023

Contents

1. Overview of Methodology and Key Findings

Quadra Partners, LLC was engaged by Willkie Farr & Gallagher LLP to prepare, on behalf of the Shortwave Modernization Coalition ("SMC"), this study of coexistence between fixed, long-distance transmitters using frequencies above 2 MHz and below 25 MHz (the "2-25 MHz Band") to transmit data and provide other services. The characteristics of the long-distance 2-25 MHz Band transmitters studied are representative of the transmitters that SMC member companies use in an experimental capacity, and this study assumes that these long-distance 2-25 MHz Band transmissions will occur only on frequencies above 2 MHz and below 25 MHz in the Part 90 Industrial/Business Pool, which are designated as "Part 90" in the "FCC Rule Part" column of the table of allocations.[1]

The study employs a combination of analytic tools, including the industry-standard Voice of America Coverage Analysis Program ("VOACAP") propagation model, with additional processing of results using MATLAB and QGIS. Using these tools, this study examines the 2-25 MHz Band transmitters' coexistence with both adjacent band and co-channel use. The analysis is limited to the contiguous United States (CONUS).

Propagation and noise in the 2-25 MHz Band are highly variable. In addition to "ground wave" propagation along the surface of the earth, 2-25 MHz Band waves will reflect off the ionosphere, referred to as "sky wave" propagation, and even a low power 2-25 MHz Band transmitter can reach around the earth. However, the effective height of the ionosphere varies due to solar radiation, and the geographic areas that can be reached via sky wave propagation vary depending on time of day, time of year, and time in the approximately 11-year sunspot cycle.[2] 2-25 MHz Band noise is also variable and is much higher than in many other frequency bands.

This study finds that, even with this high variability, a fixed, long-distance 2-25 MHz Band transmitter is very unlikely to cause harmful interference to any adjacent-band services assuming out-of-band emissions ("OOBE") are attenuated at least 35 dB. Therefore, adjacent band harmful interference can be prevented with a reasonable out-of-band emission mask, and systems on nearby channels are not problematic. It also means that coexistence with any 2-25 MHz Band frequencies that are not licensed under Part 90 – including all amateur 2-25 MHz Band and broadcast 2-25 MHz Band frequencies – is straightforward and requires no special rules or procedures, assuming the rules limit OOBE outside the Part 90 frequencies by at least 35 dB.

This study also finds that interference might occur between co-channel systems, that is, operations on the same channel, because the power from the long-distance 2-25 MHz Band transmitter is above the noise floor in certain times at certain places. However, there are hundreds to thousands of effective channels in the Part 90 Industrial/Business Pool given typical signal bandwidths. Furthermore, the power above the noise floor metric indicates only the potential for interference for co-channel users, not certainty that harmful interference will occur. The exact location in which interference could possibly occur varies by time of day, time of year, sunspot activity, and, perhaps most importantly, frequency. And, in a number of cases, the co-channel power will be below the noise floor at receiver locations encompassing much of the population of CONUS. Critically, this interference potential due to long-distance 2-25 MHz Band transmission is not significantly different from the potential interference from other uses of the 2-25 MHz Band, all of which are subject to sky wave propagation and can potentially reach any part of the U.S.

[1] *See* 47 C.F.R. 90 Subpart C as well as 47 C.F.R. § 2.106. The relevant frequencies are also given in Appendix E.

[2] Solar radiation is variable, and, in particular, varies with the number of sunspots, which itself shows long term variation over an approximately 11-year cycle. *See* Space Weather Prediction Ctr., *Sunspots/Solar Cycle*, https://www.swpc.noaa.gov/phenomena/sunspotssolar-cycle.

under the right conditions. Therefore, it appears that the FCC can continue to allow prospective licensees to apply for multiple Part 90 2-25 MHz Band frequencies throughout the Industrial/Business Pool and encourage licensees to use those diverse 2-25 MHz Band frequencies with frequency agility techniques that will minimize the potential for harmful interference. This could be as simple as allowing Part 90 2-25 MHz Band licensees to change frequencies whenever they detect impairment of their transmissions. In fact, the SMC member companies have tested exactly this method under experimental authority from the FCC, and it has been effective in allowing them to coexist with each other and with 2-25 MHz Band licensees. Importantly, none of the member companies has received interference complaints from other 2-25 MHz Band licensees over several years of operation.

2. Inputs

This section describes the inputs to the study. In general, long distance transmission in the 2-25 MHz Band is referred to as “sky wave” propagation and involves reflections off the ionosphere. Sky wave propagation is significantly affected by sunspot number, time of day, time of year, and frequency of transmission. In addition, the level of background noise in the 2-25 MHz Band depends on a number of factors, including time of day, time of year, and variations in the human-made environment. Accordingly, 2-25 MHz Band noise is higher in urban areas and lower in rural areas. Given these factors, the study takes the general approach of modeling a number of different times of day, times of year, sunspot numbers, and frequencies.

2.1. Transmitter Characteristics

This study considers four transmission cases that are representative of long-distance use cases for the 2-25 MHz Band:

- New York, NY, USA transmitting west, such as to Los Angeles, CA, USA
- Chicago, IL, USA transmitting west, such as to Seattle, WA, USA
- New York, NY, USA transmitting south, such as to São Paulo, Brazil
- Chicago, IL, USA transmitting east, such as to London, United Kingdom

In each case, a directional antenna is oriented at the azimuth to reach the city listed above, and similar results would be obtained for transmissions between locations at similar azimuths. For example, the results for transmission from New York to Los Angeles would be similar for transmissions from New York to any location in California, and the results for transmissions from Chicago to Seattle would be similar to results for transmission from Chicago to locations in Korea or Japan. Similarly, the New York to São Paulo scenario is similar to transmissions from New York to other locations in South America, and the Chicago to London scenario will be similar to transmissions from Chicago to other locations in western Europe. Locations and directions other than these scenarios are possible; however, we would also expect broadly similar results for other transmit locations. Although in some cases the specific areas in which there is potential for interference might be different than for these four scenarios, we expect that analysis of alternative scenarios would reach the same general conclusion that areas in which there is potential for interference are in different parts of the U.S. over time and are different for different frequencies.

2.1.1. Transmitter Location

The transmitters were placed approximately in New York and Chicago at hypothetical locations using the online VOACAP interface. We also used the online VOACAP interface to choose azimuths to reach Los Angeles, Seattle, São Paulo, and London. The resulting coordinates and azimuths are shown in Table 1.

Table 1 – Transmitter locations, transmitter azimuths, and receiver locations

Scenario	TX Latitude	TX Longitude	TX Azimuth
New York transmitting west	40.76° N	74.01 W	274°
Chicago transmitting west	41.85° N	87.69° W	295°
New York transmitting south	40.76° N	74.01 W	153°
Chicago transmitting east	41.85° N	87.69° W	51°

No attempt was made to utilize specific geographic locations in New York and Chicago that would support a tower, as VOACAP does not consider local terrain or clutter, but, rather, assumes unobstructed transmit and receive locations.

2.1.2. Transmitter Frequency

Because the FCC's Part 90 rules generally treat licensed operations below 25 MHz as a distinct category, and the relevant portion of Part 90 Industrial/Business Pool is between 2 and 25 MHz, this study focuses on frequencies between 2 and 25 MHz. Specifically, we consider five frequencies within this range: 4.9, 10.2, 14.9, 19.9, and 24.8 MHz. We selected these frequencies based on even spacing across the 2-25 MHz Band in 5 MHz intervals. Because the exact frequencies 5, 10, 15, 20, and 25 MHz are not available in the Part 90 Industrial/Business Pool, we selected comparable nearby frequencies that are in the Industrial/Business Pool and available for fixed service under Part 90 of the FCC's rules.

2.1.3. Transmitter Power, Bandwidth, and Emissions

We assume a 20 kW transmit power and a transmitter bandwidth of 10 kHz as representative of long-distance 2-25 MHz Band communications. This means the power spectral density in channel is 2 W/Hz or 3 dBW/Hz. To the extent actual deployments use higher bandwidths subject to the same power limitation, the PSD would be lower and therefore less likely to cause interference. In addition to this transmitter output power, as discussed below, we assume 1 dB of losses and 10 dBi of antenna gain. For out-of-band emissions, we considered attenuations of 30, 35, 40, 45, and 50 dB. As discussed in the results section, we found 35 dB sufficient to make adjacent channel harmful interference very unlikely.

2.1.4. Transmit Antenna

The SMC member companies use a variety of antennas for long-distance 2-25 MHz Band communications. This study uses a genericized 10 dBi 2-25 MHz Band antenna. It is expected that transmit antennas used for long-distance 2-25 MHz Band communications will be at least as directional as this antenna pattern.

Figure 1 shows the horizontal antenna pattern used in this analysis, Figure 2 shows the vertical pattern at 10 MHz and higher frequencies, and Figure 3 shows the vertical pattern below 10 MHz. The horizontal plot in Figure 1 shows that all points more than 60° outside the main beam will have a net gain of less than 0 dBi. As such, they will radiate less gain in those directions than would an isotropic antenna. In fact, past approximately ±65°, the pattern will always be at least 5 dB below isotropic, or -5 dBi or lower. The vertical pattern for 10 MHz and above shows the strongest transmission is at an elevation angle of about 10°, but there are several lobes at higher angles. The vertical pattern for below 10 MHz shows the strongest transmission is at an elevation angle of about 25°, with one higher lobe.

Figure 1 – Horizontal pattern of genericized 10 dBi antenna

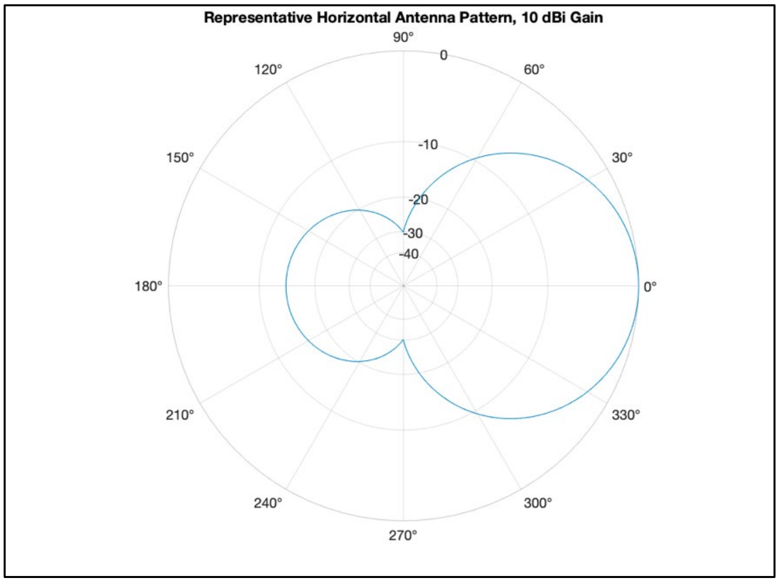


Figure 2 – Vertical pattern of genericized 10 dBi antenna at and above 10 MHz

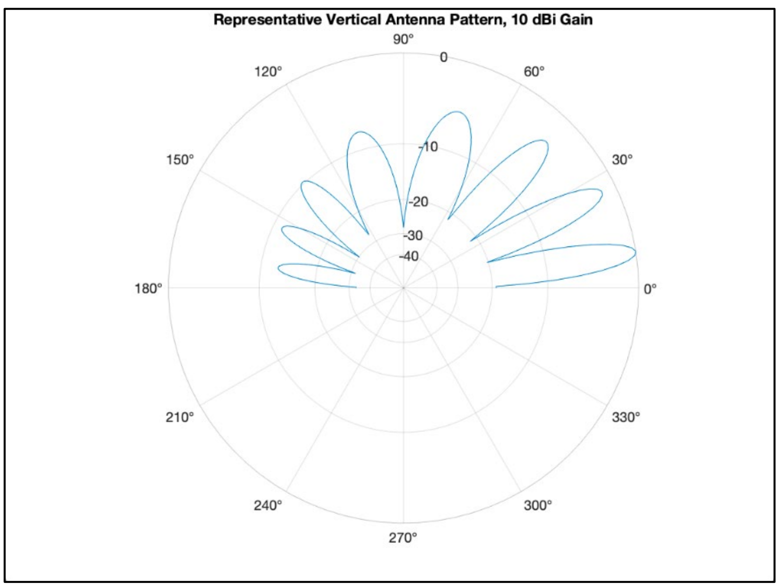
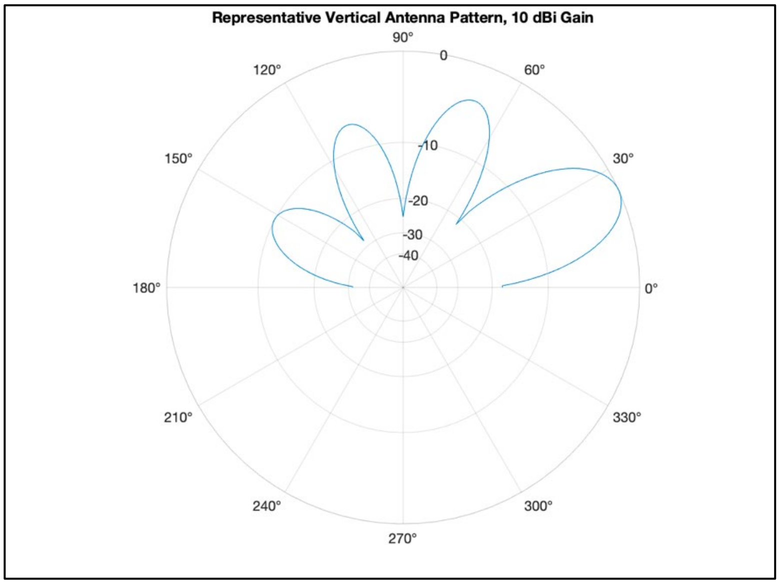


Figure 3 – Vertical pattern of genericized 10 dBi antenna below 10 MHz



2.2. Receiver Characteristics

As explained further below, in the 2-25 MHz Band external noise is much greater than internal receiver noise, so there is no need to consider the receiver's noise figure.

For the receive antenna, we assume a simple whip antenna, specifically the "swwhip.voa" pattern included as a default omnidirectional antenna pattern in VOACAP.[3] This is a conservative choice, as a higher gain receiver antenna would be directional and unlikely to be pointed toward the transmitter, resulting in less gain than this omnidirectional antenna, which results in 0 dBi gain in all azimuths. The horizontal and vertical patterns of this antenna are shown in Figure 4 and Figure 5, respectively. Figure 4 shows the standard omnidirectional pattern of 0 dBi at all azimuths. Figure 5 shows that this antenna has a single broad vertical lobe, which is strongest at elevation angles between 20° and 30°, and has significant rejection of very low or very high elevations.

[3] *See, e.g.*, VOACAP, *Data Files FAQ*, https://www.voacap.com/itshfbc-help/datafile-faq html.

Figure 4 – Horizontal pattern of 0 dBi receive antenna

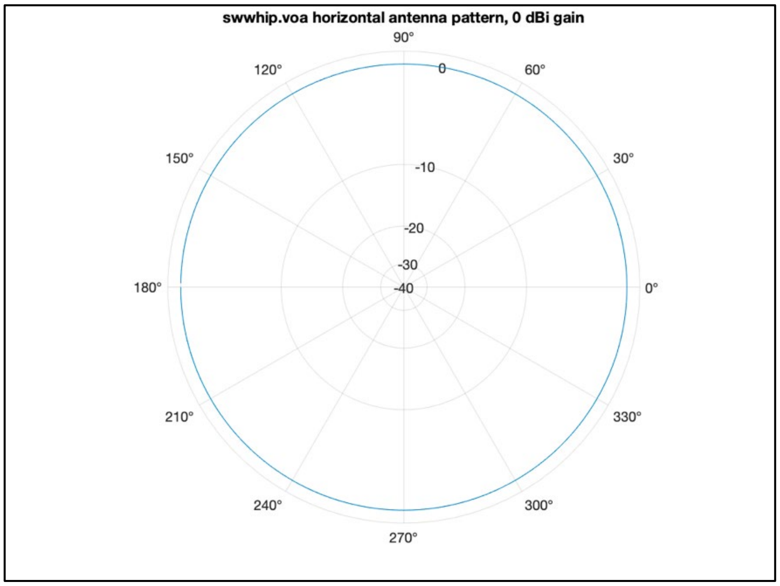
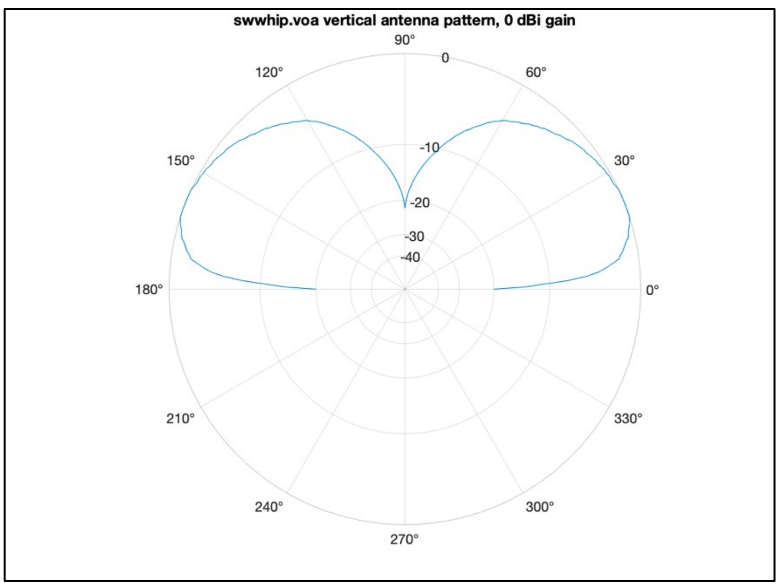


Figure 5 – Vertical pattern of 0 dBi receive antenna



2.3. Time-Based Inputs

Propagation in the 2-25 MHz Band varies by the hour of the day, the season of the year, and the position in the 11-year sunspot cycle. This is because solar radiation has a major effect on the ionosphere, causing variation in the height and density of ions in the atmosphere. We therefore must consider each of these inputs.

2.3.1. Time of Day and Year

VOACAP uses a variety of tables of parameters as internal inputs to its calculations. Many of these inputs, such as the ITU recommendations for atmospheric noise discussed below, look at four quarters or seasons of the year, and six times of day.

Following this approach, we consider six times of day: 02:00, 06:00, 10:00, 14:00, 18:00, and 22:00, all UTC times, as well as the four months in the middle of each of the four quarters of the calendar year: February, May, August, and November.

2.3.2. Smoothed Sunspot Number

VOACAP uses smoothed sunspot number (SSN) as a key input.[4] This number varies over an approximately eleven-year cycle. At the low point of the cycle, the SSN is near zero. At the peak of a cycle, SSN is approximately 120. For this analysis we use SSNs of 0, 60, and 120, representative of the minimum, midpoint, and maximum SSNs of the eleven-year cycle. The SSN was 75.4 in August 2022, and the current cycle is predicted to peak in mid-to-late 2025 at 110-115.[5]

2.4. Population Inputs

This study incorporates population in two ways. First, we use population density to classify human-made environments to determine the level of human-made noise. Second, we present results in terms of the percentage of the CONUS population over which the long-distance transmissions would be below the noise floor.

We obtained population data from Gridded Population of the World ("GPW") v4, which is available from NASA's Socioeconomic Data and Applications Center ("SEDAC").[6] This dataset is based on U.S. Census data, among other sources, but has the advantage of being organized into a 30-arcsecond (approximately 1 km) grid, rather than irregularly shaped census blocks, block groups, tracts, and so forth.

As described further below, the VOACAP analysis is run on a 20-km grid, so we used QGIS to bin the GPW data into the grid used in the analysis. That is, a QGIS analysis allowed us to assign GPW population to each analysis grid cell to determine the total population and population density in each 20-km analysis grid cell. In fact, the VOACAP grid uses the transmit location as its origin, so we have two slightly different grids, one for transmissions from New York and one for transmissions from Chicago. Figure 6 shows the population density in the GPW data over CONUS, and Figure 7 shows the data binned into the New York analysis grid.

[4] *See, e.g.*, VOACAP, *Setting VOACAP Input Parameters*, https://www.voacap.com/setup.html, VOACAP, *Choosing the Correct Sunspot Number*, https://www.voacap.com/choosingssn.html.

[5] *See* Space Weather Prediction Ctr., *Solar Cycle Progression*, https://www.swpc.noaa.gov/products/solar-cycle-progression.

[6] *See* SEDAC, *Gridded Population of the World (GPW), v.4*, https://sedac.ciesin.columbia.edu/data/set/gpw-v4-population-density-adjusted-to-2015-unwpp-country-totals-rev11.

Figure 6 – GPW v4 population density, 30 arcsecond grid

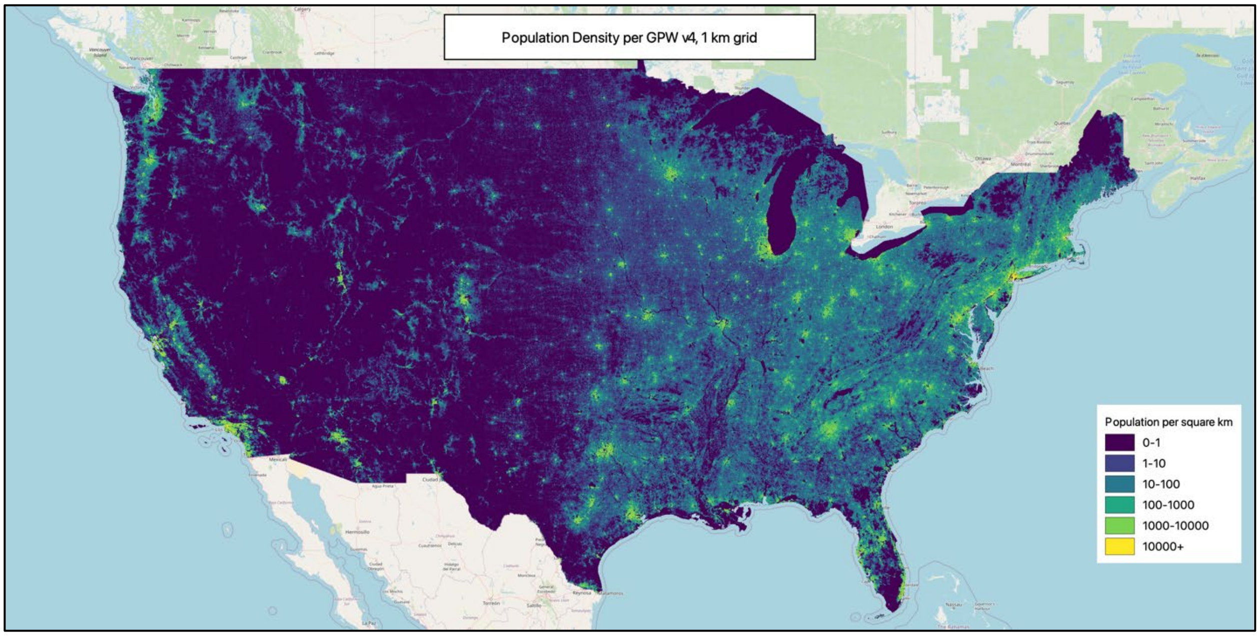
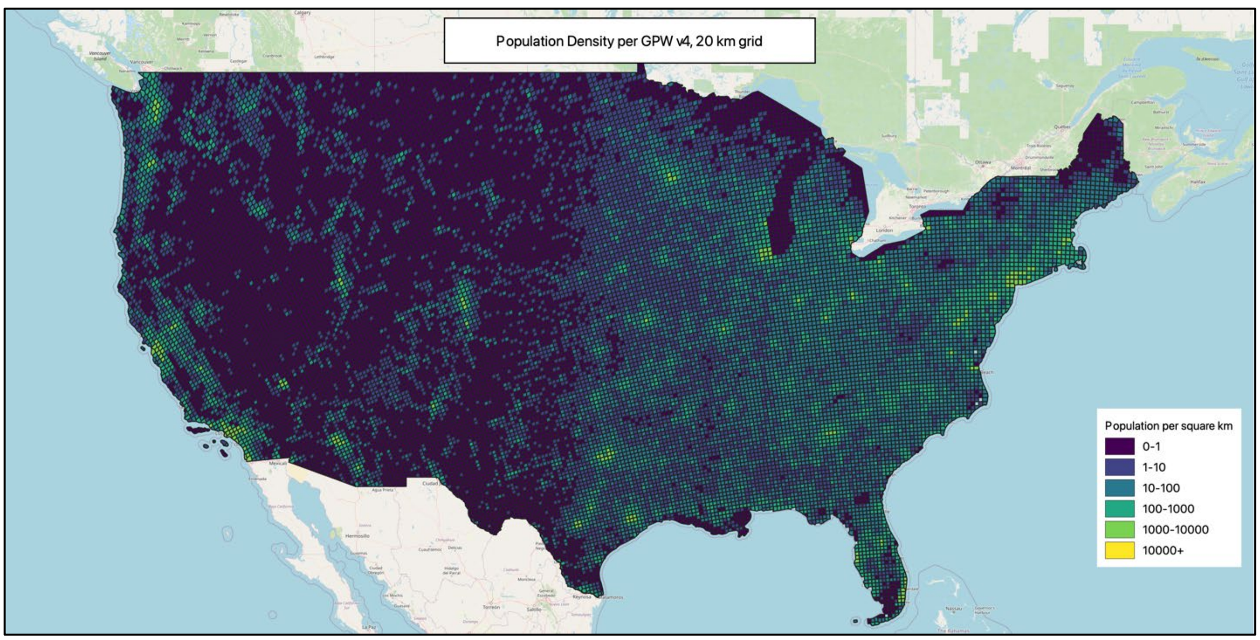


Figure 7 – GPW v4 population density, 20 km grid



3. Analysis

This section describes the analysis that we performed.

3.1. Tools

The primary tool used in this analysis is the VOACAP 2-25 MHz Band propagation tool originally developed by NTIA/ITS to model propagation loss in the 2-25 MHz Band.[7] There are three versions of the VOACAP tool: an online version, a standalone version for Microsoft Windows, and a command-line version for Linux and MacOS. The vast majority of this analysis was performed using the command-line version of the VOACAP tool, although the online version was used for a few calculations.

In addition to VOACAP, we used two more well-known tools, MATLAB and QGIS.[8] We used MATLAB for post-processing VOACAP outputs, including adjusting for antenna patterns and bandwidths, averaging results, counting population, and generating programmatic inputs. We used QGIS primarily to generate maps for displaying VOACAP and MATLAB results, but also for binning GPW population data. VOACAP is based on the earlier ICEPAC propagation model. VOACAP differs from ICEPAC primarily in the coefficients used.[9]

Although the online version of VOACAP is convenient and useful, four limitations make it unsuitable for this analysis. First, it has a preset list of antennas and does not easily allow users to substitute their own antenna patterns. Second, it treats the selected antenna in a quasi-omni-directional fashion when generating area coverage. In each direction, rather than using side lobes or back lobes, it calculates signal strength as if the antenna were reoriented to point toward the predicted point. Third, although the online version of VOACAP allows selection of an isotropic antenna, the coverage plot does not work when both transmit and receive antennas are isotropic. Fourth, it does not have an interface for running many different scenarios programmatically. For these reasons, we used the command-line version of VOACAP.

3.2. Noise

There are a number of sources of noise in the 2-25 MHz Band, some of which vary over time. Using VOACAP and post-processing tools to determine the noise at each grid point in each scenario therefore is a major part of the analysis.

3.2.1. 2-25 MHz Band Noise Overview

In the 2-25 MHz Band, the significant sources of noise are atmospheric noise, galactic noise, and human-made noise. ITU recommendation ITU-R P.372-15, Radio Noise, gives a good explanation of these sources of noise and how to calculate them.[10] Moreover, these sources of noise are incorporated into the VOACAP tool. The ICEPAC technical manual explains how noise from these sources is calculated, which is essentially the same as the methods described in P.372-15.[11]

Noise sources in these references are expressed as power spectral densities, that is dBW/Hz, or in dB relative to the theoretical thermal noise kT, where k is the Boltzmann constant, 1.38×10^{-23} J/K, and T is

[7] Information on VOACAP can be found at www.voacap.com.

[8] More information about these programs can be found at https://www mathworks.com/products/matlab html and https://qgis.org/en/site/ respectively.

[9] A technical description of how ICEPAC models propagation, including ionospheric modeling, can be found at http://www.greg-hand.com/manuals/icepac_tech_manual.pdf (ICEPAC Manual).

[10] ITU-R Recommendation ITU-R P.372-16, 08/2022, Radio noise, https://www.itu.int/rec/R-REC-P.372/en (P.372).

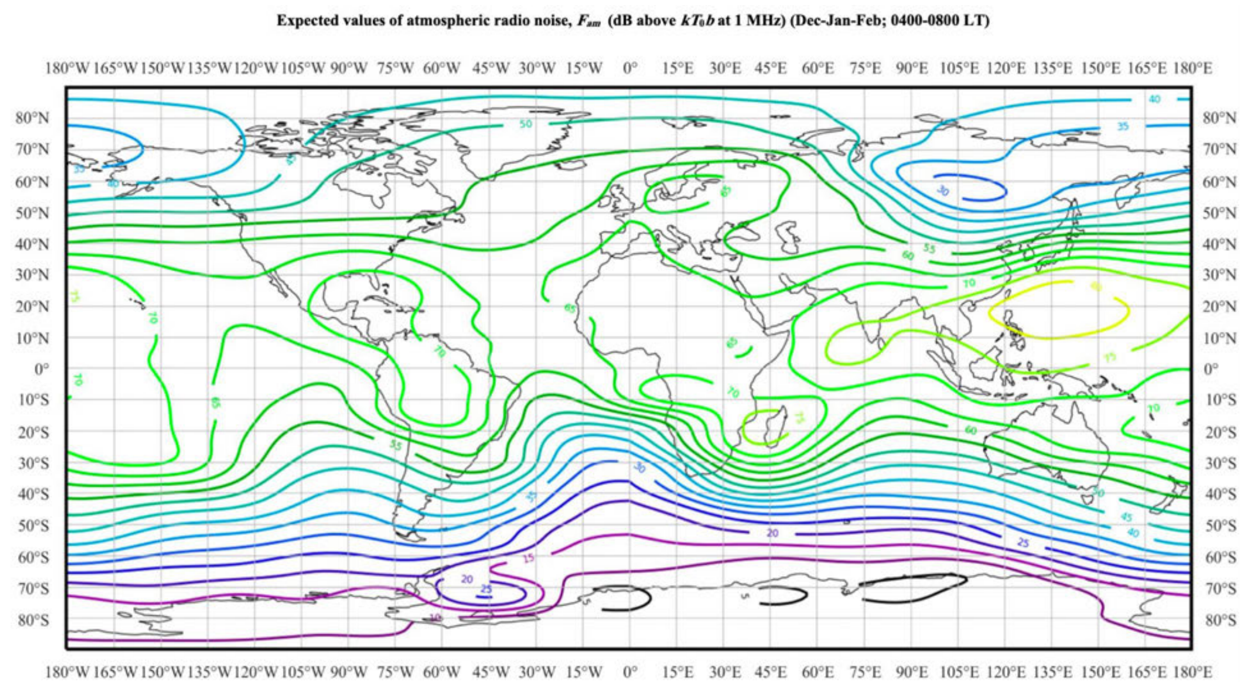
[11] ICEPAC Manual at 44 and following.

the temperature in Kelvin. *T* is generally taken to be 290 K, meaning *kT* is -204 dBW/Hz. So, a noise level of -180 dBw/Hz may also be expressed as 24 dB above thermal or just 24 dB.

It is simplest to calculate galactic noise. Equation 13 of P.372-15 indicates that this will be 52 – 23*$\log_{10}(f)$ dB above thermal noise where *f* is in MHz. For example, for 15 MHz, this formula indicates that galactic noise is 25 dB above thermal.[12] This is also shown in equation 4.1 of the ICEPAC Technical Manual.[13]

By contrast, calculation of atmospheric noise is complicated and requires the use of tables of contours of atmospheric noise at various locations, times, and frequencies. For example, Figure 8 below, reproduced from P.372-15, shows atmospheric noise contours at 1 MHz in the winter months from 4:00 am to 8:00 a.m. local time.[14] Figure 9, also from P.372-15, shows curves that can be used to adjust this noise to other frequencies.[15]

Figure 8 – Figure 14a from ITU-R P.372-15, atmospheric noise at 1 MHz, morning, winter



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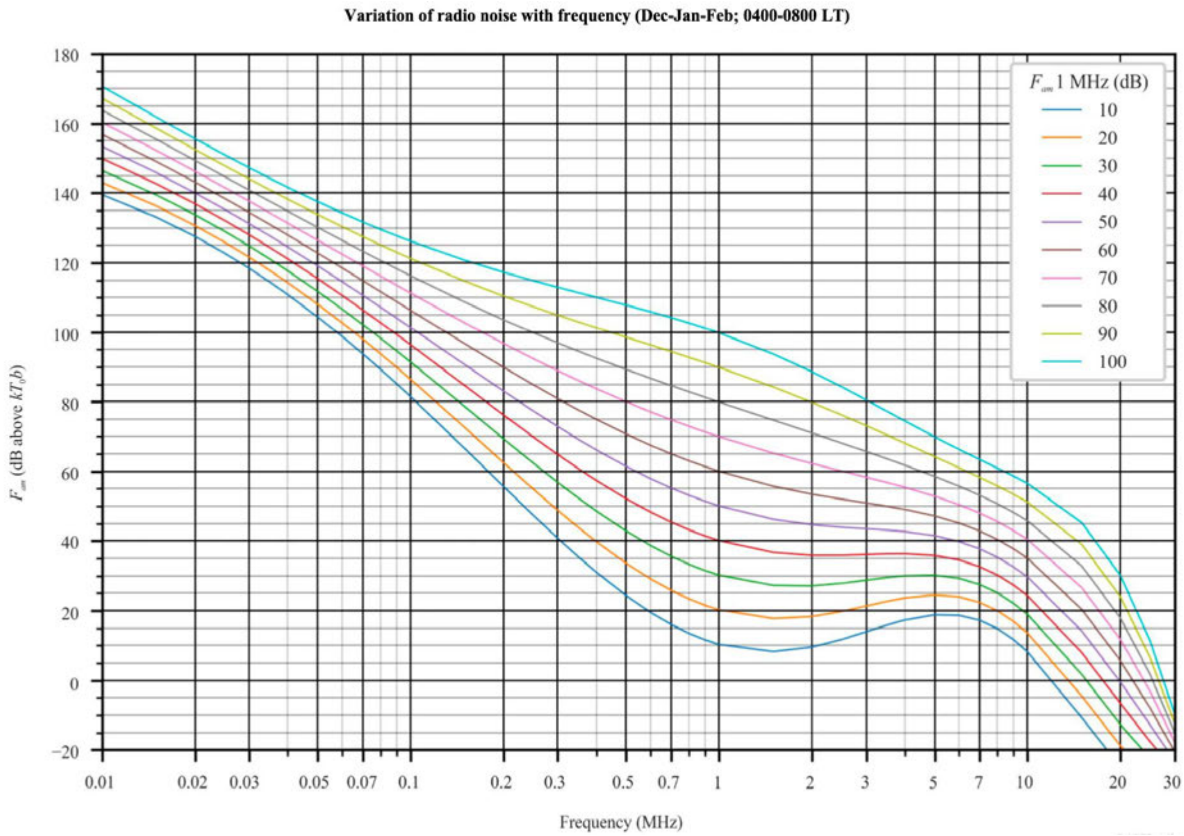
[12] P.372 at 16.

[13] ICEPAC Manual at 44.

[14] P.372 at 27.

[15] *Id.* at 28.

Figure 9 – Figure 14b from ITU-R P.372-15, frequency adjustment for atmospheric noise, morning, winter



As described in Section 4.2 of the ICEPAC Technical Manual, all of these curves are incorporated into the VOACAP tool.[16] VOACAP evaluates these curves to calculate the atmospheric noise at each prediction point for the prediction time and frequency.

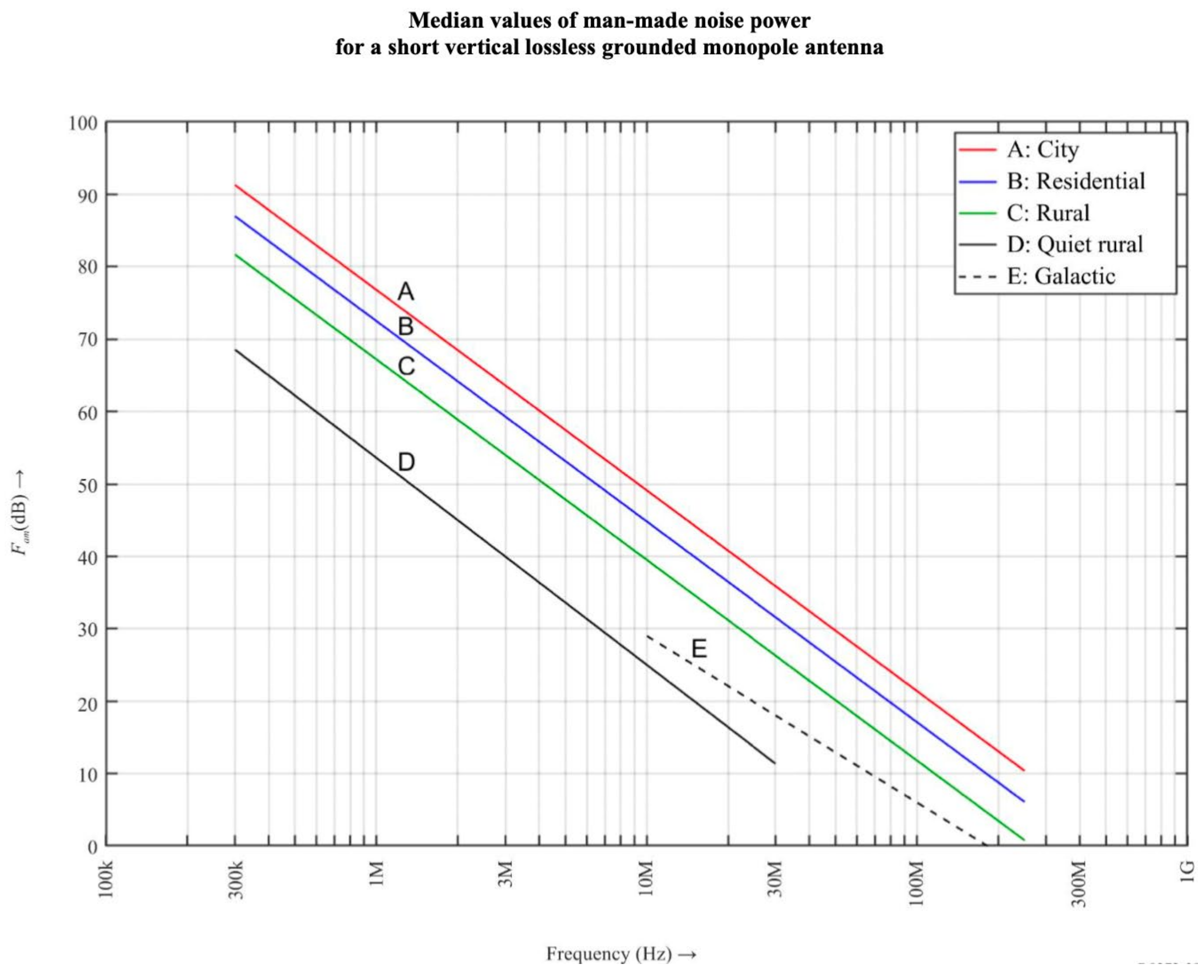
Calculation of human-made noise, the third relevant source of 2-25 MHz Band noise, follows simple curves as a function of frequency, as is the case with the calculation of galactic noise. P.372-15 Table 1 and Section 4.3 in the ICEPAC Technical Manual provide the same coefficients for these curves, with separate curves for city/business, residential, rural, and quiet rural geographic areas.[17] Figure 10 reproduces Figure 39 from P.372-15, showing these curves.[18]

[16] ICEPAC Manual at 45.

[17] P.372 at 99, ICEPAC Manual at 46.

[18] P.372 at 100.

Figure 10 – Figure 29 from ITU-R P.372-15, comparison of human-made noise curves

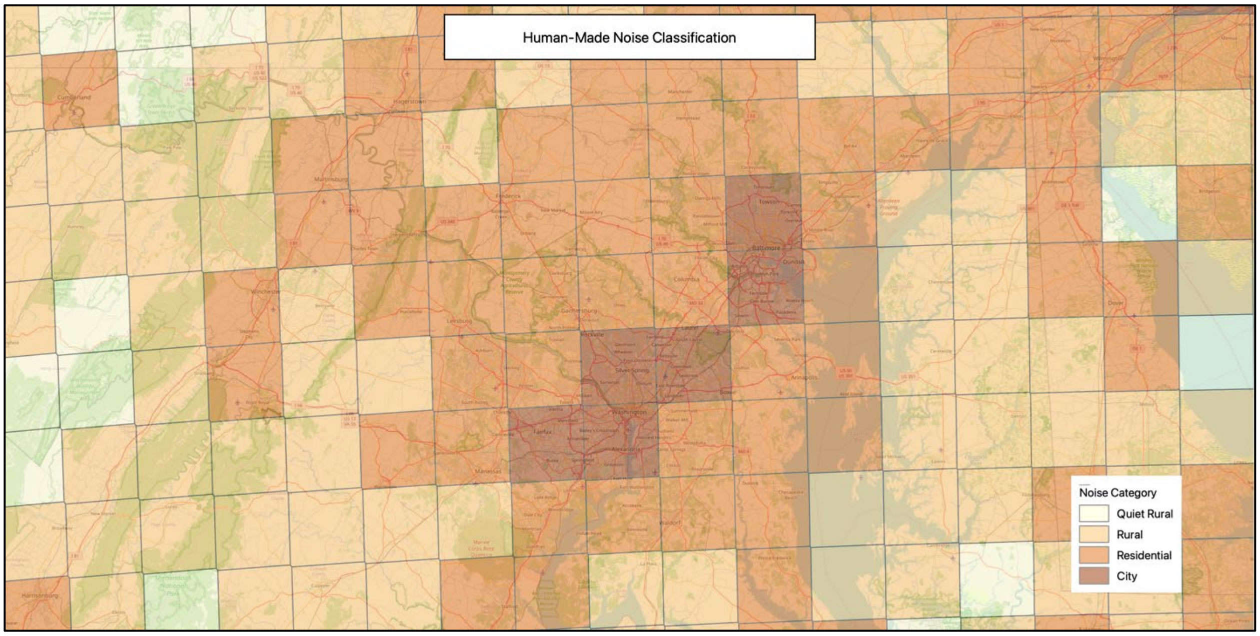


3.2.2. Human-Made Noise and Population Density

Although ITU-R P.372-15 provides separate curves for City, Residential, Rural, and Quiet Rural environments, it is left to the engineer to determine which of these is appropriate for a given receive location.[19] For this analysis we set the noise at each grid point based on population density: more than 1000 people per square km is City, between 100 and 1000 people per square km is Residential, between 10 and 100 people per square km is Rural, and fewer than 10 people per square km is Quiet Rural. Figure 11 displays the Baltimore and Washington, DC areas with these thresholds. As shown, these thresholds yield reasonable results, with the grid squares containing the cities of Washington, DC and Baltimore showing as City, their suburbs as Residential, the farther-out areas as Rural, and parts of the Appalachians and the Delmarva Peninsula as Quiet Rural.

[19] *See, e.g.,* VOACAP, *Setting VOACAP Input Parameters*, https://www.voacap.com/setup html.

Figure 11 – Classification of human-made noise



3.2.3. Noise Analysis

VOACAP calculates the three types of noise described above for each prediction point and power sums them to derive the total noise. Galactic noise and atmospheric noise are calculated based on the input frequency, time of day, and month. For human-made noise, the user must input the expected value at 3 MHz, which VOACAP then extends to the study frequency using the curves of ITU-R P.372-15.

For each scenario in this study we ran VOACAP in area mode four times, with the human-made noise at 3 MHz set to -140 dBW/Hz, -145 dBW/Hz, -150 dBW/Hz, and -164 dBW/Hz, which are the recommended values for City, Residential, Rural, and Quiet Rural respectively. In post-processing, we created a single composite noise map by using the population density to classify each grid point and selecting the calculated noise from the corresponding VOACAP run for that grid point.

Figure 12 and Figure 13 show examples of the resulting noise map for two scenarios. In both figures, we can see that population density is a significant driver of noise levels. Thus, the highest noise levels are in cities, and noise levels in the Eastern United States generally are higher than noise levels in the west. Comparing the two figures, we also see higher noise in Figure 13 than Figure 12, as Figure 13 is lower frequency than Figure 12, 14.9 MHz versus 19.9 MHz.

Figure 12 – Noise example

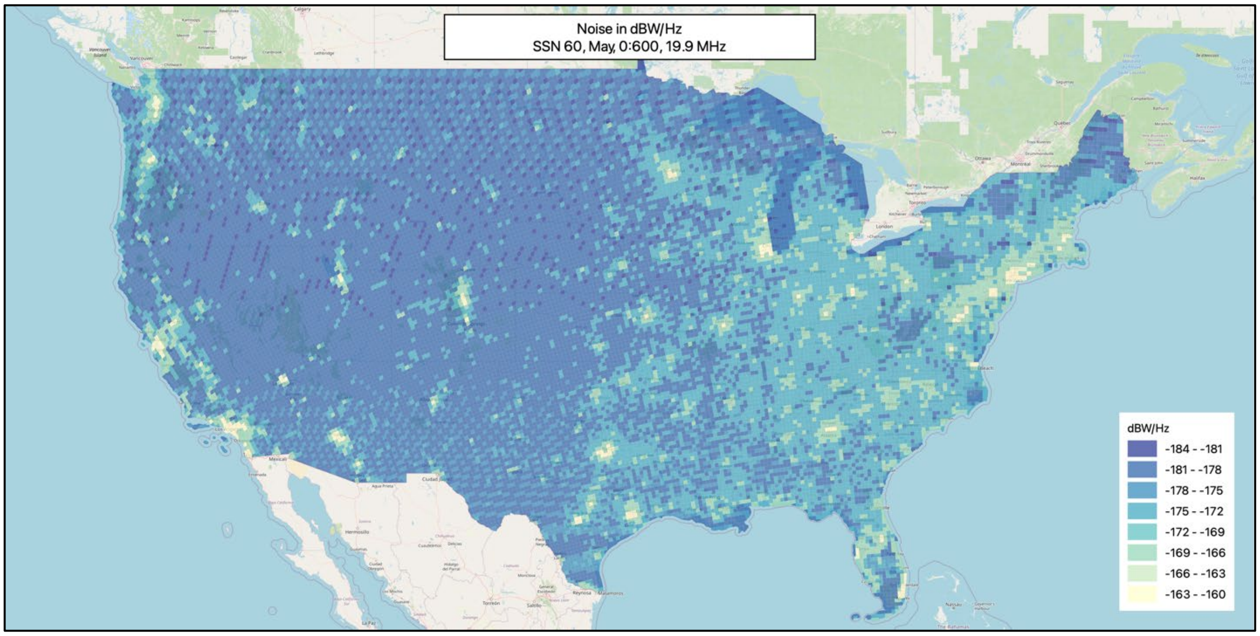
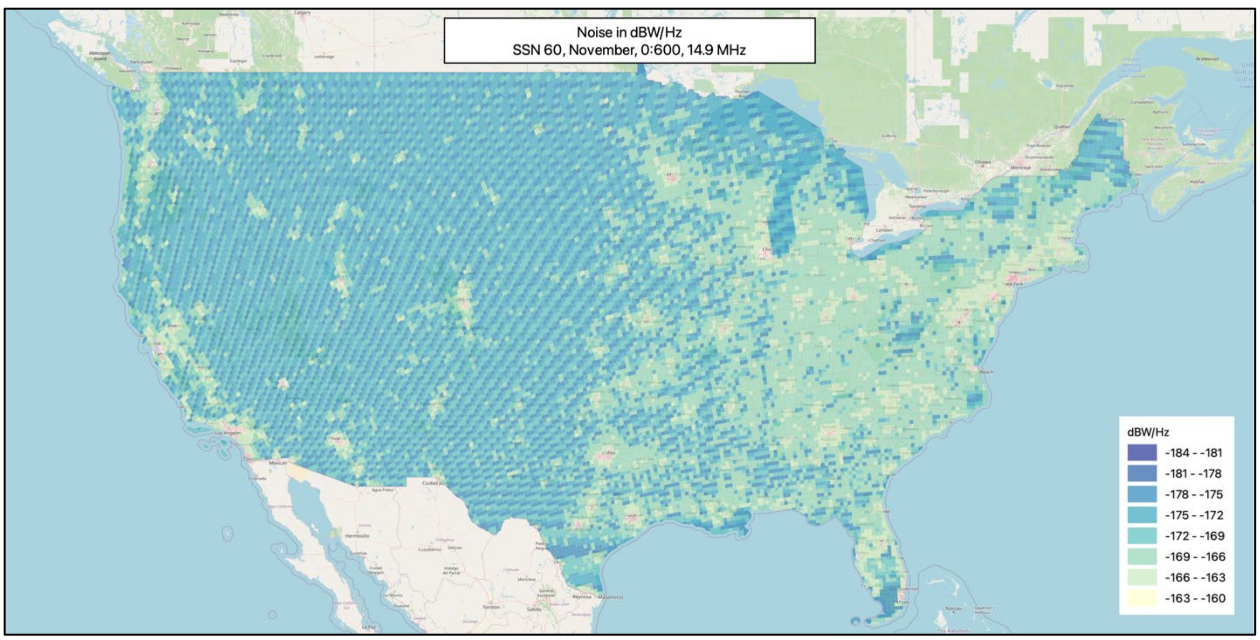


Figure 13 – Noise example



3.3. Propagation and Signal Power

For this analysis we ran VOACAP in area mode, which uses the VOACAP propagation model to determine path loss and signal strength from a single transmitter to a number of receive points arranged in a grid. Area mode also calculates noise at each receiver grid point. We used a 20-km grid.

For each of the four transmitter cases analyzed, we ran 360 scenarios: 3 values for SSN, 5 values for frequency, 4 values for season, and 6 values for time of day. As mentioned in Section 3, it is necessary to run four levels for each noise scenario, so we ran the VOACAP area prediction a total of 5,760 times.

We then adjusted each prediction of signal strength to account for three factors: (1) transmit bandwidth, (2) co-channel versus adjacent channel, and (3) antenna patterns.

We used a transmit power of 20 kW, which we input as 16 kW in accordance with the VOACAP suggestion that the total radiated power is 80 percent of the transmitter power.[20] Put another way, we assume 1 dB of losses in the transmission lines and antenna connections. VOACAP's signal strength predictions are continuous wave (CW), which means that VOACAP assumes all of the transmit power is in a 1 Hz bandwidth, as is the received power.[21] Accordingly, we adjusted this for our signal's 10 kHz bandwidth by subtracting $10*\log_{10}(10{,}000 \text{ Hz})$, or 40 dB, from the VOACAP signal strength. This gave us the co-channel PSD in dBW/Hz, comparable to and in the same units as the predicted noise.

For the adjacent-channel PSD, we examined five scenarios: subtracting 30 dB, subtracting 35 dB, subtracting 40 dB, subtracting 45 dB, and subtracting 50 dB. Therefore, instead of the on-channel transmit PSD of 3 dBW/Hz, we considered adjacent channel PSDs of -27, -32, -37, -42, and -47 dBW/Hz.

We also accounted for the horizontal and vertical patterns of the transmit and receive antennas. Although VOACAP does have some antenna support, it is not appropriate for this analysis. This is because VOACAP calculates the signal strength assuming that antennas are reoriented to maximize reception. That is, in VOACAP the antennas are reoriented for the desired signal, but we are interested in the undesired signal. Therefore, we configured VOACAP to use isotropic antennas for transmit and receive, effectively obtaining the propagation without accounting for antennas, which we then added in post-processing.

For each point analyzed, we determined the azimuth from the transmitter to the receive point, the elevation angle at the transmitter, and the elevation angle at the receiver. For elevation, VOACAP provides the takeoff angle from the transmitter for the path to the receive point as well as the elevation angle at the receiver.[22] For azimuth, we compare the azimuth to the receive point to the azimuth of the main beam to get the horizontal angle relative to the antenna pattern. Using the transmit antenna angles, the transmit antenna patterns, and the peak transmit antenna gain of 10 dBi, we obtained the net transmit antenna gain to the point being analyzed. Since the receive antenna is omnidirectional (equal gain in the horizontal plane), we only need the elevation angle, the vertical pattern of the receive antenna, and the peak gain of 0 dBi for the receiver antenna to get the net receive antenna gain at the analysis point. We then use the transmit and receive antenna gain to adjust the signal strength accordingly.

Figure 14 and Figure 15 show two examples of the resulting signal strength predictions and demonstrate significant variations in both signal strength and the location of the strongest signal at different frequencies and times of day. In Figure 14, the signal is strong near the Chicago transmitter and also in

[20] The online version automatically applies 80 percent, *see* https://voacap.blogspot.com/2018/06/voacap-online-hf-predictions-users.html. Other documents on voacap.com recommend more loss, such as https://www.voacap.com/10mistakes html (70 percent) and https://www.voacap.com/setup html (65 percent). We stayed with 80 percent to be conservative.

[21] The use of power per Hz can be verified by running VOACAP and comparing the received power, SNR, and noise levels, which show that the power is in the same units as the noise, which is dBW/Hz, *see, e.g.*, VOACAP, *Textual Circuit Prediction*, https://www.voacap.com/circuit html.

[22] *See, e.g.*, *id.*

the southwestern U.S., but it is weaker in the central U.S. and the south. By contrast, in Figure 15 the signal is weaker in western U.S., and stronger in the central and southern U.S. where the Figure 14 signal was the weakest. The impact of the transmit antenna pattern also is visible around Chicago in both figures with stronger signal to the northeast where the antenna main beam is directed and noticeable nulls to the northwest and southeast.

Figure 14 – Signal strength example, Chicago transmitting east

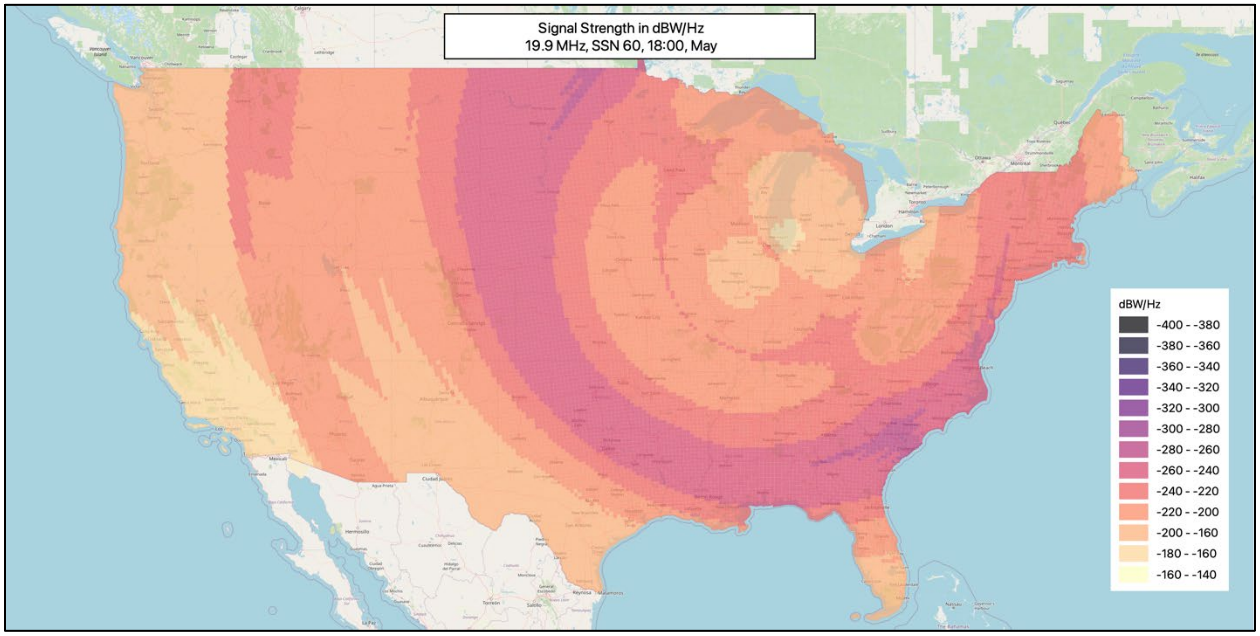
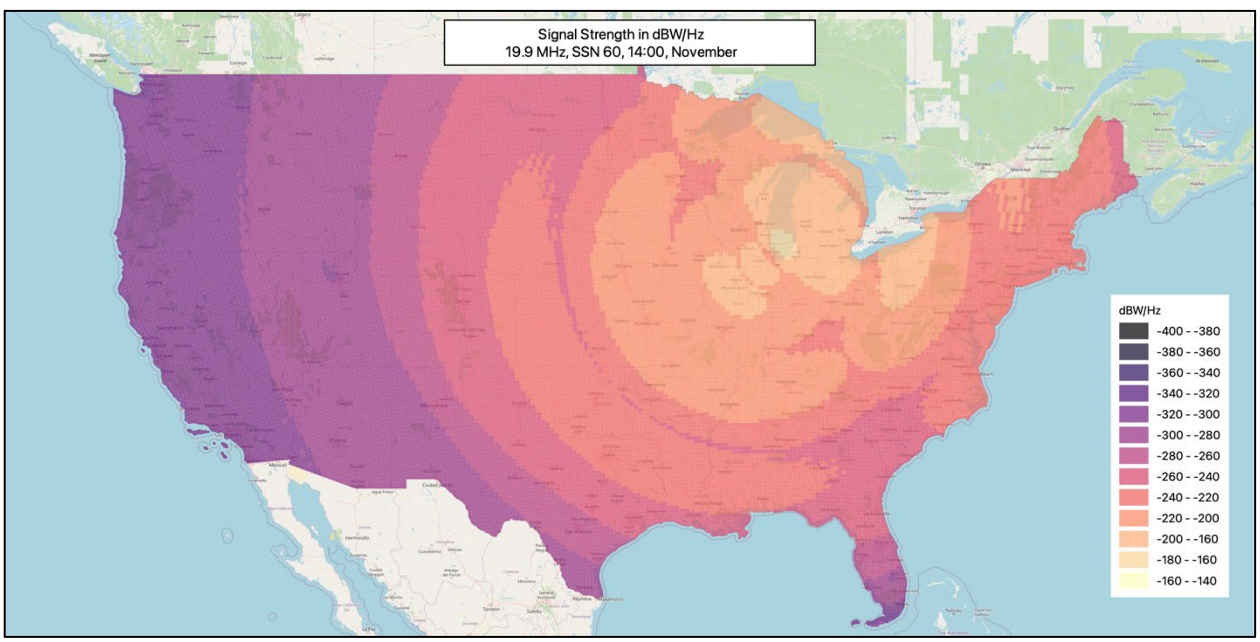


Figure 15 – Signal strength example, Chicago transmitting east



3.4. Power and Noise Comparison

For each scenario, we compared the potentially-interfering signal power from the transmitter to the noise at each prediction point. We did so by subtracting the noise in dBW/Hz from the predicted signal power in dBW/Hz. This difference is commonly known as the interference-to-noise ratio, or I/N.

Example I/N plots for a number of scenarios are presented in the appendices. Each appendix shows plots varying one input parameter while the other three input parameters are held constant. Aggregate data summarizing the 360 scenarios for each transmit case are shown in the next section.

I/N is commonly used for interference analyses, although there are significant drawbacks to using I/N as an interference metric. This is because interference is determined by S/(I+N), where S is the strength of the desired signal and I+N is the sum of all sources of interference and noise. This ratio is often referred to as SINR (signal-to-interference-and-noise ratio). A low I/N indicates no or minimal change to the SINR, while a high I/N indicates some reduction in SINR, which may or may not be material. Consequently, a low I/N can show that a new source of power has no impact on incumbent users. But a high I/N only shows that the SINR is reduced, which is not necessarily indicative of an increased likelihood that harmful interference could occur. For example, mobile voice systems have a maximum distance, driven by path loss, at which they can communicate. But when they communicate at less than the maximum distance, SINR margins are significant, such that a rise in the noise floor would not be audible. In the 2-25 MHz Band, noise varies significantly, and users often have to try several channels to find one that works. In sum, negative I/N values generally indicate harmful interference is very unlikely, but positive I/N ratios are ambiguous and do not necessarily represent an impact to operations.

4. Results

This section presents the results of the study for fixed, long-distance, non-voice transmissions where the transmitter is operating (1) on a co-channel basis with other 2-25 MHz Band users and (2) on an adjacent-channel basis with other 2-25 MHz Band users. The appendices to this study contain additional maps that illustrate how different parameters can cause significant variation in the resulting plots. However, the tables in this section summarize all scenarios run, not the just the small number of specific examples plotted as maps in this section and the appendices. Ultimately, consideration of all of the analyses leads to the conclusions that:

(1) co-channel interference could occur at some times and places, but is sufficiently limited to enable the prevention of *harmful* interference, provided that licensees are granted multiple Part 90 2-25 MHz Band frequencies throughout the Industrial/Business Pool, and licensees use those diverse 2-25 MHz Band frequencies with frequency agile techniques, and

(2) with an attenuation of 35 dB for out-of-band emissions, harmful interference to spectrally adjacent and out-of-band services is extremely unlikely.

4.1. Co-channel Results

The results in this section apply when two users of the band are co-channel. It is worth noting that, given the relatively small bandwidths used by typical 2-25 MHz services, hundreds or thousands of channels are available in the Part 90 Industrial/Business Pool. At a 3 kHz bandwidth, as is sometimes used in analog voice transmissions, there are 3,600 potential non-overlapping channels. At the 10 kHz bandwidth used for calculation in this study there are potentially 1,071 channels, and even at a 50 kHz bandwidth, as might be used for higher data rates, there are 200 channels. Details of these channel counts are given in

Appendix E. In short, even with the use of 2-25 MHz Band frequencies pursuant to Part 90 contemplated by the SMC member companies' Petition for Rulemaking, co-channel transmission will not necessarily be a common occurrence in the 2-25 MHz Band.

Regardless, the results of our co-channel analysis show that much of CONUS is free of potential harmful interference between co-channel operations, especially at higher frequencies closer to 25 MHz, as shown in Tables 2 through 5 below. Although significant parts of CONUS have poor I/N at some frequencies and times, this does not necessarily indicate increased risk of harmful interference. In addition, the specific areas in which the I/N is high vary by scenario. For example, comparing the first two plots in Appendix D, which show Chicago transmitting east at 4.9 MHz and 10.2 MHz at an SSN of 60 at 18:00 in May, we see that while 4.9 MHz transmissions are above the noise floor around Chicago in this scenario, the 10.2 MHz transmissions in the same scenario are strongest farther away, and below the noise floor in the areas near Chicago where the 4.9 MHz transmissions were above the noise floor. Thus, co-channel interference might have the potential to occur in some cases, but co-channel operations will also often be able to coexist. As expected, if the FCC continues to allow prospective licensees to apply for multiple Part 90 2-25 MHz Band frequencies throughout the Industrial/Business Pool and encourages licensees to use those diverse 2-25 MHz Band frequencies with frequency agility techniques, that should be sufficient to manage co-channel operations. This simple solution will enable licensed users to change channels whenever they realize that communications are impaired on their current channel.

Figures 16 through 19 show example I/N plots for the four transmit cases studied. Each of these plots is for the same hour, month, SSN, and frequency to facilitate comparison. In each of these figures the transmit antenna pattern is fairly visible, especially for the cases where the transmitter is in Chicago. We also see that for an SSN of 60 at 06:00 in May using 19.9 MHz, the strongest signal is generally not near the transmitter, but rather in the western U.S. Greens and blues indicate signal below the noise floor, which generally covers the entire eastern and mid-western U.S., and as indicated in the figure titles, means the potential interference is below the noise floor for 82 percent to 100 percent of the CONUS population in these cases. These are examples, and the results can be quite different for other times, SSNs, and frequencies. Therefore, in the next part of this section we summarize the results of all scenarios, not just these examples, to draw meaningful conclusions over the full set of possibilities.

Figure 16 – New York transmitting west co-channel example

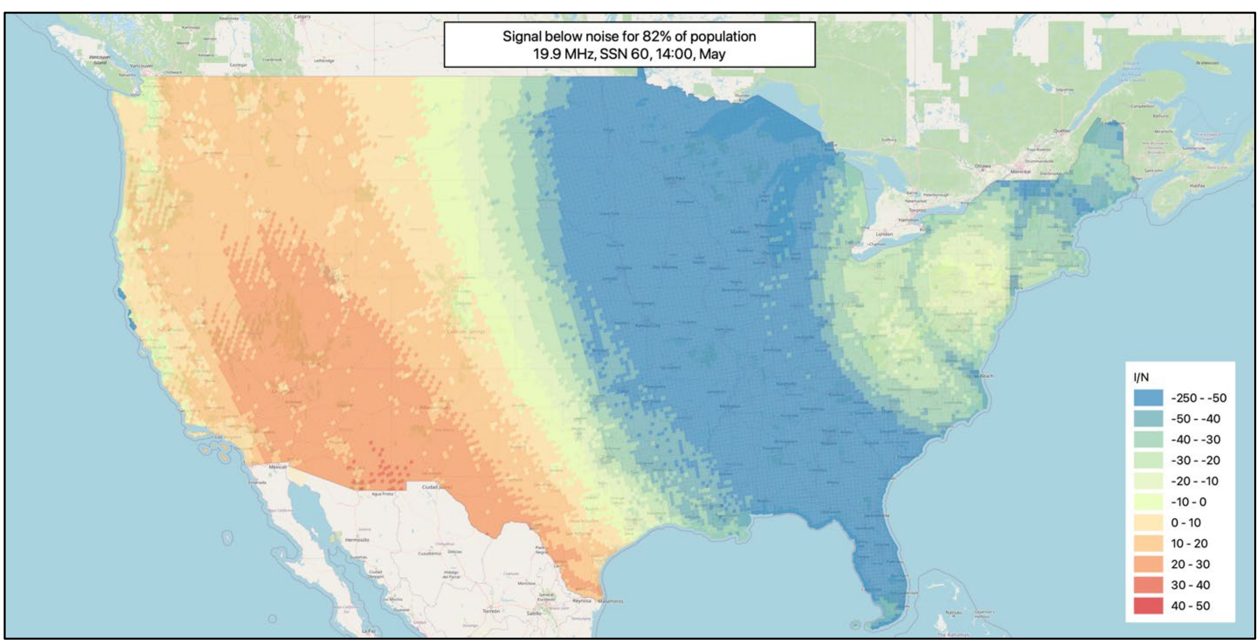


Figure 17 – Chicago transmitting west co-channel example

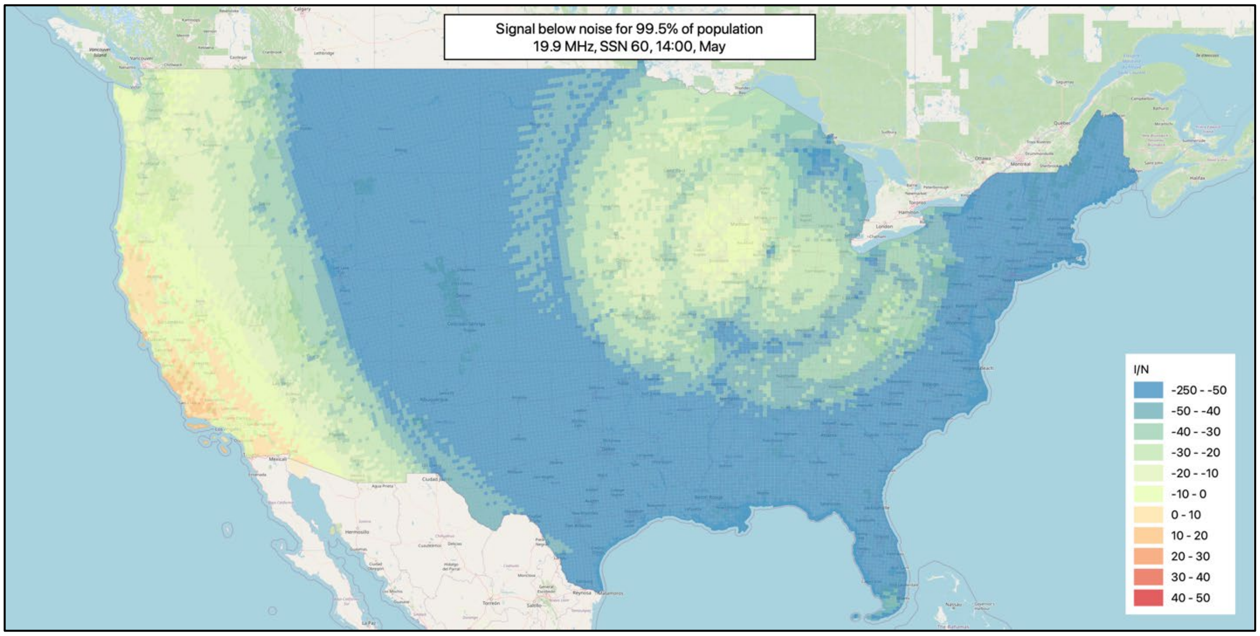


Figure 18 – New York transmitting south co-channel example

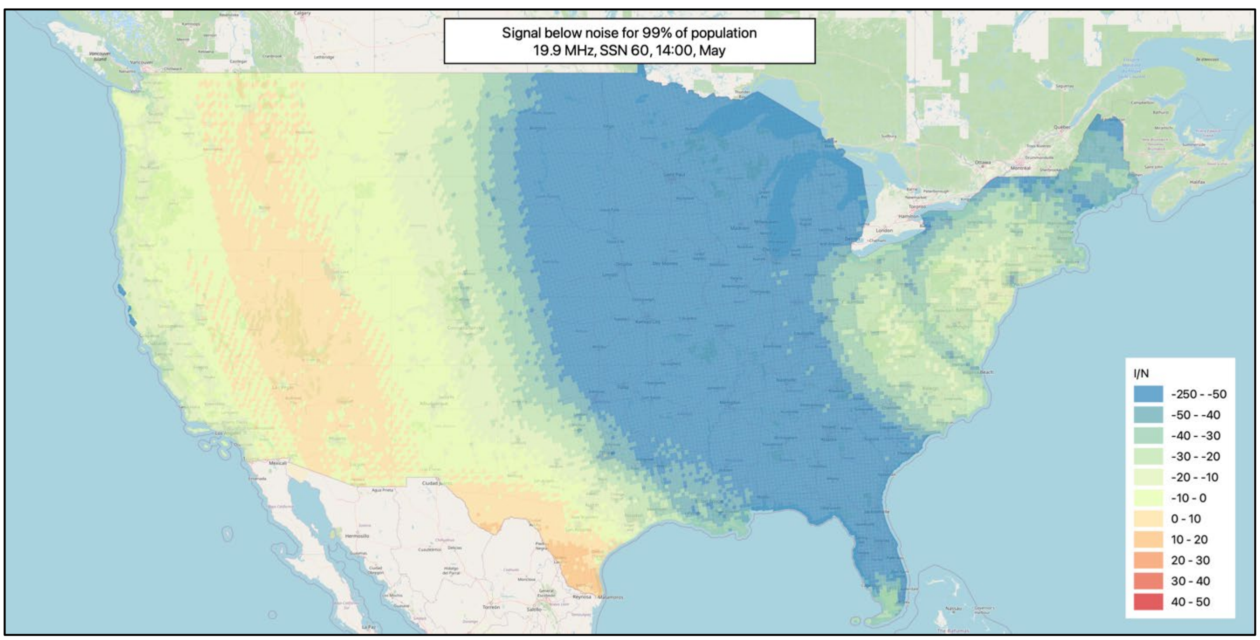
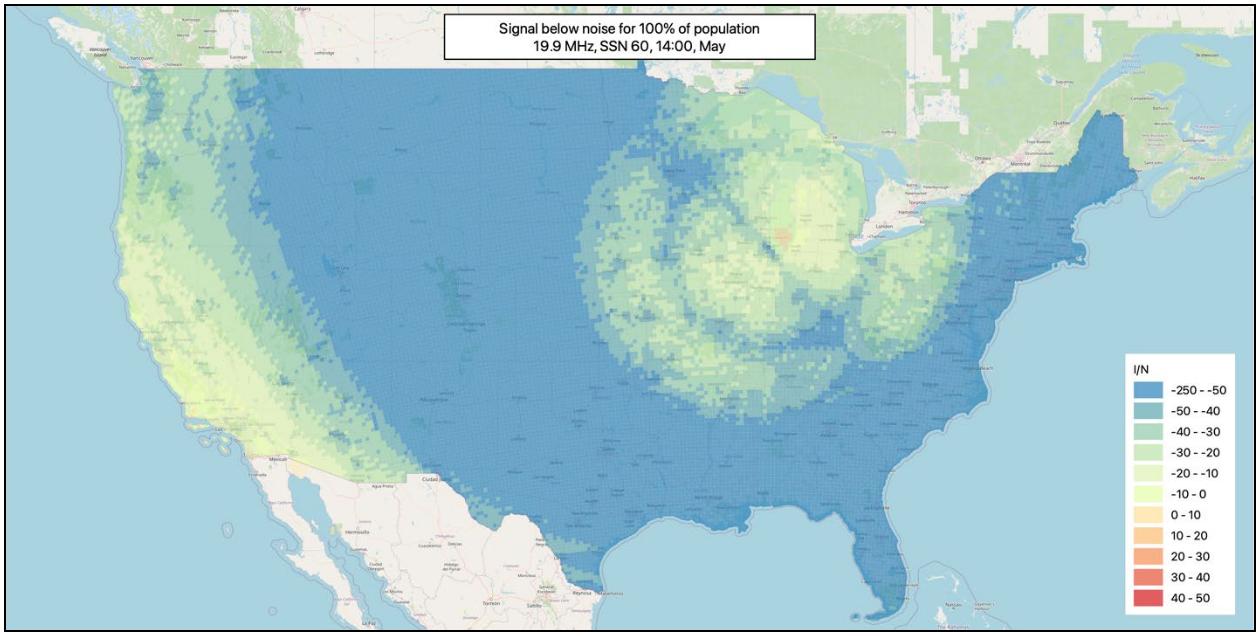


Figure 19 – Chicago transmitting east co-channel example



The appendices show examples of how these geographic plots vary by parameter, causing significant variation in the results. To summarize the 360 scenarios for each link, we aggregated them per SSN per frequency. That is, for each SSN and frequency pair, there are 24 scenarios per link: 6 times of day repeated in each of the four seasons. We calculated the percentage of CONUS population where a receiver would have a negative I/N in each of those 24 scenarios if it was co-channel with the transmitter. We then averaged those scenarios to derive a representation of that SSN and frequency combination over a year. In doing so, we calculated the average percentage of population-weighted locations where the signal from the long-distance 2-25 MHz Band transmitter would be below the noise floor on its transmit channel. Table 2, Table 3, Table 4, and Table 5 show these results for each link.

Table 2 – New York transmitting west, percentage of CONUS population with long-distance 2-25 MHz signal below noise floor

	SSN 0	**SSN 60**	**SSN 120**
4.9 MHz	35%	35%	39%
10.2 MHz	54%	39%	33%
14.9 MHz	79%	65%	53%
19.9 MHz	96%	79%	71%
24.8 MHz	99.4%	95%	81%

Table 3 – Chicago transmitting west, percentage of CONUS population with long-distance 2-25 MHz signal below noise floor

	SSN 0	**SSN 60**	**SSN 120**
4.9 MHz	31%	32%	35%
10.2 MHz	52%	39%	34%
14.9 MHz	84%	68%	60%
19.9 MHz	96%	86%	77%
24.8 MHz	99%	96%	90%

Table 4 – New York transmitting south, percentage of CONUS population with long-distance 2-25 MHz signal below noise floor

	SSN 0	SSN 60	SSN 120
4.9 MHz	47%	47%	50%
10.2 MHz	68%	53%	48%
14.9 MHz	85%	74%	66%
19.9 MHz	98%	88%	80%
24.8 MHz	99.9%	96%	90%

Table 5 – Chicago transmitting east, percentage of CONUS population with long-distance 2-25 MHz signal below noise floor

	SSN 0	SSN 60	SSN 120
4.9 MHz	39%	41%	45%
10.2 MHz	60%	45%	37%
14.9 MHz	87%	71%	63%
19.9 MHz	97%	90%	81%
24.8 MHz	99.9%	96%	92%

As these tables demonstrate, we find for the higher frequencies that the signal is below the noise floor for much of the population, up to 99.9 percent in some cases. But for 4.9 MHz and 10.2 MHz the percentage of the population where the signal is below the noise floor is smaller. We can also see the percentage of population where the signal is below the noise floor is lower for the western transmission than the southern or eastern transmissions, which is to be expected as the western paths lie over more of CONUS than the other paths. The lowest percentages of population where the signal is below the noise floor occur in the Chicago transmitting west case.

Therefore, although signal above the noise floor by no means guarantees interference, we conclude that co-channel interference is a possibility, and the possibility that it could occur is not limited by proximity to the transmitter or to certain geographic areas within the U.S. However, as discussed above, the specific areas where interference could occur vary by frequency, and many channels are available on similar frequencies. Thus, if the FCC continues to allow prospective licensees to apply for multiple Part 90 2-25 MHz Band frequencies throughout the Industrial/Business Pool and encourages licensees to use those diverse 2-25 MHz Band frequencies with frequency agility techniques, this can prevent harmful interference.

4.2. Out-of-Band Results

This section of the study analyzes the amount of out-of-band attenuation that is required to make harmful interference with services in adjacent spectrum unlikely. That is, it analyzes how various attenuation levels affect the percentage of CONUS population with potential interference below the noise floor. As mentioned above, this is conservative, as potential interference above the noise floor does not necessarily result in harmful interference.

As in the previous section, the lowest percentages of population with signal above the noise floor are for the Chicago transmitting west case. Looking at the co-channel results, we estimated that 30 dB or more of attenuation would greatly reduce the risk of harmful interference. To check this estimate, we ran this same transmit case with five attenuation levels: 30 dB, 35 dB, 40 dB, 45 dB, and 50 dB. Figure 20, Figure 21, and Figure 22 show example plots for the same example scenarios plotted in the previous section but at 30, 40, and 50 dB of attenuation. In all three figures 100 percent of the CONUS population would receive power below the noise floor. As before, our conclusions are based on looking at all scenarios, not just the few examples in these plots. All scenarios for all five attenuation levels are summarized in the tables in the next part of this section.

Figure 20 – Example OOBE plot, Chicago transmitting west, 30 dB attenuation

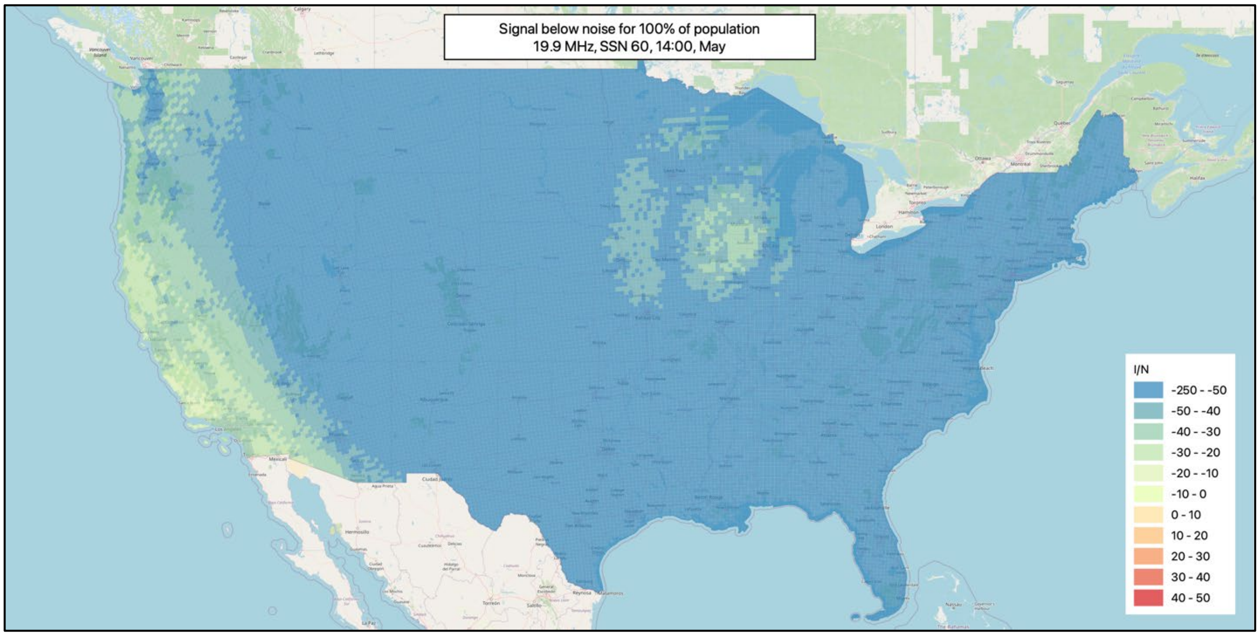


Figure 21 – Example OOBE plot, Chicago transmitting west, 40 dB attenuation

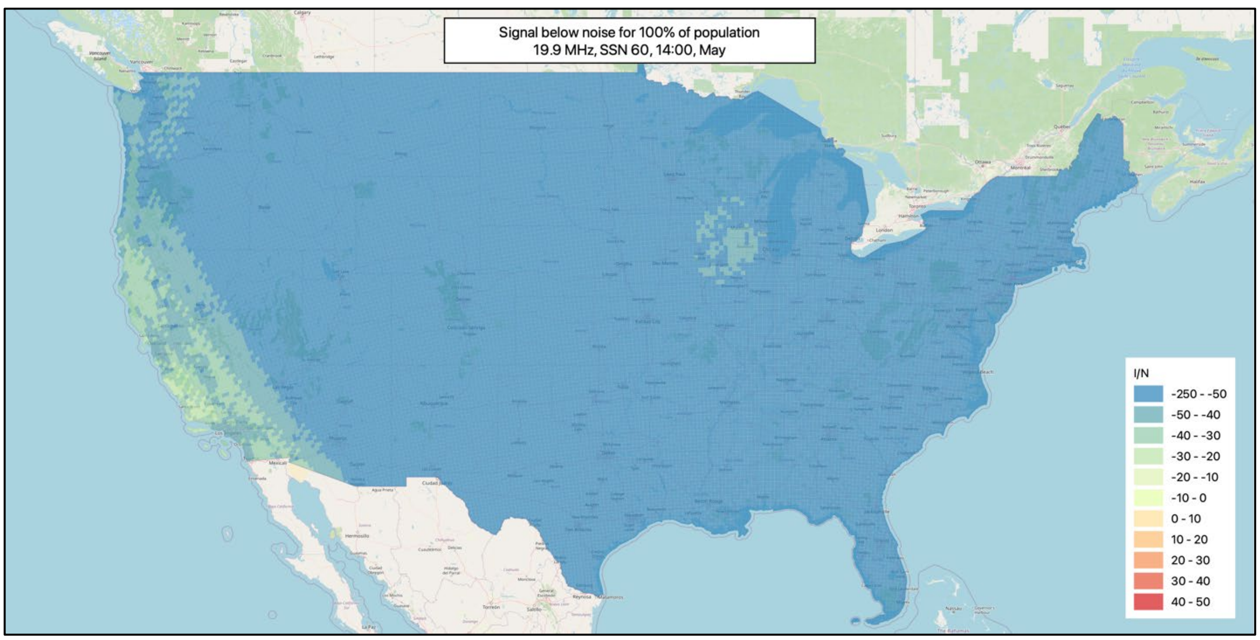
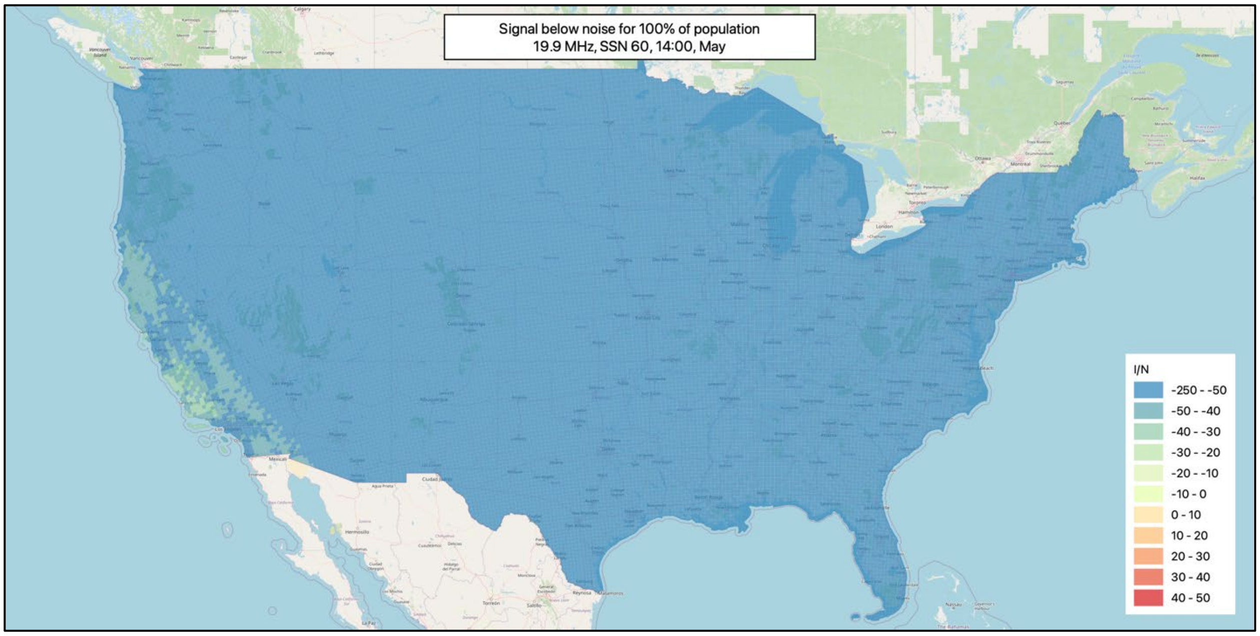


Figure 22 – Example OOBE plot, Chicago transmitting west, 50 dB attenuation



As in the co-channel analysis, to summarize the 360 scenarios for a link, we aggregated them per SSN per frequency to derive a representation of that SSN and frequency combination over a year. Because the Chicago transmitting west case has the lowest co-channel percentages, we examined that case only as a worst case and considered the five attenuation levels discussed above, 30 dB, 35 dB, 40 dB, 45 dB, and 50 dB.

Tables 6 through 10 show the percentage of the CONUS population for which the signal is below the noise floor considering all scenarios. At 35 dB, all the percentages are over 90 percent, and, other than the 4.9 MHz case, all the percentages are 99 percent or higher. Given the conservative nature of the I/N metric and our choice of the worst case, we conclude 35 dB of out-of-band attenuation is sufficient to make adjacent band harmful interference extremely unlikely. At 50 dB of out-of-band attenuation, the signal level is below the noise floor for all of CONUS for all scenarios.

Table 6 – Chicago transmitting west, 30 dB attenuation, percentage of CONUS population with long-distance 2-25 MHz signal below noise floor

	SSN 0	**SSN 60**	**SSN 120**
4.9 MHz	87%	88%	90%
10.2 MHz	98%	96%	95%
14.9 MHz	99%	98%	97%
19.9 MHz	100%	99%	97%
24.8 MHz	100%	99%	99%

Table 7 – Chicago transmitting west, 35 dB attenuation, percentage of CONUS population with long-distance 2-25 MHz signal below noise floor

	SSN 0	**SSN 60**	**SSN 120**
4.9 MHz	94%	95%	96%
10.2 MHz	100%	99%	99%
14.9 MHz	100%	100%	99%
19.9 MHz	100%	100%	99%
24.8 MHz	100%	100%	99%

Table 8 – Chicago transmitting west, 40 dB attenuation, percentage of CONUS population with long-distance 2-25 MHz signal below noise floor

	SSN 0	SSN 60	SSN 120
4.9 MHz	97%	98%	99%
10.2 MHz	100%	100%	100%
14.9 MHz	100%	100%	100%
19.9 MHz	100%	100%	100%
24.8 MHz	100%	100%	100%

Table 9 – Chicago transmitting west, 45 dB attenuation, percentage of CONUS population with long-distance 2-25 MHz signal below noise floor

	SSN 0	SSN 60	SSN 120
4.9 MHz	99%	99%	100%
10.2 MHz	100%	100%	100%
14.9 MHz	100%	100%	100%
19.9 MHz	100%	100%	100%
24.8 MHz	100%	100%	100%

Table 10 – Chicago transmitting west, 50 dB attenuation, percentage of CONUS population with long-distance 2-25 MHz signal below noise floor

	SSN 0	SSN 60	SSN 120
4.9 MHz	100%	100%	100%
10.2 MHz	100%	100%	100%
14.9 MHz	100%	100%	100%
19.9 MHz	100%	100%	100%
24.8 MHz	100%	100%	100%

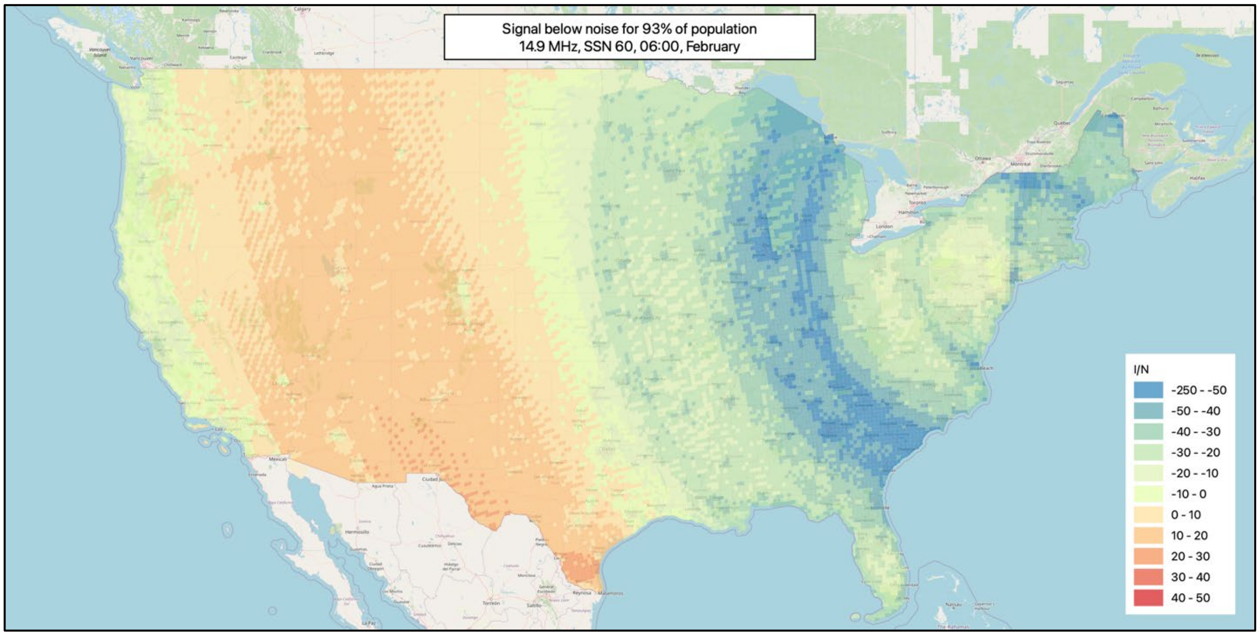
5. Conclusion

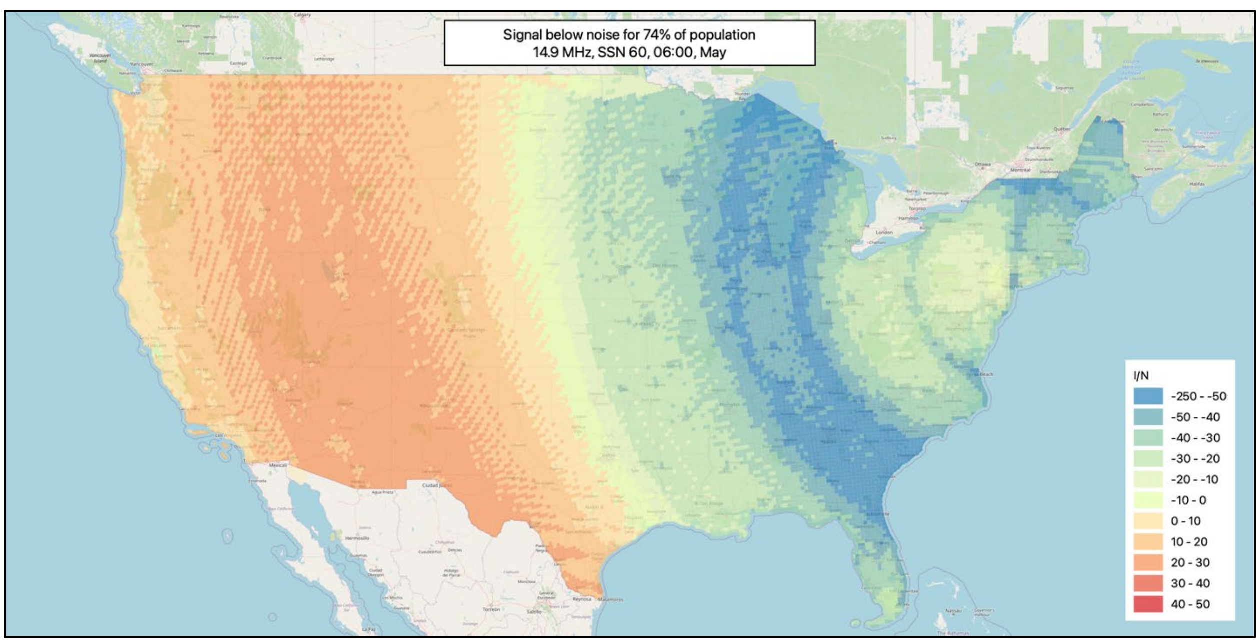
Interference between co-channel users of the 2-25 MHz Band is a possibility and is not limited to areas near the transmitter. However, for many scenarios the potentially interfering signal is below the noise floor over significant portions of CONUS, meaning it cannot cause harmful interference in those areas. In addition, at the transmit bandwidths proposed by the SMC, a large number of potential channels are available for the frequencies allocated to the Part 90 Industrial/Business Pool. Therefore, the risk of co-channel interference is sufficiently limited to enable the prevention of harmful interference, provided that licensees are granted multiple Part 90 2-25 MHz Band frequencies throughout the Industrial/Business Pool, and licensees use those diverse 2-25 MHz Band frequencies with frequency agile techniques.

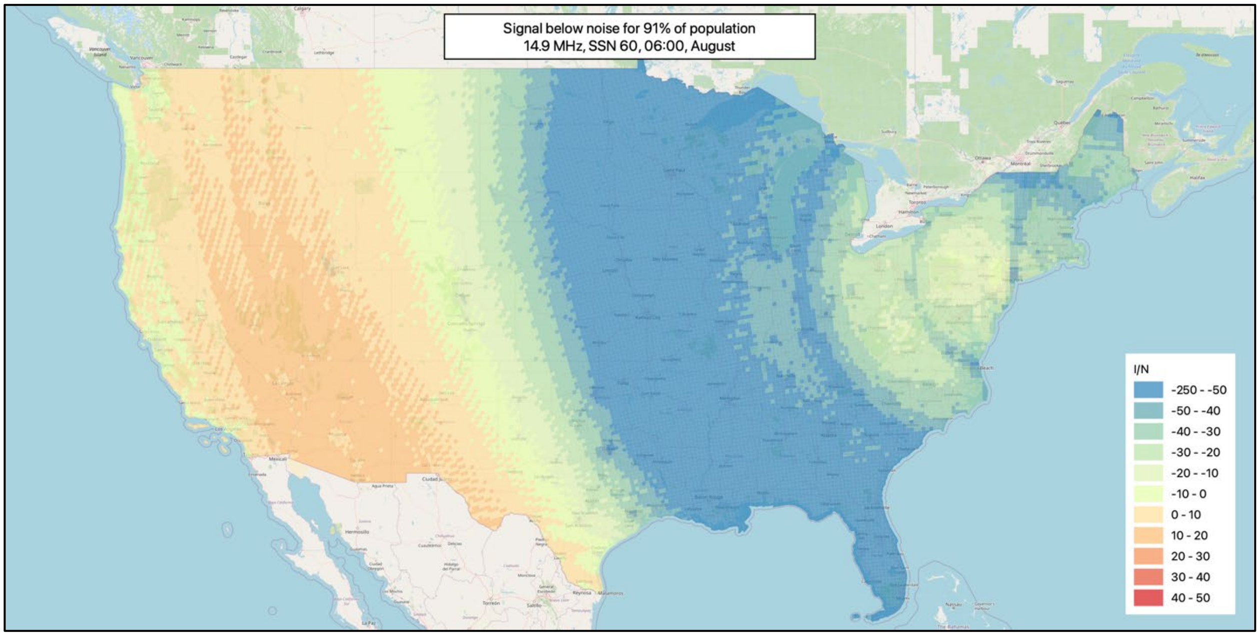
For cases in which 2-25 MHz Band users are not operating on the same channel, if out-of-band emissions are attenuated by 35 dB, adjacent band harmful interference becomes extremely unlikely. Therefore, no special techniques are needed to prevent adjacent channel harmful interference beyond a reasonable out-of-band emissions mask.

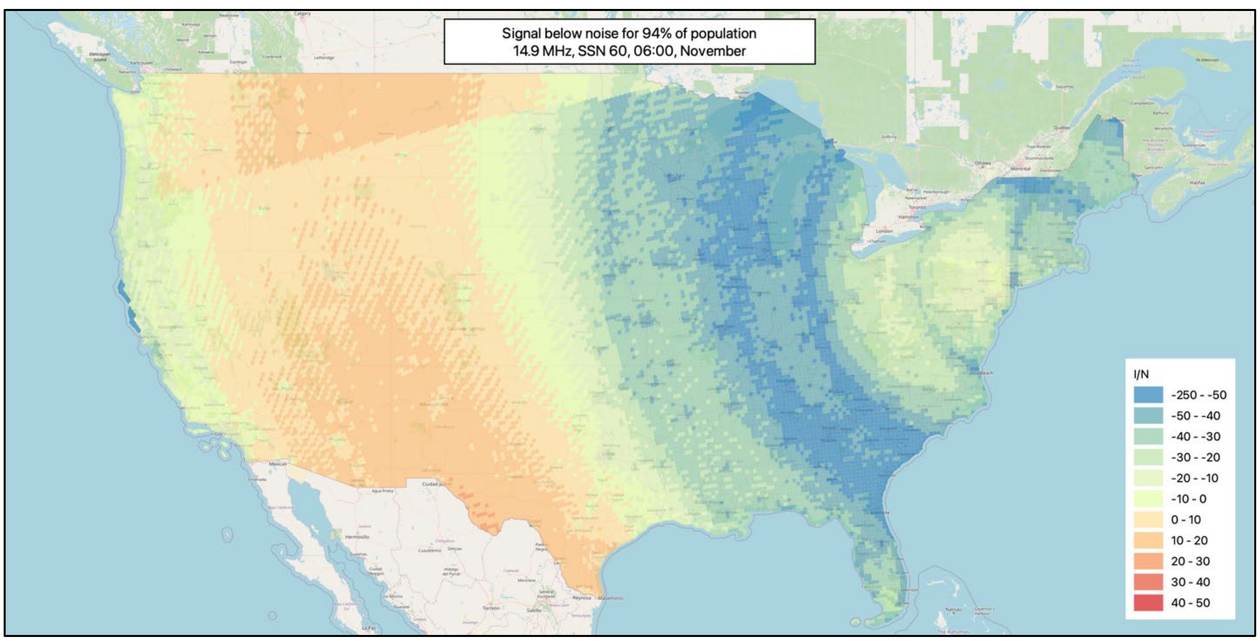
Appendix A – Variation by Season

This appendix shows how the seasons (represented by February, May, August, and November) affect the New York transmitting west case using 14.9 MHz, an SSN of 60, and occurring at 06:00. That is, each plot is using the same parameters except for the season. As can be seen, this particular transmit scenario is similar in all four seasons, but there is significant variation. For example, the area between the Appalachian Mountains and the Mississippi River shows varying amounts of blue, indicating signal levels 50 dB or more below the noise floor, with the lowest signals in the summer (August).



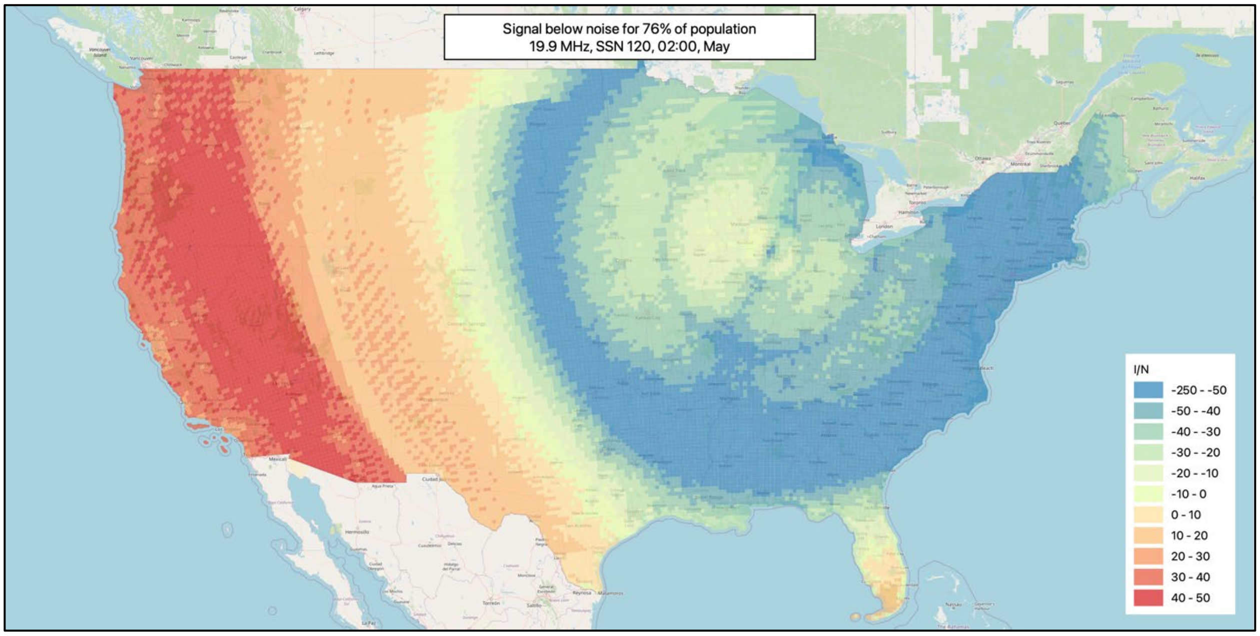


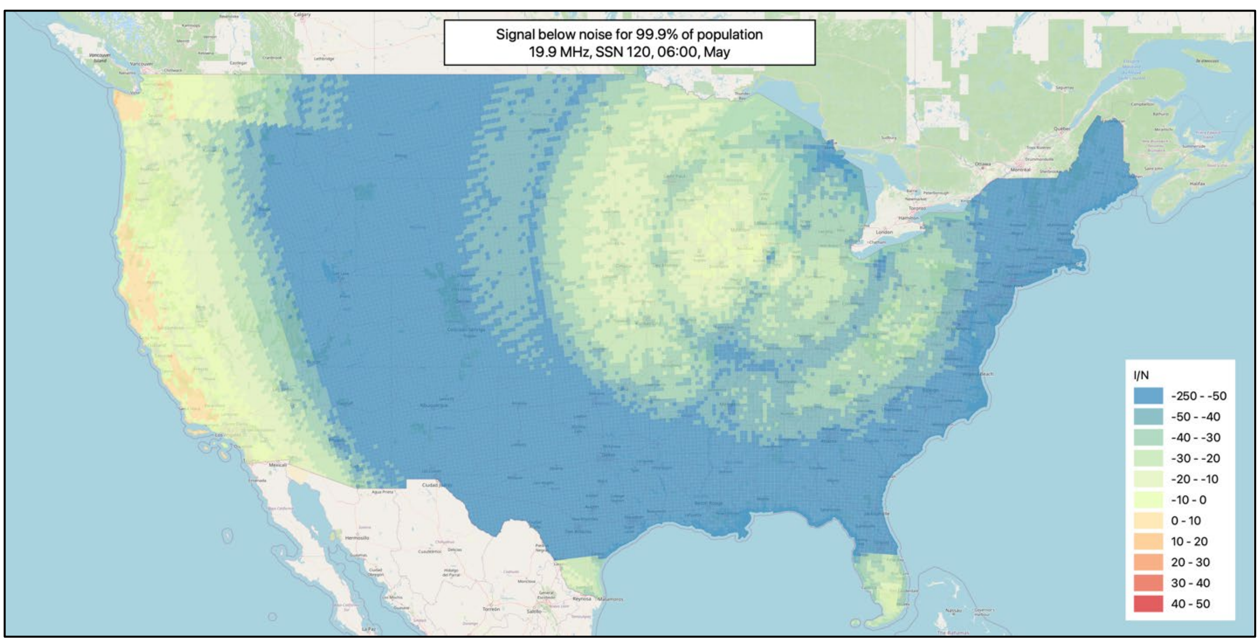

Signal below noise for 91% of population
14.9 MHz, SSN 60, 06:00, August
I/N
-250 - -50
-50 - -40
-40 - -30
-30 - -20
-20 - -10
-10 - 0
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50

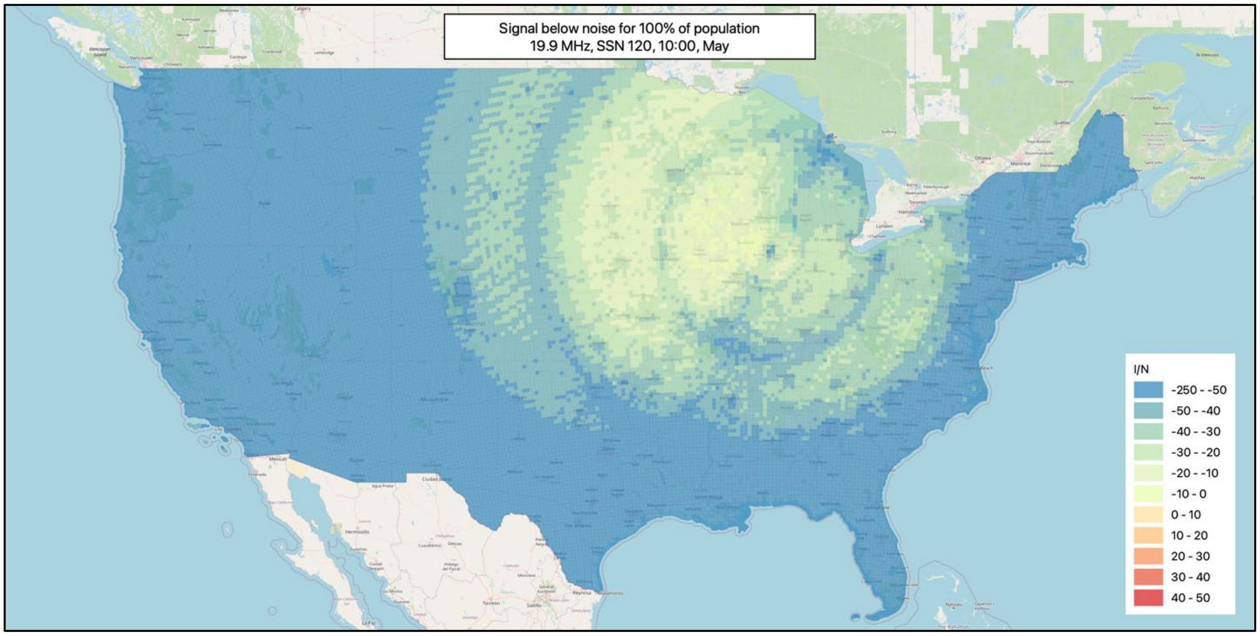

Signal below noise for 94% of population
14.9 MHz, SSN 60, 06:00, November
I/N
-250 - -50
-50 - -40
-40 - -30
-30 - -20
-20 - -10
-10 - 0
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50

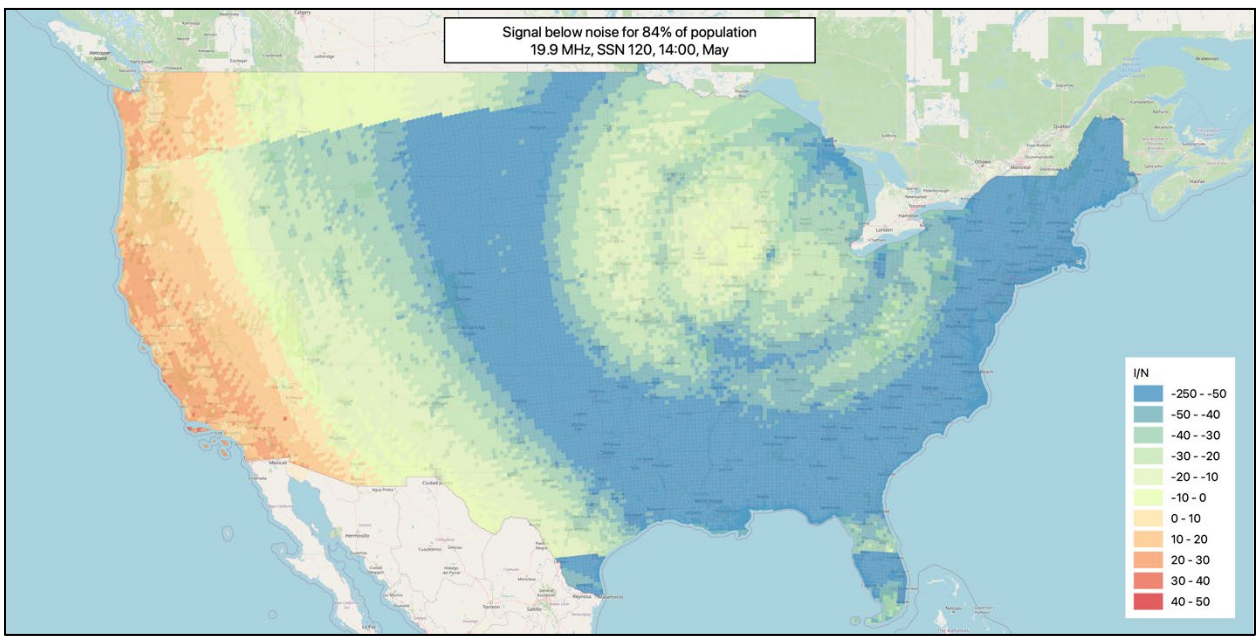
Appendix B – Variation by Hour of Day

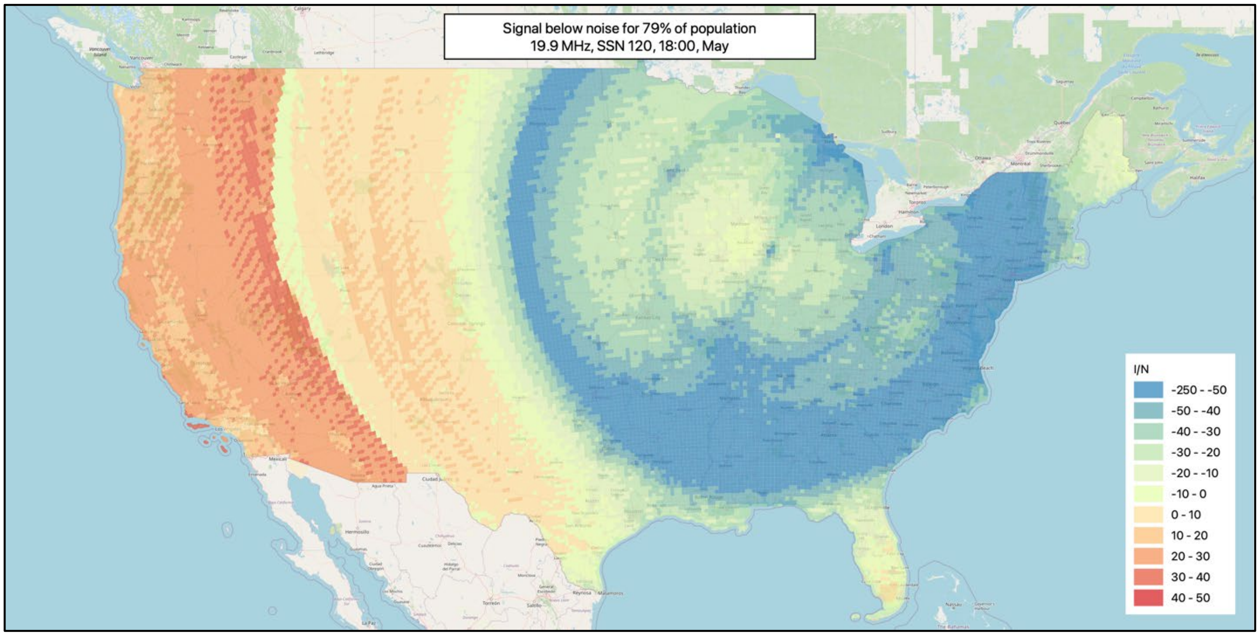
This appendix shows how the time of day affects the Chicago transmitting west scenario using 19.9 MHz, an SSN of 120, and occurring in May. The changes over a day are large. For example, the first plot shows that at 02:00 the West Coast is receiving signals 20-50 dB above the noise floor, while the third plot shows that at 10:00 the signal in the same area is more than 50 dB below the noise floor.

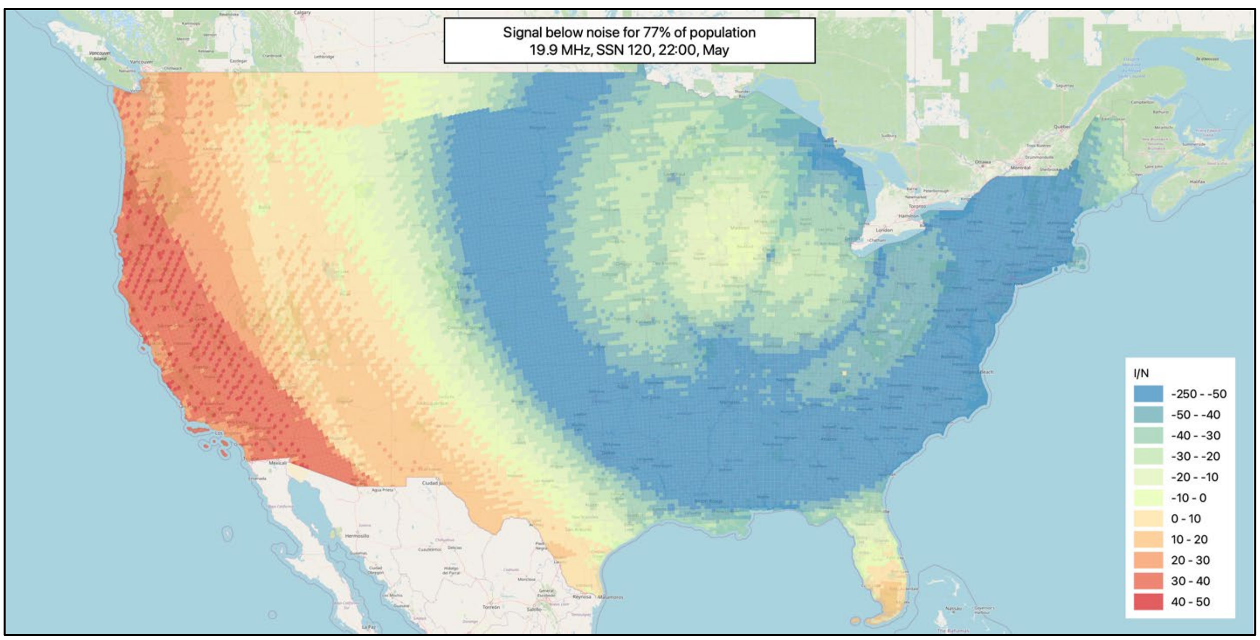





Signal below noise for 100% of population
19.9 MHz, SSN 120, 10:00, May
I/N
-250 - -50
-50 - -40
-40 - -30
-30 - -20
-20 - -10
-10 - 0
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50

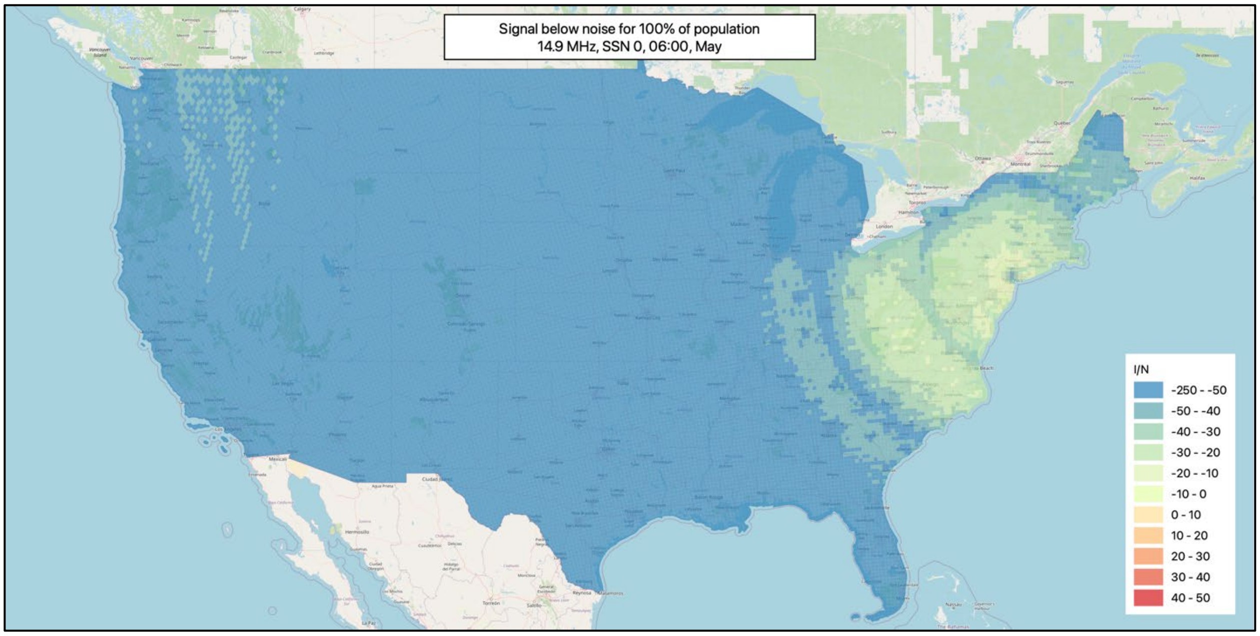

Signal below noise for 84% of population
19.9 MHz, SSN 120, 14:00, May
I/N
-250 - -50
-50 - -40
-40 - -30
-30 - -20
-20 - -10
-10 - 0
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50

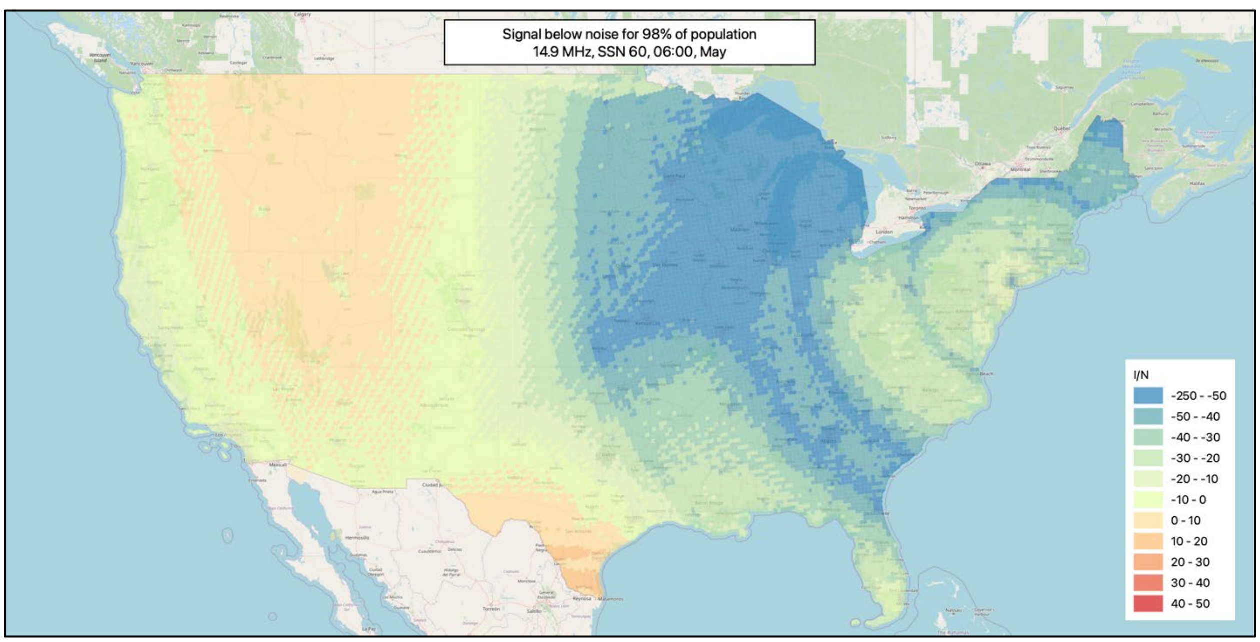

Signal below noise for 79% of population
19.9 MHz, SSN 120, 18:00, May
I/N
-250 - -50
-50 - -40
-40 - -30
-30 - -20
-20 - -10
-10 - 0
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50

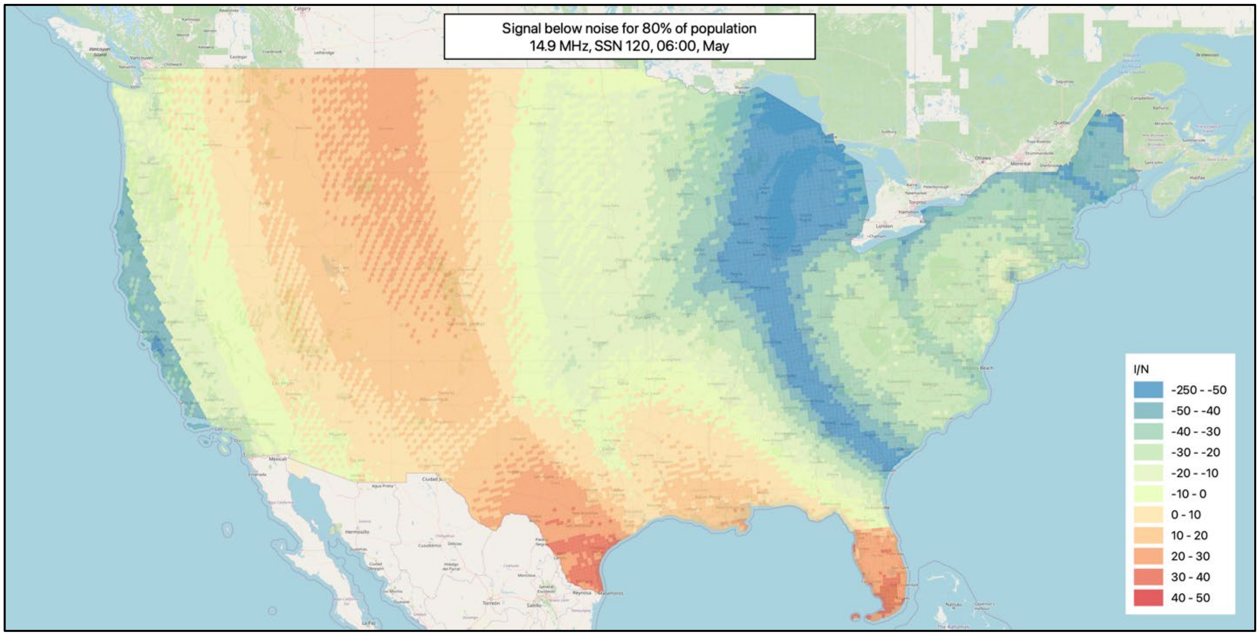

Signal below noise for 77% of population
19.9 MHz, SSN 120, 22:00, May
I/N
-250 - -50
-50 - -40
-40 - -30
-30 - -20
-20 - -10
-10 - 0
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50

Appendix C – Variation by SSN

This appendix shows how the SSN affects the New York transmitting south case using 14.9 MHz at 06:00 occurring in May. The changes are significant, with higher power levels as the SSN increases.

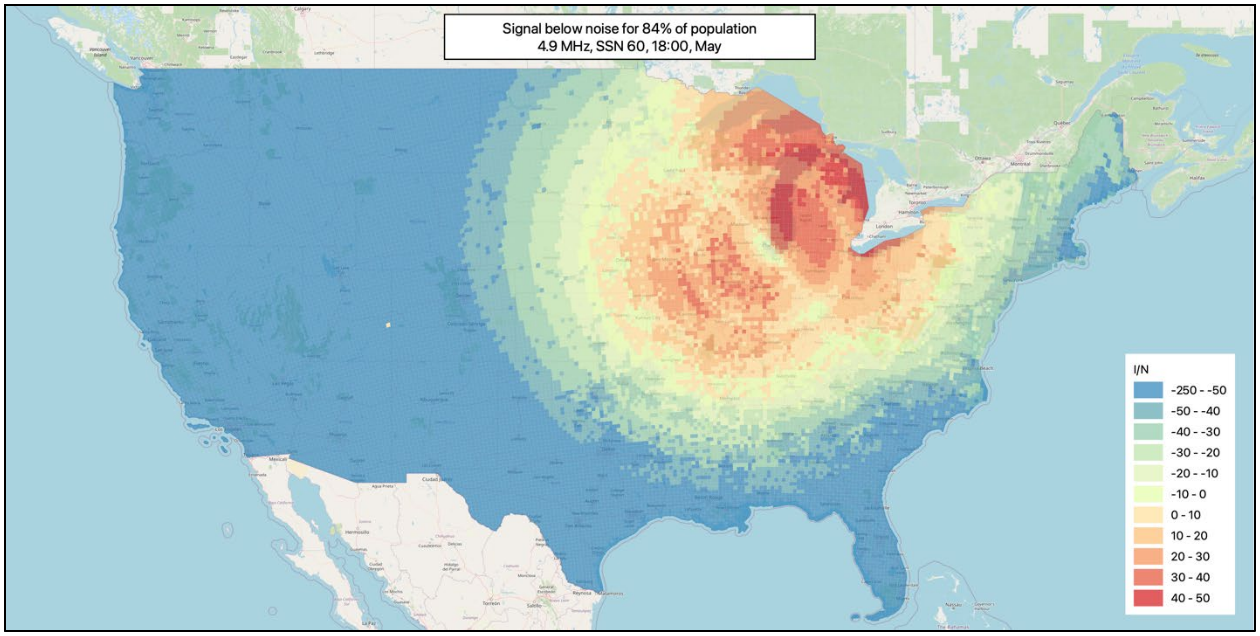


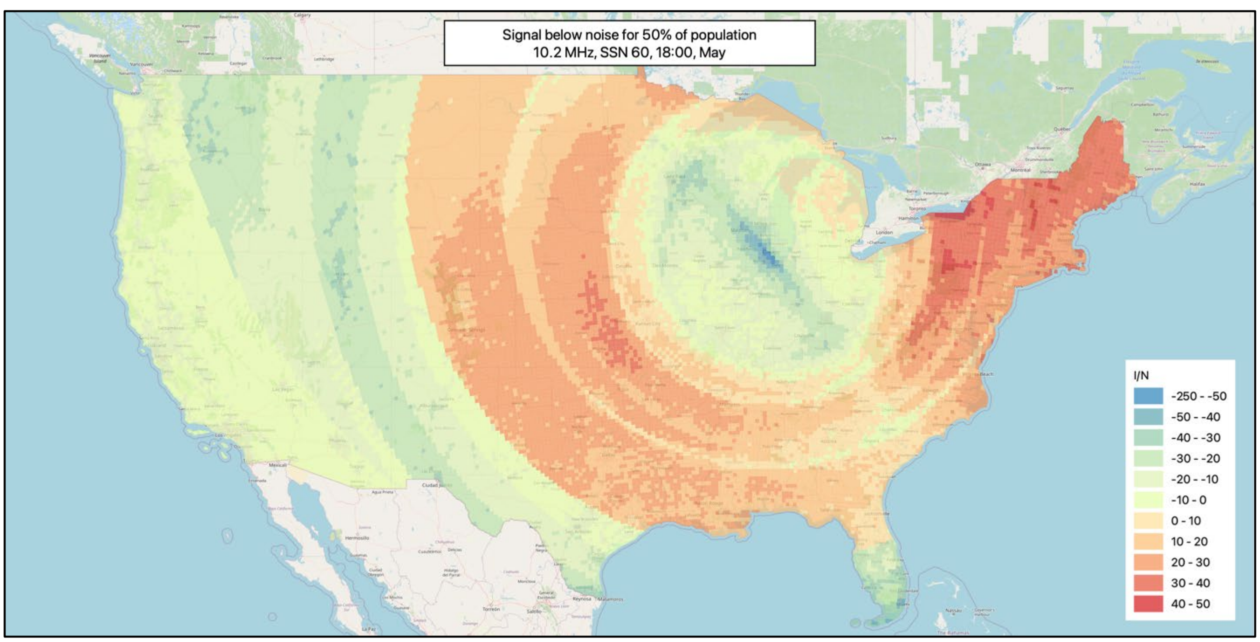


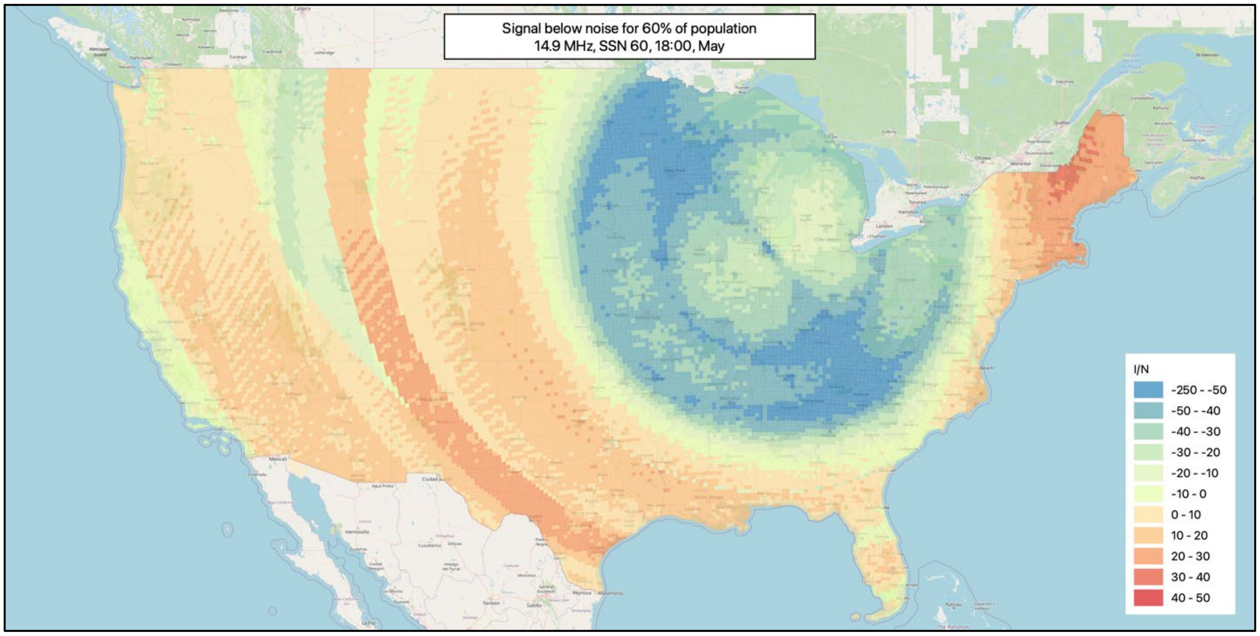

Signal below noise for 80% of population
14.9 MHz, SSN 120, 06:00, May
I/N
-250 - -50
-50 - -40
-40 - -30
-30 - -20
-20 - -10
-10 - 0
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50

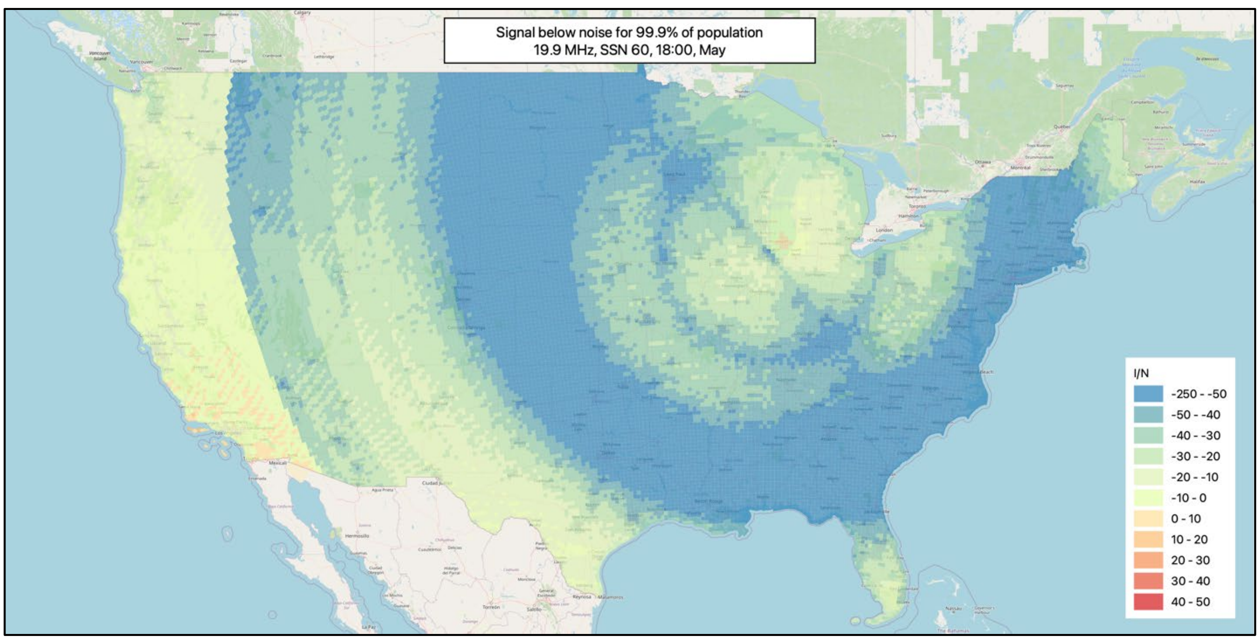
Appendix D – Variation by Frequency

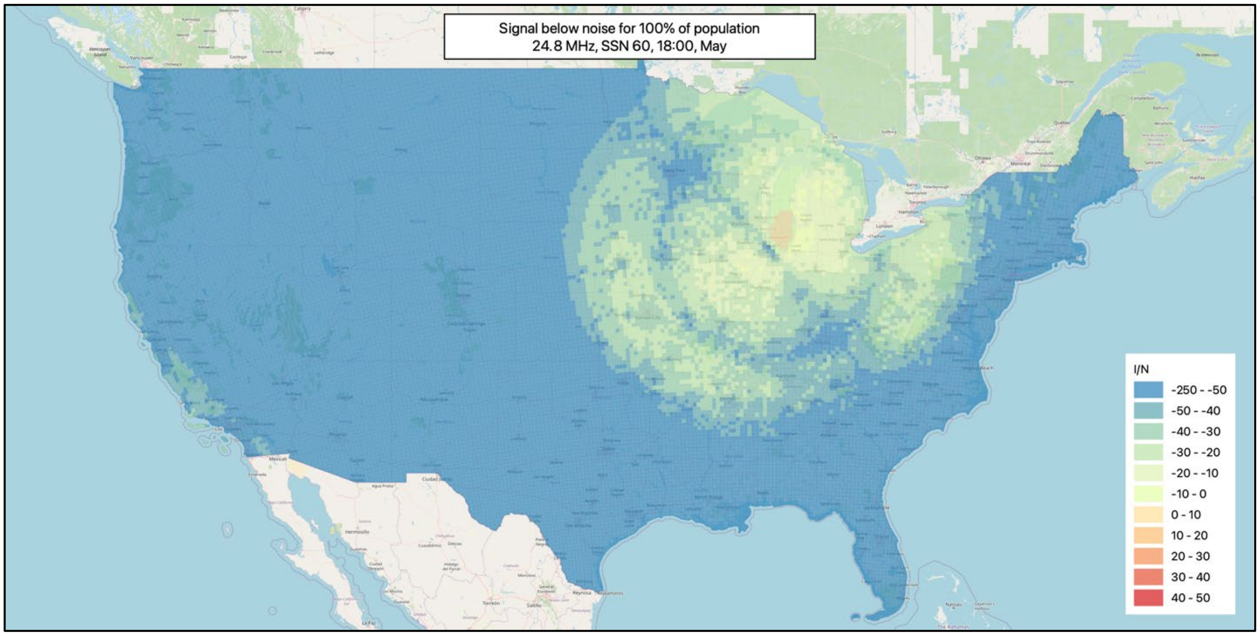
This appendix shows how the frequency affects the Chicago transmitting east case with an SSN of 60 at 18:00 occurring in May. There are large differences in the signal levels at different frequencies. Notably, while the first three plots, corresponding to 4.9, 10.2, and 14.9 MHz, have areas of signal above the noise floor (orange or red), these areas are different in the three plots. This illustrates how even if two users have a co-channel interference issue in part of the band, they would likely not have that issue if they were co-channel in another part of the band.






Signal below noise for 60% of population
14.9 MHz, SSN 60, 18:00, May
I/N
-250 - -50
-50 - -40
-40 - -30
-30 - -20
-20 - -10
-10 - 0
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50


Signal below noise for 99.9% of population
19.9 MHz, SSN 60, 18:00, May
I/N
-250 - -50
-50 - -40
-40 - -30
-30 - -20
-20 - -10
-10 - 0
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50


Signal below noise for 100% of population
24.8 MHz, SSN 60, 18:00, May
I/N
-250 - -50
-50 - -40
-40 - -30
-30 - -20
-20 - -10
-10 - 0
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50

Appendix E – Spectrum in the Industrial/Business Pool

The table below shows the frequencies above 2 MHz and below 25 MHz in the Part 90 Industrial/Business Pool. For each segment of the pool, corresponding to a row in the table, the table shows the bandwidth of the segment in MHz, and then the number of channels that could be supported for 10, 25, and 50 kHz bandwidths. The number of channels that could be supported for other services, such as voice services at 2.8 to 3.0 kHz, would be significantly higher. Note that the Part 90 Industrial/Business Pool is not channelized in these bandwidths, nor does this report recommend it be channelized. This table merely serves to quantify the amount of spectrum in the pool by showing how many transmissions of various sizes could be supported.

F low (MHz)	F high (MHz)	Bandwidth (MHz)	Channels of a given bandwidth 10 kHz	25 kHz	50 kHz
2.107	2.170	0.063	6	2	1
2.194	2.495	0.301	30	12	6
2.505	2.850	0.345	34	13	6
3.155	3.400	0.245	24	9	4
4.000	4.063	0.063	6	2	1
4.438	4.650	0.212	21	8	4
4.750	4.995	0.245	24	9	4
5.005	5.450	0.445	44	17	8
5.730	5.900	0.170	16	6	3
6.765	7.000	0.235	23	9	4
7.400	8.100	0.700	69	27	13
9.040	9.400	0.360	36	14	7
9.900	9.995	0.095	9	3	1
10.150	11.175	1.025	102	41	20
11.400	11.600	0.200	19	7	3
12.100	12.230	0.130	13	5	2
13.410	13.570	0.160	16	6	3
13.870	14.000	0.130	13	5	2
14.350	14.990	0.640	64	25	12
15.800	16.360	0.560	55	22	11
17.410	17.480	0.070	7	2	1
18.030	18.068	0.038	3	1	0
18.168	18.780	0.612	61	24	12
19.020	19.680	0.660	66	26	13
19.800	19.990	0.190	18	7	3
20.010	21.000	0.990	98	39	19
21.850	21.924	0.074	7	2	1
22.855	23.200	0.345	34	13	6
23.350	24.890	1.540	153	61	30
Total channels 2 to 25 MHz			1071	417	200

APPENDIX B

Declaration of Eric Bellerive on Behalf of DRW Holdings, LLC

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of Shortwave Modernization Coalition Petition for Rulemaking to Amend the Commission's Rules to Allow Fixed, Long-Distance, Non-Voice Communications Above 2 MHz and Below 25 MHz.	)	RM- ______________________

DECLARATION OF ERIC BELLERIVE
ON BEHALF OF DRW HOLDINGS, LLC

1. My name is Eric Bellerive. My U.S. business address is 540 W Madison Street, Suite 2500, Chicago, Illinois, 60661. I am the Director for DRW NX LLC, a subsidiary of DRW Holdings, LLC (DRW). I have held this position since July 2007. In this role, I oversee the business unit at DRW responsible for building proprietary low-latency networks around the world. This unit built and operates a transcontinental 2-25 MHz Band link pursuant to an experimental license, call sign WI2XER, held by Skycast Services LLC (Skycast), a DRW-related entity. I hold an undergraduate degree in Computer Sciences, and I have 20+ years of experience in network engineering. I personally designed and deployed many of the wireless and fiber networks built by DRW, and I was personally involved in the efforts to bring on the air the network authorized under call sign WI2XER.

2. I supervised and led Skycast's application for the FCC experimental license for call sign WI2XER to enable transmissions in the 2-25 MHz Band, specifically, between 7 MHz and

21 MHz. Upon grant of the experimental license, I oversaw the development of technology for, and construction of, a 2-25 MHz Band transmission system in Long Island, New York. This system, which relies primarily on 2-25 MHz Band frequencies that the FCC has allocated for licensed use under 47 C.F.R. Part 90, is used to conduct various technical experiments to, among other things, determine the extent to which time-sensitive financial market information can be reliably transmitted intercontinentally using 2-25 MHz Band frequencies at a reduced latency as compared to other wireless frequencies or trans-oceanic fiber.

3. The experimental license also has enabled Skycast to prove the viability of modern wideband 2-25 MHz Band technology, which includes channel sizes up to 48 kilohertz for ultra-long-haul data transmission at distances up to 4,000 miles. Skycast's experiments have included the testing and use of an active interference avoidance technology built into its transmit and receive systems, described in paragraph 5 below, to validate the use of wideband 2-25 MHz Band technology without interfering with other 2-25 MHz Band users, including incumbents and other experimental licensees.

4. These experiments have shown the following:

   a. reduced latency can be achieved for long-distance data communications using 2-25 MHz Band frequencies allocated for Part 90 use;

   b. no other known wireless (e.g., microwave point-to-point, or LEO/VLEO satellite systems) or terrestrial (e.g., fiber) technology currently can achieve the same or better latency, and 2-25 MHz Band transmissions have proved to be a valid back-up for primary communications systems that have advantages other than reduced latency (such as increased bandwidth and/or throughput); and

c. multiple licensees can use Part 90 2-25 MHz Band frequencies in this manner without causing harmful interference to incumbent users (or each other) with a sufficient amount of authorized frequency diversity.

5. Skycast achieved these results through the use of an active interference avoidance system built into its 2-25 MHz Band transmit and receive subsystems. The interference avoidance system utilizes "listen before transmit" (LBT) functionality, monitors real time signal-to-noise ratio (SNR), and includes station identification capability to prevent interference scenarios. The LBT system works by proposing an unoccupied channel, while remaining within the boundaries of the experimental license. Real-time monitoring of SNR enables identification of overlapping signals on the same channel, which prompts the system to be reconfigured for another unoccupied channel. The station identification capability enables incumbents and other experimental 2-25 MHz Band licensees to identify the Skycast signal in the event that a transmission causes temporary interference.

6. This interference avoidance system has proven effective on both transmit and receive sides of the link during the experimentation completed to date. In fact, during the seven years in which Skycast has operated in the 2-25 MHz Band pursuant to experimental authority, Skycast has not experienced harmful interference to its experimental operations, nor has it received harmful interference complaints or inquiries from the FCC or other 2-25 MHz Band licensees.

7. Skycast continues to develop its wideband 2-25 MHz Band technology through improved hardware and software advancements and currently is studying the impact of these innovations in the context of the evolving 11-year solar cycle. Skycast hopes to test a new link with more challenging channel characteristics, which include higher Doppler shift and

increased multipath delay between North America and Asia. Skycast anticipates that such an experiment will leverage the increased robustness of its system to overcome the challenges that a more complex link will have on wideband 2-25 MHz Band data transmissions.

I declare, under penalty of perjury under the laws of the United States of America, that the foregoing is true and correct.

Dated: March 24, 2023
Montreal, Canada

Eric Bellerive
Director
DRW NX LLC

APPENDIX C

Declaration of Thomas Maxwell on Behalf of IMC Trading

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of Shortwave Modernization Coalition Petition for Rulemaking to Amend the Commission's Rules to Allow Fixed, Long-Distance, Non-Voice Communications Above 2 MHz and Below 25 MHz.	)	RM- ______________________

DECLARATION OF THOMAS MAXWELL ON BEHALF OF IMC TRADING

1. My name is Thomas Maxwell. My business address is 233 S. Wacker Drive #4300, Chicago, IL 60606. I am a Network Specialist for IMC Trading ("IMC"). I have held this position since September 2018. In this role, I serve as a global project engineering lead for wide area network communications, including shortwave radio. I hold a BS in Engineering and have 22 years of experience in the telecommunications industry.

2. IMC and several commonly owned and controlled global affiliates (together, "IMC Group") work collectively across regions to operate as a worldwide trading firm and leading market maker. Two (2) companies within IMC Group, Toggle Communications LLC ("Toggle") and RCA Telecom LLC ("RCA"), hold FCC experimental licenses that authorize the use of certain frequencies above 2 MHz and below 25 MHz (the "2-25 MHz Band"). Toggle holds FCC experimental licenses for two call signs, WI2XAJ and WL2XYM, and RCA

holds an FCC experimental license for one call sign, WM2XTS, to enable the testing of fixed, long-distance, non-voice communications on frequencies between 5.06 MHz and 24.45 MHz. Since 2018, I have participated in the development of technology for, and the construction of, a 2-25 MHz Band system used to conduct various technical experiments to, among other things, determine the extent to which time-sensitive short message signals can be reliably transmitted using 2-25 MHz Band frequencies, especially at reduced latency as compared to other technologies.

3. This experimental activity, which primarily has relied on 2-25 MHz Band frequencies otherwise allocated for licensed use under Part 90 of the FCC's rules, has supported IMC Group's development of new technologies, processes, and methods used to augment existing commercially available 2-25 MHz Band communications technologies.

4. RCA's experimental license was granted recently, and experimentation began in December 2022. The experiments conducted by Toggle over the last several years have shown the following:

a. Reduced latency can be achieved for fixed, long-distance, non-voice communications using these 2-25 MHz Band frequencies as compared to other frequencies and technologies.

b. No other known technologies – e.g., microwave point-to-point, LEO/VLEO satellite systems, and/or fiber – currently can achieve the same or better latency for the distances and use case sought by IMC Group.

c. Transmission in the 2-25 MHz Band have proved to be a valid back-up for, or means of redundancy to, primary communications systems (e.g., fiber), *and* have other advantages in addition to reduced latency, such as infrastructure diversity and decreased costs. Specifically, Toggle has been able to rely on 2-25 MHz Band transmissions for communications in instances of submarine cable outages and terrestrial fiber cuts.

d. Based on Toggle's experience, multiple licensees can use Part 90 2-25 MHz Band frequencies for fixed, long-distance, non-voice communications of short duration, without causing harmful interference to incumbent users (or to each other).

5. Toggle's and RCA's experimental use of 2-25 MHz Band frequencies avoids interference with licensed users, and with other experimental licensees, primarily by utilizing listen-before-transmit technology. This allows Toggle and RCA to carefully select channels, and to change channels when interference potentially could occur. The interference avoidance system that Toggle and RCA utilize, which currently is under active experimentation and development, is automated but also supports manual override. Finally, Toggle and RCA have provided the FCC with stop buzzer contact information in their experimental application materials, although they have never received a request from the FCC to cease transmissions in the 2-25 MHz Band.

6. During the approximately seven years in which it has conducted testing in the 2-25 MHz Band pursuant to experimental authority, Toggle has not received interference complaints or inquiries from the FCC or other licensees in the 2-25 MHz Band. Nor has Toggle experienced harmful interference to its experimental operations; any third-party interference that Toggle has received has been *de minimis* and has not been detrimental to Toggle's experimental transmissions. RCA also has not received such interference complaints or inquiries from the FCC or other licensees in the 2-25 MHz Band or experienced harmful

interference in connection with its testing in the 2-25 MHz Band pursuant to its experimental license. For these reasons, I believe that users can successfully share the band for the requested fixed, long-distance, non-voice communications use case.

7. IMC Group, through its affiliates RCA and Toggle, intends to conduct additional experiments in the 2-25 MHz Band. These experiments include testing channel selection methods and processes for the requested Part 90 operations.

I declare, under penalty of perjury under the laws of the United States of America, that the foregoing is true and correct.

Dated: March 24, 2023
Chicago, Illinois

Thomas Maxwell
Network Specialist
IMC Trading

APPENDIX D

Declaration of John P. Madigan on Behalf of NLN Holdings LLC

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of Shortwave Modernization Coalition Petition for Rulemaking to Amend the Commission's Rules to Allow Fixed, Long-Distance, Non-Voice Communications Above 2 MHz and Below 25 MHz.	)	RM- ______________________

DECLARATION OF JOHN P. MADIGAN ON BEHALF OF NLN HOLDINGS LLC

1. My name is John P. Madigan. My business address is Jump Trading Group, 600 West Chicago Ave, Suite 600, Chicago, IL 60654. I have been employed by the Jump Trading Group as a Technologist since 2017. I also am a member of the Board of Directors of NLN Holdings LLC ("NLN"), the parent company of New Line Networks LLC, which in turn owns 10Band LLC ("10Band"). I have held this position since the inception of NLN in 2015. NLN is a joint venture whose beneficial ownership is held by Virtu Financial, Inc. (NYSE: VIRT) and the owners of the Jump Trading Group.

2. In these roles, I have worked with a team of internal communications experts to deploy, operate, and conduct experiments in frequencies above 2 MHz and below 25 MHz (the "2-25 MHz Band"). I have been involved in communications since serving as a U.S. Army Lieutenant in 1985, and I founded various commercial communications ventures after my military service. I was recently appointed to the FCC's rechartered Federal Advisory Committee

for the 2023 World Radiocommunication Conference.

3. I have supervised and participated in the preparation, submission, and prosecution of 10Band's applications for an FCC experimental license (call sign WI2XNX) for transmissions on 2-25 MHz Band frequencies. Upon grant of the experimental license, I supervised the development of technology for, and construction of, a 2-25 MHz Band transmission system used to conduct various technical experiments. This system includes (1) a low latency 2-25 MHz Band radio (Trellisware TW-6210); (2) antenna and amplifier configurations using ACOM, TCI, Rhode & Schwarz, and SteppIR equipment; and (3) custom, in-house software tools for monitoring and operating equipment, including to facilitate frequency agility.

4. 10Band's successful experiments using 2-25 MHz Band frequencies allocated for licensed use under Part 90 of the FCC's rules have significantly improved the art and science of radio frequency transmission and digital signal processing in the 2-25 MHz Band, resulting in the following conclusions:

a. Frequencies in the 2-25 MHz Band can be reliably leveraged as a primary (or backup) digital communications solution despite the greater variability of propagation in the 2-25 MHz Band as compared to other spectrum bands. This could lead to wider adoption of 2-25 MHz Band transmission systems in industries such as manufacturing, petroleum, or mining, or by other firms that do business in global trouble spots and need or desire to avoid reliance upon vulnerable alternative facilities (e.g., satellite, terrestrial/subsea fiber).

b. Frequencies in the 2-25 MHz Band reduce latency for long-distance, non-voice communications. No other known wireless (e.g., microwave point-to-point, or LEO/VLEO satellite systems) or terrestrial (e.g., fiber) technology currently can achieve the same or better latency over the distances utilized by 2-25 MHz Band transmissions.

c. Transmission and receive facilities utilizing the 2-25 MHz Band can be deployed at a lower cost versus other long-distance wireless and terrestrial communications means.

d. Multiple licensees can use Part 90 2-25 MHz Band frequencies in this manner without causing harmful interference to incumbent users (or to each other).

5. 10Band takes measures to minimize the risk of causing harmful interference to other 2-25 MHz Band users, including limiting transmissions to the allocated frequency range, spectrum monitoring to ensure a particular frequency is not in use before transmitting, and using a relatively low transmit power level. By leveraging wider channels and relatively low transmit power, 10Band is able to minimize power spectral density (PSD) to reduce potential impact on other licensed transmissions in the 2-25 MHz Band.

6. During the six years in which 10Band has operated pursuant to experimental authority in the 2-25 MHz Band, 10Band has not become aware of harmful interference to our experimental operations from other licensees in the 2-25 MHz Band. In addition, 10Band has received neither complaints nor inquiries from the FCC regarding harmful interference to Commission licensees from our experimental operations.

7. Experiments conducted to date have resulted in significant improvements in 2-25 MHz Band radio frequency performance. NLN and 10Band anticipate that continued experimentation conducted with both industry participants and leading academics will advance both 2-25 MHz Band radio frequency performance and digital signal processing improvements, to the benefit of multiple industries.

I declare, under penalty of perjury under the laws of the United States of America, that the foregoing is true and correct.

Dated: March 24, 2023
Chicago, IL

John Madigan

John P. Madigan
Director
NLN Holdings LLC

APPENDIX E

Declaration of Kevin Nielsen
on Behalf of
County Information Services, LLC,
an Affiliated Company
of Optiver Services B.V.

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of Shortwave Modernization Coalition Petition for Rulemaking to Amend the Commission's Rules to Allow Fixed, Long-Distance, Non-Voice Communications Above 2 MHz and Below 25 MHz.	)	RM- ______________________

DECLARATION OF KEVIN NIELSEN ON BEHALF OF COUNTY INFORMATION SERVICES, LLC, A SUBSIDIARY OF OPTIVER SERVICES B.V.

1. My name is Kevin Nielsen. My United States business address is 130 E. Randolph Street, Suite 1300, Chicago, IL 60601. I am an employee of Optiver Services B.V., an affiliated company of County Information Services, LLC ("CIS"). I have held this position since January 9, 2005. In this role, I have supervised and participated in the development and implementation of technologies such as modems, RF power amplifiers, custom combining and tuning units, antenna systems, and the development of criteria and testing methodologies for the acquisition and construction of transmit and receive stations related to the use of frequencies between 2 and 25 MHz (the "2-25 MHz Band") in long-distance communications.

2. I have supervised CIS's preparation, submission, and prosecution of two FCC experimental licenses, call signs WH2XWU, and WN2XCR, for transmissions on certain 2-25 MHz Band frequencies. Upon grant of the first CIS experimental license, I oversaw the

development of technology for, and construction of, a 2-25 MHz Band transmission system used to conduct an experiment investigating the feasibility and technologies required to send time-sensitive information using 2-25 MHz Band frequencies at a reduced latency as compared to other wireless frequencies or fiber.

3. The experiments have primarily used 2-25 MHz Band frequencies that the FCC has allocated for licensed use under Part 90 of the FCC's rules and required the investigation and development of equipment and techniques, including:

- A purpose-built 2-25 MHz Band modem. The modem uses modulation techniques allowing CIS to comply with the FCC Part 90 mask C requirements.

- High power amplifiers. We have designed and built a large-scale transmitter (10 kW max transmit power), covering a frequency range of 14-20 MHz and meeting the technical requirements of Part 90. This transmitter uses our ground-up designed and built modular amplifiers and is remotely controllable in accordance with Part 90 rules.

- Link control systems. The 2-25 MHz Band transmitter is operated and controlled from sites several hundreds of miles away. As such, CIS developed a wide-ranging set of software systems to remotely monitor and control the transmitter and site facilities.

- Antenna array designs. We have designed and built a log-periodic antenna array, customized and optimized for long-distance point-to-point 2-25 MHz Band links within a limited frequency range. An extensive design, modeling, and field-testing trajectory led to the realization of an log-periodic dipole array that has a directivity close to the theoretically achievable maximum for these antenna types.

- Encoding and selection schemes for data. An algorithm has been developed which detects changes in information in one marketplace, codifies this data, and then automatically selects a queue priority to send the information via the 2-25 MHz Band link. The queue priority is determined by a set of user-controlled parameters. The data is later analyzed for timeliness, accuracy, and overall pertinence.

- Low noise receive stations. Because of the strict requirements for the ambient noise level at a 2-25 MHz Band RX site, during the experimental period, a methodology was developed for the design and build-out of 2-25 MHz Band Receive sites with an extremely low noise floor.

- Channel selection technology. Using a set of rule-based parameters derived from propagation studies along with interference checks of power-in-band in nearby channels, CIS has built a channel selection tool to automatically determine the best available channel.

- Interference detection methods. These methods enable checking of power-in-band changes in the current center frequency and over the next user-configurable set of center frequencies. This information is used by software and operators to determine interference risk and to recommend new channels.

4. These experiments have shown the following:

   a. reduced latency can be achieved for fixed, long-distance, non-voice communications using 2-25 MHz Band frequencies allocated for Part 90 use;

   b. no other known wireless (e.g., microwave point-to-point, or LEO/VLEO satellite systems) or terrestrial (e.g., fiber) technology currently can achieve the same or better latency, and 2-25 MHz Band transmissions have proved to be a valid back-up for primary communications systems that have advantages other than reduced latency (such as increased bandwidth and/or throughput); and

   c. multiple licensees can use Part 90 2-25 MHz Band frequencies in this manner without causing harmful interference to incumbent users (or each other).

5. CIS uses a "listen-before-speak" system and a continuous channel monitor to detect and mitigate its own interference on other stakeholders in the 2-25 MHz Band, the technology relies on a mix of automation and human oversight. The interference avoidance techniques and software were developed in-house.

6. During the seven (7) years in which it has operated pursuant to experimental authority in the 2-25 MHz Band, CIS has not experienced harmful interference to our experimental operations, nor have we received harmful interference complaints or inquiries from the FCC or other licensees in the 2-25 MHz Band.

7. CIS is still executing experiments to improve the reliability and scalability of its

2-25 MHz Band technology. While the instant rulemaking petition is pending, CIS will continue to make improvements to its systems to ensure compliance with the proposed future Part 90 authorizations. These efforts include:

- Refining novel harmonic filter and suppression techniques;
- Improving the system interface, automated control, and monitoring techniques;
- Widening the usable frequency range of transmit and receive systems using our existing RF amplifier platform;
- Simplifying and refining signal generation and modulation; and
- Investigating multiple transmission paths and techniques.

Techniques and technologies developed from these tests, such as the widening of the frequency range, simplifications, refinements, and advanced filtering and signal processing techniques, will improve the reliability of the link and ensure compliance with Part 90 Mask C or variants thereof.

I declare, under penalty of perjury under the laws of the United States of America, that the foregoing is true and correct.

Dated: March 30, 2023
Chicago, Illinois

Kevin Nielsen
Optiver Services B.V.

APPENDIX F

Declaration of Tom Proudley on Behalf of Tower Research Capital LLC

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	RM- ______________________________
Shortwave Modernization Coalition Petition for Rulemaking to Amend the Commission's Rules to Allow Fixed, Long-Distance, Non-Voice Communications Above 2 MHz and Below 25 MHz.	)	

DECLARATION OF TOM PROUDLEY
ON BEHALF OF TOWER RESEARCH CAPITAL LLC

1. My name is Tom Proudley. My business address is 377 Broadway, New York NY. I am the Director, Global Head of Telecom Operations for Tower Research Capital LLC ("**TRC**"). I have held this position since July 2016. In this role, I am responsible for TRC's in-house initiative to explore and further the use of frequencies between 2 MHz and 25 MHz (the "**2-25 MHz Band**"), coupled with proprietary 2-25 MHz Band modem hardware, for the transmission of data integral to TRC's business. I oversee a team of wireless and radio specialists, network engineers, and telecommunication experts who all contribute to the design, deployment, maintenance, and operations of TRC's 2-25 MHz Band transmission sites in the United States, and the associated hardware. I have worked within the telecommunications sector for 18 years across various functions of: Network Engineering; Network Operations; Network Support; Provisioning and Service Delivery; Network Operations Center Manager; and Vendor and Carrier Relations. Over the last seven (7) years I have been responsible primarily for the

design, build, and operations of a bespoke, global, low-latency financial trading network composed of fiber, wireless, and proprietary transmission technology.

2. I supervised the preparation, submission, and prosecution by TRC's subsidiaries Rockland Wireless, M-Wave Networks, and Alpha Bravo Communications of applications for FCC experimental licenses (call signs WK2XJK, WL2XEE, WM2XZU, respectively) for 2-25 MHz Band transmissions. Upon grant of each of these experimental licenses, I supervised the development of technology for, and construction of, a 2-25 MHz Band transmission system used to conduct various technical experiments to, among other things, determine the extent to which time-sensitive financial market information can be reliably transmitted using 2-25 MHz Band frequencies at a reduced latency as compared to other wireless frequencies or fiber.

3. In preparation for and as a result of these experiments, the TRC team I supervise has overseen development of the following technological innovations and new devices to make feasible the use of 2-25 MHz Band frequencies for the purposes noted above:

a. Automated Real-time Interference Avoidance System – automatically changes frequency as soon as another signal appears on our position. This mechanism will give "right of way" to other users and virtually eliminate service disruption, disturbance, and interference to other operators.

b. Dynamic Service Power Throttling – automatically and dynamically adapts transmission power to the minimum level required to maintain the link, minimizing local RF exposure levels and likelihood of interference.

c. Rapid Link Establishment – enables transmission-on-demand with rapid shut-off and reactivation, so the carrier is only present when transmitting data and is switched off at all other times, thereby keeping the band clear when not transmitting.

d. Multi-path Error Correction Stage – reduces error rate by compensating for multi-path propagation conditions which can otherwise distort the received signals.

e. Software systems to collect open-source space weather data for propagation prediction and monitoring.

f. Real-time monitoring of spectrum occupancy and propagation by collecting data from publicly networked software defined receivers.

4. TRC's experiments have primarily used 2-25 MHz Band frequencies that the FCC has allocated for licensed use under Part 90 of the FCC's rules.

5. These experiments have shown the following:

a. Reduced latency can be achieved for long-distance, non-voice communications using 2-25 MHz Band frequencies allocated for Part 90 use;

b. No other known wireless (e.g., microwave point-to-point, or LEO/VLEO satellite systems) or terrestrial (e.g., fiber) technology currently can achieve the same or better latency, and 2-25 MHz Band transmissions have proved to be a valid back-up for primary communications systems that have advantages other than reduced latency (such as increased bandwidth and/or throughput); and

c. Multiple licensees can use Part 90 2-25 MHz Band frequencies in this manner without causing harmful interference to incumbent users (or each other).

6. TRC's system avoids interference with licensed users via multiple traditional methods and practices such as narrow channel-width relative to other data-based systems;

extremely effective filtering; and the use of directional antennas. In addition to these practices, TRC's most effective means of avoiding interference are those developments listed above in paragraph 3.

7. During the four (4) years in which TRC's subsidiaries have operated systems in the 2-25 MHz Band pursuant to FCC experimental authority, we have not experienced harmful interference to our experimental operations caused by other licensed users, nor have we received harmful interference complaints or inquiries from other licensees in the 2-25 MHz Band.

8. TRC's experimental efforts in the 2-25 MHz Band are ongoing, and our transmission systems would benefit from further experimentation in the following areas:

a. Coordinated coexistence testing with other operators in the 2-25 MHz Band;
b. Further development of antenna systems and back-end automation; and
c. Further development of our spectrum-wide monitoring system with regional polling stations and public/privately available SDR systems.

I declare, under penalty of perjury under the laws of the United States of America, that the foregoing is true and correct.

Dated: March 24, 2023
New York, NY

Tom Proudley
Director, Global Head of Telecom Operations
Tower Research Capital LLC