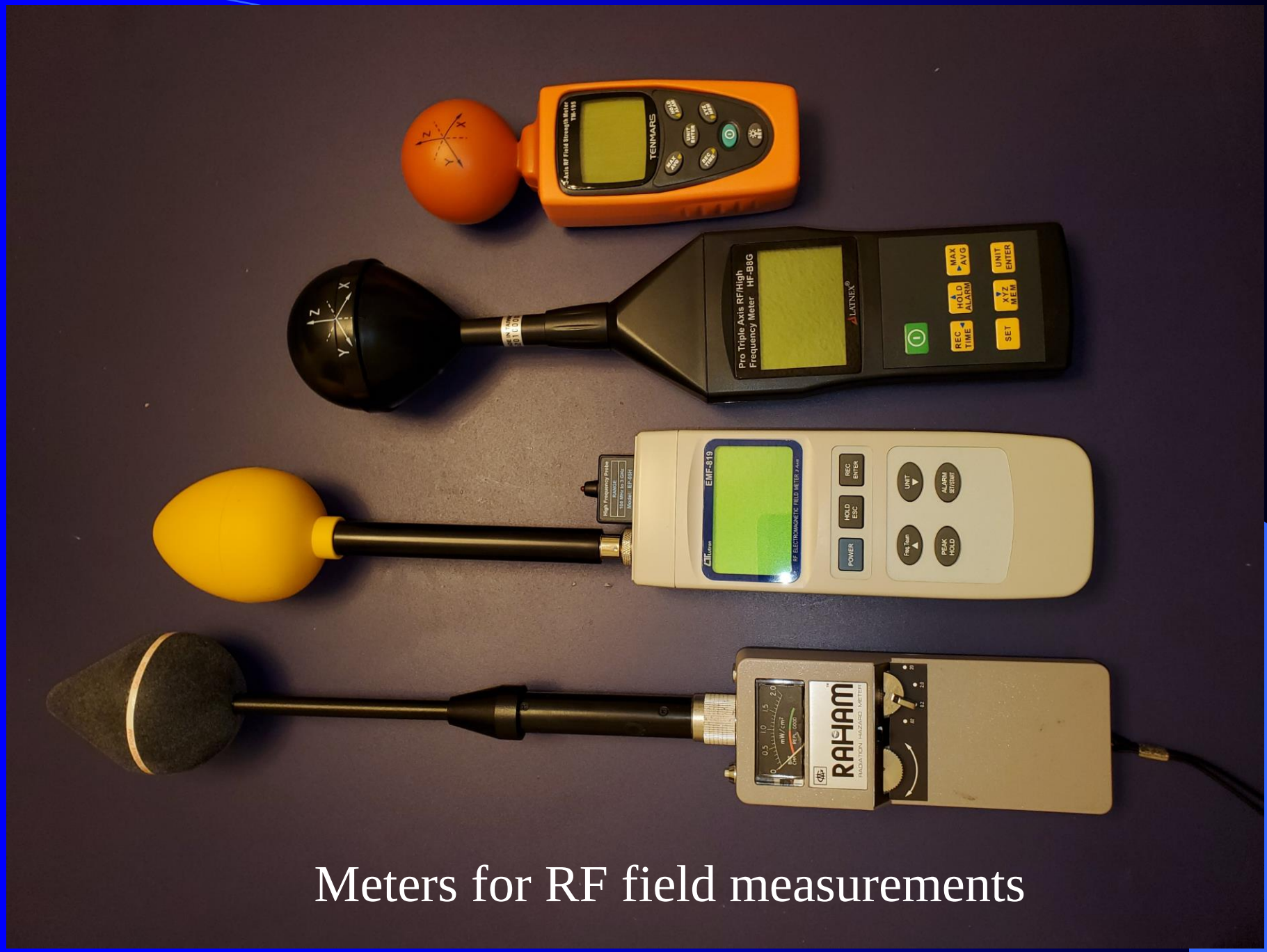
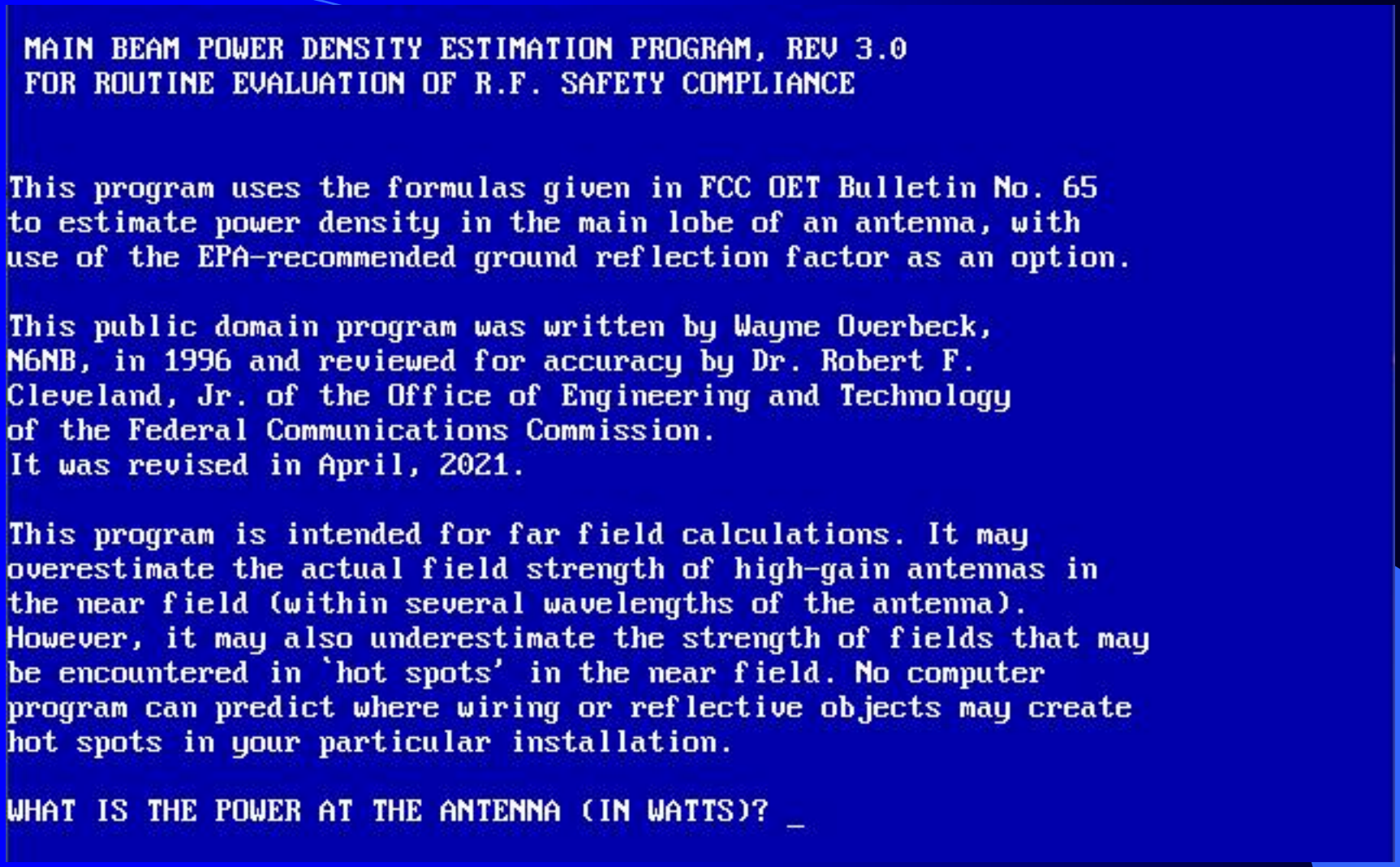
Electromagnetic Radiation and Amateur Radio Safety

A presentation by
Wayne Overbeck, Ph.D., J.D., N6NB

www.n6nb.com



Meters for RF field measurements



Opening screen of RFSafety.exe

How I got involved in RF safety compliance…

Legal Department, National Association of Broadcasters, Washington, D.C.

1-3-88

Los Angeles Times

Ham Radio Operators' High Cancer Rate Poses a Puzzle

TACOMA, Wash. (AP)—Amateur radio operators in Washington and California appear to die at abnormally high rates from several forms of cancer, suggesting a possible link between cancer and electromagnetic fields, according to data collected by a state epidemiologist.

Others cautioned that evidence of such a link has been inconsistent and that other factors may be involved.

Dr. Samuel Milham Jr. of the Washington Department of Social and Health Services studied the deaths of 2,485 Washington and California ham operators between 1979 and 1984.

He reported in the American Journal of Epidemiology that 29 leukemia deaths would be expected in a group of people that size, but he found 36 deaths. Statistically, he expected to find 72 lymphatic and blood-forming organ cancers, but found 89. And he expected to find 67.6 deaths from prostate cancer, but found 78.

'Excess Mortality'

The study "indicates that amateur radio operator licensees in Washington state and California have significant excess mortality due to acute myloid leukemia, multiple myeloma and perhaps certain types of malignant lymphoma," Milham reported.

Leonard Sagan, program manager for radiation studies at the Electric Power Research Institute in Palo Alto, Calif., warned that studies like Milham's can be misinterpreted. Milham's findings could be simple associations that have nothing to do with cancer causes among people who work with electricity, he said.

Sagan said his own research hasn't shown whether electricity causes cancer. But he predicted that if it does, it's rare.

"I think it would be unfortunate for people with children to become overly concerned about this," he said. "Evidence is weak and inconsistent and in a few years we will have better evidence."

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The ARRL board-level Bio-Effects Committee enters (and exits) the picture…

Is Amateur Radio Hazardous to our Health?

What really was said about cancer rates and Amateur Radio, and what we can do about it.

By Ivan A. Shulman, MD, WC2S

6041 Cadillac Ave
Los Angeles, CA 90034

When it was reported in an Associated Press release that there was an increased rate of death due to certain types of cancer in Amateur Radio operators, this information was rapidly picked up by the radio community. As a physician who specializes in cancer surgery, I received many calls from amateur and nonamateur friends to find out more about what was going on and what I thought about it. As in many reports on medical topics in the lay literature and on television, there frequently is a difference between what is reported and what actually was said in medical articles, and this and other recent reports are no different.

After much time and consideration, several important concepts became apparent to me, and I hope that by making this report in *QST*, it will help us all to better understand what really was said, and what is known about the reported association of leukemias and other blood cancers with Amateur Radio. This article does not purport to completely cover all the important articles and research studies which have ever been written on the effects of electromagnetic radiation on human biology, but is instead, an effort to review that literature which might be useful to Amateur Radio operators interested in responding to the questions that have been asked.

Biologic Background

Radio-frequency waves are a form of electromagnetic waves, and in the frequencies of concern to Amateur Radio operators, these represent a form of nonionizing radiation. The terms ionizing and nonionizing radiation are frequently confused, and it is helpful to clarify what I mean by these terms early in our discussion.

Ionization occurs when there is enough energy in the radiation to displace an electron from an atom. Radiation that produces this effect has a very short wavelength, a high frequency and high energy level, and is typically that described as X-rays and gamma rays. Nonionizing radiation is otherwise known as infrared and radio-frequency waves, which are at a lower energy level, and have lower frequencies and longer wavelengths than ionizing radiation. Ionizing radiation is dangerous to living organisms in that it affects cellular elements such as DNA in the cell nucleus, leading to genetic damage in the individual cell, and mutations in future generations of cells. Although the energy level of nonionizing radiation is lower and thus may not affect large molecules or generate measurable amounts of heat in the same manner as ionizing radiation, there is substantial evidence that nonionizing radiation has subtle effects at a more basic cellular level, including effects on hormones, enzymes and the cooperative mechanisms involved in maintaining the integrity of intracellular systems.[1]

Experiments regarding the effects on human tissue of nonionizing electromagnetic fields have been conducted for many years.[2] The findings of these studies indicate that a modulated electromagnetic field, that is, one in which the energy is cycled on and off or is varied by intensity or frequency, has a greater inhibitory effect on the ability of cells in the body to communicate with each other than does a field in which the current remains at a steady and unmodulated strength.

Studies indicate that even in a weak electromagnetic field there is a modification of calcium binding at the cell membrane, as well as an alteration of a variety of calcium dependent enzyme systems which work between cells.[3] Experiments have noted that the effect on calcium flow in and out of cells is frequency dependent, and that curves can be drawn demonstrating these "frequency windows." Specifically, the combination of a very high or ultra high frequency carrier (147 or 450 MHz) modulated at specific extremely low frequencies (16, 40 or 60 Hz) has been studied and appears to be of biologic significance.[4]

Other studies have looked at the effects of electromagnetic energy on cells that have specific immune functions. An important type of white blood cell called a T-lymphocyte is involved in the recognition and destruction of foreign and malignant cells. There is evidence that the normal functioning of these cells is significantly reduced by electric fields that simulate 60-Hz high voltage power line fields and by weak microwave fields that are amplitude modulated at 60 Hz.[5,6] The mechanism of this process is not clear, but may also be related to interactions at the level of the cell membrane.

More rapidly dividing cells, such as those in the bone marrow or small intestine, are usually more sensitive to the effects of both ionizing and nonionizing radiation than are those which divide more slowly. Thus, it is rapidly dividing cells that are more likely to demonstrate changes in response to exposure to these types of energy. However, cells which divide more slowly have less of an ability to repair any damage done to them by exposure over a long period of time. It is important to recognize that these effects are not necessarily dependent on damage to DNA or other cellular markers.

Evidence at this time seems to suggest that an appropriate interpretation of this data is not that nonionizing energy necessarily causes cancer, but that it may act instead to promote the efficacy of other agents in doing so.

Previous Studies

In 1979, initial questions were raised regarding a positive relationship between high current electrical configurations in homes and the incidence of cancer deaths in children living in the Denver area.[7] Later, similar findings were noted for adults living near high current 60-Hz wiring as well.[8] Because of criticisms relating to the methodologies and assumptions used in these studies, other investigators looked at these same issues again, and came to similar conclusions.[9,10]

It had been reported as early as 1982 that there appeared to be an increased death rate due to leukemia in people who were exposed to magnetic and electric fields in the course of their work.[11,12] Additional articles appeared in 1983[13,14] and 1985[15-18] which also suggested that electrical workers in general were at an increased risk of leukemia and that electromagnetic fields might be a cause of this form of cancer. A time/effect relationship has also been suggested for certain forms of brain tumors and occupational exposure to microwave and radio-frequency electromagnetic radiation,[19,20] where the risk was 10 times as great in those workers who had industrial exposure to soldering fumes, solvents and a variety of other chemicals. Other reports have reviewed the possible relationship between spontaneous abortion rates and the use of electric blankets,[21] video display terminals,[22] and ceiling cable electric heat.[23] Cataract formation and damage to the retina has also been reported in humans exposed to high intensity electromagnetic fields and microwaves.[24]

Dr Milham's Study

The recent report which stirred up the most

[1]Notes appear on page 33.

Electromagnetic Fields and Your Health

Are the electromagnetic fields generated by power lines, TVs, ham radio gear and hundreds of other devices bathing us in damaging radiation? The jury is still out, but you can take steps to protect yourself from danger—real and potential.

By Wayne Overbeck, N6NB
14021 Howland
Tustin, CA 92680
Photos by the author

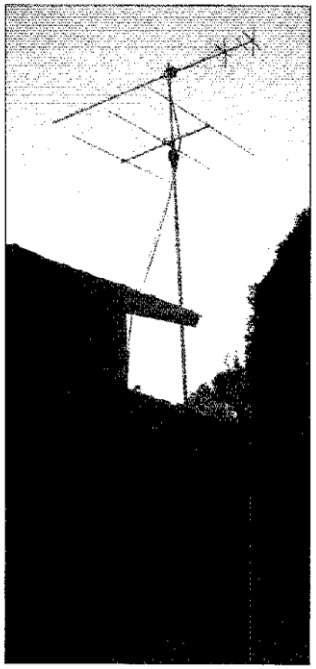
There is a growing public debate about the safety of electric power lines and the electrical equipment that we use every day in our homes and workplaces. Not long ago, a lawsuit was filed alleging that a Florida woman's brain cancer was caused by electromagnetic radiation from a hand-held cellular telephone. Although the filing of a lawsuit proves nothing (thousands are filed every week, and this one was promptly dismissed by a court), the lawsuit made national headlines for weeks and caused cellular telephone industry stock prices to decline on Wall Street.

The news media regularly cover many facets of the controversy over the possible health effects of electromagnetic fields (EMFs). In addition to stories about lawsuits, there have been numerous media accounts of medical research concerning EMFs—some of them confusing and seemingly contradictory. And there have been news stories about activist groups fighting the construction of new power lines or cellular telephone towers in their neighborhoods.

This intense publicity has alarmed many people, prompting them to worry about the safety of their homes, neighborhoods, schools and workplaces. There is a growing concern that the electromagnetic fields produced by power lines and everyday household appliances may be hazardous. As the tension mounts, more and more hams are faced with this difficult question: *Is your Amateur Radio station hazardous to our health?*

Fortunately, enough research has now been done that we know most Amateur Radio activities are quite safe. In fact, scientists from the Federal Communications Commission and the Environmental Protection Agency conducted a field survey of EMFs at typical Amateur Radio stations in 1990. They concluded that most amateur operations do not produce EMFs strong enough to pose any health hazard. And for many years, the American Radio Relay League's Board of Directors has also been monitoring the ongoing research about EMFs and health through a board-appointed Committee on the Biological Effects of RF Energy. There is extensive coverage of the issue of EMFs and health in both *The ARRL Handbook* and *The ARRL Antenna Book*—with recommendations for safe Amateur Radio operating practices.

Amateur Radio is a hobby that can be pursued safely, provided everyone observes a few simple precautions. This article was written to summarize what we know about EMFs and health, and to suggest safe operating practices.

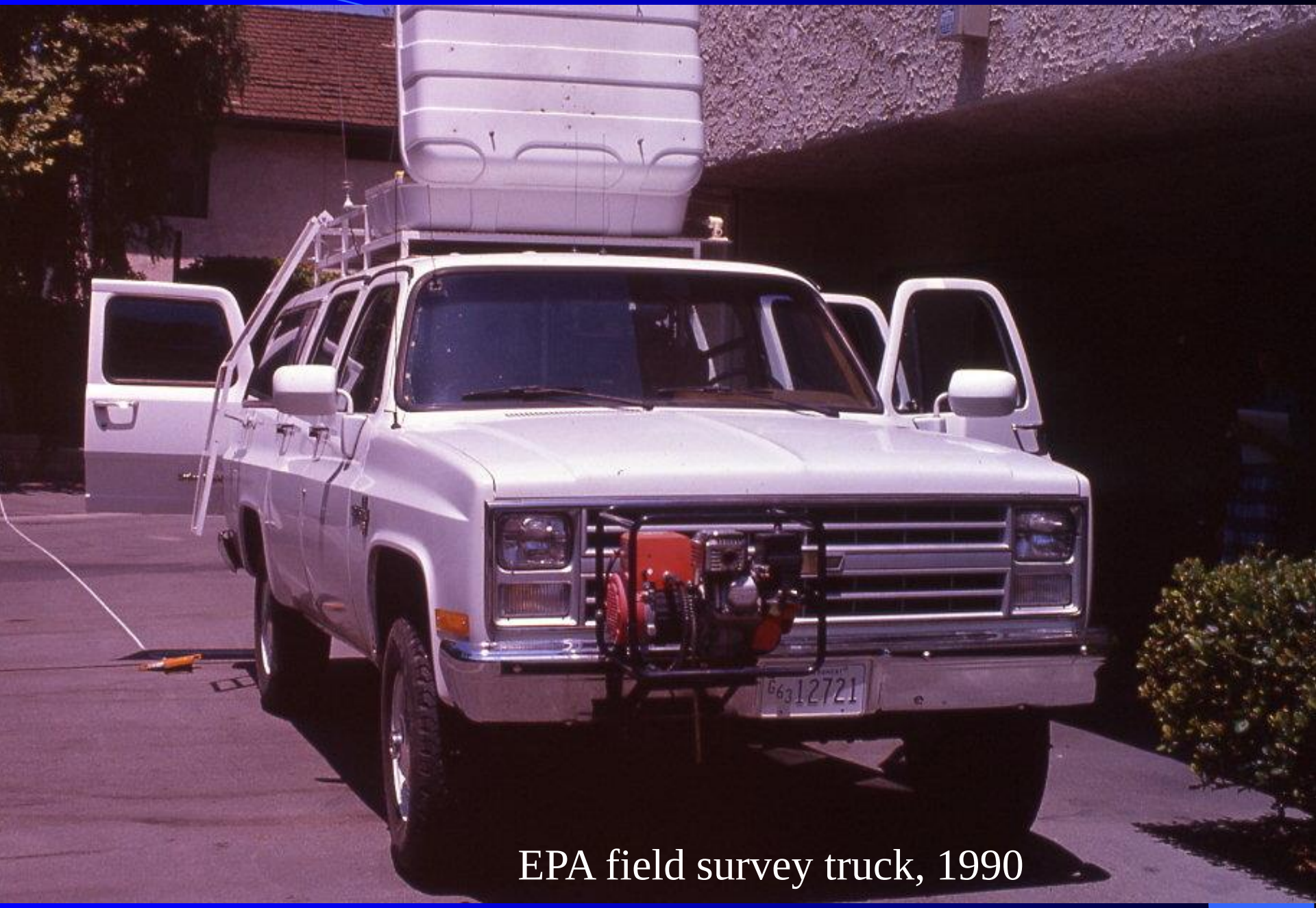


This 3-element 6-meter beam is only a few feet above N6NB's second-story hamshack. When the antenna is pointed toward the operating position, fields in excess of ANSI standards were measured in the shack on a laboratory-grade hazard monitor. The transmitter power output was set to 900 watts.

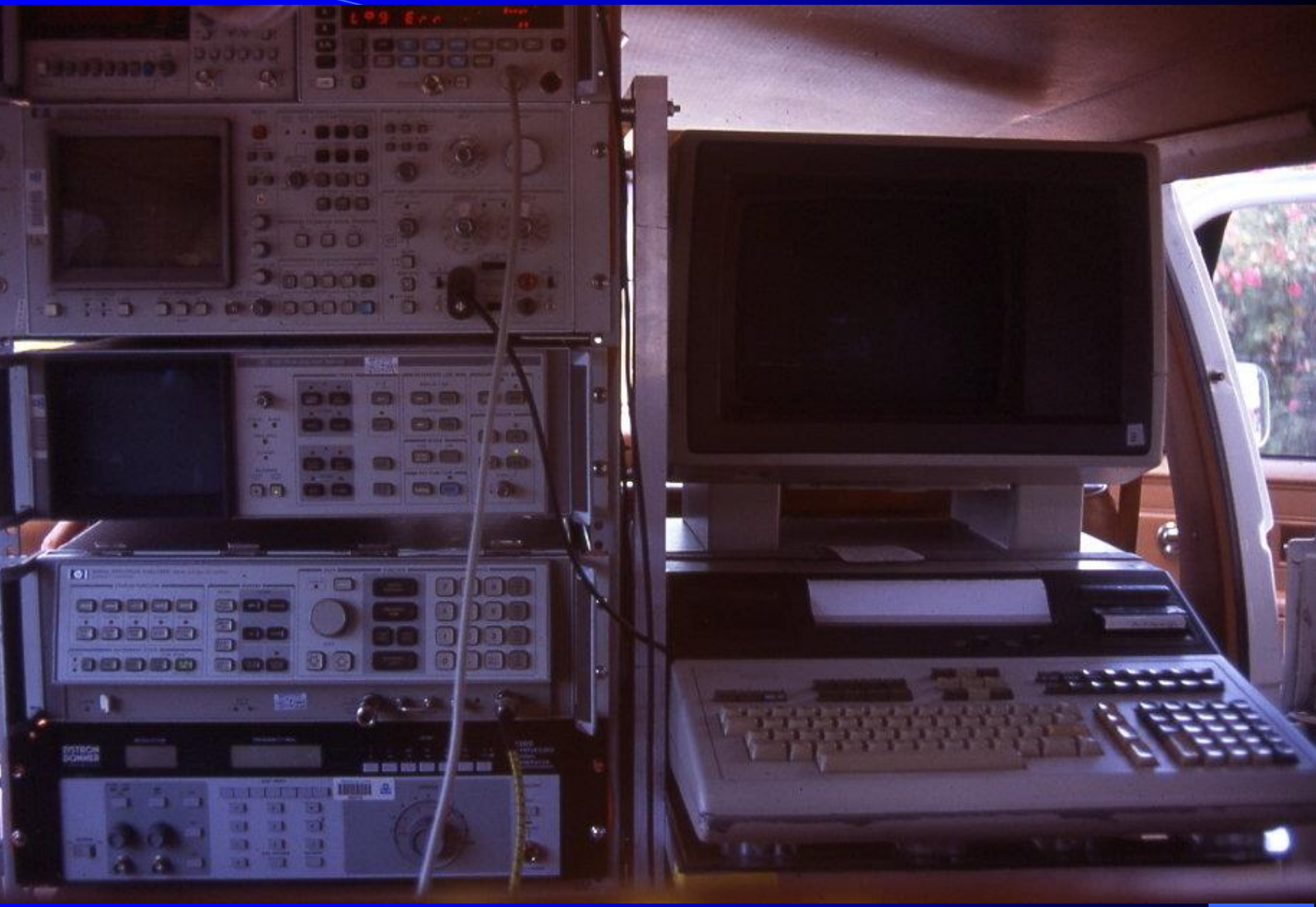
Scientific Background

When scientists talk about electromagnetic fields, they're talking about several very different forms of energy. *Low frequency* or "power line frequency" fields are produced by electric power lines and appliances, typically operating at a frequency of 60 Hz. Much research is now under way concerning the health effects of 60-Hz

FCC, EPA launch field survey of ham stations in 1990 (I went along with them)



EPA field survey truck, 1990



Measuring RF field near
a rover running 1 kw.
on six and two meters

EPA’s tri-axis probe

Measuring RF from 19” whip with 100 watts on two meters

(Dr. Robert Cleveland, FCC, and Toni West, EPA)


0.5
1.0
1.5
2.0
mW/cm²
RAHAM

Measuring HF Yagi on tower at 75’

(Ed Mantiply, EPA, and Bob Cleveland, FCC)

Measuring HF Yagi at 60’

Measuring field near base of vertical antenna

Measuring RF field near antenna hidden in tree

A worst-case scenario: a VHF “rover” station

FCC adopts 1992 ANSI standard for RF exposure, making public exposure limit five times stricter than workplace exposure limit, but still based on *thermal effects only*

In 1996, FCC removes “categorical exemption” of amateur radio stations but adds new exemption for low-power, mobile and hand-held radio equipment.

In 2019, FCC removes exemption for low-power, mobile and hand-held radios. This requires most hams to do “routine evaluations” of their stations for RF safety compliance.

2019 FCC order retains the 1992 ANSI standard for RF exposure, based only on thermal effects. FCC declines to adopt a stricter standard for *athermal* effects.

An international appeal from more than 250 EMF Scientists

- 255 scientists from 44 nations have appealed to the United Nations and its members to adopt stricter standards to protect the public from exposure to electromagnetic fields.
- These scientists, mostly not industry-funded, have published more than 2,000 peer-reviewed scholarly journal articles concerning the health effects of EMFs.

The appeal says…

Numerous recent scientific publications have shown that EMF affects living organisms at levels well below most international and national guidelines. Effects include increased cancer risk, cellular stress, increase in harmful free radicals, genetic damages, structural and functional changes of the reproductive system, learning and memory deficits, neurological disorders, and negative impacts on general well-being in humans.

(see EMFScientist.org)

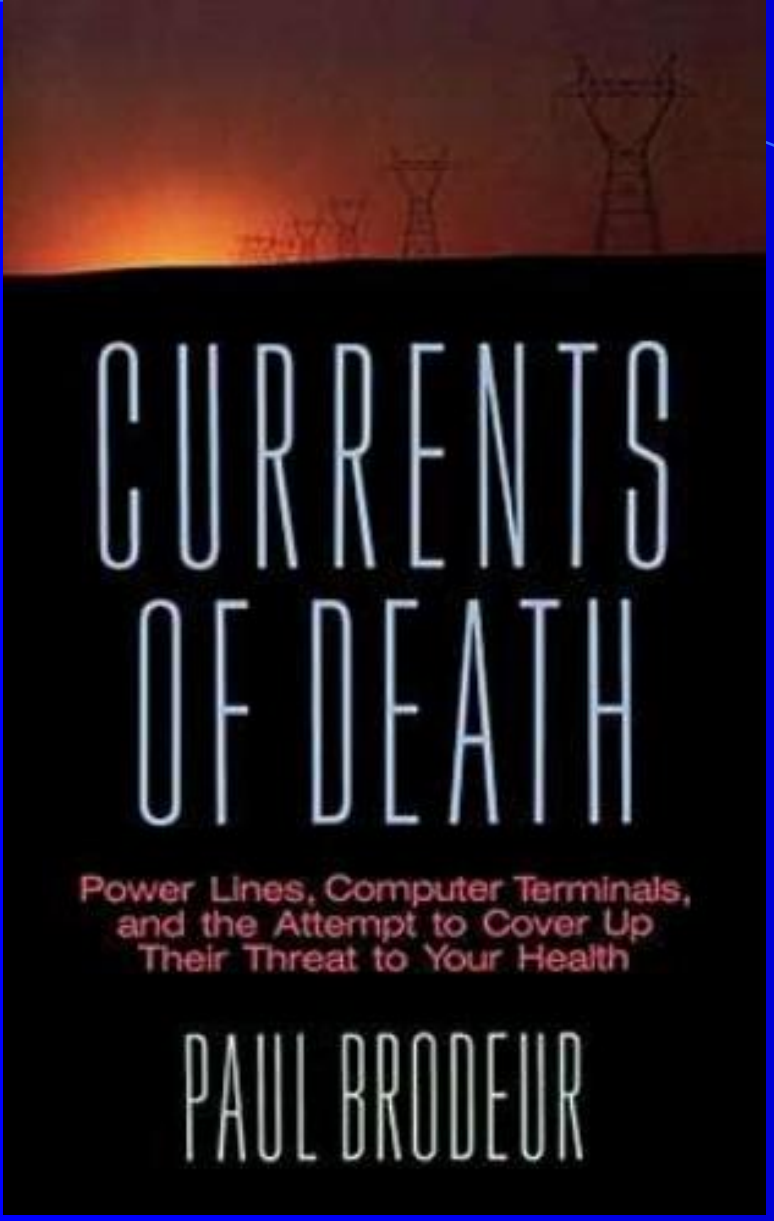
Current safety standards and health

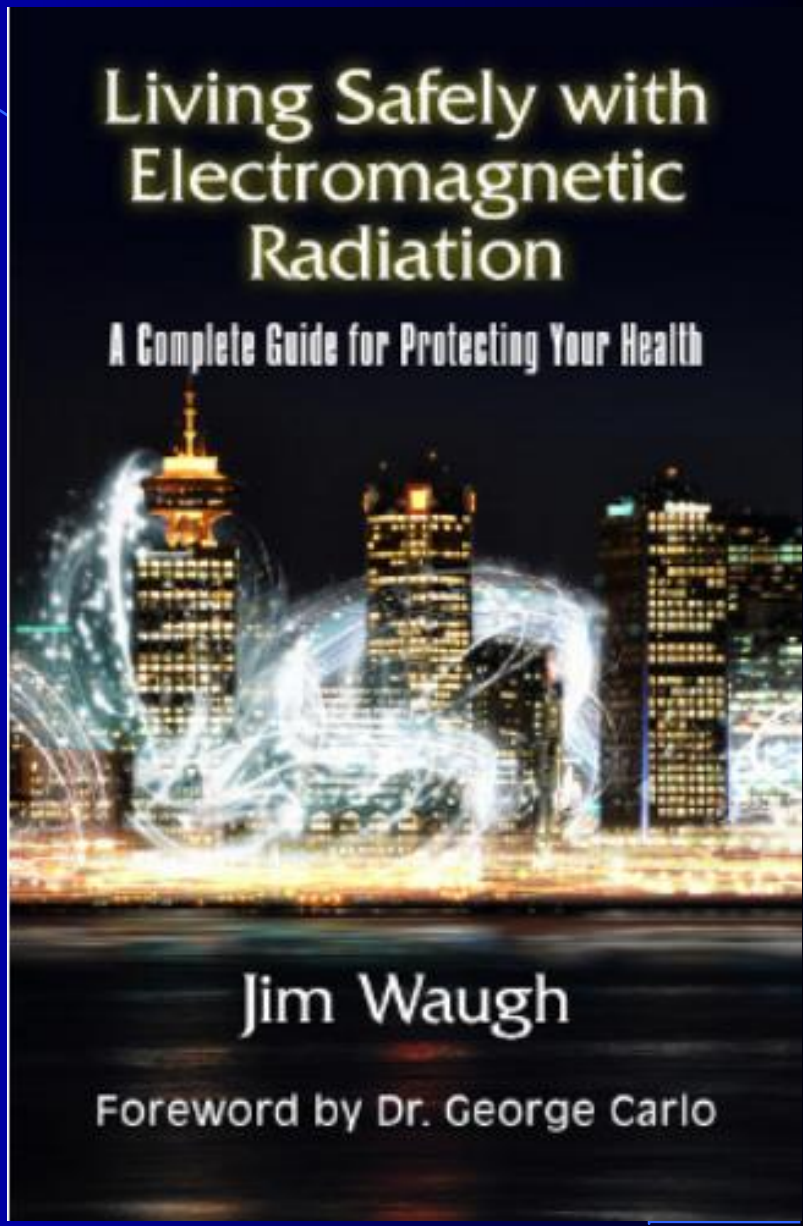
- The recent EMF scientists' appeal does not propose a specific standard for exposure to EMFs.
- Current U.S. standards (and most others) are intended to protect only from the *thermal* effects of EMFs (i.e., excessive *body heating).*
- EMFs at *athermal* levels are a major concern now, with college textbooks and an international academic body (the Bioelectromagnetics Society) addressing the issue of weak EMFs and health.

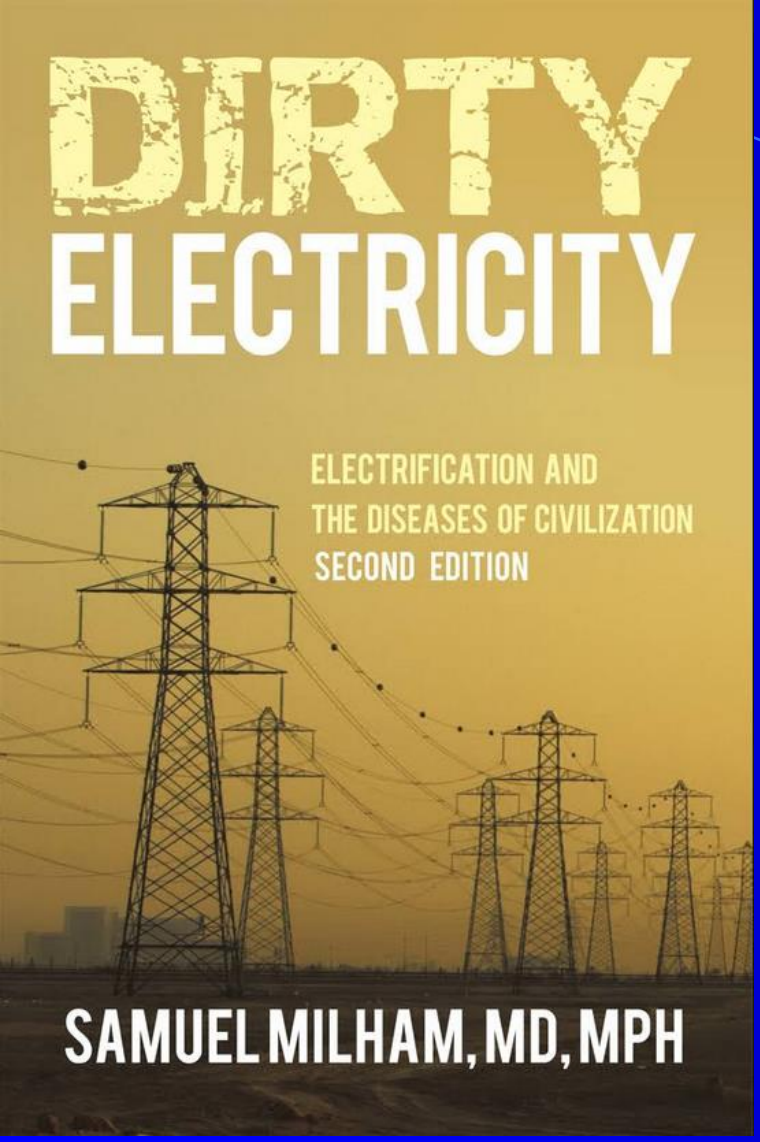
Opposition to change…

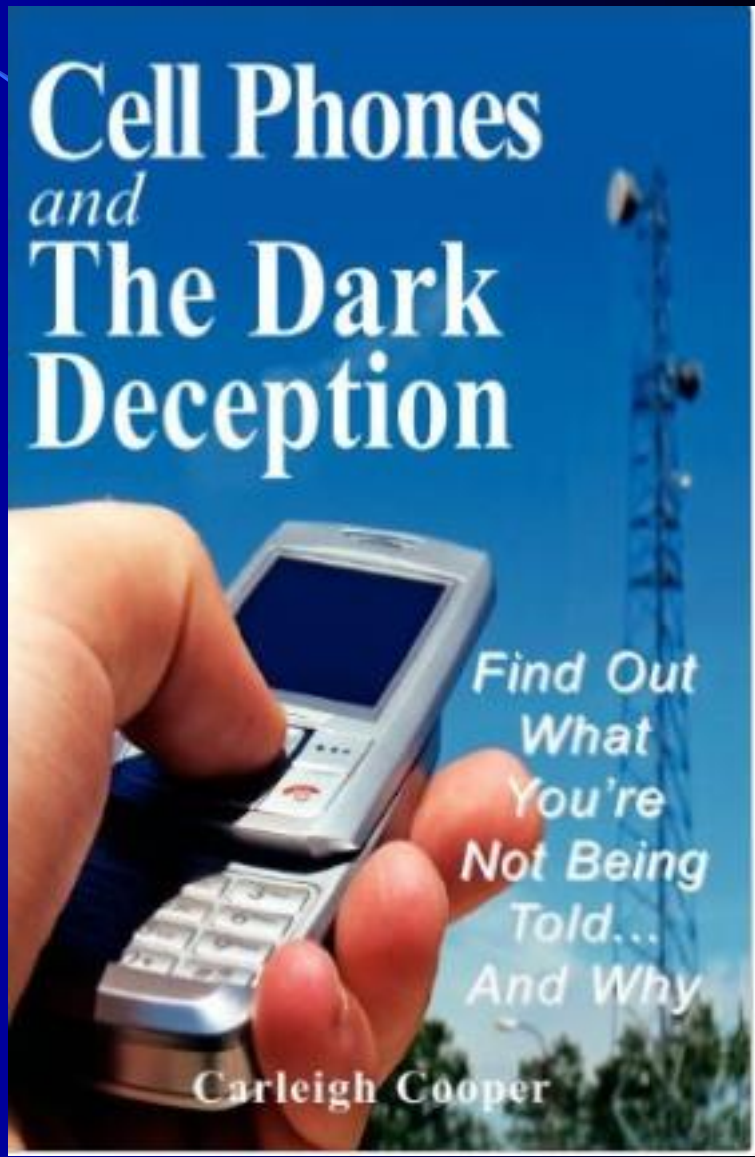
- Many government bodies deny that athermal EMFs pose any health hazard, as do EMF-producing corporations worldwide.
- Implementing stricter RF safety standards would be very expensive for governments and industry.
- Stricter standards would affect how five *billion* cellphone owners use their phones.
- Thousands of radio facilities would have to be modified to provide more protection from EMFs.
- Amateur radio antennas in residential areas and on vehicles would have to be farther from people.

Meanwhile, the popular media are giving this issue more coverage…


CURRENTS OF DEATH
Power Lines, Computer Terminals, and the Attempt to Cover Up Their Threat to Your Health
PAUL BRODEUR


Living Safely with Electromagnetic Radiation
A Complete Guide for Protecting Your Health
Jim Waugh
Foreword by Dr. George Carlo


DIRTY
ELECTRICITY
ELECTRIFICATION AND
THE DISEASES OF CIVILIZATION
SECOND EDITION
SAMUEL MILHAM, MD, MPH


Cell Phones
and
The Dark
Deception
Find Out
What
You're
Not Being
Told...
And Why
Carleigh Cooper

60 Hz. and RF EMFs

- A number of studies have linked power-line EMFs to childhood leukemia and other cancers.
- Other studies have linked low-frequency EMFs in the workplace to various cancers.
- Many industry-backed studies have denied the validity of these findings.
- Several government agencies with industry backing have concluded that any hazard caused by power-line EMFs is minimal. But a body of the World Health Organization has now declared EMFs to be a possible carcinogen.

FCC RF safety regulations

- Maximum permissible exposure (MPE) limit varies by frequency and is lowest at VHF (30-300 MHz) because the human body is most susceptible to RF heating at those frequencies.
- The lowest MPE is 1 mw/cm^2 (averaged over 6 minutes) in *controlled environments* and .2 mw/cm^2 (averaged over 30 minutes) in *uncontrolled environments.*
- Amateurs must meet the controlled-environment standard on their own property and uncontrolled-environment standard in public places and on neighbors' properties.

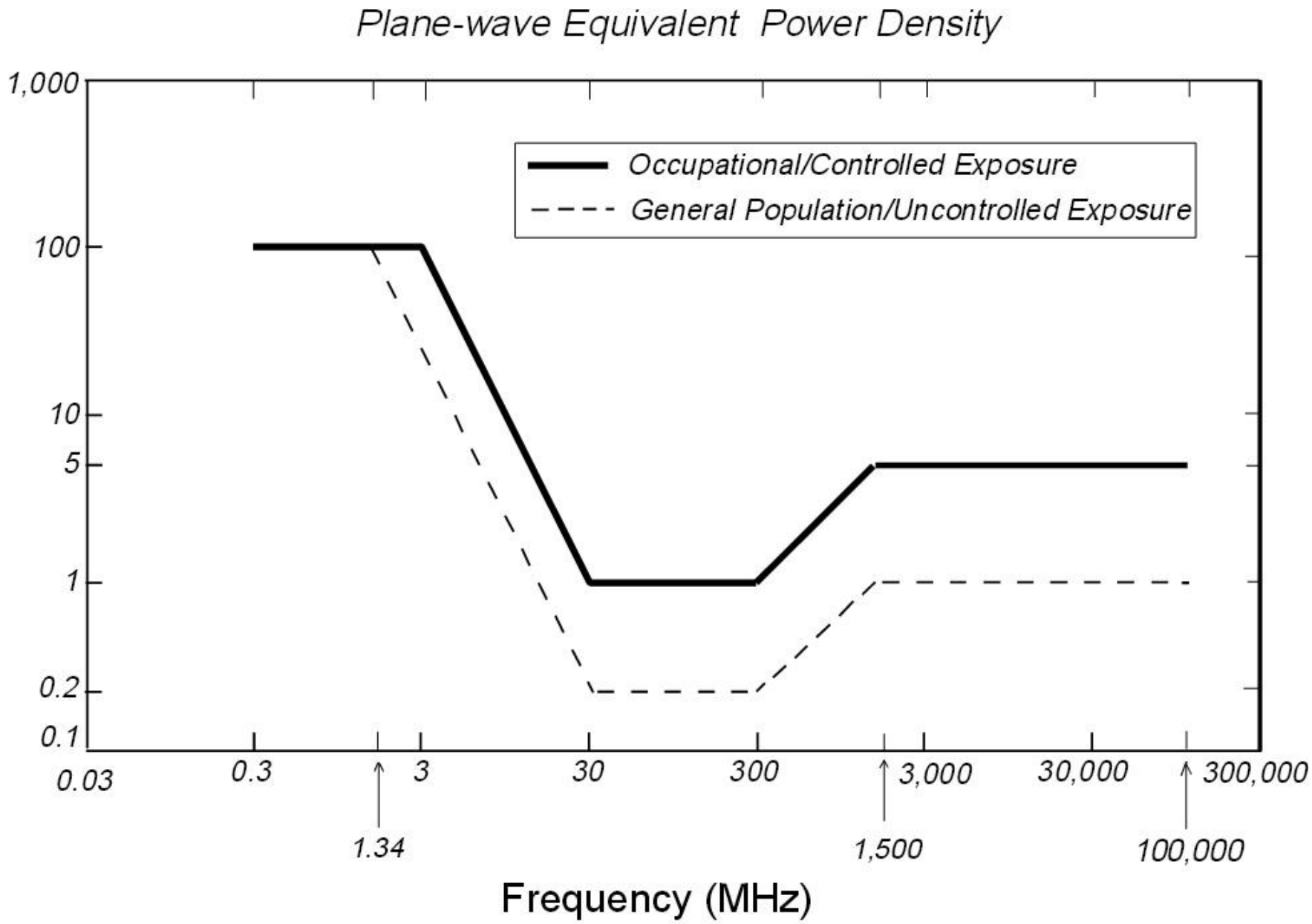
FCC regulations (2)

- FCC/EPA field survey in 1990 found that only a few amateur stations exceeded the less-strict RF exposure standard in effect at the time.
- IEEE proposed a new and tougher standard, which ANSI adopted as C95.1-1992.
- FCC ET Docket 93-62 (1996) adopted the bulk of C95.1-1992, with modifications, setting stricter exposure limits for all FCC licensees.
- 93-62 removed amateurs' former categorical exemption from doing routine evaluations.

FCC regulations (3)

- Low-power ham stations and push-to-talk mobiles were exempt from doing “routine evaluations” until recently.
- Now most amateurs must do routine evaluations of their stations to assure compliance.
- Routine evaluations can be done with a simple computer program or by consulting tables in Supplement B to FCC Bulletin 65.
- Test questions on RF safety were added to amateur license exams (elements 2, 3A and 3B).

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



From FCC OET Bulletin 65

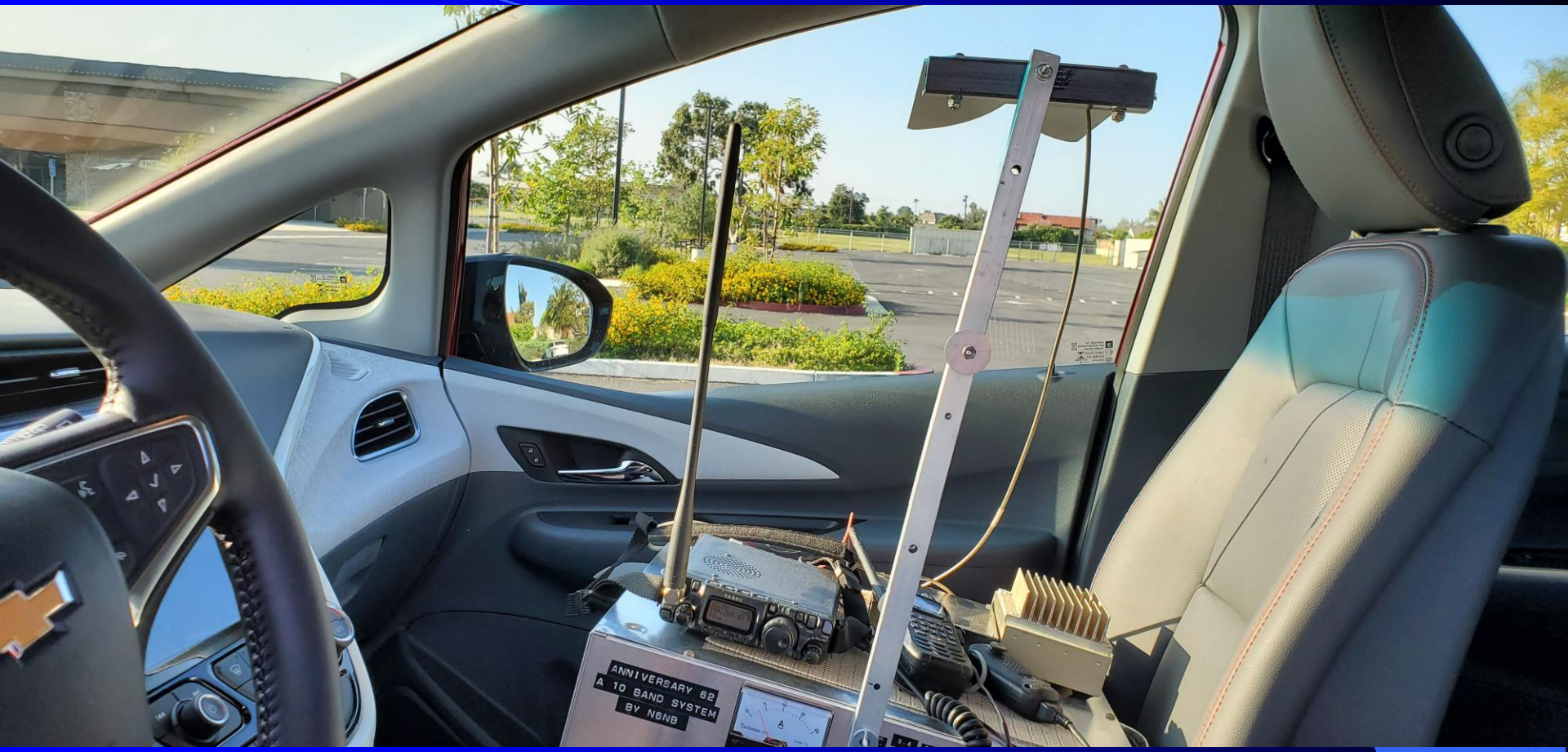
More field measurements, 2021


RAHAM


RAHAM


RAHAM

A sample calculation



This inside-the-car station covers all bands from 50 MHz to 10 GHz. It was shown in QST for May, 2021. The primary antenna is a Vivaldi aimed out the passenger window that covers 850 MHz to 12 GHz. It is evaluated for RF safety on 2304 MHz in the following slides.

```
 MAIN BEAM POWER DENSITY ESTIMATION PROGRAM, REV 3.0
 FOR ROUTINE EVALUATION OF R.F. SAFETY COMPLIANCE


This program uses the formulas given in FCC OET Bulletin No. 65
to estimate power density in the main lobe of an antenna, with
use of the EPA-recommended ground reflection factor as an option.

This program is intended for far field calculations. It may
overestimate the actual field strength of high-gain antennas in
the near field (within several wavelengths of the antenna).
However, it may also underestimate the strength of fields that may
be encountered in `hot spots' in the near field. No computer
program can predict where wiring or reflective objects may create
hot spots in your particular installation.

This is a public domain program by Wayne Overbeck, N6NB

WHAT IS THE POWER AT THE ANTENNA (IN WATTS)? 18


1LIST  2RUN←  3LOAD"  4SAVE"  5CONT←  6,"LPT1 7TRON←  8TROFF← 9KEY   0SCREEN
```

```
WHAT IS THE POWER AT THE ANTENNA (IN WATTS)? 18

Power is averaged over 6 minutes in 'controlled environments'
(like your home or car) and over 30 minutes in 'uncontrolled
environments' (places accessible to others).
WHAT PERCENT OF THE TIME DO YOU TRANSMIT (e.g., 50 or 100)
(ENTER 50 FOR WSJT MODES OR TYPICAL AMATEUR QSOs)? 50

The FCC standard also considers the 'duty cycle' of various modes
(e.g. 100 for key-down modes like FM or digital or 40 for CW or SSB).
ENTER 40, 100 OR ANY NUMBER BELOW 100 THAT YOU CAN JUSTIFY? 40

WHAT IS THE ANTENNA GAIN IN DBI?
(Enter 2.2 for dipoles; add 2.2 for antennas rated in DBD): 11

WHAT IS THE DISTANCE TO AREA OF INTEREST FROM ANTENNA CENTER IN FEET? 4

WHAT IS THE FREQUENCY IN MHZ? 2304

NOW, DO YOU WISH TO INCLUDE EFFECTS OF GROUND REFLECTIONS?
(Ground effects need not be included in most main-beam calculations
but including them may yield more accurate results with very low
antennas, non-directional antennas, and calculations below the
main lobe of directional antennas.) INCLUDE GROUND EFFECTS (Y/N)? Y_
1LIST  2RUN←  3LOAD"  4SAVE"  5CONT←  6,"LPT1 7TRON←  8TROFF← 9KEY    0SCREEN
```

```
HERE ARE THE RESULTS. PRINTED AT 01:07:07 ON 05-05-2021

WITH 18 WATTS AVERAGED FOR TRANSMITTING 50 PERCENT OF THE TIME
AND A MODE-BASED DUTY CYCLE OF 40 PERCENT
WITH 11 DBI GAIN WITH GROUND REFLECTIONS, AT 3 FEET
FROM THE ANTENNA CENTER THE ESTIMATED POWER DENSITY IS 1.1042 MW/CM2.

AT 2304 MHZ, THE MAXIMUM PERMISSIBLE EXPOSURE (MPE) IN `CONTROLLED
ENVIRONMENTS' (SUCH AS YOUR OWN HOUSEHOLD OR CAR) IS 5 MW/CM2.
THE MPE IN `UNCONTROLLED ENVIRONMENTS' (PLACES ACCESSIBLE TO OTHERS)
IS 1 MW/CM2. THIS INSTALLATION WOULD MEET THE CONTROLLED MPE
LIMIT AT 1.4 FEET AND THE UNCONTROLLED LIMIT AT 3.2 FEET.

ALTERNATE CALCULATION FOR EXPOSURE OUTSIDE AN ANTENNA'S MAIN LOBE:
If you wish to estimate the power density at a point outside the main
lobe of a directional antenna and if the antenna's pattern is known
or can be estimated, recalculate using the antenna's gain in the relevant
direction. Example: for a Yagi with 7 dBi forward gain and a front-to-back
ratio of 20 dB, run the program again and enter the antenna gain as
-13 to estimate exposure off the back of the antenna.
Ok
_


1LIST  2RUN←  3LOAD"  4SAVE"  5CONT←  6,"LPT1 7TRON←  8TROFF←  9KEY  0SCREEN
```

A few online information sources

- FCC Bulletin 65, supplement B (*Google* oet65b.pdf
- EMF scientists' appeal: www.emfscientist.org
- The N6NB website (www.n6nb.com/rfsafety.htm)
- http://www.lakewashingtonhamclub.org/resources/rf-exposure-calculator/