Microwave Exposure: Safeguarding Public Health in the Absence of National Standards

Henry A. Kues, Phyllis E. Mazik, and John C. Monahan

The lack of a national safety standard for exposure to electromagnetic radiation has generated considerable public concern and a plethora of court cases. The involvement of the Applied Physics Laboratory in this arena began in the mid-1960s following disclosure of Soviet irradiation of the U.S. embassy in Moscow, and over the years has included measurements, research, education, and assistance to governments around the world. This article describes a recent case in which the scientific expertise and knowledge developed at the Laboratory were used to assist a local government. It presents one city's attempt to deal with health concerns associated with electromagnetic exposure by endeavoring to protect and educate the public while allowing for the development of beneficial technologies.
(Keywords: Antenna ordinance, Electromagnetic radiation, Radio frequency protection guidelines, Telecommunications.)

INTRODUCTION

Frequently, scientists and engineers at The Johns Hopkins University are asked to provide advice in their field of expertise to public organizations, scientific panels, and local and national governments. Public service has long been the mission of the University, and staff members at APL, as part of the University, support this role regularly. In fact, the Laboratory's Mission Statement includes ". . . public service through education, research, and the application of knowledge to human affairs."[1] Laboratory staff members are also asked to provide individual consulting services, requests for which are reviewed by the Laboratory on a case-by-case basis. This article describes one such consulting relationship. The case is representative of the increasing need for research to provide the appropriate scientific base necessary to support a national standard for exposure to electromagnetic radiation.

During the last half century, use of electromagnetic radiation has increased tremendously, especially the portion of the electromagnetic spectrum commonly called radio frequency (RF) radiation that includes the microwave region (Fig. 1). To the general public, the proliferation of military, industrial, and consumer applications of RF radiation are evident in everyday life—

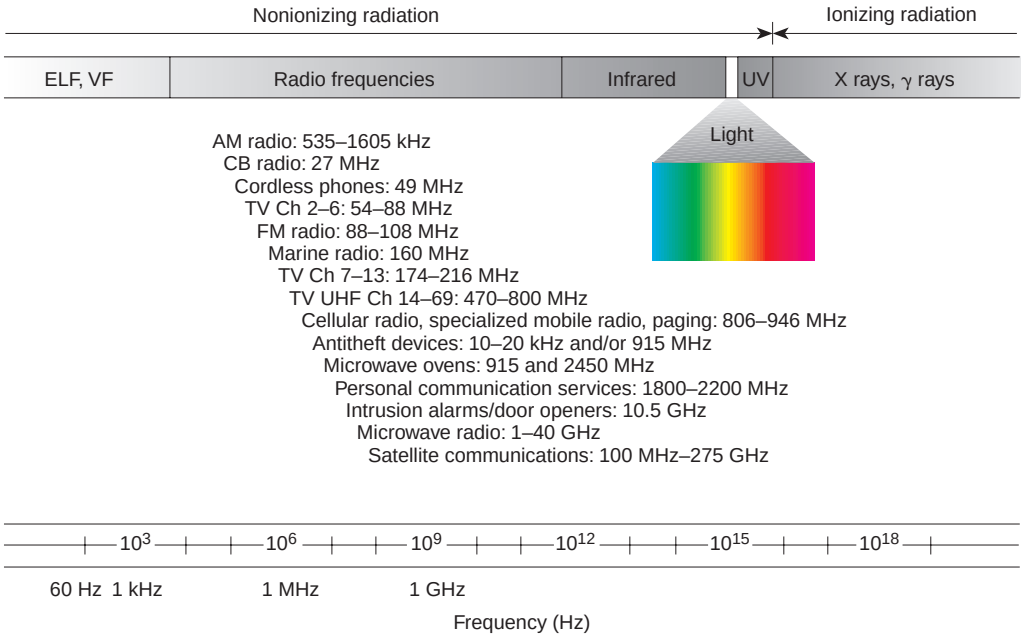

Figure 1. Diagram of the electromagnetic spectrum (ELF = extremely low frequency, VF = voice frequency).

from numerous radar sites, industrial and commercial use of microwave ovens, radio and television stations, advanced medical devices, and computers, to the increasing use of communication systems such as cellular telephones and satellite–Earth stations. The societal benefits from these technological advances and their numerous applications are self-evident. However, the increased use of new technologies results in a complex electromagnetic environment, and, ultimately, an increase in exposure of the population to RF radiation. Increased exposure to RF or microwave radiation and the potential for adverse health effects due to exposure have raised concerns of the medical and scientific communities, government agencies, and the public. Unfortunately, with ever-tightening federal budget constraints, there is a lack of funding for the research necessary to provide a definitive scientific base for any national exposure standard.

The lack of a national safety standard for exposure to microwave radiation and the continuing reports of potential health hazards associated with exposure have alarmed the general public, and it is no longer uncommon for a legal challenge to be instituted whenever a company undertakes the installation of a new facility, especially for communications systems. In an effort to protect the public health, to provide a forum for public education and public input regarding the installation of a facility, and to allow for monitoring of power density exposure levels, the city of Stamford, Connecticut, instituted a novel approach to address these issues.

BACKGROUND

In the mid-1960s, investigation of the effects of microwave radiation exposure began at APL with Project Pandora.[2] At that time, a multidisciplinary team of investigators, including Eugene V. Byron, an electrical engineer at the Laboratory, was assembled by the Department of Defense and tasked by the Department of State to evaluate the exposure of personnel at the U.S. embassy in Moscow, following concerns raised by the disclosure of routine Soviet irradiation of the embassy building. Subsequently, Laboratory employee Robert C. Mallalieu performed a retrospective study for the Department of State, encompassing the period from January 1966 to February 1977, which provided a model of the microwave intensity distribution within the embassy.[3]

Over the years, the Laboratory has been tasked by the U.S. Armed Forces with numerous systems engineering evaluations, and in 1982, a major biological research program was begun to investigate potential health hazards from exposure to microwave radiation. This research program, under the direction of APL's Henry A. Kues, is a cooperative effort with The Wilmer Ophthalmological Institute of The Johns Hopkins University School of Medicine, the Tri-Service Microwave Bioeffects Program (formerly the Walter Reed Army Institute of Research/Microwave Branch), and the Food and Drug Administration. Using animal models, studies conducted under this

program demonstrated a direct relationship between RF exposure and the production of ocular changes, including increased vascular permeability, altered electrophysiological responses indicative of impaired visual function, and the frank destruction of corneal and retinal tissue.[4]

Numerous animal studies have documented the production of other biological consequences from RF exposure, including compromised immunity, altered neurological function, genetic effects, altered drug activity, and a variety of behavioral effects.[5–11] However, not all experimental studies demonstrated clear effects, and, in fact, some studies failed to find any effect for a given endpoint, especially at low exposure levels. The lack of consistent findings has fueled debate within the scientific community concerning the applicability of some of the data to humans, especially regarding safe or unsafe exposure levels. This lack of complete agreement has resulted in some foreign governments and several nongovernmental bodies in the United States adopting somewhat different recommendations for safe exposure levels.[12–17] Currently, the United States has no national standard to ensure safe exposure to RF radiation. Thus, industry, the military, and local municipalities usually adopt one of the nonbinding recommendations such as the American National Standards Institute/Institute of Electrical and Electronics Engineers (ANSI/IEEE) C95.1-1991 or the National Council on Radiation Protection and Measurements guidelines. A few local jurisdictions have set their own standards as has the Laboratory.[18–20]

In 1982, considerable concern was raised about the effects of exposure to electromagnetic radiation on human health when Westinghouse Broadcasting Company announced plans to locate an Earth station microwave transmission facility in Stamford, Connecticut. To address these concerns, Ralph M. Gofstein, M.D., then Director of Health for the city of Stamford, with input and review by other public officials, promulgated an ordinance regulating antennas with more than 5 W of input power to the antenna array. In 1984, the city of Stamford incorporated ANSI C95.1-1982[21] RF protection guidelines into Chapter 160 of the Code of Ordinances, City of Stamford, Connecticut.[22] This ordinance set safety levels based on the ANSI C95.1-1982 protection guide for RF; required an application process for an advisory permit to construct, maintain, and operate a telecommunications facility with review by members of the scientific community; allowed for a public hearing; and required annual permits for continued operation and quarterly measurements of exposure levels at operating facilities by Health Department staff.

In 1991, the ordinance was amended so that the city of Stamford would follow the most stringent applicable federal, state, or municipal standard. The amendment also included a provision specifying a field survey by a scientific panel with sensitive RF detection meters prior to the public hearing. Presently, the city of Stamford is the only municipality to have such an ordinance regulated by a local health department. It should be noted that public utilities with antennas mounted on towers fall under the exclusive jurisdiction of the state of Connecticut's Department of Public Utility Control.

THE CITY OF STAMFORD RF PROTECTION ORDINANCE

After receiving an application for a microwave-emitting facility, the Director of Health convenes a panel of three experts in the field of bioelectromagnetic science. The Stamford Health Department selects an expert, the applicant selects one, and the third expert is a neutral party chosen by the other two experts. In lieu of an application fee, the applicant is responsible for paying any fees and expenses charged by the three experts for their services. A timeline of this application review process is shown in Fig. 2.

The department then schedules an evening public hearing. Before the hearing, the panel of experts conducts a field survey of the proposed site and surrounding neighborhood with Health Department staff. The applicant provides sensitive electronic equipment to measure background RF levels in the vicinity of the site, and, if possible, power density measurements are taken at similar operating sites at other nearby locations to obtain comparative data on existing facilities.

The applicant provides public notice of the evening hearing through newspaper announcements and a letter to each landowner within 500 ft of the property boundary of the proposed antenna site. At the public hearing, the Health Department staff introduces the panel of experts and explains the process outlined in the ordinance. The panel then explains the application, technical data, and site measurements taken that day. Finally, the public is invited to participate in the hearing. The applicant's representatives are present to respond to any questions directed to them.

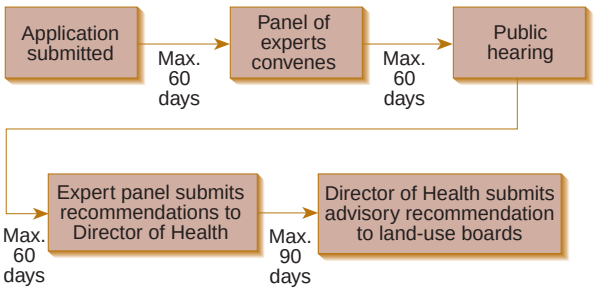

Figure 2. Timeline: Application process for a microwave-emitting facility (Max. = maximum).

The focus of this ordinance is intended to address the potential adverse health consequences of exposure to electromagnetic fields. The ordinance now states that Stamford shall require compliance with the most stringent federal, state, or municipal standard. Recent applications have been required to comply with the safety levels specified in the Commonwealth of Massachusetts' Radio Frequency Exposure Limits (Table 1). Following the hearing, the expert panel has 60 days to submit its recommendations to the Director of Health. Panel members review and consider the application, comments and data submitted by the public at the hearing, field measurements obtained at the proposed facility and comparable sites, and existing RF exposure guidelines. They are expected to apply their scientific knowledge relative to the application while preparing their report and recommendations for the Director of Health.

The Director of Health then recommends to the building inspector or appropriate land-use boards that the proposal be either accepted as is, modified, accepted with conditions, or rejected. The building inspector, planning and zoning boards, zoning board of appeals, and land-use boards are bound to include the advisory recommendations as part of the total consideration given the application prior to issuance of a building permit.

The ordinance provides for an annual permit for continued use of antenna facilities. The Director of Health has discretionary power to require permit holder adherence to stricter standards if such standards are adopted by a government agency. In addition, the Health Department conducts quarterly unannounced power density measurements at antenna facilities. The Director requires compliance with the relevant standards. Noncompliance can result in penalties ranging from fines to revocation of permits.

Table 1. Massachusetts radio frequency exposure limits for public exposures.

Frequency range	Maximum allowed mean-squared electric field strength (V/m)	Maximum allowed mean-squared magnetic field strength (A/m)	Maximum allowed equivalent plane wave free-space power density (mW/cm^2)
300 kHz–3 MHz	80,000	0.5	20.0
3 MHz–30 MHz	800 (900/*f*)	0.005 (900/*f*)	180/*f*
30 MHz–300 MHz	800	0.005	0.2
300 MHz–1500 MHz	800 (*f*/300)	0.005 (*f*/300)	*f*/1500
1500 MHz–100 GHz	4000	0.025	1.0

Note: *f* = frequency.

A RECENT APPLICATION SCENARIO

The operation of this ordinance can best be illustrated by examining a recent case in some detail. In September 1995, an application was submitted by Cellco Partnership doing business as Bell Atlantic NYNEX Mobile to the Director of the City of Stamford Health Department for an advisory permit to construct, maintain, and operate a telecommunications facility. The Director of Health convened an expert panel to evaluate the proposed siting of this cellular telephone facility consisting of 12 directional antennas mounted on the facade of a mechanical penthouse on the roof of a building. The telecommunication equipment associated with the antennas would be located in a small room elsewhere in the building. The Laboratory's long involvement in bioelectromagnetics research resulted in the Director of Health selecting Henry A. Kues to chair the expert panel. The applicant selected Ronald C. Petersen, an engineer from Lucent Technologies (formerly AT&T Bell Labs), as its expert on the panel. The third member of the panel, chosen by the other two panel members, was Om P. Gandhi, chairman of the electrical engineering department at the University of Utah, which has a long history in the area of bioelectromagnetic research.

The evaluation of the proposed facility began with the panel taking broadband measurements to characterize the existing RF background radiation at the proposed cell site installation. These measurements were obtained at two locations on the roof of the building to be used. These values were combined into a single value representing the total ambient background radiation from all sources including contributions from AM and FM radio; VHF and UHF TV; specialized mobile radio; cellular radio; citizens band radio; and police, fire, and other emergency service radio stations.

The broadband measurements were taken with isotropic field-strength meters with high-sensitivity electric-field-strength probes. These meters allow the measurements to be displayed or electronically stored in the memory of peripheral equipment. A data logger was used to record data from the field-strength meter. It was programmed to determine and store the maximum, minimum, and average values of all detected signals over 6-min periods. In this case, all frequencies from 0.5 to 1500 MHz were measured. At the proposed cell site, the background RF radiation averaged over 6-min periods was not detectable with the equipment used (<0.005 $\mu W/cm^2$).

A second set of measurements was obtained to characterize the RF fields from a local cell site similar to the one proposed. These measurements consisted of both broadband (for ambient RF fields between 0.5 and 1500 MHz, including the cell site radiation) and narrowband determinations (to identify and quantify fields from the existing cell site). The antenna type, effective radiated power, and background RF environment were similar to the proposed facility. Therefore, these measurements were intended to serve as a reliable predictor of the total RF environment that will be encountered in the vicinity once the proposed facility becomes operational.

Broadband measurements were made in the same manner at this location as at the proposed site. Narrowband measurements were taken using a spectrum analyzer and a tunable dipole antenna. These measurements were taken in an office directly across the street from the cell site because this was the nearest location accessible to the public. The peak-hold feature of the spectrum analyzer was used to determine the maximum value of each signal, even though most were intermittent. To determine the worst-case estimate for the proposed cell site, the highest value determined at this location was multiplied by 19 (the maximum number of channels operating at a given time). Even under the projected worst-case scenario, the proposed cell site would emit only 0.46 μW/cm^2 or approximately 0.08% of the level permitted by the city of Stamford ordinance.

As prescribed in the ordinance, a public hearing was convened to provide a forum to discuss the issues and an opportunity for public input and education. Following opening remarks by Phyllis Mazik of the Stamford Health Department, the applicant's representative at the hearing provided a description of the proposed facility and the rationale for choosing this particular location for its cell phone antenna site. A member of the expert panel then described to the audience the measurement of background electromagnetic fields at the proposed site and the measurements obtained at a similar cell site. These measurements were compared with the standard set by Chapter 160 of the city of Stamford ordinance. To provide an additional reference point for the audience, the measurements were also compared with other guidelines and international standards. As noted previously, a worst-case scenario would produce exposure levels that are considerably less than the most stringent safety standards.

The general public was then invited to present specific questions or concerns to members of the panel. The panel addressed each of the issues raised by the public in detail, with a primary focus toward education. For example, the panel was asked if the proposed facility would significantly affect the existing complex electromagnetic environment in the immediate area as well as distances up to 1 mi from the facility. Each member of the panel (Kues, Petersen, and Gandhi), in responding to this question, informed the public that background measurements were conducted at the site, and when these measurements were added to the calculated emissions for the proposed facility, the panel felt that the new facility would not substantially alter the current environment to a point of concern for the public's safety. Further, the calculated emissions added to environmental levels at a distance greater than 0.5 mi or more would be insignificant.

Another question concerned the possibility of tampering with the equipment used to measure emissions to give biased readings in favor of the applicant. Petersen responded that all test equipment was calibrated as recommended by the manufacturer and is traceable back to the National Institute of Standards and Technology, and that there was no evidence of tampering with the calibration of the equipment. Further, Kues stated that the measurements were witnessed not only by the panel members but by Stamford Health Department representatives.

During this period of public questioning, an individual stated that she had an ocular problem. She asked whether the antennas would adversely affect someone with eye problems or if the antennas could possibly generate ocular problems. Kues responded that although it has been reported that exposure to electromagnetic radiation can produce ocular effects such as cataracts, the levels calculated for the proposed facility are far below those known to cause any ocular problems.

Other questions were asked regarding the number of studies that directly address the question of health effects from low-level, long-term exposure; whether the measurements were taken at a time of day that represented peak usage of the proposed facility; and whether the proposed facility will be accessible to the public. Each question was addressed by members of the panel. However, questions pertaining to issues other than potential exposure levels and health, such as zoning and property values, were not addressed because they were beyond the scope and purpose of the meeting. The public was also given an opportunity to submit documents for consideration by the panel in making its recommendation to the Health Department concerning the proposed facility. A letter from a physician with Kaiser Permanente and documents from The Planetary Association for Clean Energy, Inc., and The Environmental Council of Stamford were received and considered.

The expert panel unanimously recommended approval of the proposed facility after reviewing the application, the RF measurements from the facility and a comparable operating cell site, the concerns raised during the public hearing, and other pertinent documents. On the basis of the available scientific information, the panel concluded that adverse health effects were unlikely to result from the RF or microwave

emissions from the proposed antenna installation, and that potential exposure levels were substantially below the most stringent existing standards. The panel recommended that the proposal be accepted without modification on the condition that a caution sign be posted at all rooftop entrances that allow public access to the antennas.

SUMMARY

The question of electromagnetic radiation and its effect on people is of national and international importance. The need and desire for technological advancement have outpaced science's ability to provide an answer to the question of public safety because of severely limited research funding, which has declined steadily since 1981. Because of the lack of funding and the inability of our government to provide an enforceable safety standard, municipalities such as Stamford have resorted to alternative measures. The general public looks to government to protect public health with conservative standards that provide maximum safety. A federal standard, in contrast to numerous local ordinances, would provide uniformity. In lieu of an absolute answer to safety, the Stamford Health Department, via its ordinance, applies existing scientific knowledge and expertise to its decision-making process.

Facility inspections and ordinance enforcement are usually most efficient at the local level. Local agencies are readily accessible and interface more directly with the public. At the Stamford Health Department, local residents can peruse information, reports, and exposure measurements regarding antenna installations. The antenna ordinance has proved to be of tremendous value in providing a forum for educating the public and in allowing the Health Department to consider the best available science prior to facility installation. To date, no application has been denied, some safety concerns have been addressed, and the process appears to have reduced or eliminated legal challenges. Overall, this process offers a current scientific base that allays many fears and concerns of both the general public and the local government. The boxed insert provides a recent update on the status of the Stamford ordinance.

EPILOGUE

Over the past several years, the Stamford ordinance has been challenged. For example, in 1994, the Electromagnetic Energy Association (formerly the Electromagnetic Energy Policy Alliance) petitioned the Federal Communications Commission (FCC) to preempt state and local regulations on the licensing of cellular telephone towers, citing examples of local and state regulations that have set tighter emissions standards than those used by the FCC.[23] On 8 February 1996, President Clinton signed a law stipulating that state and local governments will retain general authority in "placement, construction and modification of personal wireless service facilities," but can no longer deny permits based on RF or microwave levels. The FCC will be responsible for RF and microwave guidelines and was required to adopt an exposure standard by 5 August 1996.[24] On 1 August 1996, the FCC adopted new guidelines for evaluating the environmental effects of RF emissions from regulated transmitters, such as cellular and personal communications service antennas and telephones, broadcast antennas, and satellite communications antennas.[25] These guidelines are based on existing recommendations by the National Council on Radiation Protection and Measurement and the American National Standards Institute/Institute of Electrical and Electronics Engineers.

The new FCC guidelines provide for federal preemption of state and local regulation of personal wireless service facilities. Therefore, the city of Stamford is now required to use the FCC exposure limits to assess the potential health effects of proposed facilities rather than the safety levels specified in the Commonwealth of Massachusetts' Radio Frequency Exposure Limits. Ironically, the maximum permissible exposure (power density) levels outlined by the FCC guidelines are identical to the Commonwealth of Massachusetts' exposure limits, i.e., from 3 MHz to 100 GHz. In addition, the FCC guidelines require timely processing of applications for proposed facilities. City of Stamford Health Department officials are attempting to streamline their application process to abide by this requirement, and will continue to enforce its ordinance to protect the public from exposure to excessive levels of RF radiation.

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ACKNOWLEDGMENTS: The authors would like to thank Andrew D. McBride, M.D., M.P.H., Director, Department of Health, and the city of Stamford for the opportunity to present the work described in this article. We extend our thanks also to Terry L. Kues for her assistance in bringing our thoughts together.

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