
**Report to
The Vermont Legislature**

**The Possible Health Consequences from Exposure to the Radio Frequency Fields Produced
by Wireless Technologies, Including Cellular Telephones and FCC Regulated Transmitters
2020 Report to the Legislature**

**In Accordance with Act 79 (2019), Section 24, An act relating to broadband deployment
throughout Vermont.**

Submitted to: Senate Committees on Health and Welfare and on Finance
House Committees on Health Care and on Energy and Technology

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The Possible Health Consequences from Exposure to the Radio Frequency Fields Produced by Wireless Technologies, Including Cellular Telephones and FCC Regulated Transmitters

Executive Summary

This report provides an overview of what is currently known about health effects caused by radio frequency radiation (RFR) from wireless telecommunications technologies, including from the nascent 5G wireless technology.¹ The primary findings included in this report are:

- The only consistently proven negative health effects of RFR are local or systemic hyperthermia, shock (electrocution) and burns caused by tissue heating (what are called thermal effects). These effects are almost exclusively a risk for individuals who work on large transmitters and are not a regular risk to the public.
- Cancer from RFR exposure has been extensively investigated in laboratory and epidemiological studies. Results from these studies provide some evidence that RFR is associated with cancer in animals and humans. More studies are needed to understand how RFR may contribute to cancer, and more work is needed to understand how the animal studies can be translated to the risk in humans.
- 5G wireless RFR does not penetrate the human skin to harm other tissues but may be a thermal or other unknown risk to the skin itself and the eyes when the transmitter is in close proximity.
- To help protect worker safety and public health, Federal Communications Commission (FCC) information on RFR effects and assessment of transmitter emissions (particularly FCC Office of Engineering Technology Bulletins 65 and 56) needs to be updated and include newer wireless technologies, including 5G wireless.
- The Federal Communications Commission affirmed the maximum permissible exposure limits for RFR on December 4, 2019 including those for the frequencies of 5G wireless which remain the same as previously affirmed. Current FCC regulations, based on recommendations from scientific committees that have reviewed thousands of studies, are adequate to protect people from the thermal effects of RFR. These regulations also preempt state regulations of RFR.

Background

People are exposed to RFR at all time. Natural sources of RFR include the earth, the sun, other celestial bodies, and the ionosphere.¹ People are also exposed to RFR from a variety of technologies, including radar for navigation, AM and FM radio and television broadcast signals, and wireless telephones.

RFR is a form of non-ionizing radiation. Non-ionizing radiation does not have the ability to create charged particles, negative ions or positive ions as it interacts with matter. Technologies that utilize non-ionizing radiation appear to the left of x-rays on the electromagnetic spectrum (Figure 1) and include radio waves and microwaves produced by wireless telecommunications

¹ The Department of Health reported on the health implications of radio frequency radiation (RFR) in a February 2012 report on smart meters entitled *Radio Frequency Radiation and Health: Smart Meters*,¹ and in a “Smart Meters Fact Sheet”.¹

which are collectively referred to as RFR. Ionizing radiation, such as x-rays and gamma rays, can create charged particles, negative ions or positive ions, and are known to cause cancer through direct and indirect damage of DNA.

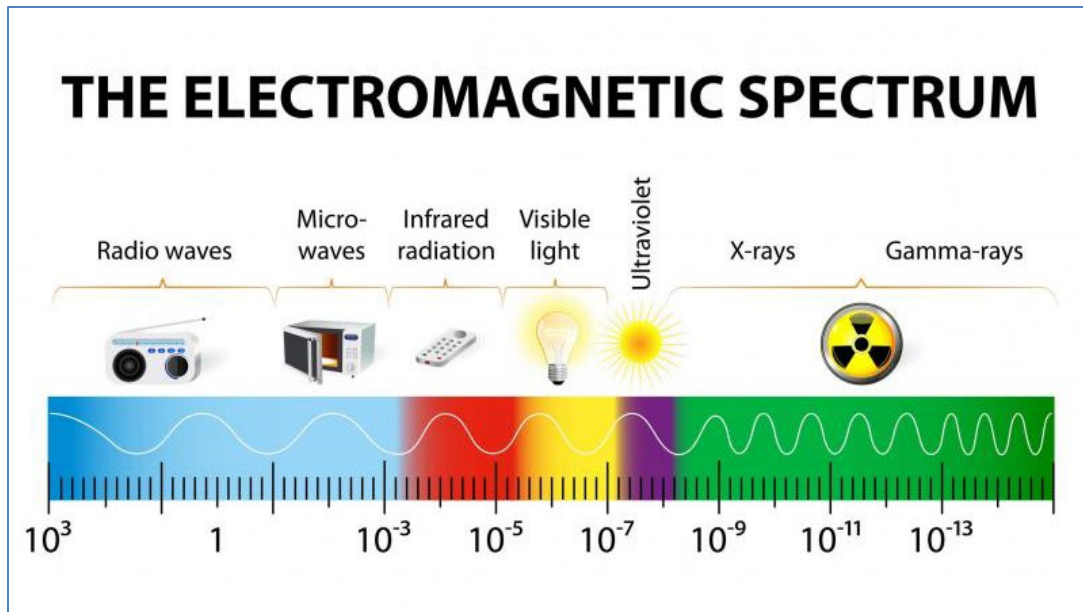


Figure 1: The Electromagnetic Spectrum with Wavelength Expressed in Metersⁱⁱ

The Scientific Literature on RFR

Summary

The effects of RFR on humans have been investigated and reported on by numerous scientific committees since the 1950s. The relevant findings from the most comprehensive and credible of these reports — including those that address wireless telecommunications RFR such as 5G — have been summarized in Appendix B.

Overall, the only effects to humans from RFR that have been clearly demonstrated are heat exhaustion, heat stroke, shock, and burns caused by excessive heating of the human body.^{iii,iv,v} This heating is similar to that which occurs in a microwave oven except that the power levels most people are exposed to are much lower. There is some evidence to indicate that RFR is carcinogenic in animals and humans, but more studies are needed to understand how RFR could lead to cancer. The current science on the cancer risk of RFR is not robust enough to create standards based on cancer protection. Importantly, the body of evidence regarding the health effects of RFR from 5G technologies is limited, and in order to fully understand the potential health effects, additional research is needed.

Findings in the Literature Review by Scientific Committees

Thermal Effects

There is broad scientific consensus that RFR exposure to humans causes thermal effects. As RFR interacts with the human body, heat is generated. If that heat exceeds the local or whole-body capacity to manage it effectively, the local area or whole body heats up. If core body temperature increases by greater than one degree Celsius (1.8 degrees Fahrenheit), bodily harm is possible. Early effects of this hyperthermia are similar to those of a fever and the risk increases with

temperature. Whole body temperature increases may result in heat exhaustion, heat stroke or death, while localized thermal increases may lead to cell and organ disfunction from tissue overheating and to varying degrees of pain and burns. Shock and RFR electrocution may also occur with certain acute exposures. RFR electrocution may be fatal. Temperature increases are the result of a radiation-induced vibration of molecules in tissue, especially water molecules similar to how microwaves heat food or water in an oven.

Carcinogenic Effects

Conclusions from the scientific community regarding the carcinogenic potential of RFR exposure are inconsistent. Some reports (summarized in Appendix B) suggest there is “no well-documented evidence” that exposure to RFR increases the risk of cancer, while others suggest there is “limited evidence” of this potential effect. This evidence is found in some epidemiological studies of long-time, heavy users of wireless telephones and increased incidence of brain cancers. Studies of animals exposed to whole-body RFR indicated “clear evidence” of the formation of heart tumors associated with RFR exposure, though the applicability of these observations which occurred at much higher power levels and for longer exposure times than is typical of people have not been directly extrapolated to assess human health risks.

Based on the available evidence from 2G and 3G wireless telecommunications RFR, it is reasonable to conclude that high levels of RFR from cell phones may be harmful to humans if they are exposed for long hours each day over their entire lifetime. Current FCC regulations for these wireless telecommunications technologies limit levels of exposure to much less. Still, this reinforces efforts in public health to minimize the dose to RFR. Absent additional research, the conclusion cannot be extrapolated to 5G wireless RFR, nor can those risks be ruled out.

5G RFR

The millimeter waves emitted from 5G technologies have limited penetrating capabilities. RFR from 5G is not able to travel through the exterior walls of most structures — unlike other wireless telecommunications RFR generations — and they also do not travel as far through air as other frequencies used by wireless telecommunications. This means 5G base stations, that connect wireless handsets to the rest of the telecommunications network, must be located closer together and within our living and working spaces. Standards and best practices from research scientists and scientific working groups that dictate maximum power densities for transmitters and minimum separation distances between a user and a transmitting device can prevent RFR exposures that would exceed dose recommendations (and the potential for associated health effects), and have been cited in Appendix B.

There is a relatively small body of scientific literature on RFR from the frequencies used by 5G wireless technologies. The studies that do exist have found that RFR from 5G wireless technologies does not penetrate the skin, and the only known health effects are associated with excessive heating of the skin and eyes.^{vi} The limited body penetration capabilities of 5G RFR may make deeper tissue effects, including cancer, less likely. Nonetheless, the body of literature regarding potential health effects from 5G RFR remains inconclusive, and additional research on the long-term risks from exposure to RFR from 5G technologies — particularly for effects to the skin and eyes — is needed.

Regulation

In the United States, the Federal Communications Commission (FCC) regulates RFR from interstate and international communications services provided by radio, television, wire, satellite and cable. In 1996, the FCC adopted exposure and dose limits (Title 47 of the Code of Federal Regulations § 1.1310) which have been included in Attachment A.

Additionally, the FCC's Office of Engineering and Technology (OET) publishes two documents that address RFR and human health. The *OET Bulletin 56, Questions and Answers About the Biological Effects and Potential Hazards of Radio Frequency Electromagnetic Fields*^{vii} provides information about exposure limits and the effects of RFR when exposures exceed the limits. The *OET Bulletin 65, Evaluating Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields*^{viii} provides guidance for those designing and installing RFR telecommunications facilities so they can determine if their facility complies with the limits. These bulletins were published in 1999 and 1997, respectively, and are therefore too outdated to provide the public and health protection professionals with relevant guidance to verify compliance to FCC regulations for newer RFR-generating telecommunications technologies such as 5G wireless.

The FCC's online RFR safety documents are a little more up to date and address RFR from earlier generation cell phones, telecommunications towers, vehicle mounted antennas and general wireless devices. Additionally, consumers can look up the dose in what is called specific absorption rate or SAR (see Attachment A) for particular cell phones using the device's FCC ID number.^{ix} Facility developers can review guidance on tower and antenna siting criteria.^x The FCC regulations also specify the conditions under which a wireless facility is required to conduct an Environmental Assessment.^{xi} Importantly, some FCC rules preempt other authorities from regulating RFR emissions from transmitters licensed by the FCC.^{xii} The FCC affirmed the maximum permissible exposure limits for RFR on December 4, 2019 including those for the frequencies of 5G wireless which remain the same as previously affirmed.^{xiii}

Recommendations to reduce personal exposure

The Food and Drug Administration (FDA)^{xiv}, National Cancer Institute (NCI)^{xv} and Centers for Disease Control and Prevention (CDC)^{xvi} provide fact sheets on RFR from wireless technologies. None of these entities provides information on the actual health risks from wireless telecommunications devices, but in recognition of the potential for adverse health effects each provides recommendations for reducing personal exposure to RFR from cell phones.

Recommendations include:

- Using functions like a hands-free headset directly connected to the cell phone to allow cell phone users to operate their phones at a distance.
- Using the speaker phone function to increase distance from the transmitter.
- Using wireless telephones less time.
- Turning off the wireless handset RFR features (which includes the Bluetooth connectivity) when not in use.
- Obtaining a wireless telephone with lower emissions.

Attachment A: Table 2 FCC Limits for Maximum Permissible Exposure^{xvii}

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm ²)	Averaging time (minutes)
(A) 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
300-1,500			f/300	6
1,500-100,000			5	6
(B) Limits for General Population/Uncontrolled Exposure				
0.3-1.34	614	1.63	* 100	30
1.34-30	824/f	2.19/f	* 180/f ²	30
30-300	27.5	0.073	0.2	30
300-1,500			f/1500	30
1,500-100,000			1.0	30

f = frequency in MHz * = Plane-wave equivalent power density

The table describes two exposure scenarios: (A) the occupational or controlled environment and (B) the general population or uncontrolled environment. The frequency range of the RFR source is given in the first column in megahertz (MHz). Emissions for frequencies between 0.3 and 300 MHz may be measured in three different ways. For frequencies between 300 and 100,000 MHz, emissions are measured in one way. If measurements of exposure are less than or equal to the values in the table above, the dose to people will be within safety limits. The dose from RFR is regulated in terms of specific absorption rate (SAR). This dose limit is designed to prevent the heat generated in tissues from radio waves, microwaves or millimeter waves from exceeding the heat regulating capacity of the body. If the SAR is less than the dose limit, the effects of heat exhaustion, heat stroke, burns and shock will not occur.

Appendix B: Scientific Committee Reviews of the Literature

The National Council on Radiation Protection and Measurements (NCRP) recommendations on RFR safety are based on studies reviewed in detail in *NCRP Report No. 86, Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields*. It provides detailed descriptions of the effects of RFR on every part of the body. The chapter on how RFR interacts with our bodies illustrates the varying effects by frequencies. An important reason for the varying effects is that each frequency penetrates the body to different depths. Radio waves penetrate deeply, while microwaves penetrate less so. The frequencies of 5G wireless, called millimeter waves, only effect the outer skin surface. The NCRP report covers research studies conducted between 1885 and 1985. The most recent research is described in the IEEE, IARC and ICNIRP reports.

The Institute of Electrical and Electronic Engineers (IEEE) International Committee on Electromagnetic Safety is similarly composed of people of many disciplines and membership is open to all. The IEEE periodically reviews the new scientific literature and updates recommendations for RFR dose control and exposure measurements. The IEEE's latest recommendations are found in *IEEE Standard for Safety Level with Respect to Human Exposure to Electric, Magnetic and Electromagnetic Fields, 0 Hz to 300 GHz* and based on studies published between 1948 and December 2017. This revision of the IEEE Standard was published in October 2019.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is similar to the NCRP in that it is relied upon to provide recommendations to regulatory authorities who establish guidelines to control occupational and public exposure and dose. ICNIRP recommendations are published by the WHO and used by nations, especially those that have no internal agency providing scientific guidance. The ICNIRP Guidelines were published in 1998^{xviii} and reinforced as adequate for continued use in an ICNIRP Statement in 2009. A revision of 1998 Guidelines is in draft form at this time^{xix}. The bases for the guidelines are provided in *Exposure to High Frequency Electromagnetic Fields, Biological Effects and Health Consequences (100 kHz-300 GHz)*^{xx}.

Scientists within the International Agency for Research on Cancer (IARC) have independently reviewed the scientific literature and classified more than 1,000 agents for their likelihood to cause cancer. Table 1 shows how these agents are grouped according to their carcinogenicity. The classifications and the reasons the classification is made are found in IARC Monographs. The IARC monograph that explains the classification of RFR is volume 102, *Non-ionizing Radiation, Part 2: Radiofrequency Electromagnetic Fields*^{xxi}.

Agents Classified by the IARC Monographs, Volumes 1-124		
Group 1	Carcinogenic to humans	120 agents
Group 2A	Probably carcinogenic to humans	82 agents
Group 2B	Possibly carcinogenic to humans	311 agents
Group 3	Not classifiable as to its carcinogenicity to humans	500 agents

Table 1: International Agency for Research on Cancer Agent Classifications^{xxii}.

Ultraviolet light, solar radiation and all the ionizing radiations are among the 120 agents classified by IARC as Group 1 Carcinogenic to Humans. No non-ionizing radiations are among the 82 agents classified as Group 2A Probably Carcinogenic to Humans. RFR is classified with 310 other agents as Group 2B Possibly Carcinogenic to Humans.

The IEEE standards have consistently refuted an association of RFR exposure and cancer, the 2019 IEEE Standard also has not found sufficient evidence of any non-thermal effects of RFR including carcinogenesis: “A review of numerous supportive studies addressing cancer and basic cellular interactions show no consistent evidence for a reproducible biological effect of low-level (nonthermal) RF exposure...The majority of studies report no effect^{xxiii}.” The IEEE references the World Health Organization (WHO) EMF Project Fact Sheet #193 which states that “to date, no adverse health effects have been established as being caused by mobile phone use^{xxiv}.” ICNIRP has examined the scientific literature and concluded that only tissue heating is a demonstrable health effect^{xxv}.

These positions have recently been challenged by the release of the National Toxicology Program (NTP) wireless telecommunications studies. The NTP Technical Report Series began in 1976 to report on mouse and rat toxicological and carcinogenic risk laboratory studies they conduct. The results are frequently used by health regulatory bodies in risk assessment activities leading to rulemaking. The NTP’s cell phone RFR studies have been long anticipated because they were long-term studies, used actual wireless telephone frequencies, were conducted under widely accepted laboratory practices and used widely accepted test animals. The methods, results and conclusions of the mouse and rat studies are available on-line^{xxvi,xxvii}.

The NTP’s conclusions about carcinogenicity are based on their four categories of evidence that a substance may cause cancer: clear evidence, some evidence, equivocal evidence, and no evidence. The NTP exposed mice and rats to high levels of RFR (used in 2G and 3G wireless) for two years. 2G and 3G were the standard when the NTP study was designed. There are some important differences between higher frequency RFR from 2G and lower frequency RFR from 5G. Importantly, the 5G wavelengths do not penetrate the skin as well as the 2G wavelengths.

The NTP studies found *clear evidence* of tumors in the hearts of male rats exposed to RFR. These tumors were schwannomas, tumors of the tissues that cover nerves. The NTP studies found *some evidence* of tumors in the brains of male rats exposed to RFR. These tumors were malignant gliomas, the same type of tumors for which IARC found limited evidence in humans to connect them to RFR. The NTP study found *some evidence* of tumors in the adrenal glands of male rats. In female rats, and male and female mice, NTP found *equivocal* (unclear) evidence whether cancers observed in the animals were due to RFR.

Some agencies have questioned the validity of the NTP studies, given that the conclusions were limited to male rats. Some chemicals have sex-specific toxicity in animals and humans^{xxviii}. Since the potential mechanism for RFR-induced carcinogenesis is unknown, we don't know if it's biologically plausible for RFR to lead to cancer in males versus females. Others have questioned the relevance of schwannomas only in the heart. Schwannomas are tumors of the tissue that covers nerves, so schwannomas are not specific or expected to only be in the heart.

There are some differences in the way the NTP study was conducted and the way that people are exposed to RFR. First, the animals were exposed to much higher doses of RFR, and for longer periods of time, than the general public is exposed to. This has been criticized by some^{xxix,xxx,xxxi} and defended by others^{xxxii}. However, it is a common practice in toxicology to administer high levels of chemicals to animals in order to clearly see the health effects that are produced in animals. The effects seen at high doses to animals are extrapolated downward to estimate the amount of human exposure associated with no health effects.

Second, the animals' whole bodies were exposed to RFR. With humans, usually just our heads are exposed to RFR. These differences in the NTP study and human exposure mean the study results cannot be directly applied to humans.

Still, these studies question the long-held belief that RFR does not have health effects other than heating up bodily tissues. One conclusion that may be drawn from the NTP toxicological and carcinogenic studies is that high levels of RFR from cell phones may be harmful should users be exposed for long hours each day over their entire lifetime. This reinforces efforts in public health to minimize the dose to RFR, especially to children. A question that arises is whether the NTP study using older 2G and 3G wireless telecommunications RFR is applicable to 5G wireless RFR.

Specific Health Implications Related to 5G

There are a limited number of scientific papers that focus on RFR from the frequencies of 5G wireless technologies. The key points from them is that RFR from 5G wireless technologies does not penetrate the skin, so it only doses the skin and eyes, and additional research is required about what those skin and eye effects may be for long-term exposure. Limitations on body penetration may make deeper tissue effects including cancer less likely, and this deserves additional scientific research, too.

In a 2019 literature review, Myrtil Simko and Mats-Olof Mattson^{xxxiii} review 94 cell and animal experiments using RFR millimeter wave frequencies between 6 and 100 GHz, the frequencies of some 5G wireless services. They state that no conclusions can be drawn because of the many differences among the studies, the contradictory nature of some studies when compared to

others, and the poor quality of dose assessment and temperature control for the subjects irradiated.

In a separate 2019 review, Miller *et al.*^{xxxiv} examine carcinogenicity, reproductive effects and childhood exposure. They cite the IARC classification of RFR from cell phones as possibly carcinogenic to humans and the NTP toxicological and carcinogenicity studies as evidence of harm to well-being. They do not share evidence that these conclusions mean more or less for 5G wireless RFR exposures. Their recommendations include improving RFR information sharing for device users, especially for devices used near children or close to the skin.

Russell^{xxxv} describes the potential for increased RFR dose to the skin and eyes in a paper that is more opinion than science. Researchers, however, have demonstrated how millimeter waves cannot penetrate the human body as well as building facades. Wu *et al.*^{xxxvi} presented the skin and eye dose issues along with numerous other millimeter wave concepts. They confirmed skin and eye dose could be a greater risk with 5G versus other frequencies, recommended more study be conducted on the thermoregulatory response of the skin and eyes, and that effective means to assure RFR device compliance to skin and eye exposure criteria be created.

With their limited penetrating ability, millimeter waves do not go through the exterior walls of most structures like other wireless telecommunications RFR. They also do not travel as far in air as compared to other frequencies used by wireless telecommunications. This means 5G base stations that connect wireless handsets to the rest of the telecommunications network have to be closer together and within our living and working spaces. Colombi *et al.*^{xxxvii} provide mathematical analyses that result in maximum power densities for transmitter and minimum separation distances between a user and a transmitting device to prevent exposures that exceed dose recommendations. The IEEE Standard and the soon to be published ICNIRP^{xxxviii} criteria address the skin, eye, maximum power density and minimum separation distances for millimeter waves, including for the frequencies used by 5G wireless.

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