

GAO

Report to the Chairman, Subcommittee
on Telecommunications and Finance,
Committee on Energy and Commerce,
House of Representatives

November 1994

TELECOMMUNICATIONS

Status of Research on the Safety of Cellular Telephones





United States
General Accounting Office
Washington, D.C. 20548

**Resources, Community, and
Economic Development Division**

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November 4, 1994

The Honorable Edward J. Markey
Chairman, Subcommittee on
Telecommunications and Finance
Committee on Energy and Commerce
House of Representatives

Dear Mr. Chairman:

In response to your request, this report addresses the status of scientific knowledge on the biological effects of the radio-frequency radiation that portable cellular telephones emit and the federal government's regulatory actions to ensure the safety of these telephones. The report contains a recommendation aimed at increasing the potential usefulness to federal agencies of a current industry research initiative.

As agreed with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after the date of this letter. At that time, we will send copies to the commissioners of the Federal Communications Commission, the Commissioner of the Food and Drug Administration, the Administrator of the Environmental Protection Agency, and other interested parties. We will also make copies available to others on request.

This report was prepared under the direction of Kenneth M. Mead, Director, Transportation and Telecommunications Issues, who may be reached on (202) 512-2834 if you and your staff have any questions. Major contributors to this report are listed in appendix VI.

Sincerely yours,

Keith O. Fultz
Assistant Comptroller General

Executive Summary

Purpose

Over 16 million Americans now use cellular telephones—about a third of which are hand-held portable cellular telephones—and the industry estimates that by the year 2000 over 60 million people will be using a portable cellular communications device. In response to reports in the media alleging that hand-held cellular telephones may pose a health risk, the Chairman, Subcommittee on Telecommunications and Finance, House Committee on Energy and Commerce, asked GAO to review (1) the status of scientific knowledge on the potential health risks of the radio-frequency radiation emitted by portable cellular telephones and the status of federal involvement in any related research and (2) the actions of responsible federal agencies to ensure the safety of cellular telephones.

Background

All devices that transmit radio-frequency signals—such as radio broadcast towers and cellular telephones—emit radio-frequency radiation. At sufficient power levels, radio-frequency radiation can produce immediate biological damage, such as burns (thermal effects). The American National Standards Institute's (ANSI) 1982 standard for radiation exposure indicates that devices operating on 7 watts or less of power at frequencies below 1,000 megahertz will not produce immediate thermal effects. Portable cellular telephones operate on much less than 7 watts of power (up to a maximum of only 0.6 watts) at frequencies between 800 and 900 megahertz. While the telephones operate below the threshold for thermal effects, the low-level radiation emitted from an antenna that is held close to the user's head raises questions about whether long-term exposure to low-level radiation near the body can also produce biological damage.

Several federal agencies play a role in ensuring the safety of cellular telephones. The Federal Communications Commission (FCC) approves cellular telephones for use and is responsible for ensuring that FCC-approved equipment does not emit radiation at levels determined to adversely affect the human environment. To ensure electronic product safety, the Food and Drug Administration (FDA) is responsible for establishing performance standards for products that emit radiation and for conducting, coordinating, and supporting research to minimize the emission of, and exposure of people to, such radiation. The agency reviews industry research on products and may subsequently use such research in carrying out its responsibilities for product safety. It also works with manufacturers on the voluntary redesign of equipment as a cost-effective strategy when safety questions are raised but the scientific evidence does not necessarily justify issuing a performance standard. The Environmental Protection Agency (EPA) is responsible for advising the

President on radiation matters, including providing guidance to other federal agencies on permissible levels of exposure to radio-frequency radiation.

Results in Brief

No research has been completed on long-term human exposure to low levels of radiation specifically from portable cellular telephones. Research findings on exposure to other sources of low-level radio-frequency radiation are inconclusive. Some laboratory studies show that biological effects can occur when animals and cells have undergone extended exposure to low-level radio-frequency radiation; others do not. Scientists at FDA and EPA said that existing research does not provide enough evidence to determine whether portable cellular telephones pose a risk to human health. The National Institutes of Health (NIH) is beginning an epidemiological study, which could determine the relationship between portable cellular telephone use and disease.¹ However, according to FDA and the National Science Foundation, both epidemiological and laboratory studies are needed to determine any linkage between the use of portable cellular telephones and adverse health effects. The cellular telecommunications industry is planning to do both types of studies. If federal regulators want to use this research, they need to be assured that it is carried out objectively.

On the basis of present scientific knowledge, FDA and EPA have had no reason to take regulatory actions on the use of portable cellular telephones. However, FDA, consistent with its adherence to the principle that human exposure to radiation should be “as low as reasonably achievable,” is working with cellular telephone manufacturers on the possibility of redesigning portable cellular telephones and on providing users with instructions for proper use. FCC has proposed adopting a revised ANSI standard for equipment it approves; this standard may be applied to cellular telephones.

Principal Findings

Status of Research

Studies on exposure to low levels of radio-frequency radiation from sources other than portable cellular telephones have found biological and behavioral effects in animals and certain cell systems. However, both FDA

¹An epidemiological study is a statistical study that relates the occurrence of a disease to the characteristics of people and their environment.

and EPA believe that the evidence is insufficient to conclude that these effects pose a health risk to humans as a result of exposure to radio-frequency radiation from low-power sources like portable cellular telephones.

The federal government is beginning research that specifically focuses on the safety of cellular telephone use. For example, NIH's National Cancer Institute has begun an epidemiological study of patients with brain cancer to determine if there is a statistical relationship between cellular telephone use and cancer. However, controlled laboratory studies on animals and living cells are also needed, according to FDA and the National Science Foundation, to determine if radiation from portable cellular telephones poses a human health risk. The Cellular Telecommunications Industry Association is funding a science advisory group that will sponsor research on the safety of cellular telephones. This research initiative, which includes human and laboratory studies, could provide the kind of comprehensive information necessary to assess the health risks of cellular telephones. To the extent that federal regulators may want to use this research, they will need to be assured that the research is well designed and carried out objectively. The chairman of the advisory group said that it would be open to federal participation in order to increase the acceptance and usefulness of the research.

Federal Actions Are Limited

When evidence is insufficient to justify developing a product standard, FDA sometimes works with manufacturers of electronic products to develop voluntary precautionary measures. In the case of portable cellular telephones, FDA has been working with manufacturers on the possibility of redesigning the placement of the antenna so that this source of radiation is farther from the user's head. It also is working with manufacturers on practical instructions for use to limit users' exposure to radiation. Unless future research provides sufficient evidence of a health problem, or a substantial number of complaints are filed with FDA, the agency does not plan to use its limited resources to develop product standards for portable cellular telephones. Instead, it plans to undertake higher-priority research—on the safety of medical devices, for example.

EPA is working on developing exposure limits to protect the public from exposure to high levels of radiation. However, the agency said that present scientific information does not provide a basis for recommending exposure limits for low-level radiation—the type emitted by cellular telephones. EPA has funded a 2-year study by the National Council on

Radiation Protection and Measurements to gain a better understanding of the status of research on the effects of long-term exposure to low levels of radio-frequency radiation and future research needs.

FCC does not consider itself a health agency and turns to health and radiation experts outside the agency for guidance on these issues. There are no federal product safety standards for cellular telephones, and because there is no federal guidance on radiation exposure limits, FCC has incorporated the 1982 ANSI standard into its environmental rules. The Commission considers portable cellular telephones safe under this standard. However, FCC has proposed updating its environmental rules by adopting the revised version of the ANSI standard. According to an agency official, portable cellular telephones could then become subject to routine environmental evaluation for radiation emissions before FCC approves them for use.

Recommendation

GAO recommends that the Commissioner of the Food and Drug Administration and the Administrator of the Environmental Protection Agency, in coordination with the Chairman of the Federal Communications Commission, work with the industry's Science Advisory Group on Cellular Telephone Safety to maximize the usefulness, independence, and objectivity of the group's planned research initiative. This effort could include participating in the selection of research proposals to determine whether they meet federal research standards and reviewing research results. This effort would be in addition to ongoing and planned federal research.

Agency Comments

GAO discussed a draft of this report with officials from (1) FDA's Office of Science and Technology, including the Chief of the Radiation Biology Branch; (2) EPA's Office of Radiation and Indoor Air, including the Electromagnetic Fields Team Leader in the Radiation Studies Division; and (3) FCC's Office of Engineering and Technology, including the Chief Engineer. The FDA and EPA officials generally agreed that the information was accurate and that the current state of scientific knowledge is insufficient to determine whether portable cellular telephones pose health risks. In addition, the FDA and EPA officials said they plan to review the industry's completed research. These officials' comments have been incorporated in the text as appropriate. As requested, GAO did not obtain written agency comments on this report.

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Abbreviations

ANSI	American National Standards Institute, Inc.
CDMA	code division multiple access
CTIA	Cellular Telephone Industry Association
DOD	Department of Defense
EPA	Environmental Protection Agency
FDA	Food and Drug Administration
FCC	Federal Communications Commission
GAO	General Accounting Office
IEEE	Institute of Electrical and Electronics Engineers, Inc.
MHz	megahertz
mW	milliwatt
NCI	National Cancer Institute
NEPA	National Environmental Policy Act of 1969
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
TDMA	time division multiple access

Introduction

Cellular telephones, first marketed in 1983, have become one of the fastest selling consumer electronic products. By the end of 1993, over 16 million Americans were using cellular telephones, and the industry estimates that in less than a decade, over 60 million Americans will be using a cellular communications device. About one-third of all cellular telephones currently in use are hand-held portable models, which are growing in popularity. Industry forecasters predict a high demand for a new generation of personal communications devices that will offer a greater range of uses. Technology enthusiasts envision a future in which nearly all Americans will have a wireless portable communications device.

Cellular Communications Equipment and Technology

Cellular telephones come in a variety of styles, but all fall into the following three general categories:

- car telephones, in which the telephone is installed in the vehicle and the antenna is mounted on the roof, trunk, or rear window;
- transportable telephones, in which the telephone body, antenna, and handset are carried in a briefcase or bag, but the handset is separated from the body and antenna for use; and
- portable telephones,² in which a self-contained handset houses a battery and an antenna in a unit generally small enough to fit in a purse or pocket.

Portable cellular telephones are the subject of this report because—unlike with car telephones and transportable telephones—their antenna is very close to the user's head when the telephone is in use. Figure 1.1 shows some typical models of portable cellular telephones and the proximity of the antenna to the user's head.

²Portable cellular telephones are not the same as the cordless telephones commonly used in the home. Cordless telephones transmit to a base unit connected to the telephone wiring in a house and operate at far lower power levels and frequencies than portable cellular telephones.

Figure 1.1: Four Typical Models of Portable Cellular Telephones



(From left to right) Telephone A is an example of the first style of hand-held portable cellular telephone; it is characterized by a bulky body and a nonretractable antenna. It is heavier than most of the newer portable cellular telephones. Telephone B is an example of the “flip-style” cellular telephone; it features a mouthpiece that can be folded over the keypad and a retractable antenna for storage while not in use. Telephone C is an example of a nonflip-style telephone; it has a shorter nonretractable antenna. Telephone D is the newest style of portable cellular telephone; it is designed to transmit and receive digital signals.

All devices that transmit radio signals—such as radio broadcast towers and cellular telephones—emit radio-frequency radiation. Radio-frequency radiation is electromagnetic energy emitted in the form of waves. Cellular telephones transmit voice messages by sending electronic signals from an antenna over radio waves at frequencies between 824 and 894 megahertz (MHz).³ These signals are a form of radio-frequency radiation.

At sufficient power levels, radio-frequency radiation can heat body tissue and cause biological damage such as burns. These effects of exposure to radio-frequency radiation, called thermal effects, are immediately observable. According to the 1982 American National Standards Institute’s (ANSI) standard for radiation exposure, a nongovernment standard that some federal agencies use, devices operating on 7 or less watts of power at frequencies below 1,000 MHz will not produce immediate thermal effects.⁴ Portable cellular telephones operate on well below 7 watts of power. They use up to a maximum of 0.6 watts of power—less than the amount of power required to light a flashlight bulb. However, questions have been raised about whether long-term or frequent exposures to low levels of radio-frequency radiation have other biological effects that are delayed or not immediately observed in human cells and animals.

Portable cellular telephones transmit messages to a cellular transmitter tower. More power is required to transmit a signal when the telephone is farther away from a tower. For example, if a caller is located at a great distance from the tower, the telephone may use the full 0.6 watts of power to transmit the signal. However, if the caller is near the tower, the

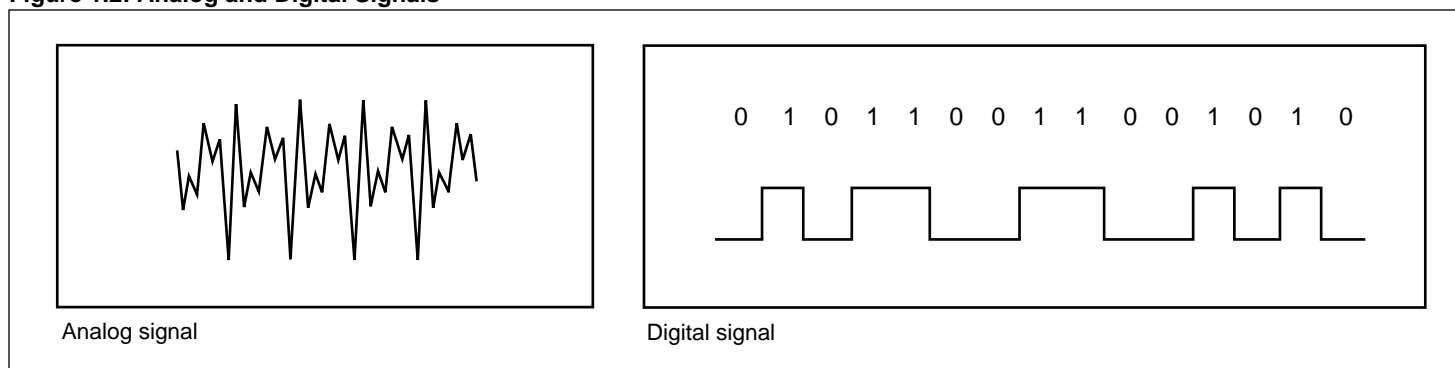
³Some other uses of radio frequencies are FM radio stations, which broadcast between 88 and 108 MHz, and television stations, which broadcast between 54 and 806 MHz. Microwave ovens heat food using radio frequencies ranging from 890 to 6,000 MHz.

⁴Safety Levels With Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 300 kHz to 100 GHz, ANSI C95.1-1982, American National Standards Institute, Inc. (1982).

telephone may only need to use about 0.2 watts of power to transmit the signal.

Cellular telephones transmit either analog or digitized voice messages, depending on the type of cellular telephone used and the service available. In analog radio communication systems, messages are transmitted by modulating, or varying, either the amplitude (height) or the frequency (number of wave crests) of the radio wave. In digital communication systems, messages are transmitted as a series of digits in rapid bursts, or pulses. These are sometimes referred to as pulse-modulated signals. An advantage of digital transmission is that it increases channel capacity by allowing several users to transmit messages over the same radio wave simultaneously. As figure 1.2 shows, analog signals are continuous radio waves, while digital signals are binary—usually represented by ones and zeroes. (See app. I for additional information on these two technologies.)

Figure 1.2: Analog and Digital Signals



The next generation of cellular communications is called personal communications services. In this system, inexpensive, pocket-sized communications devices that use digital technology will deliver voice, data, and images. They will operate at higher radio frequencies (between 1,850 and 2,200 MHz) and will likely use less power to operate than the current generation of portable cellular telephones. A personal communications device carried from place to place will enable the person to be reached at any location by dialing a single telephone number. Because personal communications services devices are still under development, it is not clear whether the antenna will be in close proximity to the user's head when the device is in use.

Federal Regulation

Three federal agencies play a role in ensuring the safety of cellular telephones by sharing responsibility for regulating devices that emit radio-frequency radiation and protecting the public from exposure to radiation: the Food and Drug Administration (FDA), the Environmental Protection Agency (EPA), and the Federal Communications Commission (FCC).

Under the Radiation Control for Health and Safety Act of 1968, as amended, FDA is responsible for establishing and carrying out a program, designed to protect public health and safety, to control radiation from electronic products. These responsibilities include (1) developing and administering performance standards for electronic products; (2) planning, conducting, coordinating, and supporting research, development, training, and operational activities to minimize the emissions of, and exposure of people to, unnecessary radiation from electronic products; and (3) developing, testing, and evaluating the effectiveness of procedures and techniques for minimizing exposure to electronic product radiation. FDA has the authority to set performance standards for electronic products if it determines that such standards are necessary for the public health and safety. In carrying out its responsibilities, FDA reviews and comments on industry research and also works with electronic product manufacturers when it receives complaints or has some concerns about a product but lacks sufficient scientific evidence to determine if a performance standard is necessary. Consistent with the principle of keeping exposure “as low as reasonably achievable,” FDA has worked with a variety of manufacturers to reduce radiation emissions. For example, FDA has worked with manufacturers of video display terminals and police radar devices to address concerns about excessive exposure to radiation and with manufacturers of electric blankets to redesign the blankets to reduce electric and magnetic fields.

Under the Federal Radiation Council Authority, transferred to EPA by Reorganization Plan No. 3 of 1970, EPA is responsible for, among other things, advising the President on radiation matters, including providing guidance for all federal agencies on formulating protective standards on radiation exposure. Upon presidential approval of EPA’s recommendation on formulating standards, the pertinent federal agencies would be responsible for implementing the guidance. Under the National Environmental Policy Act of 1969 (NEPA), FCC is required to consider whether its actions—including actions that may lead to human exposure to radio-frequency radiation—in authorizing communications equipment significantly affect the quality of the human environment.

Objectives, Scope, and Methodology

The Chairman of the Subcommittee on Telecommunications and Finance, House Committee on Energy and Commerce, requested that we review (1) the status of scientific knowledge on the potential health risks of radio-frequency radiation emitted by portable cellular telephones and federal involvement in any related research and (2) the actions of the responsible federal agencies to ensure the safety of portable cellular telephones and similar communications devices.

To assess the status of scientific knowledge on the health risks of portable cellular telephone use, we met with scientists who have conducted research on cellular telephones and visited industry, university, and government laboratories where research is taking place. We met with scientists and researchers in the field of electromagnetic radiation at the Department of Defense, EPA, FCC, FDA, and the National Academy of Sciences. (See app. II for a list of the researchers and scientists we consulted for this report.) We also obtained the opinions of many federal agencies with representation on the Committee on Interagency Radiation Research and Policy Coordination within the Executive Office of the President.⁵

We discussed the safety of portable cellular telephones with the president of the Bioelectromagnetics Society; the co-chairs of a subcommittee established by the Institute of Electrical and Electronics Engineers, Inc., which set the latest exposure standard for radio-frequency radiation exposure; and a vice-president of Motorola, Inc., a leader in cellular telephone research. In addition, we met with officials from the National Council on Radiation Protection and Measurements and the Cellular Telecommunications Industry Association.

We collected information on regulatory actions regarding the safety of portable cellular telephones from the responsible federal agencies. We discussed with FCC officials the actions they have taken to ensure the safe use of cellular telephones. We examined FCC's records and rulemakings on the agency's process for authorizing portable cellular telephones and FCC's implementation of requirements under NEPA. We discussed with FDA officials their procedures for setting performance standards for electronic products and their plans for cellular telephones. Finally, we discussed

⁵The Committee on Interagency Radiation Research and Policy Coordination, made up of representatives from 18 federal agencies, acts as a coordinator and evaluator of the federal research effort on radiation issues. It also coordinates radiation policy among agencies, resolves policy conflicts, and advises on the formulation of broad radiation policy. At the time of this report, the committee's technical adviser told us that the committee had not evaluated federal research needs for radio-frequency radiation (which is non-ionizing radiation) but instead has focused on ionizing radiation from sources such as nuclear energy.

Chapter 1
Introduction

with EPA officials, and reviewed documents on, EPA's efforts to develop federal guidance for setting standards for human exposure to radio-frequency radiation. We conducted our review between March 1993 and October 1994 in accordance with generally accepted government auditing standards.

Existing Data on Exposure to Low-Level Radio-Frequency Radiation Are Inconclusive

To date, neither the federal government nor the telecommunications industry has completed any studies to determine specifically if the use of portable cellular telephones poses health risks. While a few recent studies suggest that long-term exposure to low levels of radio-frequency radiation (similar to that emitted by portable cellular telephones) may prompt interactions within and among cells and organs that could possibly lead to adverse effects, other studies do not. FDA and EPA agree that the research completed to date is insufficient to determine whether using portable cellular telephones presents risks to human health.

Available Scientific Data Are Insufficient to Assess Health Risks of Cellular Telephones

The two basic sources of evidence of the relationship between a potential risk factor, such as exposure to radio-frequency radiation, and a disease are epidemiological studies (statistical studies that relate the occurrence of a disease to the characteristics of people and their environment) and laboratory studies on animals and biological tissue samples. According to FDA and the National Science Foundation, both types of research are needed to determine whether cellular telephone use poses any health risks.

To date, no epidemiological studies have been conducted of human exposure to radio-frequency radiation as a result of using cellular telephones. Some recent biological and behavioral laboratory studies on animals and cell samples have provided information on the potential health effects posed by low-level exposure to radio-frequency radiation, although none has examined radiation exposure specifically from cellular telephones. FDA has questioned the interpretation, significance, or applicability of the studies' findings to cellular telephones. According to EPA, the significance of recent research suggesting a potential for adverse health effects cannot be determined until these studies have been independently confirmed. Because of the limitations of the research, FDA and EPA agree that more research would be necessary to determine whether portable cellular telephones pose a human health risk.

The following are examples of some research results that scientists say have raised questions about exposure to low-level radiation similar to that emitted by portable cellular telephones, especially pulse-modulated radiation, which is comparable to digital signals. (See app. III for more information about some of these studies and app. IV for a list of other relevant studies.)

- A University of Washington study found that rats had difficulty learning a maze exercise after 45 minutes of exposure to low-level, pulsed radio-frequency radiation near the frequencies that personal communications devices will use.⁶ The researchers concluded that exposure to low-power radio-frequency radiation appears to decrease certain chemical agents in the rodents' central nervous system essential for spatial learning.
- In a 1983 study of cells from the immune system,⁷ the researchers found that the effectiveness of certain immune system cells in fighting off tumor cells was temporarily diminished after only 4 hours of exposure to low-power, pulsed radio-frequency radio signals. The researchers found that the effectiveness of the immune system cells was diminished most when the radio-frequency radiation was pulse-modulated 60 times per second, slightly more than the 50 times per second that digital cellular telephone signals "pulse." (See app. I for information on digital signals.)
- In a 1991 study,⁸ the researchers found that low-power radio-frequency radiation may facilitate the development of cancer in the presence of other substances known to cause cancer. They found that when cells were exposed for 24 hours to low-level, pulsed radio-frequency radiation alone, there was no effect on the cells' survival or transformation into tumor cells. However, when the cells were treated with a tumor-promoting chemical, exposure to radio-frequency radiation significantly enhanced the transformation of the cells into tumor cells.

Although these and a few other studies suggest that exposure to low levels of radio-frequency radiation may cause effects in animals and certain cell systems, other studies do not. For example, in a 1993 study, researchers injected brain tumor cells into rats and exposed them to low levels of radio-frequency radiation—near the frequency that cellular telephones use—that was either continuous (as in analog technology) or pulsed 50 times per second (as in digital technology).⁹ The rats were exposed for 5

⁶H. Lai, A. Horita, and A. W. Guy, "Neural Mechanisms Involved in Microwave-Induced Deficit in Radial-Arm Maze Performance," Department of Pharmacology and Center for Bioengineering, University of Washington, Seattle, Wash. (presented at the Bioelectromagnetics Society meeting, Feb. 1993).

⁷D. B. Lyle, P. Schechter, W. R. Adey, and R. L. Lundak, "Suppression of T-Lymphocyte Cytotoxicity Following Exposure to Sinusoidally Amplitude-Modulated Fields," *Bioelectromagnetics*, 4:281-292 (1983).

⁸E. K. Balcer-Kubiczek and G. H. Harrison, "Neoplastic Transformation of C3H/10T-1/2 Cells following Exposure to 120-Hz Modulated 2.45-GHz Microwaves and Phorbol Ester Tumor Promoter," *Radiation Research*, 126:65-72 (1991).

⁹L. G. Salford, A. Brun, B. R. R. Persson, and J. Eberhardt, "Experimental Studies of Brain Tumor Development During Exposure to Continuous and Pulsed 915 MHz Radiofrequency Radiation," *Biochemistry and Bioenergetics*, 30:313-318 (1993).

days a week until clinical signs of tumor development occurred. Researchers found no evidence that radio-frequency radiation treatment altered the course of tumor development in the rats.

Federal Research Has Been Limited

Several federal agencies sponsor radiation research, but none has sponsored or performed any studies on portable cellular telephones. Of 15 federal departments and agencies we contacted, only 4 had conducted, funded, or planned research on radio-frequency radiation that these agencies said may be relevant to questions about the safety of cellular telephones. These four were FDA, the National Institutes of Health's National Cancer Institute (NCI), the Department of Commerce's National Institute of Standards and Technology, and the Department of Defense. Only NCI has planned research that specifically focuses on portable cellular telephone use.

Food and Drug Administration (FDA)

FDA is not performing or contracting for research specifically addressing the power levels or frequencies of cellular telephones. However, FDA officials said that some research the agency supports may be relevant to safety questions about these telephones. According to officials, FDA-supported research at the Johns Hopkins Applied Physics Laboratory found that permanent damage occurred to the eyes of test animals when the animals were exposed to low-level microwave radiation. According to one of the researchers, this effect was enhanced when the test animals were treated with drugs commonly used in glaucoma treatment and exposed to radio-frequency radiation at power levels several times lower than those typically emitted by portable cellular telephones.

National Cancer Institute (NCI)

In 1993, NCI launched an epidemiological study to assess the relationship between the use of cellular telephones, among other variables, and the brain cancer newly diagnosed in 800 patients. An NCI official expects this study to be completed between 1998 and 1999. In addition, NCI has planned other epidemiological studies to determine whether (1) exposure to radio-frequency radiation, among other possible risk factors, is associated with an increased risk of brain tumors, and (2) the incidence of cancer can possibly be linked with the use of portable cellular telephones. These studies involve comparing the names on lists of cellular telephone users in New York State with the names on New York's statewide cancer registry. According to NCI, these studies should be initiated during 1995. However, it is important to note that epidemiological studies do not prove causality

between two factors; they merely show that two factors, such as exposure to radio-frequency radiation and a disease such as cancer, tend to occur together.

National Institute of
Standards and Technology
(NIST)

In 1990, NIST measured the amount of radiation emitted by portable police radios operated at frequencies near those used by portable cellular telephones. NIST researchers found that the strength of the electric fields emanating from the police radios exceeded the exposure levels recommended as safe under the 1982 ANSI standard. However, this study did not attempt to assess whether exposure to these electric field emissions could present risks to human health.

Department of Defense
(DOD)

DOD is sponsoring research into the biological effects of radio-frequency radiation but not radiation from portable cellular telephones. However, with the anticipated proliferation of new telecommunications devices, DOD supports continued work to characterize and measure the absorption and distribution of radio-frequency energy in the human body. The Department's official position is that harmful effects will not occur as a result of exposure to portable cellular telephones as long as the amount of radio-frequency energy absorbed by the human body is maintained at or below permissible levels. DOD relies on the "permissible levels" recommended by the 1982 ANSI standard, which states that devices operating on 7 watts of power or less, like portable cellular telephones, are not likely to exceed permissible levels.

Industry Is
Undertaking Research
on Safety of Cellular
Telephones

We identified two major efforts by the cellular telephone industry to specifically address the safety of portable cellular telephones: one sponsored by Motorola, Inc., and one proposed by the Cellular Telecommunications Industry Association (CTIA), a cellular telephone industry association.

In 1991, Motorola, Inc., entered into a multiyear contract with a researcher—considered by many in the scientific community to be the most eminent U.S. researcher in this area—to conduct a series of laboratory studies on radio-frequency radiation from portable cellular telephones. These studies are examining the effects of analog and digital signals from these telephones on animals and cells but do not include studies of effects on humans. Results from the animal studies are anticipated within the year.

In January 1993, in response to public concern that portable cellular telephones may cause health risks, including brain cancer, CTIA announced an initiative to spend from \$15 million to \$25 million over the next 3 to 5 years to fund studies addressing the safety of portable cellular telephones. In May 1993, CTIA, along with other members of the cellular telephone industry, established a Science Advisory Group on Cellular Telephone Safety. The science advisory group's planned research agenda includes multidisciplinary studies involving epidemiology, cell cultures, test animals, and genetic research. The research will examine the effects of exposure to analog and digital radio-frequency radiation at the power levels and frequencies that cellular telephones use and that personal communications devices will use. The research agenda also includes scientific peer review of proposed research projects by a separate board coordinated through the Harvard University Center for Risk Analysis.

The chairman of the science advisory group also informed us that CTIA funds the group's activities on a monthly basis; each month the chairman submits an estimate of costs for the coming month, and CTIA provides money for that month's research activities. The chairman explained that the peer review board will evaluate and recommend research proposals for funding. According to the chairman, payment for peer review activities will be provided through a blind trust established by the advisory group. The chairman stated that the purpose of creating the blind trust for peer review was to provide independence. However, the science advisory group does not enjoy similar financial independence. The direct funding of the research by CTIA raises questions about the objectivity and credibility of the research effort. In September 1994, the chairman of the science advisory group told us that CTIA would consider giving up direct financial control by putting the research funds into a blind trust fund.

In September 1993, FDA told the chairman of the science advisory group that the agency would like to provide appropriate support within its means to assist in ensuring that the industry-sponsored research program was successful and credible. As a regulatory agency, FDA considers that reviewing research data and commenting on it is part of its job. However, the agency is reluctant to endorse research that is not yet completed resulting from programs it has not helped direct. Although the science advisory group has sought input from federal agencies and has had informal discussions with officials at FDA and EPA, no mechanism has been established for federal participation in or comments on the research program. However, in September 1994 the advisory group's chairman told

us that he was open to any role for federal agencies to increase the acceptance and usefulness of the research program.

Conclusions

FDA and EPA believe that there is insufficient evidence to determine whether exposure to low-level radio-frequency radiation presents a human health risk. Some recent studies have found that this radiation can produce biological effects. However, because none of these studies examined radio-frequency radiation specifically from portable cellular telephones, FDA and EPA agree that the value of the studies' findings is limited in determining whether using portable cellular telephones poses risks to human health.

FDA and National Science Foundation officials said that both epidemiological and laboratory research are needed to determine whether portable cellular telephones present risks to users. The federal government and private industry are beginning to undertake some of this needed research. NCI (the only federal agency performing research on the safety of cellular telephones) has started an epidemiological study to determine if there is a relationship between cellular telephone use and cancer. But epidemiological studies alone cannot conclusively establish whether using portable cellular telephones poses health risks. Motorola is funding a series of laboratory studies on the effects of radiation from portable cellular telephones on animals and cells but no epidemiological studies observing the effects on humans.

The cellular telephone industry is sponsoring a research initiative through a science advisory board that includes both types of research that federal officials say is needed. However, direct funding of this research by CTIA—an industry association—raises questions about the independence and objectivity of the science advisory group's planned research program. The chairman of the science advisory group has had informal discussions with federal agencies and has expressed a willingness to accept a greater federal role to increase the independence and objectivity of the research. Such a role could also increase the usefulness of the research results to federal regulators. To date, neither the science advisory group nor any of the federal agencies have attempted to define what this role might entail.

Federal Actions Have Been Limited by Lack of Evidence of Health Risks

Given the current state of scientific knowledge, FDA and EPA have not had a basis for taking regulatory actions on portable cellular telephones. However, FDA, EPA, and FCC are undertaking or considering limited activities that could affect the use of such telephones. FDA is working with cellular telephone manufacturers on possible design changes for these telephones and improved instructions for use. EPA is sponsoring a study on the status of research on the effects of exposure to low levels of radio-frequency radiation to determine if protective guidance is needed on exposure to radiation from devices such as cellular telephones. FCC has proposed adopting the revised ANSI standard in its environmental rules and, as a result, may no longer exempt portable cellular telephones from routine radiation evaluation.

FDA Is Working With Cellular Telephone Manufacturers to Minimize Exposure to Radiation

An FDA official told us that FDA has primary responsibility for responding if communications devices, such as portable cellular telephones, pose a health risk. Although FDA says there is no evidence that cellular telephones are harmful, an FDA official stated that recent research on exposure to low-level radio-frequency radiation from other sources has the agency concerned about the possible adverse health effects of this type of radiation. In carrying out its responsibility for controlling public exposure to radiation from electronic products, FDA follows the principle that exposure to radiation should be kept to a level as low as can reasonably be achieved.

In early 1993, following allegations about the safety of portable cellular telephones, FDA met with the cellular telephone industry, including industry associations and cellular telephone manufacturers. The purpose of these meetings was to discuss potential problems and their solutions. As a result of these meetings, cellular telephone manufacturers agreed to examine all practical routes to reduce exposure, including possibly redesigning the telephones and providing users with adequate instructions for proper use. The goal of redesigning these telephones would be to change the placement of the antenna so that this source of radiation is farther from the user's head. According to an FDA official, instructions for use should include practical information on how users can limit their exposure. Although the industry representatives who met with FDA agreed to set up committees to work on these topics, as of October 1994, they had not reported back to FDA on the status of their efforts. Meanwhile, FDA says that if individuals are concerned about avoiding even potential risks, they could consider holding lengthy conversations on conventional telephones

and reserving the hand-held cellular telephones for shorter conversations or for situations in which conventional telephones are not available.

FDA does not believe it is justified in setting performance standards for cellular telephones at this time. The formal process for setting performance standards for electronic products is time-consuming and expensive, and FDA will not set them without clear scientific evidence that an electronic product poses a hazard to human health. FDA does not have such evidence for portable cellular telephones. In addition, an FDA official stated that the agency has received no reports through its complaint process of radiation injuries resulting from the use of cellular telephones. FDA officials said that the agency has invested its limited research resources into higher-priority work, such as medical devices that expose individuals to much higher levels of radio-frequency radiation than cellular telephones.

EPA Is Assessing Status of Scientific Knowledge on Prolonged Exposure to This Type of Radiation

EPA is responsible for advising the President on radiation matters, including developing federal guidance on radiation protection that can be used by other federal regulatory agencies. For example, FCC could use such guidance in approving communications equipment and FDA in determining if performance standards are needed for devices like portable cellular telephones. EPA officials told us that the agency expects to issue, by the end of 1994, recommended maximum permissible levels of exposure to radio-frequency radiation to protect people from immediate thermal effects. However, EPA officials also told us that because research on exposure to lower levels of radio-frequency radiation is inconclusive, the agency cannot issue any guidance for these exposures. To gain a better understanding of the status of research on the effects of long-term exposure to low levels of radiation and future research needs, EPA has funded a 2-year study by the National Council on Radiation Protection and Measurements, a nonprofit corporation chartered by the Congress. EPA officials expect this work to provide information that will be helpful for understanding whether the agency needs to provide protective guidance on exposure to low levels of radiation.

EPA's recent activities on radiation guidance followed a 1992 report by the agency's Science Advisory Board. The board recommended that EPA complete a process to provide guidance that it began in the late 1970s. As part of this process, EPA requested comments on four alternative

approaches for controlling public exposure to radio-frequency radiation.¹⁰ However, EPA discontinued its efforts to issue guidance in 1988 when it did not obtain agreement from federal agencies on which approach it should take.¹¹

FCC Depends on Other Agencies in Developing Health-Related Regulations

FCC is responsible for regulating cellular telephone service and authorizing the equipment used in providing that service. NEPA requires all federal agencies to consider whether their actions significantly affect the human environment. In carrying out its responsibilities under NEPA, FCC formulated environmental rules that require the Commission to consider whether its actions—including actions that may lead to human exposure to radio-frequency radiation—significantly affect the quality of the human environment.

FCC does not consider itself a health agency with the expertise to determine what levels of radiation exposure are unsafe. Instead, it relies on health and radiation expertise found in other federal agencies, such as FDA and EPA. According to an FCC official, FCC considers FDA the principle agency responsible for determining the health implications of using specific devices such as cellular telephones and for issuing performance standards. Similarly, FCC would prefer to rely on EPA for information on exposure to radio-frequency radiation.

Because there are no federal guidelines on radiation exposure, in 1985 FCC incorporated the 1982 ANSI exposure standard into its environmental rules. This standard applies to higher-powered transmitting equipment, such as radio and television broadcast towers, but excludes devices that operate on or below 7 watts of power at frequencies below 1,000 MHz. FCC does not require routine environmental evaluation of portable cellular telephones in authorizing their use because they operate on less than 1 watt of power. However, as a safeguard, FCC's rules permit any interested party, including FCC, to move that the exempted equipment be required to undergo environmental evaluation. Thus far, no such motion has been made about portable cellular telephones. In addition, the Commission considers portable cellular telephones safe under this standard. (See app. V for more information on the evolution of FCC's environmental rules and rules on cellular telephone service.)

¹⁰Three of the alternatives were EPA's proposals for specific exposure limits based on varying degrees of safety from thermal effects. The fourth alternative called for EPA, in lieu of issuing federal guidance, to provide information and technical assistance programs to federal agencies, states, or industry.

¹¹According to EPA, under this notice and comment procedure, it is EPA's practice to recommend an alternative to the President as proposed federal guidance only if all the federal agencies providing comments agree on one of the proposed alternatives.

In 1993, FCC proposed adopting the revised version of the ANSI standard to update its environmental rules.¹² According to an FCC official, the revised version is more stringent than the older version, and, for the first time since FCC began regulating cellular telephone service, portable cellular telephones could be subject to environmental evaluation. Until this new standard is adopted, cellular telephones will continue to be excluded from routine environmental evaluation for public exposure to radiation. In contrast, FCC has already decided that it will require certain emerging hand-held personal communications services devices to comply with the revised ANSI standard, pending its adoption of this standard in its environmental rules.¹³

Conclusions

FDA, EPA, and FCC are undertaking limited activities that may affect the use of portable cellular telephones. Without additional scientific information, FDA and EPA have no basis for taking regulatory actions. The federal and industry research discussed in chapter 2 could provide information that would help these agencies determine whether any regulatory actions are needed.

Recommendation

We recommend that the Commissioner of the Food and Drug Administration and the Administrator of the Environmental Protection Agency, in coordination with the Chairman of the Federal Communications Commission, work with the industry's Science Advisory Group on Cellular Telephone Safety to maximize the usefulness, independence, and objectivity of its planned research initiative. This effort could include participating in the selection of research proposals to determine whether they meet federal research standards and reviewing research results. This effort would be in addition to ongoing and planned federal research.

Agency Comments

As requested, we did not obtain written agency comments on a draft of this report. However, we discussed the information in the report with

¹²In 1991 the Institute of Electrical and Electronics Engineers, Inc., (IEEE) an engineering trade association, revised the 1982 ANSI standard to reflect scientific research principally completed through 1985. The details of this standard are described in IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, IEEE C95.1-1991 (revision of ANSI C95.1-1982), Institute of Electrical and Electronics Engineers, Inc. (1992).

¹³Hand-held personal communications services devices with (1) a maximum input power to the antenna greater than 0.1 watts or (2) a distance between the antenna and the user of less than 2.5 centimeters will be required to be evaluated for compliance with the revised ANSI standard.

officials from FDA's Office of Science and Technology, including the Chief of the Radiation Biology Branch; EPA's Office of Radiation and Indoor Air, including the Electromagnetic Fields Team Leader in the Radiation Studies Division; and FCC's Office of Engineering and Technology, including the Chief Engineer. These officials generally agreed that the information was accurate. The FDA and EPA officials agreed that the current state of scientific knowledge is insufficient to determine whether cellular telephones pose health risks. The agencies assisted us in characterizing the scientific studies and brought us up to date on their most recent activities related to radio-frequency radiation exposure and cellular telephones. The FDA and EPA officials said they plan to review the industry's completed research.

We also asked officials from the National Cancer Institute's Division of Cancer Etiology, the National Institute on Standards and Technology's Management and Organization Division, and the Department of Defense's Office of the Undersecretary of Defense for Acquisitions and Technology to review the information in the sections of this report pertaining to their agency. These officials generally agreed that the information provided in this report was accurate, and we incorporated their comments where appropriate.

Analog and Digital Transmission Signals

Some researchers have suggested that digital transmission signals, under certain circumstances, may be more likely to produce nonthermal effects with consequences for human health than analog signals. Voice communications systems have traditionally relied on analog signals to transmit messages. Using analog technology, voice messages are electronically reproduced and amplified while being sent to the receiver of the message. A problem with analog amplification is that the voice message is imperfectly reproduced and tends to pick up “noise” through amplification.

To reduce this noise in voice communications, engineers have developed the technology to convert voice messages into “digits”—that is, sound is converted into a pattern of 0’s and 1’s representing the intensity of sound at points in time. Because the digitized message is repeated exactly as it is transmitted to the receiver, no additional noise is added. In addition to better sound quality, digital technology affords more efficient use of radio-frequency channels. When sound data are converted into digital bits, information is more compact. Thus, capacity is added to the radio waves over which the data are transmitted.

The cellular telephone industry’s efforts to implement digital technology have focused primarily on providing multiple access over one frequency, or channel, by either (1) code division multiple access (CDMA) or (2) time division multiple access (TDMA).

- Under TDMA, several users share the same frequency, or channel, by transmitting portions, or bursts, of data in short time intervals. To do this, the signal is turned on and off 50 times per second, causing the signal to appear to pulse.
- Under CDMA, several users share the same frequency, or channel, at the same time. Messages are transmitted digitally as various sequences of 0’s and 1’s with a special code attached so that only the intended receiver is able to decode the message.

Radiation researchers sometimes describe TDMA signals as “pulse-modulated” or “extremely low frequency modulated” radio-frequency radiation, meaning that a radio-frequency wave carries a signal that varies 50 times per second.

Radio-Frequency Radiation Researchers and Scientists Consulted for This Report

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Appendix II
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Examples of Research Indicating Biological and Behavioral Effects

Many scientists we consulted said that some recent research studies have reported biological and behavioral effects as a result of exposure to radio-frequency radiation. For example, a series of laboratory studies have shown that exposure to radio-frequency radiation may cause the release of calcium ions in the brain tissue of live animals and in brain tissue samples.¹⁴ According to the Environmental Protection Agency, calcium ions play an essential role in many cell processes, including the initiation of cell growth and the promotion of tumors. However, no studies have shown that the mobility of calcium ions induced by radio-frequency radiation poses a health risk in humans.

In a 1990 study,¹⁵ researchers exposed human tumor cells to 27 megahertz (MHz) and 2,450 MHz radio-frequency radiation at slightly higher power levels than those used by portable cellular telephones. (Personal communications services devices will transmit signals between 1,850 and 2,200 MHz.) The researchers reported that the tumor cells increased their uptake of the biological chemicals required for cell reproduction after a single, 2-hour exposure to either 27 or 2,450 MHz radio-frequency radiation. Because the temperatures of the cells did not increase during exposure, the researchers concluded that the increased reproduction rate was not caused by heating. In addition, the tumor cells continued to show signs of an increased reproduction rate for up to 5 days after exposure, leading the researchers to suggest that the effects of radio-frequency radiation could

¹⁴W. R. Adey, S. M. Bawin, and A. F. Lawrence, "Effects of Weak Amplitude-Modulated Microwave Fields on Calcium Efflux from Awake Cat Cerebral Cortex," *Bioelectromagnetics*, 3:295-307 (1982).

S.M. Bawin, L.K. Kaczmarek, and W. R. Adey, "Effects of Modulated VHF Fields on the Central Nervous System," *Annals of the N.Y. Academy of Science*, 247:74-81 (1975).

C. F. Blackman, J. A. Elder, C. M. Weil, S. G. Benane, D. C. Eichinger, and D. E. House, "Induction of Calcium Ion Efflux from Brain Tissue by Radiofrequency Radiation: Effects of Modulation Frequency and Field Strength," *Radio Science*, 14(6S):93-98 (1979).

C. F. Blackman, S. G. Benane, J. A. Lampe, J. A. Elder, D. E. House, and J. M. Faulk, "Induction of Calcium Ion Efflux from Brain Tissue by Radiofrequency Radiation: Effect of Sample Number and Modulation Frequency on the Power-Density Window," *Bioelectromagnetics*, 1:35-43 (1980).

C. F. Blackman, S. G. Benane, J. R. Rabinowitz, D. E. House, and W. T. Joines, "A Role for the Magnetic Field in the Radiation-Induced Efflux of Calcium Ions from Brain Tissue in Vitro," *Bioelectromagnetics*, 6:327-337 (1985).

C. F. Blackman, L. S. Kinney, D. E. House, and W. T. Joines, "Multiple Power-Density Windows and Their Possible Origin," *Bioelectromagnetics*, 10:115-128 (1989).

S. K. Dutta, A. Subramoniam, B. Ghosh, and R. Parshad, "Microwave Radiation-Induced Calcium Ion Efflux From Human Neuroblastoma Cells in Culture," *Bioelectromagnetics*, 5:71-78 (1984).

¹⁵S. F. Cleary, L. M. Liu, and R. E. Merchant, "Glioma Proliferation Modulated In Vitro by Isothermal Radiofrequency Radiation Exposure," *Radiation Research*, 121:38-45 (1990).

possibly be cumulative when exposures occur at intervals of 5 days or less.

According to the experts we consulted, other recent studies suggest that pulsed radio-frequency signals—similar to digital signals—trigger biological events that could potentially lead to adverse health effects. Reported findings include the (1) inhibition of neurotransmitter activity, (2) suppression of immune responses, and (3) copromotion of tumors.

Neurotransmitters are chemical agents that transmit information from cell to cell within the nervous system. Certain neurotransmitters are essential in the learning process. A University of Washington study found that rats exposed to 1 milliwatt (mW)—much less power than portable cellular telephones use—of pulsed 2,450 MHz radio-frequency radiation for 45 minutes showed a deficit in their ability to learn to perform in a radial-arm maze.¹⁶ The study concluded that exposure to low-power radio-frequency radiation appears to decrease certain neurotransmitters in the central nervous system involved in spatial learning in rodents.

The immune system is the physiological defense against a wide variety of harmful agents, including bacteria, viruses, and tumors. Specialized cells designed to kill abnormal cells form one line of defense within the immune system. In a replicated study of the responses of immune cells after exposure to radio-frequency radiation, researchers found that the effectiveness of T-lymphocyte cells (a type of natural “killer” cell) at fighting off tumor cells was diminished after 4 hours of exposure to 1.5 mW of 450 MHz radio-frequency radiation that was amplitude-modulated (or “pulsed”) at 3, 16, 40, 60, 80, and 100 times per second.¹⁷ The killer cells’ effectiveness was diminished most when the radiation pulsed 60 times per second. According to the scientists we consulted, this finding is significant because digital cellular telephones, as well as proposed personal communications devices, transmit signals at 50 bursts per second.

Some research is exploring the possibility that low-power radio-frequency radiation may act as a copromoter of cancer in the presence of known

¹⁶H. Lai, A. Horita, and A. W. Guy, “Neural Mechanisms Involved in Microwave-Induced Deficit in Radial-Arm Maze Performance,” Department of Pharmacology and Center for Bioengineering, University of Washington, Seattle, Wash. (presented at the Bioelectromagnetics Society meeting, Feb. 1993).

¹⁷D. B. Lyle, P. Schechter, W. R. Adey, and R. L. Lundak, “Suppression of T-Lymphocyte Cytotoxicity Following Exposure to Sinusoidally Amplitude-Modulated Fields,” *Bioelectromagnetics*, 4:281-292 (1983).

Appendix III
Examples of Research Indicating Biological
and Behavioral Effects

carcinogens. For example, in a 1991 study,¹⁸ researchers exposed mouse embryo cells to low doses of 2,450 MHz radio-frequency radiation pulsing 120 times per second for 24 hours. Exposure to radiation alone had no effect on the cells' survival or transformation into tumor cells. However, when the cells were treated with a tumor-promoting chemical, the radiation exposure significantly enhanced the transformation of the cells into tumor cells.

According to the researchers and scientists we consulted, few data are available to suggest that these triggering effects will occur in humans under the exposures created by using portable cellular telephones and the proposed personal communications services devices. However, health and radiation experts told us that recent research findings do raise questions about the potential health risks posed by low-power radio-frequency radiation.

¹⁸E. K. Balcer-Kubiczek and G. H. Harrison, "Neoplastic Transformation of C3H/10T-1/2 Cells following Exposure to 120-Hz Modulated 2.45-GHz Microwaves and Phorbol Ester Tumor Promoter," Radiation Research, 126:65-72 (1991).

Selected Research Relevant to Health Risks of Radio-Frequency Radiation

The researchers and scientists we consulted cited the following research studies as relevant to the biological effects of radio-frequency radiation and the use of cellular telephones and the proposed personal communications services devices. This compilation is not all-inclusive.

Adey, W. R., S. M. Bawin, and A. F. Lawrence. "Effects of Weak Amplitude-Modulated Microwave Fields on Calcium Efflux from Awake Cat Cerebral Cortex." Bioelectromagnetics, 3:295-307 (1982).

Bawin, S. M., L. K. Kaczmarek, and W. R. Adey. "Effects of Modulated VHF Fields on the Central Nervous System." Annals of the N.Y. Academy of Science, 247:74-81 (1975).

Balcer-Kubiczek, E. K., and G. H. Harrison. "Evidence for Microwave Carcinogenesis In Vitro." Carcinogenesis, 6:859-864 (1985).

_____. "Induction of Neoplastic Transformation in C3H/10T-1/2 Cells by 2.45-GHz Microwaves and Phorbol Ester." Radiation Research, 117:531-537 (1989).

_____. "Neoplastic Transformation of C3H/10T-1/2 Cells Following Exposure to 120-Hz Modulated 2.45-GHz Microwaves and Phorbol Ester Tumor Promoter." Radiation Research, 126:65-72 (1991).

Blackman, C. F., J. A. Elder, C. M. Weil, S. G. Benane, D. C. Eichinger, and D. E. House. "Induction of Calcium Ion Efflux from Brain Tissue by Radiofrequency Radiation: Effects of Modulation Frequency and Field Strength." Radio Science, 14(6S):93-98 (1979).

_____. S. G. Benane, J. A. Lampe, J. A. Elder, D. E. House, and J. M. Faulk. "Induction of Calcium Ion Efflux from Brain Tissue by Radiofrequency Radiation: Effect of Sample Number and Modulation Frequency on the Power-Density Window." Bioelectromagnetics, 1:35-43 (1980).

_____. S. G. Benane, J. R. Rabinowitz, D. E. House, and W. T. Joines. "A Role for the Magnetic Field in the Radiation-Induced Efflux of Calcium Ions from Brain Tissue In Vitro." Bioelectromagnetics, 6:327-337 (1985).

_____. L. S. Kinney, D. E. House, and W. T. Joines. "Multiple Power-Density Windows and Their Possible Origin." Bioelectromagnetics, 10:115-128 (1989).

Byus, C. V., K. Kartum, S. Pieper, and R. Adey. "Increased Ornithine Decarboxylase Activity in Cultured Cells Exposed to Low Energy Modulated Microwave Fields and Phorbol Ester Tumor Promoters." Cancer Research, 48:4222-4226 (1988).

Chou, C. K., A. W. Guy, L. L. Kunz, R. B. Johnson, J. J. Crowley, and J. H. Krupp. "Long-Term, Low-Level Microwave Irradiation of Rats." Bioelectromagnetics, 13:469-496 (1992).

Cleary, S. F., L. M. Liu, and R. E. Merchant. "Glioma Proliferation Modulated In Vitro by Isothermal Radiofrequency Radiation Exposure." Radiation Research, 121:38-45 (1990).

Dutta, S. K., A. Subramoniam, B. Ghosh, and R. Parshad. "Microwave Radiation-Induced Calcium Ion Efflux From Human Neuroblastoma Cells in Culture." Bioelectromagnetics, 5:71-78 (1984).

Environmental Epidemiology Program, State of Hawaii Department of Health. "Cancer Incidence in Census Tracts with Broadcasting Towers in Honolulu, Hawaii." Report to the City Council, City and County of Honolulu, Hawaii (1986).

Hill, D. A Longitudinal Study of a Cohort with Past Exposure to Radar: The MIT Radiation Laboratory Follow-Up Study. (Ph.D. dissertation, University of Michigan, 1988.)

Kues, H. A., J. C. Monahan, S. A. D'Anna, S. McLeod, G. A. Luty, and S. Koslov. "Increased Sensitivity of the Non-Human Primate Eye to Microwave Radiation Following Ophthalmic Drug Treatment." Bioelectromagnetics, 13:379-393 (1992).

Kuster, Niels, Thomas Schmid, and Klaus Meier. "Studies of Absorption in the Extreme Near Field of Transmitters." Proceedings of the VDE Meeting, Nov. 9-10, 1993, Manheim, Germany.

Lai, H., A. Horita, and A. W. Guy. "Neural Mechanisms Involved in Microwave-Induced Deficit in Radial-Arm Maze Performance." Department of Pharmacology and Center for Bioengineering, University of Washington, Seattle, Wash. (Presented at the Bioelectromagnetics Society meeting, Feb. 1993.)

Appendix IV
Selected Research Relevant to Health Risks
of Radio-Frequency Radiation

Litovitz, T. A., D. Krause, Miguel Penafiel, Edward C. Elson, and J. M. Mullins. "The Role of Coherence Time in the Effect of Microwaves on Ornithine Decarboxylase Activity," Bioelectromagnetics, 14:395-403 (1993).

Lyle, D. B., P. Schechter, W. R. Adey, and R. L. Lundak. "Suppression of T-Lymphocyte Cytotoxicity Following Exposure to Sinusoidally Amplitude-Modulated Fields." Bioelectromagnetics, 4:281-292 (1983).

Milham, S. Jr. "Silent Keys: Leukemia Mortality in Amateur Radio Operators." Lancet, 1:812 (1985).

Salford, L. G., A. Brun, B. R. R. Persson, and J. Eberhardt. "Experimental Studies of Brain Tumor Development During Exposure to Continuous and Pulsed 915 MHz Radiofrequency Radiation." Biochemistry and Bioenergetics, 30:313-318 (1993).

Sznigielski, S., et. al. "Immunological and Cancer-Related Aspects of Exposure to Low-Level Microwave and Radiofrequency Fields." In Marino, A., ed., Modern Electricity (Marcel-Dekker, Inc., 1988).

Evolution of FCC's Environmental Rules

Table V.1 illustrates the chronology of key Federal Communications Commission (FCC) rulemaking proceedings on the regulation of cellular telephone service and the evolution of the Commission's environmental rules to protect people from radio-frequency radiation.

Table V.1: Key FCC Actions on Regulation of Cellular Service and Radio-Frequency Radiation Safety Levels

Date	FCC action
May 1974	Reserves the 806-947 MHz frequency band for land mobile service operations, including cellular communications.
September 1974	Adopts rules complying with the National Environmental Policy Act, which requires federal agencies to consider whether their major actions significantly affect the human environment.
June 1979	Requests comments on its responsibility to consider the biological effects of radio-frequency radiation when authorizing devices.
April 1981	Allocates the 825-845 MHz and 870-890 MHz bands for cellular communications and implements rules governing cellular service.
February 1985	Amends its environmental rules by incorporating the 1982 ANSI standard for radio-frequency radiation exposure (for lack of a federal standard or guideline) that excludes devices operating on or below 7 watts of power, such as cellular telephones, from compliance.
May 1987	Further amends its environmental rules by exempting certain categories of its actions, including those on cellular telephone services, from routine evaluation under its environmental rules.
March 1993	Proposes to update its environmental rules by incorporating the updated version of the ANSI standard on exposure to radio-frequency radiation.
June 1994	Issues rules governing personal communications services that require manufacturers to ensure that certain equipment used in these services complies with the revised ANSI standard that the Commission has proposed incorporating into its environmental rules.

Source: FCC.

As the table shows, FCC adopted environmental rules implementing the National Environmental Policy Act of 1969 (NEPA) shortly after reserving radio channels for cellular telephone service in 1974. However, in developing its environmental rules, the Commission concluded that only a few of its actions would significantly affect the environment. Among such actions, for example, was authorizing construction of communications and broadcast facilities, like antenna towers, where damaging the physical environment could be a concern. The operation of communications facilities, in FCC's opinion, would have little or no effect on the environment. In the Report and Order implementing its environmental rules, FCC states that “[Communications facility operations] do not contribute in any distinctive or significant way to air or water pollution. They do not use hazardous substances, and . . . do not produce them.”

FCC did acknowledge that electromagnetic radiation, such as radio waves, can be hazardous. However, at the time the only known hazard that radio-frequency radiation posed was biological damage from heating at sufficiently high power levels. The Commission believed that the only radio facilities with sufficient power to cause heat damage were radio transmission facilities such as antenna towers.

Prompted by increased public awareness and concern over radio-frequency radiation, in 1979 FCC began evaluating its responsibilities to consider the biological effects of radio-frequency radiation when authorizing equipment and issued a Notice of Inquiry for comments from interested parties. On the basis of comments received in response to this inquiry, FCC proposed in 1982 to amend its environmental rules by including an exposure standard. This standard would trigger FCC's environmental assessment process if equipment emitted radio-frequency radiation in excess of the standard. However, no federal standard, or guideline, for exposure to radio-frequency radiation existed, and FCC maintained that it did not have the expertise to develop such a standard. Under the Office of Management and Budget Circular A-119, federal agencies may use voluntary industry standards in the absence of federal standards. In 1985, FCC incorporated the 1982 ANSI standard into its environmental rules.¹⁹ This standard exempts devices that use 7 watts of power or less and operate at 1 gigahertz or lower, such as cellular telephones, from complying with the standard's limits on radiation exposures.

After adopting the ANSI standard, FCC exempted its decisions and actions on cellular telephones from routine environmental evaluation. According to an FCC official, because portable cellular telephones operate on much less than 7 watts of power, the Commission considered that these telephones would be safe on the basis of the ANSI standard.

The ANSI standard was updated and revised in 1991, and in 1993 FCC proposed adopting this revised standard to update its environmental rules.²⁰ An FCC official told us that the revised standard is stricter and that portable cellular telephones will probably be subjected to environmental evaluation under the new standard. Until this new standard is adopted,

¹⁹Safety Levels With Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 300 kHz to 100 GHz, ANSI C95.1-1982, the American National Standards Institute, Inc. (1982).

²⁰IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, IEEE C95.1-1991 (Revision of ANSI C95.1-1982), the Institute of Electrical and Electronics Engineers, Inc. (1992).

cellular telephones will continue to be excluded from routine environmental evaluation for public exposure to radiation.

In contrast, FCC has already decided that it will require certain emerging hand-held personal communications services devices to comply with the revised ANSI standard, pending its adoption of this standard in its environmental rules. Hand-held personal communications services devices with (1) a maximum input power to the antenna greater than 0.1 watts or (2) a distance between the antenna and the user of less than 2.5 centimeters will have to undergo evaluation for compliance with the revised ANSI standard.

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