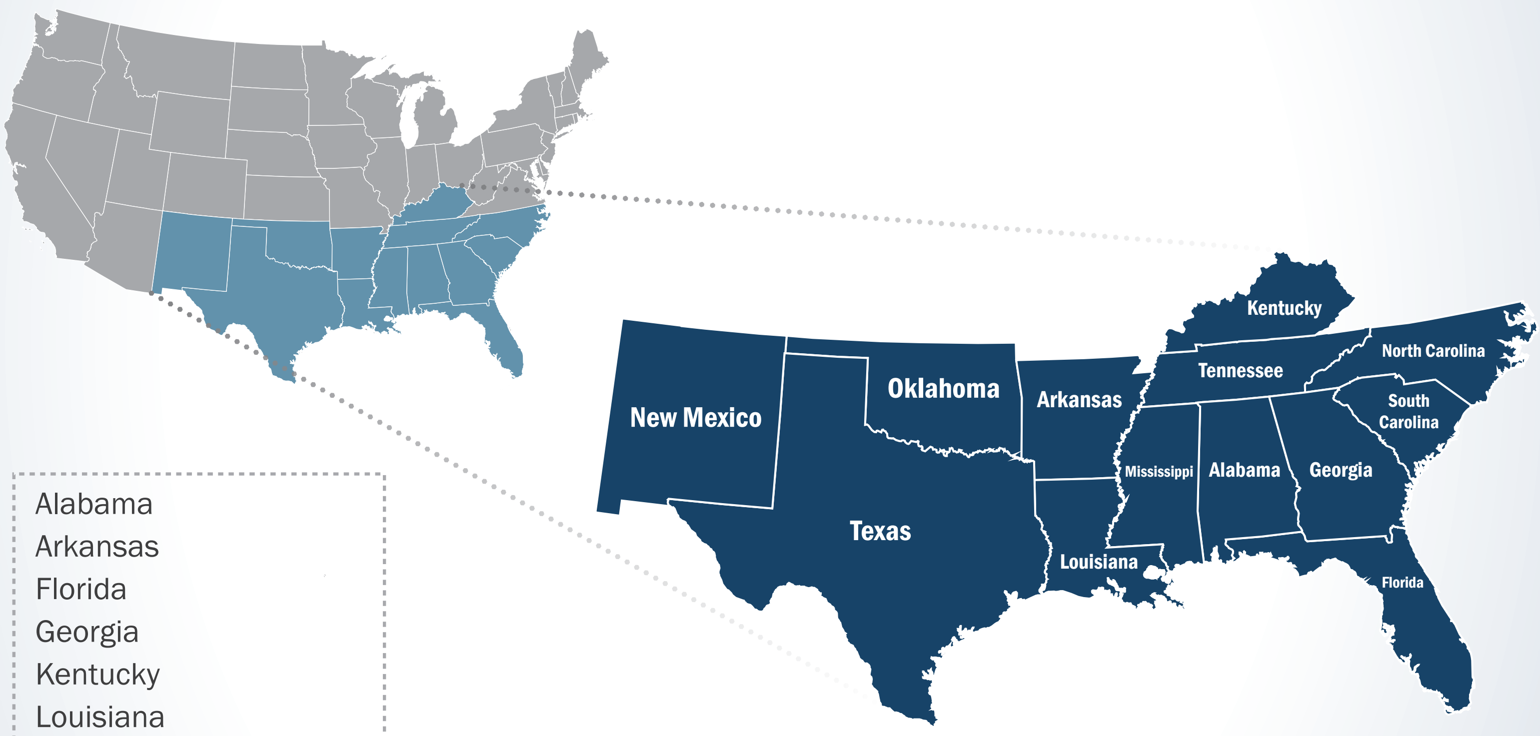
FirstNet®

Nationwide Public Safety Broadband Network

Draft Programmatic Environmental Impact Statement for the Southern United States

VOLUME 1 - CHAPTER 2



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First Responder Network Authority

FirstNet®

Nationwide Public Safety Broadband Network

Draft Programmatic Environmental Impact Statement for the Southern United States

VOLUME 1 - CHAPTER 2

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Cooperating Agencies
Federal Communications Commission
General Services Administration
U.S. Department of Agriculture—Rural Utilities Service
U.S. Department of Agriculture—U.S. Forest Service
U.S. Department of Agriculture—Natural Resource Conservation Service
U.S. Department of Defense—Department of the Air Force
U.S. Department of Energy
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2. DESCRIPTION OF THE PROPOSED ACTION AND ALTERNATIVES

In accordance with the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321 et seq.), FirstNet must examine a range of reasonable alternatives to design, construct, and operate the nationwide public safety broadband network (NPSBN). These alternatives must be reasonable ways in which FirstNet could meet the purpose and need for the Proposed Action. In addition to the range of reasonable alternatives, this document also describes those alternatives considered but not carried forward for analysis. Alternatives not carried forward were initially considered but found to not reasonably meet the purpose and need. FirstNet is also required to "include the alternative of no action" as part of the alternatives analysis in the PEIS. The "No Action Alternative" describes what would happen if FirstNet did not construct the NPSBN, and is used as a baseline against which the potential impacts of the action alternatives can be compared.

2.1. PROPOSED ACTION

The Proposed Action would encompass the design, deployment/construction, operation, and maintenance of the NPSBN by FirstNet or a partner organization (s) through a comprehensive network procurement process, currently underway. FirstNet anticipates a competitive process to procure a comprehensive technical and business solution to meet its stated mission and objectives. By statute, the network must have several characteristics, including security, resiliency, backwards compatibility with existing commercial networks, integration with public safety answering points (PSAPs)[1] or their equivalents, and substantial rural coverage; it must be built to open, non-proprietary, commercially available standards; and it must use existing infrastructure to the maximum extent economically desirable. The FirstNet network would have two components, the core network, and the radio access network (RAN). The core network is a key component for ensuring that users have a single interoperable platform nationwide, and would consist of a wide range of telecommunications infrastructure including fiber optic cable, towers, data centers, microwave technology, and others. The core has six primary functions: it switches data, processes and reformats information, stores and maintains data, and keeps it secure. The core network would interface with local, tribal, state, and federal networks, including 911 and the internet, thereby serving as the backbone connecting the 50 states, 5 territories, and the District of Columbia. The core network would be constructed and maintained to the most up-to-date technological standards, comprised of all standard Evolved Packet Core (EPC) elements under the 3rd Generation Partnership Project (3GPP). The EPC is the collection of systems that manages the connection of all voice calls, data sessions, messaging, and video services in a wireless network. Since the EPC is responsible for the management of all services, it is the central "brain" of the network. The RAN would consist of all radio base station infrastructure that would connect user devices. This infrastructure would include communication towers, cell site equipment, antennas, deployable mobile hotspots, and backhaul equipment required to enable wireless communications with devices using the public safety broadband

[1] Public safety answering points (PSAPs) are call centers responsible for answering calls to an emergency telephone number for police, fire, and emergency medical services.

spectrum. Finally, the Act states that FirstNet must continue to maintain and improve the NPSBN to account for new and evolving technologies.

FirstNet may enter into Spectrum Manager Lease Agreements (SMLAs) with states that opt-out of the FirstNet network. The range of methods that would be employed by states to connect their RAN to the FirstNet core network are expected to include methods described and analyzed in the various alternatives listed below.

2.1.1. Characteristics of the NPSBN

The Act specifies that the FirstNet network would be based on the minimum technical requirements on the commercial standards for Long Term Evolution (LTE) service. LTE is a proven upgradeable technology, now in its fourth generation (4G). Improvements in speed and function are achieved with each subsequent generation, and 4G LTE standards are continuing to evolve. FirstNet is involved in the research and development of new standards and is working closely with the public safety community as part of this process, with the goal of ensuring that the unique needs of public safety can be met.

The core network would have six primary functions: it would switch data, process and reformat information, store and maintain data, and keep that data secure. Other functions, such as applications, services, and operational and business support systems would also be part of the core network. The backhaul, or intermediate links that carry user traffic, including voice, data, and video, and signaling from radio base stations to the core network, would likely be accomplished through fiber optic and microwave technology, with an emphasis on redundancy to allow the network to continue to function in events of extreme demand.

The RAN would place an emphasis on reliability, prioritizing physical hardening and security. Redundant power backup, redundant backhaul capabilities, structural hardening, and security measures would be implemented as appropriate to provide a resilient and reliable radio base station infrastructure.

2.1.2. Proposed Action Infrastructure

There is currently a wide range of technologies that FirstNet may use to implement and deploy the NPSBN, ranging from fixed assets to mobile, deployable infrastructure. The following are general descriptions of the types of wired, wireless, and deployable projects that FirstNet may consider.

2.1.2.1. Wired Projects

New Build – Buried Fiber Optic Plant

The installation of fiber optic cable would generally consist of plowing or trenching cable alongside the road usually in utility corridors or within public road right-of-way (ROW), where possible. ROWs could also include utility corridors or other easements and may be public or private. This could involve either burying both conduit and cable inside the conduit or only direct buried cable. Installation may involve plowing, trenching (including vibratory plowing), or directional boring, and may involve the construction of points of presence (POPs),[2] huts, or other facilities to house outside plant equipment or hand-holes to access the fiber.

Use of Existing Conduit – New Buried Fiber Optic Plant

The installation of new fiber optic cable in existing conduit typically requires blowing or pulling new fiber optic cable into existing, buried conduit. In this project scenario, any ground disturbance would usually be limited to the entry and exit points of the existing conduit.

New Build – Aerial Fiber Optic Plant

Construction of new aerial fiber optic cable would generally consist of installing new poles and hanging cables in previously disturbed or new (undisturbed) ROWs or easements, or installing replacement poles in previously disturbed ROWs or easements. Installation of new poles and fiber may involve construction of access roads, depending on the availability of ROWs. This type of activity may also involve the constructions of POPs, huts, or other facilities to house outside plant equipment.

Collocation on Existing Aerial Fiber Optic Plant

Installation of new fiber on existing poles may require structural hardening or reinforcement to improve disaster resistance and resiliency. It may also require pole replacement to accommodate an increased load from new users. All replacement poles must be placed in the exact same hole in order for the action to qualify as "collocation."

Use of Existing Buried or Aerial Fiber Optic Plant or Existing Submarine Cable

This project type would involve lighting up dark fiber owned by and leased from various providers. Dark fiber is fiber that has been installed without a transmitter and receiver, typically to provide capacity for future growth.

New Build – Submarine Fiber Optic Plant

Deployment of new submarine cable, if implemented, would involve the installation of specially sealed cables in limited near-shore or inland bodies of water, and construction of landings / facilities on the shore to accept a cable, which is typically buried close to shore. Transoceanic submarine cables are not anticipated to be used as part of the Proposed Action; therefore, submarine repeaters and large marine vessels for installation or repairs would not be used. However, small marine vessels could be required for installation and repairs of smaller, non-transoceanic cables in limited near-shore or inland bodies of water.

Installation of Optical Transmission or Centralized Transmission Equipment

All fiber installation activities may require additional installation of equipment to enhance the digital signals travelling through the fiber, depending on the network configuration. FirstNet may also install transmission equipment as part of the core network construction. This

[2] Points of Presence are connections or access points between two different networks, or different components of one network.

equipment is usually installed in small boxes or huts in the ROW of the utility corridor, and may involve construction of access roads, depending on the availability of public ROW.

2.1.2.2. Wireless Projects

New Wireless Communication Towers

FirstNet may undertake the construction of new towers of various heights and configurations (e.g., monopoles, lattice, and guy-wired) to support wireless infrastructure, such as antennas and microwave dishes. Tower construction may also include associated structures including generators, equipment sheds, fencing, security lighting, aviation lighting, electrical feeds, and concrete foundations and pads. This type of project may require the construction of access roads, depending on the availability of public ROW.

Collocation on Existing Wireless Tower, Structure, or Building

Collocation projects would involve mounting or installation of equipment such as antennas or microwave dishes on an existing tower to transmit and/or receive signals, or provide backhaul. Installation of power units, such as an uninterruptible power supply could be added. Existing towers, structures, or buildings may require structural hardening or increased physical security measures.

2.1.2.3. Deployable Technologies

As part of the Proposed Action, there may be areas where permanent, fixed infrastructure cannot be erected due to a variety of factors. Deployable technologies may provide an option to either provide coverage in such areas, or they may be used to supplement existing coverage during a large-scale planned or emergency event. In addition, deployable technologies could also be used in areas where potential permanent impacts to significant sensitive resources/receptors cannot be avoided or mitigated. In general, some limited construction could be associated with the implementation of deployable technologies, such as land clearing or paving for parking or staging areas.

Cell on Wheels

The Cell on Wheels (COW) deployable technology consists of a cellular base station on a trailer with an expandable antenna mast, typically between 15 feet to 40 feet in height, and usually a microwave or satellite link back to the main controller. COWs typically contain a small generator and may also connect to utility power cables. This type of technology is designed to be part of a cellular network and augment existing capacity.

Cell on Light Truck

The Cell on Light Truck (COLT) deployable technology consists of a cellular base station on a light truck platform with an expandable antenna mast, typically between 15 feet and 40 feet in height, and usually a microwave or satellite link back to the main controller. COLTs typically contain a small generator and may also connect to utility power cables. This type of technology is designed to be part of a cellular network and augment existing capacity.

System on Wheels

The System on Wheels (SOW) deployable technology consists of a full base station and controller on a large towable trailer or truck. A SOW is a fully self-contained cellular system that can provide an island system with no need for satellite/microwave link back. SOWs typically contain a power generator and a larger antenna mast (ranging from approximately 50 feet to 120 feet in height), suitable to address larger localized coverage or capacity shortages in the event of planned or unplanned incidents.

Deployable Aerial Communications Architecture

Deployable Aerial Communications Architecture (DACA) consists of aerial vehicles, including, but not limited to, drones, balloons, blimps, and piloted aircraft, which would be deployed at a variety of altitudes and are capable of providing wide-area coverage, although with relatively low capacity/throughput. DACAs would be used for addressing wide scale loss of coverage after a major catastrophic event, which would have the network down for a significant period.

2.1.2.4. Satellites and Other Technologies

Satellite-Enabled Devices and Equipment

FirstNet may install permanent equipment on existing structures or support the use of portable devices that use satellite technology, such as satellite phones or video cameras.

Deployment of Satellites

FirstNet does not anticipate launching satellites as part of the deployment of the NPSBN; however, it could include equipment on satellites that are already being launched for other purposes and may work with other federal agencies or commercial entities that engage in satellite launches to use Global Positioning System satellites to support devices requiring location information.

2.2. DESCRIPTION OF ALTERNATIVES

In accordance with NEPA, FirstNet has considered a variety of alternatives to ensure the building, deployment/construction, operation, and maintenance of the NPSBN. CEQ has defined reasonable alternatives as those that are economically and technically feasible ways to meet the purpose and need. NEPA also requires the analysis of the No Action Alternative, which provides a baseline against which the potential impacts of the Action Alternatives may be compared. FirstNet is carrying two alternatives plus the No Action Alternative, forward for analysis. Furthermore, FirstNet has considered three additional alternatives and dismissed them from further consideration.

2.2.1. Preferred Alternative

Under the Preferred Alternative, FirstNet and its partner(s) would construct a nationwide broadband LTE network using a combination of wired, wireless, deployable, and satellite technologies. This may include, but is not limited to, the following methods: collocation of the network equipment on existing towers, poles and structures; construction of new communication towers, poles and associated structures to include generators, equipment sheds, fencing, and concrete pads; use of existing fiber facilities, including lighting up dark fiber and installation of new fiber on existing poles and in existing conduit; installation of new conduit and fiber using trenching (including vibratory plowing) or directional boring (including horizontal directional drilling); deployment of satellite phones and other portable satellite technology; installation of microwave facilities for cell-site backhaul communication; and the utilization of deployable technologies.

2.2.2. Deployable Technologies Alternative

Under the Deployable Technologies Alternative, FirstNet would procure, deploy, and maintain a nationwide fleet of mobile communications systems, including ground-based and aerial deployable technologies, to provide temporary coverage in areas not covered by existing, usable infrastructure, as there would be no collocation of equipment or new construction associated with wired or wireless projects discussed above under the Preferred Alternative. Generally, these units would be deployed at times of an incident to the affected area for either planned or unplanned incidents or events. Equipment would be stationed in every state and territory, often at multiple locations in each state or territory, to facilitate suitable response. These mobile communication units would be temporarily installed and may use existing satellite, microwave, or radio systems for backhaul. In general, some limited construction could be associated with the implementation of deployable technologies, such as land clearing or paving for parking or staging areas. However, these construction activities would be minimal in comparison to the combination of project types associated with the Preferred Alternative as described above.

2.2.3. No Action Alternative

Under the No Action Alternative, the NPSBN would not be constructed; there would be no nationwide, coordinated system dedicated to public safety interoperable communications. The existing multiplicity of communications networks would remain in place, as would the current, known limitations and problems of existing communication networks during times of emergency or disaster. This alternative would require an act of Congress to revise the Act, which currently requires the NPSBN.

2.3. ALTERNATIVES CONSIDERED BUT NOT CARRIED FORWARD

During the course of the development of the Proposed Action, several additional alternatives to implement the Proposed Action were considered. Each of these alternatives was found deficient in some way, and did not meet the purpose and need for the Proposed Action as discussed below.

2.3.1. New Construction Only Alternative

Under the New Construction Only Alternative, FirstNet would construct a nationwide network using all new construction and installation of fiber optic cable, conduit, utility poles, communication towers, and installed equipment. This alternative has been dismissed from further consideration because it is counter to FirstNet’s legislative mandate to leverage existing infrastructure. Furthermore, new construction of the entire network would be cost-prohibitive and the construction timeline would cause unnecessary delays in network implementation as a result of the need for building an entirely new NPSBN from the ground up, which would not meet the agency's legislative purpose and the needs of the Proposed Action.

2.3.2. New Satellite Alternative

Under the New Satellite Alternative, FirstNet would construct a nationwide network using new and existing satellite technology only. Generally, satellite technology is not cost effective due to limited spectrum, and technical issues such as limited in-building coverage and performance. This alternative has been dismissed from further consideration because it is counter to FirstNet's mandate to use standards-based LTE technology to provide coverage, and its performance capabilities would not meet the purpose and need of the Proposed Action.

2.3.3. Collocation-Only Alternative

Under the Collocation-Only Alternative, FirstNet would construct the NPSBN using existing infrastructure only, by collocating equipment exclusively on existing towers, buildings, or other structures. This alternative has been dismissed from further consideration because suitable infrastructure does not exist to provide nationwide broadband coverage using only existing infrastructure. Many areas of the country, particularly rural areas, would have little to no service options from FirstNet if existing infrastructure alone were required to build the network. Therefore, this alternative would not meet the purpose and need of the Proposed Action.

2.4. Analysis of the Science Evaluating and the Regulatory Framework Governing the Potential Effects of Radiofrequency (RF) Emissions Exposure on Humans and Animal and Plant Species

General interest in the topic of the safety of radiofrequency electromagnetic field emissions (RF emissions),[3] a form of radiation, from communication towers and their relationship to human health and the environment has increased with the number of devices being used and the degree of connectivity needed for people to go about their daily lives. This interest has been demonstrated in the comments received by FirstNet for its PEIS for the NPSBN (or "project"), other telecommunications projects, as well as active discussions within the human health and environmental science communities, and among the general public. Accordingly, FirstNet has determined it is important to analyze the potential human and environmental effects for the PEIS.

This document provides a general overview regarding (RF) emissions, the existing regulatory framework for limiting RF exposures, the general discussions on the current state of research for potential effects on humans, as well as information on animal and plant species, and some of the general conclusions on data gaps and the paths forward. While this document is not intended to be a complete analysis of all aspects of RF emissions and their potential effects, it does provide a

[3] RF emissions refer to RF radiation emitted by devices. OSHA defines RF radiation as "electromagnetic radiation in the frequency ranges 3 kilohertz (kHz) - 300 Megahertz (MHz), and 300 MHz - 300 gigahertz (GHz), respectively" (Occupational Health and Safety Administration, 2015).

general discussion of some of the credible scientific literature and information that relates to RF emissions and potential effects to human health and other species.

In general, radiation is the product of a wide range of energies that form the electromagnetic spectrum. A number of radiation sources exist in nature (such as the radon emitted from the breakdown of certain minerals in the ground or the radiation from energy in space) and others are artificial (such as RF emissions created by broadcasting, radio, and cellular equipment).

The electromagnetic spectrum is divided into two main classes: non-ionizing radiation (NIR) and ionizing radiation (IR):

- **Non-ionizing radiation**. NIR is at the low end of the electromagnetic spectrum. Visible Light, AM/FM radio, cellular, and microwaves are all classified as NIR. FirstNet system would operate in the 700 MHz frequency band, which means that it would emit NIR (Zamanian, 2005).
- **Ionizing radiation**. IR can produce charged particles (ions) in matter and is produced by unstable atoms that have an excess of energy or mass or both. Gamma radiation and x-rays are examples of IR. FirstNet equipment would not produce any IR (Zamanian, 2005).

This review focuses on NIR related to cellular systems (e.g., tower and building-mounted equipment) and, specifically, the 700 MHz LTE spectrum band licensed for use by FirstNet. Figure 2.3.3-1 details the full electromagnetic spectrum (U.S. Department of Energy, 2009). The red band on each line of Figure 2.3.3-1 indicates the 700 MHz frequency band.

Radiation is frequently presented in the terms of *power intensity* or *irradiance*. The power intensity is the radiant flux[4] received by a specific surface area. The units for irradiance are watts per meters squared (W/m^2). Frequently, RF emissions and exposure standards are defined in terms of power density. Some standards are explicitly defined while others are a function of the frequency of the radiation. Table 2.3.3-1 summarizes the current Federal Communications Commission (FCC) standards for RF emissions for occupational/controlled exposure, as well as uncontrolled exposure.

[4] The radiant flux is the amount of energy per unit time radiated from a source.

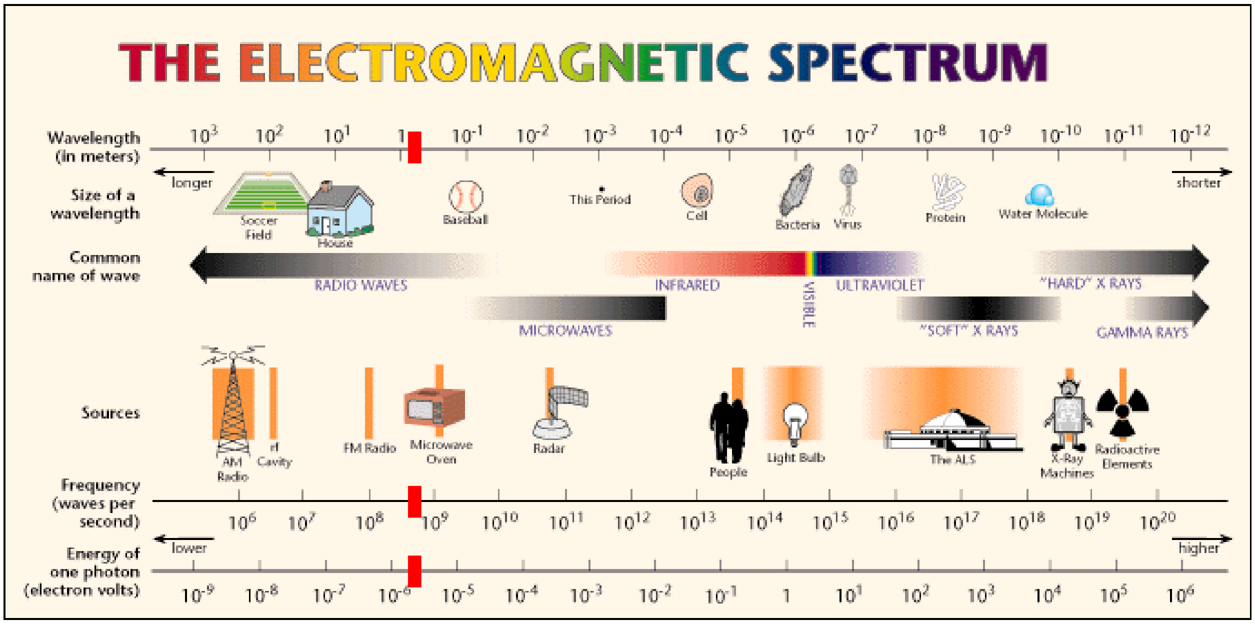

Figure 2.3.3-1: The Electromagnetic Spectrum

Source: (U.S. Department of Energy, 2009)

Since FirstNet is licensed to operate in the 700 MHz range,[5] the FCC regulations establishing exposure limits would govern FirstNet operations and (power density) would be between 2.33 mW/cm^2 and 2.66 mW/cm^2 for occupational or controlled exposure for frequencies of 700 and 799 MHz, respectively.[6] For these same frequencies and general population/uncontrolled exposure, the FCC standard exposure limits are 0.47 mW/cm^2 to 0.53 mW/cm^2. This analysis is intended to outline some preliminary information on the topic in order to describe the state of current research, science, and the unsettled issues surrounding RF emissions that better aid FirstNet in making its decisions.

2.4.1. RF Emissions and Humans

For 20 years, the regulatory levels for human exposure to RF emissions have been established by the FCC as a means of protecting both workers and the general public from any potential effects.[7] Concerns about RF emissions have been raised for a number of years by various nongovernmental stakeholder groups about whether the FCC's exposure levels—and similar standards established by other developed nations—are protective enough based upon the current science on the potential health effects.

The FCC's standards were first established in 1996 based upon the guidelines formulated by the National Council on Radiation Protection and Measurements (NCRP), a Congressionally-chartered nonprofit corporation that prepares recommendations on matters of radiation protection, as well as those promoted by two independent nonprofit organizations, the Institute of

[5] FirstNet holds a single 700 MHz Public Safety Broadband Nationwide License, under Call Sign WQQE234.

[6] See 47 U.S.C. § 1421(a).

[7] See 47 Code of Federal Regulations (CFR) 1.1307(b), 1.1310, 2.1091, 2.1093. (To search for and locate CFR records, see the Electronic Code of Federal Regulations (e-CFR): www.ecfr.gov).

Electrical and Electronic Engineers (IEEE) and the American National Standards Institute (ANSI), both of whom have helped set industry standards for decades (FCC, 2013) (FCC, 2014).

These standards set effective radiated power (ERP) of no more than 500 watts per channel (WPC), depending on tower height and the total number of radio channels (transmitters) authorized at a specific site, so that the RF power transmitting at any particular location will vary, with most urban and suburban sites operating at an ERP of less than 100 WPC (FCC, 2014).

According to the FCC and depending upon the type of antenna being used, the typical cell site emits an ERP of 100 WPC which corresponds to an actual radiated power of 5-10 watts (FCC 2014). Measurements taken of typical ground-level exposures are usually well-below the FCC exposure standards, because the power of RF emissions rapidly decrease as the distance from the transmitter increases (FCC, 2014).

Demonstrating cause and effect in humans from low-level[8] environmental exposures is considered to generally require multiple studies over many years before consensus is reached and a clear cause and effect can be established (Webb, P. and C. Bain, 2011). In order to respond to a request by Congress to study the potential health effects of electric and magnetic fields on humans and other living organisms, the Department of Energy entered into an agreement with the National Research Council (NRC) for the National Academy of Science to prepare a study.

That report, in looking at routine exposures to electric and magnetic fields found in homes and communities as the cause of disease and abnormalities, stated, “There is no widely accepted understanding of how extremely low-frequency electric and magnetic fields, such as those associated with the distribution and use of electric power, could cause a disease or whether it causes a disease. Considerable research has been conducted in this area, and numerous research data can be found on the subject, but given the lack of a specific disease end point to track or a well-accepted theory of how the fields might affect biologic systems, the data are discordant; they have been gathered using different exposure conditions and have resulted in conflicting observations of different effects or no effects” (National Research Council, 1997). Hence, the investigations into RF have not yet achieved scientific consensus on cause and effect.

Some of the major problems with demonstrating cause and effect for RF are listed below:

- No consistent measures of exposure. Exposure is changing with the proliferation of cell phone use, and there is no real unexposed or “control” population (Ahlbom et al., 2004) (Khurana et al., 2010);
- No scientifically agreed upon biological mechanism for harm. The lack of a clear biological mechanism increases uncertainty into whether the health end point that the study examined is the correct endpoint to try and measure (Hauri et al., 2014) (Ahlbom et al., 2004); and

[8] For the purposes of this review, “low-level” is a qualitative description of the small amount of energy contained in these emissions.

- Some potential effects of major concern are rare, such as brain cancer and acoustic neuroma, both of which have been potentially linked to RF exposure. If the health outcome is rare, it is even harder to demonstrate cause and effect (Ahlbom et al., 2004).

However, there is an active scientific research effort worldwide concerning the potential health effects of RF emissions, with new studies being published frequently. This research environment reflects the public interest in the topic, the increased level of interest within the scientific community, and the desire by governments and health organizations to determine conclusively whether there are any potential effects from RF emissions to either people or the environment.

2.4.2. Regulatory Framework for RF Emissions

As indicated above, RF emissions have been identified by the FCC as a potential environmental factor to be weighed in evaluating a transmitter's effect on the human environment. Currently, the FCC implements and enforces both occupational and public exposure limits to RF electromagnetic fields through its authorization and licensing process. In order for a facility operation or transmitter to be authorized or licensed, FCC requires licensees to be in compliance with its regulations relating to RF emissions.

In 1996, as a consequence of the authority granted by Congress to the FCC in the Telecommunications Act of 1996 (TCA) to "prescribe and make effective rules regarding the environmental effects of radio frequency emissions" (TCA, 104 Pub. L. 104), the agency adopted new guidelines and procedures reflected in its revised Office of Engineering and Technology (OET) Bulletin 65, *Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields*, originally issued in 1985 (FCC, 1997). The revised guidelines include limits for Maximum Permissible Exposure (MPE) for transmitters operating between 300k Hz and 100 GHz which are averaged over a specified time-interval. The limits are different based on whether an occupational setting or a general population exposure setting is being evaluated. These standards have been challenged in federal courts and have been upheld (*See*, for example, *Cellular Phone Taskforce et al. v. FCC,* 205 F.3d 82 (2^{nd} Cir. 2000)).

The FCC has updated its standards for evaluating mobile or personal communication device "localized absorption" as well. The FCC's MPE "localized absorption" limits are based on recommendations from the NCRP and the IEEE [9] and were adopted by ANSI to replace the earlier ANSI guidelines of 1982. These limits are based on thermal effects (i.e., the amount of RF energy required to heat tissue). According to the FCC, the established limits are well below levels that are considered to have adverse health effects. These levels are shown in Table 2.4.2-1 below. Additionally, the IEEE's Committee on Man and Radiation (COMAR) states that the amount of RF emissions in buildings "will be lower than outside, since a substantial fraction of the signal is absorbed when it passes through most building materials" (IEEE COMAR, 2000).

[9] Outside of the United States, many countries (including most of Europe) use exposure guidelines developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The ICNIRP safety limits are similar to those of the NCRP and IEEE (Classic, K., 2015).

COMAR cites a study (Petersen *et al.* 1997) that measured the power density of radiation on the top floors of buildings with roof-mounted antennas (IEEE COMAR, 2000). The study found that radiation emissions on these floors "were less than 0.0004 mW/cm^2 per 100 W Effective Radiated Power (ERP) per channel." For purposes of reference, this indicates that it is 1,000 times less than the FCC standard for general population exposure and 5,000 times less than the FCC standard for occupational workers.

COMAR also found that "roof-mounted base station antennas are normally designed to radiate energy in the horizontal direction away from the building, and they radiate very little energy into the building itself. Therefore, exposure to residents inside a building with roof-mounted base station antennas is invariably very low" (IEEE COMAR, 2000).

In March of 2013, the FCC voted to review current RF rules and regulations and put forth a *Notice of Inquiry*. The *Inquiry* was intended to open discussion around whether the existing RF exposure limits and policies need to be reassessed. Through this process, the FCC has gathered input from industry, scientific experts, and members of the public to help the agency to determine whether current policies and rules need to be changed (FCC, 2013).

Table 2.3.3-1: FCC Regulatory Levels

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $(E)^2$, $(H)^2$, or S (minutes)
Limits for Occupational/Controlled Exposure				
0.3-3.0	614	1.63	(100)*	6
3.0-30	1842/f	4.89/f	$(900/f^{2)*}$	6
30-300	61.4	0.163	1.0	6
300-1500	--	--	f/300	6
1500-100,000	--	--	5	6
Limits for Occupational/Controlled Exposure				
0.3-1.34	614	1.63	(100)*	30
1.34-30	842/f	2.19/f	$(180/f^{2)*}$	30
30-300	27.5	0.073	0.2	30
300-1500	--	--	f/1500	30
1500-100,000	--	--	1.0	30

f=frequency in MHz
*Plane-wave equivalent power density
Source: (FCC, 1996)

2.4.3. Overview of Research for Potential Non-Thermal Effects to Humans

A few organizations have provided research that is useful as a framework for the state of the research on RF and the basis of some of the concerns. For example, several studies of the potential non-thermal health effects cited below have focused on cancer outcomes (primarily childhood leukemia and brain cancers); however, reproductive/neonatal problems, neurological and neurobehavioral issues, and genotoxicity have also been studied. In addition to these studies, one group (the International Association of Fire Fighters) has raised concerns about potential non-thermal effects resulting from RF emissions coming from telecommunications equipment (International Association of Fire Fighters, 2015).

As with any source, RF emissions from the FirstNet system would be dependent on the location, type, and power of antennas used. There are three basic forms of antennas: omnidirectional, narrow horizontal gain (focused beam), and panel.

The most common type of antenna is a panel antenna, as these are easily mounted on towers or rooftops and provide approximately 60 degrees of horizontal and vertical coverage. Omnidirectional antennas are frequently used for things such as Wi-Fi where a widespread area needs to be covered by a signal. Directional beam antennas are used to propagate a strong, focused beam to a specific location which is ideal for sending a stronger signal for greater distances without affecting areas outside the target. Thus, the omnidirectional and beam antennas are generally not suitable for deploying a cellular network.

Panel antennas do not produce a significant amount of radiation outside of the primary lobe, making them an ideal candidate for providing widespread coverage while maintaining control of the radiation beam. Figure 2.4.3-1 shows a typical lattice cell tower with multiple panel antennas arranged radially.

Figure 2.4.3-1: Monopole Cell Tower with Multiple Panel Antennas

Source: (Connecticut Department of Public Health, 2015)

Using the power intensity formula described above and assuming an antenna fixed to a base station transmits 60 watts (W) of power:

- The power density 0.30 m (1 ft) from the base station would be 4.77 W/m^2;
- The power density 0.61 m (2 ft) from the base station drops to 1.2 W/m^2; and
- At 100 m, the power intensity drops to 0.000477 W/m^2, a 99.99% reduction.

Figure 2.4.3-2 depicts the radiation beam from a panel antenna on a 200 ft (61 m) tower. Assuming a 60-degree vertical spread and no vertical tilt, the primary lobe of the radiation beam (shaded blue) would not reach the ground until 346 ft (106 m) from the tower. At the point where the beam reaches the ground (approximately 346 ft [106 m] from the base), there is a 99.99% reduction in power density compared to the power intensity 0.30 ft (1 m) from the panel.

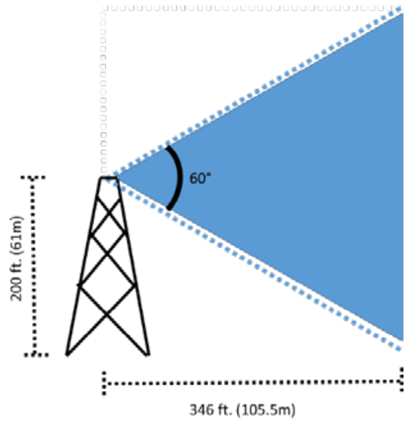

Figure 2.4.3-2: Depiction of Primary Radiation Lobe of a Panel Antenna Attached to a 200 ft (61 m) Cell Tower

Source: (FCC, 1997)

Correspondingly in Figure 2.4.3-2, the zone outside of the blue-shaded area is not within the primary radiation lobe of the antenna, and thus, would receive very little radiation (<0.01% of the density 0.30 m [1 ft] in front of the antenna). This means that buildings and people under the tower would receive little RF emissions from those antennas, assuming none of the antennas are tilted downward.

Figure 2.4.3-3 depicts the decrease of power intensity from a 60W antenna as a function of distance from the antenna and displays the FCC standards for 780 MHz frequency. The 780 MHz frequency is used for these calculations since it splits the two operating frequency bands the FirstNet system would operate at (i.e., 758-769 MHz and 788-799 MHz). While the FirstNet system would not operate specifically at 780 MHz, this frequency best represents all of the possible frequencies at which the system would operate.

Figure 2.4.3-3 further demonstrates that the FCC occupational standard is met at 0.42 m while the standard for the general public is met at 0.96 m. While these distances may seem small and insignificant, this chart only represents one 60W antenna. Generally speaking, there may be three or more antennas serving one area (1 transmitter, 2 receivers). Assuming there are three antennas operating at a power of 60W at 780 MHz each, the standards are then met at 0.72 m and 1.66 m, respectively using the formulas in Table 2.3.3-1.

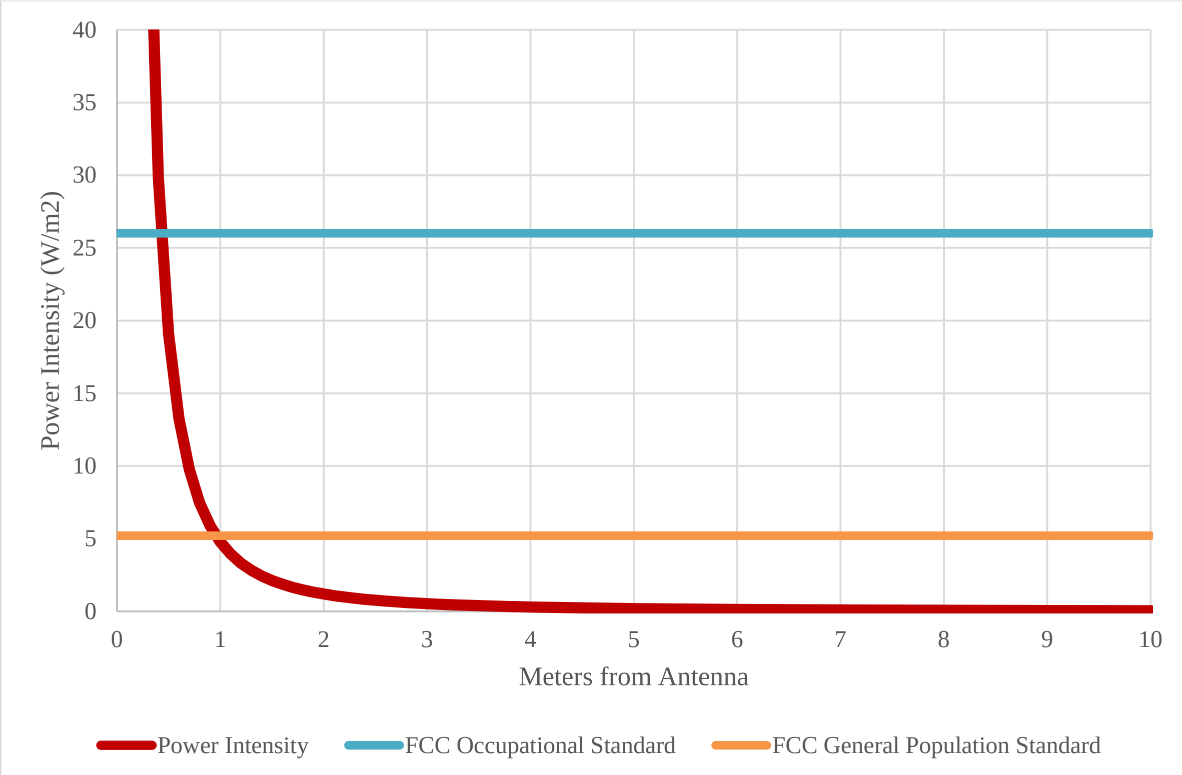

Figure 2.4.3-3: 60W Antenna (780MHz) - Power Intensity vs Distance with Respect to FCC Guidelines for Limiting Thermal Radiation

Note: This figure is a simple representation of the power intensity versus distance from a 60W antenna. There are many other factors that may affect the power intensity at a specific location, which are not accounted for in this graph. Some factors include positive or negative interference with other electromagnetic waves, absorption by building materials or other items, and varying power outputs dependent on signal demand.
Source: (FCC, 1997)

As previously described, radiation can elicit both thermal and non-thermal effects in humans and other biological organisms. Given that thermal effects are only elicited when exposed to intense amounts of radiation, this section summaries the available credible scientific information about potential non-thermal effects of RF emissions, particularly at low power intensities.

Among the research organizations studying RF emissions, the World Health Organization (WHO)—as an agency of the United Nations—is the most prominent. According to the WHO, there have been tens of thousands of papers published on RF, extremely low frequency (ELF) and potentially related health effects over the last 30 years. A recent (May 2015) statement on the WHO website states:

> *The heating effect of radio waves forms the underlying basis for current guidelines. Scientists are also investigating the possibility that effects below the threshold level for body heating occur as a result of long-term exposure. To date, no adverse health effects from low level, long-term exposure to radiofrequency or power frequency fields have been confirmed, but scientists are actively continuing to research this area* (World Health Organization, 2015).

In 2011, based upon the inconclusive data and in an abundance of caution, WHO classified RF exposures due to cell phone use as a 2B carcinogen—indicating that it was possibly carcinogenic to humans—based upon some studies that found a potential increased risk of glioma (a type of brain cancer) associated with cell phone use (International Agency for Research on Cancer, 2011). However, WHO's International Agency for Research on Cancer (IARC) noted that the evidence for carcinogenicity for occupational and environmental exposures (exposures to emissions from cell towers would fall into the "environmental" category) was inadequate to draw conclusions regarding carcinogenic potential.

The conclusions made by the IARC specifically identify RF emissions from wireless phones as the source for positive associations with negative health effects. Many of the studies examined by the IARC for fixed transmitter emissions sued that living close to fixed transmitters increased the risk of developing either brain cancer, leukemia, or lymphoma; nonetheless, the IARC identified several shortcomings of these studies, including:

- Not accounting for mobile phone use or exposure to RF emissions from other sources (ambient RF emissions levels or confounding factors);
- Not accounting for buildings or other geographic features which impact the strength of the radiation;
- Small population size;
- Lack of controls;
- Poor exposure assessment (no individual data);
- Non-differential disease misclassification; and
- Lack of cumulative measure of exposure to RF emissions (take into account individual's place of residence between birth and diagnosis of cancer/disease) (International Agency for Research on Cancer, 2013).

While some of the studies indicated a positive correlation between distance from transmitters and risk of cancer, the caveats identified by the IARC indicate general lack of scientific rigor of previous research projects. Furthermore, most of the studies reviewed by the IARC focus on cellular telephone use rather than low-level, background radiation emitted from fixed transmitter sites. Overall, these studies do not indicate a clear trend, reproducible with regard to the effects of fixed transmitter radiation.

WHO is currently undertaking a health risk assessment of radiofrequency electromagnetic fields, to be published as a monograph in the Environmental Health Criteria Series. WHO scientists themselves began conducting research on RF emissions, and electromagnetic fields more broadly, when it established the International EMF Project in 1996 (Repacholi, M., 2001). However, recent studies on behalf of WHO have concluded that "there is insufficient data to draw firm conclusions about health effects from long-term low-level exposure [to RF electromagnetic fields] typically occurring in the everyday environment" (Roosli et al., 2010).

In contrast to the WHO's statement on health effects, a public advocacy group of scientists, known as the BioInitiative Working Group (BWG), published the BioInitiative Report, first in

2007 and followed by a revised version in 2012 (Sage, C. and D. Carpenter, eds., 2012), that found substantial evidence of adverse health effects associated with RF and ELF exposures. However, the BWG itself has been criticized by other scientific, professional, and governmental bodies for ignoring conflicting, inconsistent, or other credible evidence that clashed with its report (e.g., (Dolan, M. and J. Rowley, 2009)).

The BWG report concluded that there was evidence to support adverse health effects resulting from sustained low-intensity electromagnetic radiation on decreased male fertility, fetal and neonatal effects, brain tumors, childhood leukemia, genotoxicity, and several other effects. The BioInitiative Report noted further that health effects due to emissions from cell towers were cited in a number of studies that possibly linked headaches/sleep disturbance/ concentration issues in children, adolescents, and adults at levels in the range of 0.003 to 0.05 $\mu gW/cm^2$, much lower than current regulatory standards shown on Table 2.3.3-1. BWG recommends lower standards be established and that cell phone towers not be built within certain distances of sensitive receptors, such as schools, daycare centers, and hospitals (Sage, C. and D. Carpenter, eds., 2012).

These two positions illustrate the scientific and philosophical divide. First, there is some evidence of adverse health effects at levels below the current standards in a number of studies, but as is the case with other epidemiological studies attempting to prove causality, these studies are subject to a variety of uncertainties inherent in the epidemiological process.[10] Consequently, it appears that the preponderance of the evidence to date does not definitively demonstrate that there are adverse health effects caused by RF emissions and there is still no single, plausible biological mechanism to indicate adverse effects. Second, although there is some scientific data in certain studies to warrant further investigation, some researchers urge that the precautionary principle should apply to reduce exposures as much as possible (Sage, C. and D. Carpenter, eds., 2012).

2.4.4. RF Emissions and Non-Human Species

Unlike those established for human exposure, no federal regulatory levels have been set for non-human species exposure to RF emissions. This is partly due to the nature of how environmental assessment is conducted under NEPA and how the mechanisms for potential environmental effects are enforced under that statute, as well as with other federal environmental laws and regulations.

Under NEPA, an environmental analysis is required to be conducted by the lead federal agency prior to undertaking any major federal action. This analysis requires the federal agency to consider any and all types of environmental impacts associated with the project and make qualitative decisions concerning the likelihood and severity of the potential effects and give potential environmental effects parity with engineering and economic decisions.

As is the case with considering the potential effects of RF emissions on humans, demonstrating cause and effect in animal and plant species from low-level environmental exposures is

[10] It is difficult to attribute causation when other effects cannot be ruled out. The complexity of health conditions also makes it difficult to imply causation. Epidemiological studies can never provide proof or 100% certainty of an effect (Webb and Bain 2011).

equally—if not more—challenging and it too requires multiple studies over many years and across many species. Although there is some research that shows that there could be potential effects on some animal species associated with RF emissions, here too there is no clear or definitive scientific research and literature, especially for animals or plants in North America, to achieve scientific consensus on whether there exists demonstrable cause and effect.

Undoubtedly, there is considerable public interest into the potential effects of RF emissions on both humans and other species. Research is continuing with a number of scientific and academic centers, although there is still no consensus within the larger scientific community. Consequently, there is still the need for more targeted information, research, and studies on RF emissions and human, plant, and animal life. This means that we should expect that additional research will likely both continue and increase over the coming years.

2.4.5. Research on the Potential Effects to Animal and Plant Species

Since about the year 2000, a number of research studies have been conducted that focus on RF emissions and the potential effects to animal and plant species. However, general discussions of RF exposure to ground migrating and flying animal species, specifically bird species, are largely grouped as a component of broader discussions of direct and indirect effects of transmission and communication towers; many of these studies are from outside the United States (Bhattacharya, R. and R. Roy, 2013) (Bhattacharya, R. and R. Roy, 2014). Many of these studies focus on the effects to population abundance and habitat use resulting from anthropogenic features, such as tower siting and construction, as well as bird collision hazards caused by equipment siting and lighting. As a result, RF emission concerns and potential effects are used as a collective piece of information in some of these studies to discuss broader species impacts related to transmission and communication towers rather than being the focus of the study.

Mirroring the sentiments expressed by the larger environmental community, the USFWS has indicated that RF emissions could be potentially harmful to migratory birds, even at levels too low to cause thermal effects (Manville II, A., 2007) (Manville II, A., 2009) (Manville II, A., 2014).[11] Although there has been more recent discussion on the RF emission potential of communication towers in the U.S., these discussions still focus on the European research that has been carried out on RF emission effects to birds. The emphasis of the research is on two areas: impacts on avian reproduction and interruption to avian navigation.

Research conducted in Balmori (2005), Balmori and Hallborg (2007), and DiCarlo (2002) suggests that the presence of electromagnetic fields in the microwave range may be a consideration in the decline of some urban bird populations (Balmori, A., 2005), (Balmori, A. and O. Hallberg, 2007), and (DiCarlo et al., 2002). Research in Balmori (2005) focused on several species of wild birds in relation to cellular tower sites in Spain and indicated negative correlations between levels of RF emissions and bird breeding, nesting, and roosting. Also, nest and site abandonment, plumage deterioration, locomotion issues, and even death were noted for

[11] It should be noted that although discussions of RF emissions generally involve "biological effects," meaning terrestrial and avian species, the research and environmental community have focused largely on bird species, especially migratory.

some house sparrows, white storks, rock doves, magpies, collared doves, and other species that had historically been documented to roost and nest in close proximity to cellular antennas. The research suggested that these symptoms were not observed prior to construction of the cellular towers.

Balmori and Hallberg (2007) reported that declines of urban house sparrows in Spain increased as electromagnetic field strength increased. A report by Everaert and Bauwens (2007) also found negative correlations between the amount of RF emissions present and the presence of male house sparrows and concluded that long-term exposure to higher emission levels may be affecting bird abundance or bird behavior in this species (Everaert, J. and D. Bauwens, 2007).

Similarly, Bhattacharya and Roy (2014) looked at bird and nest occurrence in relation to tower proximity and electromagnetic fields in India. The study examined bird species within proximity to towers and used the point count method to identify the presence of birds and nests at various distances in all four cardinal directions from towers. This study found that bird occurrence was lowest within 20 meters of towers, which is the zone where power density was at peak values. Also, it was found that within this zone food sources were readily available and avoided. Additionally, no nests were identified within this zone and the closest nest was well outside this zone (approximately 80 meters) (Bhattacharya, R. and R. Roy, 2014).

Laboratory studies conducted with domestic chicken embryos have shown that emissions at the same frequency and intensity as that used in cellular telephones have appeared to result in death (DiCarlo et al., 2002) (Manville II, A., 2007). These studies have been used to suggest that RF emissions at low levels (far below the existing exposure guidelines for humans) may be harmful to wild birds; however, given the controlled nature of the studies and potential exposure differences in the wild, this causation is left to interpretation and extrapolation. A number of other studies generally touch upon the nature of RF exposure and the disruption of biological processes that are fundamental to plant and animal growth and health, including but not limited to behavior, DNA damage, immune deficiencies, reproductive system effects, hormone dysregulation, degraded cognition and sleep, and desynchronization of neural activity (BioInitiative Working Group, 2012) (Balmori, A., 2005).

Further, it has been suggested that RF emissions may act as an attractant to certain other species of birds. Magnetite is a mineral found in high concentrations in bird eye, beak, and brain tissues and is used by birds for navigation. Since magnetite is highly sensitive to the electromagnetic frequencies, it has been suggested that RF emissions could lead to increased bird strikes and/or direct exposure to high levels of RF emissions due to the attractant quality of materials used in some equipment (Ritz, 2004) (Balmori, A., 2005). Along these same lines, Balmori (2005) has noted that other flying species that use magnetic fields for navigation purposes have been found to be affected by RF emissions, primarily honeybees and butterflies.

There are no available studies indicating that low-level RF emissions affect honeybees. After several studies were published regarding the effects of cell phones on bees, the author of one of the studies, Stefan Kimmel, "emailed *The Associated Press* to say that there is 'no link between our tiny little study and the Colony Collapse Disorder (CCD)-phenomenon… Anything else said or written is a lie" (U.S. Department of Agriculture, 2015). Other, less defensible studies have purported to find that RF emissions from cell towers affect bees' behavior and could be responsible for colony collapse disorder. In general, these studies are not published in peer-reviewed and in credible journals. An Appendix contains some well-known honeybee studies either published in predatory journals or that are informal in nature.

2.4.6. Conclusions on RF Emissions and Humans

Based on the analysis above, there is insufficient and inconclusive data to make a definitive determination of effect of RF emissions on humans. Although there is some evidence of adverse health effects at levels below the current standards in a number of studies, these studies are subject to a variety of uncertainties inherent in the epidemiological process. Conversely, the preponderance of the evidence to date does not definitively demonstrate that there are adverse health effects caused by RF emissions and there is still no single, plausible biological mechanism to indicate adverse effects.

2.4.7. Conclusions on RF Emissions and Animal/Plant Species

The amount of research related to determining whether there are identifiable effects from RF emissions to species is fairly extensive and growing, although inconclusive. Those referenced above are merely a few of the more recent studies that are directly applicable to RF emissions and communication towers and potentially pertinent to the evaluation of the proposed Project. The conclusions to be drawn by these studies vary, as the research is still too fragmented and inconclusive to demonstrate the needed cause and effect to various species caused by RF emissions. However, even in those studies that conducted quantitative analysis and research, the widespread conclusion is that more research is essential to better understand the patterns of cause and effect, variations among species, and the potential sensitivities and severity to such species.

The common practice for NEPA documents related to cellular towers is to cite FCC standards and point to the fact that they would be built and operated according to allowable FCC RF emission limits. Some NEPA documents that have more directly addressed the RF emissions potential largely point to the existing literature and suggest that although there is evidence that RF emissions could potentially affect some species, the evidence is insufficient to support a finding of adverse impacts on these species due to RF emissions (Ballistic Missile Defense Organization, 2000) (FCC, 2012).

2.4.8. Summary

FirstNet is a licensee of the FCC and FirstNet's operations in the 700 MHz range are governed by FCC regulations establishing exposure limits for RF emissions. Federal law authorizes the FCC to establish regulatory levels for human exposure to RF emissions. Over the years, the FCC has revised its standards and guidelines for protecting both workers and the general public—including limits for Maximum Permissible Exposure (MPE) for transmitters covering the 700MHz range and localized absorption limits for mobile devices—and these have been upheld by the federal courts.

Scientific investigations into RF emissions and the possible effects of exposure on humans, animals, and plants are inconclusive. These studies do not indicate any clearly reproducible trend and, consequently, there is insufficient and inconclusive data to make a definitive determination of effect of RF emissions on humans.

As discussed in detail above, while the science is currently inconclusive regarding the effects of RF emissions on humans and animals, FirstNet will continue to monitor any new studies or information that may come to light before the PEISs are finalized. Any new information or studies will be considered as part of the final analysis and incorporated, as appropriate, into the final document.

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