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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Guidelines for Evaluating the Environmental Effects of Radiofrequency Radiation	)	ET Docket No. 93-62

COMMENTS

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January 25, 1994

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SUMMARY

AT&T supports the proposal in the NPRM to adopt the 1992 ANSI/IEEE standard for exposure to radio frequency emissions in place of the 1982 standard referred to in the present Commission rule. The 1992 standard represents the broadest consensus of experts in the field and is based on the most recent review of the relevant information. That standard is in the process of adoption by other expert bodies and has already been mandated by the Commission in other proceedings, pending completion of the present docket. Earlier standards developed by other bodies are not superior to the 1992 ANSI standard.

Because the evidence shows that radiation from common carrier microwave stations, cellular base stations and vehicle-mounted cellular terminals does not exceed the new limits, Commission action regarding such equipment should remain categorically excluded from environmental processing. On the other hand, because emissions from some Part 15 devices and hand-held terminals of various kinds may exceed the new limits, categorical exclusion of these types of equipment would not be appropriate.

The Commission's proposal to apply the new standard to all applications filed after the effective date of the new rule should be adopted because it affords the benefits of the new standard as early as is practical.

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COMMENTS

American Telephone and Telegraph Company ("AT&T") respectfully submits the following comments in response to the Notice of Proposed Rulemaking("NPRM") FCC 93-142, released April 8, 1993.

The NPRM proposes to amend and update the guidelines and methods for evaluating environmental effects of radio-frequency ("RF") radiation from FCC regulated facilities. It proposes the adoption of ANSI/IEEE C95.1-1992, the new standard for RF exposure issued by the Institute of Electrical and Electronics Engineers ("IEEE") and adopted by the American National Standards Institute ("ANSI"). The new standard would replace the 1982 ANSI guidelines currently

specified in the Commission's Rules.[1] AT&T supports the Commission's proposal.

I. THE 1992 ANSI STANDARD SHOULD BE ADOPTED.

The new ANSI standard reflects the view of a large group of experts in all relevant disciplines working in government, academia and industry.[2] Because the 1992 standard represents the most recent and comprehensive review of relevant information and the broadest consensus of the engineering and scientific community, it should be adopted at this time. IEEE Subcommittee IV, the developer of the 1992 ANSI standard, regularly reviews the results of new research[3] and will revise the standard as needed in light of such

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[1] § 1.1307(b), 47 CFR § 1.1307(b).

[2] Specifically, the 1992 ANSI standard was developed by Subcommittee IV of IEEE Standards Coordinating Committee 28, consisting of over 120 scientists and engineers, over 75% of whom worked in government, universities, or other non-profit organizations. Only about 15% can be classified as working in or for industry. The remaining developers were independent consultants or from the general public. The approximate distribution of the principal disciplines of these individuals was physical sciences - 33%, life sciences - 43%, medicine - 10%, radiology, pharmacology, toxicology -approximately 3%, and other (law, medical history, safety, etc.) - 11%.

[3] One such item will be the result of a three-to five-year research program undertaken by the Cellular Telecommunications Industry Association. Telecommunications Reports, July 19, 1993, pp. 28-29.

research. The Commission should thereafter consider amending its rules accordingly.[4]

The IEEE Subcommittee noted that no verified reports existed of injury or adverse health effects to people caused by exposure complying with the 1982 standard or any previous ANSI standards (p. 23). Despite the lack of scientific support for the need for tighter standards, the 1992 ANSI standard contains separate and sharply lower Maximum Permissible Exposure ("MPE") limits for uncontrolled environments (defined as locations where the exposure is incurred by persons lacking knowledge or control of the exposure) in the frequency range where energy absorption by the human body is an important consideration.[5] The higher MPE limits for controlled environments (defined as locations where the exposure is incurred by persons aware of the potential for exposure or by persons briefly passing through the area) are based on the available scientific evidence, but nevertheless contain "multiple conservative assumptions" (p. 29).

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[4] As has been done in the past (e.g., Procedures for Measuring Electromagnetic Emissions From Digital Devices, 7 FCC Rcd. 3128 (1992)), the Commission should delegate to the Chief Engineer authority to modify the rules to reference future revisions of the 1992 ANSI standard that do not raise substantive compliance issues and should commit the staff to consult with Subcommittee IV on major interpretation issues that may arise.

[5] From about 1.5 MHz to 15 GHz.

Another important change from the 1982 version is in the provisions permitting the MPE limits to be exceeded in certain circumstances, characterized as exclusions. Both the 1982 and 1992 ANSI standards permit the MPE limits to be exceeded by low power devices. The 1992 standard significantly lowers the power level at which the low power exclusion is available in controlled environments for frequencies above 450 MHz and lowers it even more in uncontrolled environments throughout the applicable frequency range.[6] Moreover, the 1992 ANSI standard makes the low power exclusion unavailable for devices wherein the radiating structure is maintained within 2.5 centimeters of the body.[7]

Both the 1982 and 1992 standards contain exclusions expressed in terms of specific absorption rates ("SAR"s). SAR is a measure of the mass-averaged energy absorption rate in the body and is the physical quantity upon which the MPEs are

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[6] Another illustration of the conservative approach embodied in the 1992 ANSI standard is that this reduction was made across the board even though the only new studies involved the 800-900 MHz range.

[7] Because the low power exclusion is intended to be available for devices held in the hand, the hand is obviously not a part of the body requiring 2.5 cm separation from the device. The substantially higher absorption permitted by hands, wrists, feet and ankles than by other body parts (p. 17) supports this obvious reading.

derived at frequencies between 0.1 MHz and 6 GHz[8]. These exclusions allow the MPE limits to be exceeded so long as the SAR limits are not exceeded. The 1992 ANSI standard contains the same SAR threshold for controlled environments as the 1982 version, but significantly reduces it for uncontrolled environments. All of the changes from the 1982 ANSI standard made in the 1992 standard make it appropriate for the Commission now to reference the new standard in the rules.

The Commission noted that guidelines issued by the National Council on Radiation Protection and Measurements (NCRP) in 1986 and by the International Radiation Protection Association (IRPA) in 1988 contain lower exposure limits at higher frequencies than the 1992 ANSI standard and asked for comment on whether exposure limits different than the 1992 ANSI standard should be adopted (NPRM, ¶ 24). Neither the NCRP nor the IRPA standard establishes that the Commission should not adopt the 1992 ANSI standard. The ANSI standard represents the work of a broad body of experts and reflects consideration of more recent data than is the case regarding the NCRP or IRPA recommendations.[9]

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[8] Above 6 GHz energy is absorbed superficially and incident power density is the meaningful parameter, not SAR.

[9] An additional point supporting the ANSI standard is that the MPE of 10mW/cm^2 beginning at 3 GHz in the controlled, and at 15 GHz in the uncontrolled environment, and the averaging time of 10 seconds are the same as the MPE in the American National Standard for the Safe Use of Lasers, ANSI Z136.1-1993 (unchanged in this regard from its 1986

(footnote continued on following page)

The fact that the 1992 ANSI standard is already in the process of adoption by other expert bodies further supports its adoption by the Commission. Specifically, the American Conference of Governmental and Industrial Hygienists has recently announced its intention to adopt Threshold Limit Values and a SAR exclusion the same as the MPE limits and SAR exclusion for controlled environments in the 1992 ANSI standard, and a low power device exclusion not as limited as that in the 1992 ANSI standard.[10] At a recent NATO Advanced Research Workshop, Working Group IV (Standards Drafting) recommended using the 1992 ANSI standard as the basis for a NATO standards agreement.[11] Moreover, the Commission itself requires that PCS licensees and equipment

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(footnote continued from previous page)

predecessor) at 300 GHz, where both standards apply. Because the depth of penetration into the human body of radiofrequency energy beginning at around 30 GHz is similar to that of infrared energy at 300 GHz, the biological effects would be expected to be about the same. Therefore, the 10mW/cm^2 MPE in the ANSI laser safety standard, and other internationally recognized laser standards such as IEC Publication 825, support that same limit where applicable in the 1992 ANSI standard and show that the NCRP and IRPA standards unjustifiably limit the MPE to 1mW/cm^2 beginning at 1.5 and 2GHz, respectively.

[10] Annual Reports of the Committees on Threshold Limit Values and Biological Exposure Indices (May, 1993). This Conference is only concerned with standards for controlled environments.

[11] NATO Advanced Research Workshop, Developing a New Standardization Agreement (STANAG) for Radio-Frequency Radiation, Rome, Italy (May, 1993).

manufacturers comply with the 1992 ANSI standard pending completion of this docket.[12]

II. COMMON CARRIER MICROWAVE STATIONS, CELLULAR BASE STATIONS AND VEHICLE-MOUNTED CELLULAR TERMINALS, BUT NOT PART 15 DEVICES AND HAND-HELD TERMINALS, SHOULD BE CATEGORICALLY EXCLUDED.

The Commission (NPRM, ¶ 20) also asked for comment on the propriety of the existing categorical exclusions in light of the new ANSI standard.[13] The Commission's current rules provide that the 1982 ANSI standard applies to Commission actions granting construction permits, licenses to transmit or renewals thereof, or Commission actions authorizing modifications in existing facilities, under specified rule parts, and that actions under other rule parts are categorically excluded from consideration of the need to comply with the ANSI standard.[14] Part 21(L) of the Rules, governing common carrier microwave, is not now on the list of rule parts subject to the 1982 ANSI standard. That categorical exclusion exists because the data showed exposure

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[12] New Personal Communications Services, Second Report and Order, FCC 93-451, released October 22, 1993 at ¶ 191; New Narrowband Personal Communications Services, 8 FCC Rcd. 7162, 7171 (1993).

[13] AT&T comments only on certain categorical exclusions and takes no position on the others.

[14] § 1.1307(b) and Note 1, 47 CFR § 1.1307(b) and Note 1.

well below those limits.[15] The same is true regarding even the uncontrolled environment MPE limits in the 1992 standard and therefore the present categorical exclusion should be maintained. Appendix A to these Comments contains supporting data.

Commission actions under Part 15 are also not subject to the 1982 ANSI standard.[16] Categorical exclusion for all Part 15 devices is, however, no longer appropriate because some such devices may exceed the MPE for the uncontrolled environment[17] and the low power exclusion may be unavailable.[18] Such devices would then comply with the 1992

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[15] Responsibility of the Federal Communications Commission to Consider Biological Effects of Radiofrequency Radiation, 2 FCC Rcd. 2064, 2065 (1987).

[16] Section 1.1307(b) of the Commission's Rules, 47 CFR § 1.1307(b), does not apply at all to equipment authorizations and Part 15 is not listed in Note 1 to that section as being subject to the ANSI standard.

[17] Part 15 devices will often be used by people lacking knowledge or control of the exposure, or could cause exposure to non-users. There is no practical way to ensure that Part 15 devices will only be used in a controlled environment. Therefore, the uncontrolled environment limits should apply in the authorization process. While it might be appropriate in some circumstances to apply the controlled environment limits to some hand-held devices and amateur facilities (NPRM, fn. 16), this is not the case regarding Part 15 devices.

[18] The low power exclusion may be unavailable for several reasons: the device may operate outside of the 0.1 MHz to 1.5 GHz range in which that exclusion is available, or may radiate too much power, or may have a radiating element maintained within 2.5 cm of the body.

ANSI standard only if compliance with the uncontrolled environment SAR exclusion can be demonstrated.[19] Categorical exclusion for devices operating between 0.1 MHz and 1.5 GHz, meeting the uncontrolled environment limit for the low power device exclusion, and not having the radiated element maintained within 2.5 cm of the body[20] would, however, be appropriate because these devices comply with the 1992 standard. But, applicants for authorizations of devices operating outside that frequency range, or with too much power, or with a radiating element maintained within 2.5 cm of the body, should not be freed by means of categorical exclusion from the requirement to satisfy the 1992 ANSI standard by meeting the uncontrolled environment SAR limit.[21]

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[19] The Commission recognized as much by asking (NPRM, ¶ 17) for comments on whether proof of SAR measurements should be required as part of the equipment authorization process. AT&T sees no reason to impose a data submission requirement only in this limited circumstance. Rather, as discussed below, the Commission should consider what information it should require in light of its resources to evaluate such data.

[20] As discussed in footnote 7, supra, 2.5 cm separation is not required between the hand and the device.

[21] The NPRM states (¶ 16) that compliance with the SAR standard "can be demonstrated through appropriate laboratory measurements." The 1992 ANSI standard does not require laboratory measurements but rather permits establishing compliance "by appropriate techniques" (p. 17). The Commission should make it clear that use of numerical methods such as the High-Resolution Finite Difference Time Domain technique is also permitted.

The existing categorical exclusion for cellular base stations should not be eliminated. The evidence gathered by AT&T indicates that the overwhelming number of cellular base stations produce potential exposures that comply with the new limits for the uncontrolled environment.[22] While it is possible to envision a cellular base station that may not meet the new limits for the uncontrolled environment, e.g., antennas mounted on a roof in such manner that people may remain within a few feet of the antenna's main beam for a period of time exceeding the applicable averaging time (30 minutes), such cases would be anomalies. The expansion of cellular systems by subdivision of cells and the resulting reduction in effective radiated power, together with the relative ease of configuring a base station to ensure the new standard is met, e.g., elevating roof-mounted antennas, will effectively preclude such anomalous sites.

The present categorical exclusion for vehicle-mounted cellular mobile stations should be maintained. Such stations do not pose any threat of exceeding the uncontrolled environment limits. Appendix B to these Comments contains supporting data. As is the case for Part 15 devices, hand-held cellular mobile terminals and PCS handsets could exceed

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[22] R.C. Petersen and P.A. Testagrossa, Radiofrequency Electromagnetic Fields Associated With Cellular-Radio Cell-Site Antennas, 13 Bioelectromagnetics 527-42 (1992).

the applicable MPE limit,[23] and the low power exclusion might not be available because the unit operates outside of the 0.1 MHz to 1.5 GHz range, radiates too much power, or has a radiating element maintained within 2.5 cm of the body. In such cases, compliance with the applicable SAR limit would be required. Accordingly, such units should not be categorically excluded. If the Commission establishes categorical exclusion for some Part 15 devices, a similarly limited categorical exclusion would be appropriate for hand-held cellular mobile terminals and PCS handsets.

III. THE 1992 STANDARD SHOULD APPLY TO APPLICATIONS FILED AFTER THE EFFECTIVE DATE OF THE NEW RULE.

The Commission asked for comments on its proposal to apply the 1992 ANSI standard to all applications filed after the effective date of the new rule so as to implement that standard as rapidly as possible while minimizing impact on the applicants. (NPRM ¶ 26).[24] Because there are no verified reports of injury or adverse health effects to people caused by exposure to equipment that complied with prior ANSI

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[23] Because use of some PCS systems might be confined to people aware of the potential for exposure, the controlled environment limits might sometimes apply.

[24] The Commission does not indicate any intention to establish an effective date either more or less than the 30-day period in § 1.427 of the Commission's Rules, 47 C.F.R. § 1.427.

standards,[25] applying the new rule to applications being processed when the rule becomes effective would not produce benefits outweighing the resulting administrative burdens and costs on Commission staff and applicants, and the delayed availability of new services and equipment. On the other hand, a long transition period would deny the public the benefits of the new rule. The Commission's proposal to apply the 1992 ANSI standard to all applications filed after the effective date of the new rule should be adopted.

The Commission also asked for comment on the related issue of how to address equipment and facilities in use that do not comply with the 1992 ANSI standard, suggesting the possibility of requiring re-submission of certain applications. (Id.) For the same reasons that the 1992 standard should not be applied to pending applications, there is no need for Commission action addressed to equipment presently in use.

The fact that an entire category of equipment is not categorically excluded does not mean that environmental processing is required under the present Commission Rules. Rather, under the present rules if the 1982 ANSI standard applies and is met, Commission action is deemed not to have a significant impact on the environment and is categorically

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[25] See p. 23 of the 1992 ANSI standard.

excluded from environmental processing.[26] If, however, that standard is not met, the applicant must submit an Environmental Assessment to the Commission.[27] Thereafter, unless any significant environmental impacts found by the Commission are eliminated, further proceedings involving an Environmental Impact Statement occur.[28]

This procedural posture underlies the Commission's request for comment on what documentation should be required in order to show compliance with the 1992 ANSI standard (NPRM, ¶ 27). The Commission stated that its experience is that a simple "No" answer to the question of significant environmental impact may not be sufficient (Id.). AT&T does not object to providing whatever additional information the Commission needs. The Commission should recognize, however, that requesting a more elaborate response, such as requiring the applicant to identify whether the controlled or uncontrolled environment limits apply, and whether compliance with the applicable MPE, or reliance on the low power device exclusion or the SAR exclusion, is the basis for the "No" answer, does not provide assurance that the 1992 ANSI standard is indeed met. Only examination of the applicant's underlying

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[26] § 1.1306(a) and (b)(3), 47 CFR § 1.1306(a) and (b)(3).

[27] § 1.1308(a), 47 CFR § 1.1308(a).

[28] § 1.1308(c), 47 CFR § 1.1308(c).

data is sufficient for that purpose. The Commission will have to decide if it has the resources to evaluate such data meaningfully.

Finally, the Commission asks (NPRM, ¶ 28) for Comments on its proposal to adopt the new ANSI recommended practice for measuring potentially hazardous electromagnetic fields. AT&T supports that proposal. The new practice represents the best and most up-to-date practices for making such measurements.

CONCLUSION

For the reasons discussed above, the Commission should adopt the 1992 ANSI standard and modify the present categorical exclusions as suggested in these Comments.

Respectfully Submitted,

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January 25, 1994

APPENDIX A

Electromagnetic Radiation from Selected Telecommunications Systems

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Abstract—Because of the growing interest in potential health effects associated with exposure to electromagnetic (EM) radiation at microwave and radio frequencies (RF's), a study was initiated within the Bell System to document existing levels of EM energy associated with various radio transmission systems. To this end, power density and electric field strength measurements were made at selected facilities, particularly at locations judged to be representative of those frequently encountered by various crafts personnel.

For the case of point-to-point microwave radio, measurements were made in the vicinity of various antenna towers in order to obtain information that could be compared with the corresponding levels predicted by analytical techniques. These data allow one to assess the environmental impact, with respect to EM radiation, of the microwave radio system as well as the impact of future standards and guidelines on the system.

This paper describes the instrumentation and measurement techniques used for this study and provides a summary of the results obtained for several different types of radio systems including high frequency (HF) radio, tropospheric scatter, earth-satellite and ubiquitous microwave radio relay.

Introduction

During the past several years, a series of microwave power density and electric field strength measurements were made at various Bell System radio transmission facilities. The particular facilities were so selected as to include a representative sampling of the various types of radio systems used by the telephone industry, each of which operate in some discrete frequency band between 1 MHz and 11 GHz. Included in this study were high-frequency (HF) radio systems (1–30 MHz), tropospheric scatter systems (0.8 to 2 GHz), satellite communication systems (4 and 6 GHz), and microwave point-to-point radio systems (4, 6, and 11 GHz).

The purpose of this continuing program is to more fully document the levels of exposure potentially experienced by radio personnel and by others whose assignments place them in the vicinity of the various radio systems, and to compare these levels with existing standards and guidelines. These data also provide information useful for assessing the impact of future occupational and/or environmental guidelines and standards. In addition, measurements made in the vicinity of microwave radio antenna towers provide data to support the theoretical methods commonly [1]–[3] used for estimating the upper bound of the power density at ground level, particularly at points in the near-field region of the antenna.

Site Selection

Because of the relatively small number of HF and tropospheric scatter sites remaining in operation, only one of each was selected for this study. Each of these systems represent high power emitters, typically operating at output power levels of 2 kW and 30 kW/transmitter, for the tropospheric scatter and HF radio, respectively. (However a comparison of this system with other tropospheric scatter systems, some of which operate at power levels up to 50 kW, would suggest that the system investigated in this study should be considered *low power*.)

Measurements at satellite communication system earth stations were made at two sites. Such a system is also regarded as *high power* with typical operation at power levels of 500 W/transmitter and maximum transmitter power capabilities of approximately 2 kW.

The system considered most important for this study is point-to-point microwave radio, because of the relatively large number of such sites in the U.S. (approximately 5000 are operated by the Bell System) and because of the relatively uniform geographical distribution of these sites. Compared with satellite communication systems, HF radio, and tropospheric scatter systems, microwave radio is considered to be a low power system, with transmitter output powers of 20 W or less. The majority of the 4-GHz transmitters operate at a level of 2 W; the majority of the 6-GHz transmitters operate at a level of 12.5 W or less. Although several different transmitters are usually combined to provide several microwave channels per antenna, there are very few cases where the total antenna input power exceeds 100 W.

In order to ensure that the representative sampling of point-to-point microwave radio sites was adequate, measurements were made in remote repeater stations, in large junction stations, in radio rooms of large metropolitan (as well as small suburban) central office buildings, on rooftops of urban and suburban central office buildings, in proximity to several remote microwave towers, and in residential areas, near microwave transmitting antennas.

Instrumentation

The instrumentation and techniques used for the measurements were considered to be optimum for each situation. Measurements at frequencies below 1 GHz and at levels lower than a few microwatts per centimeter squared ($\mu W/cm^2$) were made using field intensity meters, such as the Singer-Stoddart NM17/27 and NM37/57 with the appropriate calibrated antennas. Measurements of higher levels, particularly in leakage situations, were made with an appropriate near-field survey instrument, such as the Narda 8600 or 8300 series.

Measurements of low levels at frequencies above 1 GHz were made with a Hewlett-Packard 141T Spectrum Analyzer and Tracking Preselector, with an appropriate conical log-spiral antenna or a standard gain horn. Measurements of higher levels (above a few $\mu W/cm^2$) such as could be found in the vicinity

Manuscript received April 20, 1979; revised September 12, 1979.
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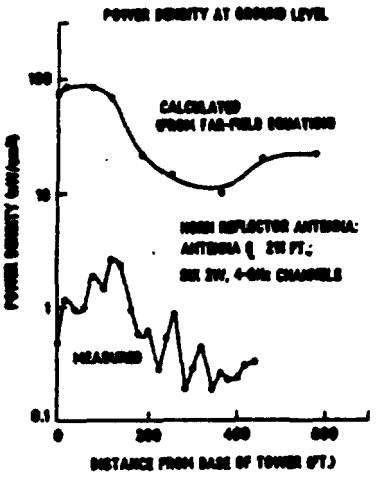


Fig. 1.

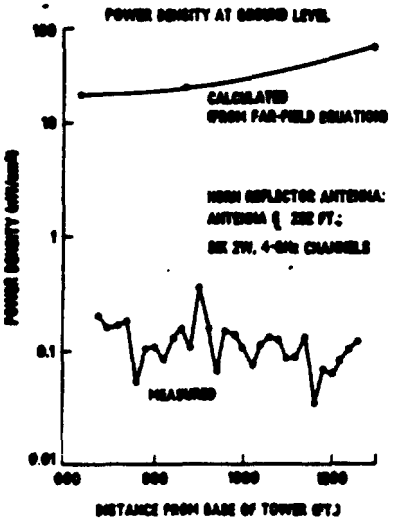
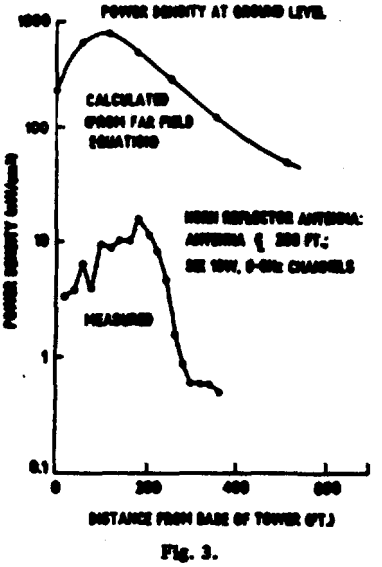


Fig. 2.



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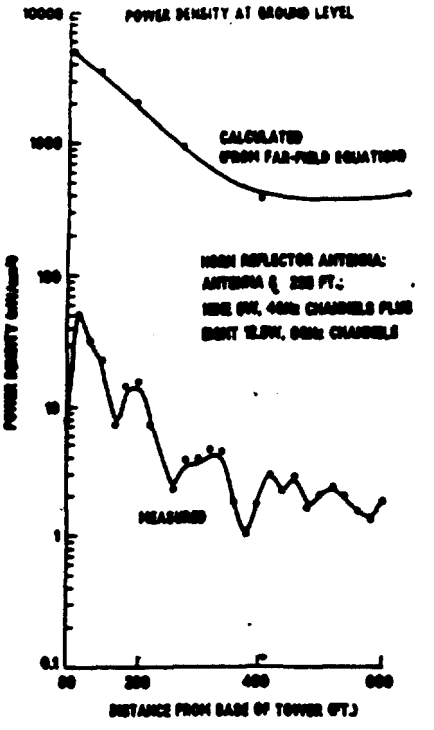

Fig. 4.

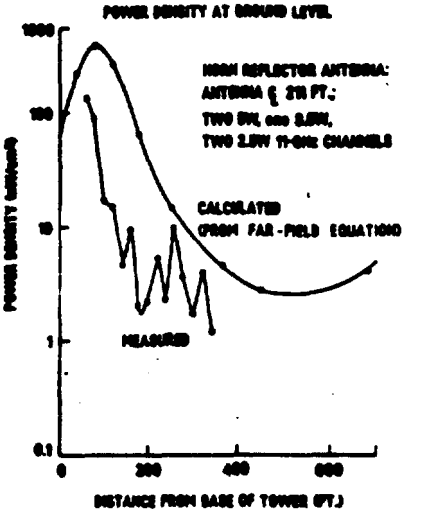

Fig. 5.

antenna characteristics (very low sidelobes, narrow beamwidth), and low antenna input powers.

Conclusion

The maximum electric field strengths associated with the normal operation of HF radio systems (1–30 MHz) in areas accessible to or occupied by radio personnel, performing their various assigned tasks, was found to be less than 36 V/m. Although higher levels could be measured, these occurred at points normally inaccessible, such as on top of transmitter cabinets near the output antenna feed pairs.

The maximum power densities in normally accessible areas associated with the operation of tropospheric scatter systems, satellite communication earth stations, and point-to-point

microwave radio systems were found to be less than 1 $\mu W/cm^2$. In some cases, microwave radio rooms in the upper floors of hi-rise metropolitan central office buildings exhibited maximum levels due to VHF and UHF transmitters on the order of a few tens of $\mu W/cm^2$. These levels represent typical ambient background levels in urban areas where the contribution from microwave radio equipment is negligible.

A comparison of the power densities, measured at ground level, near representative microwave antenna towers with the corresponding calculated estimates, indicated that the methods commonly used for calculating such estimates are extremely conservative, yielding values that are always larger (in some cases by more than a factor of 1000 depending on the analytical method used) than the corresponding measured values and, therefore, yield very large factors of safety.

References

[1] M. A. Stuchly, "Potentially hazardous microwave radiation sources—A review," *J. of Microwave Power*, vol. 12, pp. 369-381, 1977.

[2] D. H. Shinn, "Avoidance of radiation hazards from microwave antennas," *Marconi Rev.* (G.B), vol. 39, pp. 61-80, 1976.

[3] W. W. Mumford, "Some technical aspects of microwave radiation hazards," *Proc. IRE*, vol. 49, pp. 427-445, 1961.

[4] S. Baranski and P. Czerski, *Biological Effects of Microwaves*. Stroudsburg, PA: Dowden, Hutchenson, and Ross, 1976, p. 177.

State of the Knowledge for Electromagnetic Absorbed Dose in Man and Animals

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Abstract—The paper gives the EM absorbed dose for man and animals at various frequencies for the plane wave irradiation condition for different orientations of the body relative to incident fields. Also included are the results for the whole-body absorption for conditions of electrical contact with ground and in the presence of reflecting surfaces of high conductivity and multiple animals. The data are given for the distribution of power deposition in man models for the resonance conditions of highest whole-body electromagnetic absorption. The highlights of the results obtained with proportionately scaled saline- and biological-phantom-filled models of man have been confirmed by experiments with small laboratory animals, from 25-g mice to 2250-g rabbits.

I. Introduction

THE EXPANDING usage of electromagnetic (EM) radiation has necessitated an understanding of its interaction with humans. Such knowledge is vital in evaluating and establishing radiation safety standards, determining definitive hazard levels, and a physical understanding of the effects which have been reported in the literature. The need for research in this area is clearly exemplified by the widely disparate safety levels that are used worldwide at the present time. In the United States the safety level is 10 mW/cm^2 for long-term human exposure at any frequency and regardless of physical environment, whereas the recommended maximum safe-power density in Eastern Europe and the USSR is 1000 times less at a level of 0.01 mW/cm^2. Several countries, including Canada [1] and Sweden [2], are in the process of revising their safety standards downward from the previously accepted levels of 10 mW/cm^2.

Biological studies of the effects of EM radiation have used laboratory animals such as rats, rabbits, etc., for the study of behavioral and/or biochemical changes. For these experiments to have any projected meanings for humans, it is necessary to be able to quantify the whole-body power absorption and its distribution for the irradiation conditions. It is furthermore necessary that dosimetric information be known for humans subjected to irradiation at different frequencies and for realistic exposure conditions.

Unlike the field of ionizing radiation, where the absorption cross section of a biological target is directly related to its geometrical cross section, the whole-body EM energy absorption has been shown [3]–[13] to be strongly dependent on polarization (orientation of electric field $\vec{E}$ of the incident waves), frequency, and physical environments such as a conducting ground and other reflecting surfaces. A prescribed power density of, say, 10 mW/cm^2 tells almost nothing about the absorbed dose except perhaps at very high frequencies where the wavelength of irradiation is an order of magnitude or more smaller than the dimensions of the animal. This is best illustrated by examples from Schrot and Hawkins' work [14] on times of lethality of rats and mice at several frequencies and for different polarizations of incident waves. For a free-space irradiation power density of 150 mW/cm^2 at 985 MHz, mice oriented along the electric field (E-orientation) convulsed in an average time of 9 min, while similar animals oriented along the microwave magnetic field (H-orientation) lived through an experimental observation time of 60 min without significant stress. Also, identical power densities at several frequencies resulted in substantially different times to convulsion. For mice irradiated with an incident power density of 150 mW/cm^2 in the E-orientation, mean times to convulsion of 3260 and 160 s were observed for 710 and 1700 MHz, respectively.

Manuscript received April 5, 1979; revised August 15, 1979.

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0018-9219/80/0100-0024$00.75 © 1980 IEEE

LEVELS OF ELECTROMAGNETIC ENERGY IN THE IMMEDIATE VICINITY OF REPRESENTATIVE MICROWAVE RADIO RELAY TOWERS

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ABSTRACT

This paper describes the results of a series of measurements of the power density levels in the immediate vicinity of several representative microwave radio relay towers. The results of these measurements, for systems operating in the 4, 6, and 11 GHz common carrier bands, are compared with the corresponding theoretical approximations and with existing international general population exposure standards. The results of these comparisons indicate that theoretical techniques, currently used for estimating power densities at off-axis points in the near field, are extremely conservative, yielding an upper bound up to several orders of magnitude greater than the measured corresponding values. The measured power density levels are significantly lower than the most stringent exposure standards used by any nation.

INTRODUCTION

Primarily as a result of a recently published book[1], a number of articles in the popular press, and programs on network radio and television pertaining to the biological implications associated with exposure to electromagnetic energy at microwave frequencies, the public is becoming increasingly aware of the various microwave emitters in the environment. One readily identifiable emitter about which there is a great deal of concern, confusion, and misunderstanding, is the microwave radio-relay antenna support tower or as it is commonly referred to, the "microwave tower." This confusion concerns the magnitude and the spatial distribution of the microwave energy, particularly at off-axis points in the near field; i.e. at points near the base of a tower where human occupancy is a possibility.

Because the points of greatest concern are generally in the near field region of the transmitting antenna, (taken here to mean distances from the antenna less than $2A/\lambda$ where A is the projected aperture area of the antenna and λ is the wavelength at the frequency of interest), exact calculations of the levels, in terms of power density, are difficult. Instead, one relies on one of several techniques[2,3,4] that are useful for estimating upper bounds for the power density in this region. Although each of the various techniques yields slightly different results, all are extremely conservative, yielding values greater than the actual or measured values.

Theoretical techniques and calculated values are not always convincing to citizens concerned about the safety of an existing or a proposed tower. Therefore measurements have been made in the immediate vicinity of a number of representative microwave towers in order to compare actual values with theoretically predicted estimates and to insure that the calculated values are indeed greater than the actual values, i.e., that the calculated values actually afford a factor of safety. The following describes the results of these measurements and a comparison with the predicted values for four tower heights and for systems operating at 4,6, and 11 GHz. In each case the antenna was the ubiquitous horn reflector.

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INSTRUMENTATION

The measurements were made using a Hewlett Packard (H.P.) 141T/8552B/8555A Spectrum Analyzer and a H.P. 8445B Automatic Tracking Preselector. A Singer Stoddart Broadband (1-10GHz) Conical Log Spiral Antenna was used for measurements in the 4 and 6 GHz frequency bands and a Narda Standard Gain Horn was used at 11 GHz. Coaxial cable, type RG-214U, was used to connect the antenna and preselector for the measurements made at 4 GHz; B & W Associates 55-142-55 semi-rigid coaxial cable was used for the measurements at 6 and 11 GHz. The overall sensitivities of the above described system are approximately 1×10^{-9}, 5×10^{-9} and 3×10^{-10} mW/cm^2 at 4, 6 and 11 GHz, respectively.

RESULTS

The towers and the particular antenna type, the horn reflector, discussed here, are typical of those used for long haul microwave radio service. The horn reflector antenna was selected for this study because methods for estimating the off-axis power density in the near field region are not as readily found in the literature as are the methods applicable to the more familiar circular parabolic reflector antenna. Fig. 1 shows a typical antenna tower, at a microwave junction station, with several horn reflector antennas mounted at various heights.

Fig. 2 shows the calculated worst case estimate of the power density and the corresponding measured values at points 5 ft. above ground level, under the axis of the major lobe of the antenna radiation pattern. The system corresponding to the data shown in Fig. 2 operates at frequencies in the 4 GHz common carrier band utilizing six transmitters, each having an output power of 2 watts. The antenna centerline height above grade level is 211 ft.

The calculated values shown in Fig. 2 were obtained from the free space transmission formula

$$W = \frac{PG}{4\pi R^2} \qquad (1)$$

and the appropriate antenna input parameters. In the above equation W is the power density, P is the antenna input power, G is the antenna directional gain along the radial of interest, and R is the path length from the face of the antenna to the point of interest. The above equation is valid for points in the far field region, taken here to be distances greater than $2A/\lambda$ where A is the projected antenna aperture area ($\sim 64 ft^2$) and λ is the wavelength at the frequency of interest. At points in the near field region, equation (1) loses accuracy as one gets closer to the antenna unless appropriate gain correction factors are applied. However, accuracy is not of prime concern as we are trying to estimate an upper bound of the near field power density. To insure this, various assumptions are also made. For example, the power densities calculated from equation (1) are multiplied by a factor of 4 to include the possibility of field reinforcement due to in-phase addition of reflected field components; each transmitter is assumed to be polarized in the direction that yields the largest antenna side lobes; and the gain, G, is obtained from the antenna directional gain pattern, smoothed over the maxima of the side lobes.

Fig. 3 shows the measured and calculated values for a system similar to that shown in Fig. 2. This was also a 6 channel 4 GHz system with an antenna centerline height of 232 ft. above grade level. In this case, however, measurements were made in the far field region.

Figs. 4 and 5 are similar data for two different 6 GHz systems. Fig. 4 is for six 10 watt channels and an antenna centerline height of 298 ft., and Fig. 5 is for a single 5 watt channel and an antenna centerline height of 182.5 ft.

Fig. 6 shows the measured and calculated values for an 11 GHz digital radio system operating with two 5 watt, one 3.5 watt, and two 2.5 watt channels. The antenna centerline height is 211 ft.

The particular towers and systems described above represent typical, not worst case installations. However, as will be shown below, the data in Figs. 2-6 can be scaled to represent the fully loaded, or worst case situation.

DISCUSSION

A comparison of the measured and the corresponding calculated power density for the 4 and 6 GHz systems shown in Figs. 2-5 indicates that the analytical method used here, equation (1), is extremely conservative. This has always been found to be the case, not only for the horn reflector but for the circular parabolic reflector antenna as well. The method described above predicts levels lower than those predicted by various other methods of calculation. The method currently used by the U.S. Environmental Protection Agency[2] for calculating upper bounds of the power density at points in the near field region is to calculate the average power density, W, in the main beam of the antenna pattern from the equation

$$W=\frac{4P\eta}{A} \qquad (2)$$

where P is the antenna input power, η is the antenna aperture efficiency, and A is the physical area of the aperture. The power density at off-axis points in the near field is then assumed to be less than one one-hundredth of the value predicted by equation (2). Following this technique, values of 2, 2, 10 and 1 $\mu W/cm^2$ are obtained for the systems shown in Figs. 2, 3, 4, and 5 respectively. However, the results predicted using equation (1) and the assumptions described above and the results predicted by using equation (2), as described, converge with increasing distance from the antenna.

The measured values shown in Figs. 2-5 may be scaled to yield estimates for the actual power density for systems operating at other power levels. For example, Figs. 2 and 5 may be used to estimate the maximum power density at points within a distance of 200 ft. from the base of a 200 ft. tower and a fully loaded antenna, i.e., twelve 5 watt 4 GHz channels and eight 12.5 watt 6 GHz channels. The maximum measured value of $\sim 3 nW/cm^2$ for the six 2 watt channels, (Fig. 2), may be multiplied by a scaling factor of 5 to represent the 12 channel 5 watt transmitter case. Similarly, the measured value of $\sim 2.5 nW/cm^2$ for the single 5 watt system, (Fig. 5), may be multiplied by a factor of 20 to represent the 8 channel 12.5 watt case. Adding these values results in a maximum power density that is less than 65 nW/cm^2. As indicated in Fig. 3, the power density at points more distant would be significantly lower. The measured value for a 5 channel 11 GHz digital radio system was found to approach 150 nW/cm^2 at distances close (60ft.) to the base of a 200 ft. tower. At distances greater than 200 ft., this level decreased to less than 10 nW/cm^2. Intermodulation problems limit the number of 11 GHz digital radio channels per antenna to approximately 8, therefore, the results for a fully loaded system are approximately double the above values for a similar situation, i.e., from 10 to 20 nW/cm^2 for distances greater than 200 ft., less than 300 nW/cm^2 for distances on the order of 60 ft.

A comparison of the measured power densities with the corresponding calculated values for systems operating at 4, 6 and 11 GHz indicates that the theoretical estimates are extremely conservative at 4 and 6 GHz, i.e., there is a large difference between the measured and the calculated values. Although the theoretical values at 11 GHz always exceed the corresponding measured values, the difference is smaller than for 4 and 6 GHz.

At no generally accessible point for any system described in this study did the power densities approach $1 \mu W/cm^2$, the most stringent general population exposure standard used by any nation.[5] Such has been the case for all systems investigated by the author during the past seven years, e.g., systems using various diameter circular parabolic reflector antennas at various heights as well as passive reflector systems, i.e., where an antenna is mounted a few feet above ground level directed upwards toward a tower mounted reflector. Such results are to be expected because of the low transmitter powers used (the majority are either 2, 5 or 10 watts) and the excellent antenna characteristics in terms of sidelobe suppression and narrow beamwidth. Such characteristics serve to reduce route to route interference and to limit exposure of the general public to levels well below any established standards.

REFERENCES

1 Brodeur, P., The Zapping of Americas: Microwaves, Their Deadly Risk, and the Cover-Up., (New York: Norton, 1977).

2 Stuchly, M. A., "Potentially Hazardous Microwave Radiation Sources - A Review," Journal of Microwave Power, 12 1977, pp. 369-381.

3 Shinn, D. H., "Avoidance of Radiation Hazards from Microwave Antennas," Marconi Rev. (GB), 39 1976, pp.61-80.

4 Mumford, W. W., "Some Technical Aspects of Microwave Radiation Hazards," Proc. IRE, 49 1961, pp. 427-445.

5 Baranski, S., Czerski, P., Biological Effects of Microwaves, (Stroudsburg, Pa: Dowden, Hutchenson and Ross, Inc., 1976), p. 177.

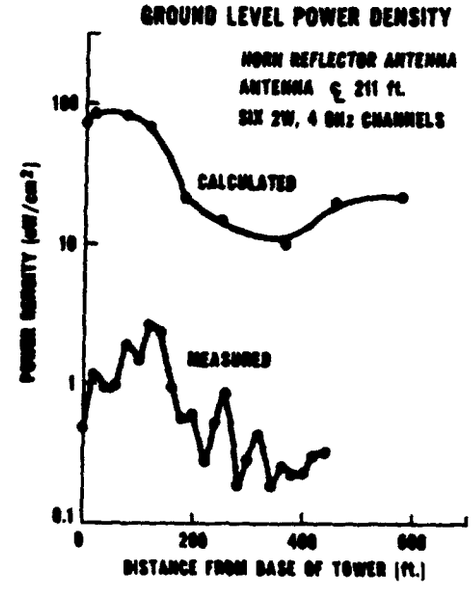

Fig. 2

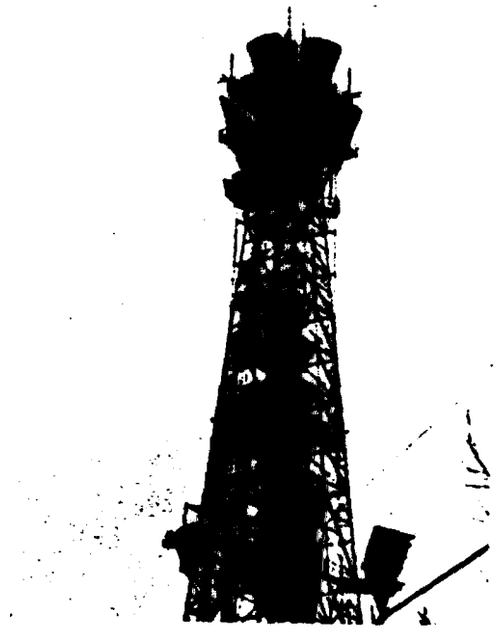

Fig 1.

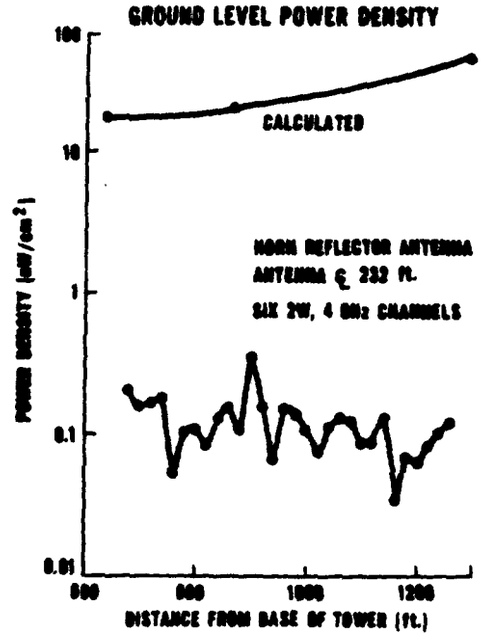

Fig. 3

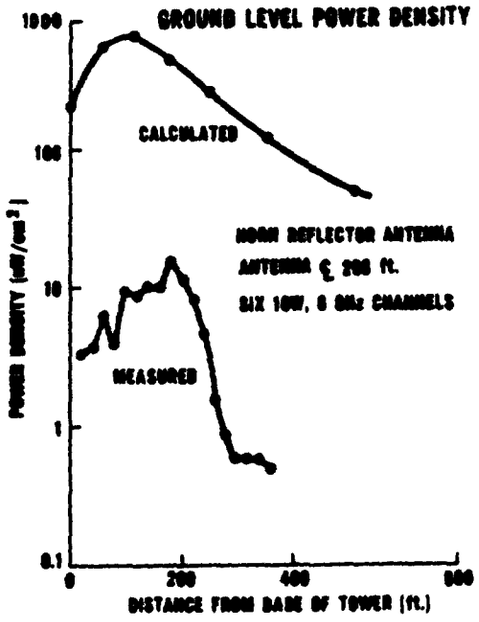

Fig. 4

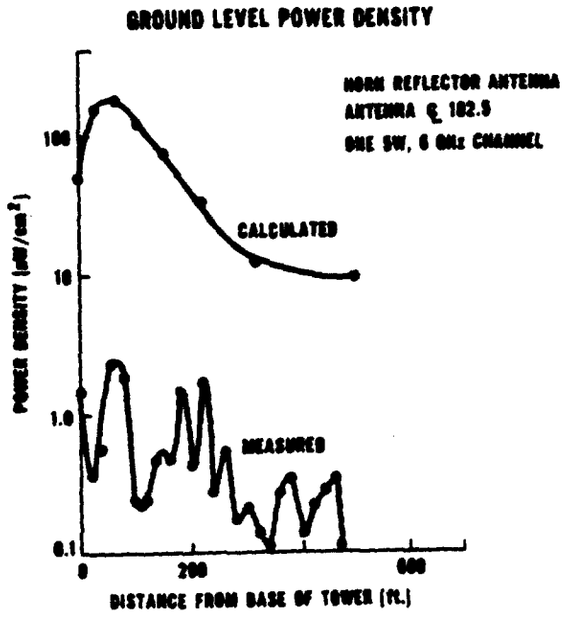

Fig. 5

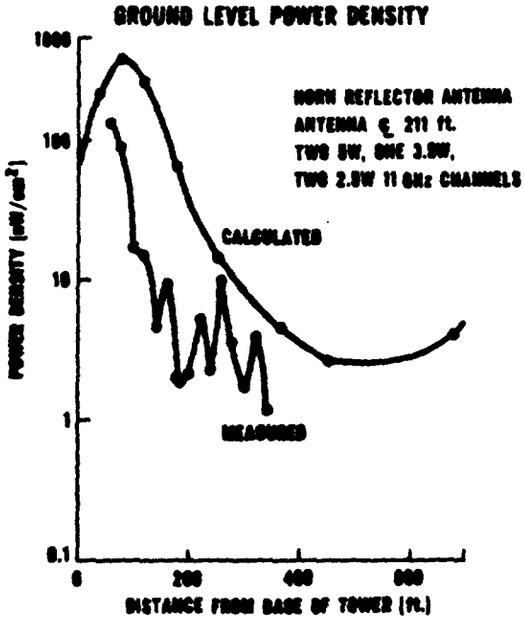

Fig. 6