Dr. Christopher C. Davis

Qualifications

Educational and Training

B.A. with Honors, Natural Sciences, Trinity College, Cambridge University (England).

Diploma, with Distinction, Advanced Studies in Science (Physics), University of Manchester (England).

M.A. Natural Sciences (Physics), Trinity College, Cambridge University (England).

Ph.D. Physics, University of Manchester (England).

Post-Doctoral Fellow, Applied and Engineering Physics, Cornell University (United States).

Present Position

Minta Martin Endowed Professor of Engineering and Research Professor of Electrical and Computer Engineering, University of Maryland. Professor at the University of Maryland for over 30 years; also served as the Associate Dean of the School of Engineering at the University of Maryland.

Research Experience

Conducted research for over 40 years on a wide variety of scientific studies in the fields of physics, biophysics, and electrical engineering, and particularly studies on electromagnetics, bioelectromagnetics, and radio frequency electromagnetics, bioelectromagnetics, and dosimetry. Conducted a substantial amount of research on radio frequency fields of the type produced by AMI meters.

Publications

Authored or co-authored two books, twelve book chapters, 264 articles published in peer-reviewed scientific journals and 327 papers presented at scientific conferences. Among those publications,

2 book chapters and 24 peer-reviewed articles on radio frequency fields. Presented 55 papers at scientific conferences on radio frequency fields.

Teaching Experience

Many subjects in the fields of Physics and Electrical Engineering, particularly Electromagnetics, including RF electromagnetics, to students seeking Bachelor's degrees, Master's degrees, and Doctorate (Ph.D.) degrees. Supervised 73 students who ultimately earned Master of Science or Ph.D. degrees in Electrical Engineering, Physics, or Biophysics.

Professional Recognition

Fellow of the Institute of Electrical and Electronics Engineers (IEEE). Previously Chair of Subcommittee on Radio Frequency Fields of IEEE Committee on Man and Radiation (COMAR).

Fellow of the Institute of Physics. Fellow of The International Society for Optics and Photonics)

Invited presentations about the science of electromagnetics and bioelectromagnetics from institutions, including: The Johns Hopkins University Applied Physics Laboratory; Stanford University; Universities In Canada, Denmark, Korea, Turkey, Taiwan, England, And Australia; The Korean Institute Of Science And Technology; The Los Alamos National Laboratory; The National Bureau Of Standards; The National Institute Of Standards And Technology; The U.S. Food and Drug Administration; and the NASA Goddard Space Flight Center.

Reviewer of papers for a number of scientific publishers, including: the American Industrial Hygiene Association Journal, Australian National Health Research Council, Bioelectromagnetics, Cambridge University Press, Radiation Research, Biochimica et Biophysics Acta, Biopolymers, Environmental Biophysics, Applied Physics Letters, The British Council, IEEE Journal Of Quantum Electronics, IEEE Journal on Selected Areas In Communication, IEEE Transactions On

Biomedical Engineering, International Journal of Modern Physics, Journal of Applied Physics, Journal of Manufacturing Science and Engineering, Microelectronic Engineering, Ohio Board of Regents, Radiation and Environmental Biophysics, Physiological Measurement, Physics in Medicine And Biology, Environmental Biophysics, The National Institutes of Health, and The National Science Foundation.

Expert Advice Experience

Provided expert advice on both power frequency and radio frequency fields, including dosimetry and proposed mechanisms for biological effects, to the United Kingdom Health Protection Agency, the U.S. National Institutes of Health, and the U.S. Food and Drug Administration's Center for Devices and Radiological Health.

Fields of Expertise Related to Testimony In This Case

Physics, Biophysics, Chemistry, Electrical Engineering, Electromagnetics, Bioelectromagnetics, and Radio Frequency Bioelectromagnetics and Dosimetry.

Recognized as an expert in those fields in Pennsylvania Public Utility Commission proceedings 2016 - 2020.

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Terminology and Some Basic Concepts Relevant to My Testimony in This Case

"**EMF**" is used as an abbreviation for several somewhat different terms. Sometimes it is used as an abbreviation for "electric and magnetic fields," particularly those around electrical appliances and powerlines, which can be easily separately measured; sometimes it is used as shorthand to refer to just the "magnetic fields" around electrical appliances and powerlines; and sometimes it is used as an abbreviation for "electromagnetic fields," particularly by physicists and electrical engineers. (I use it as an abbreviation for electromagnetic fields at frequencies where the electric and magnetic fields are normally measured together rather than separately.)

A "**field**" is an area around an object where an electric and magnetic component can be detected. An easy way to understand what a field is to think about the gravitational field we have on Earth, or the cool temperature field near an open refrigerator.

"**Dosimetry**" is the measurement and calculation of the level of electric and magnetic fields produced from a source. At the low frequencies used by powerlines and appliances, electric and magnetic fields are sometimes measured or calculated and referred to separately. At higher frequencies, such as radio frequency, the fields are normally measured or calculated together and referred to together as an electromagnetic field.

"**Radiation**" is a scientific term that describes how energy travels from a source, i.e., it "radiates" out from the source. An example of radiation is the waves that radiate out in a circle when a stone is tossed into a pond. TV and radio broadcast towers, powerlines, appliances, home wiring, and TV remote controls all produce fields that radiate out from the source. NASA has a good and simple statement about radiation on its website: "Radiation is energy that travels and spreads out as it goes - the visible light that comes from a lamp in your house and the radio

waves that come from a radio station are two types of electromagnetic radiation." It is technically accurate to refer to radio frequency "radiation," but doing so sometimes confuses people into thinking about radio signals as though they can be harmful like sources of ionizing radiation such as medical X-rays.

There are 2 basic categories of electromagnetic radiation based on their fundamental capability and within those categories there are different types of electromagnetic fields that have different properties and thus different uses.

Physicists list sources of electromagnetic radiation on an electromagnetic spectrum in order from the longest wavelength, which has the lowest energy, to the shortest wavelength, which has the most energy. (A simplified representation of the electromagnetic spectrum is shown in Penelec Exhibit CD-4.) The two fundamental categories of the electromagnetic spectrum are Non-ionizing radiation and Ionizing radiation.

The Ionizing Radiation category consists of the sources of waves that have enough energy to break chemical bonds in DNA. The Ionizing radiation category includes several types of ionizing radiation, such as Medical X-rays and Radioactive Sources, like the uranium used in bombs. The Ionizing radiation category also includes the Ultraviolet Light from the Sun (which we know can damage our skin).

The Non-ionizing category of the electromagnetic spectrum consists of waves that do not have enough energy to break any chemical bonds including the chemical bonds in DNA. That category has a number of types of radiation grouped in order starting with lower frequencies: from Extremely Low Frequency (produced from the electricity we use), up to Radio Frequency, and up to Infrared (e.g., used by TV remote controls), none of which has enough energy to break the chemical bonds in DNA and therefore are in the Non-ionizing Radiation category.

A radio frequency field is produced when an object sends a signal in the radio frequency range, most commonly for radio communications. The radio frequency range is generally considered to be from 3 kHz (kilo Hertz) to 300 GHz (Giga Hertz).

Microwave signals are the part of the radio frequency range between 300 MHz and 3GHz. Therefore, all microwave signals are radio frequency waves. When the term "microwaves" is used in communicating about devices that produce microwave signals but are not microwave ovens, people who are not physicists or electrical engineers can incorrectly assume that the devices have the same properties as microwave ovens.

Microwaves ovens are designed to produce radio frequency waves that are intense enough to quickly heat biological matter (food and liquids) to a very high temperature and exposure to those intense waves is dangerous. All devices that use radio frequency fields in the microwave portion of the radio frequency range, however, do not produce a wave that is intense enough to heat biological matter. Smart meters are a good example of those kinds of devices. They operate in the microwave frequency range but they do not produce a wave that is intense enough to heat biological matter. In communicating with people who are not physicists or electrical engineers, unless I am talking about the properties of a microwave oven, I use the term "radio frequency" to avoid giving a false impression that a particular device produces a wave that is as intense as that of a microwave oven.

Almost all of the electricity we use in our houses and other structures has always been produced by rotating generators at power stations. Those generators produce electricity that is transmitted to us at 60 Hz (in the United States) but it also includes harmonic waves at multiples of 60 Hz (120 Hz, 180 Hz, 240 Hz, etc.). Harmonics are not considered "dirty electricity" because they are a natural byproduct of generating electricity. AMI meters do not *generate*

electricity and therefore do not produce harmonics or "dirty electricity". They simply measure the electricity flowing into a house or other structure.

Some people have expressed concern about switching-mode power supplies in electrical devices like appliances and smart meters. Switching-mode power supplies generate radio frequency fields at up to about 10 MHz at very low levels. Many modern electrical appliances use switching mode power supplies. Switching mode power supplies have filters to reduce radio frequency and other signals to avoid interference with other devices.

AMI meters do not interfere with the operation of house wiring. In that regard, they behave no differently than old mechanical meters. The very low amplitude radio frequency signals generated by the power supplies in modern electronics, including smart meters, are largely filtered out and are heavily attenuated by resistance when they try to travel along house wiring. That is why, when we want to transmit radio frequency signals for cable TV, we use coaxial cables and not ordinary house wiring. Typical household appliances can generate radio frequency fields that are much larger than those generated by AMR or AMI meters.

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WPP AMI Meters and FCC Exposure Limits for RF Fields

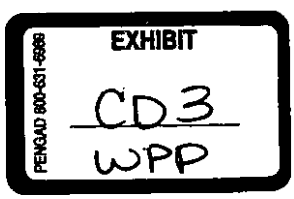
The company's AMI meters send only radio signals. A natural result of sending a radio signal is the creation of a radio frequency (RF) field near the source of the signal. The AMI meters produce RF fields only when they are sending signals, not otherwise. RF fields move away from the source of transmission – in this case the AMI meter – at the speed of light. When the meter is not signaling, there is no RF field surrounding or near the meter.

There is nothing unusual about the RF fields from the AMI meters, other than that their level is extremely low. The RF fields from the AMI meters are the same types of fields that are used for radio communications by common everyday equipment and devices, including radio stations, TV stations, garage door openers, baby monitors, cell phones, Wi-Fi, and other wireless communications devices. The RF fields from the AMI meters are not ionizing radiation and do not have the energy to break chemical bonds in DNA.

In communications physics and engineering, "pulsed" means using 1) amplitude modulation that is 2) done in a way that produces a signal that has abrupt changes in the amplitude of the sine wave. The company's AMI meters do not send out pulsed signals.

There is a scientifically reliable basis for determining whether the radio signals periodically sent by AMI meters produce safe levels of RF fields. That is by determining whether the radios in AMI meters exceed or do not exceed the Federal Communications Commission's (FCC) Maximum Permissible Exposure Limits for non-portable devices that transmit RF signals, which cover smart meters.

The FCC's Maximum Permissible Exposure (MPE) limits vary depending on the frequency range used for the radio transmission. The FCC's limits for the general population are a 30-minute



average power density. The FCC RF MPE Limits are based on exposure guidelines developed by expert scientific organizations, which took into consideration studies of both thermal exposure levels (those that can produce heating) and non-thermal levels (those that are lower and do not produce heating). Based on scientific studies those expert organizations analyzed, both organizations identified the threshold level (i.e., lowest level) of RF exposure at which a potentially adverse biological effect could occur. Then they applied safety factors that resulted in lower exposure levels that they adopted as their exposure guidelines. In adopting its exposure limits, the FCC consulted with the U.S. Food and Drug Administration, the Environmental Protection Agency, the Occupational Safety and Health Administration, and the National Institute of Occupational Safety and Health, and each supported the FCC setting its exposure limits based on the exposure guidelines issued by those expert organizations.

The FCC has recently reaffirmed its RF exposure standards, finding that, "The record does not demonstrate that the science underpinning the current RF exposure limits is outdated or insufficient to protect human safety. Nor does the record include actionable alternatives or modifications to the current RF limits supported by scientifically rigorous data or analysis." https://www.fcc.gov/document/fcc-maintains-current-rf-exposure-safety-standards

The FCC is aware of the research on non-thermal RF fields and has specifically concluded that for RF "levels lower than those that would produce significant heating, the evidence for production of harmful biological effects is ambiguous and unproven." The FCC also notes that the research on RF fields continues to be monitored and assessed on an ongoing basis. The FCC explains the reasons for its view on non-thermal effects as follows: "A number of reports have appeared in the scientific literature describing the observation of a range of biological effects resulting from exposure to low levels of RF energy. However, in most cases, further experimental

research has been unable to reproduce these effects. Furthermore, since much of the research is not done on whole bodies (in vivo), there has been no determination that such effects constitute a human health hazard." The FCC's reasons for its position are scientifically sound and reflect the consensus of independent scientists who are expert in RF bioelectromagnetics.

A number of federal agencies, such as the U.S. Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), and the National Institute on Occupational Safety and Health (NIOSH) work with the FCC on RF issues. The FCC's December 2019 decision reaffirming the existing RF exposure standards emphasizes that "no evidence has moved our sister health and safety agencies to issue substantive policy recommendations for strengthening RF exposure regulation." https://www.fcc.gov/document/fcc-maintains-current-rf-exposure-safety-standards. The FDA concludes that: "The current limit on radio frequency (RF) energy set by the Federal Communications Commission remains acceptable for protecting the public health." https://www.fda.gov/radiation-emitting-products/cell-phones/scientific-evidence-cell-phone-safety#invivo.

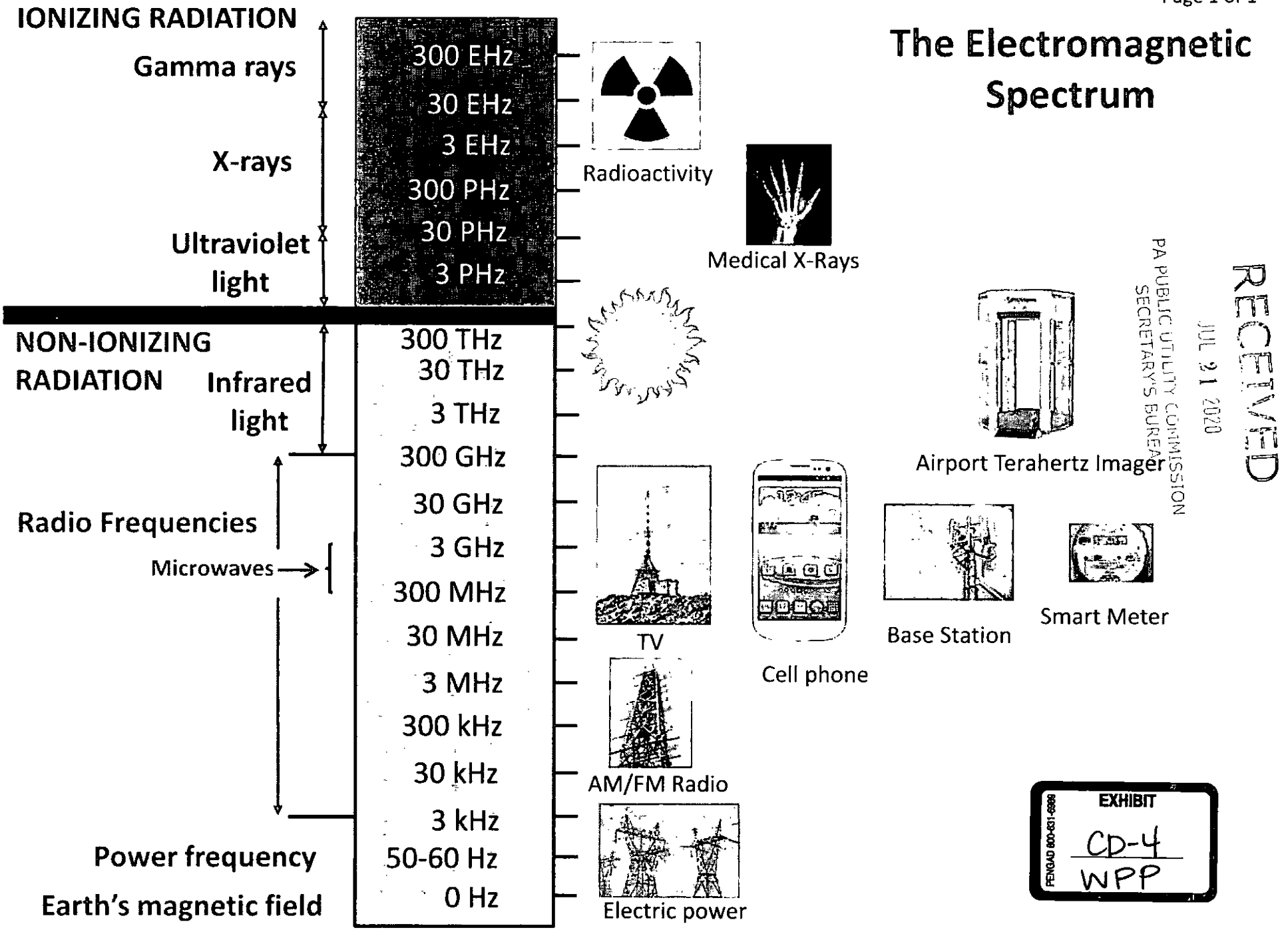
The FDA also says:

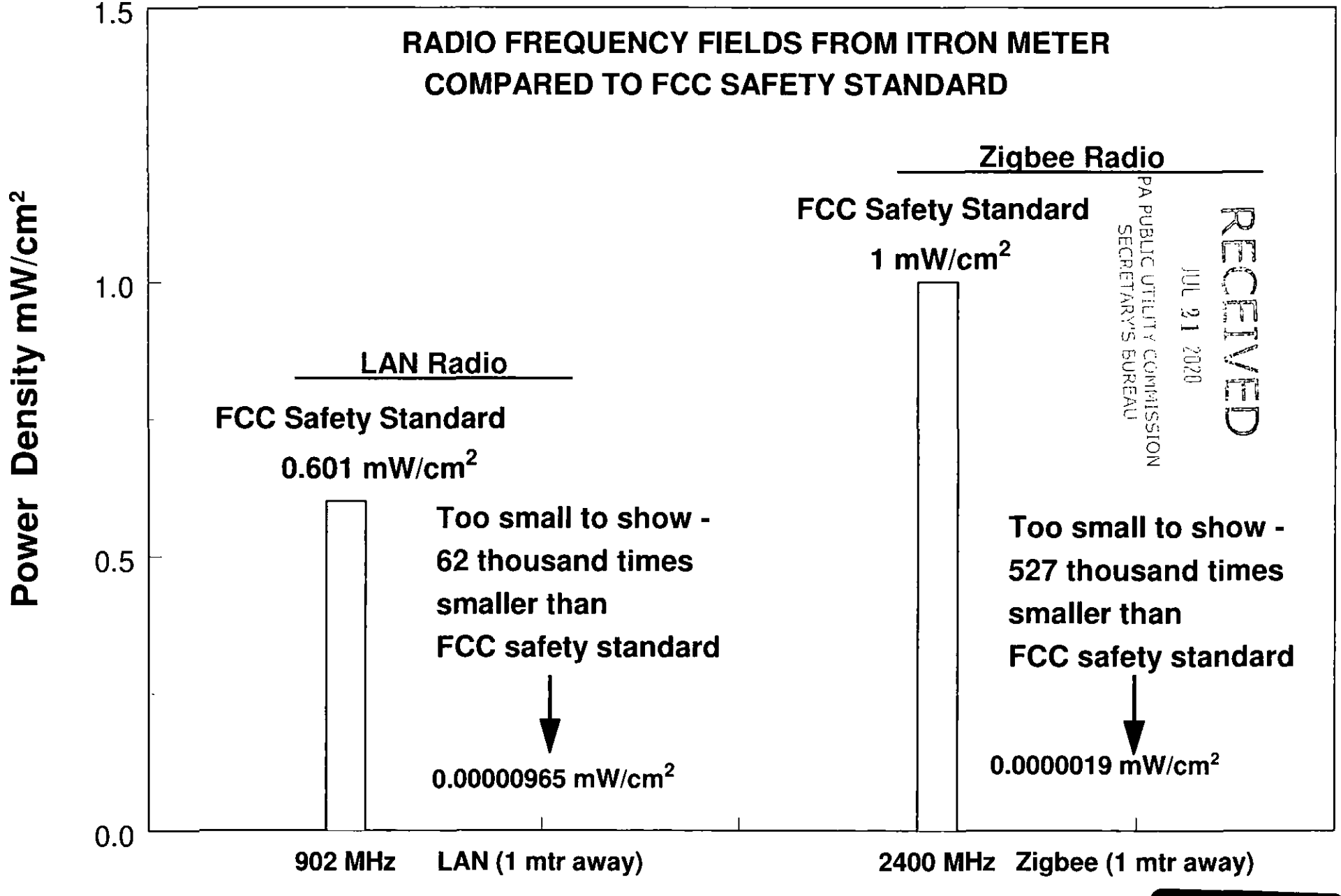
- "Based on the evaluation of the currently available information, the FDA believes that **the weight of scientific evidence has not linked exposure to radio frequency energy from cell phone use with any health problems** at or below the radio frequency exposure limits set by the FCC." https://www.fda.gov/radiation-emitting-products/cell-phones/do-cell-phones-pose-health-hazard (emphasis in original).
- "Current scientific evidence does not show a danger to any users of cell phones from radio frequency (RF) energy, including children and teenagers."

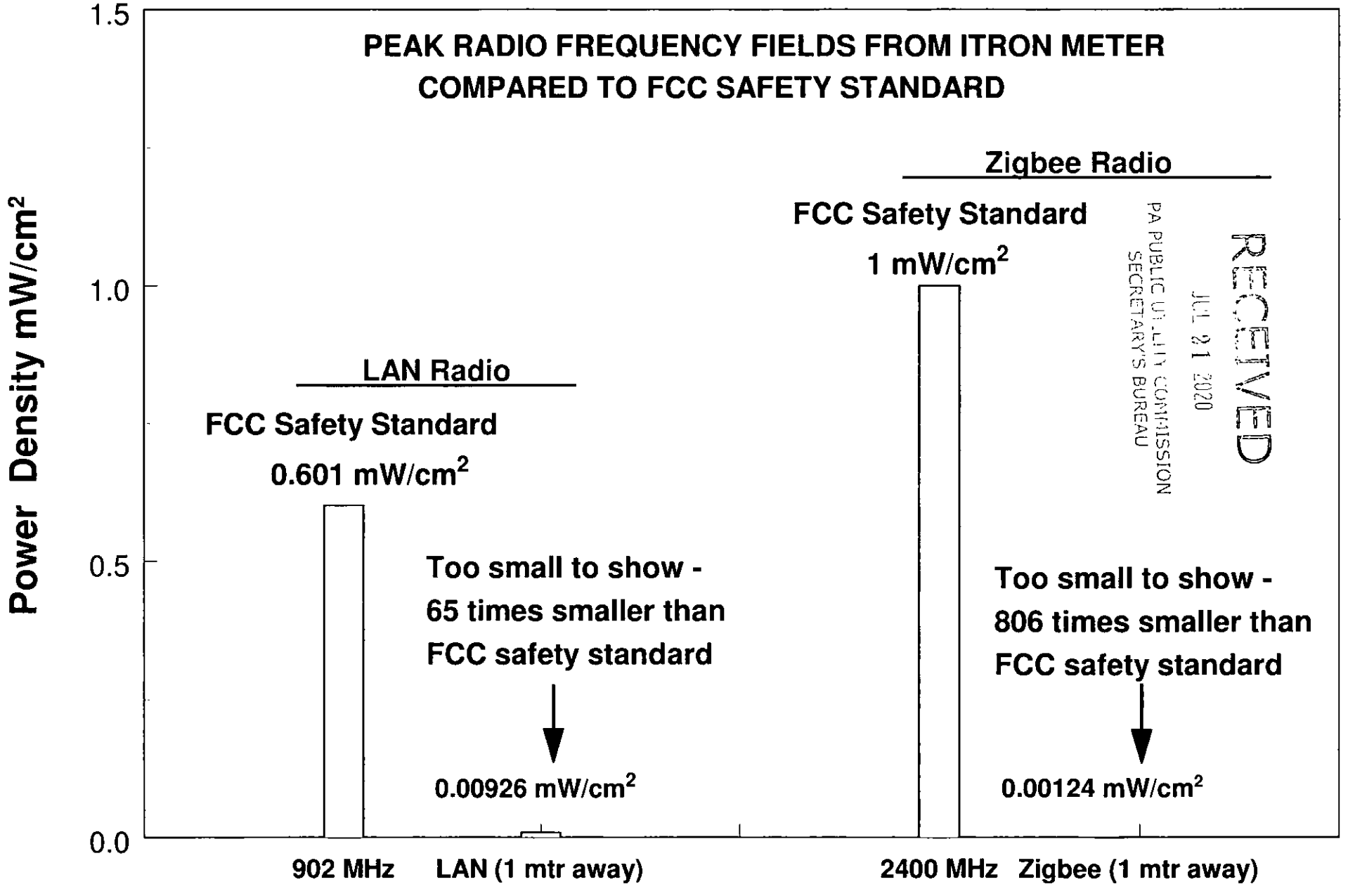
https://www.fda.gov/radiation-emitting-products/cell-phones/children-and-teens-and-cell-phones

The levels of RF fields from the AMI meters being used by Penelec are extremely low (for the LAN radio 62,000 times lower than the RF exposure safety limits established by the FCC; for the Zigbee radio 527,000 lower) and are not high enough to produce tissue hearing. The RF fields from the AMI meters being used by the company also are many times lower than the RF fields people are commonly encounter from everyday sources such as radios, UHF TV broadcast, cellphones, garage door openers, baby monitors, Wi-Fi routers, and other wireless communications devices.

The Electromagnetic Spectrum







*FCC Safety Standard is based on 30 minute average not peak levels