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Covering the Health Effects of ElectroMagnetic Fields

power lines appliances MRI video display terminals radio VHF-TV cellular phones microwaves UHF-TV radar

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Cellular Towers
Exposure Levels and Public Health

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Every day, new cellular telephone base stations seem to go up all over the country. Most of these cell sites have fairly tall towers (50 to 200 feet) on which the antennas are mounted and often need a zoning variance to permit their construction. This may require a zoning hearing which can focus the public's fears over the possible effects of exposure to EMF. What kind of EMF radiation do these cellular towers produce? Here, we put the potential risks associated with this technology into perspective.

Cell-site antennas emit radiofrequency, or *RF*, energy. They are mounted on the tops of towers and therefore are at some distance from the general public. The radiated power from each antenna, 50 to 200 watts, is equivalent to the power of a typical household light bulb. (As I write this, my head is about six inches from a 75-watt light bulb in my desk lamp.) The broadcast power levels used by cellular base stations are therefore much lower than the radiated power from commercial FM and television stations, which ranges from a few thousand to five million watts (for UHF TV).

Measuring RF Around Cellular Towers

Some of the antennas used at cell sites focus the RF energy in a fairly narrow range of specific

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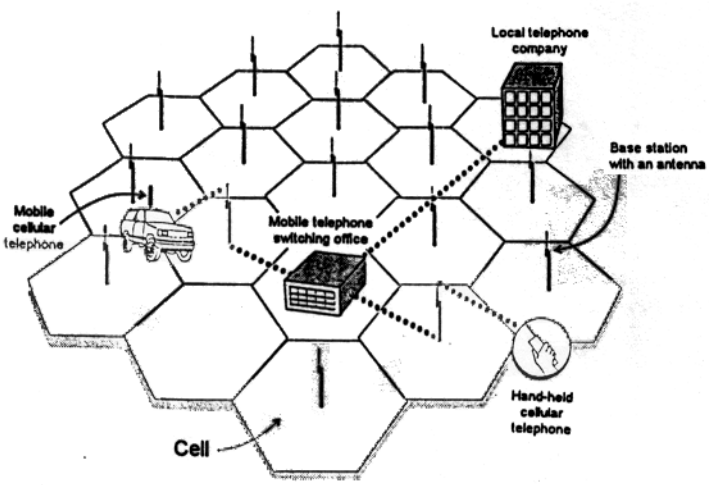
Cellular Communications Architecture

Cellular telephones are a part of the technological change that is sweeping our culture. Personal wireless communications, such as cellular phones, are rapidly replacing older means of communicating.

Cellular telephones got their name because the system divides the coverage area up into small "cells" that are served by individual antennas, usually located near the center of the "cell". As one travels from one cell to another, the communication from the cell phone is "handed off" from the cell being left to the cell being entered.



Source: General Accounting Office

directions while others transmit energy equally in all directions. Like the lens on a flashlight, the more directive, or "sectorized," antenna systems focus the energy into a more intense beam than the omni-directional antennas.

Our firm is frequently called upon to measure RF field levels around cellular towers. The two graphs in Figure 1 show the computed and measured RF exposure levels from two typical cellular towers. In each case the fields are the result of the combined effects of several sectorized antennas on each tower. The emissions from cell sites are measured with an RF power density meter and are reported as microwatts per square centimeter, abbreviated as $\mu W/cm^2$. Most of these meters are "isotropic," which means that they are sensitive to fields from all directions. Power density is determined indirectly by commercially available meters from the electric field component of the RF emission.

It can be seen from the graphs in Figure 1 that the highest power densities occur at distances of 100 to 800 feet from the towers and are a little higher than 1 $\mu W/cm^2$ maximum. In the majority of locations the power densities are much less than 1 $\mu W/cm^2$ (typically 0.01 to 0.1 $\mu W/cm^2$). Much of the variation of the power density with distance (peaks and valleys) shown on the graphs is caused by the directional nature of the antennas, along with effects caused by the varying heights of the antennas. The two different antenna models shown in the graphs have peaks and valleys at different locations. Even though there are peaks in the power density, even the highest levels are approximately a hundred thousand times less than the limits established for human exposure to RF EMF.

...many objects in the real world...have the effect of attenuating the cellular signal...

Calculated power density patterns are usually, but not always, higher than the measured RF fields due to the fact that the computations are biased toward giving the highest possible values (they assume worst case conditions in order to have a built-in "safety factor"). Another factor that causes disagreement between measured and calculated power densities is the fact that many objects in the real world, that are unknown when calculations are made, have the effect of attenuating the cellular signal (see the measured points at about 800 feet on the first graph in Figure 1).

The power density at a given location (in $\mu W/cm^2$) can be calculated from

$$(ERP \times 360)/(distance)^2$$

where ERP (Effective Radiated Power) is the antenna output power in a given direction as specified by the known antenna radiation pattern; the distance (in feet) is measured from the center of the antenna to the location where the power density is to be calculated. This expression includes a factor from the U.S. Environmental Protection Agency

What Kind of Power from a Cellular Tower

The cellular method of mobile telephone communication provides better coverage, for less power usage, than would be provided by one large tower serving the entire area. Unlike radio or TV broadcast where boosting the power can increase the audience, cell areas are limited by the number of simultaneous callers, so it is necessary to have more cells rather than more powerful cells as demand increases.

Cellular telephones operate in the 800 to 900 megahertz (MHz) band using frequency modulation (FM) or a form of digital modulation. The frequencies used by cellular telephones are lower than those used by microwave ovens (2,450 MHz) but higher, by a factor of 15 million, or so, than the 60 hertz electricity used in the home. The equivalent magnetic field from cellular towers would be a few hundredths of a milligauss.

Cell site antennas do radiate more power than the cellular telephones themselves. But human exposure is much less near a cell site than from a cellular telephone because the cell phone user is within a couple of inches of a one-piece phone's antenna while the distance where normal exposure from a cell site antenna occurs is typically hundreds of feet.

The power density around a cellular tower decreases with the square of the distance. In contrast, the dominant magnetic field exposures from power distribution lines usually decrease more slowly with distance. However, because RF fields travel as waves, there are effects from reflections, interactions between waves from multiple antennas, and peaks of intensity due to each antenna pattern. This produces a pattern of peaks and valleys in field intensity as you move away from the source. Although the wave nature of EMFs at these frequencies adds some complexity to the pattern, cell tower field distribution can still be predicted, as illustrated by Figure 1.

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for the inclusion of ground reflections. While cellular signals are highly reflective, the effects of reflections are not usually great enough to convert a low-level RF field into a hazardous field. I have made many measurements on rooftop cellular antennas and have found that the power levels from these antennas at points where people can walk are generally below the ANSI C95.1 Standard once you are a few feet from the antenna (see "Standards Limiting RF EMF Exposure").

Cellular Tower Hearings

The ANSI C95.1-1992 standard is very similar to the standards adopted by Massachusetts, New Jersey, Colorado, King County & Seattle, Washington, and Washington County, Multnomah County and the city of Portland, Oregon. The standards adopted in these states and local jurisdictions were adopted after long (several years for King County, Washington), and often rancorous, public hearings. Committees of the public and other interested parties held extensive meetings before the standards were adopted. Thus, there was a great deal of public involvement in the adoption of Radio Frequency exposure standards by these state and local governments.

...the power levels from these antennas are generally below the ANSI C95.1 Standard at distances greater than a few feet from the antenna.

In spite of the public's involvement in setting local standards, one frequently reads statements decrying the antennas as a major health hazard or simply suggesting that there is no scientific proof to show that they are safe. It is always difficult to prove the safety of new technology under all circumstances, and one could logically have some doubts about cellular tower RF fields. However, such hazards have never been demonstrated and the power densities from the typical base station are a fraction of the ANSI Uncontrolled Environment MPE, and that standard is in turn 1/50th of the levels which have been demonstrated to cause biological effects in humans. It must be realized that one can never prove a negative. Standards based on scientific principles are all referenced to dose levels where human biological effects can be shown to exist by, or can reasonably be extrapolated from, a repeatable, peer reviewed, body of research. Any other conclusion is speculation without scientific foundation.

The electric and magnetic fields from cellular tower antennas can be put into perspective by comparing them to other environmental fields to which

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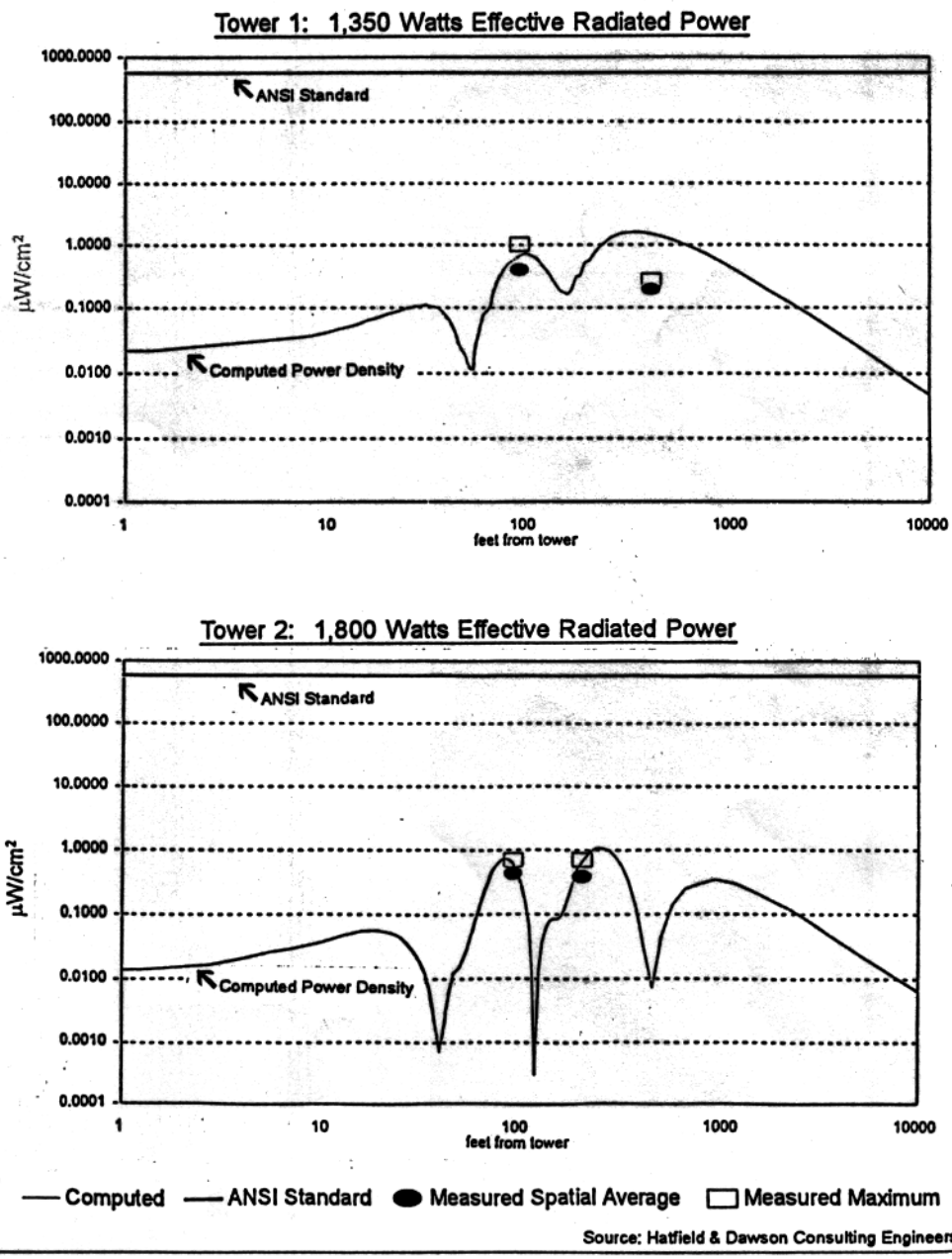
Figure 1: Power Distribution from Two Cellular Towers

Computed and Measured Power Density



Source: Hatfield & Dawson Consulting Engineers

we are all exposed on a daily basis. The highest power density from the cellular antennas mentioned above as examples result in exposures equal to, or slightly greater than, 1 μW/cm² at specific locations (see Figure 1). This represents an electric field of about 2 volts per meter (V/m) and a magnetic field of about 0.005 amperes per meter (A/m) or 0.06 milligauss (mG).

I measured the Extremely Low Frequency (ELF) electric field from my "Low Radiation" computer video display terminal (VDT) and found that it was about 30 V/m at a distance of two feet while the magnetic field measured 2 mG at the same distance. The electric field from my desk lamp was 45 V/m at a distance of two feet. There is a difference in the way ELF fields and cellular frequency RF fields are propagated and their reputed biological effects are also different, but the comparison is still instructive in establishing an exposure baseline.

Background RF Exposures

Ambient RF levels are generally lower than ELF fields, but higher than those from cellular towers. In the early 1980s, a group from the U.S. Environmental Protection Agency surveyed public exposure at 373 FM radio stations and VHF and UHF TV stations, and found average exposure levels of 0.005 μW/cm². They estimated that approximately 1% of the population, or about 380,000 persons in the U.S., would be potentially exposed to levels greater than 1 μW/cm² from commercial broadcast towers.

The average ELF magnetic field exposure in houses in the Seattle area is about 1 mG as averaged over twenty four hours. When I measured the RF from a cordless telephone (the type used inside your house) I found that a user is exposed to an electric field of 4 V/m (4 μW/cm²) at a distance of 2 inches from the cordless telephone antenna.

The RF fields from cellular base station antennas cause varying, but continuous, exposure throughout the day. The calculations and measurements are for maximum site utilization which occurs a few hours a day. There is no reputable research, or other data, that indicates that chronic exposure to the maximum possible power densities from the referenced sites (about 1 μW/cm²) has any potential to be hazardous to human health.

Standards Limiting RF EMF Exposure

Currently there are several U.S. and international standards to limit human exposure to EMF. These standards were established by groups of engineers and scientists who evaluated research studies and formulated exposure limit guidelines based on recognized effects such as heating stress and behavioral disruption in animals. They then applied an additional safety factor to reduce recommended exposure levels well below the levels known to produce any potentially harmful effect.

The American National Standards Institute (ANSI) 1992 human exposure standard, and most of the local standards that are based upon the ANSI standard, specify "spatially averaged" measurements so that the measured values have a better chance of corresponding to the "whole body averaged" absorption upon which the standards are based. For the situations depicted in the graphs in Figure 1, there is not a great deal of difference between the maximum field measured at a location and the spatially averaged field at that location. The distinction between maximum and spatially averaged measured values can have some relevance to discussions concerning exposure to sensitive organs such as eyes and testes. ANSI C95.1-1992, ***"Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz,"*** discusses this issue.

The C95.1-1992 standard is a revision of a 1982 standard. As the revision process was described by the ANSI C95.1-1992 authors, "a total of 321 papers selected from the archival literature... was reviewed for biological, engineering, and statistical validity." The papers were selected and reviewed without regard to possible thermal or non-thermal mechanism. The Maximum Permissible Exposures (MPEs) for the general public in "Uncontrolled Environments" are from 1/10 to 1/50 of the electromagnetic field levels where "potentially-deleterious health effects" occur. "No verified reports exist of injury to human beings or of adverse effects on the health of human beings who have been exposed to electromagnetic fields within the limits...of ANSI C95.1-1982".

ANSI C95.1-1992 Maximum Permissible Exposure (MPE) varies from 533 to 600 μW/cm² in the part of the spectrum occupied by cellular telephone communications services (800 to 900 MHz). This means that the maximum exposure shown in the graphs in Figure 1 for the two typical cellular sites is 0.2 percent, or less, of the "Uncontrolled Environment" (applicable to the general public) MPE of the ANSI C95.1-1992 standard.

J.B.H.

"...one cannot argue rationally that cellular base station antennas...present a risk to the health of residents."

Concerns Unfounded

The conclusion is that if we do not consider frequency, the exposure from cell-site antennas is much lower than the daily exposure from other EMF sources in the home or office. As a friend of mine in a knowledgeable position in a US government regulatory agency recently said: "In short, one cannot argue rationally that cellular base station antennas on towers in residential areas generate ground level radiofrequency fields that present a

risk to the health of residents. Typical exposure at these sites is similar to that from distant high-power broadcast sources."

There was a time when the reputed hazards of microwave ovens were a source of great public concern. Since then, however, as almost everyone seems to have purchased a microwave oven, these concerns seem to have diminished in direct proportion to the number of microwave ovens in use. If the same thing happens with increasing cellular telephone market penetration, the banality of the commonplace may cause current cellular telephone base station health concerns to evaporate.

James B. Hatfield, P.E., is a partner of the firm Hatfield & Dawson Consulting Engineers, Inc., in Seattle, WA. He is an engineering graduate of the University of Washington in Seattle and a registered professional engineer in three states. He is a member of several IEEE committees, subcommittees and working groups which set human electromagnetic exposure limits and write procedures for the measurement of potentially hazardous electromagnetic fields.