Federal Communications Commission
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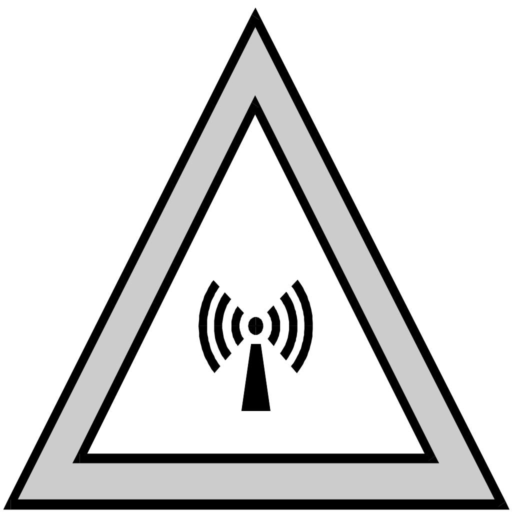
Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields



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Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields

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NOTE: Mention of commercial products does not constitute endorsement by the Federal Communications Commission or by the authors.

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INTRODUCTION

This revised OET Bulletin 65 has been prepared to provide assistance in determining whether proposed or existing transmitting facilities, operations or devices comply with limits for human exposure to radiofrequency (RF) fields adopted by the Federal Communications Commission (FCC). The bulletin offers guidelines and suggestions for evaluating compliance. ***However, it is not intended to establish mandatory procedures, and other methods and procedures may be acceptable if based on sound engineering practice.***

In 1996, the FCC adopted new guidelines and procedures for evaluating environmental effects of RF emissions. The new guidelines incorporate two tiers of exposure limits based on whether exposure occurs in an occupational or "controlled" situation or whether the general population is exposed or exposure is in an "uncontrolled" situation. In addition to guidelines for evaluating fixed transmitters, the FCC adopted new limits for evaluating exposure from mobile and portable devices, such as cellular telephones and personal communications devices. The FCC also revised its policy with respect to categorically excluding certain transmitters and services from requirements for routine evaluation for compliance with the guidelines.

This bulletin is a revision of the FCC's OST Bulletin 65, originally issued in 1985. Although certain technical information in the original bulletin is still valid, this revised version updates other information and provides additional guidance for evaluating compliance with the the new FCC policies and guidelines. The bulletin is organized into the following sections: Introduction, Definitions and Glossary, Background Information, Prediction Methods, Measuring RF Fields, Controlling Exposure to RF Fields, References and Appendices. Appendix A provides a summary of the new FCC guidelines and the requirements for routine evaluation. Additional information specifically for use in evaluating compliance for radio and television broadcast stations is included in a supplement to this bulletin (Supplement A). A supplement for the Amateur Radio Service will also be issued (Supplement B), and future supplements may be issued to provide additional information for other services. This bulletin and its supplements may be revised, as needed.

In general, the information contained in this bulletin is intended to enable an applicant to make a reasonably quick determination as to whether a proposed or existing facility is in compliance with the limits. In addition to calculations and the use of tables and figures, Section 4, dealing with controlling exposure, should be consulted to ensure compliance, especially with respect to occupational/controlled exposures. In some cases, such as multiple-emitter locations, measurements or a more detailed analysis may be required. In that regard, Section 3 on measuring RF fields provides basic information and references on measurement procedures and instrumentation.

For further information on any of the topics discussed in this bulletin, you may contact the FCC's RF safety group at: +1 202 418-2464. Questions and inquiries can also be e-mailed to: rfsafety@fcc.gov. The FCC's World Wide Web Site provides information on FCC decision documents and bulletins relevant to the RF safety issue. The address is: www.fcc.gov/oet/rfsafety.

DEFINITIONS AND GLOSSARY OF TERMS

The following specific words and terms are used in this bulletin. These definitions are adapted from those included in the American National Standards Institute (ANSI) 1992 RF exposure standard [Reference 1], from NCRP Report No. 67 [Reference 19] and from the FCC's Rules (47 CFR § 2.1 and § 1.1310).

Average (temporal) power. The time-averaged rate of energy transfer.

Averaging time. The appropriate time period over which exposure is averaged for purposes of determining compliance with RF exposure limits (discussed in more detail in Section 1).

Continuous exposure. Exposure for durations exceeding the corresponding averaging time.

Decibel (dB). Ten times the logarithm to the base ten of the ratio of two power levels.

Duty factor. The ratio of pulse duration to the pulse period of a periodic pulse train. Also, may be a measure of the temporal transmission characteristic of an intermittently transmitting RF source such as a paging antenna by dividing average transmission duration by the average period for transmissions. A duty factor of 1.0 corresponds to continuous operation.

Effective radiated power (ERP) (in a given direction). The product of the power supplied to the antenna and its gain relative to a half-wave dipole in a given direction.

Equivalent Isotropically Radiated Power (EIRP). The product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna.

Electric field strength (E). A field vector quantity that represents the force (**F**) on an infinitesimal unit positive test charge (**q**) at a point divided by that charge. Electric field strength is expressed in units of volts per meter (V/m).

Energy density (electromagnetic field). The electromagnetic energy contained in an infinitesimal volume divided by that volume.

Exposure. Exposure occurs whenever and wherever a person is subjected to electric, magnetic or electromagnetic fields other than those originating from physiological processes in the body and other natural phenomena.

Exposure, partial-body. Partial-body exposure results when RF fields are substantially nonuniform over the body. Fields that are nonuniform over volumes comparable to the human body may occur due to highly directional sources, standing-waves, re-radiating sources or in the near field. See **RF "hot spot".**

Far-field region. That region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna. In this region (also called the free space region), the field has a predominantly plane-wave character, i.e., locally uniform distribution of electric field strength and magnetic field strength in planes transverse to the direction of propagation.

Gain (of an antenna). The ratio, usually expressed in decibels, of the power required at the input of a loss-free reference antenna to the power supplied to the input of the given antenna to produce, in a given direction, the same field strength or the same power density at the same distance. When not specified otherwise, the gain refers to the direction of maximum radiation. Gain may be considered for a specified polarization. Gain may be referenced to an isotropic antenna (dBi) or a half-wave dipole (dBd).

General population/uncontrolled exposure. For FCC purposes, applies to human exposure to RF fields when the general public is exposed or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential for exposure or cannot exercise control over their exposure. Therefore, members of the general public always fall under this category when exposure is not employment-related.

Hertz (Hz). The unit for expressing frequency, (***f***). One hertz equals one cycle per second.

Magnetic field strength (H). A field vector that is equal to the magnetic flux density divided by the permeability of the medium. Magnetic field strength is expressed in units of amperes per meter (A/m).

Maximum permissible exposure (MPE). The rms and peak electric and magnetic field strength, their squares, or the plane-wave equivalent power densities associated with these fields to which a person may be exposed without harmful effect and with an acceptable safety factor.

Near-field region. A region generally in proximity to an antenna or other radiating structure, in which the electric and magnetic fields do not have a substantially plane-wave character, but vary considerably from point to point. The near-field region is further subdivided into the reactive near-field region, which is closest to the radiating structure and that contains most or nearly all of the stored energy, and the radiating near-field region where the radiation field predominates over the reactive field, but lacks substantial plane-wave character and is complicated in structure. For most antennas, the outer boundary of the reactive near field region is commonly taken to exist at a distance of one-half wavelength from the antenna surface.

Occupational/controlled exposure. For FCC purposes, applies to human exposure to RF fields when persons are exposed as a consequence of their employment and in which those persons who are exposed have been made fully aware of the potential for exposure and can exercise control over their exposure. Occupational/controlled exposure limits also apply where exposure is of a transient nature as a result of incidental passage through a location where exposure levels may be above general population/uncontrolled limits (see definition above), as long as the exposed person has been made fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means.

Peak Envelope Power (PEP). The average power supplied to the antenna transmission line by a radio transmitter during one radiofrequency cycle at the crest of the modulation envelope taken under normal operating conditions.

Power density, average (temporal). The instantaneous power density integrated over a source repetition period.

Power density (S). Power per unit area normal to the direction of propagation, usually expressed in units of watts per square meter (W/m^2) or, for convenience, units such as milliwatts per square centimeter (mW/cm^2) or microwatts per square centimeter ($\mu W/cm^2$). For plane waves, power density, electric field strength (E) and magnetic field strength (H) are related by the impedance of free space, i.e., 377 ohms, as discussed in Section 1 of this bulletin. Although many survey instruments indicate power density units ("far-field equivalent" power density), the actual quantities measured are E or E^2 or H or H^2.

Power density, peak. The maximum instantaneous power density occurring when power is transmitted.

Power density, plane-wave equivalent or far-field equivalent. A commonly-used terms associated with any electromagnetic wave, equal in magnitude to the power density of a plane wave having the same electric (E) or magnetic (H) field strength.

Radiofrequency (RF) spectrum. Although the RF spectrum is formally defined in terms of frequency as extending from 0 to 3000 GHz, for purposes of the FCC's exposure guidelines, the frequency range of interest in 300 kHz to 100 GHz.

Re-radiated field. An electromagnetic field resulting from currents induced in a secondary, predominantly conducting, object by electromagnetic waves incident on that object from one or more primary radiating structures or antennas. Re-radiated fields are sometimes called "reflected" or more correctly "scattered fields." The scattering object is sometimes called a "re-radiator" or "secondary radiator".

RF "hot spot." A highly localized area of relatively more intense radio-frequency radiation that manifests itself in two principal ways:

> (1) The presence of intense electric or magnetic fields immediately adjacent to conductive objects that are immersed in lower intensity ambient fields (often referred to as re-radiation), and
>
> (2) Localized areas, not necessarily immediately close to conductive objects, in which there exists a concentration of RF fields caused by reflections and/or narrow beams produced by high-gain radiating antennas or other highly directional sources. In both cases, the fields are characterized by very rapid changes in field strength with distance. RF hot spots are normally associated with very nonuniform exposure of the body (partial body exposure). This is not to be confused with an actual thermal hot spot within the absorbing body.

Root-mean-square (rms). The effective value, or the value associated with joule heating, of a periodic electromagnetic wave. The rms value is obtained by taking the square root of the mean of the squared value of a function.

Scattered radiation. An electromagnetic field resulting from currents induced in a secondary, conducting or dielectric object by electromagnetic waves incident on that object from one or more primary sources.

Short-term exposure. Exposure for durations less than the corresponding averaging time.

Specific absorption rate (SAR). A measure of the rate of energy absorbed by (dissipated in) an incremental mass contained in a volume element of dielectric materials such as biological tissues. SAR is usually expressed in terms of watts per kilogram (W/kg) or milliwatts per gram (mW/g). Guidelines for human exposure to RF fields are based on SAR thresholds where adverse biological effects may occur. When the human body is exposed to an RF field, the SAR experienced is proportional to the squared value of the electric field strength induced in the body.

Wavelength (λ). The wavelength (λ) of an electromagnetic wave is related to the frequency (f) and velocity (v) by the expression $v = f\lambda$. In free space the velocity of an electromagnetic wave is equal to the speed of light, i.e., approximately 3×10^8 m/s.

Section 1: BACKGROUND INFORMATION

FCC Implementation of NEPA

The National Environmental Policy Act of 1969 (NEPA) requires agencies of the Federal Government to evaluate the effects of their actions on the quality of the human environment.[1] To meet its responsibilities under NEPA, the Commission has adopted requirements for evaluating the environmental impact of its actions.[2] One of several environmental factors addressed by these requirements is human exposure to RF energy emitted by FCC-regulated transmitters and facilities.

The FCC's Rules provide a list of various Commission actions which may have a significant effect on the environment. If FCC approval to construct or operate a facility would likely result in a significant environmental effect included in this list, the applicant for such a facility must submit an "Environmental Assessment" or "EA" of the environmental effect including information specified in the FCC Rules. It is the responsibility of the applicant to make an initial determination as to whether it is necessary to submit an EA.

If it is necessary for an applicant to submit an EA that document would be reviewed by FCC staff to determine whether the next step in the process, the preparation of an Environmental Impact Statement or "EIS," is necessary. An EIS is only prepared if there is a staff determination that the action in question will have a significant environmental effect. If an EIS is prepared, the ultimate decision as to approval of an application could require a full vote by the Commission, and consideration of the issues involved could be a lengthy process. Over the years since NEPA implementation, there have been relatively few EIS's filed with the Commission. This is because most environmental problems are resolved in the process well prior to EIS preparation, since this is in the best interest of all and avoids processing delays.

Many FCC application forms require that applicants indicate whether their proposed operation would constitute a significant environmental action under our NEPA procedures. When an applicant answers this question on an FCC form, in some cases documentation or an explanation of how an applicant determined that there would ***not*** be a significant environmental effect may be requested by the FCC operating bureau or office. This documentation may take the form of an environmental statement or engineering statement that accompanies the application. Such a statement is ***not*** an EA, since an EA is only submitted if there is evidence for a significant environmental effect. In the overwhelming number of cases, applicants attempt to mitigate any potential for a significant environmental effect before submission of either an environmental statement or an EA. This may involve informal

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[1] National Environmental Policy Act of 1969, 42 U.S.C. Section 4321, et seq.

[2] See 47 CFR § 1.1301, et seq.

consultation with FCC staff, either prior to the filing of an application or after an application has been filed, over possible means of avoiding or correcting an environmental problem.

FCC Guidelines for Evaluating Exposure to RF Emissions

In 1985, the FCC first adopted guidelines to be used for evaluating human exposure to RF emissions.[3] The FCC revised and updated these guidelines on August 1, 1996, as a result of a rule-making proceeding initiated in 1993.[4] The new guidelines incorporate limits for Maximum Permissible Exposure (MPE) in terms of electric and magnetic field strength and power density for transmitters operating at frequencies between 300 kHz and 100 GHz. Limits are also specified for localized ("partial body") absorption that are used primarily for evaluating exposure due to transmitting devices such as hand-held portable telephones. Implementation of the new guidelines for mobile and portable devices became effective August 7, 1996. For other applicants and licensees a transition period was established before the new guidelines would apply.[5]

The FCC's MPE limits are based on exposure limits recommended by the National Council on Radiation Protection and Measurements (NCRP)[6] and, over a wide range of frequencies, the exposure limits developed by the Institute of Electrical and Electronics Engineers, Inc., (IEEE) and adopted by the American National Standards Institute (ANSI) to

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[3] *See Report and Order*, GEN Docket No. 79-144, 100 FCC 2d 543 (1985); and *Memorandum Opinion and Order*, 58 RR 2d 1128 (1985). The guidelines originally adopted by the FCC were the 1982 RF protection guides issued by the American National Standards Institute (ANSI).

[4] See *Report and Order*, ET Docket 93-62, FCC 96-326, adopted August 1, 1996, 61 Federal Register 41,006 (1996), 11 FCC Record 15,123 (1997). The FCC initiated this rule-making proceeding in 1993 in response to the 1992 revision by ANSI of its earlier guidelines for human exposure. The Commission responded to seventeen petitions for reconsideration filed in this docket in two separate Orders: *First Memorandum Opinion and Order,* FCC 96-487, adopted December 23, 1996, 62 Federal Register 3232 (1997), 11 FCC Record 17,512 (1997); and *Second Memorandum Opinion and Order and Notice of Proposed Rulemaking,* adopted August 25, 1997.

[5] This transition period was recently extended. With the exception of the Amateur Radio Service, the date now established for the end of the transition period is October 15, 1997. See *Second Memorandum Opinion and Order and Notice of Proposed Rule Making,* ET Docket 93-62, adopted August 25, 1997. Therefore, the new guidelines will apply to applications filed on or after this date. For the Amateur Service only, the new guidelines will apply to applications filed on or after January 1, 1998. In addition, the Commission has adopted a date certain of September 1, 2000, by which time all existing facilities and devices must be in compliance with the new guidelines (see *Second Memorandum Opinion and Order*).

[6] *See Reference 20*, "Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields," NCRP Report No. 86 (1986), National Council on Radiation Protection and Measurements (NCRP), Bethesda, MD. The NCRP is a non-profit corporation chartered by the U.S. Congress to develop information and recommendations concerning radiation protection.

replace the 1982 ANSI guidelines.[7] Limits for localized absorption are based on recommendations of both ANSI/IEEE and NCRP. The FCC's new guidelines are summarized in Appendix A.

In reaching its decision on adopting new guidelines the Commission carefully considered the large number of comments submitted in its rule-making proceeding, and particularly those submitted by the U.S. Environmental Protection Agency (EPA), the Food and Drug Administration (FDA) and other federal health and safety agencies. The new guidelines are based substantially on the recommendations of those agencies, and it is the Commission's belief that they represent a consensus view of the federal agencies responsible for matters relating to public safety and health.

The FCC's limits, and the NCRP and ANSI/IEEE limits on which they are based, are derived from exposure criteria quantified in terms of specific absorption rate (SAR).[8] The basis for these limits is a whole-body averaged SAR threshold level of 4 watts per kilogram (4 W/kg), as averaged over the entire mass of the body, above which expert organizations have determined that potentially hazardous exposures may occur. The new MPE limits are derived by incorporating safety factors that lead, in some cases, to limits that are more conservative than the limits originally adopted by the FCC in 1985. Where more conservative limits exist they do not arise from a fundamental change in the RF safety criteria for whole-body averaged SAR, but from a precautionary desire to protect subgroups of the general population who, potentially, may be more at risk.

The new FCC exposure limits are also based on data showing that the human body absorbs RF energy at some frequencies more efficiently than at others. As indicated by Table 1 in Appendix A, the most restrictive limits occur in the frequency range of 30-300 MHz where whole-body absorption of RF energy by human beings is most efficient. At other frequencies whole-body absorption is less efficient, and, consequently, the MPE limits are less restrictive.

MPE limits are defined in terms of power density (units of milliwatts per centimeter squared: mW/cm^2), electric field strength (units of volts per meter: V/m) and magnetic field strength (units of amperes per meter: A/m). In the far-field of a transmitting antenna, where the electric field vector (E), the magnetic field vector (H), and the direction of propagation

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[7] *See Reference 1*, ANSI/IEEE C95.1-1992, "Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz." Copyright 1992, The Institute of Electrical and Electronics Engineers, Inc., New York, NY. The 1992 ANSI/IEEE exposure guidelines for field strength and power density are similar to those of NCRP Report No. 86 for most frequencies except those above 1.5 GHz.

[8] Specific absorption rate is a measure of the rate of energy absorption by the body. SAR limits are specified for both whole-body exposure and for partial-body or localized exposure (generally specified in terms of spatial peak values).

can be considered to be all mutually orthogonal ("plane-wave" conditions), these quantities are related by the following equation.[9]

$$S = \frac{E^2}{3770} = 37.7H^2 \qquad (1)$$

where: S = power density (mW/cm^2)
E = electric field strength (V/m)
H = magnetic field strength (A/m)

In the near-field of a transmitting antenna the term "far-field equivalent" or "plane-wave equivalent" power density is often used to indicate a quantity calculated by using the near-field values of E^2 or H^2 as if they were obtained in the far-field. As indicated in Table 1 of Appendix A, for near-field exposures the values of plane-wave equivalent power density are given in some cases for reference purposes only. These values are sometimes used as a convenient comparison with MPEs for higher frequencies and are displayed on some measuring instruments.

The FCC guidelines incorporate two separate tiers of exposure limits that are dependent on the situation in which the exposure takes place and/or the status of the individuals who are subject to exposure. The decision as to which tier applies in a given situation should be based on the application of the following definitions.

Occupational/controlled exposure limits apply to situations in which persons are exposed as a consequence of their employment and in which those persons who are exposed have been made fully aware of the potential for exposure and can exercise control over their exposure. Occupational/controlled exposure limits also apply where exposure is of a transient nature as a result of incidental passage through a location where exposure levels may be above general population/uncontrolled limits (see below), as long as the exposed person has been made fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means. As discussed later, the occupational/controlled exposure limits also apply to amateur radio operators and members of their immediate household.

General population/uncontrolled exposure limits apply to situations in which the general public may be exposed or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential for exposure or cannot exercise control over their exposure. Therefore, members of the general public would always be considered under this category when exposure is not employment-related, for example, in the case of a telecommunications tower that exposes persons in a nearby residential area.

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[9] Note that this equation is written so that power density is expressed in units of mW/cm^2. The impedance of free space, 377 ohms, is used in deriving the equation.

For purposes of applying these definitions, awareness of the potential for RF exposure in a workplace or similar environment can be provided through specific training as part of an RF safety program. Warning signs and labels can also be used to establish such awareness as long as they provide information, in a prominent manner, on risk of potential exposure and instructions on methods to minimize such exposure risk.[10] However, warning labels placed on low-power consumer devices such as cellular telephones are not considered sufficient to achieve the awareness necessary to qualify these devices as operating under the occupational/controlled category. In those situations the general population/uncontrolled exposure limits will apply.

A fundamental aspect of the exposure guidelines is that they apply to power densities or the squares of the electric and magnetic field strengths that are spatially averaged over the body dimensions. Spatially averaged RF field levels most accurately relate to estimating the whole-body averaged SAR that will result from the exposure and the MPEs specified in Table 1 of Appendix A are based on this concept. This means that local values of exposures that exceed the stated MPEs may not be related to non-compliance if the spatial average of RF fields over the body does not exceed the MPEs. Further discussion of spatial averaging as it relates to field measurements can be found in Section 3 of this bulletin and in the ANSI/IEEE and NCRP reference documents noted there.

Another feature of the exposure guidelines is that exposures, in terms of power density, E^2 or H^2, may be averaged over certain periods of time with the average not to exceed the limit for continuous exposure.[11] As shown in Table 1 of Appendix A, the averaging time for occupational/controlled exposures is 6 minutes, while the averaging time for general population/uncontrolled exposures is 30 minutes. It is important to note that for general population/uncontrolled exposures it is often not possible to control exposures to the extent that averaging times can be applied. In those situations, it is often necessary to assume continuous exposure.

As an illustration of the application of time-averaging to occupational/controlled exposure consider the following. The relevant interval for time-averaging for occupational/controlled exposures is six minutes. This means, for example, that during any given six-minute period a worker could be exposed to two times the applicable power density limit for three minutes as long as he or she were not exposed at all for the preceding or following three minutes. Similarly, a worker could be exposed at three times the limit for two minutes as long as no exposure occurs during the preceding or subsequent four minutes, and so forth.

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[10] For example, a sign warning of RF exposure risk and indicating that individuals should not remain in the area for more than a certain period of time could be acceptable. Reference [3] provides information on acceptable warning signs.

[11] Note that although the FCC did not explicitly adopt limits for ***peak*** power density, guidance on these types of exposures can be found in Section 4.4 of the ANSI/IEEE C95.1-1992 standard.

This concept can be generalized by considering Equation (2) that allows calculation of the allowable time(s) for exposure at [a] given power density level(s) during the appropriate time-averaging interval to meet the exposure criteria of Table 1 of Appendix A. The sum of the products of the exposure levels and the allowed times for exposure must equal the product of the appropriate MPE limit and the appropriate time-averaging interval.

$$\sum S_{\mathrm{exp}} t_{\mathrm{exp}} = S_{limit} t_{avg} \qquad (2)$$

where:

S_{exp} = power density level of exposure (mW/cm^2)
S_{limit} = appropriate power density MPE limit (mW/cm^2)
t_{exp} = allowable time of exposure for S_{exp}
t_{avg} = appropriate MPE averaging time

For the example given above, if the MPE limit is 1 mW/cm^2, then the right-hand side of the equation becomes 6 $mW\text{-}min/cm^2$ (1 mW/cm^2 X 6 min). Therefore, if an exposure level is determined to be 2 mW/cm^2, the allowed time for exposure at this level during any six-minute interval would be a total of 3 minutes, since the left side of the equation must equal 6 (2 mW/cm^2 X 3 min). Of course, many other combinations of exposure levels and times may be involved during a given time-averaging interval. However, as long as the sum of the products on the left side of the equation equals the right side, the ***average*** exposure will comply with the MPE limit. It is very important to remember that time-averaging applies to ***any*** interval of $\boldsymbol{t_{avg}}$. Therefore, in the above example, consideration would have to be given to the exposure situation both before and after the allowed three-minute exposure. The time-averaging interval can be viewed as a "sliding" period of time, six minutes in this case.

Another important point to remember concerning the FCC's exposure guidelines is that they constitute ***exposure*** limits (not ***emission*** limits), and they are relevant only to locations that are ***accessible*** to workers or members of the public. Such access can be restricted or controlled by appropriate means such as the use of fences, warning signs, etc., as noted above. For the case of occupational/controlled exposure, procedures can be instituted for working in the vicinity of RF sources that will prevent exposures in excess of the guidelines. An example of such procedures would be restricting the time an individual could be near an RF source or requiring that work on or near such sources be performed while the transmitter is turned off or while power is appropriately reduced. In the case of broadcast antennas, the use of auxiliary antennas could prevent excessive exposures to personnel working on or near the main antenna site, depending on the separation between the main and auxiliary antennas. Section 4 of this bulletin should be consulted for further information on controlling exposure to comply with the FCC guidelines.

Applicability of New Guidelines

The FCC's environmental rules regarding RF exposure identify particular categories of existing and proposed transmitting facilities, operations and devices for which licensees and applicants are required to conduct an initial environmental evaluation, and prepare an Environmental Assessment if the evaluation indicates that the transmitting facility, operation or device exceeds or will exceed the FCC's RF exposure guidelines. For transmitting facilities, operations and devices not specifically identified, the Commission has determined, based on calculations, measurement data and other information, that such RF sources offer little potential for causing exposures in excess of the guidelines. Therefore, the Commission "categorically excluded" applicants and licensees from the requirement to perform routine, initial environmental evaluations of such sources to demonstrate compliance with our guidelines. However, the Commission still retains the authority to request that a licensee or an applicant conduct an environmental evaluation and, if appropriate, file environmental information pertaining to an otherwise categorically excluded RF source if it is determined that there is a possibility for significant environmental impact due to RF exposure.[12]

In that regard, all transmitting facilities and devices regulated by this Commission that are the subject of an FCC decision or action (e.g., grant of an application or response to a petition or inquiry) are expected to comply with the appropriate RF radiation exposure guidelines, or, if not, to file an Environmental Assessment (EA) for review under our NEPA procedures, if such is required. It is important to emphasize that the categorical exclusions are ***not*** exclusions from ***compliance*** but, rather, exclusions from performing routine evaluations to demonstrate compliance. Normally, the exclusion from performing a routine evaluation will be a sufficient basis for assuming compliance, unless an applicant or licensee is otherwise notified by the Commission or has reason to believe that the excluded transmitter or facility encompasses exceptional characteristics that could cause non-compliance.

It should also be stressed that even though a transmitting source or facility may not be categorically excluded from routine evaluation, no further environmental processing is required once it has been demonstrated that exposures are within the guidelines, as specified in Part 1 of our rules. These points have been the source of some confusion in the past among FCC licensees and applicants, some of whom have been under the impression that filing an EA is always required.

In adopting its new exposure guidelines, the Commission also adopted new rules indicating which transmitting facilities, operations and devices will be categorically excluded from performing routine, initial evaluations. The new exclusion criteria are based on such factors as type of service, antenna height, and operating power. The new criteria were adopted in an attempt to obtain greater consistency and scientific rigor in determining requirements for RF evaluation across the various FCC-regulated services.

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12 *See* 47 CFR §§ 1.1307(c) and (d).

Routine environmental evaluation for RF exposure is required for transmitters, facilities or operations that are included in the categories listed in Table 2 of Appendix A or in FCC rule parts 2.1091 and 2.1093 (for portable and mobile devices). This requirement applies to some, but not necessarily all, transmitters, facilities or operations that are authorized under the following parts of our rules: 5, 15, 21 (Subpart K), 22 (Subpart E), 22 (Subpart H), 24, 25, 26, 27, 73, 74 (Subparts A, G, I, and L), 80 (ship earth stations), 90 (paging operations and Specialized Mobile Radio), 97 and 101 (Subpart L). Within a specific service category, conditions are listed in Table 2 of Appendix A to determine which transmitters will be subject to routine evaluation. These conditions are generally based on one or more of the following variables: (1) operating power, (2) location, (3) height above ground of the antenna and characteristics of the antenna or mode of transmission. In the case of Part 15 devices, only devices that transmit on millimeter wave frequencies and unlicensed Personal Communications Service (PCS) devices are covered, as noted in rule parts 2.1091 and 2.1093 (see section on mobile and portable devices of Appendix A).

Transmitters and facilities not included in the specified categories are excluded from routine evaluation for RF exposure. We believe that such transmitting facilities generally pose little or no risk for causing exposures in excess of the guidelines. However, as noted above, in exceptional cases the Commission may, on its own merit or as the result of a petition, require environmental evaluation of transmitters or facilities even though they are otherwise excluded from routine evaluation. Also, at multiple-transmitter sites applications for non-excluded transmitters should consider significant contributions of other co-located transmitters (see discussion of multiple-transmitter evaluation in Section 2).

If a transmitter operates using relatively high power, and there is a possibility that workers or the public could have access to the transmitter site, such as at a rooftop site, then routine evaluation is justified. In Table 2 of Appendix A, an attempt was made to identify situations in the various services where such conditions could prevail. In general, at rooftop transmitting sites evaluation will be required if power levels are above the values indicated in Table 2 of Appendix A. These power levels were chosen based on generally "worst-case" assumptions where the most stringent uncontrolled/general population MPE limit might be exceeded within several meters of transmitting antennas at these power levels. In the case of paging antennas, the likelihood that duty factors, although high, would not normally be expected to be 100% was also considered. Of course, if procedures are in place at a site to limit accessibility or otherwise control exposure so that the safety guidelines are met, then the site is in compliance and no further environmental processing is necessary under our rules.

Tower-mounted ("non-rooftop") antennas that are used for cellular telephone, PCS, and Specialized Mobile Radio (SMR) operations warrant a somewhat different approach for evaluation. While there is no evidence that typical installations in these services cause ground-level exposures in excess of the MPE limits, construction of these towers has been a topic of ongoing public controversy on environmental grounds, and we believe it necessary to ensure that there is no likelihood of excessive exposures from these antennas. Although we believe there is no need to require routine evaluation of towers where antennas are mounted high above the ground, out of an abundance of caution the FCC requires that tower-mounted installations be evaluated if antennas are mounted lower than 10 meters above ground and the total power of all channels being used is over 1000 watts effective radiated power (ERP), or 2000 W ERP for broadband PCS.[13] These height and power combinations were chosen as thresholds recognizing that a theoretically "worst case" site could use many channels and several thousand watts of power. At such power levels a height of 10 meters above ground is not an unreasonable distance for which an evaluation generally would be advisable. For antennas mounted higher than 10 meters, measurement data for cellular facilities have indicated that ground-level power densities are typically hundreds to thousands of times below the new MPE limits.

In view of the expected proliferation of these towers in the future and possible use of multiple channels and power levels at these installations, and to ensure that tower installations are properly evaluated when appropriate, we have instituted these new requirements for this limited category of tower-mounted antennas in these services. For consistency we have instituted similar requirements for several other services that could use relatively high power levels with antennas mounted on towers lower than 10 meters above ground.

Paging systems operated under Part 22 (Subpart E) and Part 90 of our rules previously have been categorically exempted from routine RF evaluation requirements. However, the potential exists that the new, more restrictive limits may be exceeded in accessible areas by relatively high-powered paging transmitters with rooftop antennas.[14] These transmitters may operate with high duty factors in densely populated urban environments. The record and our own data indicate the need for ensuring appropriate evaluation of such facilities, especially at multiple transmitter sites. Accordingly, paging stations authorized under Part 22 (Subpart E) and Part 90 are also subject to routine environmental evaluation for RF exposure if an antenna is located on a rooftop and if its ERP exceeds 1000 watts.

Mobile and Portable Devices

As noted in Appendix A, mobile and portable transmitting devices that operate in the Cellular Radiotelephone Service, the Personal Communications Services (PCS), the General Wireless Communications Service, the Wireless Communication Service, the Satellite Communications services, the Maritime Services (ship earth stations only) and Specialized Mobile Radio Service authorized, respectively, under Part 22 (Subpart H), Part 24, Part 25, Part 26, Part 27, Part 80, and Part 90 of the FCC's Rules are subject to routine environmental evaluation for RF exposure prior to equipment authorization or use. Unlicensed PCS, NII and millimeter wave devices are also subject to routine environmental evaluation for RF exposure

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[13] For broadband PCS, 2000 W is used as a threshold, instead of 1000 W, since at these operating frequencies the exposure criteria are less restrictive by about a factor of two.

[14] For example, under Part 90, paging operations in the 929-930 MHz band may operate with power levels as high as 3500 W ERP.

prior to equipment authorization or use. All other mobile, portable, and unlicensed transmitting devices are normally categorically excluded from routine environmental evaluation for RF exposure (see Section 2 and Appendix A for further details).

For purposes of these requirements mobile devices are defined by the FCC as transmitters designed to be used in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimeters is normally maintained between radiating structures and the body of the user or nearby persons. These devices are normally evaluated for exposure potential with relation to the MPE limits given in Table 1 of Appendix A.

The FCC defines portable devices, for purposes of these requirements, as transmitters whose radiating structures are designed to be used within 20 centimeters of the body of the user. As explained later, in Section 2 and in Appendix A, portable devices are to be evaluated with respect to limits for specific absorption rate (SAR).

Operations in the Amateur Radio Service

In the FCC's recent *Report and Order,* certain amateur radio installations were made subject to routine evaluation for compliance with the FCC's RF exposure guidelines.[15] Also, amateur licensees will be expected to demonstrate their knowledge of the FCC guidelines through examinations. Applicants for new licenses and renewals also will be required to demonstrate that they have read and that they understand the applicable rules regarding RF exposure. Before causing or allowing an amateur station to transmit from any place where the operation of the station could cause human exposure to RF radiation levels in excess of the FCC guidelines amateur licensees are now required to take certain actions. A routine RF radiation evaluation is required if the transmitter power of the station exceeds the levels shown in Table 1 and specified in 47 CFR § 97.13(c)(1).[16] Otherwise the operation is categorically excluded from routine RF radiation evaluation, except as a result of a specific motion or petition as specified in Sections 1.1307(c) and (d) of the FCC's Rules, (see earlier discussion in Section 1 of this bulletin).

The Commission's *Report and Order* instituted a requirement that operator license examination question pools will include questions concerning RF safety at amateur stations. An additional five questions on RF safety will be required within each of three written examination elements. The Commission also adopted the proposal of the American Radio

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[15] *See* para. 160 of *Report and Order*, ET Dkt 93-62. *See also*, 47 CFR § 97.13, as amended.

[16] These levels were chosen to roughly parallel the frequency of the MPE limits of Table 1 in Appendix A. These levels were modified from the Commission's original decision establishing a flat 50 W power threshold for routine evaluation of amateur stations (*see Second Memorandum Opinion and Order,* ET Docket 93-62, FCC 97-303, adopted August 25, 1997).

TABLE 1. Power thresholds for routine evaluation of amateur radio stations.

Wavelength Band	Transmitter Power (watts)
MF	
160 m	500
HF	
80 m	500
75 m	500
40 m	500
30 m	425
20 m	225
17 m	125
15 m	100
12 m	75
10 m	50
VHF (all bands)	50
UHF	
70 cm	70
33 cm	150
23 cm	200
13 cm	250
SHF (all bands)	250
EHF (all bands)	250

Relay League (ARRL) that amateur operators should be required to certify, as part of their license application process, that they have read and understand our bulletins and the relevant FCC rules.

When routine evaluation of an amateur station indicates that exposure to RF fields could be in excess of the exposure limits specified by the FCC (see Appendix A), the licensee must take action to correct the problem and ensure compliance (see Section 4 of this bulletin on controlling exposure). Such actions could be in the form of modifying patterns of operation, relocating antennas, revising a station's technical parameters such as frequency, power or emission type or combinations of these and other remedies.

In complying with the Commission's *Report and Order*, amateur operators should follow a policy of systematic avoidance of excessive RF exposure. The Commission has said that it will continue to rely upon amateur operators, in constructing and operating their stations, to take steps to ensure that their stations comply with the MPE limits for both occupational/controlled and general public/uncontrolled situations, as appropriate. In that regard, amateur radio operators and members of their immediate household are considered to be in a "controlled environment" and are subject to the occupational/controlled MPE limits. Neighbors who are not members of an amateur operator's household are considered to be members of the general public, since they cannot reasonably be expected to exercise control over their exposure. In those cases general population/uncontrolled exposure MPE limits will apply.

In order to qualify for use of the occupational/controlled exposure criteria, appropriate restrictions on access to high RF field areas must be maintained and educational instruction in RF safety must be provided to individuals who are members of the amateur operator's household. Persons who are not members of the amateur operator's household but who are present temporarily on an amateur operator's property may also be considered to fall under the occupational/controlled designation provided that appropriate information is provided them about RF exposure potential if transmitters are in operation and such persons are exposed in excess of the general population/uncontrolled limits.

Amateur radio facilities represent a special case for determining exposure, since there are many possible antenna types that could be designed and used for amateur stations. However, several relevant points can be made with respect to analyzing amateur radio antennas for potential exposure that should be helpful to amateur operators in performing evaluations.

First of all, the generic equations described in this bulletin can be used for analyzing fields due to almost all antennas, although the resulting estimates for power density may be overly-conservative in some cases. Nonetheless, for general radiators and for aperture antennas, if the user is knowledgeable about antenna gain, frequency, power and other relevant factors, the equations in this section can be used to estimate field strength and power density as described earlier. In addition, other resources are available to amateur radio operators for analyzing fields near their antennas. The ARRL Radio Amateur Handbook contains an excellent section on analyzing amateur radio facilities for compliance with RF guidelines (Reference [4]). Also, the FCC and the EPA conducted a study of several amateur radio stations in 1990 that provides a great deal of measurement data for many types of antennas commonly used by amateur operators (Reference [10]).

Amateur radio organizations and licensees are encouraged to develop their own more detailed evaluation models and methods for typical antenna configurations and power/frequency combinations. The FCC is working with the amateur radio community to develop a supplement to this bulletin that will be designed specifically for evaluating amateur radio installations. For example, the supplement will contain information on projected minimum exclusion distances from typical amateur antenna installations. The supplement should be completed soon after release of this bulletin. Once the amateur radio supplement is released by the FCC it will be made available for downloading at the FCC's World Wide Web Site for "RF safety." Amateur radio applicants and licensees are encouraged to monitor the Web Site for release of the supplement. The address is: www.fcc.gov/oet/rfsafety. Information on availability of the supplement, as well as other RF-related questions, can be directed to the FCC's "RF Safety Program" at: (202) 418-2464 or to: rfsafety@fcc.gov.

Section 2: PREDICTION METHODS

The material in this section is designed to provide assistance in determining whether a given facility would be in compliance with guidelines for human exposure to RF radiation. The calculational methods discussed below should be helpful in evaluating a particular exposure situation. However, for certain transmitting facilities, such as radio and television broadcast stations, a specific supplement to this bulletin has been developed containing information and compliance guidelines specific to those stations.[17] Therefore, applicants for radio and television broadcast facilities may wish to first consult this supplement that concentrates on AM radio, FM radio and television broadcast antennas. Applicants for many broadcast facilities should be able to determine whether a given facility would be in compliance with FCC guidelines by simply consulting the tables and figures in this supplement. However, in addition, with respect to occupational/controlled exposure, all applicants should consult Section 4 of this bulletin concerning controlling exposures that may occur during maintenance or other procedures carried out at broadcast and other telecommunications sites.

Applicants may consult the relevant sections below, which describe how to estimate field strength and power density levels from typical, general radiators as well as from aperture

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[17] *Supplement A to* OET Bulletin 65, Version 97-01, *Additional Information for Radio and Television Broadcast Stations.* This supplement can be downloaded from the FCC's RF Safety World Wide Web Site: www.fcc.gov/oet/rfsafety. For further information contact the RF safety program at: +1 (202) 418-2464.

antennas such as microwave and satellite dish antennas. The general equations given below can be used for predicting field strength and power density in the vicinity of most antennas, including those used for paging and in the commercial mobile radio service (CMRS). They can also be used for making conservative predictions of RF fields in the vicinity of antennas used for amateur radio transmissions, as discussed earlier.

Equations for Predicting RF Fields

Calculations can be made to predict RF field strength and power density levels around typical RF sources. For example, in the case of a single radiating antenna, a prediction for power density in the far-field of the antenna can be made by use of the general Equations (3) or (4) below [for conversion to electric or magnetic field strength see Equation (1) in Section 1]. These equations are generally accurate in the far-field of an antenna but will over-predict power density in the near field, where they could be used for making a "worst case" or conservative prediction.

$$S = \frac{PG}{4\pi R^2} \qquad (3)$$

where: S = power density (in appropriate units, e.g. mW/cm^2)
P = power input to the antenna (in appropriate units, e.g., mW)
G = power gain of the antenna in the direction of interest relative to an isotropic radiator
R = distance to the center of radiation of the antenna (appropriate units, e.g., cm)

or:

$$S = \frac{EIRP}{4\pi R^2} \qquad (4)$$

where: EIRP = equivalent (or effective) isotropically radiated power

When using these and other equations care must be taken to use the ***correct units*** for all variables. For example, in Equation (3), if power density in units of mW/cm^2 is desired then power should be expressed in milliwatts and distance in cm. Other units may be used, but care must be taken to use correct conversion factors when necessary. Also, it is important to note that the power gain factor, ***G***, in Equation (3) is normally ***numeric*** gain. Therefore, when power gain is expressed in logarithmic terms, i.e., dB, a conversion is required using the relation:

$$G = 10^{\frac{dB}{10}}$$

For example, a logarithmic power gain of 14 dB is equal to a numeric gain of 25.12.

In some cases operating power may be expressed in terms of "effective radiated power" or "ERP" instead of EIRP. ERP is power referenced to a half-wave dipole radiator instead of to an isotropic radiator. Therefore, if ERP is given it is necessary to convert ERP into EIRP in order to use the above equations. This is easily done by multiplying the ERP by the factor of 1.64, which is the gain of a half-wave dipole relative to an isotropic radiator. For example, if ERP is used in Equation (4) the relation becomes:

$$S = \frac{EIRP}{4\pi R^2} = \frac{1.64\ ERP}{4\pi R^2} = \frac{0.41\ ERP}{\pi R^2} \qquad (5)$$

For a truly worst-case prediction of power density at or near a surface, such as at ground-level or on a rooftop, 100% reflection of incoming radiation can be assumed, resulting in a potential doubling of predicted field strength and a four-fold increase in (far-field equivalent) power density. In that case Equations (3) and (4) can be modified to:

$$S = \frac{(2)^2 PG}{4\pi R^2} = \frac{PG}{\pi R^2} = \frac{EIRP}{\pi R^2} \qquad (6)$$

In the case of FM radio and television broadcast antennas, the U.S. Environmental Protection Agency (EPA) has developed models for predicting ground-level field strength and power density [Reference 11]. The EPA model recommends a more realistic approximation for ground reflection by assuming a maximum 1.6-fold increase in field strength leading to an increase in power density of 2.56 (1.6 X 1.6). Equation (4) can then be modified to:

$$S = \frac{2.56\ EIRP}{4\pi R^2} = \frac{0.64\ EIRP}{\pi R^2} \qquad (7)$$

If ERP is used in Equation (7), the relation becomes:

$$S = \frac{0.64\ EIRP}{\pi R^2} = \frac{(0.64)(1.64)\ ERP}{\pi R^2} = \frac{1.05\ ERP}{\pi R^2} \qquad (8)$$

It is sometimes convenient to use units of microwatts per centimeter squared (µW/cm^2) instead of mW/cm^2 in describing power density. The following simpler form of Equation (8) can be derived if power density, **S**, is to be expressed in units of µW/cm^2:

$$S = \frac{33.4\ ERP}{R^2} \qquad (9)$$

where: S = power density in µW/cm^2
ERP = power in watts
R = distance in meters

An example of the use of the above equations follows. A station is transmitting at a frequency of 100 MHz with a total nominal ERP (including all polarizations) of 10 kilowatts (10,000 watts) from a tower-mounted antenna. The height to the center of radiation is 50 meters above ground-level. Using the formulas above, what would be the calculated "worst-case" power density that could be expected at a point 2 meters above ground (approximate head level) and at a distance of 20 meters from the base of the tower? Note that this type of analysis ***does not*** take into account the vertical radiation pattern of the antenna, i.e., no information on directional characteristics of signal propagation is considered. Use of actual vertical radiation pattern data for the antenna would most likely significantly reduce ground-level exposure predictions from those calculated below (see later discussion), resulting in a more realistic estimate of the actual exposure levels.

From simple trigonometry the distance **R** can be calculated to be 52 meters [square root of: $(48)^2 + (20)^2$], assuming essentially flat terrain. Therefore, using Equation (9), the calculated conservative "worst case" power density is:

$$S = \frac{33.4\ (10{,}000\ watts)}{(52\ m)^2} = about\ 124\ \mu W/cm^2$$

By consulting Table 1 of Appendix A it can be determined that the limit for general population/uncontrolled exposure at 100 MHz is 0.2 mW/cm^2 or 200 μW/cm^2. Therefore, this calculation shows that even under worst-case conditions this station would comply with the general population/uncontrolled limits, at least at a distance of 20 meters from the tower. Similar calculations could be made to ensure compliance at other locations, such as at the base of the tower where the shortest direct line distance, R, to the ground would occur.

Relative Gain and Main-Beam Calculations

The above-described equations can be used to calculate fields from a variety of radiating antennas, such as omni-directional radiators, dipole antennas and antennas incorporating directional arrays. However, in many cases the use of equations such as Equations (3) and (4) will result in an overly conservative "worst case" prediction of the field at a given point. Alternatively, if information concerning an antenna's vertical radiation pattern is known, a relative field factor (relative gain) derived from such a pattern can be incorporated into the calculations to arrive at a more accurate representation of the field at a given point of interest. For example, in the case of an antenna pointing toward the horizon, if the relative gain in the main beam is 1.0, then in other directions downward from horizontal the field may be significantly less than 1.0. Therefore, radiation from the antenna directly toward the ground may be significantly reduced from the omni-directional case and a more realistic prediction of the field can be obtained for the point of interest.

For example, in the calculation above, it can be shown from trigonometry that the depression angle below horizontal of the vector corresponding to the distance, R, is about 68^o. For purposes of illustration, assume that the antenna in this example has its main beam pointed approximately toward the horizon and, at a depression angle of 68^o, the field relative to the main beam (relative gain) is −6 dB (a factor of 0.5 in terms of field strength and 0.25 in terms of power density). In that case the calculation above can be modified giving a more accurate representation of the power density at the ground-level point of interest, as follows.

$$S = \frac{33.4\ F^2\ ERP}{R^2} = \frac{33.4\ (0.5)^2\ (10{,}000\ watts)}{(52\ m)^2} = about\ 31\ \mu W/cm^2$$

where: F = the relative field factor (relative numeric gain)

In general, Equation (9) can be modified to:

$$S = \frac{33.4\ (F^2)\ ERP}{R^2} \qquad (10)$$

where: S = power density in $\mu W/cm^2$
F = relative field factor (relative numeric gain)
ERP = power in watts
R = distance in meters

When the point of interest where exposure may occur is in or near the main radiated beam of an antenna, Equation (3) or its derivatives can be used. In other words, the factor, F, in such cases would be assumed to be 1.0. Such cases occur when, for example, a nearby building or rooftop may be in the main beam of a radiator. For convenience in determining exposures in such situations, Equation (3) has been used to derive Figures 1 and 2. These figures allow a quick determination of the power density at a given distance from an antenna in its main beam for various levels of ERP.[18] Intermediate ERPs can be estimated by interpolation, or the next highest ERP level can be used as a worst case approximation.

Figure 1 assumes no reflection off of a surface. However, at a rooftop location where the main-beam may be directed parallel and essentially along or only slightly above the surface of the roof, there may be reflected waves that would contribute to exposure. Therefore, Figure 2 was derived for the latter case using the EPA-recommended reflection factor of $(1.6)^2 = 2.56$ (see earlier discussion), and the values shown are more conservative. When using Figures 1 or 2 a given situation should be considered on its own merits to determine which figure is more appropriate. For rooftop locations it is also important to note that exposures ***inside*** a building can be expected to be reduced by at least 10-20 dB due to attenuation caused by building materials in the walls and roof.

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[18] To convert to EIRP use the relation: EIRP = ERP ***X*** 1.64.

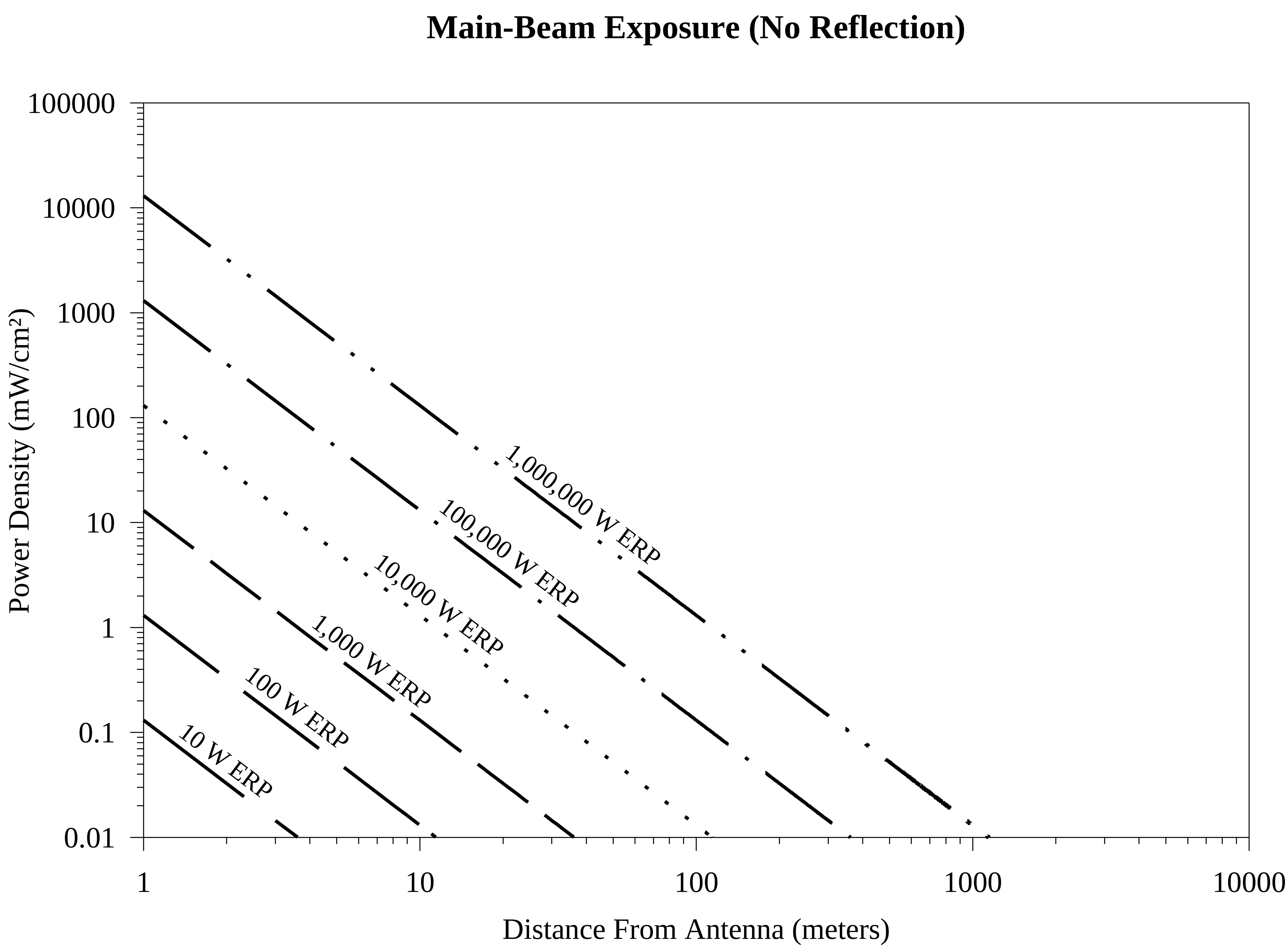

FIGURE 1. Power Density vs. Distance (assumes no surface reflection).

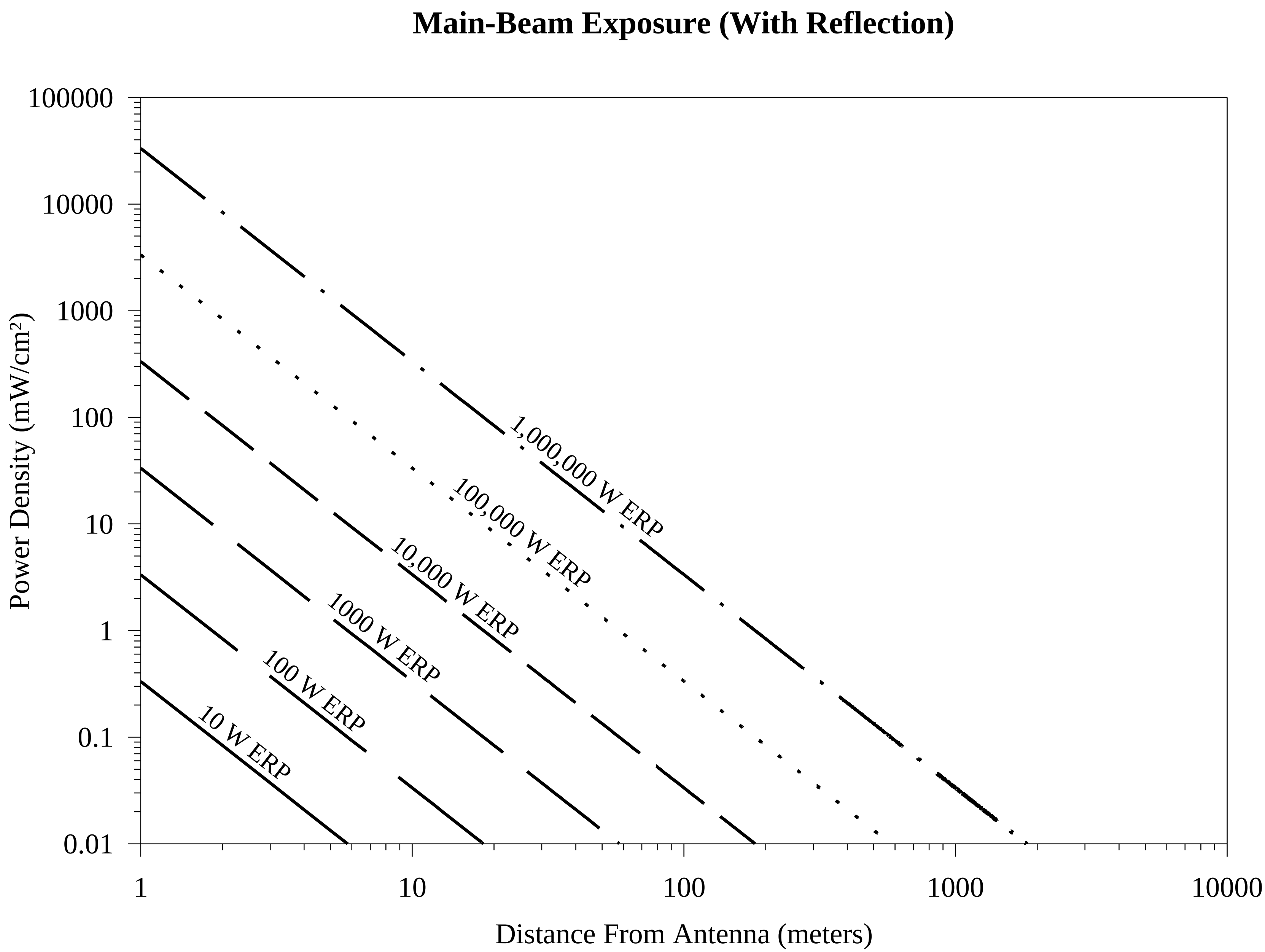

FIGURE 2. Power Density vs. Distance (assumes surface reflection).

Aperture Antennas

Aperture antennas include those used for such applications as satellite-earth stations, point-to-point microwave radio and various types of radar applications. Generally, these types of antennas have parabolic surfaces and many have circular cross sections. They are characterized by their high gain which results in the transmission of power in a well-defined collimated beam with little angular divergence. Systems using aperture antennas operate at microwave frequencies, i.e., generally above 900 MHz.

Those systems involved in telecommunications applications operate with power levels that depend on the distance between transmit and receive antennas, the number of channels required (bandwidth) and antenna gains of transmit and receive antennas. The antennas used typically have circular cross sections, where antenna diameter is an important characteristic that determines the antenna gain. With regard to some operations, such as satellite-earth station transmitting antennas, the combination of high transmitter power and large antenna diameter (high gain) produces regions of significant power density that may extend over relatively large distances in the main beam. Many "dish" type antennas used for satellite-earth station transmissions utilize the Cassegrain design in which power is fed to the antenna from a waveguide located at the center of the parabolic reflector. Radiation from this source is then incident on a small hyperbolic sub-reflector located between the power feed and the focal point of the antenna and is then reflected back to the main reflector resulting in the transmission of a collimated beam. An example of this is illustrated in Figure 3.

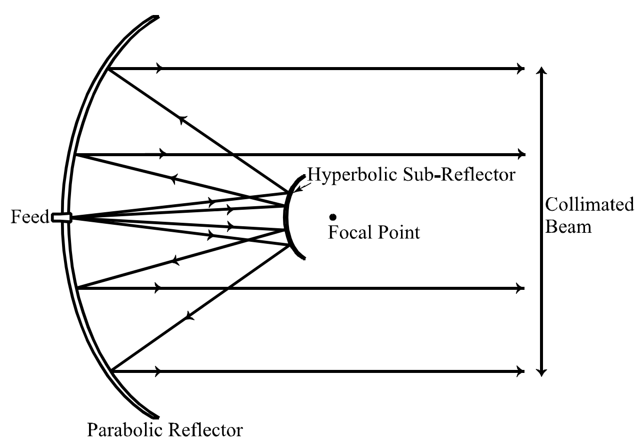

FIGURE 3. Cassegrain Antenna

Because of the highly directional nature of these and other aperture antennas, the likelihood of significant human exposure to RF radiation is considerably reduced. The power densities existing at locations where people may be typically exposed are substantially less than on-axis power densities. Factors that must be taken into account in assessing the potential for exposure are main-beam orientation, antenna height above ground, location relative to where people live or work and the operational procedures followed at the facility.

Satellite-earth uplink stations have been analyzed and their emissions measured to determine methods to estimate potential environmental exposure levels. An empirical model has been developed, based on antenna theory and measurements, to evaluate potential environmental exposure from these systems [Reference 15]. In general, for parabolic aperture antennas with circular cross sections, the following information and equations from this model can be used in evaluating a specific system for potential environmental exposure. More detailed methods of analysis are also acceptable. For example, see References [18] and [21].

Antenna Surface. The maximum power density directly in front of an antenna (e.g., at the antenna surface) can be approximated by the following equation:

$$S_{surface} = \frac{4P}{A} \tag{11}$$

where: $S_{surface}$ = maximum power density at the antenna surface
P = power fed to the antenna
A = physical area of the aperture antenna

Near-Field Region. In the near-field, or Fresnel region, of the main beam, the power density can reach a maximum before it begins to decrease with distance. The extent of the near-field can be described by the following equation (**D** and **λ** in same units):

$$R_{nf} = \frac{D^2}{4\lambda} \tag{12}$$

where: R_{nf} = extent of near-field
D = maximum dimension of antenna (diameter if circular)
λ = wavelength

The magnitude of the on-axis (main beam) power density varies according to location in the near-field. However, the maximum value of the near-field, on-axis, power density can be expressed by the following equation:

$$S_{nf} = \frac{16\eta P}{\pi D^2} \tag{13}$$

where: S_{nf} = maximum near-field power density
η = aperture efficiency, typically 0.5-0.75
P = power fed to the antenna
D = antenna diameter

Aperture efficiency can be estimated, or a reasonable approximation for circular apertures can be obtained from the ratio of the effective aperture area to the physical area as follows:

$$\eta = \frac{\left(\frac{G\lambda^2}{4\pi}\right)}{\left(\frac{\pi D^2}{4}\right)} \tag{14}$$

where: η = aperture efficiency for circular apertures
G = power gain in the direction of interest relative to an isotropic radiator
λ = wavelength
D = antenna diameter

If the antenna gain is not known, it can be calculated from the following equation using the actual or estimated value for aperture efficiency:

$$G = \frac{4\pi\eta A}{\lambda^2} \tag{15}$$

where: η = aperture efficiency
G = power gain in the direction of interest relative to an isotropic radiator
λ = wavelength
A = physical area of the antenna

Transition Region. Power density in the transition region decreases inversely with distance from the antenna, while power density in the far-field (Fraunhofer region) of the antenna decreases inversely with the ***square*** of the distance. For purposes of evaluating RF exposure, the distance to the beginning of the far-field region (farthest extent of the transition region) can be approximated by the following equation:

$$R_{ff} = \frac{0.6\ D^2}{\lambda} \qquad (16)$$

where: R_{ff} = distance to beginning of far-field
D = antenna diameter
λ = wavelength

The transition region will then be the region extending from $\mathbf{R_{nf}}$, calculated from Equation (12), to $\mathbf{R_{ff}}$. If the location of interest falls within this transition region, the on-axis

$$S_t = \frac{S_{nf}\ R_{nf}}{R} \qquad (17)$$

power density can be determined from the following equation:

where: S_t = power density in the transition region
S_{nf} = maximum power density for near-field calculated above
R_{nf} = extent of near-field calculated above
R = distance to point of interest

Far-Field Region. The power density in the far-field or Fraunhofer region of the antenna pattern decreases inversely as the square of the distance. The power density in the far-field region of the radiation pattern can be estimated by the general equation discussed earlier:

$$S_{ff} = \frac{PG}{4\pi R^2} \qquad (18)$$

where: S_{ff} = power density (on axis)
P = power fed to the antenna
G = power gain of the antenna in the direction of interest relative to an isotropic radiator
R = distance to the point of interest

In the far-field region, power is distributed in a series of maxima and minima as a function of the off-axis angle (defined by the antenna axis, the center of the antenna and the specific point of interest). For constant phase, or uniform illumination over the aperture, the main beam will be the location of the greatest of these maxima. The on-axis power densities calculated from the above formulas represent the maximum exposure levels that the system can produce. Off-axis power densities will be considerably less.

For off-axis calculations in the near-field and in the transition region it can be assumed that, if the point of interest is at least one antenna diameter removed from the center of the main beam, the power density at that point would be at least a factor of 100 (20 dB) less than the value calculated for the equivalent distance in the main beam (see Reference [15]).

For practical estimation of RF fields in the off-axis vicinity of aperture antennas, use of the antenna radiation pattern envelope can be useful. For example, for the case of an earth station in the fixed-satellite service, the Commission's Rules specify maximum allowable gain for antenna sidelobes not within the plane of the geostationary satellite orbit, such as at ground level.[19] In such cases, the rules require that the gain of the antenna shall lie below the envelope defined by:

$$\mathbf{32 - \{25\log_{10}(\theta)\}\ dBi} \quad \textit{for} \quad \mathbf{1^{o} \leq \theta \leq 48^{o}}$$
$$\textit{and:} \quad \mathbf{-10\ dBi} \quad \textit{for} \quad \mathbf{48^{o} < \theta \leq 180^{o}}$$

Where: θ = the angle in degrees from the axis of the main lobe
dBi = dB relative to an isotropic radiator

Use of the gain obtained from these relationships in simple far-field calculations, such as Equation 18, will generally be sufficient for estimating RF field levels in the surrounding environment, since the apparent aperture of the antenna is typically very small compared to its frontal area.

Special Antenna Models

There are various antenna types for which other models and prediction methods could be useful for evaluating the potential for exposure. To discuss models for each of the numerous types of antennas in existence would be beyond the scope of this bulletin. However, some specific cases and applications will be mentioned. In addition, a model that

19 See 47 CFR 25.209 (a)(2).

was developed for FM radio broadcast antennas is discussed in Supplement A to this bulletin.[20]

Prediction methods have been developed for certain specialized antennas used for paging, cellular radio and personal communications services (PCS). In 1995, a study was performed for the FCC by Richard Tell Associates, Inc., that included developing prediction methodology for RF fields in the vicinity of such antennas, particularly those that may be located on rooftops (see References [29] and also [22]). In that study it was found that at distances close to these antennas a power density model based on inverse distance was more accurate than predictions based on the typical far-field equations such as Equations (3) and (4) above. In other words, in these equations the factor $\mathbf{R}$ could be substituted for the factor $\mathbf{R^2}$ for a more realistic approximation of the true power density close to the antennas. The distance over which this relation holds appears to vary with the antenna under study, but can extend for several meters according to the Tell study.

Tell has observed that the use of a cylindrical model can be useful in evaluating RF fields near vertical collinear dipole antennas similar to those used for cellular, PCS, paging and two-way radio communications.[21] This model can also be used in estimating near-field exposures adjacent to television and FM radio broadcast antennas where workers may be located during tower work. In general, this model is a more accurate predictor of exposure very close to an antenna where "far-field" equations, such as Equation 1, may significantly ***overpredict*** the RF environment. However, as one moves away from an antenna the cylindrical model becomes overly conservative and the far-field model becomes more accurate. The exact distance ("crossover point") where this occurs is not a simple value but depends on characteristics of the antenna such as aperture dimension and gain. One can determine this crossover point by calculating and plotting power densities using a far-field model and the cylindrical model described below and finding the distance where the predictions coincide.

For Tell's cylindrical model, spatially averaged plane-wave equivalent power densities parallel to the antenna may be estimated by dividing the net antenna input power by the surface area of an imaginary cylinder surrounding the length of the radiating antenna. While the actual power density will vary along the height of the antenna, the average value along its

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20 *Additional Information for Radio and Television Broadcast Stations*, Supplement A to OET Bulletin 65, Version 97-01. This supplement will be made available for downloading from the FCC RF Safety Web Site: www.fcc.gov/oet/rfsafety. Otherwise contact the FCC RF Safety Program at: (202) 418-2464.

21 Tell, Richard A. (1996). *EME Design and Operation Considerations for Wireless Antenna Sites.* Technical report prepared for the Cellular Telecommunications Industry Association, Washington, D.C. 20036.

length will closely follow the relation given by the following equation.

$$S = \frac{P_{net}}{2\pi Rh} \tag{19}$$

where: S = power density
P_{net} = net power input to the antenna
R = distance from the antenna
h = aperture height of the antenna

For sector-type antennas, power densities can be estimated by dividing the net input power by that portion of a cylindrical surface area corresponding to the angular beam width of the antenna. For example, for the case of a 120-degree azimuthal beam width, the surface area should correspond to 1/3 that of a full cylinder. This would increase the power density near the antenna by a factor of three over that for a purely omni-directional antenna. Mathematically, this can be represented by Equation (20) in which the angular beam width, θ_{BW}, can be taken as the appropriate azimuthal "power dispersion" angle for a given reflector. For example, a conservative estimate could be obtained by using the 3 dB (half-power) azimuthal beam width for a given sectorized antenna.

$$S = \left(\frac{180}{\theta_{BW}}\right)\frac{P_{net}}{\pi Rh} \tag{20}$$

where: S = power density
P_{net} = net power input to the antenna
θ_{BW} = beam width of the antenna in degrees
R = distance from the antenna
h = aperture height of the antenna

Equation (20) can be used for any vertical collinear antenna, even omni-directional ones. For omni-directional antennas, θ_{BW} would be 360 degrees and Equation (20) reduces to the simpler Equation (19) above.

Multiple-Transmitter Sites and Complex Environments

It is common for multiple RF emitters to be co-located at a given site. Antennas are often clustered together at sites that may include a variety of RF sources such as radio and television broadcast towers, CMRS antennas and microwave antennas. The FCC's exposure guidelines are meant to apply to any exposure situation caused by transmitters regulated by the FCC. Therefore, at multiple-transmitter sites, all significant contributions to the RF environment should be considered, not just those fields associated with one specific source. When there are multiple transmitters at a given site collection of pertinent technical information about them will be necessary to permit an analysis of the overall RF environment by calculation or computer modeling. However, if this is not practical a direct measurement survey may prove to be more expedient for assessing compliance (see Section 3 of this bulletin that deals with measurements for more information).

The rules adopted by the FCC specify that, in general, at multiple transmitter sites actions necessary to bring the area into compliance with the guidelines are the shared responsibility of all licensees whose transmitters produce field strengths or power density levels at the area in question in excess of 5% of the exposure limit (in terms of power density or the square of the electric or magnetic field strength) applicable to their particular transmitter.[22] When performing an evaluation for compliance with the FCC's RF guidelines ***all*** significant contributors to the ambient RF environment should be considered, including those otherwise excluded from performing routine RF evaluations, and applicants are expected to make a good-faith effort to consider these other transmitters. For purposes of such consideration, significance can be taken to mean ***any*** transmitter producing more than 5% of the applicable exposure limit (in terms of power density or the square of the electric or magnetic field strength) at accessible locations. The percentage contributions are then added to determine whether the limits are (or would be) exceeded. If the MPE limits are exceeded, then the responsible party or parties, as described below, must take action to either bring the area into compliance or submit an EA.

Applicants and licensees should be able to calculate, based on considerations of frequency, power and antenna characteristics the distance from their transmitter where their signal produces an RF field equal to, or greater than, the 5% threshold limit. The applicant or licensee then shares responsibility for compliance in any accessible area or areas within this 5% "contour" where the appropriate limits are found to be exceeded.

The following policy applies in the case of an application for a proposed transmitter, facility or modification (not otherwise excluded from performing a routine RF evaluation) that would ***cause non-compliance*** at an accessible area previously in compliance. In such a case, it is the responsibility of the applicant to either ensure compliance or submit an EA if emissions from the applicant's transmitter or facility would result in an exposure level at the non-complying area that exceeds 5% of the exposure limits applicable to that transmitter or facility in terms of power density or the square of the electric or magnetic field strength.

For a renewal applicant whose transmitter or facility (not otherwise excluded from routine evaluation) contributes to the RF environment at an accessible area ***not in compliance*** with the guidelines the following policy applies. The renewal applicant must submit an EA if emissions from the applicant's transmitter or facility, at the area in question, result in an exposure level that exceeds 5% of the exposure limits applicable to that particular transmitter

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[22] *See* 47 C.F.R. 1.1307(b)(3), as amended.

in terms of power density or the square of the electric or magnetic field strength. In other words, although the renewal applicant may only be responsible for a fraction of the total exposure (greater than 5%), the applicant (along with any other licensee undergoing renewal at the same time) will trigger the EA process, unless suitable corrective measures are taken to prevent non-compliance before preparation of an EA is necessary. In addition, in a renewal situation if a determination of non-compliance is made, other co-located transmitters contributing more than the 5% threshold level must share responsibility for compliance, regardless of whether they are categorically excluded from routine evaluation or submission of an EA.

Therefore, at multiple-transmitter sites the various responsibilities for evaluating the RF environment, taking actions to ensure compliance or submitting an EA may lie either with a newcomer to the site, with a renewal applicant (or applicants) or with all significant users, depending on the situation. In general, an applicant or licensee for a transmitter at a multiple-transmitter site should seek answers to the following questions in order to determine compliance responsibility.

(1) New transmitter proposed for a multiple-transmitter site.

- Is the transmitter in question already categorically excluded from routine evaluation?

- If ***yes***, routine evaluation of the application is not required.

- If ***not excluded***, is the site in question already in compliance with the FCC guidelines?

- If ***no,*** the applicant must submit an EA with its application notifying the Commission of the non-compying situation, unless measures are to be taken to ensure compliance. Compliance is the responsibility of licensees of all transmitters that contribute to non-complying area(s) in excess of the applicable 5% threshold at the existing site. If the existing site is subsequently brought into compliance ***without*** consideration of the new applicant then the next two questions below apply.

- If ***yes***, would the proposed transmitter cause non-compliance at the site in question?
- If ***yes***, the applicant must submit an EA (or submit a new EA in the situation described above) with its application notifying the Commission of the potentially non-complying situation, unless measures will be taken by the applicant to ensure compliance. In this situation, it is the responsibility of the applicant to ensure compliance, since the existing site is already in compliance.

- If ***no***, no further environmental evaluation is required and the applicant certifies compliance.

(2) Renewal applicant at a multiple-transmitter site

- Is the transmitter in question already categorically excluded from routine evaluation?

- If ***yes***, routine evaluation of the application is not required.

- If ***not excluded,*** is the site in question already in compliance with the FCC guidelines?

- If ***no***, the applicant must submit an EA with its application notifying the Commission of the non-compying situation, unless measures are taken to ensure compliance. Compliance is the responsibility of licensees of all transmitters that contribute to non-complying area(s) in excess of the applicable 5% threshold.

- If ***yes,*** no further environmental evaluation is necessary and the applicant certifies compliance.

The Commission expects its licensees and applicants to cooperate in resolving problems involving compliance at multiple-transmitter sites. Also, owners of transmitter sites are expected to allow applicants and licensees to take reasonable steps to comply with the FCC's requirements. When feasible, site owners should also encourage co-location and common solutions for controlling access to areas that may be out of compliance. In situations where disputes arise or where licensees cannot reach agreement on necessary compliance actions, a licensee or applicant should notify the FCC licensing bureau. The bureau may then determine whether appropriate FCC action is necessary to facilitate a resolution of the dispute.

The FCC's MPE limits vary with frequency. Therefore, in mixed or broadband RF fields where several sources and frequencies are involved, the fraction of the recommended limit (in terms of power density or square of the electric or magnetic field strength) incurred within each frequency interval should be determined, and the sum of all fractional contributions should not exceed 1.0, or 100% in terms of percentage. For example, consider an antenna farm with radio and UHF television broadcast transmitters. At a given location that is accessible to the general public it is determined that FM radio station X contributes 100 $\mu W/cm^2$ to the total power density (which is 50% of the applicable 200 $\mu W/cm^2$ MPE limit for the FM frequency band). Also, assume that FM station Y contributes an additional 50 $\mu W/cm^2$ (25% of its limit) and that a nearby UHF-TV station operating on Channel 35 (center frequency = 599 MHz) contributes 200 $\mu W/cm^2$ at the same location (which is 50% of the applicable MPE limit for this frequency of 400 $\mu W/cm^2$). The sum of all of the percentage contributions then equals 125%, and the location is not in compliance with the MPE limits for the general public. Consequently, measures must be taken to bring the site into compliance such as restricting access to the area (see Section 4 of this bulletin on controlling exposure).

As noted above, in such situations it is the shared responsibility of site occupants to take whatever actions are necessary to bring a site into compliance. In the above case, the allocation of responsibility could be generally based on each station's percentage contribution to the overall power density at the problem location, although such a formula for allocating responsibility is not an FCC requirement, and other formulas may be used, as appropriate.

When attempting to predict field strength or power density levels at multiple transmitter sites the general equations discussed in this section of the bulletin can be used at many sites, depending on the complexity of the site. Individual contributions can often be determined at a given location using these prediction methods, and then power densities (or squares of field strength values) can be added together for the total predicted exposure level.
In addition, time-averaging of exposures may be possible, as explained in Section 1 of this bulletin. For sites involving radio and television broadcast stations, the methods described in Supplement A for broadcast stations can be used in some circumstances when a site is not overly complex. Also, for wireless communications sites, some organizations have developed commercially-available software for modeling sites for compliance purposes.[23]

When considering the contributions to field strength or power density from other RF sources, care should be taken to ensure that such variables as reflection and re-radiation are considered. In cases involving very complex sites predictions of RF fields may not be possible, and a measurement survey may be necessary (see Section 3 of this bulletin).

The following example illustrates a simple situation involving multiple antennas. The process for determining compliance for other situations can be similarly accomplished using the techniques described in this section and in Supplement A to this bulletin that deals with radio and television broadcast operations. However, as mentioned above, at very complex sites measurements may be necessary.

In the simple example shown in Figure 4 it is desired to determine the power density at a given location **X** meters from the base of a tower on which are mounted two antennas. One antenna is a CMRS antenna with several channels, and the other is an FM broadcast antenna. The system parameters that must be known are the total ERP for each antenna and the operating frequencies (to determine which MPE limits apply). The heights above ground level for each antenna, **H1** and **H2,** must be known in order to calculate the distances, **R1**and **R2**, from the antennas to the point of interest. The methods described in this section (and in Supplement A for FM antennas) can be used to determine the power density contributions of each antenna at the location of interest, and the percentage contributions (compared to the applicable MPE limit for that frequency) are added together as described above to determine if the location complies with the applicable exposure guidelines. If the location is accessible
to the public, the general/population limits apply. Otherwise occupational/controlled limits should be used.

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[23] For example, the following two U.S. companies have recently begun marketing such software: (1) Richard Tell Associates, Inc., telephone: (702) 645-3338; and (2) UniSite, telephone: (972) 348-7632.

Another type of complex environment is a site with multiple towers. The same general process may be used to determine compliance as described above, if appropriate. Distances from each transmitting antenna to the point of interest must be calculated, and RF levels should be calculated at the point of interest due to emissions from each transmitting antenna using the most accurate model. Limits, percentages and cumulative percent of the limit may then be determined in the same manner as for Figure 4. Figure 5 illustrates such a situation.

Another situation may involve a single antenna that creates significant RF levels at more than one type of location. Figure 6 illustrates such a situation where exposures on a rooftop as well as on the ground are possible. The same considerations apply here as before and can be applied to predict RF levels at the points of interest. As mentioned previously, with respect to rooftop environments, it is also important to remember that building attenuation can be expected to reduce fields inside of the building by approximately 10-20 dB.

Situations where tower climbing is involved may be complicated and may require reduction of power or shutting down of transmitters during maintenance tasks (also see Section 4 of this bulletin on controlling exposure). Climbing of AM towers involves exposure due to RF currents induced in the body of the climber, and guidelines are available for appropriate power reduction (see Supplement A, Section 1, dealing with AM broadcast stations). For FM, TV and other antennas that may be mounted on towers, the highest exposures will be experienced near the active elements of each antenna and may require shutting off or greatly reducing power when a worker passes near the elements.

The equations in this section can also be used to calculate worst-case RF levels either below or above antennas that are side-mounted on towers. In the example shown in Figure 7, a more complicated situation arises when a worker is climbing an AM tower on which are side-mounted two other antennas. In this case the safest and most conservative approach would be to consult Supplement A, Section 1, for the appropriate AM power level to use and then to ensure that the transmitters for the other antennas are shut down when the climber passes near each side-mounted antenna's elements.

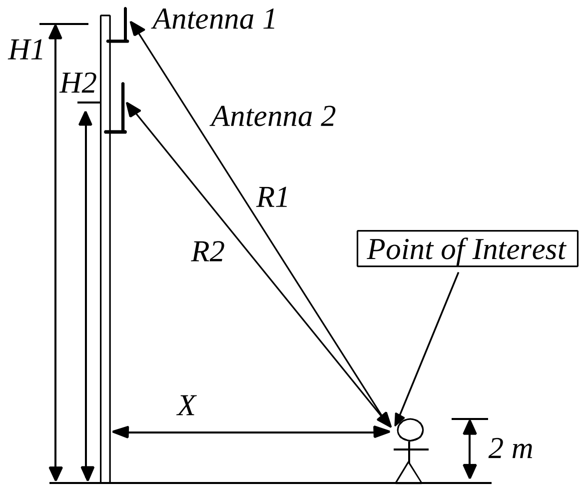

Figure 4. Single tower, co-located antennas, ground-level exposure (at 2 m).

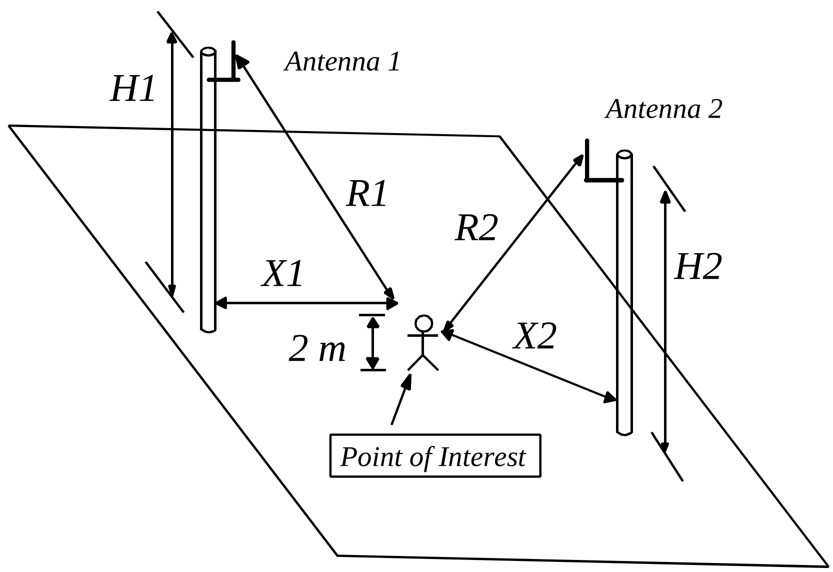

FIGURE 5. Antennas on multiple towers contributing to RF field at point of interest.

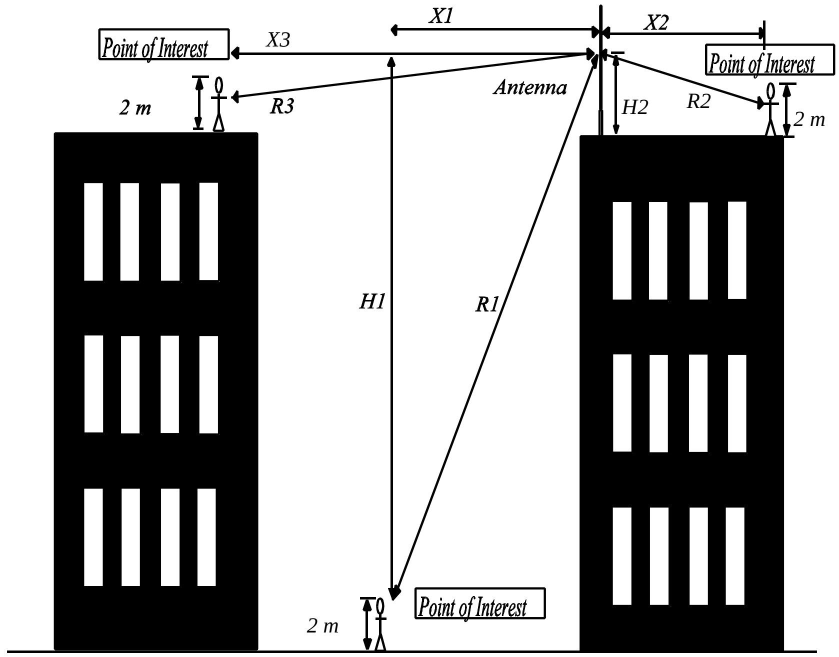

FIGURE 6. Single roof-top antenna, various exposure locations.

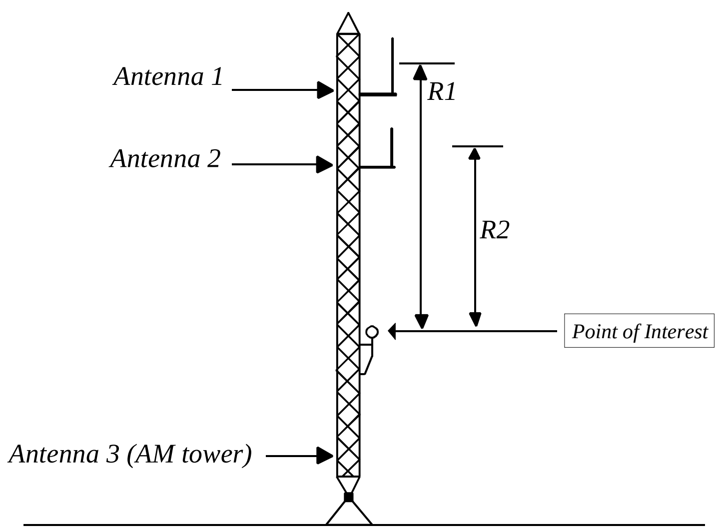

FIGURE 7. Single tower, co-located antennas, on-tower exposure.

Evaluating Mobile and Portable Devices

Portable and mobile devices present something of a special case with respect to evaluating RF exposure. The user of such a device would most likely be in the near vicinity of the RF radiator, and the predictive methods described above may not apply in all cases. Therefore, evaluation of exposure due to these devices requires special consideration. The FCC's rules for evaluating portable and mobile devices for RF compliance are contained in 47 CFR §§2.1091 and 2.1093 (see Appendix A).

The new FCC guidelines differentiate between devices according to their proximity to exposed persons. In that regard, "portable" devices are defined as those devices that are designed to be used with any part of the radiating structure of the device in direct contact with the body of the user or within 20 cm of the body of the user under normal conditions of use. This category would include such devices as hand-held cellular telephones that incorporate the radiating antenna into the handpiece. "Mobile" devices are defined by the FCC as transmitting devices designed to be used in other than fixed locations that would normally be used with radiating structures maintained 20 cm or more from the body of the user or nearby persons. In this context, the term "fixed location" means that the device is physically secured at one location and is not able to be easily moved to another location.
Examples of mobile devices, as defined above, would include transportable cellular telephones ("bag" phones), cellular telephones and other radio devices that use vehicle-mounted antennas and certain other transportable transmitting devices. Transmitting devices designed to be used by consumers or workers that can be easily re-located, such as wireless devices associated with a personal computer, are considered to be mobile devices if they meet the 20 centimeter separation requirement.

Evaluation of exposure from a portable or mobile device depends on how the device is to be used. With respect to portable devices, both the 1992 ANSI/IEEE standard and the NCRP exposure criteria, upon which the FCC guidelines are based, permit devices designed to be used in the immediate vicinity of the body, such as hand-held telephones, to be excluded from compliance with the limits for field strength and power density provided that such devices comply with the limits for specific absorption rate (SAR). Therefore, portable devices, as defined by the FCC, are to be evaluated with respect to SAR not MPE limits. For most consumer-type devices, such as hand-held cellular telephones, the appropriate SAR limit is 1.6 watt/kg as averaged over any one gram of tissue, defined as a tissue volume in the shape of a cube (see Appendix A for details).

The selection of the 20-cm value for differentiating between "portable" and "mobile" devices is based on the specification in the 1992 ANSI/IEEE standard that 20 cm should be the minimum separation distance where reliable field measurements to determine adherence to MPEs can be made.[24] Therefore, although at closer distances a determination of SAR is

[24] Although ANSI/IEEE does not explicitly state a rule for determining when SAR measurements are preferable to MPE measurements, we believe that the 20 cm distance is appropriate based on Sec. 4.3(3) of ANSI/IEEE C95.1-1992.

normally a more appropriate measure of exposure, for "mobile" devices, as defined above, compliance can be evaluated with respect to MPE limits, and the generic equations of this section, such as Equations (3) and (4), can be used for calculating exposure potential.

For portable devices SAR evaluation is routinely required by the FCC prior to equipment authorization or use for the following categories: (1) portable telephones or portable telephone devices to be used in the Cellular Radiotelephone Service authorized under Part 22, Subpart H of the FCC's rules or to be used in the Private Land Mobile Radio Services for SMR systems under Part 90 of our rules; (2) portable devices to be used in the Personal Communications Services (PCS) authorized under Part 24; (3) portable devices that operate in the General Wireless Communications Services or the Wireless Communications Service authorized under Parts 26 and 27; (4) portable devices to be used for earth-satellite communication authorized under Part 25 and Part 80; and (5) portable unlicensed PCS, portable unlicensed NII and portable millimeter-wave devices authorized under Part 15 of our rules (see Appendix A for specific rule parts).

Mobile devices, as defined above, are to be evaluated with respect to the MPE limits specified in Table 1 of Appendix A (and in 47 CFR § 1.1310). Evaluation prior to equipment authorization or use is routinely required for the following mobile transmitters if the operating frequency is 1.5 GHz or below and the effective radiated power (ERP) of the station, in its normal configuration, will be 1.5 watts or greater, ***or*** if the operating frequency is above 1.5 GHz and the ERP is 3 watts or more: (1) mobile telephones or portable telephone devices to be used in the Cellular Radiotelephone Service authorized under Part 22 Subpart H of the FCC's rules or to be used in the Private Land Mobile Radio Services for SMR systems under Part 90 of our rules; (2) mobile devices to be used in the Personal Communications Services (PCS) authorized under Part 24; (3) mobile devices that operate in the General Wireless Communications Services or the Wireless Communications Service authorized under Parts 26 and 27; (4) mobile devices to be used for earth-satellite communication authorized under Part 25 and Part 80; and (5) unlicensed PCS, unlicensed NII and millimeter-wave mobile devices authorized under Part 15 of our rules.

Although the FCC's exposure criteria apply to portable and mobile devices in general, at this time routine evaluation for compliance is not required for devices such as "push-to-talk" portable radios and "push to talk" mobile radios used in taxicabs, business, police and fire vehicles and used by amateur radio operators. These transmitting devices are excluded from routine evaluation because their duty factors (percentage of time during use when the device is transmitting) are generally low and, for mobile radios, because their antennas are normally mounted on the body of a vehicle which provide some shielding and separation from the user. This significantly reduces the likelihood of human exposure in excess of the RF safety guidelines due to emissions from these transmitters. Duty factors associated with transmitting devices that are not "push-to-talk," such as transportable cellular telephones ("bag" phones) or cellular telephones that use vehicle-mounted antennas, would be generally higher, and these devices are subject to routine evaluation. Although we are not requiring routine evaluation of all portable and mobile devices, under Sections 1.1307(c) and 1.1307(d) of the FCC's Rules, 47 CFR 1.1307(c) and (d), the Commission reserves the right to require evaluation for environmental significance of any device (in this case with respect to SAR or compliance with MPE limits).

The following guidelines should be used to determine the application of the exposure criteria to portable and mobile devices in general. First of all, devices may generally be evaluated based on whether they are designed to be used under occupational/controlled or general population/uncontrolled conditions. Devices that are designed specifically to be used in the workplace, such as many hand-held, two-way portable radios, would be considered as operating in an occupational/controlled environment and the applicable limits for controlled environments would apply. On the other hand, devices designed to be purchased and used primarily by consumers, such as cellular telephones and most personal communications devices, would be considered to operate under the general population/uncontrolled category, and limits for uncontrolled environments would apply. Devices that can be used in either environment would normally be required to meet uncontrolled exposure criteria.

In situations where higher exposure levels may result from unusual or inappropriate use of a device, instructional material should be provided to the user to caution against such usage. With regard to mobile devices that are not hand-held, labels and instructional material may be useful as when a minimum separation distance is desired to be maintained. For example, in the case of a cellular "bag" phone a prominent warning label as well as instructional information on minimum required distances for compliance would be an acceptable means of ensuring that the device is used safely.

With respect to evaluating portable devices, various publications are available that describe appropriate measurement techniques and methods for determining SAR for compliance purposes.[25] The use of appropriate numerical and computational techniques, such as FDTD analysis, may be acceptable for demonstrating compliance with SAR values. Studies have indicated that such techniques can be used to determine energy absorption characteristics in exposed subjects (e.g., see Reference [24]). However, in order for numerical techniques to be valid the basic computational algorithm and modeling of the portable device should be validated, and appropriate models of the human body should be used which will provide reasonable accurate estimates of SAR. Accurate models of the adult human body exist at the present time, but developing models of devices may be more problematic. In general, numerical device and antenna models should represent the actual device under test and should be confirmed accordingly, e.g., with appropriate techniques, analytical data, published data or far-field radiation patterns.

For purposes of evaluating compliance with localized SAR guidelines, portable devices should be tested or evaluated based on normal operating positions or conditions. Because of the location of the antenna, the antenna may be closer to the body, e.g., the head, when the

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[25] For example, see sections of ANSI/IEEE C95.3-1992 and NCRP Report No. 119, discussed below, that describe SAR evaluation techniques. Also, see References [5], [7], [12], [13], [14], [16], [17], [23] and [24]. Other organizations are developing information on SAR evaluation procedures, and SAR evaluation services and systems are commercially available.

device is held against the left side of the head or body versus when it is held against the right side. In such cases, there will be differences in coupling to the body resulting in higher SARs when the device is held on one side rather than the other. Since various users may hold these devices in either position, both positions should be tested to determine compliance.

Industry groups and other organizations are expected to develop product performance standards and other information to ensure compliance with SAR criteria in the future. This effort will be very helpful in facilitating the provision of compliance guidelines and services to manufacturers and others. In that regard, a sub-committee sponsored by the IEEE has been recently formed to develop specific and detailed recommendations for experimental and numerical evaluation of SAR from portable devices.[26] FCC staff participate as members of this sub-committee, and it is expected that the FCC will be able to use the recommendations made by this group to provide future guidance on SAR evaluation.[27] In the meantime, the FCC expects to periodically issue statements or guidance on compliance with SAR requirements pending the issuance of any recommended protocols or guidelines from the IEEE or other organizations. Inquiries with respect to FCC requirements for SAR evaluation should be directed to the FCC's laboratory in Columbia, Maryland, telephone: (301) 725-1585.

For portable devices operating at frequencies above 6 GHz special considerations are necessary. The localized SAR criteria used by the FCC, and specified in the ANSI/IEEE 1992 standard, only apply at operating frequencies between 100 kHz and 6 GHz.[28] For portable devices that operate above 6 GHz (e.g., millimeter-wave devices) localized SAR is not an appropriate means for evaluating exposure. At these higher frequencies, exposure from portable devices should be evaluated in terms of power density MPE limits instead of SAR. Power density values can be either calculated or measured, as appropriate.

If power density is to be measured at these higher frequencies to show compliance of portable devices, a question arises as to an appropriate minimum distance at which to make such a measurement. The ANSI/IEEE 1992 standard specifies 20 cm as a minimum separation distance for such measurements. The guidelines delineated in NCRP No. 86 indicated that measurements should be made at least 5 cm "from any object in the field."[29] The more recent NCRP Report 119 seems to endorse the 20 cm value, at least for the case of

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[26] IEEE Standards Coordinating Committee 34 (IEEE SCC34), sub-committee II. For further information contact the IEEE at 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

[27] It should also be noted that in February 1997 the European Committee for Electrotechnical Standardization released a CENELEC document entitled, "Considerations for Human Exposure to EMFs from Mobile Telecommunications Equipment (MTE) in the Frequency Range 30 MHz - 6 GHz." This document contains information and guidance on techniques for evaluating SAR compliance for RF devices.

[28] ANSI/IEEE C95.1-1992, Section 4.2.

[29] See Reference [20], NCRP Report No. 86 at Section 17.5.

"secondary" sources.[30] In some cases, for example, near an open-ended waveguide or consumer device operating at a millimeter-wave frequency, a 20 cm separation requirement from the ***primary*** radiating source for measurements would not be practical for determining exposure potential. Therefore, in such cases a 5 cm separation requirement can be justified to allow for evaluation of potential exposure at distances closer than 20 cm. Some research relevant to this issue has been done in the VHF band that indicates there is no practical reason why a 5 cm minimum distance cannot be used for measuring power density.[31] Since a 5 cm separation distance is already built-in to many isotropic broadband RF probes, performing measurements at this distance is straightforward.

In view of these facts, it is appropriate to evaluate ***both*** mobile and portable devices that operate at frequencies above 6 GHz for compliance with FCC RF guidelines in terms of the FCC MPE limits for power density. In that regard, it is appropriate to make measurements of power density at a minimum distance of 5 cm from the radiator of a portable device to show compliance.

Section 3: MEASURING RF FIELDS

Reference Material

In some cases the prediction methods described in Section 2 of this bulletin cannot be used, and actual measurements of the RF field may be necessary to determine whether there is a potential for human exposure in excess of the MPE limits specified by the FCC. For example, in a situation such as an antenna farm, with multiple users the models discussed previously would not always be applicable. Measurements may also be desired for cases in which predictions are slightly greater or slightly less than the threshold for excessive exposure or when fields are likely to be seriously distorted by objects in the field, e.g., conductive structures.

Techniques and instrumentation are available for measuring the RF environment near broadcast and other transmitting sources. In addition, references are available which provide detailed information on measurement procedures, instrumentation, and potential problems. Two excellent references in this area have been published by the IEEE and by the NCRP. The ANSI/IEEE document (ANSI/IEEE C95.3-1992) is entitled, "Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields - RF and Microwave,"

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[30] Reference [21], NCRP Report 119 at Section 3.3.6.

[31] R.A. Tell, *"An Investigation of RF Induced Hot Spots and their Significance Relative to Determining Compliance with the ANSI Radiofrequency Protection Guide."* Report prepared for the National Association of Broadcasters, July 3, 1989.

(Reference [2]) and the NCRP publication (NCRP Report No. 119) is entitled, "A Practical Guide to the Determination of Human Exposure to Radiofrequency Fields" (Reference [21]). Both of these documents contain practical guidelines and information for performing field measurements in broadcast and other environments, and the FCC strongly encourages their use. Other selected references are given in the reference section of this bulletin.

Instrumentation

Instruments used for measuring radiofrequency fields may be either broadband or narrowband devices. A typical broadband instrument responds essentially uniformly and instantaneously over a wide frequency range and requires no tuning. A narrowband instrument may also operate over a wide frequency range, but the instantaneous bandwidth may be limited to only a few kilohertz, and the device must be tuned to the frequency of interest. Each type of instrument has certain advantages and certain disadvantages, and the choice of which instrument to use depends on the situation where measurements are being made.

All instruments used for measuring RF fields have the following basic components: (1) an antenna to sample the field, (2) a detector to convert the time-varying output of the antenna to a steady-state or slowly varying signal, (3) electronic circuitry to process the signal, and (4) a readout device to display the measured field parameter in appropriate units.

The antennas most commonly used with broadband instruments are either dipoles that respond to the electric field (E) or loops that respond to the magnetic field (H). Surface area or displacement-current sensors that respond to the E-field are also used. In order to achieve a uniform response over the indicated frequency range, the size of the dipole or loop must be small compared to the wavelength of the highest frequency to be measured. Isotropic broadband probes contain three mutually orthogonal dipoles or loops whose outputs are ***summed*** so that the response is independent of orientation of the probe. The output of the dipoles or loops is converted to a proportional steady-state voltage or current by diodes or thermocouples, so that the measured parameter can be displayed on the readout device.

As described in the first edition of this bulletin, there are certain characteristics which are desirable in a broadband survey instrument. The major ones are as follows:

(1) The response of the instrument should be essentially isotropic, i.e., independent of orientation, or rotation angle, of the probe.

(2) The frequency range of the instrument and the instruments response over that range should be known. Generally this is given in terms of the error of response between certain frequency limits, e.g. , ± 0.5 dB from 3 to 500 MHz.

(3) Out-of-band response characteristics of the instrument should be specified by the manufacturer to assist the user in selecting an instrument for a particular application.

For example, regions of enhanced response, or resonance, at frequencies outside of the band of interest could result in error in a measurement, if signals at the resonant frequency(ies) are present during the measurement.

(4) The dynamic range of the instrument should be at least $\pm$ 10 dB of the applicable exposure guideline.

(5) The instrument's readout device should be calibrated in units that correspond to the quantity actually being measured. An electric field probe responds to E or E^2, and a magnetic field probe responds to H or H^2, equally well in both the near-field and far-field. However, a readout device calibrated in units of power density does not read true power density if measurements are made in the near-field. This is because under plane-wave conditions, in which E, H, and power density are related by a constant quantity (the wave impedance which, for free space, is equal to 377 ohms), do not exist in the near-field where the wave impedance is complex and generally not known. Readout devices calibrated in "power density" actually read "far-field equivalent" power density or "plane-wave equivalent" power density (see discussion of MPE limits in Section 1 of this bulletin).

(6) The probe and the attached cables should only respond to the parameter being measured, e.g. , a loop antenna element should respond to the magnetic field and should not interact significantly with the electric field.

(7) Shielding should be incorporated into the design of the instrument to reduce or eliminate electromagnetic interference.

(8) There should be some means, e.g., an alarm or test switch to establish that the probe is operating correctly and that none of the elements are burned out. Also, a means should be provided to alert the user if the measured signal is overloading the device.

(9) When the amplitude of the field is changing while measurements are being made, a "peak-hold" circuit may be useful. Such a change in amplitude could result either from variation in output from the source or from moving the probe through regions of the field that are non-uniform.

(10) For analog-type meters, the face of the meter should be coated with a transparent, conductive film to prevent false readings due to the accumulation of static charge in the meter itself. Also, the outer surface of the probe assembly of electric-field survey instruments should be covered with a high-resistance material to minimize errors due to static charge buildup.

(11) The instrument should be battery operated with easily replaceable or rechargeable batteries. A test switch or some other means should be provided to determine whether the batteries are properly charged. The instrument should be capable of operating

within the stated accuracy range for a time sufficient to accomplish the desired measurements without recharging or replacing the batteries.

(12) The user should be aware of the response time of the instrument, i.e., the time required for the instrument to reach a stable reading.

(13) The device should be stable enough so that frequent readjustment to zero ("rezeroing") is not necessary. If not equipped with automatic zeroing capability, devices must be zeroed with the probe out of the field, either by shielding them or turning off the RF source(s). Either method is time consuming, making stability an especially desirable feature.

(14) If the instrument is affected by temperature, humidity, pressure, etc., the extent of the effect should be known and taken into account.

(15) The sensor elements should be sufficiently small and the device should be free from spurious responses so that the instrument responds correctly to the parameter being measured, both in the near-field and in the far-field. It should be emphasized that an instrument with a readout expressed in terms of power density will only be correct in the far-field. However, the term "far-field equivalent" or "plane-wave equivalent" power density is sometimes used in this context and would be acceptable as long as its meaning is understood and it is appropriately applied to the situation of interest (see discussion in Section 1).

(16) The instrument should respond to the average (rms) values of modulated fields independent of modulation characteristics. With respect to measurements of pulsed sources such as radar transmitters, many commercially-available survey instruments cannot measure high peak-power pulsed fields accurately. In such cases, the instrument should be chosen carefully to enable fields close to the antenna to be accurately measured.

(17) The instrument should be durable and able to withstand shock and vibration associated with handling in the field or during shipping. A storage case should be provided.

(18) The accuracy of the instrument should not be affected by exposure to light or other forms of ambient RF and low-frequency electromagnetic fields.

(19) The markings on the meter face should be sufficiently large to be easily read at arm's length.

(20) Controls should be clearly labeled and kept to a minimum, and operating procedures should be relatively simple.

(21) Typical meters use high-resistance leads that can be particularly susceptible to flexure noise when measuring fields at relatively low intensities. Therefore, when a broadband isotropic meter is used for measuring power density levels that fall into the lower range of detectability of the instrument (e.g., a few $\mu W/cm^2$), the meter should exhibit low noise levels if such measurements are to have any meaning.

(22) When measuring fields in multiple-emitter environments, the ability of many commonly available RF broadband survey meters to accurately measure multiple signals of varying frequencies may be limited by how the meter sums the outputs of its diode detectors. This can lead to over-estimates of the total RF field that may be significant. Although such estimates can represent a "worst case," and are allowable for compliance purposes, users of these meters should be aware of this possible source of error.

A useful characteristic of broadband probes used in multiple-frequency RF environments is a frequency-dependent response that corresponds to the variation in MPE limits with frequency. Broadband probes having such a "shaped" response permit direct assessment of compliance at sites where RF fields result from antennas transmitting over a wide range of frequencies. Such probes can express the composite RF field as a percentage of the applicable MPEs.

Another practical characteristic of some RF field instruments is their ability to automatically determine spatial averages of RF fields. Because the MPEs for exposure are given in terms of spatial averages, it is helpful to simplify the measurement of spatially variable fields via data averaging as the survey is being performed. Spatial averaging can be achieved via the use of "data loggers" attached to survey meters or circuitry built into the meter.

Narrowband devices may also be used to characterize RF fields for exposure assessment. In contrast to broadband devices, narrowband instruments may have bandwidths of only a few hundred kilohertz or less. Narrowband instruments, such as field-strength meters and spectrum analyzers, must be tuned from frequency to frequency, and the field level at each frequency measured. Spectrum analyzers can be scanned over a band of frequencies, and the frequency and peak-amplitude information can be stored and printed for later analysis. The results of all narrowband measurements may then be combined to determine the total field.

As with broadband instruments, narrowband devices consist of basically four components: an antenna, cables to carry the signal from the antenna, electronic circuitry to process the output from the antenna and convert it to a steady-state signal proportional to the parameter being measured, and a readout device. Narrowband instruments may use various antennas, such as rods (monopoles), loops, dipoles, biconical, conical log spiral antennas or aperture antennas such as pyramidal horns or parabolic reflectors. A knowledge of the gain, the antenna factor, or the effective area for a particular antenna provides a means for determining the appropriate field parameter from a measurement of voltage or power. Cable loss also should be taken into account. Tunable field strength meters and spectrum analyzers are appropriate narrowband instruments to use for measuring antenna terminal voltage or power at selected frequencies. Each has certain advantages and disadvantages.

Field Measurements

Before beginning a measurement survey it is important to characterize the exposure situation as much as possible. An attempt should be made to determine:

(1) The frequency and maximum power of the RF source(s) in question, as well as any nearby sources.

(2) Duty factor, if applicable, of the source(s).

(3) Areas that are accessible to either workers or the general public.

(4) The location of any nearby reflecting surfaces or conductive objects that could produce regions of field intensification ("hot spots").

(5) For pulsed sources, such as radar, the pulse width and repetition rate and the antenna scanning rate.

(6) If appropriate, antenna gain and vertical and horizontal radiation patterns.

(7) Type of modulation of the source(s).

(8) Polarization of the antenna(s).

(9) Whether measurements are to be made in the near-field, in close proximity to a leakage source, or under plane-wave conditions. The type of measurement needed can influence the type of survey probe, calibration conditions and techniques used.

If possible, one should estimate the maximum expected field levels, in order to facilitate the selection of an appropriate survey instrument. For safety purposes, the electric field (or the far-field equivalent power density derived from the E-field) should be measured first because the body absorbs more energy from the electric field, and it is potentially more hazardous. In many cases it may be best to begin by using a broadband instrument capable of accurately measuring the total field from all sources in all directions. If the total field does not exceed the relevant exposure guideline in accessible areas, and if the measurement technique employed is sufficiently accurate, such a determination would constitute a showing of compliance with that particular guideline, and further measurements would be unnecessary.

When using a broadband survey instrument, spatially-averaged exposure levels may be determined by slowly moving the probe while scanning over an area approximately equivalent to the vertical cross-section (projected area) of the human body. An average can be estimated by observing the meter reading during this scanning process or be read directly on those meters that provide spatial averaging. Spatially averaging exposure is discussed in more detail in the ANSI/IEEE and NCRP documents referenced above. A maximum field reading may also be desirable, and, if the instrument has a "peak hold" feature, can be obtained by observing the peak reading according to the instrument instructions. Otherwise, the maximum reading can be determined by simply recording the peak during the scanning process.

The term "hot spots" has been used to describe locations where peak readings occur. Often such readings are found near conductive objects, and the question arises as to whether it is valid to consider such measurements for compliance purposes. According to the ANSI C95.3 guidelines (Reference [2]) measurements of field strength to determine compliance are to be made, "at distances 20 cm or greater from any object." Therefore, as long as the 20 cm criterion is satisfied, such peak readings should be considered as indicative of the field ***at that point.*** However, as far as ***average*** exposure is concerned such localized readings may not be relevant if accessibility to the location is restricted or time spent at the location is limited (see Section 4 of this bulletin on controlling exposure). It should be noted that most broadband survey instruments already have a 5 cm separation built into the probe.

In many situations there may be several RF sources. For example, a broadcast antenna farm or multiple-use tower could have several types of RF sources including AM, FM, and TV, as well as CMRS and microwave antennas. Also, at rooftop sites many different types of CMRS antennas are commonly present. In such situations it is generally useful to use both broadband and narrowband instrumentation to fully characterize the electromagnetic environment. Broadband instrumentation could be used to determine what the overall field levels appeared to be, while narrowband instrumentation would be required to determine the relative contributions of each signal to the total field if the broadband measurements exceed the most restrictive portion of the applicable MPEs. The "shaped" probes mentioned earlier will also provide quantification of the total field in terms of percentage of the MPE limits.

In cases where personnel may have close access to intermittently active antennas, for example at rooftop locations, measurement surveys should attempt to minimize the uncertainty associated with the duty cycle of the various communications transmitters at the site to arrive at a conservative estimate of maximum possible exposure levels.

At broadcast sites it is important to determine whether stations have auxiliary, or stand-by, antennas at a site in addition to their main antennas. In such cases, either the main antenna or the auxiliary antenna, which may be mounted lower to the ground, may result in the highest RF field levels in accessible areas, and contributions from both must be properly evaluated.

At frequencies above about 300 MHz it is usually sufficient to measure only the electric field (E) or the mean-squared electric field. For frequencies equal to or less than 30

MHz, for example frequencies in the AM broadcast band, measurements for determining compliance with MPE limits require independent measurement of ***both*** E field and the magnetic field (H). For frequencies between 30 and 300 MHz it may be possible through analysis to show that measurement of only one of the two fields, not both, is sufficient for determining compliance. Further discussion of this topic can be found in Sections 4.3(2) and 6.6 of Reference [1]. At sites with higher frequency sources, such as UHF-TV stations, only E-field measurements should be attempted since the loop antennas used in H-field probes are subject to out-of-band resonances at these frequencies.

In many situations a relatively large sampling of data will be necessary to spatially resolve areas of field intensification that may be caused by reflection and multipath interference. Areas that are normally occupied by personnel or are accessible to the public should be examined in detail to determine exposure potential.

If narrowband instrumentation and a linear antenna are used, field intensities at three mutually orthogonal orientations of the antenna must be obtained at each measurement point. The values of E^2 or H^2 will then be equal to the sum of the squares of the corresponding, orthogonal field components.

If an aperture antenna is used, unless the test antenna responds uniformly to all polarizations in a plane, e.g., a conical log-spiral antenna, it should be rotated in both azimuth and elevation until a maximum is obtained. The antenna should then be rotated about its longitudinal axis and the measurement repeated so that both horizontally and vertically polarized field components are measured. It should be noted that when using aperture antennas in reflective or near-field environments, significant negative errors may be obtained.

When making measurements, procedures should be followed which minimize possible sources of error. For example, when the polarization of a field is known, all cables associated with the survey instrument should be held perpendicular to the electric field in order to minimize pickup. Ideally, non-conductive cable, e.g., optical fiber, should be used, since substantial error can be introduced by cable pick-up.

Interaction of the entire instrument (probe plus readout device) with the field can be a significant problem below approximately 10 MHz, and it may be desirable to use a self-contained meter or a fiber-optically coupled probe for measuring electric field at these frequencies. Also, at frequencies below about 1 MHz, the body of the person making the measurement may become part of the antenna, and error from probe/cable pickup and instrument/body interaction may be reduced by supporting the probe and electronics on a dielectric structure made of wood, styrofoam, etc. In all cases, it is desirable to remove all unnecessary personnel from an area where a survey is being conducted in order to minimize errors due to reflection and field perturbation.

In areas with relatively high fields, it is a good idea to occasionally hold the probe fixed and rotate the readout device and move the connecting cable while observing the meter reading. Alternatively, cover the entire sensor of the probe with metal foil and observe the meter reading. Any significant change usually indicates pickup in the leads and interference problems. When a field strength meter or spectrum analyzer is used in the above environments, the antenna cable should occasionally be removed and replaced with an impedance matched termination. Any reading on the device indicates pickup or interference.

As noted previously, substantial errors may be introduced due to zero drift. If a device is being used which requires zeroing, it should frequently be checked for drift. This should be done with the probe shielded with metal foil, with the probe removed from the field or, ideally, with the source(s) shut off.

With regard to compliance with the FCC's guidelines in mixed or broadband fields where several sources and frequencies are involved, the fraction or percentage of the recommended limit for power density (or square of the field strength) incurred within each frequency interval should be determined, and the sum of all contributions should not exceed 1.0 or 100% (see discussion of this topic in Section 1 of this bulletin). As mentioned before, probes with "shaped" responses may be useful in these environments.

Section 4: CONTROLLING EXPOSURE TO RF FIELDS

Public Exposure: Compliance with General Population/Uncontrolled MPE Limits

Studies have indicated that the majority of the United States population is normally exposed to insignificant levels of RF radiation in the ambient environment (e.g. see References [22] and [30]). However, there are some situations in which RF levels may be considerably higher than the median background, and in those cases preventive measures may have to be taken to control exposure levels.

As discussed in Section 1 of this bulletin (also see Appendix A), the FCC's guidelines for exposure incorporate two tiers of limits, one for conditions under which the public may be exposed ("general population/uncontrolled" exposure) and the other for exposure situations usually involving workers ("occupational/controlled" exposure). Exposure problems involving members of the general public are generally less common than those involving persons who may be exposed at their place of employment, due to the fact that workers may be more likely to be in close proximity to an RF source as part of their job. However, if potential exposure of the general public is a problem there are several options available for ensuring compliance with the FCC RF guidelines.

In general, in order for a transmitting facility or operation to be out of compliance with the FCC's RF guidelines an area or areas where levels exceed the MPE limits must, first of all, be in some way ***accessible*** to the public or to workers. This should be obvious, but there is often confusion over an ***emission*** limit, e.g., a limit on field strength or power density at a specified distance from a radiator that always applies, and an ***exposure*** limit, that applies anywhere people may be located. The FCC guidelines specify exposure limits not emission limits, and that distinction must be emphasized. This is why the accessibility issue is key to determining compliance. The MPE limits indicate levels above which people may not be safely exposed regardless of the location where those levels occur. When accessibility to an area where excessive levels is appropriately restricted, the facility or operation can certify that it complies with the FCC requirements.

Restricting access is usually the simplest means of controlling exposure to areas where high RF levels may be present. Methods of doing this include fencing and posting such areas or locking out unauthorized persons in areas, such as rooftop locations, where this is practical.[32] There may be situations where RF levels may exceed the MPE limits for the general public in remote areas, such as mountain tops, that could conceivably be accessible but are not likely to be visited by the public. In such cases, common sense should dictate how compliance is to be achieved. If the area of concern is properly marked by appropriate warning signs, fencing or the erection of other permanent barriers may not be necessary.[33]

In some cases, the time-averaging aspects of the exposure limits may be used by placing appropriate restrictions on occupancy in high-field areas. However, such restrictions are often not possible where continuous exposure of the public may occur. In general, time averaging of exposures is usually more practical in controlled situations where occupational exposure is the only issue.

Although restricting access may be the simplest and most cost-effective solution for reducing public exposure, other methods are also available. Such methods may be relevant for reducing exposure for both the general public and for workers. For example, modifications to antennas, elevating antennas on roof-top installations or incorporation of appropriate shielding can reduce RF fields in locations accessible to the public or to workers.

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[32] Standard radiofrequency hazard warning signs are commercially available from several vendors. They incorporate the format recommended by the American National Standards Institute (ANSI) as specified in ANSI C95.2-1982 (Reference [3]). Although the ANSI format is recommended, it is not mandatory. Complaints have been received concerning the lack of color durability in outdoor environments of the yellow triangle specified by ANSI. In that regard, long-lasting and clearly visible symbols are more important than the exact color used, and the use of the ANSI format with more durable colors may be more practical in certain environments. When signs are used, meaningful information should be placed on the sign advising of the potential for high RF fields. In some cases, it may be appropriate to also provide instructions to direct individuals as to how to work safely in the RF environment of concern. U.S. vendors of RF warning and hazard signs include: National Association of Broadcasters (800-368-5644), EMED Co., Inc. (800-442-3633) and Richard Tell Associates (702-645-3338).

[33] Regarding this issue, the Commission's Mass Media Bureau released a Public Notice, on January 28, 1986, entitled, "Further Guidance for Broadcasters Regarding Radiofrequency Radiation and the Environment," (No. 2278). This Notice lists several typical exposure situations around broadcast sites and explains what is expected of broadcast licensees and applicants with respect to ensuring compliance with the FCC's RF guidelines. This Notice may be useful as guidance for other antenna sites. A summary of the major points of the 1986 Public Notice are included as Appendix B of this bulletin. Also, another Public Notice, dealing primarily with occupational exposure, was issued by the Mass Media Bureau on August 19. 1992 (No. 24479).

With regard to antennas used for FM broadcast stations, the EPA found that there are several corrective measures that may be taken to reduce ground-level field strength and power density (Reference [11]). Some of these findings may also be relevant to other similar types of antenna systems. EPA's examination of measured elevation patterns for several different types of FM antennas has shown that some antennas direct much less radiation downward than others. Therefore, in some cases a change of antenna may be an appropriate way to reduce ground-level fields below a given level.

A more expensive, but also effective, approach for FM antennas involves modifying the array pattern by reducing the spacing between the radiating elements. The pattern of an FM antenna is the product of the element pattern and the array pattern. FM antennas typically use one-wavelength spacing between elements. Because the wave from each element adds in phase with all the other elements, at points directly beneath the elements the array pattern results in downward radiation that can be significant and, in the case of dipole elements, could equal that in the main beam. If the spacing is reduced to one-half wavelength spacing (for an antenna with an even number of bays), each wave will have a counterpart which is out-of-phase. This will result in a significant reduction in the energy radiated toward the ground.

The disadvantage of this method is that the shorter aperture that will occur with one-half wavelength spacing reduces the overall gain of the antenna. To maintain the original gain of the antenna, the number of elements (bays) has to be increased and, usually, doubled. Alternatively, the spacing between elements could be reduced so that waves from element (n) and from element (N/2 + n) are exactly out of phase, where n is a particular element in an array with a total of N bays.

Use of the latter method would result in a smaller increase in the total number of bays that would be necessary. However, EPA has noted that feeding such an array would be more difficult since the length of the transmission line between bays determines phasing. For one-half wave spacing, EPA suggests that criss-crossing the transmission line or turning alternate elements upside down will yield proper phasing.

The EPA's report (Reference [11]) contains a table showing suggested interbay spacings required to reduce downward radiation in the array pattern of FM antennas. Unfortunately, the optimum spacing may differ for different types of antennas. Coupling effects may occur at spacings of less than one wavelength that are not easy to predict theoretically. EPA has studied this problem, and Reference [11] also contains figures showing the effects of altering spacing for three types of FM antenna elements.

Another possible method for reducing downward radiation that has been suggested involves using 1.5-wavelength spacing between elements. This method reportedly results in little significant change in antenna gain.

Other actions that could be taken to reduce the potential for excessive exposure would be raising the height of an FM or TV antenna or relocating a broadcast tower. However, such actions would have to take into account other factors including signal coverage, land use limitations, and air traffic safety.

In the case of television broadcast antennas, the EPA identified two methods for reducing potential exposure, besides the obvious method of restricting access discussed above. The first measure that might be taken, as with FM antennas, would be a change of antenna. EPA verified, for example, that arrays for VHF-TV antennas can be designed to minimize downward radiation to as little as 7% of the main beam field. However, such antennas apparently are at least twice as expensive as standard antennas. Antennas used for UHF-TV have very high gain in the main beam and radiate relatively little directly down toward the ground. Therefore, these antennas already are designed for minimum downward radiation. The remaining option for both VHF-TV and UHF-TV antennas would be an increase in antenna height above ground. However, this could involve the same difficulties as discussed above with regard to FM broadcast facilities.

With respect to AM radio broadcast stations, monopole antennas are used for transmissions. The MPE limits in the AM broadcast band (see Appendix A) are given in terms of electric and magnetic field strength, since significant exposures always occur in the near-field of these antenna systems. Electric and magnetic field strengths near monopole antennas decrease rapidly with increasing distance, and normally the MPE limits can only be exceeded very close-in to these antennas. Therefore, exposure problems due to AM radio antennas are usually those involving workers or others who have access to the immediate vicinity of these antennas (see discussion below).

Occupational Exposure: Compliance with Occupational/Controlled MPE Limits

Exposure to RF fields in the workplace or in other controlled environments usually presents different problems than does exposure of the general public. For example, with respect to a given RF transmitting facility, a worker at that facility would be more likely to be close to the radiating source than would a person who happens to live nearby. Although restricting access to high RF field areas is also a way to control exposures in such situations, this may not always be possible. In some cases a person's job may require him or her to be near an RF source for some part of the workday. Depending on the level and time of exposure this may present a problem with respect to compliance with the MPE limits.

In general, a locked rooftop or other appropriately restricted area that is only accessible to workers who are "aware of" and "exercise control over" their exposure would meet the criteria for occupational/controlled exposure, and protection would be required at the applicable occupational/controlled MPE limits for those individuals who have access to the rooftop. Persons who are only "transient" visitors to the rooftop, such as air conditioning technicians, etc., could also be considered to fall within the occupational/controlled criteria as long as they also are "made aware" of their exposure and exercise control over their exposure (see Appendix A for definitions of exposure tiers and MPE limits).

As explained in Section 1 of this bulletin, the MPE limits adopted by the FCC are ***time-averaged*** exposure limits. This means that the exposure duration should be taken into account when evaluating a given exposure situation, and this is especially relevant for cases of occupational/controlled exposure. For example, a person walking into an area where RF fields exceed the ***absolute*** MPE limit (in terms of field strength or power density) might not exceed the ***time-averaged*** MPE limit as long as the exposure was for an appropriately short period of time (relative to the time-averaging interval). However, if that person were to remain in the area for an extended period it is more probable that the time-averaged limit would be exceeded. Therefore, in order to comply with the FCC's guidelines, in some situations it may be necessary to limit exposure in certain areas to specific periods of time. For example, in workplace situations where extended maintenance tasks must be performed in areas where RF fields exceed MPE limits, the work may have to be divided up and carried out during several intervals of time so that the time-averaged exposure during each interval is acceptable. The actual exposure time allowed during any given interval would have to be determined by use of the appropriate averaging time specified in the guidelines (six-minutes for occupational exposure) as explained in Section 1.

In addition to time-averaging, other means are available for controlling exposures in occupational or controlled environments. These include reducing or shutting off power when work is required in a high RF area, switching to an auxiliary transmitter (if available) while work on a main system is in progress or incorporating appropriate shielding techniques to reduce exposure.

In multiple-transmitter environments, reducing power or RF shielding may be especially important for allowing necessary work procedures to be carried out. For example, on-tower exposures due to nearby co-located transmitting sources may be more significant when work on another station's tower is required. In such complex environments power reduction agreements may often be necessary to ensure that all licensees are aware of the potential for their station to expose other individuals at the site and site occupants are generally jointly responsible for compliance with FCC guidelines (see discussion of multiple-transmitter sites in Section 2 of this bulletin).

Although reduction of power at broadcasting and other telecommunications sites is one approach to reducing personnel exposure, this may not always be possible. For example, measurements have shown that relatively high RF fields may exist in the immediate vicinity of high-powered antennas such as those used at FM broadcast stations (Reference [25]). If power reduction or other measures are not practical, alternative means for protecting personnel from excessive exposure may be necessary when access to these areas is required. In such instances, the use of radiofrequency protective clothing may facilitate compliance with RF exposure guidelines even in the presence of intense RF fields.

Radiofrequency protective clothing has become commercially available in recent years that appears to effectively attenuate fields over a broad frequency band. This clothing has been manufactured into RF protective suits that cover the entire body of the user and allow him or her to perform maintenance and other procedures in the presence of RF fields that may exceed MPE limits. A recent study performed for the FCC by Richard Tell Associates, Inc., concluded that if properly used by appropriately trained personnel, and with adequate coupling to ground potential, RF protective suits can provide significant reduction in whole-body RF absorption (Reference [29]).

Recently, direct measurements of reduction in SAR afforded by one RF protective suit were completed using a full-size human phantom filled with a dielectric fluid having the RF absorption characteristics of biological tissue.[34] The SAR was determined by scanning the interior of the body of the phantom with a robotically controlled miniature, isotropic electric-field probe with and without the suit covering the phantom. Near-field exposure conditions were duplicated at frequencies of 150 MHz, 450 MHz and 835 MHz. The measurement results supported the contention that the protective suit provides a nominal minimum reduction in SAR of 10 times or more. These measurements also were consistent with measurement data obtained by the Deutsche Telekom Technologiezentrum (German Telekom).[35]

Another observation from the tests performed by Tell is that the peak SAR in the unprotected head of the phantom clothed with the protective suit did not reach the SAR limit of 8 W/kg (localized partial-body exposure limit for occupational/controlled environments) until the 150-MHz near-field exposure was 23 times the most restrictive whole-body averaged MPE limit of 1.0 mW/cm^2. At 450 MHz, the maximum field incident on the unprotected head was found to be more than 11 times the applicable MPE limit of 1.5 mW/cm^2, and, at 835 MHz, more than 3 times the MPE limit of 2.8 mW/cm^2. Such data suggest that, at least in some environments, complete coverage of the body may not be necessary for compliance with MPE limits.

In general, the use of RF protective clothing may be considered an acceptable mitigation technique for occupational exposures as long as sufficient precautions are taken to comply with all of the clothing manufacturer's recommendations and caveats and to ensure that use of the clothing is confined to RF environments for which it is designed in terms of RF field intensity and frequency range. As with any personal protective equipment, RF protective clothing should be considered as a method of choice only when other engineering or administrative controls cannot be used to reduce exposure or are otherwise impractical. Those employing or supervising the wearer should ensure that the wearer has full knowledge of the proper use and limitations of the protective clothing being used. Also, users should be knowledgeable of the approximate RF environment before spending a prolonged period of time in areas where RF fields are believed to significantly exceed MPE limits. Users of RF protective clothing are cautioned that, in addition to evaluating RF field intensity and frequency considerations, they should routinely visually inspect the clothing material for

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[34] Tell, Richard A. (1996). *SAR Evaluation of the Naptex™ Suit for Use in the VHF and UHF Telecommunications Bands.* Presented at the International RF Safety Workshop, Schwangau, Germany, September 25-26.

[35] Heinrich, W. (1996). *Test Method for Determining the Attentuation of RF-protective Clothing.* Presented at the International RF Safety Workshop, Schwangau, Germany, September 24-26.

indications of substantial wear, such as tears and rips, that may reduce the clothing's effectiveness in reducing exposure. When users are climbing towers, special caution is advised regarding possible safety hazards from RF shocks and burns, trip hazards, decreased mobility/agility and reduced visibility (if a protective hood is worn) that may occur while climbing.

In addition to the issue of protective clothing, Tell's 1995 study for the FCC investigated the use of RF personal monitors that have become commercially available in recent years. These monitors are warning devices that are worn by the user and alert him or her by an audible or visible signal to the presence of RF fields that approach the MPE limits for occupational/controlled exposure. The Tell study concluded that such devices can act as reliable RF detectors and the device tested generally responded in accordance with the manufacturer's specifications. Such devices could be especially useful in areas where multiple transmitters are located and it may not be easy or possible to predict the presence of high RF fields. Work procedures could be instituted requiring the wearer of such a device to leave an area or take other precautions when the device alerts that an RF field approaching the MPE limit is present. These monitors can be a valuable component of an RF safety program. However, they should be viewed only as warning devices and should not be viewed as protective devices.

For workers who must occupy areas near AM broadcast antennas, MPE limits are normally only exceeded very close to an antenna. Even for a 50 kW transmitter, distances from an antenna of less than fifteen meters are required before field strengths are likely to approach the FCC limits (References [26] and [33]). For multiple-tower arrays the spacing between adjacent antennas would not be less than 35 meters, so that, as one antenna is approached, the contribution of field strength from other antennas in the array would decrease to relatively insignificant levels. However, if work on or immediately adjacent to a tower is required it may be necessary to designate zones within which a worker may remain for specified periods of time appropriate for compliance with the FCC limits.

Tuning circuits for AM broadcast antennas have been identified as a source of locally intense magnetic fields (Reference [31]). These magnetic fields decrease rapidly with distance from the tuning circuits but should be carefully considered when evaluating exposure very near the base of AM towers or at other locations where such coils may be located. It should be possible to locate the tuning circuits in such a way as to greatly reduce the potential for exposures exceeding the FCC magnetic field limits. For example, separating the circuits from normally accessible areas by a few meters should provide sufficient protection. Time-averaging exposure near such coils is another method for complying with the MPE limits.

Probably the most common means by which workers at AM radio stations may be exposed in excess of the FCC exposure guidelines occurs when persons must climb actively transmitting AM antennas to perform maintenance tasks. Measurement surveys and studies conducted by the FCC and the EPA have clearly indicated that significant RF currents exist in the body of a person climbing such a tower (References [6], [27], [28] and [32]). As addressed by the 1992 ANSI/IEEE standard, such currents can cause significant levels of RF absorption in the body that can be well in excess of allowable SAR thresholds (see discussion in Section 1 of this bulletin).

Although the FCC RF exposure guidelines did not specifically adopt limits on RF body currents, evaluation of such currents is the only practical means to control exposure of persons climbing transmitting AM radio towers. The FCC and EPA studies referenced above include data and models that allow a correlation to be made between the power fed into an AM antenna and the potential current that will be induced in the body of a person climbing the antenna. This current can be correlated with the appropriate limit on whole-body absorption specified by the FCC's guidelines and thereby can be used as a guideline for the appropriate power reduction that an AM station must undertake when a person is on a tower. Further information and guidance on controlling such exposures can be found in Supplement A to this bulletin that is designed for radio and television broadcast applications.

With regard to maintenance of FM and TV broadcast transmitters and antennas, two situations are of particular interest and should be noted. Because currents and voltages in power amplifier cabinets can be lethal, it is common practice that cabinet doors be closed when the transmitter is on. However, it may not be recognized that at multiple station locations high RF field strengths can be encountered even when the transmitter being worked on is completely shut down. This is because the antenna for a particular station is likely to pick up high levels of energy from other stations. That energy can be conducted to the final amplifier cubicle and produce high field strengths and high voltages in the vicinity of the cubicle. Therefore, if measurements are made in a multistation environment this factor should be evaluated. If such induced field strength levels are found to be a problem, it should be possible to reduce them to acceptable levels by either opening the RF transmission line leading to the antenna or by bypassing the center conductor to ground of the coaxial line wherever access can be conveniently achieved.

With regard to protecting personnel at paging and cellular antenna sites, Motorola, in association with Richard Tell Associates, Inc., has developed a video for electromagnetic energy awareness that is focused on wireless telecommunications service providers. Although this video was originally produced for Motorola's use and is copyrighted, Motorola has decided to make this video commercially available to other interested industrial users.[36] Also, as mentioned earlier, software has been developed by various organizations for use in estimating RF levels and ensuring compliance at transmitter sites, particularly rooftop sites used for personal wireless, cellular and paging services.[37]

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[36] The title of the video is: "EME Awareness for Antenna Site Safety," ©Motorola, 1996. Copies are available in the U.S.A. from Stephen Tell Productions (702-396-5912), or from Narda Microwave Corporation, (516) 231-1700 (Narda Part No. 42929000).

[37] *See* footnote 23.

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APPENDIX A
SUMMARY OF RF EXPOSURE GUIDELINES

This appendix summarizes the policies, guidelines and requirements that were adopted by the FCC on August 1, 1996, amending Part 1 of Title 47 of the Code of Federal Regulations, and further amended by action of the Commission on August 25, 1997 (see 47 CFR Sections 1.1307(b), 1.1310, 2.1091 and 2.1093, as amended). Commission actions granting construction permits, licenses to transmit or renewals thereof, equipment authorizations or modifications in existing facilities, require the preparation of an Environmental Assessment (EA), as described in 47 CFR Section 1.1311, if the particular facility, operation or transmitter would cause human exposure to levels of radiofrequency (RF) electromagnetic fields in excess of these limits. For exact language, see the relevant FCC rule sections.

FCC implementation of the new guidelines for mobile and portable devices became effective August 7, 1996. For other applicants and licensees a transition period was established before the new guidelines would apply. With the exception of the Amateur Radio Service, the date established for the end of the transition period is October 15, 1997. Therefore, the new guidelines will apply to applications filed on or after this date. For the Amateur Service only, the new guidelines will apply to applications filed on or after January 1, 1998.

Summary of Station and Transmitter Requirements

Applications to the Commission for construction permits, licenses to transmit or renewals thereof, equipment authorizations or modifications in existing facilities must contain a statement or certification confirming compliance with the limits unless the facility, operation, or transmitter is categorically excluded from routine evaluation, as discussed below. Technical information showing the basis for this statement must be submitted to the Commission upon request.

The FCC-adopted limits for Maximum Permissible Exposure (MPE) are generally based on recommended exposure guidelines published by the National Council on Radiation Protection and Measurements (NCRP) in "Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields," NCRP Report No. 86, Sections 17.4.1, 17.4.1.1, 17.4.2 and 17.4.3. Copyright NCRP, 1986, Bethesda, Maryland 20814. In the frequency range from 100 MHz to 1500 MHz, exposure limits for field strength and power density are also generally based on the MPE limits found in Section 4.1 of , "IEEE Standard for Safety

Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz," ANSI/IEEE C95.1-1992, Copyright 1992 by the Institute of Electrical and Electronics Engineers, Inc., New York, New York 10017, and approved for use as an American National Standard by the American National Standards Institute (ANSI).

The FCC's MPE limits for field strength and power density are given in Table 1 (and in 47 CFR § 1.1310) Figure 1 is a graphical representation of the limits for plane-wave (far-field) equivalent power density versus frequency. The FCC's limits are generally applicable to ***all*** facilities, operations and transmitters regulated by the Commission, and compliance is expected with the appropriate guidelines. However, ***routine*** determination of compliance with these exposure limits (routine environmental evaluation), and preparation of an EA if the limits are exceeded, is required only for facilities, operations and transmitters that fall into the categories listed in Table 2, or those specified below under the headings "mobile," "unlicensed" or "portable" devices. All other facilities, operations and transmitters are categorically excluded from routine evaluation or preparing an EA for RF emissions, except that the Commission may, on its own merits or as the result of a petition, complaint or inquiry, require RF environmental evaluation of transmitters or facilities even though they are otherwise excluded [see 47 CFR Sections 1.1307(c) and (d)].

For purposes of Table 2, the term "building-mounted antennas" means antennas mounted in or on a building structure that is occupied as a workplace or residence. The term "power" in column 2 of Table 2 refers to total operating power of the transmitting operation in question in terms of effective radiated power (ERP), equivalent isotropically radiated power (EIRP), or peak envelope power (PEP), as defined in 47 CFR. § 2.1. For the case of the Cellular Radiotelephone Service, 47 CFR § 22, Subpart H, the Personal Communications Service, 47 CFR § 24, and Specialized Mobile Radio Service, 47 CFR § 90, the phrase "total power of all channels" in column 2 of Table 2 means the sum of the ERP or EIRP of all co-located simultaneously operating transmitters owned and operated by a single licensee.

When applying the criteria of Table 2, radiation in all directions should be considered. For the case of transmitting facilities using sectorized transmitting antennas, applicants and licensees should apply the criteria to all transmitting channels in a given sector, noting that for a highly directional antenna there is relatively little contribution to ERP or EIRP summation for other directions.

For purposes of calculating EIRP of an MDS station, the power level refers to the cumulative EIRP of all channels. Further, this power limit assumes conventional NTSC transmissions with 10% aural power, and refers to peak visual power. MDS stations employing other than NTSC transmissions, e.g., digital transmissions, must apply the appropriate NTSC peak visual to average power conversion factor for their modulation scheme in order to determine whether the EIRP power criteria is exceeded.

In general, as specified in 47 C.F.R. 1.1307(b), as amended, when the FCC's guidelines are exceeded ***in an accessible area*** due to the emissions from multiple fixed transmitters the following policy applies. Actions necessary to bring the area into compliance with the guidelines are the shared responsibility of ***all*** licensees whose transmitter's contribution to the RF environment ***at the non-complying area*** exceeds 5% of the exposure limit (that applies to their particular transmitter) in terms of power density or the square of the electric or magnetic field strength. This applies regardless of whether such transmitters would, by themselves, normally be excluded from performing a routine environmental evaluation. Owners of transmitter sites are expected to allow applicants and licensees to take reasonable steps to comply with the FCC's requirements and, where feasible, should encourage co-location of transmitters and common solutions for controlling access to areas where the RF exposure limits might be exceeded.

The following policy applies in the case of an application for a proposed transmitter, facility or modification (not otherwise excluded from performing a routine RF evaluation) that would ***cause non-compliance*** at an accessible area previously in compliance. In such a case, it is the responsibility of the applicant to submit an EA if emissions from the applicant's transmitter or facility would cause non-compliance at the area in question. However, this applies only if the applicant's transmitter causes exposure levels at the area in question that exceed 5% of the exposure limits applicable to that particular transmitter in terms of power density or the square of the electric or magnetic field strength.

For a renewal applicant whose transmitter or facility (not otherwise excluded from routine evaluation) contributes to the RF environment at an accessible area ***not in compliance*** with the guidelines the following policy applies. The renewal applicant must submit an EA if emissions from the applicant's transmitter or facility, at the area in question, result in exposure levels that exceed 5% of the exposure limits applicable to that particular transmitter in terms of power density or the square of the electric or magnetic field strength. In other words, although the renewal applicant may only be responsible for a fraction of the total exposure (greater than 5%), the applicant (along with any other licensee undergoing renewal at the same time) will trigger the EA process, unless suitable corrective measures are taken to prevent non-compliance before an EA is necessary. In addition, in a renewal situation if a determination of non-compliance is made, other co-located transmitters contributing more than the 5% threshold level must share responsibility for compliance, regardless of whether they are categorically excluded from routine evaluation or submission of an EA.

<u>Table 1</u>. LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

(A) Limits for Occupational/Controlled Exposure

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)
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

(B) Limits for General Population/Uncontrolled Exposure

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)
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
300-1500	--	--	f/1500	30
1500-100,000	--	--	1.0	30

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

NOTE 1: ***Occupational/controlled*** limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where occupational/controlled limits apply provided he or she is made aware of the potential for exposure.

NOTE 2: ***General population/uncontrolled*** exposures apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or can not exercise control over their exposure.

Figure 1. FCC Limits for Maximum Permissible Exposure (MPE)

Plane-wave Equivalent Power Density

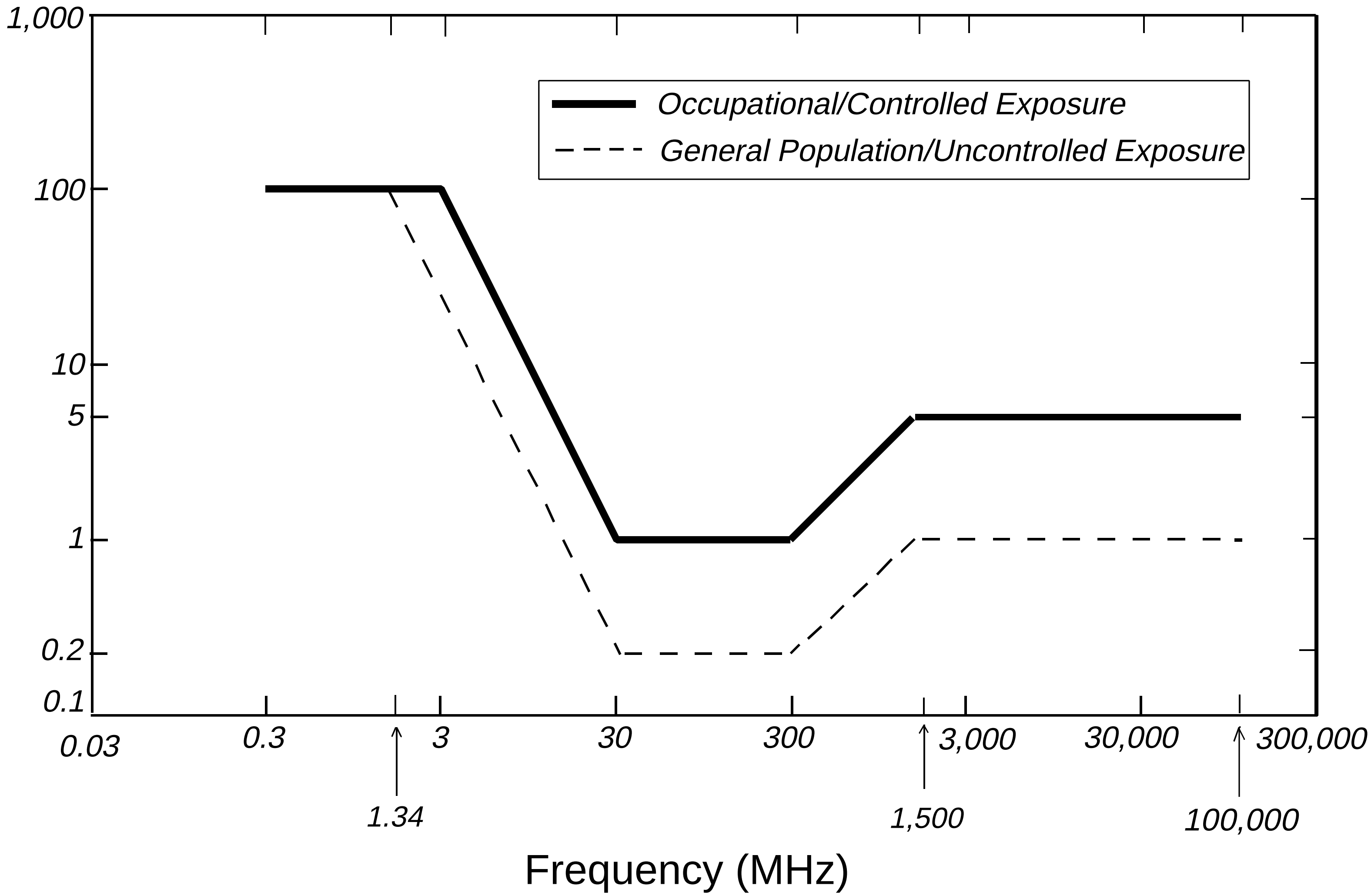

TABLE 2: TRANSMITTERS, FACILITIES AND OPERATIONS SUBJECT TO ROUTINE ENVIRONMENTAL EVALUATION

SERVICE (TITLE 47 CFR RULE PART)	EVALUATION REQUIRED IF:
Experimental Radio Services (part 5)	power > 100 W ERP (164 W EIRP)
Multipoint Distribution Service (subpart K of part 21)	non-building-mounted antennas: height above ground level to lowest point of antenna < 10 m and power > 1640 W EIRP building-mounted antennas: power > 1640 W EIRP
Paging and Radiotelephone Service (subpart E of part 22)	non-building-mounted antennas: height above ground level to lowest point of antenna < 10 m and power > 1000 W ERP (1640 W EIRP) building-mounted antennas: power > 1000 W ERP (1640 W EIRP)
Cellular Radiotelephone Service (subpart H of part 22)	non-building-mounted antennas: height above ground level to lowest point of antenna < 10 m and total power of all channels > 1000 W ERP (1640 W EIRP) building-mounted antennas: total power of all channels > 1000 W ERP (1640 W EIRP)

TABLE 2 (cont.)

SERVICE (TITLE 47 CFR RULE PART)	EVALUATION REQUIRED IF:
Personal Communications Services (part 24)	(1) Narrowband PCS (subpart D): non-building-mounted antennas: height above ground level to lowest point of antenna < 10 m and total power of all channels > 1000 W ERP (1640 W EIRP) building-mounted antennas: total power of all channels > 1000 W ERP (1640 W EIRP) (2) Broadband PCS (subpart E): non-building-mounted antennas: height above ground level to lowest point of antenna < 10 m and total power of all channels > 2000 W ERP (3280 W EIRP) building-mounted antennas: total power of all channels > 2000 W ERP (3280 W EIRP)
Satellite Communications (part 25)	all included
General Wireless Communications Service (part 26)	total power of all channels > 1640 W EIRP
Wireless Communications Service (part 27)	total power of all channels > 1640 W EIRP
Radio Broadcast Services (part 73)	all included

TABLE 2 (cont.)

SERVICE (TITLE 47 CFR RULE PART)	EVALUATION REQUIRED IF:
Experimental, auxiliary, and special broadcast and other program distributional services (part 74)	subparts A, G, L: power > 100 W ERP subpart I: non-building-mounted antennas: height above ground level to lowest point of antenna < 10 m and power > 1640 W EIRP building-mounted antennas: power > 1640 W EIRP
Stations in the Maritime Services (part 80)	ship earth stations only
Private Land Mobile Radio Services Paging Operations (part 90)	non-building-mounted antennas: height above ground level to lowest point of antenna < 10 m and power > 1000 W ERP (1640 W EIRP) building-mounted antennas: power > 1000 W ERP (1640 W EIRP)
Private Land Mobile Radio Services Specialized Mobile Radio (part 90)	non-building-mounted antennas: height above ground level to lowest point of antenna < 10 m and total power of all channels > 1000 W ERP (1640 W EIRP) building-mounted antennas: total power of all channels > 1000 W ERP (1640 W EIRP)

TABLE 2 (cont.)

SERVICE (TITLE 47 CFR RULE PART)	EVALUATION REQUIRED IF:
Amateur Radio Service (part 97)	transmitter output power > levels specified in § 97.13(c)(1) of this chapter **(see Table 1 in text)**
Local Multipoint Distribution Service (subpart L of part 101)	non-building-mounted antennas: height above ground level to lowest point of antenna < 10 m and power > 1640 W EIRP building-mounted antennas: power > 1640 W EIRP LMDS licensees are required to attach a label to subscriber transceiver antennas that: (1) provides adequate notice regarding potential radiofrequency safety hazards, *e.g.*, information regarding the safe minimum separation distance required between users and transceiver antennas; and (2) references the applicable FCC-adopted limits for radiofrequency exposure specified in § 1.1310 of this chapter.

Mobile and Portable Devices

Mobile and portable transmitting devices that operate in the Cellular Radiotelephone Service, the Personal Communications Services (PCS), the Satellite Communications Services, the Maritime Services (ship earth stations only) and the Specialized Mobile Radio (SMR) Service are subject to routine environmental evaluation for RF exposure prior to equipment authorization or use, as specified in 47 CFR § 2.1091 and § 2.1093. Unlicensed PCS and millimeter wave devices are also subject to routine environmental evaluation for RF exposure prior to equipment authorization or use, as specified in 47 C.F.R. § 15.253(f), § 15.255(g), and § 15.319(i). All other mobile, portable, and unlicensed transmitting devices are categorically excluded from routine environmental evaluation for RF exposure under 47 CFR § 2.1091 and § 2.1093, except (as described previously) as specified in 47 CFR § 1.1307(c) and (d) .

(a) Mobile Devices

This section describes the requirements of Section 2.1091 of the FCC's Rules (47 CFR § 2.1091) that apply to "mobile" devices. For purposes of these requirements mobile devices are defined as transmitters designed to be used in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimeters is normally maintained between the transmitter's radiating structure(s) and the body of the user or nearby persons. In this context, the term "fixed location" means that the device is physically secured at one location and is not able to be easily moved to another location. Transmitting devices designed to be used by consumers or workers that can be easily re-located, such as wireless devices associated with a personal computer, are considered to be mobile devices if they meet the 20 centimeter separation requirement.

Mobile devices that operate in the Cellular Radiotelephone Service, the Personal Communications Services, the Satellite Communications Services, the General Wireless Communications Service, the Wireless Communications Service, the Maritime Services and the Specialized Mobile Radio Service authorized under the following parts and subparts of the FCC's Rules: subpart H of part 22, part 24, part 25, part 26, part 27, part 80 (ship earth station devices only) and part 90 (SMR devices only), are subject to routine environmental evaluation for RF exposure prior to equipment authorization or use if they operate at frequencies of 1.5 GHz or below and their effective radiated power (ERP) is 1.5 watts or more, or if they operate at frequencies above 1.5 GHz and their ERP is 3 watts or more. Unlicensed personal communications service devices, unlicensed millimeter wave devices and unlicensed NII devices authorized under FCC Rule parts 15.253, 15.255 and subparts D and E of part 15 are also subject to routine environmental evaluation for RF exposure prior to equipment authorization or use if their ERP is 3 watts or more or if they meet the definition of a portable device as specified below, requiring evaluation under the provisions of 47 CFR §2.1093. All other mobile and unlicensed transmitting devices are categorically excluded from routine environmental evaluation for RF exposure prior to equipment authorization or use, except as specified in 47 CFR §§ 1.1307(c) and 1.1307(d), as discussed previously.

The limits to be used for evaluation of mobile and unlicensed devices (except portable unlicensed devices) are the MPE field strength and power density limits specified in Table 1 above (and in 47 CFR §1.1310). Applications for equipment authorization must contain a statement confirming compliance with these exposure limits as part of their application. Technical information showing the basis for this statement must be submitted to the Commission upon request.

All unlicensed personal communications service (PCS) devices shall be subject to the limits for general population/uncontrolled exposure. For purposes of analyzing mobile transmitting devices under the occupational/controlled criteria specified in Table 1, time-averaging provisions of the guidelines may be used in conjunction with typical maximum duty factors to determine maximum likely exposure levels. Time-averaging provisions may not be used in determining typical exposure levels for devices intended for use by consumers in general population/uncontrolled environments. However, "source-based" time-averaging based on an inherent property or duty-cycle of a device is allowed. An example of this is the determination of exposure from a device that uses digital technology such as a time-division multiple-access (TDMA) scheme for transmission of a signal. In general, maximum average rms power levels should be used to determine compliance.

If appropriate, compliance with exposure guidelines for mobile and unlicensed devices can be accomplished by the use of warning labels and by providing users with information concerning minimum separation distances from transmitting structures and proper installation of antennas.

In some cases, for example, modular or desktop transmitters, the potential conditions of use of a device may not allow easy classification of that device as either mobile or portable. In such cases, applicants are responsible for determining minimum distances for compliance for the intended use and installation of the device based on evaluation of either specific absorption rate (SAR), field strength or power density, whichever is most appropriate.

(b) Portable Devices

This section describes the requirements of Section 2.1093 of the FCC's Rules (47 CFR §2.1093) that apply to "portable" devices. For purposes of these requirements a portable device is defined as a transmitting device designed to be used so that the radiating structure(s) of the device is/are within 20 centimeters of the body of the user.

Portable devices that operate in the Cellular Radiotelephone Service, the Personal Communications Services, the Satellite Communications Services, the General Wireless Communications Service, the Wireless Communications Service, the Maritime Services and the Specialized Mobile Radio Service, and authorized under the following sections of the FCC's rules: subpart H of part 22, part 24, part 25, part 26, part 27, part 80 (ship earth station devices only), part 90 (SMR devices only), and portable unlicensed personal communication service, unlicensed NII devices and millimeter wave devices authorized under rule parts 47 CFR §§15.253, 15.255 or subparts D and E of part 15, are subject to routine environmental evaluation for RF exposure prior to equipment authorization or use. All other portable transmitting devices are categorically excluded from routine environmental evaluation for RF exposure prior to equipment authorization or use, except as specified in 47 CFR §§ 1.1307(c) and (d), as discussed previously. Applications for equipment authorization of portable transmitting devices subject to routine environmental evaluation must contain a statement or certification confirming compliance with the limits specified below as part of their application. Technical information showing the basis for this statement must be submitted to the Commission upon request.

The limits to be used for evaluation are based generally on criteria published by the Institute of Electrical and Electronics Engineers, Inc., (IEEE) for localized specific absorption rate ("SAR") in Section 4.2 of "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz," ANSI/IEEE C95.1-1992, Copyright 1992 by the Institute of Electrical and Electronics Engineers, Inc., New York, New York 10017. These criteria for SAR evaluation are similar to those recommended by the National Council on Radiation Protection and Measurements (NCRP) in "Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields," NCRP Report No. 86, Section 17.4.5. Copyright NCRP, 1986, Bethesda, Maryland 20814. SAR is a measure of the rate of energy absorption per unit mass due to exposure to an RF transmitting source. SAR values have been related to threshold levels for potentially adverse biological effects. The criteria to be used are specified below and shall apply for portable devices transmitting in the frequency range from 100 kHz to 6 GHz. Portable devices, as defined above, that transmit at frequencies above 6 GHz are to be evaluated in terms of the MPE limits specified in Table 1 above (and in 47 CFR §1.1310). Measurements and calculations to demonstrate compliance with MPE field strength or power density limits for devices operating above 6 GHz should be made at a minimum distance of 5 cm from the radiating source.

(**1) Limits for Occupational/Controlled exposure:** 0.4 W/kg as averaged over the whole-body and spatial peak SAR not exceeding 8 W/kg as averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube). Exceptions are the hands, wrists, feet and ankles where the spatial peak SAR shall not exceed 20 W/kg, as averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube). Occupational/Controlled limits apply when persons are exposed as a consequence of their employment provided these persons are fully aware of and exercise control over their exposure. Awareness of exposure can be accomplished by use of warning labels or by specific training or education through appropriate means, such as an RF safety program in a work environment.

(2) Limits for General Population/Uncontrolled exposure: 0.08 W/kg as averaged over the whole-body and spatial peak SAR not exceeding 1.6 W/kg as averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube). Exceptions are the hands, wrists, feet and ankles where the spatial peak SAR shall not exceed 4 W/kg, as averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube). General Population/Uncontrolled limits apply when the general public may be exposed, or when persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or do not exercise control over their exposure. Warning labels placed on consumer devices such as cellular telephones will not be sufficient reason to allow these devices to be evaluated subject to limits for occupational/controlled exposure.

Compliance with SAR limits can be demonstrated by laboratory measurement techniques or by computational modeling, as appropriate. Methodologies and references for SAR evaluation are described in technical publications including "IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields - RF and Microwave," IEEE C95.3-1991, and further guidance on measurement and computational protocols is being developed by the IEEE and others (see text of this bulletin for further discussion).

For purposes of analyzing a portable transmitting device under the occupational/controlled criteria only, the time-averaging provisions of the MPE guidelines identified in Table 1 above can be used in conjunction with typical maximum duty factors to determine maximum likely exposure levels. However, assurance must be given that use of the device will be limited to occupational or controlled situations, as defined previously.

Time-averaging provisions of the MPE guidelines identified in Table 1 may not be used in determining typical exposure levels for portable devices intended for use by consumers, such as hand-held cellular telephones, that are considered to operate in general population/uncontrolled environments as defined above. However, "source-based" time-averaging based on an inherent property or duty-cycle of a device is allowed. An example of this would be the determination of exposure from a device that uses digital technology such as a time-division multiple-access (TDMA) scheme for transmission of a signal. In general, maximum average rms power levels should be used to determine compliance.

APPENDIX B
Summary of 1986 Mass Media Bureau Public Notice on RF Compliance

On January 28, 1986, the FCC's Mass Media Bureau released a Public Notice providing guidance to broadcast licensees and applicants regarding compliance with the FCC's RF exposure guidelines.[38] The primary sections of that Public Notice are reproduced below (text in brackets has been added or edited). Non-broadcast applicants and licensees may also find this information helpful in evaluating compliance (see discussion in text of Section 4 on controlling exposure).

> "Most broadcasting facilities produce high RF radiation levels at one or more locations near their antennas. That, in itself, does not mean that the facilities significantly affect the quality of the human environment. Each situation must be examined separately to decide whether humans are or could be exposed to high RF radiation. . . . . . [A]ccessibility is a key factor in making such a determination. As a general principle, if areas of high RF radiation levels are publicly marked and if access to such areas is impeded or highly improbable (remoteness and natural barriers may be pertinent) then it may be presumed that the facilities producing the RF radiation do <u>not</u> significantly affect the quality of the human environment and do not require the filing of an [E]nvironmental [A]ssessment. Because we wish to avoid burdening applicants with unnecessary work, expenses and administrative filings, we offer the following guidance as to how we will view typical situations. The term "high RF level" means an intensity of RF radiation, whether from single or multiple sources, which exceeds the [FCC] guidelines.

<u>Situations</u>

(A) High RF levels are produced at one or more locations above ground level on an applicant's tower.

- If the tower is marked by appropriate warning signs, the applicant may assume that there is no significant effect on the human environment with regard to exposure of the general public.

(B) High RF levels are produced at ground level in a remote area not likely to be visited by the public.

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[38] *Further Guidance for Broadcasters Regarding Radiofrequency Radiation and the Environment,* January 28, 1986, FCC Public Notice No. 2278.

- If the area of concern is marked by appropriate warning signs, an applicant may assume that there is no significant effect on the human environment with regard to exposure of the general public. It is recommended that fences also be used where feasible.

(C) High RF levels are produced at ground level in an area which could reasonably be expected to be used by the public (including trespassers).

- If the area of concern is fenced <u>and</u> marked by appropriate warning signs, an applicant can assume that there is no significant effect on the human environment with regard to exposure of the general public.

(D) High RF levels are produced at ground level in an area which is used or is likely to be used by people and to which the applicant cannot or does not restrict access.

- The applicant must submit an [E]nvironmental [A]ssessment [*unless corrective action is taken prior to submission of an application*]. This situation may require a modification of the facilities to reduce exposure or could lead to a denial of the application.

(E) High RF levels are produced in occupied structures, on balconies, or on rooftops used for recreational or commercial purposes.

- The applicant must submit an [E]nvironmental [A]ssessment [*unless corrective action is taken prior to submission of an application*]. The circumstances may require a modification of the broadcasting facility to reduce exposure or could lead to a denial of the application.

(F) High RF levels are produced in offices, studios, workshops, parking lots or other areas used regularly by station employees.

- The applicant must submit an [E]nvironmental [A]ssessment [*unless corrective action is taken prior to submission of an application*]. The circumstances may require a modification of the facilities to reduce exposure or the application may be denied. This situation is essentially the same as (E). We have included it to emphasize the point that station employees as well as the general public must be protected from high RF levels [*also, see FCC definitions used to determine application of exposure tiers: general population/uncontrolled vs. occupational/controlled]*. Legal releases signed by employees willing to accept high exposure levels are not acceptable and may not be used in lieu of corrective measures.

(G) High RF levels are produced in areas where intermittent maintenance and repair work must be performed by station employees or others.

> - [FCC] guidelines also apply to workers engaged in maintenance and repair. As long as these workers will be protected from exposure to levels exceeding [FCC] guidelines, no [E]nvironmental [A]ssessment is needed. Unless requested by the Commission, information about the manner in which such activities are protected need not be filed. If protection is not to be provided, the applicant must submit an [E]nvironmental [A]ssessment. The circumstances may require corrective action to reduce exposure or the application may be denied. Legal releases signed by workers willing to accept high exposure levels are not acceptable and may not be used in lieu of corrective measures.

The foregoing also applies to high RF levels created in whole or in part by reradiation.

A convenient rule to apply to all situations involving RF radiation is the following:

(1) Do not create high RF levels where people are or could reasonably be expected to be present, and (2) [p]revent people from entering areas in which high RF levels are necessarily present.

Fencing and warning signs may be sufficient in many cases to protect the general public. Unusual circumstances, the presence of multiple sources of radiation, and operational needs will require more elaborate measures.

Intermittent reductions in power, increased antenna heights, modified antenna radiation patterns, site changes, or some combination of these may be necessary, depending on the particular situation.