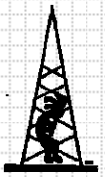

Pinnacle Telecom Group

PTG Engineering Guide No. 11

RF Compliance:

Background on the FCC Regulations

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Introduction

This document has been prepared to provide basic, "plain English" information on the federal regulations concerning the control of human exposure to RF fields.

The focus of the regulations is on assuring RF safety and compliance with the regulations as they apply to wireless communications towers and rooftop antenna installations.

This is the first in a series of PTG Engineering Guides on RF compliance. The rest of the series is as follows:

- No. 12 – RF Compliance: Assuring Personal Safety at Antenna Sites *
- No. 13 – RF Compliance: Background on On-Site Measurements **
- No. 14 – RF Compliance: Far-Field Mathematical Models **
- No. 15 – RF Compliance: Near-Field Mathematical Models **
- No. 16 – RF Compliance: Site Compliance Documentation *
- No. 17 – RF Compliance: Background Guide for Expert Witnesses **

* available to clients
** available only to PTG staff

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Background

Extensive scientific and medical research indicates that human exposure to "excessive" RF fields, such as may be caused by radio devices and communications systems, may result in harmful physiological effects in humans. The harmful effects are typically caused by heating of exposed tissue by the RF field. The extent of the heating effect depends on several factors, including the RF frequency and field strength, the size, shape and orientation of the exposed object, the duration of the exposure, environmental conditions, and the efficiency of heat dissipation by the object.

In 1996, Congress rewrote the 1934 Communications Act, focusing on competition in the telecommunications industry. The Telecommunications Act of 1996, however, also includes a directive from Congress to the Federal

Communications Commission (FCC) to establish a set of guidelines on maximum permissible RF exposure. The law also says that any related state or local RF exposure standard would be preempted by the one set on the federal level, as soon as that one was set by the FCC. That meant that no state or local governmental authority could establish or enforce an RF exposure standard more strict than that set by the federal government.

The FCC then set about collecting information and guidance from the scientific and medical communities, as well as from industry, and in late 1996 proposed a new standard. The FCC's new RF exposure regulations became effective on October 15, 1997, and the deadline for being able to demonstrate wireless base station site compliance with the new standard was September 1, 2000 for all previously existing sites. Right now, site compliance demonstrations (i.e., exposure analysis and compliance reports) are required for all new and modified sites.

In connection with implementation of the new regulations, in August 1997 the FCC published a background information bulletin (FCC OET Bulletin 65, “Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields”). That bulletin, known informally as "OET 65", provides some interpretations of the regulations, and specifies a series of mathematical models that are used to predict potential exposure levels around a variety of antenna types. OET 65 also notes that on-site measurements of RF levels is another method for determining site compliance with the exposure limits. Both the regulations and OET 65 make it clear that the exposure limits apply to accessible areas.

The FCC’s rules identify particular radio services and facility types for which demonstrations (hard-copy reports) of compliance are required. Certain services and facility types are "categorically excluded" from the requirement to certify site compliance on a routine basis – because there are certain types of RF systems and operating characteristics for which the FCC has concluded "cause no significant effect on the human environment". Note that although a categorical exclusion may apply in a particular circumstance, the operator of the system is still subject to the requirement to control potential RF exposure to acceptable levels.

The latest FCC RF exposure guidelines and related regulations are now generally more strict than the ones the FCC had in place before 1997. The earlier regulations applied to a narrower set of radio services, and also addressed the potential exposure from only one antenna at a time. The new regulations focus on the individual who may be subject to exposure from a number of antennas, and requires the total exposure from all antennas at a site to be examined.

Note that the FCC’s RF exposure limits are appropriately conservative; the “maximum permissible exposure” (MPE) levels have been set to provide a safety factor of at least 10 with respect to exposure levels known to cause even a moderate amount of tissue heating.

The Effect of Federal Pre-emption

As described earlier, the Telecommunications Act of 1996 federally preempted state and local regulation of personal wireless service facilities on the basis of RF environmental effects. Thus, by law, the FCC's RF exposure guideline overrides any related non-federal regulations. As long as compliance with the FCC's standard is demonstrated, local and/or state governments are not to deny or unduly delay construction approval on the basis of RF exposure issues. The Telecommunications Act also provides for resolution of conflicts related to the regulation of RF emissions by the courts or by petition to the FCC.

Note that the federal pre-emption does not eliminate the right of local authorities to require a specific demonstration that a proposed wireless site will be in compliance with the federal RF exposure regulations, and many municipalities have enacted rather detailed wireless siting ordinances addressing this and other related matters.

The FCC Regulations

The FCC RF exposure regulations and associated guidelines apply to FCC-authorized radio operations in the frequency range 300 kHz to 100 GHz, as identified in Part 1, Section I of the Rules and Regulations. The specified maximum permissible exposure (MPE) level varies depending on the particular frequency range, in recognition of the fact that human bodies are more susceptible to RF fields of certain frequencies and others.

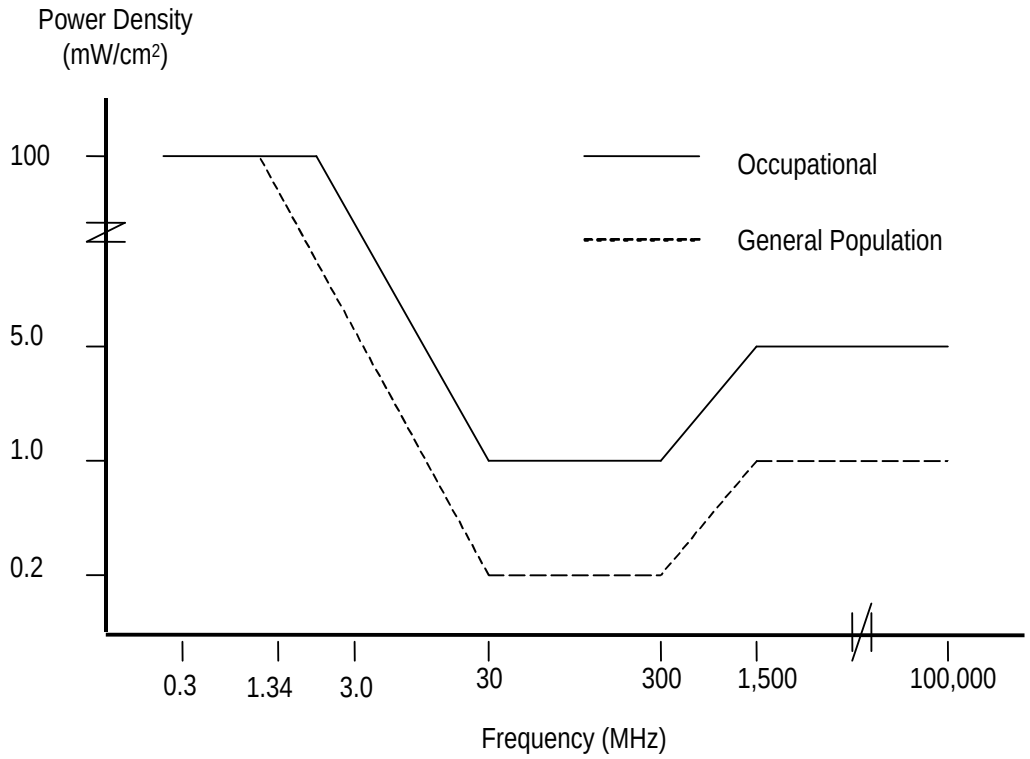
The guidelines are "two-tiered": one tier applies to occupational exposure, and the other – which is more strict – applies the potential exposure of the general public (in FCC terms, the "general population"). The table below lists the applicable MPE levels in the different frequency ranges for each tier.

Frequency Range (F) (MHz)	***Occupational Exposure Limit (mW/cm^2)***	***General Public Exposure Limit (mW/cm^2)***
0.3 - 1.34	100	100
1.34 - 3.0	100	$180 / F^2$
3.0 - 30	$900 / F^2$	$180 / F^2$
30 - 300	1.0	0.2
300 - 1,500	F / 300	F / 1500
1,500 - 100,000	5.0	1.0

The mW/cm^2 (milliwatts per square centimeter) figures represent power density – in effect, power per unit area. Exposure to RF levels below these power density levels is considered to have no detrimental biological effect on humans. Note that the FCC's exposure guideline also lists the equivalent electric (volts/meter)

and magnetic (amperes/meter) field strength equivalents of the power density values in the table. Since power density seems to be more easily understood by members of the public, we will generally use those types of units and not the others.

An equivalent graphical version of the FCC's MPE guideline is presented below, referencing the power density units.



It is important to understand that the FCC's guidelines constitute RF exposure limits – not RF emission limits *per se.* Emission limits are separately addressed in the FCC's regulations regarding specific radio services and devices, and are intended to allow for acceptable service performance while controlling potential RF interference to other services and/or devices. Independent of the emission limits, wireless operators are required to meet the exposure limits. Perhaps more important, the exposure limits are relevant only to locations that are accessible to workers or members of the general public.

Recognizing that exposure duration is as important as exposure level, the FCC regulations and guidelines also specify averaging times with the permissible levels for the two different types of exposures — which we will address in a bit more detail later.

Subject FCC Radio / Wireless Services

According to the FCC, the following services and devices are subject to routine environmental evaluation, unless they operate below specified radiated power or minimum antenna height specifications (see Section 1.1307 of the FCC Rules):

- Experimental Radio Service - Part 5
- Radio Frequency Devices - Part 15
- Multipoint Distribution Service - Part 21
- Paging and Radiotelephone Service - Part 22
- Cellular Radiotelephone Service - Part 22
- Personal Communications Services - Part 24
- Satellite Communications - Part 25
- Radio Broadcast Services - Part 73
- Experimental, auxiliary, and special broadcast and other program distribution services – Part 74
- Stations in the Maritime Service - Part 80
- Private Land Mobile Paging Operations - Part 90
- Private Land Mobile / Specialized Mobile Radio - Part 90
- Amateur Radio Service - Part 97

FCC exposure regulations also exist for mobile and portable devices used in the following services or operations:

- Cellular Radio Service
- Personal Communications Service (PCS)
- Satellite Communications
- Maritime Service
- Specialized Mobile Radio (SMR) Service
- Unlicensed PCS and millimeter wave devices

Note that this document focuses only on the application of the FCC's exposure guidelines to radio services.

"Categorical Exclusions"

The FCC recognizes that certain transmitting facilities and devices – depending on their power levels, antenna mounting heights and other characteristics – offer virtually no potential for causing RF exposure in excess of the applicable guidelines. Therefore, some radio services and some radio facilities are "categorically excluded" from what the FCC calls a "routine" requirement to evaluate potential RF exposure. The FCC lists the criteria for categorical exclusions in its regulations.

Being "categorically excluded" doesn't mean the operators of certain wireless facilities need not be concerned with potential exposure; it only means those operators do not "automatically" have to document their sites as being in

compliance with the exposure limits. The FCC still holds all operators responsible to ensure potential exposure is controlled to the limits.

Scientific Basis for the Exposure Limits

The FCC freely admits its staff is not scientifically or medically expert on the effects of human exposure to RF fields, and has consistently relied on other organizations more steeped in those matters. When the Commission was considering its new exposure limits, it relied on the input and advice of National Council on Radiation Protection and Measurements (NCRP), the American National Standards Institute (ANSI), and the Institute of Electrical and Electronics Engineers (IEEE). The NCRP is a non-profit corporation chartered by the US Congress to develop recommendations concerning radiation protection. The FCC also relied on information from the US Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), the Food and Drug Administration (FDA), and other industry and public input. As a result, the FCC RF exposure regulations are considered a "federal consensus" standard.

Frequency-Dependence of the MPE Limits

A considerable body of research has demonstrated that the human body absorbs more RF energy at some frequencies than at others, and that the relationship mostly involves one's height. When one's height is near the half-wavelength of a signal frequency, the greatest absorption of energy occurs. In effect, humans are receiving antennas. (As "black bodies", they also radiate and behave as transmitters, but not much energy is emitted.)

The relationship between height and resonant frequency is inversely proportional; a five-foot human, for example, is resonant at about 100 MHz. The range of greatest interest is generally between 30 and 300 MHz, and in that range, the FCC MPE limit is at its strictest. At much lower or much higher frequencies, the human body is a very inefficient antenna – and absorbs much less radiation. That's the reason the FCC's exposure limit is more relaxed at those other frequencies, and the guideline does not address frequencies below 300 kHz. (The wavelengths of those frequencies are so long that there isn't any significant resonance or heat absorption by the human body.) In summary, the FCC's guideline allows for exposure to more radiation at very low and very high frequencies, and much less exposure to frequencies at which the body is most RF-absorptive and susceptible. This will be addressed in more detail in the section describing the specific MPE limits.

Occupational vs. General Public Exposure

The FCC MPE limits draw a distinction between occupational and general public exposure. The former is considered "controlled" in the sense that an

occupational exposure presumably involves an individual who is aware of antennas and the risks of exposure, and has received training on how to maintain RF safety. The latter, on the other hand, is considered an "uncontrolled" exposure, because members of the general public cannot be assumed to be aware of antennas or the health effects of RF exposure, and presumably have not received any RF safety training. In effect, the exposure is either controlled or uncontrolled based on the ability of the individual exposed to control the exposure (i.e., by moving out of the area of interest).

For that reason, and to provide an additional margin of safety, the RF exposure guideline is stricter for general public exposure. The FCC's MPE limit for general public exposure applies an additional safety factor of five on top of the safety factor of at least 10 used in developing the baseline MPE guideline for occupational exposure.

Time-Averaging

The FCC exposure regulations recognize that the duration of an exposure is as important as the RF level involved. The "dosage" of an exposure is the product of level and time, and each tier of the MPE limits is thus associated with a reference "averaging time", established in such as way as to maintain dosages below the threshold(s) in the exposure standard. As long as the "time-average" over the reference averaging time does not exceed the limit for continuous exposure, no harmful effects occur.

The averaging time for occupational/controlled exposures is six minutes, while the averaging time for general population/uncontrolled exposures is 30 minutes. The specified averaging times represent references with which to calculate permissible time for exposures greater than the associated power level. Note that continuous exposure at levels equal to or less than the specified maximum permissible exposure is considered safe.

Think of the human body as an input-output device. It can absorb RF radiation and process it effectively (safely) at a certain rate. The body processes the heat effects of RF exposure through blood flow. Basically, blood flow carries excessive heat in one part of the body to other parts of the body – distributing and diluting the heating effect in a safe manner.

The product of exposure level and time is what matters. If the time of an exposure is very short, a proportionately higher-level exposure can still be safely processed by the body – as long as the average, based on the guidelines, is not exceeded.

The FCC has offered mathematics to facilitate the application of time-averaging. The simple math suggests that one can accept an exposure twice the MPE limit for half the averaging time period, as long as the exposure in the successive half of that averaging period is zero.

While the math sounds simple, though, it is not easily translatable to practical situations. If one were to experience an exposure of 200 percent of the limit, it is highly unlikely that the individual would easily find a "zero-exposure" place to go for the remainder of the averaging period.

We believe there is a practical message behind time-averaging, though. The concept supports the idea that very short-term exposure in excess of the MPE limit is acceptable and not unsafe, as long as the individual keeps moving to an area subject to considerably lower exposure. An analogy can be drawn to putting one's hand in fairly warm water, and quickly removing it. The heating effect is temporary, causes no permanent damage, and the same blood flow described earlier serves its purpose here, too.

Responsibilities for RF Compliance

According to the FCC, *licensees* are *individually and collectively* directly responsible for compliance. The “collectively” part represents a new wrinkle in the FCC's regulation, and reflects the shift in FCC focus from individual antennas to individual humans subject to exposure from *all* antennas at a site.

All licensees with co-located transmitters have to ensure that individual contributions of each transmitter do not cumulatively exceed the Commission's limits in an accessible area.

Note that while the FCC's focus is primarily on a site's compliance with the exposure limits, OSHA is primarily interested in ensuring that employees whose work "brings them into frequent contact with wireless sites" have received appropriate RF safety training.

Determination of Site RF Compliance

There are two basic ways to determine a facility’s compliance: calculations (otherwise known as predictive modeling) and on-site RF measurements.

Each is acceptable, even if neither is entirely perfect. Calculations based on worst-case parameters and assumptions provide conservative estimates of potential RF exposure, but cannot predict the existence of incidental "hot spots" created by signal re-radiation by other metal objects at a site. (One of the hotter spots at the antenna farm at Mount Wilson in California, for example, is the metal handrail near the public observation ledge overlooking the valley below). On-site RF measurements will help identify such hot spots, but otherwise may not capture the effects of antennas that operate at maximum power only intermittently.

There are techniques to improve the accuracy of both methods, and both methods may also be used in combination to achieve conservative, "safe-side" estimates of potential exposure.

Calculations are less expensive than on-site measurements (which require specialized equipment and travel), but the more complex a site is, the less likely calculations can accurately estimate overall exposure at each point of interest. In those cases, on-site measurements are often preferred – and there are municipalities that seem to accept the results of measurements more easily than they do the results of mathematics.

Note that even in cases of single-operator sites, it is important to consider the existence and possible effects of other nearby transmitters operated by other parties, remembering that the FCC's regulation focuses on overall exposure more than that caused by a single transmitter or licensee. The overlapping fields caused by the emissions from two separate but nearby facilities can cause exposures exceeding the limits in accessible areas, and the FCC in those cases holds both licensees responsible for compliance.

Finally, measurements are probably the only effective way to characterize potential occupational RF exposures in radio equipment rooms or shelters, and similarly "vertically map" the potential exposure on the way to the top of a radio tower.

Bringing Non-compliant Sites into Compliance

If a particular accessible area at a site is found to exceed the MPE limit, there are a variety of possible corrective actions to bring the site into compliance with the FCC regulations. The technical alternatives include reducing exposure levels by repositioning antennas and reducing transmitter power. Alternative administrative measures may be preferable and include, but are not limited to, restricting access to the subject areas, posting warning signs and site safety maps, and implementing an RF awareness program so workers know what to do in those areas. Obviously, the administrative measures, which are non-service-affecting and generally less expensive, are preferable. In addition, with expert assistance, an operator may take advantage of situations involving application of the "5% rule" (see below) or other analytical techniques that can reduce or eliminate mitigation costs.

The "5% Rule"

According to the FCC, operators (licensees) whose antennas at a site cause less than five percent of "their MPE" (applicable to the frequency of interest) at a spot where the overall MPE is exceeded are *exempted* from the obligation otherwise shared by all operators to bring the site into compliance. In other words, if the overall MPE is exceeded at a given spot, all operators whose antennas contribute more than five percent (of the MPE applicable at their respective frequencies) at that spot must contribute to whatever exposure mitigation is necessary to correct the problem.

If those "other words" did not adequate explain the situation, let's try an example. Suppose, on a collocated rooftop, there is one spot in an accessible area

determined to exceed the overall MPE limit. The spot of interest is 20 feet away from your antenna.

Calculations, however, demonstrate that your antenna causes less than 5% of the MPE applicable to your frequency at that spot. In fact, the calculated exposure from your antenna drops below 5% of the MPE applicable to your frequency at a distance of 10 feet. Since the spot 20 feet away is farther than your 10-foot "5% distance", you do not have to contribute anything to fixing the non-compliance problem 20 feet away from your antennas. In such a case, until the non-compliance problem is fixed (by another party), the site is effectively out of compliance but your facility is considered in compliance.

The FCC created this complicated-sounding-but-actually-reasonable "5%" provision so that low-power operators would not be automatically held responsible to correct exposure problems caused by other higher-power operators. (It also holds that operators who have designed RF safety into their installations should not suffer because other operators ignored that factor.)

Some operators, in analyzing site compliance, calculate the "worst-case" distance associated with causing 5% of the applicable MPE, and determine in advance whether any spots within that distance may present a problem. If there are none, the operator gains a degree of confidence that subsequent additional compliance costs will not be incurred.

Demonstrations of Site RF Compliance

According to Section 1.1307 of the FCC Rules, the Commission requires the preparation of an Environmental Assessment (EA) if a particular facility, operation or transmitter would cause human exposure to levels in excess of the limits in the guidelines. According to this regulation, applications to the FCC must contain a statement certifying compliance with the limits unless the facility, operation, or transmitter is categorically excluded. The FCC's application forms have a "yes/no" checkbox next to the question, "Would a Commission grant of any proposal in this application or amendment have a significant environmental effect as defined by 47 CFR 1.1307?" If the applicant checks "no", it is assumed the site is in compliance and the applicant either has documentation to that effect, or else is categorically excluded from having to "routinely" produce such documentation. If, on the other hand, the exposure levels in accessible areas exceed the MPE limits, the applicant is to check the "yes" box and attach to the application a formal Environmental Assessment. (The FCC staff has suggested such action is equivalent to "suicide" in terms of application processing. In such cases, very significant licensing delays are expected, and the five FCC commissioners themselves have to vote on approving the application.)

Note that at any time, the FCC can request information on the applicant's assessment of site RF compliance. The FCC's presumption is that an applicant subject to the FCC's exposure guidelines is required to have had some form of RF compliance assessment conducted prior to filing the related application or, if

no site-specific application was required, prior to turning up the antenna(s) of interest.

Note that since September 1, 2000, the FCC can request site RF compliance documentation for any wireless site, and has said it will do so on a “random audit” basis. For any site that is out-of-compliance, the FCC requires the filing of a formal environmental assessment.

FCC Penalties for Non-Compliance

Part 1 of the FCC Rules and Regulations includes very detailed information about the range of penalties the FCC may impose for non-compliance with its rules. The penalties can range from forfeitures (fines) to suspension of licenses, and can include revocation of a license. The specific amount of forfeitures depends on the particular circumstance and type of licensee (and not in the least how the FCC might choose to interpret its own rules), and can amount to thousands of dollars per day of continuing non-compliance, with maximum forfeiture for a given violation up to $1.1 million. (And that’s not to mention the additional risk of non-compliance should an RF exposure-related lawsuit be filed against a licensee.)

According to Dr. Robert Cleveland, head of the FCC's RF exposure staff, the Commission expects all licensees and operators to have put forth "good faith efforts" on site RF compliance.

There are some in the industry who suggest budget limitations will prevent the FCC from effectively enforcing its RF exposure regulations. Note, though, that the FCC has announced to the industry that it will “vigorously enforce” the exposure regulations, conduct random audits, and impose penalties for those operators whose sites have not been assessed or which are out-of-compliance.

Note that the FCC’s recent similar “zero tolerance” policy on antenna structure registration led to more than one instance of million-dollar fines.

Worker Safety

OSHA requires RF safety training for all whose work "brings them into frequent contact with wireless sites." OSHA and others have also recommended standard RF safety practices, which include removing the power to transmitting antennas while work is to be performed on them.

Note that the Occupational Health and Safety Administration (OSHA), while enforcing the FCC’s federal consensus exposure guidelines, is focusing more on determining whether requirements are met for RF safety training for employees and site contractors.

Conclusion

RF safety and site compliance are, for the most part, not overly complicated matters – but there do exist a host of so-called "experts" who can make it seem so. It is easy to get misled by misinterpretations of the regulations, misapplication of the FCC's mathematical models, overstatements of the possibility of FCC fines, license revocation and exposure-related litigation. You also need not be misled by the "fear, uncertainty and doubt" approach used by some parties in an effort to "cash in on the wireless boom".

Our advice: Get someone who understands the regulations and the technology, who offers provides information and offers advice in “plain English”, and also understands that RF exposure compliance is basically a regulatory burden in terms of its associated costs.

To an operator of a wireless system, RF compliance – and the costs associated with it – does nothing positive for your organization's bottom line. On the other hand, as users of the radio spectrum – a public resource – wireless operators take on an obligation to ensure their use of the spectrum does not present a health risk to workers or the public.

Make sure the RF compliance job is done right, done on time, and done at a reasonable cost.

Appendix: References

47 CFR, FCC Rules and Regulations, Part 1 (Practice and Procedure), Section 1.1310 (Radiofrequency radiation exposure limits).

47 CFR, FCC Rules and Regulations, Part 22 (Public Mobile Services).

47 CFR, FCC Rules and Regulations, Part 24 (Personal Communications Services).

FCC Second Memorandum Opinion and Order and Notice of Proposed Rulemaking (FCC 97-303), *In the Matter of Procedures for Reviewing Requests for Relief From State and Local Regulations Pursuant to Section 332(c)(7)(B)(v) of the Communications Act of 1934 (WT Docket 97-192), Guidelines for Evaluating the Environmental Effects of Radiofrequency Radiation (ET Docket 93-62), and Petition for Rulemaking of the Cellular Telecommunications Industry Association Concerning Amendment of the Commission's Rules to Preempt State and Local Regulation of Commercial Mobile Radio Service Transmitting Facilities*, released August 25, 1997.

FCC First Memorandum Opinion and Order, ET Docket 93-62, *In the Matter of Guidelines for Evaluating the Environmental Effects of Radiofrequency Radiation*, released December 24, 1996.

FCC Report and Order, ET Docket 93-62, *In the Matter of Guidelines for Evaluating the Environmental Effects of Radiofrequency Radiation*, released August 1, 1996.

FCC Office of Engineering and Technology (OET) Bulletin 65, “Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields”, Edition 97-01, August 1997.

FCC Office of Engineering and Technology (OET) Bulletin 56, “Questions and Answers About Biological Effects and Potential Hazards of RF Radiation”, edition 4, August 1999.