NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

CELLULAR PHONE AND HUMAN HEALTH

GRADUATION PROJECT
EE – 400

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Abstract

To evaluate the effects of informing the public about potential health risks of electromagnetic field (EMF) exposure, the authors compared responses to questionnaires evaluating attitudes toward EMF health risk and regulations before and after providing subjects with prepared information. In July 1990, a pretest questionnaire was administered to 60 volunteers, chosen from the Univ. of Oregon community. The volunteers then read a 16 page brochure produced at Carnegie Mellon Univ. that described physical characteristics of EMFs, the types of studies that have been done on EMF health effects, and discussion of the scientific uncertainty surrounding research results. A posttest questionnaire was administered immediately after the subjects finished reading the brochure in which subjects were specifically asked for their attitudes and opinions about 22 kinds of risks including 4 involving extremely low frequency EMF exposure (electric blankets, hair dryers, large power lines, and electric can openers), 1 associated with radio frequency no ionizing radiation exposure (microwave ovens), and 17 non-EMF risks which included handguns, cigarette smoking, nuclear reactors, automobiles, and genetic engineering research. Each subject's attitudes and opinions were scored on 8 psychometric scales to quantify perceptions about the level of: (1) risk to those exposed, (2) benefit to society, (3) knowledge about the risk held by people who are exposed, (4) knowledge about the risk held by scientists, (5) dread, (6) severity of consequences (if a mishap occurs), (7) control over the risk, and (8) equity in the distribution of benefits and risks. A second study was conducted in April 1993 in which 70 persons (group A) were given the pretest questionnaire followed by the brochure and the posttest questionnaire as in the 1990 study, while a second group of 69 subjects (group B) received only the brochure, followed by the same posttest questionnaire given to group-A subjects. Overall, approximately 59% of participants claimed to have heard about the possible health risks of exposure to EMFs, mostly from articles in newspapers or magazines (80%) or by discussions with friends or relatives (62.9%). In the 1990 study, pretest questionnaire responses indicated that risks from electric can openers, hair dryers, and electric blankets were similarly perceived as extremely low with regard to severity of consequences, dread, and knowledge. They were regarded as extremely equitable in the risk/benefit distributions, low on benefits, and high on controllability of risk. By contrast, large power lines stood out among the 4 EMF items as being perceived higher in risk; better

known to both science and the exposed; higher in severity of consequences, dread, and benefits; lower on control; and less equitable in the risk/benefit distributions. Microwave ovens were consistently rated as somewhat less risky and less beneficial than power lines, but more risky and beneficial than the other EMF items. After reading the brochure, the mean risk ratings tended to increase substantially, ranging from 56% of subjects increasing their risk rating for power lines to 76% for electric can openers. Some subjects also reported decreased risk ratings which varied from 28% (power lines) to 8% (electric blankets). The increases in mean perceived risk were large enough to move each item considerably higher in the ranking across the 22 items. Specifically, electric blankets moved up from 8 to 17 (where 1 = the lowest risk), hair dryers from 2 to 14, large power lines from 16 to 18, and electric can openers from 1 to 11. Results of the April 1993 study also indicated that perceived risks for all 4 EMF items were significantly increased after reading the brochure. The principle difference between the 1990 and 1993 results was seen in the control scale, where reading the brochure resulted in significantly increased perceptions of control in 1990, but not in 1993. The brochure had significant effects on perceived risk for all 4 EMF items. The pretest sensitized subjects in group A to material in the brochure, particularly for hair dryers and electric can openers, but overall the effect of the pretest on posttest ratings was not as great as the effect of the brochure.

INTRODUCTION

I found an article about future cellular phones online with five sub-articles explaining five unique cellular phones from Samsung Electronics' website. All of those five different cellular phones were made with state of the art technologies. Some of the functions they feature are like TV, Internet, MP3 player, video transmission, and wrist cellular phone. The first cellular phone introduces was the TV phone. Samsung introduces a normal looking folding-type cellular phone with small TV built into it. This cellular phone uses a 1.8-inch high-resolution color LCD screen instead of normal screen with colors like green and black. This screen allows the user to view the TV using the antenna attached to the cellular phone and the earphone to view TV shows anywhere, and if someone calls, the TV simply turns off and the cellular phone turns into phone mode immediately. VHF and UHF reception is possible with the antenna on the cellular phone. And this TV phone allows you to watch TV for as long as 200 minutes on a single charge with it's high-capacity battery. Some specialty of this cellular phone is that even with all those features, it only weighs 160 grams, and the TV operates on just 3 volts and gives same picture quality as any other portable TV using 9 volts. Before, using one antenna for TV and cellular phone seemed too difficult because of the interference between the TV and the phone's different frequency. However, Samsung made this possible with its newest technology they invented. Next cellular phone introduced was a Wireless Internet phone. This cellular phone has a charge 3-cm by 7-cm touch screen, which allows users to browse through the Internet, and send faxes. This phone has features like cellular phone, electronic notebook, PC data interface, character recognitions, and etc. This cellular phone's character recognition technology has 98% accuracy with Korean and 95% accuracy with English when written on the touch screen with a pen. This unit took Samsung's 110 researchers, $4.6 million, and 52 patents to develop. This Internet phone can also send e-mails, written documents or pictures through Internet just like a normal laptop computer. The third cellular phone introduced in this article was the MP3 Phone. This cellular phone plays music from its embedded memory of 32 MB in mp3 format, the most popular format of music for PC. This cellular phone allows users to put mp3 files on it's embedded memory using computer, and also allows users to create their own mp3 files by recording their phone calls or other sounds. This phone has functions that other cellular phones have like, voice dialing, morning call, and etc. This phone also has a function that allows users to whisper on their cellular phone to the other person when they cannot raise their voice at that moment. This function amplifies sound coming from short distance so that the other caller can hear the user clearly. The fourth cellular phone shown was IMT-2000 cellular phone. This is a cellular phone that that has Base Station System, Mobile Switching Center, and other system hardware as well as hand sets for high-speed packet data and moving picture data transmission. This phone allows users to sent packet data at 144 Kbps, which is about 10 times faster than normal wireless handsets can. So users can send data, graphics, still pictures, and even moving pictures. Also this unit is designed to operate and 2 GHz, which is higher compared to other units with 1.9 GHz or 1.8 MHz. Last model from this article is the Watch Phone. Cellular phone that users wear was already invented in Japan and was used in 1996 Nagano Winter Olympics by some officials. However, those were not introduced to the public to buy. So the Samsung is the first company to introduce Watch Phone to the cellular phone market. This cellular phone has about 30 features just like other normal-sized cellular phones in South Korea. Some features that this cellular phone has would be things like voice-activated dialing, phone directory, vibration, microphone, and LCD screen that displays the current mode that the user is in. This cellular phone is expected to be a big hit with the youth market because of its portability and other advantages. Some advantages can be that it is harder to lose or get stolen then normal cellular phones because it's worn on the users' wrist, and it stays out of the way for outdoor or indoor activities.

The first chapter represents wave propagation and spectrum places when the particles cluster together are volumes of high pressure so these waves are also called pressure waves. Sound waves are an example of pressure waves and they can move through gases, liquids and solids. For sound waves, the denser the medium the faster the speed.

Chapter two is devoted to the hazards, which is the effects directly at the human health. Mobile phones are low power radio devices that transmit and receive microwave radiation at frequencies of about 900 Megahertz (MHz) and 1800 MHz. There are many other sources of radio waves.

Chapter three presents the possible effects while most basic scientists avoided such questions, the clinical neurologists were convinced that something was lacking in the action potential only concept. In the 1940's Gerard and Libet reported a particularly significant series of experiments on the DC electrical potentials measurable in the brain.

Chapter four is devoted to the international standars While cellular phones are really elements of communication rather than transportation, their potential impact upon the latter is sizable. The prospect of twenty million drivers having the opportunity to place, receive, or handle a telephone call while driving is not something easily ignored.

The conclusion presents important results obtained by reaserches and practical realization of the cellular phone and human health .

Table contents

1.THE ELECTRO MAGNETIC WAVES ON HUMAN HEALTH

1.1.Wave motion as an energy transfer

Any vibrating body that is connected to its environment will transfer energy to its environment. The vibrations are then transferred though the environment from neighbour to neighbour. This energy transfer is called wave motion. Wave motion moves energy through a medium without moving the whole medium.

Leonardo di Vinci

"waves made in a field of grain by the wind, ... we see the waves running across the field while the grain remains in place."

1.2.Types of waves

1.2.1 Longitudinal waves:

When waves transfer energy by pushing neighbours in the same direction that the energy moves, the waves are called longitudinal waves. In the simulation below you can see energy move to the right while individual particles vibrate to the left and right about fixed points.

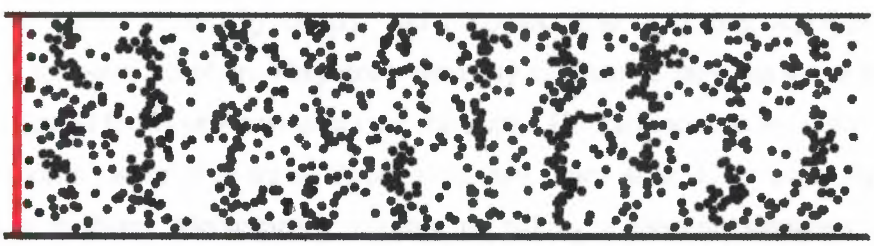


Figure 1. 1 Longitudinal waves

The places when the particles cluster together are volumes of high pressure so these waves are also called pressure waves. Sound waves are an example of pressure waves and they can move through gases, liquids and solids. For sound waves, the denser the medium the faster the speed.

Speed through air (1atm, 20^0) =344 $m.s^{-1}$

Speed through sea water = 1531 $m.s^{-1}$

Speed through iron = 5130 $m.s^{-1}$

1.2.2 Transverse waves

When waves transfer energy by pulling neighbours sideways to the direction of travel, the waves are called transverse waves. In the simulation below you can see energy move to the right while individual particles vibrate up and down about fixed points.

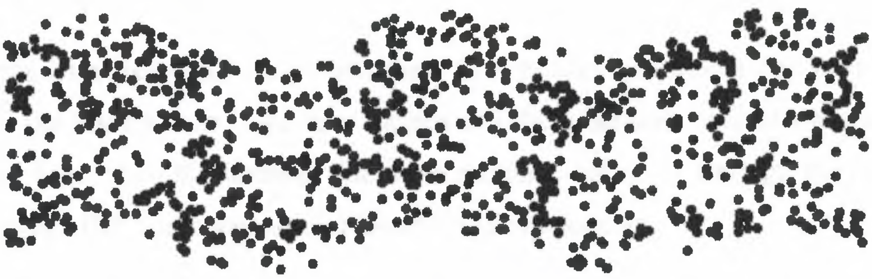


Figure 1.2 Transverse waves

Electromagnetic waves (X-rays, light, radio, radar and TV waves) are examples of transverse waves formed by electric and magnetic fields vibrating together at right angles to the wave's motion. They don't need any medium so they can move through a vacuum, (good for us or we wouldn't see the Sun!). They all move at the same speed of 300,000 $km.s^{-1}$ when they travel through vacuum. They slow down when they travel through a medium. Mechanically twisting or pulling a medium sideways is called *shearing so waves formed this way are also called shear waves.*

(a) Waves out on the ocean's surface are a combination of transverse and longitudinal waves. *(The surface can pull sideways because of surface tension.) In the simulation* below you can see energy move to the right while individual particles move clockwise in circles or ellipses.

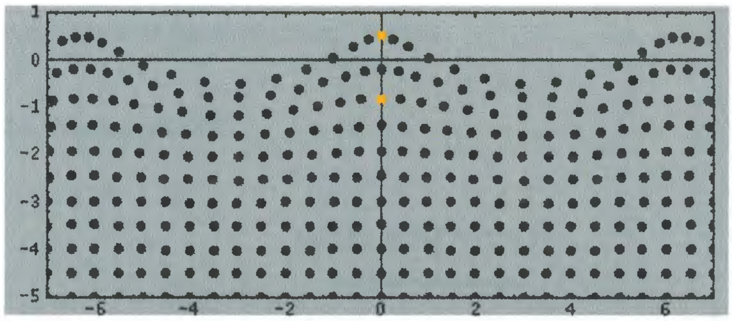


Figure 1.3 Simulation of transverse and longitudinal waves

The wave height is the distance from a trough to a peak and the wavelength is the peak to peak distance. When ocean waves get to a shelving beach the speeds of the waves change relative to each other and the peaks get closer together. When the waveheight is 1/7 the wavelength then the wave breaks.

(b) Seismic waves are formed when there is a sudden movement (or slip) between layers in the Earth's crust. This may happen anywhere between several km and several 100s km down from the surface. The wave motions that occur through the crust have both Pressure ("P") components and Shear ("S") components.

The P waves move at 5 - 14 km. s^{-1}

The S waves move at 3 - 8 km. s^{-1}

When they reach the surface an Earthquake occurs, and the timing between the arrivals of the S and P waves and their sizes at different places will enable the epicentre to be determined.

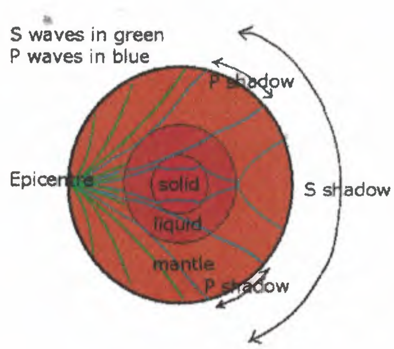


Figure 1.4 surface waves

Note: seismic waves can also have "surface" waves.

1.3.Basic Wave Parameters

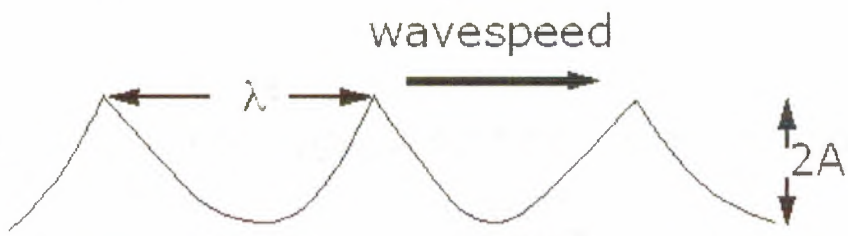


Figure1. 4 Basic Wave Parameters

the amplitude is half the height difference between a peak and a trough. The wavelength is the distance between successive peaks (or troughs). The frequency measures the number of peaks (or troughs) that pass per second in equation (1).

$$\text{Wave speed} = \frac{\text{distance between peaks}}{\text{time between peaks}}$$

$$c = \frac{\lambda}{T} = \nu\lambda \qquad \text{Eq. (1)}$$

Example 1

Seismic Shear waves travel at 4000 m.s^{-1} and they have a period of 0.12s. Find the wavelength of these waves.

$$c = \nu\lambda$$

$$\lambda = \frac{c}{\nu} = cT = 4000 \times 0.12 = 480m$$

1.4.Representing Moving Shapes

The engine and carriage below have a frame of reference with axes labelled X and Y. The shape Y = f(X) is drawn on the side of the carriage.

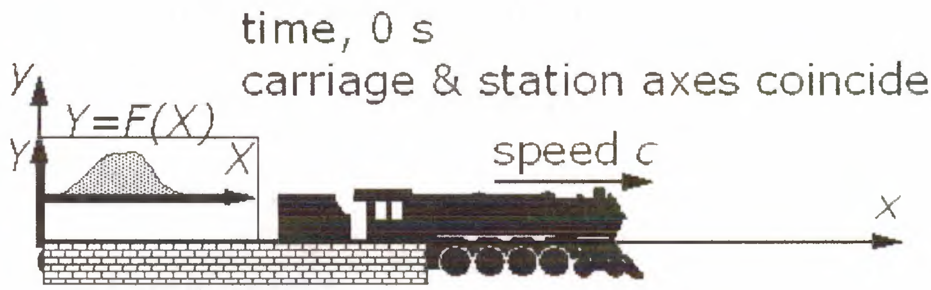


Figure1.5 Moving Shapes

The station has a frame of reference with axes labelled x and y. The engine and carriage are moving at a constant speed c to the right (positive x axis).At time t = 0 s, the carriage and the station axes coincide.

At time t s later:

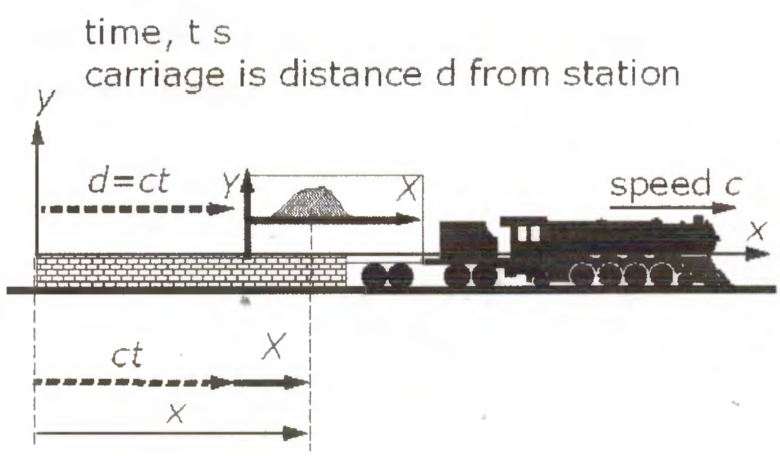


Figure 1.7 carriage and the station axes

Vertical distance references do not change, i.e. Y = y at all times.

The horizontal distance between the Y and y axes increases uniformly with time, i.e.d = ct.The distance X from the carriage origin to a point P on the side of the carriage will not change in time. The distance x from the station origin to the point P will increase with time,in equation (2).

$$x = X + ct \qquad \textit{Eq. (2)}$$

This means that the reference frames transform as; equation (3)

$$(x,y) = (X + ct, Y) \text{ and}$$

$$(X,Y) = (x - ct, y) \qquad \textit{Eq. (3)}$$

In the carriage frame of reference:

Y = f(X) defines a shape on the side of the carriage.

In the station frame of reference:

y = f(x -vt) defines a shape f(x) which moves a speed c to the right.

1.5.Transverse Sinusoidal Waves

You can only have the sine of an angle. To have a sine shape in space, the x distance has to be converted into an angle.

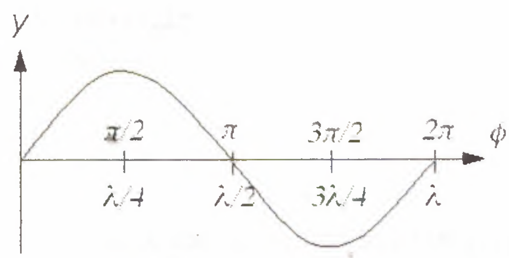


Figure 1.8 Transverse Sinusoidal Waves

One complete cycle in space (one wavelength) has to be equivalent to one cycle in phase A fractional distance of a wavelength will equal the same fractional angle Eq.(4).

$$\frac{x}{\lambda} = \frac{\phi}{2\pi} \qquad \text{Eq.(4)}$$

$$\text{phase angle}, \ \phi = \frac{2\pi}{\lambda} \cdot X = kX \quad , \qquad \text{Eq.(5)}$$

where k is called the wave number. A sine shape in space is then given by equation (6):

$$Y = A \sin\phi = A \sin \frac{2\pi}{\lambda} X = A \sin kX \qquad \text{Eq.(6)}$$

A sinusoidal wave is a sine shape that moves at speed c. A sine wave moving to the right (positive x direction) will be written in equation .(7):

$$y = A \sin \frac{2\pi}{\lambda}(x - ct) = A \sin k(x - ct) \qquad \text{Eq.(7)}$$

A sine wave moving to the left (negative x direction) will be written in Eq.(8)

$$y = A \sin \frac{2\pi}{\lambda}(x + ct) = A \sin k(x + ct) \qquad \text{Eq.(8)}$$

Now

$$\begin{aligned} \text{wavespeed} &= \frac{\text{distance between peaks}}{\text{time between peaks}} \\ &= \frac{\text{wavelength}}{\text{Period}} \\ c &= \frac{\lambda}{T} \end{aligned} \qquad \text{Eq.(9)}$$

This means the time part of the wave can be written in equation (10)

$$\begin{aligned} kct &= \frac{2\pi}{\lambda} \cdot ct \\ &= 2\pi \frac{c}{\lambda} \cdot t = 2\pi \frac{t}{T} \\ &= \omega t \end{aligned} \qquad \text{Eq.(10)}$$

where

$$\omega = \frac{2\pi}{T} = 2\pi\nu \qquad \text{Eq.(11)}$$

is called the angular frequency. Hence equation (12)

$$y = A \sin (kx - \omega t) \qquad \text{Eq.(12)}$$

is a sine curve travelling to the right, with equation(13) & equation (14)

$$k = \frac{2\pi}{\lambda} \quad \omega = \frac{2\pi}{T} = 2\pi\nu \quad \text{and} \quad c = \frac{\lambda}{T} = \frac{\omega}{k} = \nu\lambda \qquad \text{Eq.(13).Eq.(14)}$$

Adding an initial phase, that tells what is happening at time 0 s.

$$y = A \sin (kx - \omega t + \alpha) \qquad \text{Eq.(15)}$$

The waves (so far) have travelled at constant speed, but the vibrating particles which make up the wave, move with simple harmonic motions that change their initial phase with distance which shows in equation (16)

$$\begin{aligned} y &= A \sin (kx - \omega t + \alpha) \text{ m} \\ &= A \sin (\phi(x) - \omega t) \text{ m} \end{aligned} \qquad \text{Eq.(16)}$$

This shows that each point vibrates with SHM. The transverse particle speed is given by equation (17):

$$\begin{aligned} \frac{dy}{dt} &= -\omega A \cos (\phi(x) - \omega t) \\ v_{max} &= \omega A \end{aligned} \qquad \text{Eq.(17)}$$

Notice that displacement and particle speed are 90° out of phase.

Example 2

A sinusoidal wave has a wavelength of 1.4m. Find the phase difference between a point 0.3m from the peak of a wave and another point 0.7m further along from the same peak.

$$\frac{\text{distance between points}}{\text{wavelength}} = \frac{\text{phase angle}}{2\pi}$$

$$\frac{0.7 - 0.3}{1.4} = \frac{\phi}{2\pi}$$

$$\phi = \frac{2\pi \times 0.4}{1.4}$$

$$= 1.8 \text{ rad}$$

Example 3

The equation of a transverse sinusoidal wave is given by:

$$y = 2 \times 10^{-3} \sin (18x - 600t + 30^{0}) \text{ m}$$

Find

(a) the amplitude of the wave,

(b) the wavelength,

(c) the frequency,

(d) the wave speed, and

(e) the displacement at time 0 s.

(f) the maximum transverse particle speed.

Amplitude is 2 mm.

$$18 = \frac{2\pi}{\lambda} \quad \therefore \quad \lambda = \frac{2\pi}{18} = 0.35 \text{ m}$$

$$600 = 2\pi\nu \quad \therefore \quad \nu = \frac{600}{2\pi} = 95.5 \text{ Hz}$$

$$c = \frac{\omega}{k} = \frac{600}{18} = 33.3 \text{ m.s}^{-1}$$

$$\begin{aligned} y &= 2\times10^{-3} \sin\ (18x - 600t + 30^0) \\ &= 2\times10^{-3} \sin\ 30^0 \\ &= 1\times10^{-3} \text{ m} \\ &= 1 \text{ mm} \end{aligned}$$

1.6.The Intensity, Impedance and Pressure Amplitude of a Wave

$$\begin{aligned} \text{Intensity} &= \frac{\text{power}}{\text{area}} \text{ in W.m}^{-2} \\ &= \frac{\text{energy}}{\text{time} \times \text{area}} \\ &= \frac{\text{energy} \times \text{length}}{\text{time} \times \text{volume}} \end{aligned}$$

$$\text{Intensity} = \left(\frac{\text{energy}}{\text{volume}}\right) \times (\text{wave speed}) \qquad \text{Eq.(18)}$$

The energy comes from the simple harmonic motion of the particles which show in equation (19) & equation (20)

$$\text{energy} = \frac{1}{2} m v_{max}^2 = \frac{1}{2} m (A\omega)^2$$

$$\frac{\text{energy}}{\text{volume}} = \frac{1}{2}\rho (A\omega)^2 \qquad \text{Eq.(19)}$$

$$\begin{aligned} Intensity &= \left(\frac{energy}{volume}\right) \times (wave\ speed) \\ &= \frac{1}{2}\rho(A\omega)^2 \times c \end{aligned}$$

$$I = \frac{1}{2}(\rho c)(A\omega)^2 \qquad \text{Eq.(20)}$$

The quantity, Z =xc is determined by the medium that the wave is passing through, and is called the impedance of the medium. The quantity Aώ is the maximum transverse speed of the particles. The intensity of a wave increases with its wavespeed, frequency and amplitude.

Re-arranging in equation (21)

$$
\begin{aligned}
Intensity &= \frac{1}{2}(\rho c)(A\omega)^2 \\
&= \frac{1}{2}\frac{(\rho c A\omega)^2}{(\rho c)} \\
&= \frac{1}{2}\frac{P_0^2}{(\rho c)} \\
P_0 &= \rho c A\omega
\end{aligned}
\qquad \text{Eq.(21)}
$$

where P_0 is called the pressure amplitude. It is useful when dealing with pressure waves.

Example 4

A wave of frequency 1000 Hz travels in air of density 1.2 kg.m^{-3} at 340 m.s^{-1}. If the wave has intensity 10 AW.m^{-2}, find the displacement and pressure amplitudes.

$$
\begin{aligned}
I &= \frac{1}{2}(\rho c)(A\omega)^2 \\
A &= \sqrt{\frac{2I}{(\rho c)\omega^2}} \\
&= \sqrt{\frac{2\times 10^{-6}}{1.2\times 340\times(2\pi\times 1000)^2}} \\
&= 11 \text{ nm} \\
P_0 &= \rho c A\omega \\
&= 1.2\times 340\times 11\times 10^{-9}\times 2\pi\times 1000 \\
&= 28 \text{ mPa}
\end{aligned}
\qquad \text{Eq.(22)}
$$

1.7.Intensity Level

The intensity of a sound is given by power/area. It is an objective measurement and has the unit of $W.m^{-2}$. Loudness is a subjective perception. For a long time it was thought that the ear responded logarithmically to sound intensity, i.e. that an increase of 100x in intensity ($W.m^{-2}$) would be perceived as a loudness increase of 20x. The Intensity Level was defined to represent loudness. It is logarithmic and has the unit of Bel (after Alexander Graham Bell, not the Babylonian deity). The deciBel is commonly used as the smallest difference in loudness that can be detected in equation (23)

$$\beta = 10 \times \log \frac{\text{Intensity}(W.m^{-2})}{\text{Reference Intensity }(W.m^{-2})}$$

$$= 10 \times \log \frac{I}{I_0} \qquad \text{Eq.(23)}$$

The reference intensity 10^{-12} $W.m^{-2}$ is the (alleged) quietest sound that can be heard. Only about 10% of people can hear this 0 dB sound and that only in the frequency range of 2kHz to 4kHz. About 50% of people can hear 20dB at 1kHz. (The frequency response will be looked at later.)

Table 1.1 Approximate Intensity Levels

Type of sound	Intensity levelat ear (dB)
Threshold of hearing	0
Rustle of leaves	10
Very quiet room	20
Average room	40
Conversation	60
Busy street	70
Loud radio	80

Example 5

The average intensity level for each of two radios is set to 45dB. They are tuned to different radio stations. Find the average intensity level when they are both turned

$$\beta = 10 \times \log \frac{I}{I_0}$$
$$I = I_0 \times 10^{\beta/10} = I_0 \times 10^{4.5}$$

$$I_{both} = 2\left(I_0 \times 10^{4.5}\right) = 10^{0.3}\left(I_0 \times 10^{4.5}\right) = I_0 \times 10^{4.8}$$
$$\frac{I_{both}}{I_0} = 10^{4.8}$$
$$\beta_{both} = 10 \times \log \frac{I_{both}}{I_0} = 48$$

Here the Intensity doubles but the Intensity Level goes up by only 0.3 dB.

Example 6

Sound radiates in a hemi-sphere from a rock band. The sound level is 100 dB at 10 m, find the sound level at 4 m

$$\beta = 10 \times \log \frac{I}{I_0}$$
$$\frac{I}{I_0} = 10^{\frac{\beta}{10}}$$
$$I = I_0 \times 10^{\beta/10} = 10^{-12} \times 10^{10}$$
$$= 10 \text{ mW.m}^{-2}$$

Having calculated the Intensity from the Intensity Level, we now find the new Intensity.

$$\text{Power radiated} = \text{Intensity} \times \text{Area} = \text{constant}$$
$$I_1 A_1 = I_2 A_2$$
$$I_2 = \frac{A_1}{A_2} I_1 = \frac{2\pi r_1^2}{2\pi r_2^2} I_1$$
$$= \left(\frac{r_1}{r_2}\right)^2 I_1$$
$$= \left(\frac{10}{4}\right)^2 \times 10^{-2}$$
$$= 6.25 \times 10^{-3}$$

We now find the new intensity level which shows in equation (25)

$$\beta = 10 \times \log \frac{I}{I_0} = 10 \times \log \frac{6.25 \times 10^{-3}}{10^{-12}}$$
$$= 108 \text{ dB} \qquad \text{Eq.(25)}$$

1.8.Other Loudness measures

There are other ways of representing the human response, some of these are in equation (26)

$$Loudness = 10 \times \log \frac{I}{0.468 \times 10^{-12}} \qquad \text{Eq.(26)}$$

(which puts the threshold of hearing at 4dB), and

$$Loudness = \frac{1}{16}\left(\frac{I}{10^{-12}}\right)^{0.3} \; Sones \qquad \text{Eq.(27)}$$

(1 Sone = 40dB at 1kHz)

1.9.Degrees of Hearing Loss

A person can have up to 25 dB hearing level (HL) and still have "normal" hearing. Those with a mild hearing loss (26-45 dB HL) may have difficulty hearing and understanding someone who is speaking from a distance or who has a soft voice. They will generally hear one-on-one conversations if they can see the speaker's face and are close to the speaker. derstanding conversations in noisy backgrounds may be difficult. Those with moderate hearing loss (46-65 dB HL) have difficulty understanding conversational levels of speech, even in quiet backgrounds. Trying to hear in noisy backgrounds is extremely difficult. Those with severe hearing loss (66-85 dB HL) have difficulty hearing in all situations. Speech may be heard only if the speaker is talking loudly or at close range. Those with profound hearing loss (greater than 85 dB HL) may not hear even loud speech or environmental sounds. They may not use hearing as a primary method of communicating.

1.10.The Fletcher-Munson Curves

Fletcher and Munson were researchers who first accurately measured and published a set of curves showing the human's ear's frequency sensitivity versus loudness. The curves show the ear to be most sensitive to sounds in the 3 kHz to 4 kHz area, a range that corresponds to ear canal resonances.

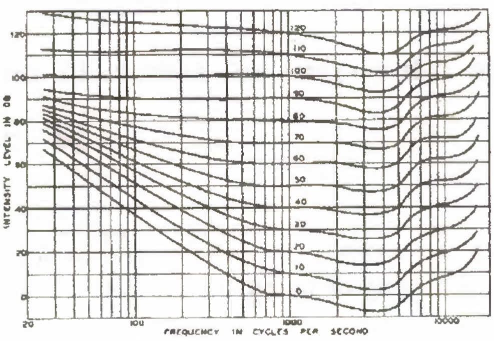


Figure 1.6 The Fletcher-Munson Curves

The lines give a unit called the phon. 100Hz at 71dB has the same apparent loudness as 60dB at 1kHz and hence it is 60 phons. The important range for speech is 300Hz - 3000Hz. Loud noise and age cause the high frequency response to decline. These data are generally regarded as being more accurate than those of Fletcher and Munson. Both sources apply only to pure tones in otherwise silent free-field conditions, with a frontal plane wave etc.

1.11.Pitch

Frequency is measured physically in Hertz. The subjective sensation of frequency is called the pitch of the note. The ear is not linear with frequency (Hertz). There is a "S" shaped curve between frequency and pitch. The ear is reasonably OK in the range 400Hz to 2.4kHz, but outside this range perception is pitch and frequency differ. For example, 300Hz is perceived as 500Hz, but 10kHz is perceived to be 3kHz. The subjective determination of frequency has a unit called the mel, and is thought to be due to the variable elastic properties of the basilar membrane in ther ear.

1.11.1 Summarising:

Waves move energy through a medium without moving the whole medium. In longitudinal waves the vibration is in the same orientation as the wave movement. In transverse waves the vibration is at right angles to the wave movement.Amplitude: A, is half the wave height. Wavelength: is the distance between successive maxima (or minima).

Frequency: is the number of maxima (or minima) that pass per second and the reciprocal of the Period, T.

Wavespeed: $c = v\lambda = \frac{\omega}{k}$ Angular frequency: $\omega = \frac{2\pi}{T} = 2\pi v$

Wave Number: $k = \frac{2\pi}{\lambda}$ Phase Angle: $\phi = 2\pi \cdot \frac{x}{\lambda} = kx$

Sinusoidal wave: $y = A \sin (kx - \omega t + \alpha)$

Intensity: $I = \frac{P}{A} = \frac{1}{2}(\rho c)(A\omega)^2$ Pressure Amplitude: $P_0 = \rho c A \omega$

deciBel: $\beta = 10 \times \log \frac{I}{I_0} = 10 \times \log \frac{I}{10^{-12}}$ Eq.(28)

Hearing depends on both frequency and intensity. Frequency is measured physically in Hertz and subjectively in Mels.

1.12. Electro Magnetic Propagation Wave

Nonlinear equations are introduced to model the behavior of the waves of cortical electrical activities that are responsible for signals observed in electroencephalography. These equations incorporate nonlinearities, axonal and dendrites lags, excitatory and inhibitory neuronal populations, and the two-dimensional nature of the cortex, while rendering nonlinear features far more tractable than previous formulations, both analytically and numerically. The model equations are first used to calculate steady-state levels of cortical activity for various levels of stimulation. Dispersion equations for linear waves are then derived analytically and an analytic expression is found for the linear stability boundary beyond which a seizure will occur. The effects of boundary conditions in determining global eigenmodes are also studied in various geometries and the corresponding eigenfrequencies are found. Numerical results confirm the analytic ones, which are also found to reproduce existing results in the relevant limits, thereby elucidating the limits of validity of previous approximations. Measurement of electrical activity in the cerebral cortex by means of electrodes on the scalp or the cortical surface is a commonly used tool in neuroscience and medicine. Detailed multichannel recordings of activity resulting from neuronal firings are routinely made, showing complex spatial and temporal patterns in the cortical regions where cognitive tasks are performed. These signals, known as electroencephalograms or EEGs, display sufficient consistency that their coarse morphological and spectral features may be empirically identified and quantified. The frequency content of EEG and variations in the power spectrum with cognitive state has been well characterized, velocities of EEG waves have been estimated, and typical features of the EEG response to external stimuli (so-called event related potentials) have been measured. Unfortunately, the connection between recorded EEGs and the underlying neuronal dynamics (and a fortiori cognition) remains poorly understood. A few of the most basic properties of cortical waves appear to be established, but virtually everything beyond this level is the subject of considerable debate and the wealth of experimental data is largely wasted in the absence of a more solid theoretical framework within which to analyze it. Numerous models of cortical activity have been developed at a variety of levels of description. At the most fundamental levels are neural networks, which attempt to describe the interconnections between individual neurons with varying degrees of idealization.

We term such simulations microscopic because of their incorporation of microstructure and neglect of long-range interconnections. Most notably, Fieeman and colleagues have modeled the EEG arising from the olfactory bulb of animals, during the perception of odors, by uniting estimates of physiological parameters within a system of nonlinear equations. However other methods are called for when models for microscopic, highly nonlinear neuronal events are extended to the large scale required to describe the macroscopic EEG. Waves of the cerebral cortex. Because of the huge numbers of neurons ($\sim 10^{10}$) in the cortex, smoothed-parameter models have been introduced to study global properties of cortical activity. Such models implicitly treat the cortex as a continuum (although they may be discredited for computation), characterized by mean densities of interconnections between neurons (which occur at synapses), mean neuronal firing rates, etc., with means taken over volumes large enough to include many neurons. Theoretical justifications for this "mass action" approximation have been given by Stevens and Wright and Liley and the resulting match with experimental findings has been discussed by several authors Both microscopic and continuum models typically include both excitatory and inhibitory inputs to a given neuron, which may itself be either excitatory or inhibitory in its action on other neurons. Excitatory inputs tend to increase the firing rate of a given neuron, while inhibitory ones reduce it, with both effects being nonlinear due, for example, to saturation at a maximum physiologically possible firing rate. Thus, in general, continuum models must incorporate mean densities of both populations of neurons, and of both types of interconnections, as well as the two neuronal firing rates. Delays in the propagation of signals through neurons (which are highly elongated) must also be included. These delays are of two types: dendrites lags, in which incoming signals are delayed in the dendrites fibers and axonal delays of outgoing signals due to the finite propagation velocity along the axon.

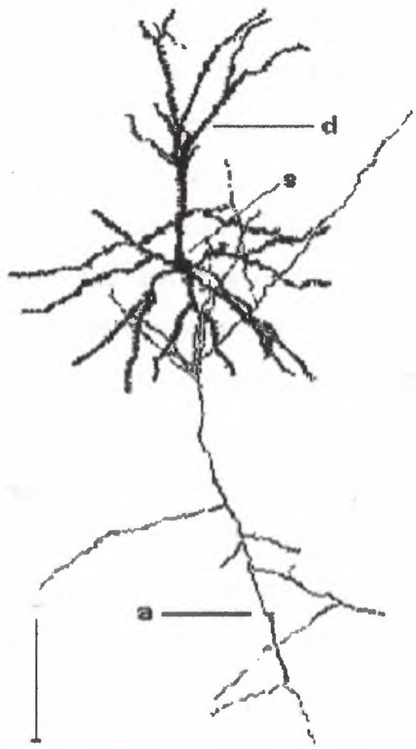


Figure 1.7 The electro magnetic propagation wave

A typical neuron of the cerebral cortex, from a Glisten. The scale bar represents 0.1mm pulsed signals are generated at the soma (S) and propagate over the axonal tree (A) to make contact, at synaptic junction with the dendrites tree (D) of thousands of other neurons , synaptic inputs are summed by the dendrites , and axonal pulses generated if the some is depolarized beyond the cells threshold. The first continuum model included excitatory and inhibitory populations in an infinite, linear zed, one dimensional (1D) model. With suitable adjustment of parameters, this model was able to reproduce the characteristic ~lO Hz frequency of the alpha rhythm, but omitted nonlinear effects, axonal delays, and the convolutions of the cortex. Nunez added axonal delays in order to investigate global modes. This model permitted wave solutions and, with the imposition of boundary conditions, the excitation of global eigenmodes. Nunez solved this model analytically for a 1D loop cortex, and for two dimensional (2D) cortexes with periodic and with spherical boundary conditions (i.e., ignoring the more complicated convoluted form of the real cortex, and the in homogeneity of cortical connections), interpreting observed cortical wave frequencies in terms of discrete eigenfrequencies.

This model predicted global modes whose frequencies approximately match those of the major cerebral rhythms. In particular the alpha rhythm was interpreted as being at the fundamental cortical eigenfrequency. Wright and coworkers introduced a spatially discredited model in which the cortex is treated as 2D and divided into patches, each of which is parameterized by the mean densities of excitatory and inhibitory neurons, their mean firing rates, and their mean densities of interconnections (i.e., of synapses). Nonlinear effects and axonal and dendrite delays were all included, with a Green function formulation describing the interconnections between patches as a function of their spatial and temporal separation. This model incorporated all relevant effects mentioned above, except convolutions and no uniformities in cortical connectivity, while allowing for the imposition of a variety of boundary conditions. Moreover, its parameters were largely physiologically measurable, a significant advantage when comparing its predictions with measurements. However, simulations based on it have been limited to very small systems (or very coarse resolution in larger systems) due to its formulation in terms of Green functions, which are very slow to evaluate, and a numerically intensive treatment of dendrites lags. The central purpose of this paper is to introduce a model of cortical electrical activity which includes nonlinearities, axonal and dendrites time lags, variable geometries and boundary conditions in 2D, and which permits analytic studies of wave properties and stability, while speeding computation to the point that whole-cortex simulations are possible with good resolution. This is accomplished in Sec. II by introducing a continuum wave equation model to replace the linear parts of Wright et al.'s discrete Green-function one, and also by simplifying their treatment of dendrites lags. The new model is not identical to Wright et al.'s, but incorporates the same underlying microphysics to a similar degree of approximation. Neither model addresses the question of filtering of cortical signals through the skull to determine the scalp EEG, a problem that can be avoided in any case by using magneto encephalograms (MEGs) based on the magnetic signals associated with neural activity. The task of the remainder of the paper is to lay the mathematical basis for analysis of this model and obtain its basic properties. In Secs III and IV we investigate the steady-state properties of the model and study the propagation and stability of small perturbations in the limit of an infinite medium. Periodic and spherical boundary conditions are imposed in Sec. V to investigate the properties of global eigenmodes and the eigenfrequencies are calculated for typical human parameters.

An algorithm for numerical study of our model is described in Sec. VI and its output is used to verify key analytic results obtained in earlier sections.

1.13 The Electromagnetic Spectrum

1.13.1 An overview of Electromagnetic Spectrum

The wavelength and the frequency for all the electromagnetic radiation (EMR) with its possible effect on the human body. We can see that the human eye is able discriminate wavelength in the visible of the spectrum, immediately to the left of the visible spectrum is infrared radiation which can be detected as heat although not very efficiently when compared with the ability to detect visible light. Further to the left are radio waves (including microwaves) and long radio waves, which complete the low energy end of the spectrum. These radiations are unable to be perceived at normal levels. The mobile phone system operating at about 900MHz is located in a region of the spectrum that is referred to as both microwave radiation and radio frequency radiation (RFR). For the purposes of this discussion both terms will be used interchangeably. The RF radiation from mobile phone base station antennas similar to the "EMF" produced by power lines Power lines produce no significant non-ionizing radiation, they produce electric and magnetic fields. In contrast to non-ionizing radiation, these fields do not radiate energy into space, and they cease to exist when power is turned off. It is not clear how, or even whether, power line fields produce biological effects; but if they do, it is not in the same way that high power RF radiation produces biological effects There appears to be no similarity between the biological effects of power line "EMF" and the biological effects of RF radiation. Work Practices for Reducing Radio-frequency Radiation Exposure:

1. Individuals working at antenna sites should be informed about the presence of RF radiation, the potential for exposure and the steps they can take to reduce their exposure.
2. "If radiofrequency radiation at a site can exceed the FCC standard for general public/uncontrolled exposures, then the site should be posted with appropriate signs." [Per Richard Tell, personal communication, Feb 2000]
3. Radio-frequency radiation levels at a site should model before the site is built.

4. Radio-frequency radiation levels at a site should measure.
5. Assume that all antennas are active at all times.
6. Disable (lock out) all attached transmitters before working on an antenna.
7. Use personal monitors to ensure that all transmitters have actually been shut down.
8. Keep a safe distance from antennas. "As a practical guide for keeping [radio-frequency radiation] exposures low, maintain a 3-4 ft [1-1.2 m] distance from any [telecommunications] antenna."
9. "Keep on moving" and "avoid unnecessary and prolonged exposure in close proximity to antennas".
10. At some site (e.g., multiple antennas in a restricted space where some antennas cannot be shut down) it may be necessary to use protective clothing.
11. Remember that there are many non-RF hazards at most sites (e.g., dangerous machinery, electric shock hazard, falling hazard), so allow only authorized, trained personnel at a site.

Assessing compliance with radio-frequency radiation guidelines for mobile phone base stations: Compliance can be assessed through measurements or calculations. Both methods require a solid understanding of the physics of RF radiation. Measurements require access to sophisticated and expensive equipment. Calculations require detailed knowledge about the power, antenna pattern and geometry of a specific antenna. Nothing as simple as distance from an antenna site is adequate for assessing compliance or estimating exposure levels. As discussed and illustrated, RF radiation exposure may not even increase as you get closer to an mobile phone base station site. alculation: If the effective radiated power (ERP), the antenna pattern and the height of the base station antenna is known, then "worst case" calculations of ground level power density can be made. However, the calculation method is not simple and the ERP and antenna pattern are often unknown. Measurement: Actual measurement of power density from mobile phone base stations requires sophisticated and expensive equipment and considerable technical knowledge. The instruments designed to measure power line fields and the instruments designed to test microwave ovens are not suitable for measuring base stations.

Determining that base stations meet ANSI/IEEE, FCC, or ICNIRP guidelines is "relatively easy", but the instruments required cost well over US$2000. Actual measurement of the power-density from a base station antenna is much more difficult, as there are many other sources of RF radiation at a typical site Calculations (and sometimes even measurements) must take into account possible sources of RF radiation other than the mobile antenna site being assessed .It is not unusual for there to be other RF radiation signals that are stronger than those from the base station being assessed. The non-ionizing radiation (RF radiation) from mobile phone base station antennas similar to ionizing radiations such as X-rays the interaction of biological material with an electromagnetic source depends on the frequency of the source. X-rays, RF radiation and "EMF" from power lines are all part of the electromagnetic spectrum, and the parts of the spectrum are characterized by their frequency. The frequency is the rate at which the electromagnetic field changes direction and is given in Hertz (Hz), where one Hz is one cycle (wave) per second, and 1 megahertz (MHz) is one million cycles (waves) per second. Electric power in the US is at 60 Hz. AM radio has a frequency of around 1 MHz, FM radio has a frequency of around 100 MHz, microwave ovens have a frequency of 2450 MHz, and X-rays have frequencies above one million million MHz. Cellular (mobile) phones operate at a variety of frequencies between about 800 and 2200 MHz . At the extremely high frequencies characteristic of X-rays, electromagnetic particles have sufficient energy to break chemical bonds (ionization). This is how X-rays damage the genetic material of cells, potentially leading to cancer or birth defects. At lower frequencies, such as RF radiation, the energy of the particles is much too low to break chemical bonds. Thus RF radiation is "non-ionizing". Because non-ionizing radiation cannot break chemical bonds, there is no similarity between the biological effects of ionizing radiation (x-rays) and nonionizing radiation (RF radiation).

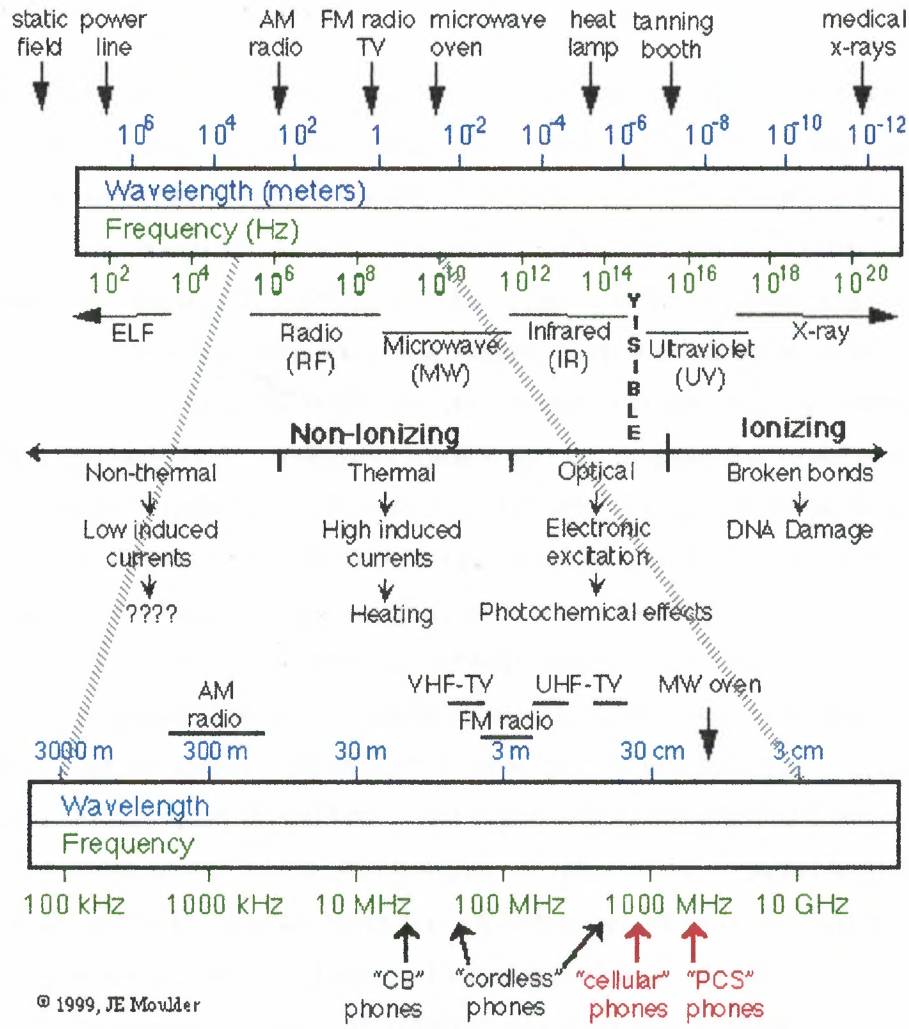


Figure 1.8 The Electromagnetic Spectrum

2. THE HAZARDS

2.1 An overview for the hazards

Mobile phones are low power radio devices that transmit and receive microwave radiation at frequencies of about 900 Megahertz (MHz) and 1800 MHz. There are many other sources of radio waves. Television broadcasts in the UK operate at frequencies between 400 MHz and 860 MHz and microwave communication links (dishes) operate at frequencies above 1000 MHz. Cellular radio systems involve communication between mobile telephones and fixed base stations. Each base station provides coverage of a given area, termed a cell. While cells are generally thought of as regular hexagons, making up a 'honeycomb' structure, in practice they are irregular due to site availability and topography. Depending on the base station location and mobile phone traffic to be handled, base stations may be from only a few hundred metres apart in major cities, to several kilometres apart in rural areas. If a person with a mobile phone moves out of one cell and into another, the controlling network hands over communications to the adjacent base station. The use of mobile phones is developing rapidly and at present there are about 14 million users in the UK with about 20,000 base stations. There is a consensus amongst international bodies that exposure guidelines for radio waves should be set to prevent adverse health effects caused by either whole or partial body heating. Some of the energy in the radio waves emitted by mobile phones is absorbed in the head of the user, mostly in superficial tissues. Exposure guidelines relevant to mobile phones are therefore expressed in terms of absorbed energy in a small mass of tissue in the head. The limit for exposure of the head, recommended by NRPB and adopted by the Government for use in the UK, is 0.1 watt of power absorbed in any 10 g of tissue (time averaged over 6 min Calculations suggest this could result in a utes). maximum rise in temperature of less than one degree centigrade in the head, even after prolonged exposure. In practice, the output from mobile phones used in the UK results in only a fraction of this amount of energy being deposited in the tissues of the head, and therefore the rise in temperature would only be a fraction of a degree. This is similar to the normal daily fluctuations in body temperature and such small changes in heat load are considered to be too low to cause adverse effects.

At positions where the public are normally exposed to fields from base stations antennas, exposure is likely to be more uniform over the whole body. The restriction averaged over the whole body mass is 0.4 watts per kilogram (time averaged over 15 minutes). The radio waves produced by transmitters used for mobile phones are sufficiently weak that the guidelines can only be exceeded if a person is able to approach to within a few metres directly in front of the antennas. Radio wave strengths at ground level and in regions normally accessible to the public are many times below hazard levels and no heating effect could possibly be detected. NRPB staff have made many measurements to support this view. Concerns about other possible, so-called athermal, effects arising from exposure to mobile phone frequencies have also been raised. These include suggestions of subtle effects on cells that could have an effect on cancer development or influences on electrically excitable tissue that could influence the function of the brain and nervous tissue. Radio waves do not have sufficient energy to damage genetic material (DNA) in cells directly and cannot therefore cause cancer. There have been suggestions that they may be able to increase the rate of cancer development (i.e. influence cancer promotion or progression). The NRPB Advisory Group on Non-Ionising Radiation concluded, however, at a meeting in May 1999: that there was no human evidence of a risk of cancer resulting from exposure to radiations that arise from mobile phones. Furthermore, the evidence from biological studies on possible effects on tumour promotion or progression, including work with experimental animals, is not convincing. The lack of evidence does not, however, prove the absence of a risk and more specific research is warranted. There has also been concern about whether there could be effects on brain function, with particular emphasis on headaches and memory loss. Few studies have yet investigated these possibilities, but the evidence does not suggest the existence of an obvious health hazard. In view of the limited amount of high quality experimental and epidemiological studies published to date, NRPB has supported the need for further research as outlined by an Expert Group, which reported to the European Commission (EC) in 1996. This recommended a comprehensive programme covering cellular studies, experimental investigations in animals together with human volunteer studies and epidemiology. The Group stressed the need to replicate studies suggesting the possibility of effects. This programme is being developed within the Fifth Framework Programme of the EC.

2.2 Cell Phone Radiation

Just by their basic operation, cell phones have to emit a small amount of electromagnetic radiation. If you've read How Cell Phones Work, then you know that cell phones emit signals via radio waves, which are comprised of radio-frequency (RF) energy, a form of electromagnetic radiation. There's a lot of talk in the news recently about whether or not cell phones emit enough radiation to cause adverse health effects. The concern is that cell phones are often placed close to or against the head during use, which puts the radiation in direct contact with the tissue in the head. There's evidence supporting both sides of the argument.

2.2.1 Source of Radiation

When talking on a cell phone, a transmitter takes the sound of your voice and encodes it onto a continuous sine wave (see How Radio Works to learn more about how sound is transmitted). A sine wave is just a type of continuously varying wave that radiates out from the antenna and fluctuates evenly through space. Sine waves are measured in terms of frequency, which is the number of times a wave oscillates up and down per second. Once the encoded sound has been placed on the sine wave, the transmitter sends the signal to the antenna, which then sends the signal out. Radiation in cell phones is generated in the transmitter and emitted through the antenna. Cell phones have low-power transmitters in them. Most car phones have a transmitter power of 3 watts.

A handheld cell phone operates on about 0.75 to 1 watt of power. The position of a transmitter inside a phone varies depending on the manufacturer, but it is usually in close proximity to the phone's antenna. The radio waves that send the encoded signal are made up of electromagnetic radiation propagated by the antenna. The function of an antenna in any radio transmitter is to launch the radio waves into space; in the case of cell phones, these waves are picked up by a receiver in the cell-phone tower. Electromagnetic radiation is made up of waves of electric and magnetic energy moving at the speed of light, according to the Federal Communications Commission (FCC). All electromagnetic energy falls somewhere on the electromagnetic spectrum, which ranges from extremely low frequency (ELF) radiation to X-rays and gamma rays. Later, you will learn how these levels of radiation affect biological tissue.

Figure 2.1 Source of Radiation

When talking on a cell phone, most users place the phone against the head. In this position, here is a good chance that some of the radiation will be absorbed by human tissue. In the next section, we will look at why some scientists believe that cell phones are harmful, and you'll find out what effects those ubiquitous devices may have .

2.2.2 Potential Health Risks

In the late 1970s, concerns were raised that magnetic fields from power lines were causing leukemia in children. Subsequent epidemiological studies found no connection between cancer and power lines. Around the same time, similar cancer fears arose about computer monitors. While there is some radiation emitted from computer monitors, studies have shown that they don't raise cancer rates. The latest health scare related to everyday technology is the potential for radiation damage caused by cell phones. Studies on the issue continue to contradict one another. All cell phones emit some amount of electromagnetic radiation. Given the close proximity of the phone to the head, it is possible for the radiation to cause some sort of harm to the 118 million cell-phone users in the United States.

What is being debated in the scientific and political arenas is just how much radiation is considered unsafe, and if there are any potential long-term effects of cell-phone radiation exposure.

2.2.3 There are two types of electromagnetic radiation:

Ionizing radiation - This type of radiation contains enough electromagnetic energy to strip atoms and molecules from the tissue and alter chemical reactions in the body. Gamma rays and X-rays are two forms of ionizing radiation. We know they cause damage, which is why we wear a lead vest when X-rays are taken of our bodies. Non-ionizing radiation - Non-ionizing radiation is typically safe. It causes some heating effect, but usually not enough to cause any type of long-term damage to tissue. Radio-frequency energy, visible light and microwave radiation are considered non-ionizing. On its Web site, the FDA states that "the available scientific evidence does not demonstrate any adverse health effects associated with the use of mobile phones." However, that doesn't mean that the potential for harm doesn't exist. Radiation can damage human tissue if it is exposed to high levels of RF radiation, according to the FCC. RF radiation has the ability to heat human tissue, much like the way microwave ovens heat food. Damage to tissue can be caused by exposure to RF radiation because the body is not equipped to dissipate excessive amounts of heat. The eyes are particularly vulnerable due to the lack of blood flow in that area. Cell-phone use continues to rise, which is why scientists and lawmakers are so concerned about the potential risks associated with the devices. The added concern with non-ionizing radiation, the type of radiation associated with cell phones, is that it could have long-term effects. Although it may not immediately cause damage to tissue, scientists are still unsure about whether prolonged exposure could create problems. This is an especially sensitive issue today, because more people are using cell phones than ever before. In 1994, there were 16 million cell-phone users in the United States alone. As of July 17, 2001, there were more than 118 million.

Here are a few illnesses and ailments that have potential links to cell-phone radiation:

Cancer

Braintumors

Alzheimer's

Parkinson's

Fatigue

Headaches

Studies have only muddled the issue. As with most controversial topics, different studies have different results. Some say that cell phones are linked to higher occurrences of cancer and other ailments, while other studies report that cell-phone users have no higher rate of cancer than the population as a whole. No study to date has provided conclusive evidence that cell phones can cause any of these illnesses. However, there are ongoing studies that are examining the issue more closely. See the links page at the end of this article for more information on these studies. At high levels, radio-frequency energy can rapidly heat biological tissue and cause damage such as burns, according to a recent report from the U.S. General Accounting Office (GAO), a nonpartisan congressional agency that audits federal programs. The report went on to state that mobile phones operate at power levels well below the point at which such heating effects would take place. The amount of radiation emitted from the devices is actually minute.

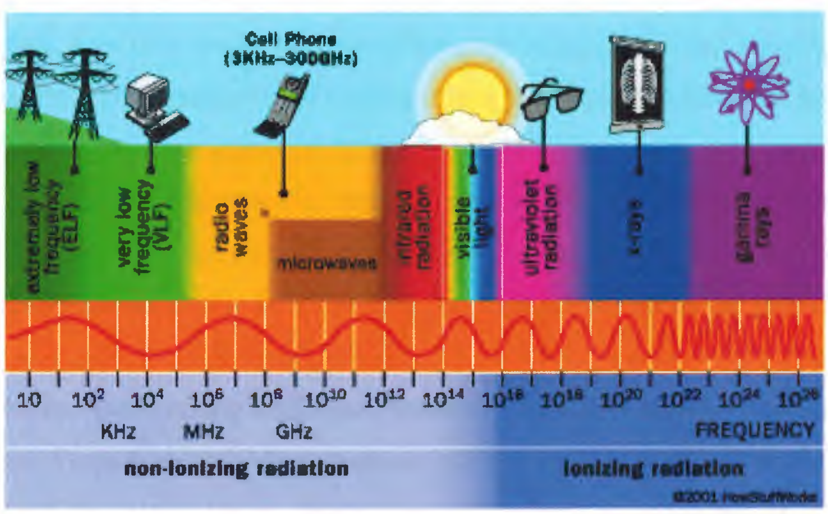


Figure 2.2 Cell-Phone Radiation

2.3 Antenna radiation and types used in GSM

The 2002 report from the Health Council of the Netherlands the differences between cell phones, PCS phones, and other types of portable (mobile) phones matter when evaluating the potential impacts of base station antennas on human health No. There are many technical differences between cell phones, PCS phones, and the types of "mobile" phones used in other counties but for evaluation of possible health hazards, the only distinction that matters is that they operate at slightly different frequencies. The RF radiation from some base stations (e.g., those for the older 800 MHz mobile phones used in the U.S.) may be absorbed by humans somewhat more than the RF radiation from other types of base stations (e.g., those for the 1800-2000 MHz "PCS" phones used in the U.S.) However, once the energy is absorbed the effects are the same. the differences between base station antennas and other types of radio and TV broadcast antennas matter when evaluating their potential impacts on human health The RF radiation from some antennas (particularly FM and VHF-TV broadcast antennas) are absorbed more by humans than the RF radiation from other sources (such as mobile phone base station antennas); but once the energy is absorbed the effects are basically the same.FM and TV antennas send out 100 to 5000 times more power than base station antennas, but are usually mounted on much higher towers (typically 800 to 1200 ft). Mobile phone base station antennas produce radiation Mobile (cellular) phones and their base station antennas are two-way radios, and produce radiofrequency (RF) radiation that's how they work. This radiofrequency radiation is "non-ionizing", and its biological effects are fundamentally different from the "ionizing" radiation produced by x-ray machines .There are safety guidelines for mobile phone base station antennas and there are national and international safety guidelines for exposure of the public to the RF radiation produced by mobile phone base station antennas. The most widely accepted standards are those developed by the Institute of Electrical and Electronics Engineers and American National Standards Institute (ANSI/IEEE) the International Commission on Non-Ionizing Radiation Protection (ICNIRP), and the National Council on Radiation Protection and Measurements (NCRP) .These radiofrequency standards are expressed in "plane wave power density", which is measured in mW/cm-sq (milliwatts per square centimeter) .

For PCS (about 1800-2000 MHz) antennas, the 1992 ANSI/IEEE exposure standard for the general public is 1.2 mW/cm-sq. For analog mobile phones (about 900 MHz), the ANSI/IEEE exposure standard for the general public is 0.57 mW/cm-sq . The ICNIRP standards are slightly lower and the NCRP standards are essentially identical . In 1996 the U.S. Federal Communications Commission (FCC) released radiofrequency guidelines for the frequencies and devices they regulate, including mobile phone base station antennas .The FCC standards for mobile phone base station antennas are essentially identical to the ANSI/IEEE standard The public exposure standards apply to power densities averaged over relatively short periods to time, 30 minutes in the case of the ANSI/IEEE, NCRP, and FCC standards (at mobile phone frequencies). Where there are multiple antennas, these standards apply to the total power produced by all antennas . Also there is a scientific basis for these radiofrequency radiation safety guidelines when scientists examined all the published literature on the biological effects of RF radiation they found that the literature agreed on a number of key points:

1. The research on RF radiation is extensive , and is adequate for establishing safety guidelines.
2. Exposure to RF radiation can be hazardous if the exposure is sufficiently intense. Possible injuries include cataracts, skin burns, deep burns, heat exhaustion and heat stroke. See Reeves for a discussion of the known effects of overexpose to RF radiation in humans.
3. Biological effects of RF radiation depend on the rate of energy absorption ; and within a broad range of frequencies (1 to 10,000 MHz), the frequency matters very little.
4. Biological effects of RF radiation are proportional to the rate of energy absorption; and the duration of exposure matters very little .
5. No biological effects have been consistently shown below a certain rate of whole body energy absorption (this rate is called the specific absorption rate or SAR).

To establish occupational exposure guidelines, ANSI/IEEE and FCC applied a 10-fold safety margin to the lowest energy absorption rate shown to have biological effects. They then applied an additional 5-fold safety margin for continuous exposure of the general public. Finally, detailed studies were done to establish the relationship of power density, which can be routinely measured, to the energy absorption rate (SAR), which really matters .The result was a highly conservative public exposure guideline that was set at a level that is only 2% of the level where replicated biological effects have actually been observed. There are differences between the standards. ANSI/IEEE, ICNIRP, NCRP and FCC all use the same biomedical data, and the same general approach to setting safety guidelines. However, there are differences in the models used by the different groups, and hence there are slight differences in the final numbers. No biological significance should be associated with these slight differences. A number of countries have their own regulations for public exposure to RF radiation from mobile phone base station antennas. While most of these regulation follow the same patterns and rationales used by ANSI/IEEE and ICNIRP , they do differ.the U. S. have safety guidelines for mobile phone base stations Until 1996 the U. S. Federal Communications Commission (FCC) used an out-dated (1982) ANSI standard. In 1996 the FCC adopted a new standard that was based on a combination of the 1992 ANSI standard and the 1986 NCRP guidelines . The new FCC standard for mobile phone base stations is 0.57 mW/cm-sq at 900 MHz and 1.0 mW/cm-sq at 1800-2000 MHz. This 1996 FCC standard applied to all new transmitters licensed after 15-Oct-97, but pre-existing facilities had until 1-Sep-2000 to demonstrate compliance. The FCC power-density standards described above apply to whole-body public exposure to radio-frequency radiation from mobile phone base stations; they do not apply to exposure from the phones themselves or to occupational exposure. For a discussion of exposure from the phones or a discussion of occupational RF radiation exposure see FCC OET Bulletin 56 ,the FCC guideline itself ,and Foster and Moulder .mobile phone base station antennas meet the safety guidelines With proper design, mobile phone base station antennas can meet all safety guidelines by a wide margin A mobile phone base station antenna, mounted 10 meters (33 ft) off the ground and operated at the maximum possible intensity, might produce a power density as high as 0.01 mW/cm-sq on the ground near the antenna site; but ground level power densities will more often be in the 0.00001 to 0.0005 mW/cm-sq range .

These power densities are far below all the safety guidelines, and the standards themselves are set far below the level where potentially hazardous effects have been seen.Within about 200 meters (650 ft) of the base of the antenna site, the power density may be greater at elevations above the base of the antenna site (for example, at the second floor of a building or on a hill). Even with multiple antennas on the same tower, power densities will be less than 5% of the FCC guidelines at all heights and at all distances of more than 55 meters (180 ft) from an antenna site. Further than about 200 meters (650 ft) from the antenna site power density does not rise with increased elevation.Power density inside a building will be lower by a factor of 3 to 20 than outside. Petersen et al measured power densities around mobile phone base stations. The measurements were for 1600 W (ERP) antennas on towers that ranged from 40 to 83 meters (130 to 275 ft) in height. The maximum power density on the ground was 0.002 mW/cm-sq, and the maximum was at 20 to 80 meters (65-265 feet) from the base of the towers. Within 100 meters (330) feet of the base of the towers, the average power density was less than 0.001 mW/cm-sq. These maximum RF power densities are all less than 1% of the FCC, ANSI/IEEE, NRPB and ICNIRP standards for public exposure. In 1999 in Vancouver Canada, Thansandote et al measured RF levels in five schools, three of which had base stations on them or near them. All schools met Canadian, US and international RF standards by a wide margin. The maximum readings are shown in the following table.

Table 1

School	Base Station Location	Maximum RF Level
1	PCS base station across street	0.00016 mW/cm-sq
2	analog base station on roof	0.0026 mW/cm-sq
3	analog base station across street	0.00022 mW/cm-sq
4 and 5	no antennas nearby	less than 0.00001 mW/cm-sq

In 2000, the U.K. National Radiation Protection Board measured radiofrequency radiation levels at 118 publicly-accessible sites around 17 mobile phone base stations. The maximum exposure at any location was 0.00083 mW/cm-sq (on a playing field 60 meters from a school building with an antenna on its roof).

Typical power densities were less than 0.0001 mW/cm-sq (less than 0.01% of the ICNIRP public exposure guidelines). Power densities indoors were substantially less than power densities outdoors. When radiofrequency radiation from all sources (mobile phone, FM radio, TV, etc.) was taken into account the maximum power density at any site was less than 0.2% of the ICNIRP public exposure guidelines.

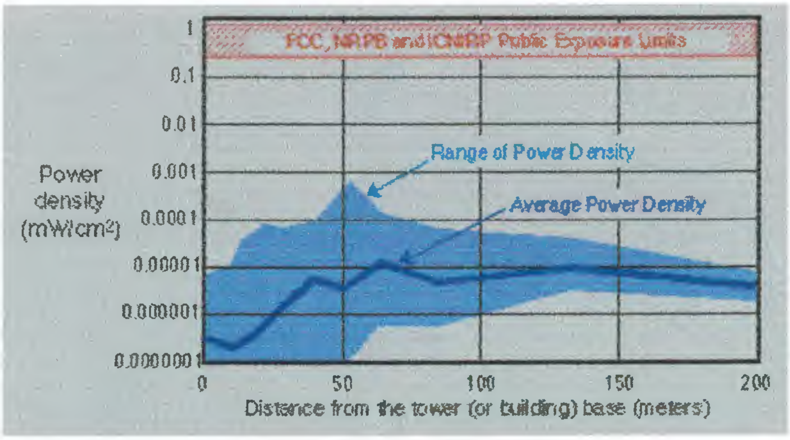


Figure2.3 Radiofrequency Radiation Levels Near Mobile Phone Base Stations in the UK

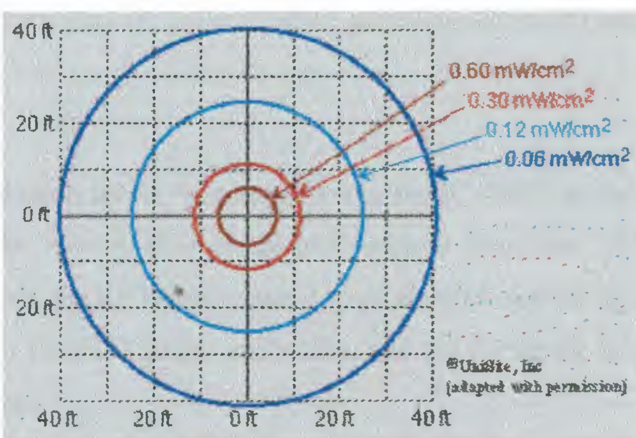


Figure 2.4 Low-gainnaer

The relationship between the RF power density and distance from the base of the tower or building on which the mobile phone base antenna was located.

Adapted from Mann et al.In 2001, the Radiocommunications Agency of the UK Department of Trade and Industry measured RF radiation levels at 100 schools that had mobile phone base stations near them. The maximum RF level measured at any school was less than 1% of the ICNIRP standard for public areas; the maximum in most schools was less than 0.1% of that standard.

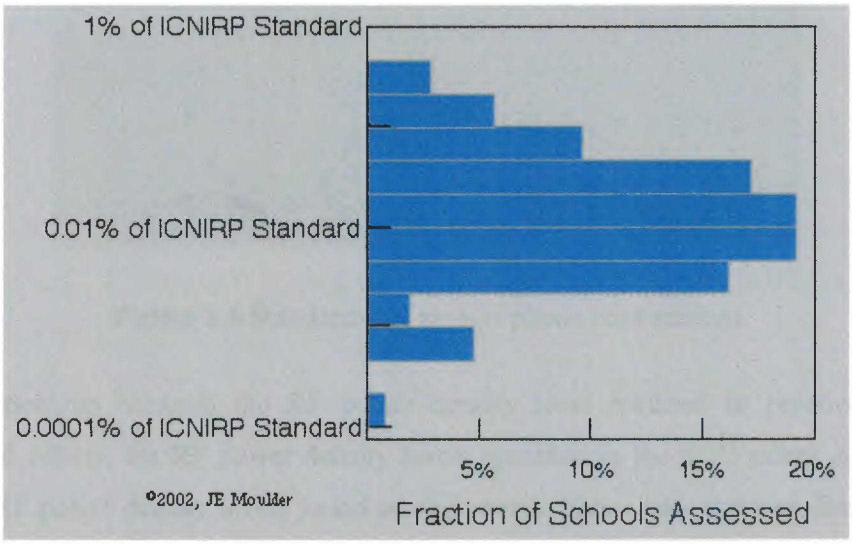


Figure 2.5 Radiofrequency radiation levels in schools near mobile phone base stations in the UK

(in comparison to the ICNIRP guidelines for public areas)

Maximum RF radiation levels (in comparison to the ICNIRP standard for public areas) in UK schools that have mobile phone base stations near them. Adapted from . The relationship between the RF levels required to produce known biological effects, the RF levels specified in the FCC safety guidelines, and the RF levels found around mobile phone base stations .

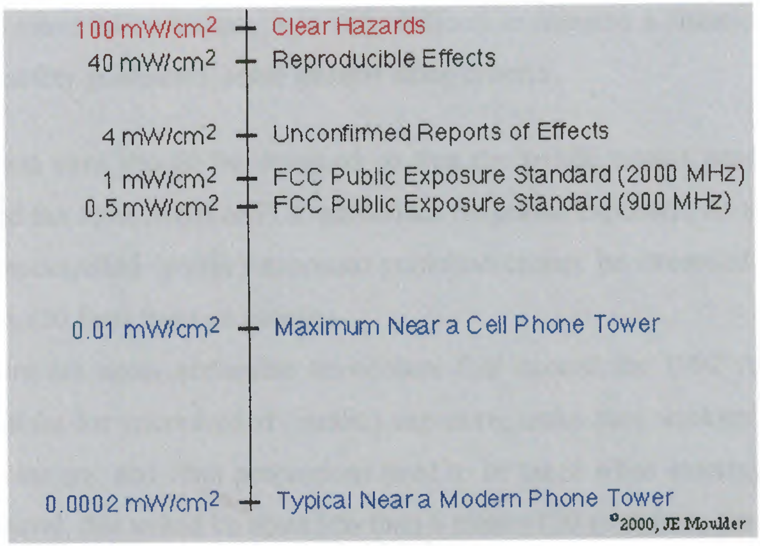


Figure 2.6 Standards for mobile phone base stations

The relationship between the RF power density level required to produce known biological effects, the RF power density levels specified in the FCC safety guidelines, and the RF power density levels found around mobile phone base stations. Because the RF power density required to produce biological effects is dependent on frequency, this figure only applies to frequencies between 800 and 2200 MHz (that is, those currently used by analog and digital mobile phones). The circumstances where mobile phone base station antennas could fail to meet the safety guidelines There are some circumstances under which an improperly designed (or inadequately secured) mobile phone base station antennas could fail to meet safety guidelines. Safety guidelines for uncontrolled (public) exposure could be exceeded if antennas were mounted in such a way that the public could gain access to areas within 6 meters/20 feet (horizontal) of the antennas themselves .This could arise for antennas mounted on or near the roofs of buildings. Petersen et al ,for example, found that 2-3 feet (1 meter) from a 1600 W (ERP) roof-top antenna, the power density was as high as 2 mW/cm-sq (compared to the ANSI public exposure standard of 1.2 to 0.57 mW/cm-sq).

For antennas mounted on towers, it is very difficult to imagine a situation that would not meet the safety guidelines. some general siting criteria:

1. Antenna sites should be designed so that the public cannot access areas that exceed the 1992 ANSI or FCC guidelines for public exposure. As a general rule, the uncontrolled (public) exposure guideline cannot be exceeded more than 6 meters (20 feet) from an antenna .
2. If there are areas accessible to workers that exceed the 1992 ANSI or FCC guidelines for uncontrolled (public) exposure, make sure workers know where the areas are, and what precautions need to be taken when entering these areas. In general, this would be areas less than 6 meters (20 feet) from the antennas .
3. If there are areas that exceed the 1992 ANSI or FCC guidelines for controlled (occupational) exposure, make sure that workers know where these areas are, and that they can (and do) power-down (or shut down) the transmitters when entering these areas. Such areas may not exist; but if they do, they will be confined to areas within 3 meters (10 feet) of the antennas .

If there are questions about whether these guidelines are met, compliance should be verified by measurements done after the antennas are activated. The FCC guidelines require detailed calculations and/or measurement of radiofrequency radiation for some high-power rooftop transmitters, and some high-power transmitters whose antennas are mounted on low towers .In general, the above guidelines will always be met when antennas are placed on their own towers. Problems, when they exist, are generally confined to:

- Antennas placed on the roofs of buildings; particularly where multiple base station antennas for different carriers are mounted on the same building;
- Antennas placed on structures that require access by workers (both for regular maintenance, and for uncommon events such as painting or roofing).

2.4 The difference between a high-gain antenna and a low-gain antenna:

There are many different types of base station antennas, and the RF radiation patterns from them can be quite different. The most basic difference is between high-gain antennas and a low-gain antennas. Because siting and safety issues for high- and low-gain antennas are different, it is important to be able to tell them apart. In the early days of mobile phones, you could usually tell by looking. Unfortunately, the development of newer antenna designs and the variety of different ways to stealth (hide) antennas now often makes it impossible to determine what kind of antenna has been installed just by looking.

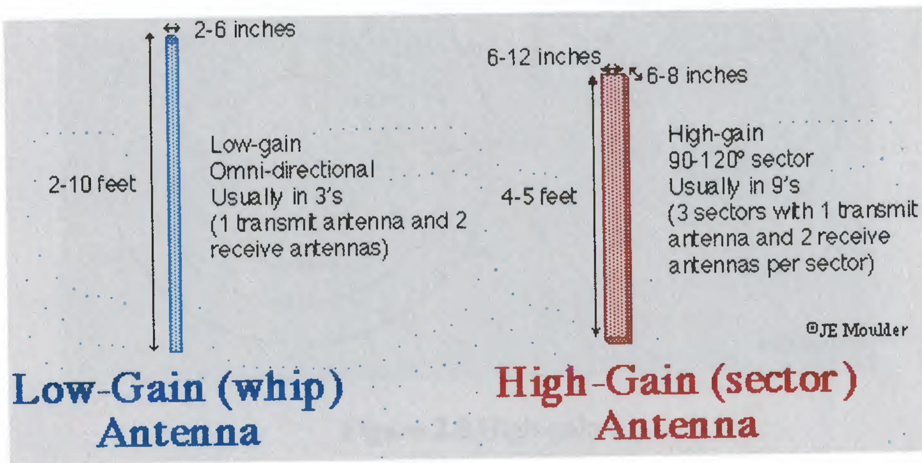


Figure 2.7 Low-gain antenna and high gain antenna

the phrases "antenna gain", "transmitter power" and "effective radiated power (ERP)" mean: The power of a mobile phone base station is usually described by its effective radiated power (ERP) which is given in watts (W). Alternatively, the power can be given as transmitter power (in watts) and the antenna gain. Transmitter power is a measure of total power, while ERP is a measure of the power in the main beam. If an antenna were omni-directional and 100% efficient, then transmitter power and ERP would be the same. But mobile phone base station antennas (like all antennas) are not omni-directional; they are moderately (low-gain antennas) to highly (high-gain antennas) directional. The fact that they are directional means that they concentrate their power in some directions, and give out much less power in other directions. Antenna gain is a measure of how directional an antenna is, and it is measured in decibels.

As a result, a 20-50 W base station transmitter with a high-gain antenna could produce an ERP of anywhere from several hundred watts to over 1000 watts. Perhaps the concept of "gain" and "ERP" are best explained by analogy to light bulbs. Compare a regular 100 W light bulb and a 100 W spot light. Both have the same total power, but the spot light is much brighter when you are in its beam and very weaker when you are outside its main beam. A mobile phone base antenna (particularly a high-gain sector antenna) is like the spot light, and ERP is equivalent to the power in the spot light's main beam.

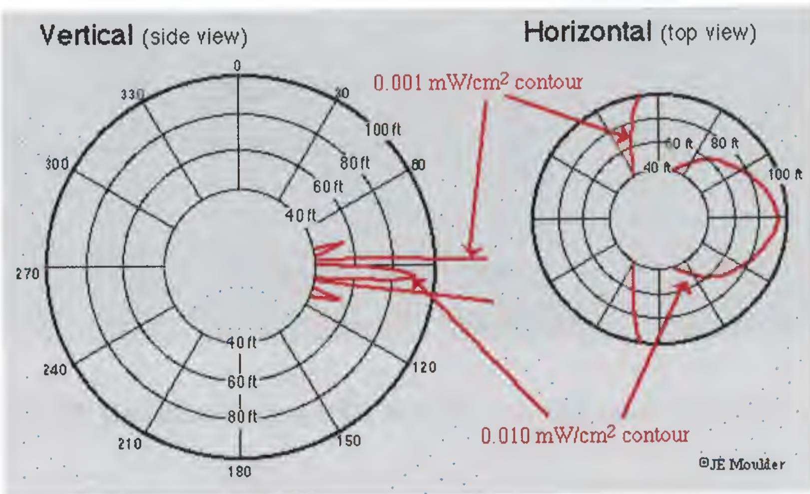


Figure 2.8 High-gain

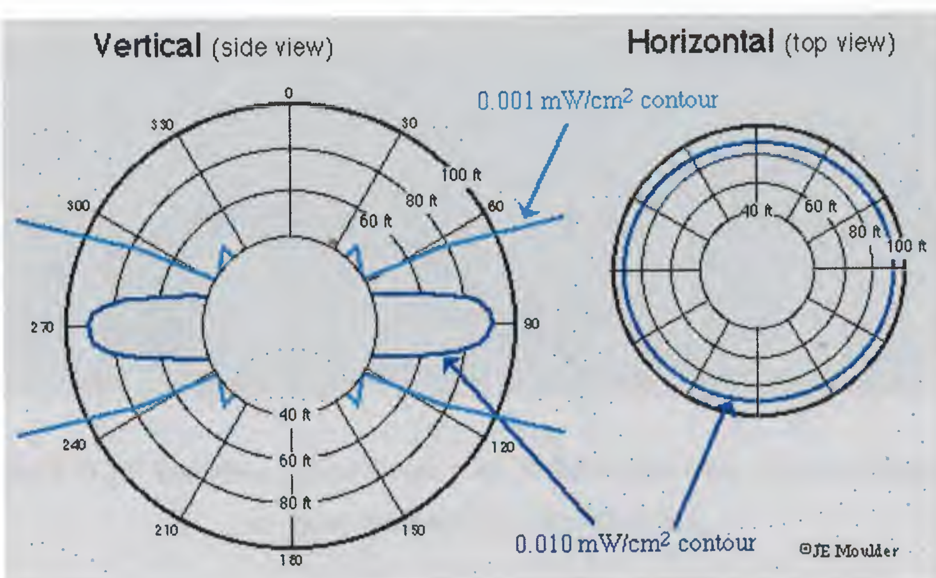


Figure 2.9 Low-gain

2.5 The difference between the RF patterns for high-gain and low-gain antennas:

The RF patterns for different types of antennas are very different. For a low-gain antenna with a 1000 W ERP of the type formerly used by many mobile phone base stations, the pattern can look like this:

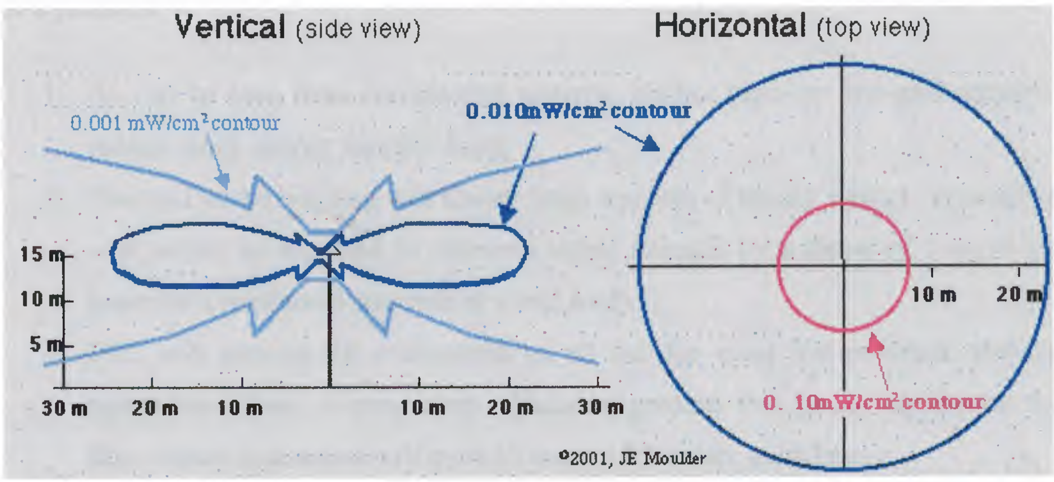


Figure 2.10 RF Radiation from a 1000 W ERP Low-Gain Antenna on a 15 m Tower

For a high-gain (sector) antenna of the type used in many of the newer base stations, the pattern can look like this:

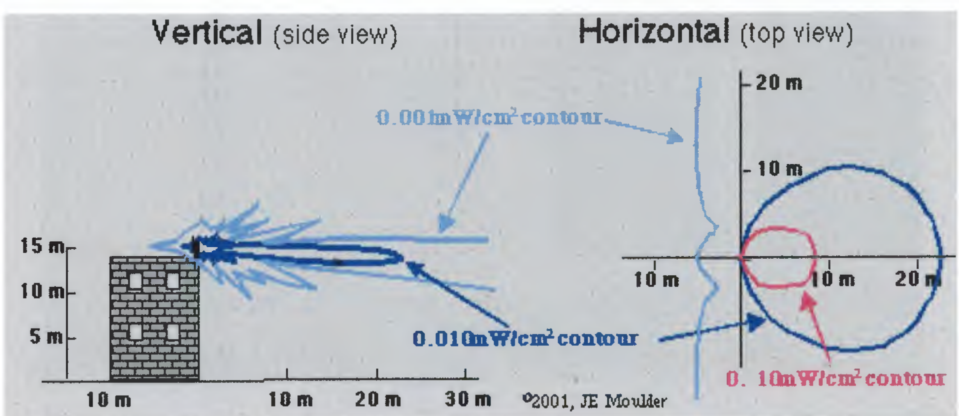


Figure 2.11 RF Radiation from a Single 1000 W ERP High-Gain Antenna Mounted 2 m above the Roof of a 13 m Building

Keep in mind that mobile phone base station that use high-high-gain sectored antennas will usually use 3 (or occasionally 4) of these transmission antennas, all pointing in different directions. The data for the above figure were adapted (with permission) from drawings provided by UniSite Inc. of Tampa, Florida. The safe to live on the top floor of a building that has a mobile phone base station antenna on it In general this will not be a problem.

1. As can be seen from the antenna patterns, neither high- or low-gain antennas radiate much energy straight down.
2. The roof of the building will absorb large amounts of the RF energy. Typically a roof would be expected to decrease signal strength by a factor of 5 to 10 (or more for a reinforced concrete or metal roof).
3. FCC will require RF evaluations of all but the most low-powered roof-top transmitters Even a worst-case calculation predicts that power density on the floor below an antenna will meet all current RF safety guidelines
4. Actual measurements in top floor apartments and corridors confirm the power density will be far below all current RF safety guidelines.

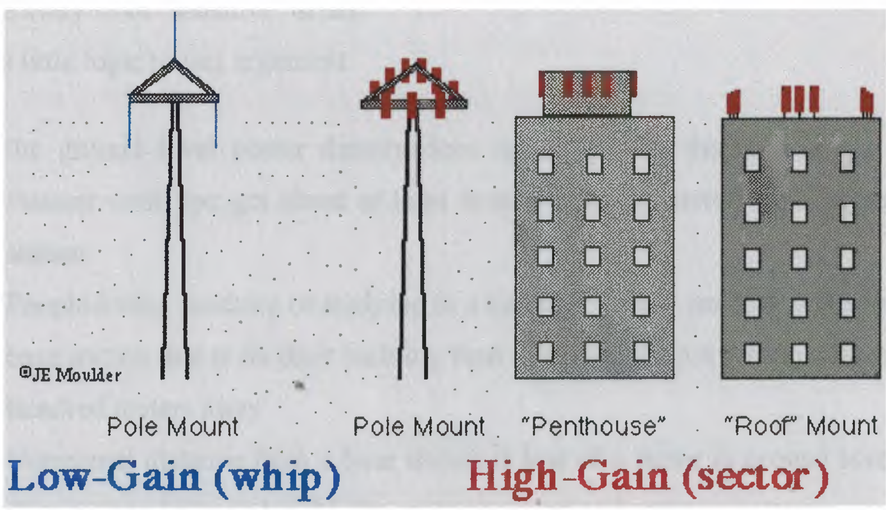


Figure 2.12 The safe to live on the top floor of a building

using restrictions or "set-backs" required around mobile phone base station antenna sites and what is the "minimum safe distance":

Radiofrequency safety guidelines do not require either setbacks or use restrictions around mobile phone base station antenna sites, since power levels on the ground are never high enough to exceed the guidelines for continuous public exposure As discussed, there may be circumstances where use restrictions will have to be placed around the antennas themselves The "Minimum Safe Distance" from a mobile phone base antenna is described by the FDA/FCC as follows:

"To be exposed to levels at or near the FCC limits for cellular or PCS frequencies an individual would essentially have to remain in the main transmitted radio signal (at the height of the antenna) and within a few feet from the antenna... In addition, for sector-type antennas RF levels to the side and in back are insignificant." Note that the above quote about safe distances applies to the actual radiating antenna, not to the tower the antenna is on. For a mobile phone base station antenna mounted on tower that is 5+ meters high, there should be no areas that will come anywhere close to the RF radiation safety guidelines, so the concept of a "minium safe distance" really doesn't mean anything. Some people have argued that base stations should be kept some distance away from "sensitive" areas.

There is little logic to this argument:

1. the ground level power density does not drop with distance in any regular manner until you get about at least several hundred meters away from a base station.
2. People living, working or studying in a building usually get less exposure from a base station that is on their building than they would from a base station several hundred meters away
3. Horizontal distance from a base station is less of a factor in ground level power density than antenna height, the antenna power and antenna pattern.

In addition, moving base antennas away from an area where there are mobile phone users may:

1. Increase the exposure of the users from their handsets.
2. Require the base antenna power to be increased.
3. Require the base antennas to placed further above the ground.
4. Increase the cell size and limit the number of users.

2.6 Specific Antenna Installation Guidelines :

For roof-mounted antennas, elevate the transmitting antennas above the height of people who may have to be on the roof.

1. For roof-mounted antennas, keep the transmitting antennas away from the areas where people are most likely to be (e.g., roof access points, telephone service points, HVAC equipment).
2. For roof-mounted directional antennas, place the antennas near the periphery and point them away from the building.
3. Consider the trade off between large aperture antennas (lower maximum RF) and small aperture antennas (lower visual impact).
4. Remember that RF standards are stricter for lower-frequency antennas (e.g., 900 Mhz) than for higher-frequency antennas (e.g., 1800 MHz).
5. Take special precautions to keep higher-power antennas away from accessible areas.
6. Keep antennas at a site as far apart as possible; although this may run contrary to local zoning requirements.

2.7 Investigators claimed that there is evidence that living near TV or FM radio broadcast towers causes an increase in cancer:

Such claims have been made, but so-ar none of these claims have been confirmed. Hocking and colleagues published an "ecological" epidemiology study that compares municipalities "near TV towers" to those further away. No RF radiation exposures were actually measured, but the authors calculate that exposures in the municipalities "near TV towers" were 0.0002 to 0.008 mW/cm-sq.

No other sources of exposure to RF are taken into account, and the study is based on only a single metropolitan area. The authors report an elevated incidence of total leukemia and childhood leukemia, but no increase in total brain tumor incidence or childhood brain tumor incidence.In 1998, McKenzie and colleagues repeated the Hocking study .McKenzie and colleagues looked at the same area, and at the same time period; but they made more precise estimates of the exposure to RF radiation that people got in various areas. They found increased childhood leukemia in one area near the TV antennas, but not in other similar areas near the same TV antennas; and they found no significant correlation between RF exposure and the rate of childhood leukemia. They also found that much of the "excess childhood leukemia" reported by Hocking occurred before high-power 24-hour TV broadcasting had started. This replication study, plus the failure to find any effect in the larger UK studies ,suggests that correlation reported by Hocking et al was an artifact. In 1997, Dolk and colleagues investigated a reported leukemia and lymphoma cluster near a high-power FM/TV broadcast antenna at Sutton Coldfield in the UK. They found that the incidence of adult leukemia and skin cancer was elevated within 2 km of the antenna, and that the incidence of these cancers decreased with distance. No associations at all were seen for brain cancer, male or female breast cancer, lymphoma or any other type of cancer. Because of this finding, Dolk and colleagues extended their study to 20 other high-power FM/TV broadcast antennas in the UK. Cancers examined were adult leukemia, skin melanoma and bladder cancer, and childhood leukemia and brain cancer. No elevations of cancer incidence were found near the antennas, and no declines in cancer incidence with distance were seen. This large study does not support the results found in the much smaller studies by the same authors at Sutton Coldfield or by Hocking et al in Australia. In 2002, Michelozzi et al reported that the incidence of childhood leukemia was elevated within 6 km of Vatican Radio (31 transmitters at 4-44 kHz and 0.5-1.6 MHz, with power of up to 600,000 W). The authors also report elevated leukemia in adult men residing near the transmitters, but not in adult women. In 2002, Hallberg and Johansson speculated that the increase in melanoma seen in Sweden (and industrialized countries) since 1960 is due to exposure to FM radio broadcasting.

How an Israeli epidemiologist claimed that there is evidence that low-level RF exposure causes a variety of health effects, In a 1995 article labeled an "opinion piece", Goldsmith argues that there is evidence that RF exposure is associated with mutations, birth defect, and cancer. This review is based largely on what the author admits to be "non-peer-reviewed sources", most of which are stated to be "incomplete" and to lack "reliable dose estimates". The author further states that "no systematic effort to include negative reports is made; thus this review has a positive reporting bias". In an article based on a 1996 meeting presentation Goldsmith argues that epidemiological studies "suggest that RF exposures are potentially carcinogenic and have other health effects". His conclusions are based largely on:

- studies of RF exposure at the US embassy in Moscow;
- the "geographical correlation" studies of Hocking et al and Dolk et al
- the study of Korean war radar operators by Robinette et al

Few scientists agree with the opinions expressed by Goldsmith; and even fewer would be willing to base a conclusion on the types of data sources that Goldsmith relies on.A University of Washington (Seattle, U.S.A) researcher claimed that there is evidence that RF exposure from base stations is hazardous, Dr. Henry Lai (Department of Bioengineering, University of Washington, Seattle) has claimed at meetings that "low intensity" RF radiation has effects on the nervous system of rats. Dr. Lai has further claimed at meetings that there are published studies showing that RF radiation can produce "health effects" at "very low field" intensities. Dr. Lai's own research has no obvious relevance to the safety of mobile phone base stations since most of his studies were conducted with RF radiation intensities far above those that would be encountered near base stations. In general, Dr. Lai's studies were done with at a power density of 1 mW/cm-sq and an SAR of 0.6 W/kg ,This RF radiation intensity is over 100 times greater than that would be encountered in publicly-accessible areas near FCC-compliant base stations ,and substantially exceeds the SAR limit that forms the basis of the FCC and ANSI safety guidelines for public exposure .For further discussion of the research on possible effects of RF radiation on the nervous system see reviews by Lai and Juutilainen and de Seze . At a meeting in Vienna in 1998, and in a letters sent to public officials, Dr. Lai referenced six studies in support of his claim that there is data showing that RF radiation can produce "health effects" at "very low field" intensities.

These studies were:

1. Changes in the blood-brain barrier (Salford et al, 1997). An unpublished meeting presentation; for earlier work from this group see Salford et al, 1994 .
2. Changes in cell proliferation (Kwee and Rasmark, 1997). This is an unpublished study that may be the same as that published by Kwee and Rasmark in 1998 .
3. Decreased fertility in mice (Magras and Xenos, 1997) .
4. Decreased eating and drinking in mice (Ray and Behari, 1990)
5. Changes in calcium transport in cells (Dutta et al, 1989)
6. DNA damage (Phillips et al, 1998)

A review of the above studies finds little actual support for Dr. Lai's claim.

- One of the studies, the report of effects on the blood-brain barrier by Salford et al, has never been published and cannot be evaluated. Note that in 2000-2002, Tsurita et al and Finnie et al reported that RF radiation had no effect on the blood-brain barrier of rats or mice.
- Two of the studies do not actually report any statistically-significant effects.
    - Ray and Behari reported that exposed animals "tended" to eat and drink less than the controls, and that the effect disappeared by the end of the exposure period.
    - Phillips et al reported that exposure caused increased DNA damage in 3 of 12 exposure regimens and decreased DNA damage in 4 of the other 9 regimens. The study found no overall effect and no pattern.
- The statistical significance of the "effects" reported in two other studies is open to question, as the effects reported are very small and appear in only some experiments.
    - Dutta et al reported increased calcium efflux for only 6 of the 19 exposure regimens that were tested. Since the increases were unrelated to exposure intensity or frequency, they may be a multiple comparison artifact.
    - The "effect" reported by Kwee and Rasmark is a 5-10% decreases in cell growth that was statistically significant in only 5 of 9 trials.
- Two of the studies have inadequate control groups, so that if there is an effect,

there is no way to be certain that it was due to the RF.

  - Magras and Xenos compared mouse fertility in breeding pairs kept in an "antenna park" with those kept in a laboratory. The conclusion that the effect on breeding was due to the RF rather than other environmental factors is purely speculative.
  - Ray and Behari tightly confined their animals during exposure, but did not appear to similarly confine their controls. This type of "confinement stress" is known to cause changes in physiology and behavior and see Stagg et al

- Several of the studies also use RF radiation intensities that substantially exceed anything that would be found in public areas near an FCC-compliant base station.
- Many of the "effects" reported have no known relationship to any human health hazard. For example, neither the changes in calcium efflux reported by Dutta et al the small decreases in cell growth reported by Kwee and Rasmark nor the small changes in food consumption reported by Ray and Behari have any known significance for human health.
- All of the "effects" quoted by Dr. Lai have been the subject of other studies that have shown no such effects, including studies done at substantially higher field intensities.

The claims on British, American and French TV that there is new data suggesting that mobile phones might cause cancer: There appears to have been no real scientific basis for these claims. In the summer and fall of 1999 (and repeated in 2000), programs on British, American and French TV claimed that there was new data suggesting that RF radiation from mobile phones could cause injury to humans. Four sources of "new" information were generally cited:

1. The study by Hardell et al
2. The study by Preece et al.
3. A new and then unpublished genotoxicity study.
4. A new and then unpublished epidemiology study.

The last two of these "new" studies were only vaguely described in the TV reports, but they appear to be references to studies sponsored by the mobile phone industry in the US (under the program called WTR). The WTR epidemiology study was presented at a meeting in June of 1999, and has now been published in the peer-reviewed literature . The published version reports no significant association between malignant or benign brain cancer and the use of hand-held mobile phones. The WTR genotoxicity study was presented at a meeting in March of 1999. Parts of this WTR study were published in early 2002 .The published version reports that RF radiation at 5 or 10 W/kg was capable of causing a one specific type of genotoxic injury (increased micronucleus formation); but did not enhance DNA strand breaks. Vijayalaxmi et al ,Bisht et al and McNamee et al have reported that they cannot replicate the micronucleus findings. The authors of the WTR genotoxicity study speculate that their reported effect on micronucleus formation may be due to heating. The epidemiological studies showing that RF exposure from base stations is safe, While there have been no epidemiology studies of cancer and mobile phone base stations, there have been epidemiology studies of cancer and other types of exposure to radiofrequency radiation. For reviews see Elwood ,Rothman ,and Boice and McLaughlin . Epidemiology studies of RF radiation from base stations have generally been concluded to be "infeasible, as there is no possibility to estimate individual exposure accurately enough" .

2.8 Mobile phones and cancer

At what side of your brain you want to add your "Microwave phone" :
Did you know that . . . .

Table 2.2 Mobile phones and cancer

The Left Part of Your Brain Controls:	The Right Part of Your Brain Controls:
• Number Skills • Written Language • Spoken Language • Scientific Skills • Right-hand Control	• Insight 3-D forms • Imagination • Music Awareness • Left-hand Control • Art Awareness

- The brain is the thinking organ of your body.
- The brain is the main part of the nervous system.
- The nervous system is made up of... The central system Contains the brain. Contains the spinal cord.
- The peripheral system Composed of your nerves throughout the rest of your body.
- The size of the brain does not matter.
- Our brain weighs a mere 3 pounds, but it is more powerful than the larger brain of an elephant.
- There are 3 divisions of the brain...
- The cerebrum Most important
- Biggest part of the brain Divided into two sections
- The cerebellum Back of the skull Controls your ability to balance and coordinate your muscles
- The mid brain Size of the end of the thumb Controls actions which happen by themselves. For example your breathing and heartbeat

Figure 2.13 Brain view

2.9 Cellular phones are unsafe

A diagnosis of cancer can be devastating. And there is good reason for this fear -- Cancer is the second leading cause of death in the United States next to heart disease, and will claim more than half a million lives this year. What we think of as "Cancer" is actually a group of more than one hundred separate diseases. These diseases are all characterized by an abnormal and unregulated growth of cells. This growth destroys surrounding body tissues and may spread to other parts of the body in a process that is known as metastasis.

You have probably heard of all kind of different types of cancer but we focus on BRAIN CANCER(braintumor): Cancer can develop anywhere in the body, and at any age. Cancer is usually caused by genetic damage that happens inside an individual cell. When cells divide at an accelerated rate, they often begin to form a mass of tissue called a tumor. The tumor is fed by nutrients that diffuse through neighboring blood vessels and can also grow by forming a substance called tumor angiogenesis (vessel forming) factor. This factor stimulates the growth Tumors invade tissues and organs directly (direct extension), often damaging or disabling themin the process. Tumors make invaded tissues and/or organs susceptible to infection. Tumors can also release substances that destroy tissues in close proximity to them. What Causes Cancer (brain tumor) Mutations in tumor suppressor genes are another common cause of cancer. As you might expect, a tumor suppressor gene is supposed to prevent tumors. But when these genes are damaged, they can allow cancer to develop instead of preventing it. One of these genes, p53, normally prevents cells with abnormal DNA from surviving. When p53 is defective, these cells with abnormal DNA survive and can multiply, increasing the probability of developing cancer (brain tumor).

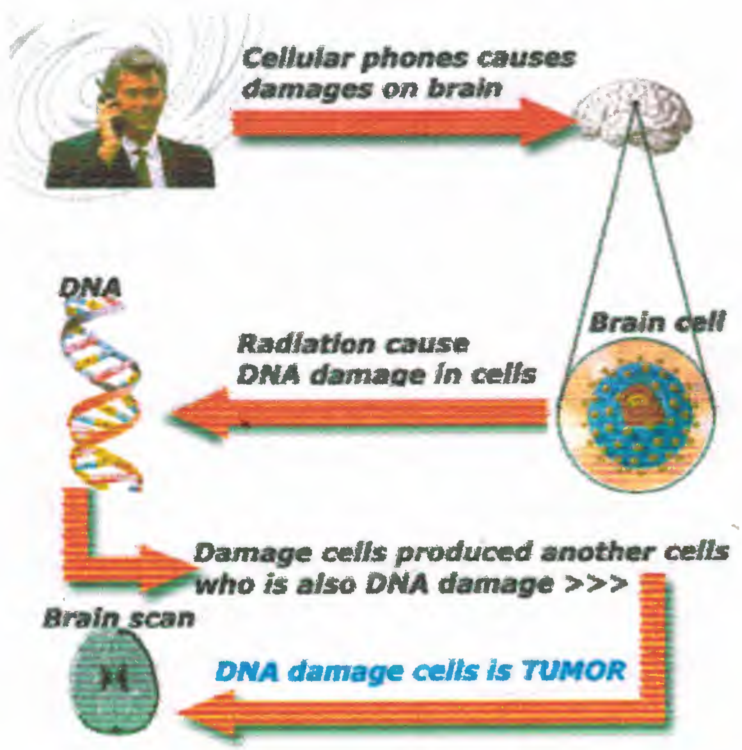


Figure 2.14 Simple image above how brain tumor start.

2.10 Blood

Changes have been reported in the cellular composition of the blood of rats, mice, dogs, guinea pigs, and rabbits following exposure to both high and low frequency EMFs . Graves exposed mice continuously to 25 and 50 kv/m for 6 weeks and found that the white blood cell count (WBC) was increased by 20% and 66% respectively. The red blood cell count (RBC) decreased by 6% and 12% at the respective fields, but these changes were not reported statistically significant. Rats exposed intermittently (30 min/day) to 100 kv/m, 50° Hz, for 8 weeks, exhibited elevated neutrophil levels and depressed lymphocyte levels . The same results were found following 2, 5, and 7 weeks' exposure at 5 hours/day. In dogs, alteration of the blood profile was seen following exposure at 10-25 kv/m . Meda found a lymphocyte decrease and a neutrophil and eosinophil increase in rats after a single 6-hour exposure to 100 kv/m, 50 Hz. A similar blood picture was found in mice after 500- and 1000-hour exposures to 100 kv/m . A significant increase in WBC was found in rabbits that had been exposed to 50 kv/m, 50 Hz, for 3 months . As has been the case with almost all biological indicators, the time course of the changes in blood parameters following EMF exposure was not the same in each test animal . Guinea pigs were exposed to 3GHz, 10 min/day, for 30 days , and both the irradiated and the sham-exposed animals were sampled before and after each daily exposure bout. The sham-exposed group revealed no significant changes, but animals exposed to 25 or 50 μW/cm2 exhibited EMF-induced alterations with time dependencies that differed with each animal. For a given exposure duration, the WBC was above the normal level in some animals, and below it in others; as a result, the average values varied little during the study. At 500 μW/cm2, however, even on the average there was a pronounced leukopenia and lymphocytosis. Gonshar exposed rats to 2.4 GHz, 7 hours/day for 30 days and studied the effect on the levels of alkaline phosphatase and glycogen (two indicators of cellular activity) in the neutrophils . Glycogen increased following 3 days' exposure at both 10 and 50 μW/cm2; after 7 days' exposure it decreased to the control level. In contrast to this apparent adaptational response, there was a sustained depressing effect on glycogen content at 500 μW/cm2 which was still observed after 30 days' exposure.

At all three intensities, the alkaline phosphatase levels first increased then decreased below the control level within 30 days. Ferrokinetic studies demonstrated that iron metabolism was affected and that erythrocyte production (measured by 59Fe incorporation) was significantly decreased in rabbits exposed to 2.95 GHz, 3000μW/cm2, for 2 hours daily . The effects seen after 37 days of irradiation with a pulsed EMF were comparable in magnitude to those seen after 79 days exposure to a continuous-wave EMF. Rats exposed to 130 gauss, 50 Hz, for 4 hours/day, exhibited a 15% reduction in RBC after 1 month's exposure: the RBC level returned to normal within a month after removal of the field . Because comparable results were obtained using widely different EMFs, the blood-composition studies suggested to us that the EMF-induced alterations were mostly transient compensatory reactions of the body to a change in the electromagnetic environment. To determine the relation between magnitude and direction of the response and the conditions of application of the external EMF, we looked for changes in hematological parameters of mice due to short-term exposure to a full-body vertical 60 Hz electric field of 5 kv/m . To ensure maximum statistical sensitivity every mouse was sampled twice, once after exposure to the field for 2 days and once following a 2-day nonexposure period. There were four consecutive experiments, two with males and two with females. In each there were two groups: one for which the control period preceded the exposure period (nF-ðF), and one in which the pattern was reversed (F-ðnF). On "day 1" of each experiment the mice were divided into the two groups and the electric field was applied to one-half the population. On "day 3" the blood parameters were measured in each mouse and immediately thereafter the exposed and nonexposed groups were interchanged. On "day 5" the blood parameters were measured again and the mice were killed. Blood was collected from the ophthalmic vessels and it was therefore necessary, before applying the field, to determine the influence of the first blood collection procedure on the values measured after the second such procedure. We measured the blood parameters in two groups of mice, one male and one female, under conditions that were identical in all respects to those employed during the field-exposure portion of the study, and we found that the method of blood collection had a tendency to produce higher RBC, Hct, and MCV values and lower values of Hb, MCH, and MCHC (Table 2.3).

Table2.3 Percent Change In Hematological Parameters

Experiment	Condition	Percentage Change					
		RBC	Hct	Hb	MCV	MCH	MCHC
A							
Male Control	nF → nF	1.7	2.0	-4.5*	1.0	-6.2*	-6.3*
Female Control	nF → nF	3.9*	4.1*	1.7	0.2	-5.0*	-5.1*
B							
Male I	F → nF	-4.7*	-5.1	NM	0	NM	NM
	nF → F	-5.2*	-4.9	NM	0.2	NM	NM
Male II	F → nF	-9.0*	-9.1*	-3.3*	-0.4	5.7*	6.0*
	nF → F	-6.5*	-7.0*	-2.4*	-0.7	3.9*	6.1*
Female I	F → nF	-4.1*	-4.6*	-4.2*	-1.2	0.5	1.2
	nF → F	-6.4*	-6.7*	-3.4*	-0.5	3.8	4.8
Female II	F → nF	-5.3*	-6.0*	3.4	-1.2*	8.3*	10.0*
	nF → F	-7.1*	-9.2*	3.5	-2.3*	11.0*	13.6*

Note: RBC, red blood cell concentration; Hct, hematocrit; Hb, hemoglobin; MCV, mean cell volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration. *A*, no change in exposure conditions; *B*, change in exposure condition as indicated. NM, not measured.

$*p < 0.05$

The results obtained in connection with the application of the electric field are In each experiment, RBC on "day 5" was significantly less than on "day 3," regardless of whether the interval between "day 3" and "day 5" was an exposure period or a nonexposure period. A decline in Hct paralleled the RBC changes, but Hb showed no consistent changes. MCV showed a tendency to decrease, but the other computed indices both increased, since the cell loss overshadowed any decrease in hemoglobin concentration. The trends in the computed indices, and especially the changes in RBC and Hct, were opposite to those induced by our method of blood collection alone. It follows, therefore, that the applied electric field had a physiological impact. The unique feature of the observed responses is that, for each parameter, a change in the same direction occurred with both the F-ðnF and nF-ðF groups. An analysis of variance confirmed that in all four experiments there was an effect associated with time but not with the order of field application. This indicated that the animals responded to the change in their electrical environment, not to the electric field itself. There are two reports of the effects of EMF on the blood globulin .

When rats were exposed to 3000 v/m at 1 KHz for 8 and 20 days (20 min./day), a reduction in coagulation activity (expressed as a lengthening of the rethrombin time, a drop in plasma tolerance for heparin, and a decrease in prothrombin consumption), and a rise in the thromboplastic and fibrinolytic activity of the blood were found . We found that rats exposed to DC electric fields of 2.8-19.7 kv/m had altered blood-protein distributions . The general trend was towards elevated albumin and decreased gamma globulin levels (expressed as a percent of the total blood proteins). One of the most common sights we see these days, is that of people with their mobile phones next to their ears. A boon for better communication, cell phone usage nonetheless has many health hazards. Various studies indicate that the emissions from a cell phone can be extremely harmful, causing genetic damage, tumors, memory loss, and increased blood pressure and weakening of the immune system. This is alarming information, and one has to take into account all these factors Though there is no evidence of cell phones causing cancer or any such illness, but the suspicion, or fear of the same is not baseless either. The electromagnetic radiation from cell phones does have a potential link to cancer. The fact that this radiation is invisible, intangible, and enters and leaves our bodies without our knowledge makes it even more intimidating.

2.11.Possible hazards:

Two minutes of exposure to emissions from mobile phones can disable a safety barrier in blood causing proteins and toxins to leak into the brain, could increase chances of developing Alzheimer's multiple sclerosis and Parkinson's. (Scientists at Sweden's Lund University) Scientists say exposure to the phones' low-level radiation causes red blood cells to leak hemoglobin and can lead to heart disease and kidney stones. Recent studies suggesting a link between cell-phone use and brain tumors, and the possibility that the microwaves could ignite petroleum fumes at gas stations. A cell phone unit, or communications tower, has so many of thee radiation emanating gadgets. This can be a problem for its immediate environment.

2.11.1Cancer / Tumors

Studies have been conducted suggesting that rats that have been exposed to microwaves similar to the sort generated by mobile phones but more powerful, showed breaks in their DNA which could indicate an adverse effect. Also, mice exposed to radiation for 18 months developed brain tumors. Though of course, these studies are not concrete proof.

2.11.2 Blood Pressure

It was observed that people using cell phones were prone to high blood pressure. Again, there isn't any concrete evidence of the same.

2.11.3 Pregnancy

A study at the University of Montpellier in France was carried out on 6000 chick embryos and suggested that the heavily exposed chick eggs were five times less likely to survive than the control group. This study raised questions about possible effects on pregnant women but it has not yet appeared in peer-reviewed scientific literature or been reproduced, so its findings aredifficulttoassess.

2.11.4Headaches, Heating Effects, Fatigue

A study brought out that longer the people used mobile phones, the more likely they were to report symptoms such as hot ears, burning skin, headaches and fatigue. The study did not include a control group (that is people who do not use mobile phones, to make a comparison); therefore the symptoms reported could have been caused by any number of other factors in the mobile phones users' environment, such as working with computers, stress, driving or reading.

2.11.5Memory

There have been various studies into the connection between mobile phones and memory loss. A study looked into the effect of radiofrequency (RF) on the section of rats' brains that is linked with the memory. The results showed that RF could modify signals in the cells in a part of the brain that is responsible for learning and short term memory.

2.11.6 Posture (holding phone between raised shoulder and ear)

Some researchers claim that holding a mobile phone between the raised shoulder and the ear could have a damaging effect on muscles, bones, tendons and discs. These problems would apply equally to a cordless phone or a landline phone as to a mobile phone and are the effect of bad posture.

2.11.7 Mobile Phones and Children

Because of their smaller heads, thinner skulls and higher tissue conductivity, children may absorb more energy from a given phone than adults. Cell phones should be used for mergencies, and not for long conversations. A small chip-like cell phone microwave radiation protection device is available, which has the ability to absorb electromagnetic energy waves from your mobile phone. It helps in reducing the potential harmful effects of these emissions to the human body. Using a mobile headset is a good idea, you don't have to hold phones next to your ears all the time Use a hands free mobile car kit while driving, without taking your hands off the steering wheel Mobile phone users should limit their exposure to harmful radio frequencies by cutting the length of calls. Hands-free devices cut exposure by keeping the instrument away from the head and body. Driving cum mobile phone talking should be banned. Mobile phones should not be used in Intensive Care Units of hospitals as they can pose a danger to patients by interfering with the working of pacemakers and defibrillators. People with hearing aids should not use mobile phones. Base stations, which have low powered antennae on their terrace to communicate with cell phones, should not be located near children's schools and playgrounds.

2.12 The Effect of Cellular Phone Use Upon Driver Attention

One of the most popular innovations in automotive travel in the past decade has nothing to do with the automobile itself, the people who drive them, or the roads over which they operate. Rather, it is the ability to carry on telephone conversations while driving.

What CB radios were to the '70s, cellular phones were to the '80s. From early 1984, when the first complete systems became operational, the number of cellular phone users has grown to over two million. By the mid-'90s, when cellular service will be available throughout most population centers in the United States, the number of subscribers is expected to grow to between ten and twenty million. While cellular phones are really elements of communication rather than transportation, their potential impact upon the latter is sizable.

PROBLEM Without "Protector"

- If you are using a cellular telephone, you must know that this cellular phone generate an electromagnetic field within a 10 cm radius.
- While you are using the cellular telephone, your head is inside this field and the energy absorbed by several parts of the head causes a heating reaction within the head and brain.
- This heating reaction rises depending on the time of conversation. Several studies have shown that this heating can have extremely negative health effects.

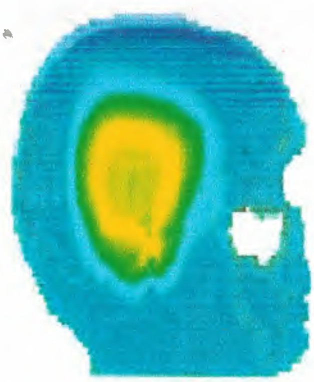


Figure 2.18 PROBLEM Without "Protector"

SOLUTION With "Protector"

The "Protector™" offers the optimal solution. This is because the shield in the "PROTECTOR" , located between your head and your cellular telephone, will reduce radiation by 99% without interfering with the operation of the cellular telephone (in fact, in some cases, it actually enhances transmissions and reception). These findings were confirmed by an independent, internationally recognized laboratory which has been approved by such international institutes as TUV (German Standards Institute), FCC (USA) as well as by IMST in Germany.

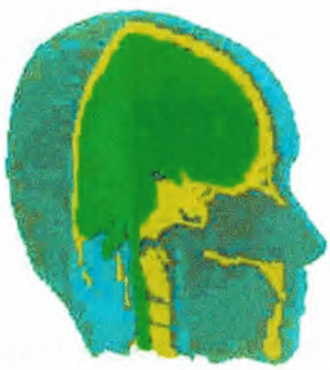


Figure 2.19 SOLUTION With "Protector"

3.THE POSSIBLE EFFECTS OF ELECTROMAGNETIC WAVE

3.1. The effects of intrinsic electromagnetic energy

3.1.1 The Nervous System

Not all neurophysiologists were convinced that the simple nerve impulse or action potential was the sole basis of all nervous system function. While it could not be questioned that this mechanism did exist and did furnish an adequate basis for the transmission of information in a single neurone, many problems remained unanswered. Most important was the question of how all of the neurones integrated and worked together to produce a coherent functioning brain (perhaps the whole was greater than the sum of the parts). While most basic scientists avoided such questions, the clinical neurologists were convinced that something was lacking in the action potential only concept. In the 1940's Gerard and Libet reported a particularly significant series of experiments on the DC electrical potentials measurable in the brain.

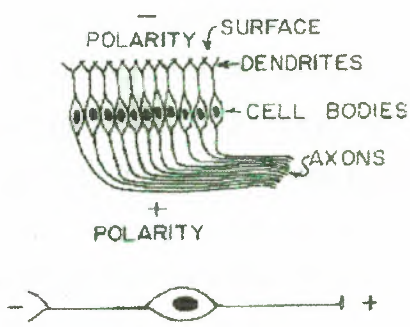


Figure 1 single neurone layer

Fig.1. Schematic representation of a typical single neurone layer of cells in the frog brain used by Libet and Gerard to measure DC electrical gradients. Their concept of the DC gradient along a single neurone is shown in the lower figure. It is likely that the polarity was the result of the neurone being removed from the brain as the polarity of the neurone intact and in the nervous system is opposite to what they found. In frogs, for example, some areas of the brain are only one neurone thick but are composed of many such neurones oriented all in one direction. In such areas steady or slowly varying potentials oriented along the axonodendritic axis were measured. These potentials changed in magnitude as the excitability level of the neurones was altered by chemical treatment.

First, it was not clear how such metabolic activity was translated into electrical potentials, and second, a number of investigators had demonstrated that applied currents (well below the level of heating) did influence general growth patterns in a nonrandom fashion. Thus by the mid-1950's serious doubts began to be expressed concerning the ability of the Bemstein semipermeable membrane hypothesis to explain all observed bioelectric phenomena both within the central nervous system and in the body as a whole. In 1960 we repeated Burr's measurements of the DC field on the surface of the intact salamander using, however, the much more stable and sensitive instrumentation then available. Rather than a simple dipole field, we found a complex field pattern with an obvious relationship to the underlying anatomy of the central nervous system . Positive areas on the skin surface overlay areas of cellular aggregation with the CNS, such as the brain and the brachial and lumbar enlargements of the spinal cord, while the nerve trunks were increasingly negative as they proceeded distally away from the spinal cord. This suggested that the potentials were related to the DC potentials of the CNS rather than being generated by the total activity of all the cells of the organism. An immediate question was whether current flowing within such a structure embedded within the volume conductor of the body could produce such a field pattern on the surface of the animal. We found that when a CNS analog (built of copper wire with solder junctions as generating sources at the brain and spinal cord enlargements) was placed within a volume conductor of the same size and relative shape as a salamander, the same pattern of potentials was measurable on the surface as was measured on the living salamander. This indicated that the total CNS could be the source of the field potentials, but it did not confirm that it had such an activity.

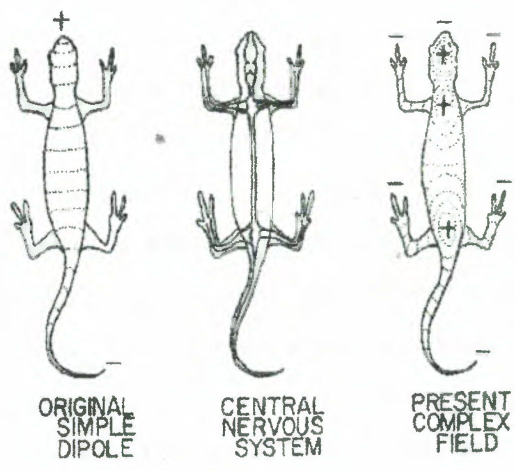


Figure 2 Plots of the surface DC electrical potential

Fig.2. Plots of the surface DC electrical potential on the surface of the salamander as reported by Burr (left) and found by us (right). The central nervous system is diagrammed in the center. The relationship between the complex field and the nervous system is evident. All of the previous neurophysiological studies on DC potentials had been made on the brain. The existence of similar electrical phenomena in the peripheral nerves could only be conjectured, but it was a necessity to relate the measured surface potentials to the total CNS. To investigate this further we measured the DC potentials along 1 cm segments of various peripheral nerves . Again, reproducible DC voltages were found; however, their polarity appeared to be dependent upon the direction of the normal nerve impulse travel. Sensory nerves were polarized distally positive, while motor nerves were polarized distally negative. Combined nerve trunks, with both sensory and motor components, demonstrated polarities and magnitudes of potentials that were related to the arithmetic addition of the potentials associated with each component. (It should be remembered that while all peripheral nerves are called axons, only those that are motor are truly so; the sensory fibers are in reality dendrites carrying information centrally.) These measured polarities seemed to indicate that each complete neurone was polarized in the same direction along its axono-dendritic axis. These observations almost exactly paralleled those made by Libet and Gerard on the cerebral neurones 30 years before. Thus the body surface fields measured by Burr and Lund, rather than being the result of the electrical activity of all the cells, appeared to be associated with some DC activity of the entire nervous system.The electrical potentials measured longitudinally along the peripheral nerves paralleled in magnitude the general state of the CNS "in toto," (i.e., they diminished with anesthesia and with section of the spinal cord). Since they could be measured constantly during periods of relatively normal CNS state, it was postulated that they had to be generated by a constant current flow.The Hall effect consists of exposing a current-carrying conductor to a magnetic field oriented at 90° to the axis of the conductor. The field will produce some deviation of the charge carriers which can then be sensed as a steady voltage at the second 90° axis to the conductor. This is called the Hall voltage and its magnitude is very dependent upon the degree of mobility of the charge carriers (being almost undetectable with ionic currents, only slightly more detectable with electron flow in metallic conductors, but easily detected with semiconducting currents due to the high mobility of their charge carriers). Since the nerve currents were obviously not metallic conduction and since the detection of ionic Hall voltages was far beyond the capability of our equipment, we reasoned that if any Hall voltages were observed, they would indicate not only the existence of the current but also that it was probably analogous to semiconducting current.

The experiment was performed using the foreleg of the salamander as the current-carrying conductor (the nerve was not exposed, the intact limb being contacted only by the two soft measuring electrodes to obviate any injury effects). In 1961 we reported observing Hall voltages under these circumstances.The magnitude varied inversely with the state of anesthesia of the test animal, indicating that the voltages were real, not artifactual, and directly related to the operational state of the CNS. There was now strong evidence that some component of the CNS generated and transmitted direct currents that produced the measurable voltages on the surface of animals, including humans. It remained to determine if these voltages were related to the functions, as described by Libet and Gerard for the nervous system and Burr and Lund for the total organism. In our measurements of the surface potentials we had noted that they varied in a definite pattern with the level of consciousness of the subject, particularly a midline, occipito-frontal voltage vector across the head, which seemed to accurately reflect the level of anesthesia. In the conscious subject this vector was frontally negative, diminishing in magnitude and going positive as anesthesia was induced and deepened. This voltage on the skin surface exactly paralleled that observed by Libet and Gerard and by Caspers in the brain and we postulated that this current vector represented current flow in median unpaired structures of the brainstem area. If Libet and Gerard and Caspers were correct, this current should be the determiner of the level of excitability (hence consciousness) of the subject, and electrically reversing the normal frontally-negative potential should induce the same loss of consciousness as chemical anesthesia. Again using the salamander, we observed that currents as small as 30 μamp administered in this direction produced loss of consciousness and responsiveness to painful stimuli. In addition, they produced in the subject animal electroencephalographic patterns typical of the anesthetized state (high amplitude delta slow waves). In the converse experiment, attempting to restore consciousness to a chemically anesthetized animal, the EEG evidence was suggestive but much less convincing.

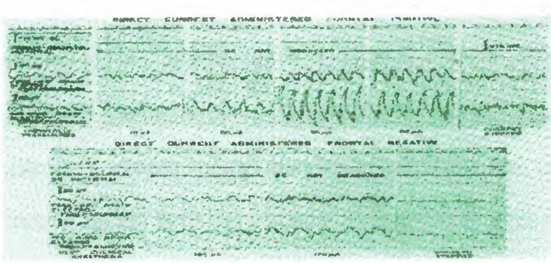


Figure 3 The effect of direct current

Fig.3. The effect of direct current administered longitudinally (fronto-occipital) through the brain of the salamander. Upper: the electroencephalogram when the current is oriented frontally positive (opposite to the normal awake pattern). The EEG demonstrates a typical delta wave pattern of deep anesthesia, with the magnitude of the delta waves proportional to the current magnitude. The animal demonstrated all the clinical signs of anesthesia. Lower: the reverse experiment. A deeply anesthetized animal is exposed to current oriented in the normal awake direction. Much more current is required to produce an objective response and while the animal did not recover consciousness as a result of the current passage, the EEG pattern did show signs (alpha waves) of an awake pattern.

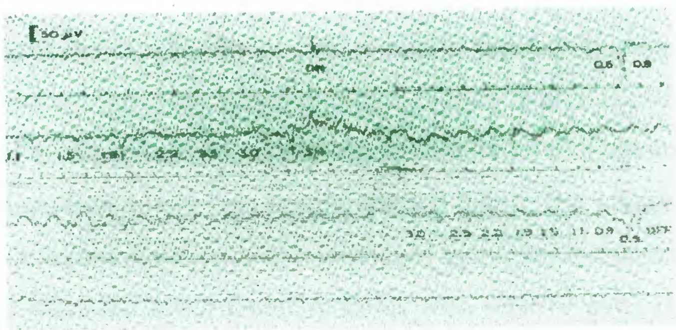


Figure 4 The effect of a magnetic field

Fig.4. The effect of a magnetic field applied across the head of a salamander in a bitemporal direction. The interaction between the field and a longitudinal electrical current in the brain (if one was present) would lead to a decrease in the total current delivered along the original fronto-occipital vector. It was predicted that this would produce a state of anesthesia, and at the level of 3000 gauss the EEG pattern became one of deep anesthesia with delta wave forms This was accompanied by a loss of response to painful stimuli. If, as these experiments seemed to indicate, there was a DC current flow organized in this fashion in the brain it should be of the same nature as the peripheral currents, and it should be subject to the same type of interaction with an applied magnetic field. The anatomical complexity of the head and brain ruled out the possibility of observing an unequivocal Hall voltage, but if the magnetic field were very high in strength and precisely oriented 90° to the fronto-occipital vector, then a sufficient number of charge carriers might be deviated from the original current vector to produce a significant decrease in the normal current along the fronto-occipital vector; possibly even sufficient to produce loss of consciousness.

Even though fields of several thousand gauss were found to be necessary to produce the effect, the results were unequivocal. At field strengths exceeding 3000 gauss, the animals were not only nonresponsive to painful stimuli but they also demonstrated the large, slow delta wave patterns typical of deep anesthesia. As mentioned earlier, the surest sign of actual electrical current flow in any biological structure would be the detection of the resulting magnetic field in space around the structure. Technology had long been quite inadequate to detect the extremely weak fields predicted. The first detection of a "biomagnetic" field was in 1963 by Baule and McFee who used classical techniques (a coil of million turns of wire and a ferrite core) to detect the field associated with the action of the human heart.The field intensity was five orders of magnitude lower then the earth's normal field and it was necessary to conduct the experiment in a rural area as free of extraneous fields as possible. Two years later, Cohen, using the same technique coupled with a signal averaging computer, found evidence of a magnetic field around the human head of even weaker strength (about eight orders of magnitude lower than earth's normal field). The invention of the SQUID (a superconducting quantum interference device based upon the Josephson junction) permitted detection of these and even lower intensity fields with relative ease. It was first applied by Cohen in 1970 for a more complete detection of the human magnetocardiogram, and in 1972 he reported that the magnetic field in space around the human head demonstrated a wave form pattern, similar to, but not identical with, the EEG as measured by skin electrodes.Cohen called this the magnetoencephalogram or MEG.

3.1.2 Growth Control

As reviewed in the first chapter, the clinical use of externally generated electrical currents to enhance healing or retard tumor growth was common in the latter half of the nineteenth century. While the technique rapidly fell into disfavor in the early decades of the present century with the mounting evidence against electrical properties of living things, some laboratory studies were continued. Frazee, for example, studied the effect of passing electrical current through the water in which salamanders were kept. In 1909 he reported that this appeared to increase the rate of limb regeneration in these animals.In their long series of investigations extending from the 20's through the 40's, both Burr and Lund reported growth effects of applied electrical currents on a variety of plants and animals. Some of their observations were confirmed and extended by Barth at Columbia University .

In 1952 Marsh and Beams reported on an interesting series of experiments on Planaria, a species of relatively simple flatworm with a primitive nervous system and simple head-to-tail axis of organization. As expected, electrical measurements had indicated a simple head-tail dipole field. This animal had remarkable regenerative powers; it could be cut transversely into a number of segments, all of which would regenerate a new total organism. Even more remarkable, the original head-tail axis would be preserved in each regenerate, with that portion nearest the original head end becoming the head of the new organism. Marsh and Beams postulated that the original head-tail electrical vector persisted in the cut segments and that it provided the morphological information for the regenerate. If this was so, then reversal of the electrical gradient by exposing the cut surface to an external current source of proper orientation should produce some reversal of the head-tail gradient in the regenerate. While performing the experiment they found that as the current levels were increased the first response was to form a head at each end of the regenerating segment. With still further increases in the current the expected reversal of the head-tail gradient did occur, indicating that the electrical gradient which naturally existed in these animals was capable of transmitting morphological information. A few years later Humphrey and Seal attempted a scientific evaluation of the old clinical techniques of electrical control of tumor growth. It had been observed many times that rapidly growing tissues were electrically negative in polarity, with tumors being the highest in magnitude. Many of the old clinical techniques therefore applied positive potentials and currents on the theory that the opposite polarity should slow or stop the growth. On this theoretical basis we measured the current of injury following foreleg amputations in salamanders compared to the same amputation in frogs . While the immediate postamputation potentials were positive in polarity and about the same in magnitude in both species, the frog's potential slowly returned to the original slightly negative potential as simple healing by scarification and epithelialization took place. In the salamander, the positive potential very quickly (3 days) returned to the original base line but then became increasingly negative in polarity, coinciding with blastema formation and declining thereafter as regeneration occurred. These observations regarding polarity and duration of the potentials have recently been confirmed by Neufeld using the same techniques .

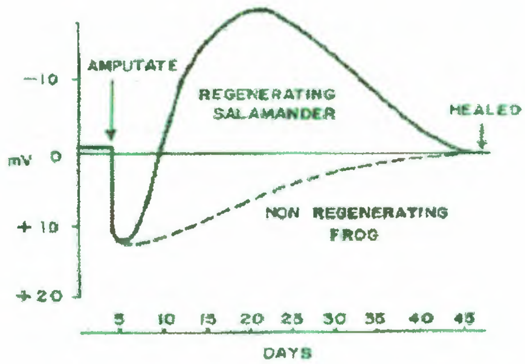


Figure 5 Measurements of the current

Fig.5. Measurements of the current of injury following forelimb amputation in the frog (not capable of regeneration) and in the salamander (capable of regeneration). The immediate effect is a shift to a highly positive polarity in both animals. The frog slowly decreases this polarity as healing by scarification occurs, while the salamander reverses the polarity, shifting negatively at about the third day. Following this the blastema appears and regeneration occurs over a 3-week period, during which the negative polarity slowly subsides. Two observations were immediately pertinent to Bernstein's original theorization that the current of injury was simply an expression of the transmembrane potential of damaged cells. The first was the polarity reversal in the salamander at 3 days and the second was the persistence of the potentials for several weeks until the injury was either healed closed or regenerated. Neither observation is compatible with Bernstein's hypothesis (the polarities of all damaged cells should be the same and they should persist no longer than the time required to repair or replace the damaged cells), but they are compatible with the concept of an organized neural DC control system with actual current flow. On the basis of these observations we theoretically divided regeneration into two separate but sequential phases; the first being the formation of a blastema in response to a signal that is stimulating to the local cells and through their dedifferentiation produces the blastema. The information content of the signal responsible for the first phase is obviously sparse and the signal may be correspondingly simple, whereas the signal responsible for the second phase must be capable of carrying an enormous amount of information (what structure is to be formed, what its orientation with respect to the rest of the body is to be, and finally all of the details of its complex structure). In our view, the DC potentials and currents generated at the site of injury by the DC control system were quite suitable as the signal for the first phase, whereas their information content was totally inadequate for the second phase.

This concept meant that there could be two mechanisms at fault in those animals normally incapable of regenerative growth. First the initial phase may fail to produce a blastema because of either an inadequate signal or an inability of the cells to respond to an adequate signal by dedifferentiation. If an adequate blastema was formed, the second phase informational signal might be missing or inadequate to produce the subsequent redifferentiation and growth. Since it is common knowledge that nonregenerating animals fail in the first phase and do not produce blastemas, and in view of our finding of the polarity differences between regenerators and nonregenerators in the first phase, we postulated that the initial stimulating signal was missing in the nonregenerating animals. Simulation of this signal by external means was technically quite feasible; however, one could not predict whether the cells would be capable of responding to it or if they did, and a blastema was formed, whether the complex informational signal that controlled the second phase would be present. The first test of this hypothesis was provided by Smith, who implanted simple bimetallic electrical generating devices (a short length of platinum wire soldered to a short length of silver wire) in amputated forelegs of adult frogs . In 1967 he reported the successful stimulation of partial limb regeneration by this technique. Theorizing that the failure to regenerate completely was due to the device being fixed in position at the original amputation level, he repeated the experiment using a device that had extensible electrode leads and in 1974 he reported securing regeneration of a complete extremity in the same animal. Meanwhile, we applied a modification of Smith's device to the foreleg amputation in the rat, reporting in 1972. the regeneration of the forelimb from the amputation level midway between the shoulder and elbow, down to and including the elbow joint complete in all anatomical detail. This was the first successful stimulation of the regeneration of a complex extremity by artificial means in a mammal. It has subsequently been substantiated by Libben and Person in 1979 and by Smith in 1981 , all using similar techniques.

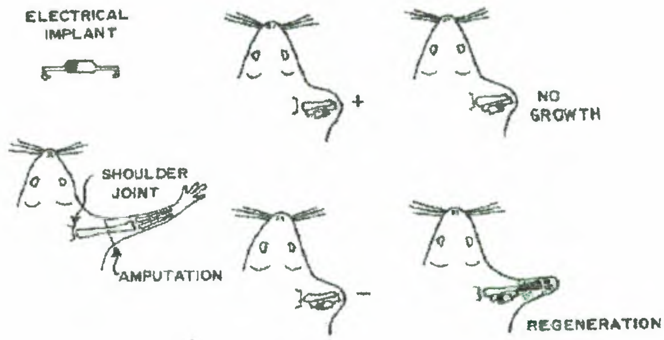


Figure 6 Implanting a small device in the amputation stump

Fig.6. Implanting a small device in the amputation stump of the rat foreleg results in a major amount of limb regeneration if the device is oriented so that the end of the stump is made negative, similar to the salamander current of injury. if the device is implanted with the distal end positive there is no regeneration. It seemed now abundantly clear that artificially generated electrical currents of appropriate polarity and magnitude could stimulate regeneration in a variety of animals not normally possessed of this facility. Nevertheless, the identification of these currents as being the analog of those currents normally produced by the nervous system was lacking. Growth could be produced by this technique, but this did not necessarily mean that the neurally related currents measured in animals that were normally capable of regeneration were the real cause of their regenerative growth. This missing factor was supplied by one of the latest experiments of Rose. In this experiment he carefully denervated the forelimbs of a number of salamanders, some of whom received daily applications of negative polarity electrical current to the amputation stump. Normal complete regeneration occurred in this group and subsequent examination demonstrated no ingrowth of nerve fibers.The control group demonstrated no regeneration whatsoever. Rose was therefore able to conclude that the factor supplied by the nerve that is normally responsible for limb regeneration in the salamander is the flow of an electrical current of the proper polarity and magnitude. However, the story is not quite over yet as the situation is actually somewhat more complex. However, it is better understood in the light of our most recent findings. As early as 1962 Rose had called attention to the importance of a peculiar relationship between the epidermis and the nerves in the salamander limb regeneration process. The first event in such regeneration is the overgrowth of the epidermis alone (not the dermis) over the cut end of the amputation stump. Following this the cut ends of the nerves remaining in the amputation stump begin to grow into this epidermal "cap" where they form peculiar "synapse-like" junctions with the epidermal cells.

This "neuroepidermal junction" (NEJ) is apparently the primary structure in the regenerative process, since following its formation the blastema appears, and if the formation of the NEJ is prevented by interference with either the nerve or the epidermis, or by simply interposing a layer of the dermis under the epidermis, blastema formation does not occur and regeneration is absent. In experiments in which limb regeneration was stimulated by electrical means no NEJ formed and we postulated that its function had been taken over by the applied electrical currents. Therefore, the NEJ could be postulated to be the single structure that produced the "regeneration type" potentials, not the nerve, nor the epidermis acting alone.

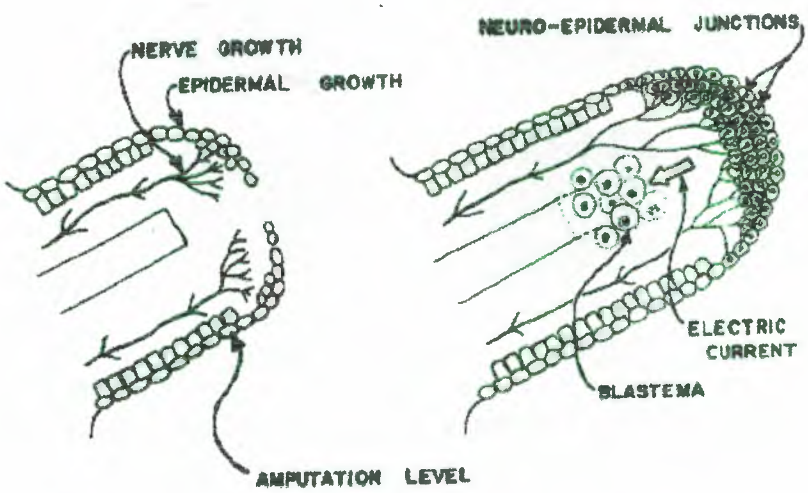


Figure 7 The electrical mechanism

Fig.7. The electrical mechanism producing regeneration of the salamander limb.After the epithelium alone grows over the end of the amputation stump, and the nerve fibers that were cut regrow, these two tissues grow together at the end of the stump. The nerve fibers attach themselves to the epithelial cells, producing a neuro-epidermal junction. This strucrure is then responsible for producing the specific electrical current that causes the cells left in the stump to dedifferentiate. If the neuro-epidermal junction fails to form for any reason, regeneration will not occur. In an attempt to evaluate this concept we attempted to surgically produce such neuroepidermal junctions in animals that normally lacked regenerative ability. Hind limb amputations were done in a series of adult rats.

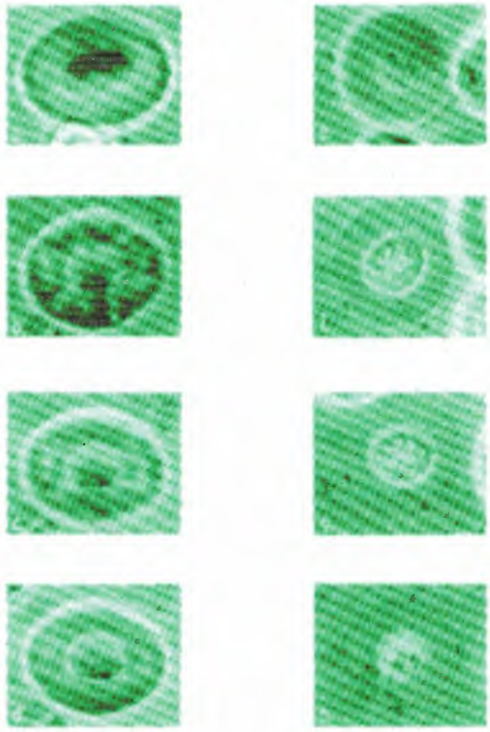


Figure 8 Sequence of morphological

Fig.8. Sequence of morphological changes in a single frog nucleated erythrocyte exposed to very low levels of electrical current. The same cell was photographed at intervals of 5 minutes, demonstrating a change from the normal red cell type to a cell that has become round, lost all its hemoglobin, and has major phase changes in its nucleus. These cells are quite alive, surviving in cell culture and chemically demonstrating a marked increase in RNA content and a complete alteration in protein composition. In later experiments, Harrington confirmed the original observation and determined that while the RNA content of the changed cells was markedly increased, the DNA content remained constant, and the protein composition changed markedly compared to the original normal cells- changes that were consistent with the dedifferentiation process. He was also able to show that the direct action of the electrical current was in the nature of a "trigger" stimulus at the level of the cell membrane which then effected the dedifferentiation by means of the messenger RNA system. (Cells in which the RNA protein mechanism was inhibited from acting by exposure to puromycin would not undergo morphological alteration when exposed to adequate electrical current for an adequate amount of time. However, if the current was then stopped and the puromycin washed out by several changes of media the cells would then undergo dedifferentiation at the expected rate.)

3.2. The effects of electromagnetic energy on the Nervous system

3.2.1 Direct Effects

We used the salamander electroencephalogram (EEG) pattern as a means to monitor for possible direct effects of high-strength magnetic fields applied along a specific axis through the head. The field induced the onset of a slow or delta-wave pattern, and a large fluctuation in activity was seen as the field was slowly decreased from 1000 gauss to zero. These observations were confirmed and extended by Kholodov in 1966 in the rabbit EEG. He found that the presence of delta waves and the number of spindles (brief bursts of 8-12 Hz waves) were both increased by 1-3 minutes' exposure at 200-1000 gauss. In about half the animals tested these reactions lasted at least 30 seconds. In addition to these changes, which occurred after a latent period of the order of 10 seconds, Kholodov sometimes observed a desynchronization reaction (an abrupt change in the main rhythm) 2-10 seconds after the field was turned on (in 14% of the cases), or off (24%). He attributed the increase in spindles and slow waves to a direct action of the magnetic field on the nervous system and the more rapid, and relatively less frequent, desynchronization reaction to the electric field which was induced in the tissue as a result of the change in magnetic field during the turn-on turn-off. Chizhenkova confirmed this hypothesis by exposing rabbits to 300 gauss for either 1 minute or 1.5 seconds. At the longer exposure period, the changes reported by Kholodov were observed, but following 1.5-second exposures only the desynchronization reaction occurred. In addition, Chizhenkova showed that a ten-factor reduction in the induced electric field (achieved by changing the magnetic field more slowly) had no effect on the number of spindles. Similar changes in the EEG due to EMFs of frequencies ranging from 50 Hz to 3 GHz have been reported.

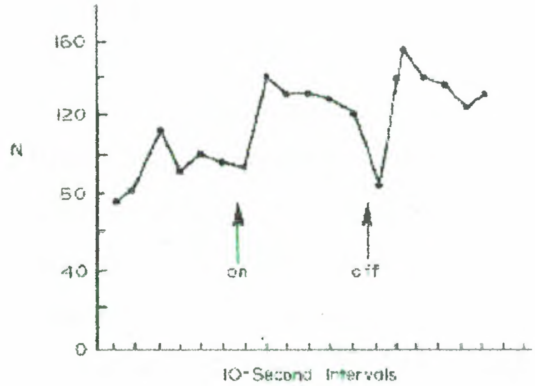


Figure 9. Change in number of spindles

Fig.9. Change in number of spindles in the rabbit induced by exposure to 300 gauss. N is the average number of spindles per 10 second periods that occurred during 604 exposures. Three additional aspects of the Kholodov-Chizhenkova studies deserve mention: (1) the number of spindles observed after a change in the magnetic field increased regardless of whether the change was on-to-off or off-to-on ; (2) there was an after-effect in which the number of spindles remained elevated even when the field was turned off ; (3) the most reactive regions were the hypothalamus and the cortex, and the least reactive region was the reticular formation of the midbrain. Kholodov found a desynchronization reaction, but no changes in spindles or delta waves, when rabbits were exposed for 1 minute to 500 kv/m DC electric fields . Lott and McCain measured the total integrated EEG in rats before, during, and after exposure to a DC field of 10 kv/m . They found a transient increase associated with either the application or removal of the field, a steady response that persisted during application of the field, and an after-effect. A 640 Hz pulsed field, 40 v/m maximum, also increased the total integrated EEG, particularly for readings from the hypothalmic region.

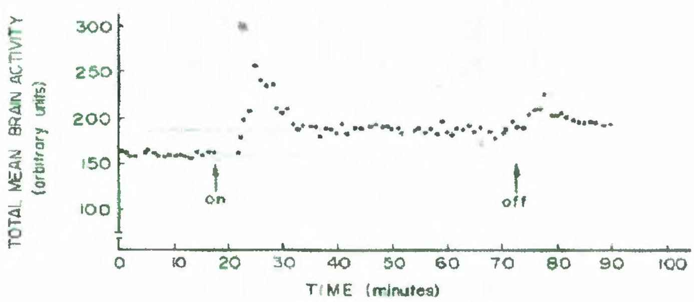


Figure 10 Total brain activity of anesthetized rats

Fig.10. Total brain activity of anesthetized rats exposed to a DC electric field of 10kv/m. Each point represents a mean of 9 experiments; readings were not taken for 6 minutes following application of the EMF. At high frequencies, a different effect on the total integrated electrical activity was observed. Goldstein exposed rabbits for 5 minutes to 700-2.800 μW/cm2, 9.3 GHz, and found no EEG changes during the exposure period. Commencing about I0 minutes after exposure, however, there occurred an interval of decreased total integrated EEG that persisted for up to 15 minutes. The authors reported that the observed changes in the EEG resembled those induced by hallucinogenic drugs. The nature of the EMF-induced EEG after-effect is determined by the exposure conditions and the physiological characteristics of the subject . For example, following a 30 minute exposure at 100 μW/cm2, 3 GHz, most of the rabbits tested exhibit either depressed or elevated slow-wave activity, and the relative number in each group varied with the location from which the EEG was recorded . The activity in the hypothalamus and the cortex was highly correlated in individual animals-it was either elevated or depressed simultaneously in both regions. After a 1 week exposure (1 hr./day) depressed EEG activity was the characteristic response , and after 3-4 weeks the after-effect phenomenon was no longer present . Dumanskiy observed a similar pattern in rabbits from exposure to 1.9-10 μW/cm2, 50 MHz ; after 2 weeks, EEG activity was elevated, but after 2. months' exposure significant slowwave inhibition occurred. Such inhibition was also found after 4 months' exposure at 1-10.5 μW/cm2, 2.5 GHz .

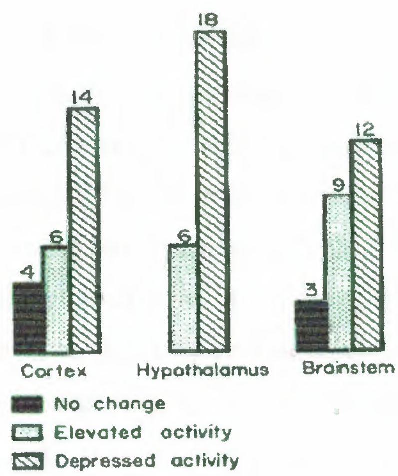


Figure 11 Relation of EEG response

Fig.11. Relation of EEG response from the cortex, hypothalamus, and brainstem due to exposure at 3 GHz.

The numbers indicate rabbits with a given response. Servantie showed that the EEG could be entrained by a pulsed EMF . For 1-2 minutes after a 10-day irradiation period at 5000 ,μW/cm2 the EEG of rats exhibited the pulse-modulation frequency of the applied 3-GHz field. Bawin also observed the production of specific EEG rhythms, and the reinforcement of spontaneous rhythms, by pulsed EMFs. Effects of EMFs have been reported on other aspects of neuroelectric behavior, such as evoked potentials , neuronal firing rate , latency and voltage threshold ,and response to drugs . One of the American scientists who pioneered the study of EMF effects on the nervous system is Allen Frey; his work has induded studies of the effects on evoked potentials , behavior , and hearing phenomena . In 1975 Frey reported an increase in the permeability of the bloodbrain barrier (the selective process by which capillaries in the brain regulate transport of substances between the blood and the surrounding neuropil) of rats exposed to 2400 μW/cm2 (continuous) or 200 μW/cm2 (pulsed) at 1.2 GHz . Frey found that dye injected into the bloodstream appeared in the brain of exposed animals, but not the control animals, and that the pulsed EMF was more effective than the continuous signal in opening the barrier, even though the average power level of the pulsed signal was only one-tenth that of the continuous signal. Frey's findings were confirmed and extended by Oscar and Hawkins in 1977 . They reported that continuous and pulsed EMFs both increased brain-tissue permeability, but that, depending on the particular pulse characteristics, pulsed energy could be either more or less effective than continuous-wave energy. Effects were observed at average powers as low as 30 ,μW/cm2. Preston et al., on the other hand, failed to find an effect on the permeability of the blood-brain barrier even at thermal-level EMFs . Frey concluded that Preston's failure resulted from an inappropriate choice of statistical procedures Biochemical studies of EMF-induced changes in brain tissue have yielded remarkably similar results at widely different frequencies. Fischer et al. found that 50Hz, 5300 v/m, resulted in an initial rise of norepinephrine in rat brain, and a subsequent decline below the control level . Grin observed the same sequence of changes at 2.4 GHz, 500 μW/cm2 ; at 50 μW/cm2, however, the norepinephrine level in Grin's study rose continuously throughout the exposure period. Noval et al. found that the activity of choline acetyltransferase (ChAC)-a neuronal enzyme which catalyses the synthesis of acetylcholine-was significantly reduced in the brainstem portion of brains from rats exposed to 10-100 v/m, 45 Hz, for 30-40 days; ChAC activity in the cerebral hemispheres was not affected by the field.

Cytochrome oxidase activity in rat-brain mitochondria was significantly reduced after 1 month's exposure at 1000 and 1000 ,μW/cm2, 2.4 GHz; no effect was found at 10 μW/cm2 Cholinesterase is the neuronal enzyme that destroys acetylcholine, thereby permitting re-establishment of the membrane potential; alteration in blood cholinesterase levels reflects changes in the functional state of the nervous system. Chronic exposure to both low-frequency and highfrequency EMFs have produced lowered blood cholinesterase levels.

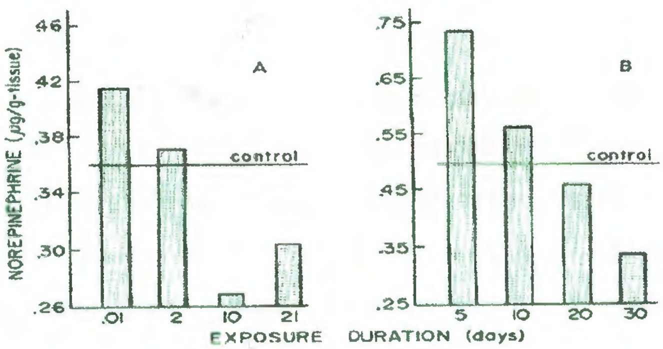


Figure 12. Norepinephrine levels

Fig.12. Norepinephrine levels in rat brain following exposure to EMFs:A, 5300 v/m, 50 Hz; B,500 μW/cm2, 2.4 GHz. Microscopic studies of brain tissue of EMF-exposed animals have disclosed several kinds of functional histopathological effects.

3.2.2 Behavioral Effects

Most of the major paradigms used in behavioral research have been employed successfully to establish the existence of EMF-induced behavioral effects. These include studies of spontaneous activity, reaction time, and conditioned responses. When motor activity was evaluated by tilt cages, traversal of open-field mazes, or other ambulatory behaviors, it was found that the responses depended on the characteristics of both the measuring system and the applied EMFs. Eakin and Thompson used 320-920 MHz, 760 μW/cm2, for 47 days and found that the exposed rats were more active than the controls during the first 20 days of exposure, and less active there after. These results were confirmed and extended by Eakin in 1970 when hypoactivity was reported following prolonged exposure to 150-430 μW/cm2 .

Roberti et al. failed to find an effect due to 3 -10 GHz for 7 days at 1000 μW/cm2,but Mitchelletal.who exposed rats to 2.45 GHz at about 600 μW/cm2 for 22 days (5 hr/day), found an EMF-induced hyperactivity in the exposed animals compared to both their pre-exposure baseline and the activity of sham-exposed controls. The field-induced activity changes in each of these studies were measured during periods when the animals were removed from the field. When activity was measured during exposure to a modulated 40-MHz electric field, it first increased, then decreased, during the 2-hour exposure period. This result supported an earlier finding by the same group that the field caused a similar pattern of change in the emotional response of rats as measured by the Olds self-stimulation response The pattern of a dual effect upon performance-stimulation or inhibition, depending on the circumstances-has not emerged at the low frequencies, most such studies having found only increased activity. At 1000 v/m, 60 Hz (5 days) , and 60,000 v/m, 50 Hz (3 hr) , the nocturnal activity of rodents was increased. An increase in activity in two strains of mice was also seen following exposure to 17 gauss at 60 Hz . Other spontaneous behaviors have been found to be susceptible to EMFs, including pain-induced aggression , escape , avoidance and sleep pattern A standard behavioral measure of a subject's ability to respond to changes in its environment is its reaction-time to a visual or auditory stimulus. In several studies this has been altered by low-frequency EMFs. According to Konig and Ankermuller , at 1 v/m, 10 Hz and 3 Hz are associated with a decrease and increase, respectively, in human reaction time as compared to the field-free situation. In an experimental design in which each subject was exposed to two frequencies in the 2-12 Hz range, at 4 v/m, Hamer found a longer reaction time at the higher frequency . Friedman et al. applied magnetic fields of 0.1 and 0.2 Hz to separate groups of male and female subjects, and for both groups he found a longer reaction time at the higher frequency compared to the lower frequency . Persinger et al. found no difference in the mean reaction time in either males or females due to 0.3-30 v/m, 3-10 Hz, but he did find a significant difference between the sexes in the variability of the response to a given field . As measured by a task consisting of the addition of sets of five two-digit numbers, a 60 Hz, 1-gauss field altered the ability to concentrate in human subjects . All 6 experimental subjects demonstrated a decline in performance in the second test session of the exposure period, and all 6 improved in the first test session of the postexposure period. In contrast, the control subjects showed no consistent changes.

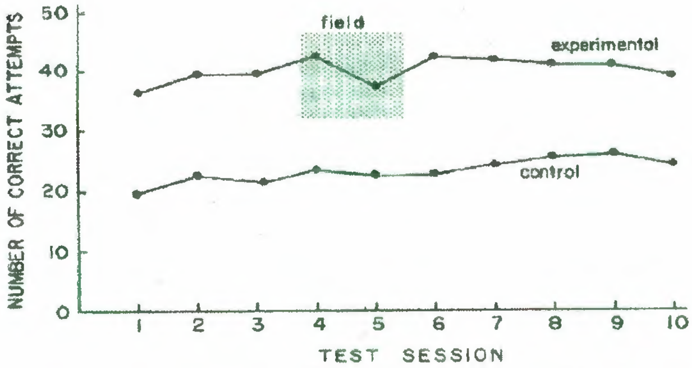


Figure 13 Average performance

Fig.13. Average performance of the experimental and control groups on the Wilkinson Adding Task. The subjects were confined to the test facility throughout the study, and were unaware of the exact timing of the 24-hour exposure period. For more than a decade, Ross Adey and his colleagues have sought to understand the molecular mechanisms that underlie field-induced behavioral changes. In the late 1960's they reported that low-frequency EMFs altered the timing behavior in humans and monkeys . The effects were frequency-dependent in the 2-12. Hz range, and later results suggested that they increased with dose . In 1973, they reported that cats exposed to 147-MHz EMFs, modulated at 0.5-30 Hz, exhibited altered EEGs . The idea that evolved from these studies and others , was that extremely weak EMFs- I0-5 v/m, as calculated on the basis of the simple spherical model described in chapter 2-could alter neuronal excitability, and presumably timing behavior and the EEG, if they were in the physiological frequency range (the EEG). An in vitro system involving calcium binding to brain tissue was then chosen to study the effect of weak EMFs on ionic movement under a hypothesis that altered ion-binding and the associated conformational changes constituted the mechanism of the EMF-induced effects. A complex series of results were then obtained concerning the levels of pre-incubated calcium that were released into solution: at 147 MHz, there was an increase when the EMF was modulated at 6- 10 Hz, but no increase at 0.5-3 or 25-35 Hz ; with EMFs of 6 and 16 Hz, there was a decrease at 10 and 56 v/m, but not at 5 or 100 v/m ; there was no change in calcium at 1 Hz or 32 Hz, at either 10 or 56 v/m ; at 450 MHz, modulated at 16 Hz, there was an increase . Some of these results have been confirmed (71). The salient features of the in vitro studies were: (1) the emphasis on calcium; (2) the opposite results obtained following low-frequency and high-frequency EMF exposure; and (3) the existence of frequency and field-strength ranges where the effects were at a maximum.

None of these features were seen in the in vivo studies. Grodsky proposed a cell-membrane model involving cooperative charge interactions as a partial explanation of Adey's results , but their molecular basis still remains speculative . There have been reports of the effects of EMFs on conditioned responses in both operant and respondent paradigms . In the operant studies, the effect of the EMFs was usually established on the basis of changes in discrete movement by the test subjects. For example, Thomas found that a pulsed EMF of 1000 µW/cm2, 2.45 GHz, altered the effect of chlordiazepoxide on behavior. The drug produced a change in the bar-pressing rate which was potentiated in the presence of the EMF.

3.3.The effects of electromagnetic energy on the endocrine system

3.3.1 The Adrenal Cortex

The adrenal corticoid response to EMF stimulation is highly time-dependent . When groups of rats were exposed to 500, I000, 2000 and 5000 v/m at 50 Hz, the average urine-corticoid level of the latter two groups changed similarly during the 4-month exposure period approximately the same maximum value was achieved in both groups and they exhibited increased corticoid levels as compared to the controls. The Iooo-v/m group, however, exhibited lower corticoid levels for the first 2 months of the exposure period followed by a rise above the control level during the last half of the exposure period; at 500 v/m the pattern of corticoid excretion was identical to that of the controls. The biological response was reversible in the sense that when the hela was removed, the corticoid level returned to normal within 2 months. One of the important factors governing the time course of the corticoid level-and hence the dynamics of the pituitary-adrenal response-is the ratio of the exposure period to the nonexposure period. This was established by Udinstev who exposed groups of rats to 200 gauss, 50 Hz, intermittently for 6.5 hours/day, for 1, 3, 5, and 7 days, and, continuously for I and 7 days The corticoid level in the continuously exposed rats was significantly greater than in the controls: following intermittent exposure, however, the corticoid response was considerably different. After 4 days-the total cumulative exposure was 26 hours-it was significantly lower in the exposed rats, and this trend continued after 5 and 7 days of intermittent exposure.

Table 1. SERUM CORTICOID LEVELS IN RATS FOLLOWING EXPOSURE TO CONTINUOUS AND INTERMITTENT (6.5 hr/day) 50-HZ MAGNETIC FIELDS

Type of Field	Serum Corticoid Level (μg/100 ml)	
	Control	Experimental
Continuous		
1 day	22.6 ± 1.6	33.4 ± 3.0*
7 days	21.2 ± 2.9	32.8 ± 2.5*
Intermittent		
1 day	16.2 ± 3.5	26.3 ± 2.9*
3 days	19.7 ± 0.8	26.1 ± 2.1*
4 days	19.8 ± 2.1	14.3 ± 0.8*
5 days	19.7 ± 1.8	16.5 ± 2.2
7 days	19.6 ± 1.0	17.4 ± 1.6

$p < 0.05$

At 3 GHz, rats exposed to 5-10, μW/cm2, 8 hours/day, had elevated levels of excreted corticoids after I-3 months of exposure . At 60 GHz, 15 minutes/day, rats exhibited depressed levels of serum corticoids after 2 months . In such high-frequency EMF studies it is usually impractical to continuously expose the animals, because the fields can interfere with normal feeding and watering practices, thereby introducing artifacts. Thus, judging from the Udinstev studies, the intermittent exposure aspect of high-frequency studies is an additional factor- along with the characteristics of the EMFs and the physiological state of the organism- that will affect the time course of the corticoid response. Changes in the gross weight of the adrenal gland reflect changes in its activity. Demokidova showed that I hour/day EMF exposure of rats produced changes in adrenal weight that were both time and frequency dependent . After 2 weeks, exposure at 3 GHz, the adrenals of the exposed rats were significantly larger than those of the sham-irradiated group: after 5 months, however, there were no adrenal-weight differences. At 70 MHz, adrenal weights, in the exposed animals were elevated after 1 week's and 1 month's exposure, but following 3 months' exposure they were depressed. After 8 months' exposure at I5 MHz, adrenal weights were similarly depressed below the corresponding control weight. There are two reports of EMF-induced histological changes in adrenal tissue . The relative size of the innermost or reticular zone of the adrenal cortex was decreased following 3 months' exposure at 70 GHz . Exposure to I 30 gauss, 50 Hz, (4 hours/day) for I month resulted in changes in the blood vessels in the reticular zone along with some hemorrhage and dystrophic cellular changes . Four months' exposure to 5000 v/m, 50 Hz, produced no histological changes and no change in gross adrenal weight .

3.3.2 The Thyroid

Thyroid activity is regulated by the thyroid-stimulating hormone (TSH) secreted by pituitary. Elevated TSH levels induce the thyroid to elaborate thyroxine, a hormone which functions in at least 20 enzyme systems; one of its major influences involves the acceleration of protein synthesis. High-frequency EMFs seem to have a general stimulatory effect on the thyroid. At 70 MHz, I50 v/m, 3 months' exposure resulted in an increase in the height of the follicular epithelium in rats-there was no change in thyroid weight . At 3 GHz, I 53 ,μW/cm2, an increase in thyroid weight was found after 2 weeks' exposure, but after 5 months' exposure the thyroid weights were normal . Following 4 months' exposure to 5000 W/crn~, cellular incorporation of radioactive iodine and serum proteinbound iodine were increased by 50 and II7%, respectively . Electron micrographs revealed enhanced cellular activity that was manifested by an increased number of cytosomes and an enlarged Golgi apparatus and endoplasmic reticulum . At 50 Hz thyroid activity was depressed as judged by radioactive iodine uptake . Continuous exposure at 1-5 kv/m depressed thyroid activity after 4 months when the field was removed thyroid activity returned to normal within 6 weeks. Four months intermittent exposure (2 hr/day) at the same field level did not affect thyroid activity, but depressed activity was observed at 7-15 kv/m . Ossenkopp et al. found that both male and female rats exposed in utero to 0.5 Hz, 0.5-30 gauss, had increased thyroid weights at 105-130 days of age . Based on this and several other physiological and behavioral studies, Persinger has implicated the thyroid as a significant factor in the rat's response to a magnetic field .

3.4.The effects of electromagnetic energy on the cardiovascular and hematological system

3.4.1 The Cardiovascular System

An electrocardiogram (ECG) is a recording of the electrical changes that accompany the cardiac cycle; a typical ECG is shown in Figure14.

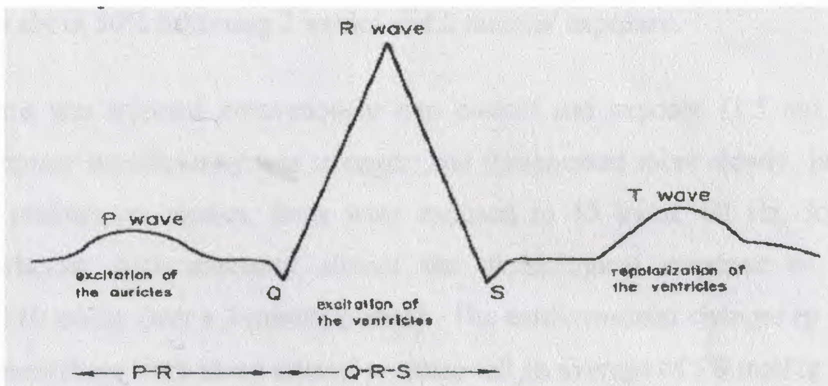


Figure 14 The structure and origin of the electrocardiogram

Fig.14. The structure and origin of the electrocardiogram. A lengthened PR interval may indicate impairment of conduction of impulses from the atrium to the ventricle; the QRS complex is associated with interventricular conduction. When mice were exposed for 1000 hours to 100 kv/m, 50 Hz, the PR interval and the QRS duration were each lengthened by 19.5% . Guinea pigs exposed acutely (30 min.) to the same field exhibited sinusal arrhythmia that began 10-20 minutes after removal from the field, and lasted 10 minutes . Fischer et al. exposed rats to 50 and 5300 v/m, 50 Hz, and observed bradycardia (decreased heart rate) at both field strengths as soon as 15 minutes after commencement of exposure . At the lower field strength the effect was about 8%, and this decrease remained statistically significant ($p < 0.01$) after 2, 10, 21, and 50 days of continuous exposure. At 5 300 v/m the decrease in heart-rate after 15 minutes' exposure was about 16%: it was not seen following 2, 10, or 21 days exposure, but it was present (about a 5% decrease) after 50 days. Bradycardia was also reported in rabbits following exposure to 50 Hz electric fields ; at 1000 v/m, the heart-rate decreased by about 9% after 30-60 days. The field also brought about a reduction in the amplitude of the ECG: the P, R, and T waves were each reduced by 40-50%.

Another effect induced by the 1000-v/m field was a reduction in the physiological reserve capacity of the rabbits. When the control animals were forced to remain in an erect position the heart-rate increased by 22-32%, but among the animals exposed to the field the range was 34-46%. No effects on heart action were seen at 500 or 100 v/m. Microwave EMFs have produced alterations in heart function that are remarkably similar to the changes observed at 50 Hz . Bradycardia was observed in rabbits after 2 weeks', but not after 2 months', exposure to 0.5 and 3 v/m. The amplitudes of the P, R, and T waves in the exposed animals were decreased by about 50% following 2 weeks' and 2 months' exposure.

When pituitrin was injected intravenously into control and exposed (1.5 mo.) rabbits, the resulting coronary insufficiency was stronger, and disappeared more slowly, in the exposed animals. In preliminary studies, dogs were exposed to 15 kv/m, 60 Hz, for 5 hours to determine whether such exposure altered the physiological response to a controlled hemorrhage (10 ml/kg, over a 3-minute period) . The cardiovascular changes ($p < 0.05$) at the end of the hemorrhage were mean arterial pressure fell an average of 5.9 mmHg in the control group and 16 mmHg in the exposed group; arterial pulse pressure fell 0.9 mmHg in the control group and 10.9 mmHg in the exposed group; average heart-rate decreased 9.3 beats per minute in the control group, but increased 57. 5 beats per minute in the exposed group. Heart action is one of several factors that influence arterial blood pressure. In studies involving the exposure of rats to 153 μW/cm2, 3 GHz both a short-term hypertensive effect and a long-term hypotensive effect were reported . During the first month of the 1 hour/day exposure regimen an increased arterial pressure was seen: beginning with the second month's exposure, the arterial pressure of the exposed animals was consistently lower than that of the controls for the next 5 months. When the exposure was terminated the arterial-pressure difference disappeared within about 1 month.

3.4.2 Blood

Changes have been reported in the cellular composition of the blood of rats, mice, dogs, uinea pigs, and rabbits following exposure to both high and low frequency EMFs . Graves exposed mice continuously to 25 and 50 kv/m for 6 weeks and found that the white blood cell count (WBC) was increased by 20% and 66% respectively. The red blood cell count (RBC) decreased by 6% and 12% at the respective fields, but these changes were not reported statistically significant. Rats exposed intermittently (30 min/day) to 100 kv/m, 50° Hz, for 8 weeks, exhibited elevated neutrophil levels and depressed lymphocyte levels . The same results were found following 2, 5, and 7 weeks' exposure at 5 hours/day. In dogs, alteration of the blood profile was seen following exposure at 10-25 kv/m . Meda found a lymphocyte decrease and a neutrophil and eosinophil increase in rats after a single 6-hour exposure to 100 kv/m, 50 Hz. A similar blood picture was found in mice after 500- and 1000-hour exposures to 100 kv/m . A significant increase in WBC was found in rabbits that had been exposed to 50 kv/m, 50 Hz, for 3 months . As has been the case with almost all biological indicators, the time course of the changes in blood parameters following EMF exposure was not the same in each test animal . Guinea pigs were exposed to 3GHz, 10 min/day, for 30 days , and both the irradiated and the sham-exposed animals were sampled before and after each daily exposure bout. The sham-exposed group revealed no significant changes, but animals exposed to 25 or 50 μW/cm2 exhibited EMF-induced alterations with time dependencies that differed with each animal. For a given exposure duration, the WBC was above the normal level in some animals, and below it in others; as a result, the average values varied little during the study. At 500 μW/cm2, however, even on the average there was a pronounced leukopenia and lymphocytosis. Gonshar exposed rats to 2.4 GHz, 7 hours/day for 30 days and studied the effect on the levels of alkaline phosphatase and glycogen (two indicators of cellular activity) in the neutrophils . Glycogen increased following 3 days' exposure at both 10 and 50 μW/cm2; after 7 days' exposure it decreased to the control level. In contrast to this apparent adaptational response, there was a sustained depressing effect on glycogen content at 500 μW/cm2 which was still observed after 30 days' exposure. At all three intensities, the alkaline phosphatase levels first increased then decreased below the control level within 30 days. Ferrokinetic studies demonstrated that iron metabolism was affected and that erythrocyte production (measured by 59Fe incorporation) was significantly decreased in rabbits exposed to 2.95 GHz, 3000μW/cm2, for 2 hours daily . The effects seen after 37 days of irradiation with a pulsed EMF were comparable in magnitude to those seen after 79 days exposure to a continuous-wave EMF. Rats exposed to 130 gauss, 50 Hz, for 4 hours/day, exhibited a 15% reduction in RBC after 1 month's exposure: the RBC level returned to normal within a month after removal of the field . Because comparable results were obtained using widely different EMFs, the blood-composition studies suggested to us that the EMF-induced alterations were mostly transient compensatory reactions of the body to a change in the electromagnetic environment. To determine the relation between magnitude and direction of the response and the conditions of application of the external EMF, we looked for changes in hematological parameters of mice due to short-term exposure to a full-body vertical 60 Hz electric field of 5 kv/m .

To ensure maximum statistical sensitivity every mouse was sampled twice, once after exposure to the field for 2 days and once following a 2-day nonexposure period. There were four consecutive experiments, two with males and two with females. In each there were two groups: one for which the control period preceded the exposure period , and one in which the pattern was reversed . On "day 1" of each experiment the mice were divided into the two groups and the electric field was applied to one-half the population.

On "day 3" the blood parameters were measured in each mouse and immediately thereafter the exposed and nonexposed groups were interchanged. On "day 5" the blood parameters were measured again and the mice were killed. Blood was collected from the ophthalmic vessels and it was therefore necessary, before applying the field, to determine the influence of the first blood collection procedure on the values measured after the second such procedure. We measured the blood parameters in two groups of mice, one male and one female, under conditions that were identical in all respects to those employed during the field-exposure portion of the study, and we found that the method of blood collection had a tendency to produce higher RBC, Hct, and MCV values and lower values of Hb, MCH, and MCHC .

Table2 . PERCENT CHANGE IN HEMATOLOGICAL PARAMETERS

Experiment	Condition	Percentage Change					
		RBC	Hct	Hb	MCV	MCH	MCHC
A							
Male Control	nF → nF	1.7	2.0	-4.5*	1.0	-6.2*	-6.3*
Female Control	nF → nF	3.9*	4.1*	1.7	0.2	-5.0*	-5.1*
B							
Male I	F → nF	-4.7*	-5.1	NM	0	NM	NM
	nF → F	-5.2*	-4.9	NM	0.2	NM	NM
Male II	F → nF	-9.0*	-9.1*	-3.3*	-0.4	5.7*	6.0*
	nF → F	-6.5*	-7.0*	-2.4*	-0.7	3.9*	6.1*
Female I	F → nF	-4.1*	-4.6*	-4.2*	-1.2	0.5	1.2
	nF → F	-6.4*	-6.7*	-3.4*	-0.5	3.8	4.8
Female II	F → nF	-5.3*	-6.0*	3.4	-1.2*	8.3*	10.0*
	nF → F	-7.1*	-9.2*	3.5	-2.3*	11.0*	13.6*

NOTE: RBC, red blood cell concentration; Hct, hematocrit; Hb, hemoglobin; MCV, mean cell volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration. *A*, no change in exposure conditions; *B*, change in exposure condition as indicated. NM, not measured.

$p < 0.05$

The results obtained in connection with the application of the electric field are shown in table 2. In each experiment, RBC on "day 5" was significantly less than on "day 3," regardless of whether the interval between "day 3" and "day 5" was an exposure period or a nonexposure period. A decline in Hct paralleled the RBC changes, but Hb showed no consistent changes. MCV showed a tendency to decrease, but the other computed indices both increased, since the cell loss overshadowed any decrease in hemoglobin concentration. The trends in the computed indices, and especially the changes in RBC and Hct, were opposite to those induced by our method of blood collection alone. It follows, therefore, that the applied electric field had a physiological impact. The unique feature of the observed responses is that, for each parameter, a change in the same direction occurred with both the F-ðnF and nF-ðF groups. An analysis of variance confirmed that in all four experiments there was an effect associated with time but not with the order of field application.

This indicated that the animals responded to the change in their electrical environment, not to the electric field itself. There are two reports of the effects of EMF on the blood globulin When rats were exposed to 3000 v/m at 1 KHz for 8 and 20 days (20 min./day), a reduction in coagulation activity (expressed as a lengthening of the rethrombin time, a drop in plasma tolerance for heparin, and a decrease in prothrombin consumption), and a rise in the thromboplastic and fibrinolytic activity of the blood were found . We found that rats exposed to DC electric fields of 2.8-19.7 kv/m had altered blood-protein distributions . The general trend was towards elevated albumin and decreased gamma globulin levels (expressed as a percent of the total blood proteins).

3.5. The effects of electromagnetic energy on biological function

3.5.1 Intermediary Metabolism

Metabolic indices of carbohydrate metabolism are sensitive to EMFs (1-6). Dumanskiy and Tomashevskaya exposed rats to 2.4 GHz (2 hr./day), for up to 4 months. At 100 and 1000 µW/cm2 the animals exhibited a series of biochemical alterations in liver tissue that included a decline in cytochrome oxidase activity, an increase in glucose-6-phosphate dehydrogenase activity, and an activation of mixed-function oxidases in the microsomal fraction of the tissue. The largest changes were seen after 1 month's irradiation, following which there was a tendency for the various enzyme levels to return to baseline. Enzyme activities were unaffected by exposure to 10 µW/cm2. In another study, Dumansky et al. reported an increase in blood glucose in humans following exposure to 15 kv/m 50 Hz, I.5 hours/day for 6 days Chernysheva and Kholodov studied the effect of a 90-gauss, 50 Hz magnetic field on several aspects of carbohydrate, protein, and nucleic acid metabolism in the rat .

They found EMF-induced alterations in each area, including changes in liver glycogen, elimination of ammonia, glutamine content in the heart, and nucleic-acid levels in brain and liver

Table 3. METABOLIC PARAMETERS IN RATS (in mg%) EXPOSED FOR 6 MONTHS TO 90 GAUSS (3 hr/day)

Tissue	Parameter				
	Glucose	Glycogen	Glutamine	RNA	DNA
Liver					
C	220 ± 27.5	1782.3 ± 214	8.5 ± 0.55	64.5 ± 3	27.3 ± 0.7
E	179 ± 15.6	812.4 ± 147*	7.4 ± 0.33	78.3 ± 4*	31.0 ± 1.3*
Heart					
C	92.3 ± 4.4	593.8 ± 56.5	7.05 ± 0.30		
E	78.2 ± 3.6*	613.0 ± 32.3	8.65 ± 0.60*		

NOTE: Date averaged over 8–10 animals. C, control; E, experimental.

$p < 0.05$

In a study of muscle metabolism , lactate dehydrogenase activity in skeletal and cardiac muscle of rats was measured by disk electrophoresis. There was an increase in the enzyme's activity in both kinds of muscle 1-2 days after exposure to 200 gauss, 50 Hz, for 24 hours; histological changes indicative of glycolytic processes were also found. These observations were consistent with an earlier report of impaired functional activity of muscle following EMF exposure . After 1 month, rabbits exposed to 30-40 kv/m, 05 Hz, were unable to lift a weight as large as that lifted by the nonexposed rabbits. The sensitivity of metabolic parameters to EMFs is underscored by studies that involve EMFs which have intensities comparable to typical environmental fields; the Mathewson et al. study is a blood example. Rats were exposed for 28 days to 2, 10, 20, 50 and 100 v/m in three replicate experiments, following which complete blood chemistries were performed; the serum glucose levels are listed in table 8.2A. Although some differences between the control and exposed groups were seen, no trend or dose-effect relationship was manifested and consequently, the authors regarded the data as having failed to show a biological effect of the EMF . But the 60-Hz electric field in the test cages was 0.18-9.15 v/m, depending on the particular test cage location . As a consequence, the 4 5 -Hz, 2v/m group is more properly viewed as a control group in relation to the 50-100 v/m exposed groups. When we did this, the Mathewson data revealed significant increases in serum glucose in each replicate . (This approach to the Mathewson data also suggests the existence of effects on other parameters, including globulins, protolipids, and triglycerides.)

Cellular bioenergetics can be altered by EMFs the changes seem to be adaptive in nature, and to depend on the exposure level and duration. A single 10-minute exposure at 25 μW/cm2, 10 GHz, produced a decrease in the phosphorylation effectiveness factor (ADP/O) in liver mitochondria, and an increase in respiratory control (RC) in kidney mitochondria (10). After ten such exposures, the oxygen consumption and RC were both increased in kidney mitochondria. A single exposure at 100 μW/cm2 caused a rise in oxygen consumption and an increase in ADP/O in liver mitochondria and a decrease in RC in kidney mitochondria . After ten such exposures, almost all the indices of oxidative phosphorylation in both mitochondria returned to normal, thereby suggesting that the enzyme systems had adapted to the EMF. A decrease in RC was also seen in guinea pig mitochondria exposed in vitro to 155 v/m, 60 Hz . Rats were exposed to 10, 25, 50, 100, 500 and 1000 μW/cm2, at 2.4 GHz, as follows: 40 minutes per day, 3 times per day, 5 days per week, for 4 months (intended to simulate the exposure received from household microwave ovens) . It was found that the EMF altered respiration and phosphorylation in liver mitochondria; there was an increase of nonphosphorylating oxidation of metabolites of the Krebs cycle, and a decrease in the oxygen consumption rates during phosphorylating respiration. A decrease in oxygen consumption rate was also found after 20 days' exposure to 1000 μW/cm2, 46 GHz . In a study of skeletal-muscle metabolism, rats were exposed to 300-900 gauss, 7 KHz for up to 6 months (1.5 hr./day) . Creatine phosphate and ATP levels decreased, and ADP levels increased following exposure. The changes were consistent with both an increased energy requirement, and an adverse effect on ATP formation. On the basis of in vitro studies of oxidative phosphorylation and oxygen consumption involving tissues from the exposed animals, the authors favored the latter possibility.Two consequences of the observed changes in cell bioenergetics involved carbohydrate and nitrogen metabolism. Decreased glycogen levels were found, indicating a compensatory glycogenolysis and, hence, an enhanced production of high-energy phosphate compounds. Secondly, EMF exposure produced an increase in tissue ammonia levels with no corresponding increase in glutamine synthesis. This may have been due to the ATP deficiency, although the influence of other factors involved in glutamine production-glutamic acid and manganese for example-could not be excluded. Shandala and Nozracher reported that kidney function and water-salt metabolism in rabbits (diuresis, chloride elimination, acid-base balance) were altered following the exposure to 50 and 500 μW/cm2, 2.4 GHz. In a comparable study , it was found that similar kinds of changes (urinary levels of potassium, sodium and nitrogen) were sex dependent; most of the metabolite levels were increased in females and decreased in males.

The altered nitrogen levels suggested an EMF effect on protein synthesis. This was confirmed by Miro et al. who found that 160 hours' exposure of mice to 2000 μW/cm2, 3 GHz, resulted in an increase in protein synthesis in the liver, thymus, and spleen as determined by cytohistological techniques. The most important study to date on lipid metabolism was performed by Dietrich Beischer and his colleagues . Volunteers, confined for up to 7 days, were exposed to a 1-gauss magnetic field, 45 Hz, for 24 hours: they did not know which 24-hour period during their confinement would be chosen for the application of the EMF. It was found that the serum triglycerides in 9 of 10 exposed subjects reached a maximum value 1-2 days after EMF exposur ; similar trends were not seen in any of the control subjects. Measurement of respiratory quotients for basal conditions established that the hyperlipemia could not have been caused by a change in the proportion of fats and carbohydrates being oxidized. Also, previous work had shown that confinement alone had no effect on serum triglycerides. This suggested that the observed effect may have been due to a change in the activity of one or several of the enzymes involved in lipid homeostatis, perhaps triglyceride lipase. The 1-2 day latency suggested that the action of the EMF involved an enzyme precursor, not the enzyme itself (the EMF influence would then be felt only after existing enzyme stores had been depleted).

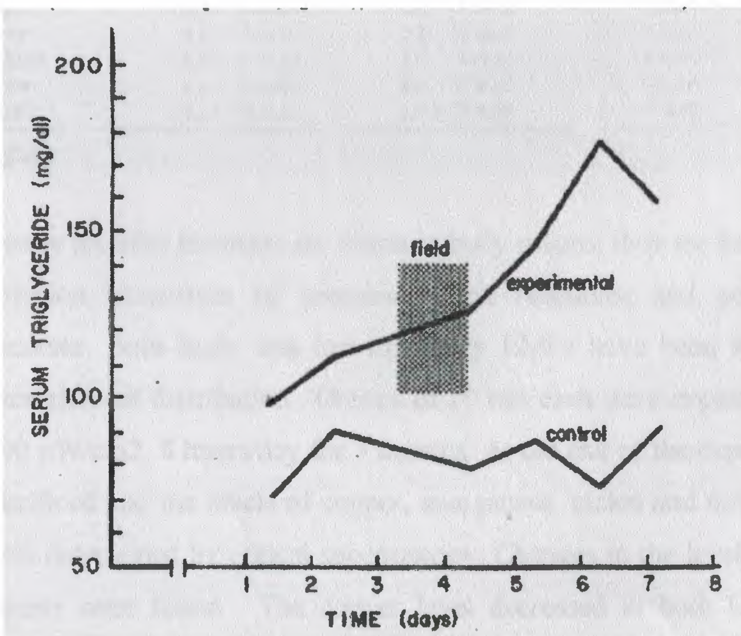


Figure 15 Average serum triglyceride levels of exposed and control subjects

Fig.15. Average serum triglyceride levels of exposed and control subjects. There are several other studies involving low-frequency magnetic field. There are several other studies involving low-frequency magnetic field effects on fat metabolism . Rabbits that were maintained on a high-cholesterol diet were exposed to the field for 5 weeks and then examined for serum lipid levels and aortic plaque formation . A reduction of both cholesterinemia and plaque formation was found in the exposed animals. A reduction in blood cholesterol (50 mg/ml on the average) was also reported in ten human subjects following local application of a magnetic field . Vitamin B6 (pyridoxine) is involved in the nonoxidative degradation of amino acids, synthesis of unsaturated fats, and the hydrolysis of glycogen. Exposure of rats to 570 μW/cm2, 2 GHz, for 15 days (3 hr./day) led to a decrease in vitamin B6 levels in blood, brain, liver, kidney, and heart; the levels of the vitamin in skeletal muscle increased (Table 4).

Table 4. EFFECT OF EMF ON VITAMIN B6 LEVELS IN RAT TISSUES

Tissue	Vitamin B_6 (μg/g-tissue)		
	Control	Experimental	Statistical Significance
Blood*	0.072 ± 0.010	0.046 ± 0.009	< 0.001
Brain	3.7 ± 0.48	2.3 ± 0.19	< 0.05
Liver	3.9 ± 0.37	2.8 ± 0.20	< 0.05
Kidney	5.6 ± 0.47	3.8 ± 0.23	< 0.01
Heart	4.9 ± 0.45	2.0 ± 0.37	< 0.01
Muscle	3.45 ± 0.44	5.10 ± 0.40	< 0.02

*μg/ml

Trace levels of many metallic elements are found in body tissues; they are known to take part in enzyme activation, formation of proteins, redox reactions, and possibly in other biochemical processes. Both high- and low-frequency EMFs have been found capable of altering body trace-element distribution. Groups of 10 rats each were exposed to 2.4 GHz at 10, 100, and 1000 μW/cm2, 8 hours/day for 3 months. At the end of the exposure period, the animals were sacrificed and the levels of copper, manganese, nickel and molybdenum in the major organs were determined by optical spectroscopy. Changes in the level and distribution of all four elements were found . The copper level decreased in both liver and kidney, possibly as a result of increased synthesis of ceruloplasmin-this would be consistent with the observed increase of copper in blood.

There was, generally, an increase in copper in those organs that use the element in hemopoiesis and redox processes, possibly indicating a basic compensatory response to EMF radiation. The copper content of hard tissue was virtually unchanged by the field.

Table5. TRACE ELEMENTS IN RAT TISSUES FOLLOWING EXPOSURE AT 2.4 GHz

Tissue	Trace Element Levels (μg%, fresh weight)			
	Control	10 (μW/cm²)	100 (μW/cm²)	1000 (μW/cm²)
Copper				
Liver	446.8 ± 12.3	416.5 ± 10.4*	389.8 ± 17.6*	332.1 ± 15.3*
Kidney	479.2 ± 25.4	405.9 ± 10.6*	309.2 ± 18.3*	398.2 ± 18.7*
Bone	237.7 ± 12.8	226.8 ± 15.3	266.5 ± 20.8	277.7 ± 25.3
Teeth	344.0 ± 25.3	360.0 ± 19.8	312.2 ± 26.7	306.3 ± 23.2
Bone marrow	380.0 ± 22.7	396.0 ± 29.3	540.3 ± 40.4*	673.2 ± 61.3*
Spleen	185.0 ± 11.4	203.5 ± 14.2	486.5 ± 30.9*	971.2 ± 60.4*
Brain	198.0 ± 13.5	198.0 ± 15.3	233.6 ± 11.1	298.2 ± 28.4*
Lung	258.0 ± 26.2	389.6 ± 35.3*	525.0 ± 50.4*	913 ± 82.4*
Myocardium	113.4 ± 8.2	142.8 ± 7.4*	189.2 ± 17.9*	266.6 ± 27.3*
Skeletal muscle	27.6 ± 1.5	32.0 ± 2.9	49.2 ± 5.1*	15.2 ± 1.8*
Skin	66.0 ± 4.8	24.5 ± 3.3*	40.7 ± 4.5*	81.5 ± 9.3*
Blood	56.2 ± 4.4	66.0 ± 5.7	85.0 ± 7.4*	74.0 ± 4.5*
Manganese				
Liver	139.2 ± 7.1	167.3 ± 10.6*	221.3 ± 14.7*	230.0 ± 16.9*
Kidney	45.2 ± 2.6	48.3 ± 3.1	66.7 ± 4.1*	70.3 ± 3.1*
Bone	71.3 ± 3.6	63.2 ± 4.7	60.5 ± 3.9	55.2 ± 2.6*
Teeth	83.9 ± 5.1	93.3 ± 4.9	97.1 ± 6.1	69.2 ± 4.3*
Spleen	9.8 ± 0.4	16.6 ± 0.8*	17.8 ± 0.8*	29.4 ± 1.7*
Brain	22.0 ± 0.8	24.1 ± 1.5	23.7 ± 1.2	24.8 ± 0.9*
Myocardium	13.8 ± 0.7	15.6 ± 1.1	18.5 ± 1.2*	20.3 ± 1.2*
Skeletal muscle	6.6 ± 0.3	5.8 ± 0.2	6.8 ± 0.4	7.8 ± 0.3*
Lung	15.2 ± 1.2	18.6 ± 1.4	12.7 ± 1.1	10.3 ± 0.9*
Skin	6.5 ± 0.3	6.6 ± 0.4	8.0 ± 0.6	9.1 ± 0.5*
Blood	2.1 ± 0.1	2.1 ± 0.1	2.2 ± 0.1	2.8 ± 0.1*
Molybdenum				
Liver	58.9 ± 3.2	57.8 ± 2.9	47.9 ± 3.1*	40.8 ± 2.5*
Kidney	9.5 ± 0.5	12.9 ± 3.1*	15.2 ± 1.4*	14.0 ± 2.8*
Femur	532.1 ± 11.6	532.6 ± 12.4	514.1 ± 11.9	485.6 ± 12.4*
Teeth	718.8 ± 19.8	714.8 ± 15.2	710.8 ± 16.7	907.1 ± 32.3*
Spleen	9.7 ± 0.4	8.3 ± 0.2	6.9 ± 0.2*	6.1 ± 0.4*
Brain	9.9 ± 0.3	8.9 ± 0.24*	7.9 ± 0.9*	5.9 ± 0.6*
Lung	5.8 ± 0.2	4.8 ± 0.18*	4.3 ± 0.1*	3.8 ± 0.15*
Myocardium	3.6 ± 0.1	3.6 ± 0.4	3.6 ± 0.3	3.6 ± 0.2
Skeletal muscle	7.8 ± 0.32	5.3 ± 0.4*	3.3 ± 0.27*	2.2 ± 0.15*
Skin	4.4 ± 0.1	3.2 ± 0.2*	2.6 ± 0.18*	9.7 ± 0.32*
Blood	2.4 ± 0.12	2.4 ± 0.14	1.7 ± 0.2*	1.4 ± 0.14*

In comparison to copper, manganese metabolism was less influenced by the EMF; it increased in most organs, and decreased in hard tissue.Teeth and bone were the principal reservoirs for molybdenum, and they exhibited no change in molybdenum concentration except following exposure to the highest strength EMF. In contrast, the molybdenum levels in the soft tissues, which accounted for less than 10% of the total body molybdenum, were altered at even 10 μW/cm2.

The content of nickel in the various organs was influenced by each EMF intensity. It rose in some tissues, and fell in others; the heart, which exhibited a sixfold increase, was the most strongly affected tissue. Trace element analysis has also been performed on rats exposed to low-frequency EMFs. Following exposure to 1, 2, 4, 7, and 15 kv/m, 50 Hz, for 4 months (2 hr./day), significant changes were found in the distributions of copper, molybdenum, and iron among the tissues, even at 1 kv/m, the lowest field strength employed . In subsequent studies by the same authors, similar changes were found after exposure to 7-15 kv/m for only 30 minutes/day .

3.5.2 Reproduction, Growth and Healing

Studies of the cells and organs of the reproductive system have revealed a general debilitating effect of EMF exposure . Altered spermatogenesis was reported in rats following exposure to 5000 v/m, 50 Hz, for up to 4.5 months . After 1.5 months' exposure, the number of atypical sperm cells was significantly greater in the exposed animals (30.7% vs. 15.9%, p<0.0I); the percentage of pathological forms increased with the duration of exposure and reached 36.8% after 4.5 months. The exposed rats also produced fewer sperm cells and exhibited a higher ratio of living to dead cells; both effects became significant after 3.5 months. Comparison of the parameters of respiration and phosphorylation of testicular mitochondria following 4.5 months' exposure revealed decreased phosphorylatic respiration, speed of phosphorylation of ADP, and respiratory control.

Table6. TRACE ELEMENTS IN RAT TISSUES FOLLOWING EXPOSURE AT 50 HZ

Tissue	Trace Element Levels (μg%, fresh weight)					
	Control	1 kv/m	2 kv/m	4 kv/m	7 kv/m	15 kv/m
Copper						
Liver	759.3 ± 39.9	603.0 ± 42.2*	603.1 ± 24.1*	389.4 ± 19.5*	331.4 ± 19.9*	288.7 ± 14.4*
Kidney	224.1 ± 13.4	224.1 ± 11.2	346.9 ± 20.8*	380.4 ± 15.2*	537.4 ± 37.6*	724.9 ± 36.2*
Spleen	65.6 ± 2.6	94.9 ± 5.7*	94.9 ± 4.7*	106.4 ± 7.4*	108.9 ± 7.6*	176.7 ± 10.6*
Brain	58.4 ± 3.5	61.2 ± 4.3	64.1 ± 4.5	193.5 ± 9.7	160.9 ± 10.4*	306.7 ± 21.4*
Myocardium	106.0 ± 7.4	111.0 ± 4.4	111.1 ± 5.5	168.1 ± 11.8*	221.6 ± 11.1*	278.9 ± 11.1*
Skeletal muscle	19.5 ± 1.2	21.4 ± 1.7	30.9 ± 2.2*	25.8 ± 2.1*	25.5 ± 0.6*	24.6 ± 1.5*
Skin	11.5 ± 0.6	9.7 ± 0.7	8.7 ± 0.5*	13.5 ± 0.7*	16.9 ± 1.0*	19.5 ± 0.8*
Bone	335.4 ± 26.8	376.4 ± 22.6	496.2 ± 19.8*	496.2 ± 37.7*	624.6 ± 45.7*	823.5 ± 41.2*
Teeth	237.8 ± 16.6	289.0 ± 14.3	283.9 ± 17.1	611.6 ± 36.7*	806.1 ± 32.2*	833.7 ± 33.0*
Molybdenum						
Liver	42.7 ± 2.6	40.8 ± 2.8	40.8 ± 1.6	29.5 ± 1.5*	16.3 ± 1.3*	23.5 ± 1.2*
Kidney	30.8 ± 2.1	27.4 ± 0.8	27.4 ± 0.8	26.9 ± 1.6	32.4 ± 1.9	36.3 ± 1.4
Spleen	8.6 ± 0.4	7.7 ± 0.5	5.7 ± 0.5*	5.7 ± 0.4*	5.6 ± 0.3*	4.8 ± 0.2*
Brain	14.0 ± 0.8	14.2 ± 0.7	9.7 ± 0.8*	7.9 ± 0.5*	7.9 ± 0.5*	5.9 ± 0.3*
Myocardium	3.6 ± 0.1	3.6 ± 0.2	3.6 ± 0.2	3.6 ± 0.2	2.7 ± 0.1	1.7 ± 0.1
Skeletal muscle	3.3 ± 0.1	3.3 ± 0.3	3.3 ± 0.1	1.6 ± 0.1*	2.5 ± 0.2*	9.6 ± 0.6*
Skin	2.9 ± 0.2	3.4 ± 0.3	4.4 ± 0.2*	6.6 ± 0.3*	1.1 ± 0.1*	1.1 ± 0.05*
Bone	1110.6 ± 55.5	1180.0 ± 59.0	1398.1 ± 83.9*	804.5 ± 64.3*	804.5 ± 56.3*	519.4 ± 31.1*
Teeth	1086.8 ± 76.1	1038.3 ± 62.3	1038.3 ± 72.7	968.7 ± 77.5	824.4 ± 41.2*	640.1 ± 25.6*
Iron						
Liver	53.8 ± 2.4	29.5 ± 1.8*	12.6 ± 0.6*	11.5 ± 0.4*	11.5 ± 0.6*	10.9 ± 0.6*
Kidney	9.2 ± 0.4	9.2 ± 0.4	11.2 ± 0.4*	13.3 ± 0.6*	14.5 ± 0.5*	14.7 ± 1.0*
Spleen	4.3 ± 0.3	5.6 ± 0.3*	5.6 ± 0.4*	5.6 ± 0.3*	4.8 ± 0.3	3.4 ± 0.2*
Brain	11.5 ± 0.8	9.7 ± 0.6*	8.4 ± 0.4*	8.4 ± 0.3*	8.3 ± 0.7*	8.2 ± 0.6*
Myocardium	2.8 ± 0.2	2.8 ± 0.2	2.8 ± 0.1	3.9 ± 0.1	2.9 ± 0.2	3.2 ± 0.2
Skeletal muscle	0.5 ± 0.02	0.5 ± 0.03	0.4 ± 0.01	0.5 ± 0.03	0.6 ± 0.03	0.4 ± 0.01
Skin	2.6 ± 0.1	2.1 ± 0.08*	2.1 ± 0.1*	2.1 ± 0.09*	1.8 ± 0.09*	1.6 ± 0.06*
Bone	37.6 ± 1.5	31.4 ± 1.6*	22.2 ± 1.5*	22.2 ± 1.5*	16.8 ± 0.7*	9.4 ± 0.5*
Teeth	28.6 ± 1.0	22.7 ± 1.8	22.7 ± 1.3*	22.7 ± 1.1*	12.7 ± 0.9*	12.8 ± 0.5*

* $p \leq 0.05$

In a study of carbohydrate metabolism in testicular tissue, Udinstev and Khlyin exposed rats continuously (for 24 hr.) or intermittently (6.5 hr./ day, for 5 days) to 200 gauss, 50 Hz . In the case of the 24-hour exposure, he observed a brief initial activation of enzyme activity followed by a depression of activity and then a return to normal levels. Intermittent exposure to the field, however, was characterized by a prolonged depression of the activity of several enzymes, including hexokinase, glucose-6-phosphate dehydrogenase, and cytochromoxidase. These changes pointed to a depression in tissue respiration which would be consistent with the authors' previous work that showed a decrease in testosterone production following exposure to the EMF. Chronic exposure of mice to a 7-KHz pulsed magnetic field produced morphological changes in the testes of rats: the seminal epithelium, ducts and sperm cells were each altered at 30 gauss, but not at 5 gauss . Female rats exhibited estrous-cycle dysfunction and some pathological changes in the uterus and ovaries following exposure to 5 kv/m 50 Hz . In males, the EMF caused a decrease sperm count and an increase in the number of dead and atypical spermatozoa. When the exposed animals were mated with unexposed rats, decreased birth rates and increased postnatal mortality were found in the offspring . Constant exposure to a 130-140 gauss magnetic field, both DC and so Hz, also produced changes in the estrous-cycle of female rats .

Disturbances in ovarian morphology and fertility, and alterations in postembryonic development were seen following exposure of female mice to 10-50 μW/cm2, 2.4 GHz . Because the developing organism is particularly sensitive to external influences, several investigators have exposed immature animals to EMFs and studied their impact on growth rate. Rats exposed to an intermittent EMF at 3 GHz, 153 μW/cm2, exhibited a smaller weight gain than the control animals . The difference became statistically significant after 4 months' exposure, and it persisted during the subsequent 3 months' exposure. Noval et al. , studied the effect on growth rate of rats of exposure to 0.5-100 v/m, 45 Hz, as compared to the growth rate of control rats maintained under Farady-cage conditions. He found a consistent depression of the body weights of the exposed animals, even for fields as low as 0.5 v/m (Table 7). Low-frequency fields-electric and magnetic-also produced growth depression in 25-day-old chicks .

Table 7. CHANGES IN AVERAGE BODY WEIGHTS OF RATS EXPOSED TO 45-HZ VERTICAL

Experiment	Field (v/m)	No. of Rats	Exposure Time (days)	Weight Gain (gm)
1	25–100	143	36	142 ± 14*
	control	47	36	209 ± 20
2	10–50	47	40	150 ± 19*
	control	16	40	215 ± 11
3	2–10	94	32	131 ± 12*
	control	32	32	166 ± 12
4	0.5–2	32	30	131 ± 11*
	control	32	30	170 ± 11

Note: The control rats were housed in a field-free environment.

$p < 0.001$

By the mid-190's, no studies had been done to assess the possible impact on successive generations of animals of the continuous presence of a low-frequency EMF; we therefore undertook such a study . Initially, mature male and female mice were split into horizontal, vertical, and control groups. Mice in the horizontal group were allowed to mate, gestate, deliver, and rear their offspring in a horizontal 60-Hz electric field of 10 kv/m. At maturity, randomly selected individuals from the first generation were similarly allowed to mate and rear their offspring while being continuously exposed. Randomly selected individuals from the second generation were then mated to produce the third and final generation.

A parallel procedure was followed for the vertical group wherein three generations were produced in a 60 Hz vertical electric field of 15 kv/m, and for the control group wherein three generations were produced in the ambient !laboratory electric field. In the first and second generations, males and females reared i both the horizontal and vertical electric field were significantly smaller than the controls when weighed at 35 days after birth In the third generation, the only group whose body weights were significantly affected were the males exposed to the vertical field. In both the second and third generation, a large mortality rate in the vertical-field mice was seen during the 8-35 day postpartum period. We repeated the multi-generation study at 3 .5 kv/m using an improved exposure system . In the first generation, no consistent effect on body weight attributable to the EMF was seen throughout a 63-day observation period. In both the vertical and horizontal groups, however, infant mortality was increased; in the vertical-control group 48 animals (about 17%) died between birth and weaning. In the vertical-exposed group, if the electric field wasn't a causative factor, a 17% mortality rate should also have been seen.However, that group exhibited a 31% mortality-82 animals died and not the expected 44. Thus, 38 animals, about 16% of those born, failed to live to weaning because of the electric field. A similar result was obtained in the horizontal-exposed group-about 11% of the animals born failed to live to weaning because of the electric field.

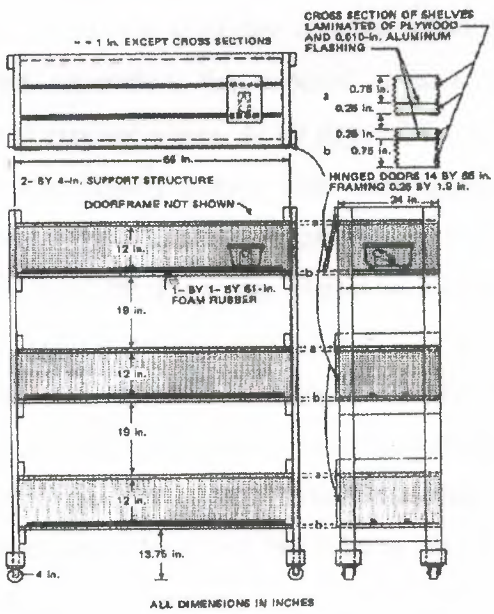


Figure 16 Assembly for vertical-field study

Fig.16. Assembly for vertical-field study. The metal plates were grounded in the control assembly.

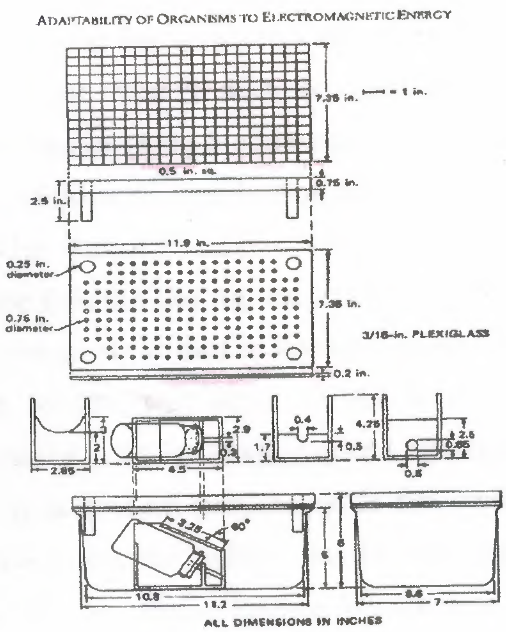


Figure 17 Cage and water-bottle holder

Fig.17. Cage and water-bottle holder.In the second generation, no consistent effect on body weight attributable to the field was seen throughout a 108-day observation period. The vertical-exposed group, however, again exhibited a higher mortality; about 6% of the animals alive at weaning failed to live to the final day of observation due to the presence of the electric field. In the third generation, the exposed animals had higher body weights, particularly in the horizontal exposed group. At 49 days after birth, the males and females in each exposed group were significantly heavier than their respective controls. At 119 days after birth only the females in the horizontal-exposed group were significantly heavier, but this was part of a consistent trend for that group. Again we saw an increased mortality in the vertical-exposed group-10% of the weaned animals failed to survive to the end because of low-frequency EMFs were also reported by Grissett . EMFs can alter the growth and development of some tumors. Batkin and Tabrah found that the development of a transplanted neural tumor could be affected by a 12-gauss, 60 Hz EMF ; they reported a slowing of early tumor growth in the exposed mice. We found that 5 kv/m, 60 Hz, had no material effect on the development of Erhlich ascites tumor in mice; the average length of time between tumor implant and death was not altered by the fields.

The process of wound-healing has been found to be susceptible to EMFs; not surprisingly, the nature of the effect depends on both the exposure conditions and the particular EMFs employed . One of the first such reports was that of Bassett et al. involving dogs.Electrical circuits, attached to leg bones that had been surgically fractured, produced a pulsed 65-Hz magnetic field at the fracture site. After 28 days, the organization and strength of the repair process as judged by the mechanical strength of the healing callus had increased significantly. We observed an opposite effect on fracture healing in rats exposed to a full-body vertical electric field of 5 kv/m, 50 Hz . Midshaft fractures were done on the rats following which half the group was exposed to the field and half was maintained as a control. The rats were housed individually in plastic enclosures maintained in wooden exposure assemblies . The extent of healing was evaluated at 14 days postfracture on the basis of blind scoring of serial microscopic sections. We used a numerical grading system that characterized both the healing process as a whole, and its anatomical components. In two replicate studies, we found a highly significant retardation in fracture healing ; the fractures in the exposed rats exhibited the development normally seen in a 10-day fracture. We found no effect on fracture-healing following exposure at 1 kv/m. The adverse effect of a 60 Hz electric field on fracture healing in the rat was confirmed by Phillips in three replicate studies .

Table 8. HISTOLOGICAL GRADINGS OF RATS EXPOSED TO 5 kv/m

Criterion	Replicate 1		Replicate 2	
	Control (N = 17)	Experimental (N = 18)	Control (N = 20)	Experimental (N = 20)
Union	5.3 ± 0.9	4.2 ± 1.0*	5.4 ± 0.8	4.4 ± 0.8*
Alignment	1.9 ± 0.3	1.4 ± 0.7	1.6 ± 0.7	1.4 ± 0.8
Callus size	2.9 ± 0.8	1.9 ± 0.8*	3.0 ± 1.0	2.0 ± 0.9*
Anchoring callus	8.2 ± 1.8	5.2 ± 1.2*	8.2 ± 1.5	4.6 ± 1.4*
Bridging callus	6.8 ± 1.9	4.0 ± 0.9*	6.7 ± 1.5	3.9 ± 1.2*
Uniting callus	7.0 ± 2.1	3.8 ± 1.2*	5.6 ± 1.2	3.7 ± 0.9*
Sealing callus	7.3 ± 2.0	4.6 ± 1.5*	6.8 ± 1.1	4.2 ± 1.7*
Healing index	39.3 ± 7.7	25.2 ± 3.5**	37.2 ± 6.1	24.0 ± 3.2**

NOTE: Numerical scales were as follows: Union (1–7); Alignment (0–2); Callus Size (1–4); Callus (0–5).
*$p < 0.01$
**$p < 0.001$

There is also a report of a beneficial effect of microwave EMFs on healing . Under sterile conditions, a linear 5-cm wound down to the dermis was made on the backs of guinea pigs. The wounds were then closed and sutured and the animals were exposed to 4000 ,µW/cm2 and sacrificed up to I1 days after surgery.

Microscopically, the wounds from the exposed animals exhibited a more advanced stage of healing, and this was confirmed by mechanical testing data; from 30% to 72% more force was required to re-open the wounds of the animals exposed to the EMF (Table 9).

Table 9. EFFECT OF EMF EXPOSURE ON THE FORCE REQUIRED TO DISRUPT A SKIN WOUND

Duration of Exposure (days)	Force (gm)	
	Control	Experimental
3	220 ± 2.3	340 ± 2.7*
5	360 ± 2.5	520 ± 2.5*
7	460 ± 2.1	790 ± 2.3*
9	680 ± 2.4	1050 ± 2.3*
11	1100 ± 2.7	1420 ± 2.6*

Note: Each control and experimental group consisted of 6 and 10 animals respectively.

4. The standards measurement and the safety levels

4.1 Introduction

One of the most popular innovations in automotive travel in the past decade has nothing to do with the automobile itself, the people who drive them, or the roads over which they operate. Rather, it is the ability to carry on telephone conversations while driving. What CB radios were to the '70s, cellular phones were to the '80s? From early 1984, when the first complete systems became operational, the number of cellular phone users has grown to over two million. By the mid-'90s, when cellular service will be available throughout most population centers in the United States, the number of subscribers is expected to grow to between ten and twenty million. While cellular phones are really elements of communication rather than transportation, their potential impact upon the latter is sizable. The prospect of twenty million drivers having the opportunity to place, receive, or handle a telephone call while driving is not something easily ignored.

4.2. Age Related Effects

The attention processes that must be shared when placing, receiving, or carrying on telephone conversations while driving are known to be vulnerable to age-related effects. The ability to share attention, as between the phone and the road, has demonstrated a relationship to age in studies by Craik (1973), Parkison, Lindholm and Urell, (1980), Temple (1989), and Ranney and Pulling (1990). Deficiencies in the ability to share attention have also been found in drivers over-involved in accidents (Mihal and Barrett 1976, Kahneman 1973). A somewhat less obvious but also relevant variable would be selective attention, the ability to focus selectively upon one set of stimuli in the presence of others. This ability has also been shown to decline with age (Clay 1956, Layton 1975, Rabbitt 1980 and Temple 1989). The studies by Kahneman and by Mihal and Barrett just cited also found declines in selective attention to be associated with over-representation in accidents. Age has evidenced relationships with a number of psychophysical processes that bear tangentially upon use of cellular phones while driving. Age-related declines have been noted in information processing (Brine et. al. 1985; Wellford 198 1; Rack off 1974; and Ranney and Pulling, 1990), problem solving (Case, Hulbert and Beers, 1970; and Are berg 1982) and short term memory (Miller 1979; Wellford 1981; and Temple 1989).

4.3. Types of Distraction

The independent variable under study was distraction. In this discussion, the term "distraction" refers to a diversion of attention from driving produced by some situation. The situation of primary concern is, of course, use of a cellular telephone. The car phone itself involves minimum distraction. The only time a driver is distracted by the apparatus is during the act of placing a call. Even when the dialing pad is placed on the dashboard and cut close to the line of sight, attention must be diverted from the path ahead. There is evidence that when people focus their attention upon one stimulus, they may fail to perceive another stimulus separated from the first by but a few degrees of visual angle. To assess the effect of placing a call upon driver attention, subjects were required (at various points of the test procedure) to dial a number given them orally by the experimenter. The conversations taking place on the telephone are also a possible distraction. As we pointed out in the Introduction, what distinguishes cellular phones from in-person conversations is the higher instance of calls carried on for business rather than social reasons. It seems likely that calls involving business would be somewhat more attention demanding than purely social conversations. To allow differences in the intensity of conversation to evidence any effects upon degree of distraction, conversation took place at two levels, casual conversation, in which subjects talked with the experimenter about a variety of largely inconsequential topics, and intense conversation in which the subjects engaged in a set of problem-solving exercises. Testing distraction at two levels of conversation does not assume that the intense cellular phone conversations are truly more intense than conversations with passengers -only that level of intensity is a variable that warrants study.

A distraction with which operation of any in-vehicle equipment is often compared is that of tuning a radio. The comparison is typically invited by someone defending introduction of a particular piece of equipment and using radio tuning as a lawyer might use a legal precedent. It has been used so often as to become something of a benchmark in studying in-car distraction. For this reason, it was included among the "distractions" with which telephone conversations were compared. To gauge the effect of various acts in distracting attention, we need to be able to compare them with a condition that offers no distraction that is, simply driving the car. The people in this situation might find things to occupy their attention other than driving; they would be at least free of any planned distraction.

To summarize, the five conditions creating different types and degrees of distraction were as follows:

No Distraction -The absence of any planned distraction Placing a Call -Dialing a telephone number on a key pad located close to the driver's line of sight Casual Conversation - Social chit-chat between subject and experimenter Intense Conversation-Subjects solving problems presented orally by the experimenter Tuning a Radio - Adjusting a car radio to pre-determined station.

4.4. Effects of Distractions

The figure displays, for each of the four potential distracters, the level of distraction with respect to response time and whether or not subjects responded. The two distraction variables displayed in the figure are not independent of one another; where subjects failed to respond to a situation, the maximum response time taken by any subject exposed to that particular situation under that distraction was entered as the response time. Had this not been done, the non-responders would not have app eared in the response time data and the results would have been meaningless.

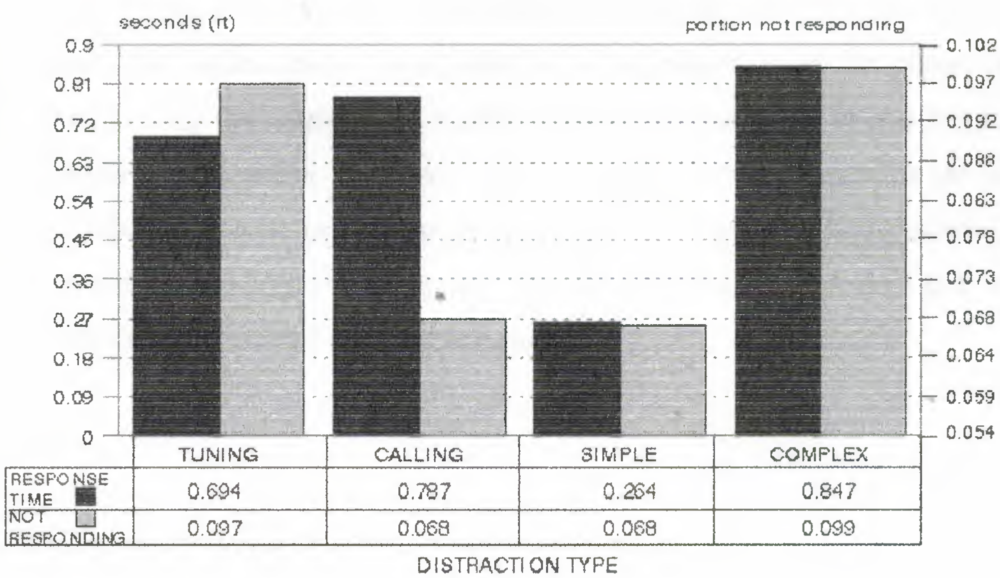
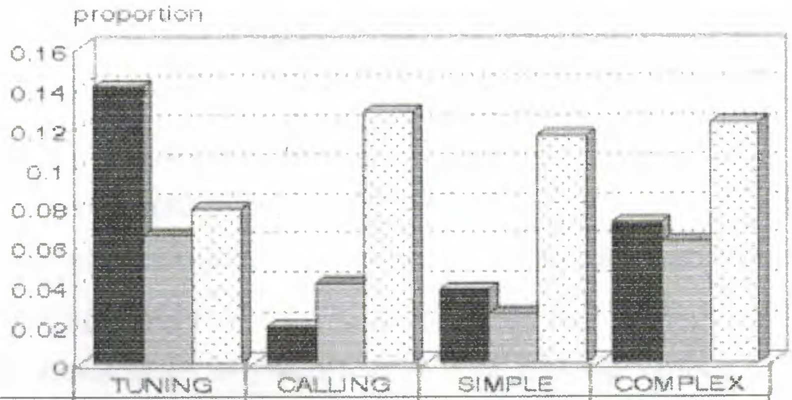


Figure 1

INCREASE IN REACTION TIME AND NON-RESPONSES BY DISTRACTION TYPE

All of the potentially distracting conditions yielded some degree of distraction, that is, they produced reaction times and non-responses that were different from the no distraction condition. The overall level of distraction was highly significant for both non-responses (F = 36.07; DF = 1,136; P<.Ol) and for response time (F = 286.75; DF = 1,136; P<.Ol) and under all four potential destructors (P = <.Ol). Overall, the various distractions increased the length of time needed to respond to highway traffic conditions by from .4 to .9 seconds, and the proportion of situations missed entirely from .06 to .09. When it comes to which condition led to the greatest distraction, the results varied somewhat from one of the two distraction variables to the other. Looking at the proportion of subjects who were distracted from responding at all, the complex converse actions yielded the greatest interference, while placing calls and carrying on simple calls yielded the least interference and tuning the radio fell somewhere in between. The differences among all destructors were only marginally significant (F=2.133; DF=3, 1 34; P=.10). However, complex conversations were significantly more distracting than simple conversations (F = 4.12, DF = 1, 134; P =.04). Turning to the time it took to respond, we see that placing a telephone call rose from one of the least distracting to one of the most distracting conditions. The differences across distractions are statistically significant (F=4.37;DF=3,134 ;P<.10). Considering that those who failed to respond are included within the response times, it is clear that it is the delay in responding among those who actually responded that account for the difference in outcomes. What the results seem to say is that the act of placing a cellular phone call may be no more distracting than carrying on a casual conversation in so far as noticing highway traffic conditions is a concern. However, it does seem to extend somewhat the delay in responding. When a non-ur gent situation arose while a call was being placed, many subjects delayed responding until they had completed the call. But they did respond, indicating that the situation had not gone unnoticed.

4.5. Effects of Age



	TUNING	CALLING	SIMPLE	COMPLEX
17 - 25	0.14	0.017	0.037	0.072
26 - 49	0.064	0.04	0.026	0.063
50 - 80	0.077	0.127	0.108	0.123

DISTRACTION TYPE

Figure 2

INCREASE IN REACTION BY AGE AND DISTRACTION TYPE

The figure displays the proportion of drivers failing to respond to highway traffic conditions as subdivided by age. It is evident that drivers in the over-50 category show strikingly higher proportions of failing to respond to highway traffic situations. The overall effect across distraction conditions is not statistically significant (F = 2.22; DF = 2,136; P. 1 13). However, the deficiencies of older drivers significantly exceed those e of the other two age groups in telephone calling (F = 7.96; DF = 1, 14 1; P <. Ol), and simple phone calls (F = 5.13; DF = 1, 14 1; P <. 05), but not complex phone calls (F = 2.34; DF = 1, 14 1; P =. 13). Also, in tuning the radio, age differences w ere not statistically significant (F =. 73; DF = 1,141; P =. 39). Part of the explanation for the failure of the radio-tuning task to show significant age an effect is the relatively high degree of distraction evidenced by the 17-25 year age group. The results suggest that this age group is somewhat more preoccupied with tuning the radio than with telephone calls, a hypothesis that most parents having children in this age group would have little difficulty accepting. But why significant age differences didn't appear in complex cal s lacks a ready explanation. It may b e that complex conversations are more or less equally distracting to everyone, while placing calls and carrying on simple conversations only distracts the older subjects.

Perhaps a more parsimonious explanation is that age amplifies the effects of all tell phone-related distractions and that the differences among the three types of distractions are largely the result of chance. Turning from whether drivers respond to how long it takes them to do so, the figure shows the effects of age to be somewhat attenuated. Over all distraction conditions, the effects of age are statistically non-significant (F = 1. 14; DF = 2,136; P = <; .32). The only two conditions showing a marked increase in reaction time for the older age group are placing telephone calls and carrying on simple conversations, of which only placing calls achieves significance (F = 3.01; DF = 2,136; P =. 05). The effect of phone use upon older drivers seems more to prevent them from noticing various highway traffic conditions rather than to retard their response to them.

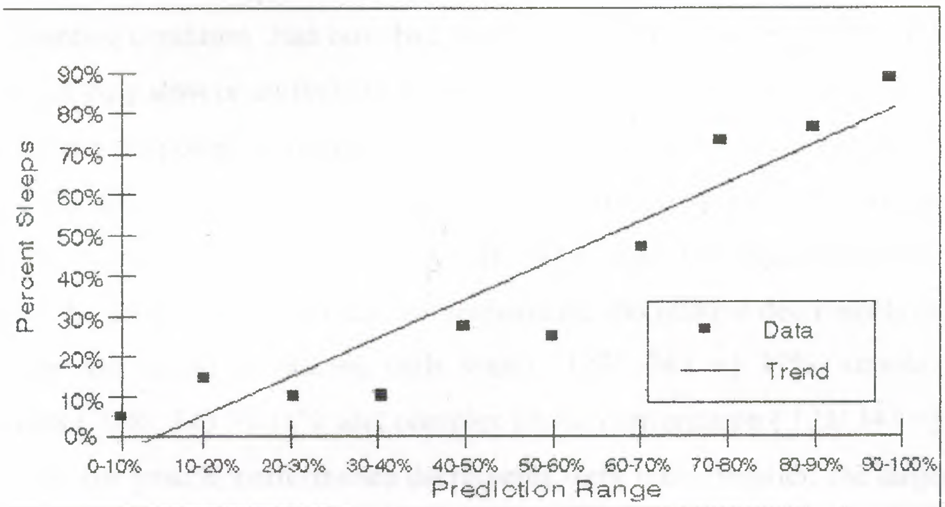


Figure5. Relationship Between Predictions and Sleep Onset

Figure 3

INCREASE IN RESPONSE TIME BY AGE AND SITUATION TYPE

4.6. Effects of Experience

Prior experience with cellular phones appeared to have no significant effect upon distraction resulting from phone use or tuning the radio. Across all distractions, differences between experienced and inexperienced subjects were statistically non significant for response time (F=1.55; DF=4,114; P=<. 19), or for the likelihood of responding at all (F=0.39; DF=4,114; P=<. 81).

What slight differences occurred seemed to favor the inexperienced, although such differences, if they exist, can be attributed to the fact that the experienced subjects tended to respond more quickly when there was no distraction and might therefore tend to evidence a slightly greater difference between the undistracted and distracted conditions. In looking simply at raw reaction times under the various distractions, the experienced subjects responded as quickly as or more quickly than the inexperienced subjects. In any case, it is clear that prior experience with cellular phones has no real impact upon the degree to which one is distracted by its use.

4.7. Relative Performance Decrements

The decrements in performance that have been discussed amount to greater response time and the probability of not responding as compared with the results obtained in the absence of any distracting condition. Just how bad these decrements are can only be understood in relation to just how slow or unlikely to respond people are in the absence of any distraction. For comparison purposes, it is necessary to know that the mean response time in the absence of any distraction (across all highway traffic conditions) was 4.45 seconds, across all situations, while the proportion not responding at all was .343, again across all situations. Considering the proportion of subjects not responding, the relative decrements experienced by the older age group in placing calls was (. 127/. 343 =) 37%, simple telephone conversations (.108/. 343 =) 31%, and complex phone conversation (.123/.343 =) 36%. For the other two age groups, performance decrements were much smaller, the largest being a (.072/. 343 =) 21 % greater probability of not responding for the 17-25 year age group when making complex phone calls. The condition leading to marked increases in response time was where the oldest age group had an increase of 1.417 seconds in placing calls. Expressed as a percent of the response lag under no distractions, this translates to increase in response time of 32%. Decrements in the remaining cases were considerably smaller, falling largely between .4 seconds (9%) and .8 seconds (18%).

4.8. Specific Situations and Distractions

The effect of using the telephone or tuning the radio upon response to highway traffic situations was not uniform across all situations. Interaction between the effects of distractions and various highway traffic situations was evident as a highly significant difference across the five "forms" i.e., the ten combinations of distractions and conditions occurring in the video. Recall that five different forms were needed to allow each of the five phone conditions to be matched with each of the highway traffic conditions without exposing the same subject to the test route more than once. Since the forms do not differ with respect to either distracters or highway traffic situations but only in the way they were combined, the significant differences among forms means that certain combinations of the two variables were particularly problematic. To see if there was any pattern to these aberrant combinations of potential destructors with highway traffic conditions, they were examined individually. Specifically, those combinations leading to proportion of non-response that were discrepant from what would be expected from the effects of the destructors or highway traffic conditions alone were identified through a logic analysis. The results were not at all revealing. The number and nature of aberrant combinations followed a chance pattern. As to the number, only four of 235 combinations fell beyond a .05 confidence interval around the expected results, whereas one would have expected (235 x .05 =) almost 12 by chance alone. As to the nature, no logical pattern could be discerned in the results. It should be noted, that with 150 subjects and five conditions, each condition was only replicated 30 times for a particular highway traffic situation.

4.9. Performance on Destructors

Thus far, our concern for the effect of various potential distracters upon response to highway-traffic situations has been limited to whether or not simply engaging in the task influenced driving performance. The distracting effect of cellular phone use or radio tuning tasks upon the response to highway-traffic conditions might be expected to vary as a function of the amount of attention devoted to the tasks.

A measure of the amount of attention paid to the distracting tasks would be performance on those tasks themselves. This aspect of performance was assessed as follows: Radio Tuning -Whether the tuning process was continuous or whether it was interrupted by the associated highway-traffic situation Placing Calls - Length of time required to complete placing the call Simple Conversation -Any interruptions in the conversation coincident with appearance of a highway traffic situation Complex Conversation - Incorrect answers to the problems being solved Time to complete the radio tuning task could not be used as a criterion since it was largely determined by how much the dial had to be manipulated to reach the target station, something that varied by chance from one trial to another.

4.10. Power measurements for GSM:

There are several measurement instruments for GSM system parameters, some is for the quality of the transmitted and received signals such as bit error rate …etc. some other used for the degree distribution of the transmitted signal that transmitted from the BTS antennas, this is in term of the power density a (w/m^2). The commercial GSM companies must be working within the standards of some safety references belong to such as the Federal Communications Commission (FCC), or Electrical and Electronics Engineers and American National Standards Institute (ANSI/ IEEE), International Commission on Non-lionizing Radiation Protection (ICNIRP). Etc. But they finally would reach good number of subscribers using the company service and that comes when it offers good coverage over where subscribers could be and not that important how to install their BTS antennas, on tower, on buildings, one very short height through a very traffic where are lots of subscribers are on a small area, with not that respect due to the human health.

4.11. BT Stations towers on building:

These cellular towers are the base stations for the cells that make up the coverage area for a cellular telephone network. Most of these towers are 50 to 200 ft tall with an antenna mounted on top. The height depends on what the station is for, if it's for a large subscribers capacity, it will be installed in short height, but some where there is relatively no capacity users so the antenna is mounted on height enough to give wide coverage area.

These antennas emit radio frequency electromagnetic waves but at a level much lower than those associated with commercial radio and television station. The radio frequency energy emitted by common household light bulbs.

The strength of these electromagnetic fields (EMFs) decreases rapidly with distance from the antennas and the exposures usually occur hundreds of feet away. So by measure the energy of these EM waves in several radiuses away from the BTS we can determine the coverage of this station and in general we assume the whole BTS as one omni-directional antenna.

4.12. The standards safety levels for power:

The emitted EM waves are received by the cellular phone antenna (MS) continuously to inform the SS the situation of the subscriber if the MS is on service (turned off or on)and some other information's ..Etc. We will mark this power as P_{rx} referred to the MS antenna (down-link power). When the subscriber warns to make a call, the MS starts to transmit EM waves carries the information toward the BT, this transmitted power will named as P_{tx} (up-link power) which is mush greater than downlink signal power. As all the safety standards tables are in term of the power density, we shall achieve all the power measured in term of WATT per CM^2.

4.13. Time duration and the frequency bands for safety standards:

In all the safety standards tables the time duration assumed is about 30 min. The frequency assumed for these tables is 900 and 1800 MHz and works for both types analog and digital mobiles.

4.13.1 Power Density (Pd):

The power density is the net power on antenna propagated (P) over the area of the vertical side of the propagation (A).

$$Pd = P/A \ [w/cm^2]$$

In our case for the mobile antenna the net propagated power (P) is equal the addition of the down and up link signal power so we can write equation.

$$P = P_{rx} + P_{tx}$$

But because down link signal power is much less compared with the up link signal power we will omit the value of P_{rx}, so the relation will be:

$$P = P_{tx}$$

In our case the surface area (A) is the area of the MS antenna that mounted on the head of the MS. It's omni-directional antenna, and there is no fixed area used for all kind of MS. Let's assume the antenna is in rod cylindrical shape (it is in most common for MS) as shown in figure .....(The shape and dimensions) The surface area in term of the radius **r**, and height **h**

$$A = 2 \Pi r h$$

We can assume the radius to be

$$r = 0.35 \text{ cm}$$

Also we can assume h =2---3.5 cm so assume h = 3.5cm , So we can write A = 2(3.14)(0.35)(3.5) = 7.693 cm^2 , We will take approximated value to be our reference for A = 7.7cm^2 , So the Pd can be rewritten as following:

$$Pd = P/7.7 = P_{tx}/7.7 \ [mW/cm^2]$$

4.13.2 Measurement Instruments:

There are currently several instruments for the signal power measurement that is used in the GSM communication companies. And we shall show the operation and some important notes about the two main instruments of them, the Net-Monitor (which was the measurement instrument we used in our project) and the Advanced N-Mon.

4.13.3. Net-Monitor (n-monitor):

It's here our measurement tool, it is software installed to the MS, and it is a product from NOKIA. The Net-Monitor can display some important parameters for the power and the network information. It's a 133-page; every page displays information about the available cell that you're mobile is networked with. The Net-Monitor is currently used the GSM BTS-technical department to test the transmission signal of the network, in most commonly it's used for the power and gives bit error rate and all cell information, and gives you exactly which time-slot you are dealing with and the carrier frequency that carries the eight channels (8-time slot per a carrier frequency). And it can display the ID of the BTS and BCS number, and the duplex distance from the BTS toward the place of the MS.

Our interest in the project is only to find the power during the calling mode in term of P_{tx}, and the radian distance toward the BTS antenna.

4.13.4. Overview and operation of the Net-Monitor:

Net-Monitor program has 133 pages, every one display specific information. Our work lies at all on the first page as.

An H, if carrier numbers are scrolled when hopping is on.

Bbb when mobile is on TCH:

DCH carrier number in decimal. When mobile is NOT on TCH:

CH means carrier number in decimal. If hopping is on, used channels are scrolled when display is updated.

CCC Rx level in dBM, minus sign not shown if <= -100

Ddd TX power level if transmitter is on, symbol*is shown in front of the power level value. (In dBM)

E Time Slot, range is 0-7

Ff Duplex distance between BSS and MS.

G rx quality (sub), range is 0-7

Mmmm Radio link Timeout value. If value is negative, 0 is shown. Maximum value is 64. When mobile is NOT on TCH then xx is shown.

Nnn value of the path loss criterion (C1). Range is -99-999.

Oooo type of current channel:

AAA MCC value in decimal (MCC = Mobile Country code)

Bbb MNC value in decimal (MNC = Mobile network Code), three digits are shown only In DCS 1900. (in other systems only two digits are shown)

Ccccc LAC value in decimal (LAC = Location Area Code)

Dddd Serving cell channel number

Eeeee Cell identifier in decimal format

Some software versions display LAC and CID differently. These can be shown in hex format or even both decimal and hexadecimal formats on the same line. There are the other manual pages that give all details for all parameters of the instantaneous application..

4.14. About the Nokia Network Monitor

4.14.1 Nokia Network monitories

The Network monitor is a mode used for testing the Nokia phone and the network. In the test mode the operator name (logo) and other information on the main display are replaced by various test displays. The mode is available in also most mass production Nokia GSM phones. Network monitor on Nokian puhelimien toimintatila, joka on tarkoitettu puhelimen ja matkapuhelinverkon toiminnan testaamiseen..

4.14.2 Activation of the monitor

The activation the Network monitor is made without opening the phone by using PC software. One good freeware application for activating the Net Monitor menu is N-Monitor by Anderas Schmidt. N-Monitor requires an FBUS cable. It activates the menu item automatically after successful connection. After activation Net monitor can selected in the main menu of the phone. Select it and type 01 to Test. (Typing 00 disables the test displays, but leaves the Net monitor in the main menu.) After this also arrow keys can be used for scrolling through the test displays. In some of the displays there are manually selectable options. To change them press Menu - (up arrow) - Select - OK at the display.

4.14.3 Removing the monitor with the phone

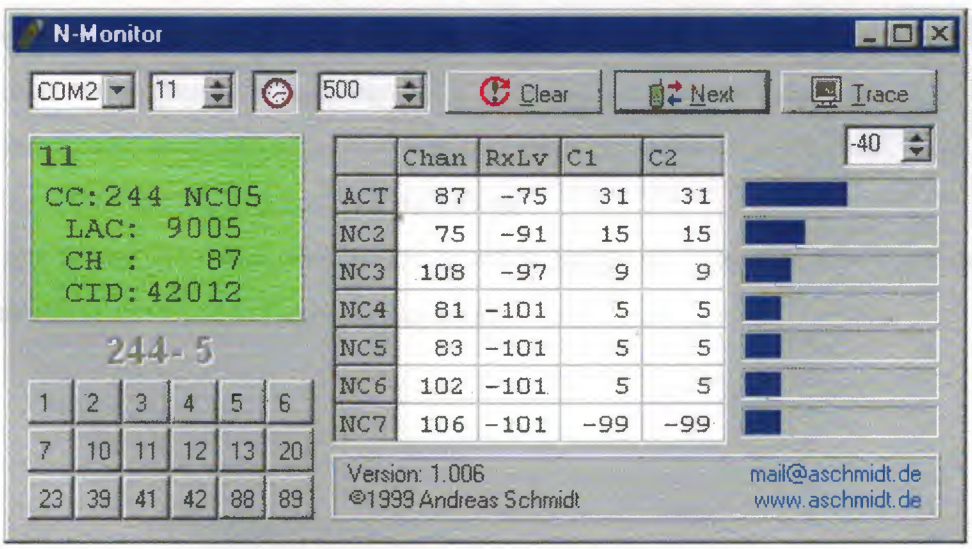
The Net monitor menu may be removed completely from the phone just by going to the Test prompt in the phone, typing 241, and pressing OK. Remember that you cannot reactivate the menu with the phone.Typing 242 to the prompt removes all tests but tests numbered 1...19 permanently (i.e. enters operator network monitor).

4.14.4 Disadvantages of the test mode

When the test displays are active, the phone functions normally, but the following disturbs using it .The number, name or caller group graphic will not be displayed when phone receives a call,
the operator name or logo and selected profile (and other normal indicators) are not displayed, you cannot edit the phone numbers entered or picked from messages at all, the short code memory cannot be accessed by pressing the arrow keys, but only by pressing Names (or Menu in the 51xx-series), dialed numbers are available only via the menu (51xx-series), and the battery consumption is slightly higher. You can still leave the Net monitor item in the menu; just disable the displays by typing 0 to the Test prompt to avoid those.

4.14.5 Monitor without any SIM card or PIN code

The phone starts the network and internal measurements immediately after power-up. No SIM card or PIN code is required. But you cannot access the Net monitor with phone user interface if you have not entered a valid PIN code. To use the monitor without SIM or PIN, you have to connect the phone to a PC and read the displays via the cable.



4.15. Advanced N-Mon:

There is another measurement instrument that similar to Net-Monitor called N-Mon, It's more advanced than Net-Monitor because of its ability to display the shape of the received and transmitted signal as the electronic oscilloscope operation. The N-Mon is software installed on the Lab top, and the MS is cabled on the Lab-top.

4.15.1. Measurement procedure using Net-Monitor:

As well as to have good accuracy in our measurement we took multiple several places for sites for BTSs. And we took the measurement in two different times in the same place; the first was at Noon and the other in the night, at the both times we took in consideration that the weather was in the optimum case of CLEAR SKY. To have the required state, in every time we read the value of the power we put the mobile on its back to the human head (on ear) while the mobile is in the calling mode. In fact this position is the condition of our project because it's the position that the human can be hazard in most.

4.15.2. BTSs that measured around:

The number of BTS was four, and we also took good care to choice several types of the antennas used in the four sites.

The first site A: of them was mounted on a small light tower. Low gain antenna (omni-directional antenna). It was installed on a very short height about four meters from the ground and the site was on a place that is traffic in subscribers.

The second site B: was on a building in height about 12 meters from ground and it consists of three sector of low-gain antenna every sector cover in angle of 120 degree, so the three are fix to cover 360 degree so we can assume it all as omni-directional antenna.

The third site C was on a high hotel building and about 35 meters from ground. Four high-gain sector antennas are fixed to coverall directions.

The third site D was in an independent tower and in height of 15 meters; also three or four high gain antennas are fixed to cover all directions.

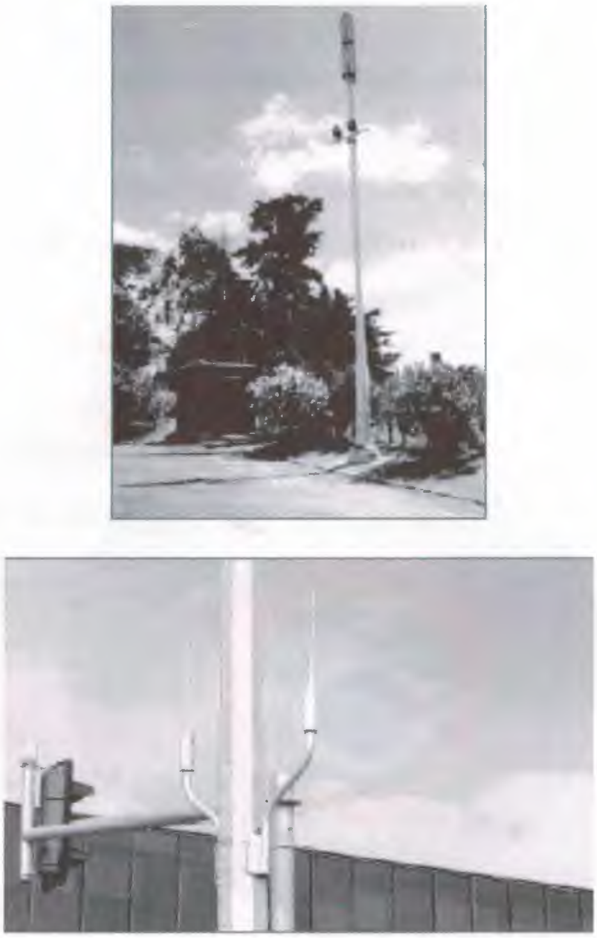


Figure 4

a low gain antenna , omni-directional antenna

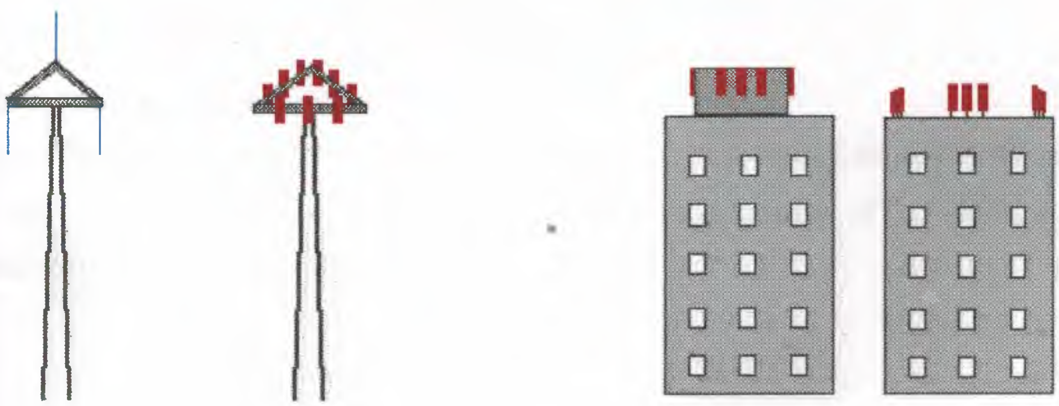


Figure 5

B BTS on independent tower

C BTS tower on building

4.16. Regions of measurements:

To make advantages of our measurements, we shall make regions for our measurement starting away from the axes of the site and the plane would be as:

We choice proper radius distances for these regions so that this BTS can performs a complete cell-network R1=10m, R2=100m, R3=300m, R4=500m, R5=1000m, R6=2000m and R7=2500.

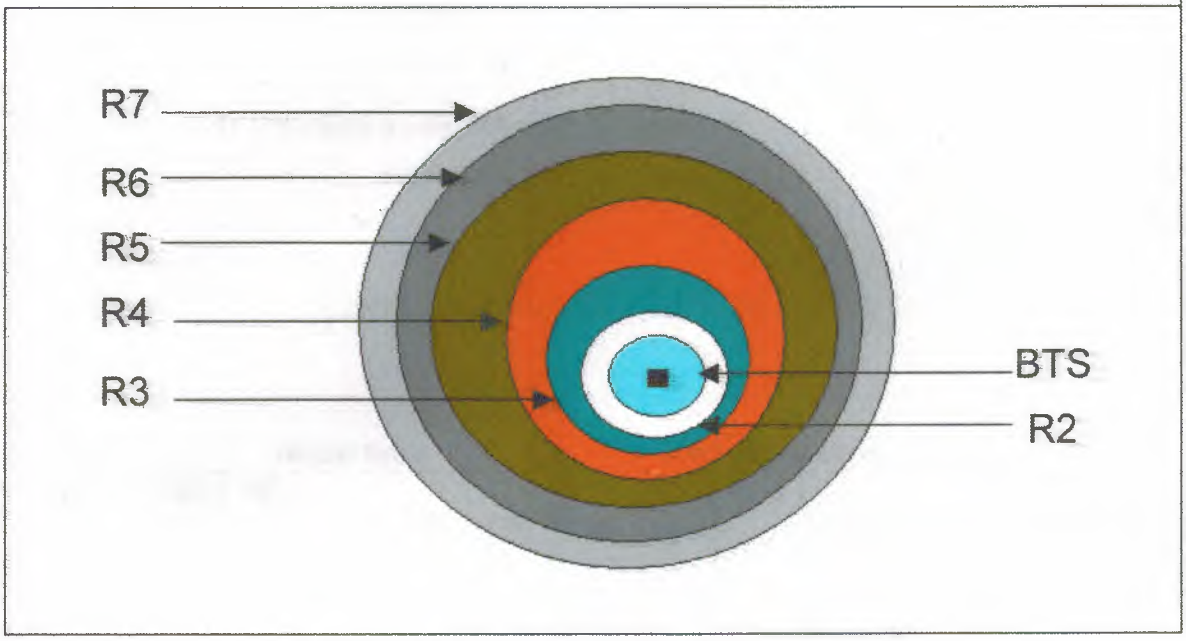


Figure 6 A Top-view regions plane for BTS

4.17. Measurements results:

Here are the measurements values shown in tables 1, 2, 3,4which consist of the measured values of the power in terms of distances R_x. Each Table consists of P_{rx}, and P_{tx} in (dBM), and then P_{tx} is converted into (mW).

Note... P_{rx} is not needed for our calculation, but we shall show that P_{rx} is much smaller then $P_{t\,x}$, and will be shown in the tables.

$$P_{[mW]} = 10^{p\,[dBM]/10}$$

$$P_1 = P_{t\,x}\text{(in noon time)}$$

$$P_2 = P_{t\,x}\text{(in night time)}$$

The average power for this BTS in term of Distance R_x is calculated by taking the average value of P_1 and P_2

$$P_{ave} = (P_1+P_2)/2$$

The power density (Pd) then is calculated by the equation:

$$Pd = p / 7.7 = P_{tx} / 7.7\ [mW/cm^2]$$

Table 1 power measurement for BTS site A

For BTS **A**	Noon time					Mid night time						
	dBm	dBm		mw	mw	dBm	dBm		mw	mw	mw	mw/cm²
Distance from BTS	P_{tx}	Ptx		Ptx	P1	Prx	Ptx		Ptx	P2	Pav	Pd
R1=10$_m$	-40	18		63.0	63.0	-33	19		79.4	79.4	71.2	9.24
R2=100$_m$	-52	19		79.4	79.4	-50	19		79.4	79.4	79.4	10.31
R3=300$_m$	-55	14		25.1	25.1	-50	16		39.8	39.8	32.4	4.21
R3=500$_m$	-65	13		19.9	19.9	-56	14		25.1	25.1	22.5	2.92
R5=1$_{km}$	-70	11		12.6	12.6	-62	12		1508	1508	14.2	1.84
R6=2$_{km}$	-74	9		7.9	7.9	-72	9		7.9	7.9	7.9	1.02
R7=3$_{km}$	-82	6		4.0	4.0	-75	5		3.2	3.2	3.6	0.46

Table 2 power measurement for BTS site B

For BTS B Distance from BTS	Noon time					Mid night time						
	dBm	dBm		mw	mw	dBm	dBm		mw	mw	mw	mw/cm^2
	Prx	Ptx		Ptx	P1	Prx	Ptx		Ptx	P2	Pav	Pd
R1=10_m	-30	14		25.1	25.1	-33	18		63.0	63.0	44.0	5.71
R2=100_m	-46	19		79.4	79.4	-37	18		63.0	63.0	71.2	9.24
R3=300_m	-56	15		31.6	31.6	-45	14		25.1	25.1	28.3	3.68
R3=500_m	-67	13		20,0	20,0	-47	15		3.16	3.16	25.8	3.35
R5=1_{km}	-60	10		10.0	10.0	-55	9		31.6	31.6	20.7	2.70
R6=2_{km}	-66	5		4.0	3.2	-60	6		4.0	4.0	3.6	0.46
R7=3_{km}	-85	6		3.2	4.0	-78	5		3.2	3.2	3.6	0.46

Table 3 power measurement for BTS site C

For BTS C Distance from BTS	Noon time					Mid night time						
	dBm	dBm		mw	mw	dBm	dBm		mw	mw	mw	mw/cm^2
	Prx	Ptx		Ptx	P1	Prx	Ptx		Ptx	P2	Pav	Pd
R1=10_m	-45	17		50.1	50.1	-50	19		79.4	79.4	64.4	8.40
R2=100_m	-38	13		20.0	20.0	-46	15		32.0	32.0	26.0	3.37
R3=300_m	-40	10		10.0	10.0	-35	12		15.8	15.8	12.9	1.67
R3=500_m	-55	8		6.3	6.3	-45	7		5.0	5.0	5.6	0.73
R5=1_{km}	-63	8		6.3	6.3	-56	6		4.0	4.0	5.15	0.66
R6=2_{km}	-70	6		4.0	4.0	-66	5		3.2	3.2	3.6	0.046
R7=3_{km}	-77	5		3.2	3.2	-78	5		3.2	3.2	3.2	0.41

Table 4 power measurement site D

For BTS **D** Distance from BTS	Noon time				Mid night time					
	dB m	dB m	mw	mw	dB m	dB m	mw	mw	mw	mw/cm^2
	Prx	Ptx	Ptx	P1	Prx	Ptx	Ptx	P2	Pav	Pd
R1=10$_m$	-25	16	39.8	39.8	-46	19	79.4	79.4	59.6	7.74
R2=100$_m$	-23	12	15.8	15.8	-35	19	79.4	79.4	47.6	6.18
R3=300$_m$	-29	12	15.8	15.8	-28	13	20.0	20.0	17.9	2.32
R3=500$_m$	-34	10	10	10	-30	11	12.6	12.6	11.3	1.46
R5=1$_{km}$	-48	8	6.3	6.3	-74	8	6.3	6.3	6.3	0.81
R6=2$_{km}$	-75	5	3.2	3.2	-73	6	4.0	4.0	3.8	0.49
R7=3$_{km}$	-92	5	3.2	3.2	-84	5	3.2	3.2	3.2	0.41

4.18. Conclusions and Recommendations:

4.18.1 Results:

As was described in the previous chapter, we made some power measurements on four different BTSs, and we figured out the power density in term of distance Rx.

Review at the measured BTSs:

Now we shall show the four functions of distance (of same power measurements we did On the previous four sites). Then the table can be rewritten in the following form:

Table 1

Distances from BTS (m)	average power (mW)	Pd (mW/cm^2)
10	71.2	9.24
100	79.4	10.31
300	32.4	4.21
500	22.5	2.92
1000	14.2	1.84
2000	7.9	1.02
2500	3.6	0 .46

That will lead us to the following graph; X-axis shows the distance in (km) where the Y-axis is the power density in (mW/cm^2)

And we can rewrite table as follows:

Table 2

Distances from BTS (m)	average power (mW)	Pd (mW/cm^2)
10	44.0	5.71
100	71.2	9.24
300	28.3	3.68
500	25.3	3.35
1000	20.7	2.7
2000	3.6	0.46
2500	3.6	0.46

And as we did for site a we can convert this table into a graph as following (where the X-axis shows the distance in (km) and the Y-axis is the power density in (mW/cm^2)

The same for site C, so table is rewritten as:

Table 3

Distances from BTS (m)	average power (mW)	Pd (mW/cm^2)
10	44.0	5.71
100	71.2	9.24
300	28.3	3.68
500	25.3	3.35
1000	20.7	2.7
2000	3.6	0.46
2500	3.6	0.46

And the same thing we did for the other sites, so the graph will look something like this

Now the table will be:

Table 4

Distances from BTS (m)	average power (mW)	Pd (mW/cm^2)
10	59.6	7.74
100	47.6	6.18
300	17.9	2.32
500	11.3	1.46
1000	6.3	0.81
2000	3.8	0.49
2500	3.2	0.41

So now we will plot table 4.4 as a graph where the X-axis is the distance measured in (km) while the Y-axis represent the power density in (mw/cm^2), To make more clearance for which site has the most power density effect, we will calculate for the total power density for each site to be our reference parameter for the compares am.

The total power density:

Pdt =Σ Pd (Rx)   where Rx = 10, 100, 300… 2500m

So for the four sites Pdt will be:

Pdt (A) = (9.24 + 10.31 + 4.21 + 2.92 + 1.84 + 1.02 + 0.46) = 30 mW/cm^2

Pdt (B) = (5.71 + 9.24 + 3.68 + 3.35 + 2.70 + 0.46 + 0.46) = 25.6 mW/cm^2

Pdt (C) = (8.40 + 3.37 + 1.67 + 0.73 + 0.66 + 0.46 + 0.41) = 15.7 mW/cm^2

Pdt (D) = (7.74 + 6.18 + 2.32 + 1.46 + 0.81 + 0.49 + 0.41) = 19.41 mW/cm^2

From that we can see that site A, which was mounted on a small light tower using low gain antenna (omni-directional antenna) as shown in the figure .it was installed about four meters from the ground; this site has the highest power density over these discrete distance Rx that we measured over. Where site C, was on a high hotel building and about 35 meters from ground. Four high-gain sector antennas had the lowest power density between the four sites.

4.18.2 Average Results:

In this section we will make an average power density function of the four sites we had studied Fav (Rx):

Table 5

Distance from BTS(m)	Pd A (mW/cm^2)	Pd B(mW/cm^2)	Pd C(mW/cm^2)	Pd D(mW/cm^2)	Pdav(R_x) (mW/cm^2)
10	9.24	5.71	8.40	7.74	7.7725
100	10.31	9.24	3.37	6.18	9.7750
300	4.21	3.68	1.67	2.32	2.9700
500	2.92	3.35	0.73	1.46	2.1150
1000	1.84	2.70	0.66	0.81	1.5025
2000	1.02	0.46	0.46	0.49	0.6075
2500	0.46	0.46	0.41	0.41	0.4350

4.18.3 Comparison:

After all we did we are ready now to compare between the results we had and the standard safety levels.

Table 6

FCC	**1.0 mW/cm^2**
ANSI/IEEE	**0.57mW/cm^2**
ICNIRP mW/cm^2	**0.90**
NCRP	**1.0 mW/cm^2**

And we can also rewrite table (the standards for mobile phone base stations)to the following table.

Table 7

Type of effect from the power density (Pd)	
100 mW/cm^2	Clear hazards
40 mW/cm^2	Reproducible effects
4 mW/cm^2	Un reproduced effects
0.5-1.0 mW/cm^2	Within international standard
0.02 mW/cm^2	Maximum near a cell phone tower

From the table of (the average power density for the BTSs) above we can see that at distance 100 m from the BTS has the maximum is at 2500m. And in general we can see that all the radiated power from the mobile phones to the BTS is relatively high (above the international standard levels). And we can also conclude that the most risky region lays between 10→100 m from the BTS antenna, this risk decrease as we go far away from the BTS, between 300→500m the Pdav is slightly above the standard levels. The safe regions would be over 1000 m away from the base transceiver station.

We can tabulate all the above conclusions as follows:

Table 8

Distance from BTS(m)	Measured power density (mW/cm^2)	Results	Notes
10	7.7725	Much more above standards	Un reproduced effects
100	9.7750	Extremely above standards	Un reproduced effects
300	2.9700	above standards	Affect on human
500	2.1150	above standards	Affect on human
1000	1.5025	Slightly above standards	Affects on the long term
2000	0.6075	Within standards	No affect
2500	0.4350	Within standards	No affect

After all we can say that the most harmful effect of cellular phones is not the exposure to the RF it self but the car accidents caused because of the mobile phones. In a separate lancet report, Massachusetts scientist Dr.Kenneth Rothman said his research indicated the main public health concern was motor vehicle collisions rather than any possible link to brain cancer, he notes that one study found that the risk of a car accident was 4 times greater when the driver was using the mobile phone or soon after a call and that heavy mobile users were involved in twice as many fatal road accidents than light users.

4.19. Sources of error:

In any research there must be a percentage of error especially if this research was based on a practical measurement, and so this research, it's based on a practical measurement.

We can classify the sources of error as follows:

- The error in estimating the distance from the BTS antenna.
- The assumption for the area of the MS antenna.
- The measurement instrument it self.
- Over lapping between the coverage areas of the BTSs.
- The standard levels could contain some source of error.

4.20. Recommendations:

So far all the studies are some how similar and has no exact results, that is because of the fast raising of the cellular phones in the last few years and also because the cellular system is relatively new, so no real affected case appeared yet. There are some recommended ways to avoid, as possible as could, the effects of the mobile phones,

4.20.1 follows some of what we recommend:

Ear-pieces:

An earpiece attachment will ensure you are not using your phone directly next to your head. These products have not undergone independent, published and reproduced research and their effectiveness can't be committed on.

Hands free:

If you use the phone in your car, invest in a fitted car kit. This will allow you to have a hand free conversation and at the same time keeps the phone away from your head.

Shields:

There are a number of shields in the market that claim to reduce the health risk to mobile phones. No independent, comparative tests on these devices have been published so it could not be true, but at the same time it's not harmful to use it.

4.21. International Standards for public exposure to RF radiation from mobile phone

base station antennas in countries other than the U.S. This list is not comprehensive or necessarily up-to-date; the information should be checked with the appropriate regulatory authorities in each country. Also see Eldritch and Klauenberg

- **Australian standard:** The Australian situation is rather complex. Until 1998, RF exposure in Australia was regulated by "AS2772.1-1990 Radio frequency radiation, Part 1: Maximum exposure levels-100 kHz to 300 GHz including Amendment No. 1/1994" from the Standards Association of Australia. In that standard the allowable general public exposure limit for the frequencies used by mobile phone services was 0.2 mW/cm-sq; this was a factor of 2 - 6 lower than the FCC, ANSI/IEEE, ICNIRP and NCRP standards. This standard was revised in 1998 on an interim basis, and the allowable general public exposure limits in the new "interim" standard [AS/NZS2772.1 (In): 1998] appeared to similar to the ICNIRP standard except at higher frequencies where the lower limits of the 1990 Standard were retained. This interim standard was effective until 5-March-99, when it was to have been "confirmed, withdrawn or revised". The committee responsible for the standard was unable to achieve the required level of consensus to confirm or revise the interim standard and it was subsequently withdrawn. When the AS/NZS2772.1 (In): 1998 lapsed, the Australian Communications Authority (ACA) stepped in and adopted its own radio communications RF standard. The ACA standard appears to be largely identical to AS/NZS2772.1 (In): 1998, except that it applies only to RF radiation used for communications.
- **New Zealand standard:** In 1998 the Australian and New Zealand standards were merged as an "interim" standard [AS/NZS2772.1 (In): 1998]. The same confusion that applied to the Australian standard occurred in New Zealand. However, unlike Australia, New Zealand has adopted a final standard, "NZS 2772.1:1999 Radio frequency fields - Part 1: Maximum exposure levels - 3 kHz to 300 GHz", that aligns fully with the ICNIRP Guidelines and does not contain the reduced exposure levels at higher frequencies that were part of the earlier standards.

- **Canadian standard:** [Health Canada: Limits of exposure to radio frequency fields at frequencies from 10 kHz - 300 GHz Safety Code 6, Canada Communication Group, Ottawa, Canada, (1993)] At the frequencies of relevance to base stations the Canadian standard appears to be identical to the FCC standard.
- **UK standard:** In mid-2000 the UK stopped using its own standard for mobile phones and mobile phone base stations and adopted the ICNIRP standard .
- **Greek standard** [Measures for protection of the public from operation of land-installed antennas. Athens, Hellenic Republic, 2000]: The standard is essentially identical to ICNIRP standard.
- **Swiss standard** [Regulation about Protection against No ionizing Radiation. Swiss Federal Council, 1999]: For wireless communication transmitters above 6 W (ERP) the standard is 4.0 V/m (0.0042 mW/cm-sq) at 900 MHz and 6.0 V/m (0.0095 mW/cm-sq) at 1800 MHz. For broadcast radio (and TV?) the standard is 3.0-8.5 V/m (0.0024-0.019 mW/cm-sq).
- **Italian standard:** Minister Dell'Ambientem, Decretory 10 September 1998, n. 381, Regalement recanted norm per la determination die tatty did radiofrequenza compatibility con la salute manna. At mobile phone frequencies the standard appears to be 0.10 mW/cm-sq. For situations where exposure is expected to exceed 4 hours/day, the limit appears are further reduced to 0.010 mW/cm-sq. Local regional administrations appear to have the authority to further reduce these limits, and several regions appear to have limits 4 times lower (0.0025 mW/cm-sq).

Conclusion

There have been many studies of the biological effects of EM radiation, many of these have been inconclusive. Using the research available, the following observations can be made:

- Electrical fields of intensity similar to that found in the proximity of overhead power lines, may cause psychological responses such as changes in complex reasoning and arousal of humans.
- In very special conditions as explained earlier, in the presence of weak radiation, the human body's biological rhythm may be altered, and in animals it has been shown the intense exposure to radiation can slow down the production of the hormone Miltonic. Changes in the level of this hormone have been linked to causing cancer.
- Acute radiation exposure in human subjects has been shown to cause headaches and alterations in visual responses evoked by the radiation.
- In the presence of intense radiation, human reproduction may experience behavioral deficiencies as well as retardation in development.

Due to the effects that EM radiation can cause, it is useful to be able to measure and limit the amount of radiation emitted from cellular transceivers which may be used to transmit data or voice signals. This requires a model of the human head, which is achieved by using the Phantom model. Radiation absorption is measured using the SAR unit.

In conclusion, the effects of EM radiation are only a threat if the dosage of radiation is very high. In the case of cellular transceivers, the dose is not very high. Most of the latest studies that have been done on the subject, have returned inconclusive results and so it is impossible to give a definite answer to the question of whether cellular communications are bad for your health.

Further research is always being carried out, with phone companies eager to invest in research so as to ease their consumer's fears. Many companies are taking advantage of the public's fear by selling products such as shielding cases, which enclose the cellular.

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Glossary and Acronyms	
A3	Authentication algorithm
A5	Ciphering algorithm
A8	Ciphering key computation
AGCH	Access Grant CHannel
AMPS	Advanced Mobile Phone Service
AoC	Advice of Charge
ARQ	Automatic Repeat reQuest mechanism
AUC	Authentication Center
BAIC	Barring of All Incoming Calls
BAOC	Barring of All Outgoing Calls
BOIC	Barring of Outgoing International Calls
BOIC-exHC	Barring of Outgoing International Calls except those directed toward the Home PLMN Country
BCCH	Broadcast Control CHannel
BCH	Broadcast CHannel
BER	Bit Error Rate
bps	bits per second
BSC	Base Station Controller
BSS	Base Station Subsystem
BTS	Base Transceiver Station
CC	Call Control
CCCH	Common Control CHannel
CDMA	Code Division Multiple Access
CEPT	Conference of European Posts and Telecommunications
CFB	Call Forwarding on mobile subscriber Busy
CFNRc	Call Forwarding on mobile subscriber Not Reachable
CFNRy	Call Forwarding on No Reply
CFU	Call Forwarding Unconditional
CGI	Cell Global Identity
C/I	Carrier-to-Interference ratio
C/I	Carrier-to-Interference ratio
CLIP	Calling Line Identification Presentation

CLIR	Calling Line Identification Restriction
CM	Communication Management
CoLP	Connected Line identification Presentation
CoLR	Connected Line identification Restriction
CUG	Closed User Group
CW	Call Waiting
DCS	Digital Cellular System
DCCH	Dedicated Control CHannel
DTX	Discontinuous transmission
EIR	Equipment Identity Register
ETSI	European Telecommunications Standards Institute
FACCH	Fast Associated Control CHannel
FCCH	Frequency-Correction CHannel
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction code
FER	Frame Erasure Rate
GIWU	GSM Interworking Unit
GMSC	GSM Mobile services Switching Center
GMSK	Gaussian Minimum Shift Keying
GP	Guard Period
GSM	Global System for Mobile communications
HLR	Home Location Register
IMEI	International Mobile Equipment Identity
IMSI	International Mobile Subscriber Identity
ISDN	Integrated Services Digital Network
JDC	Japanese Digital Cellular
LA	Location Area
LAI	Location Area Identity
LOS	Line-Of-Sight
MM	Mobility Management
MoU	Memorandum of Understanding
MS	Mobile Station
MSC	Mobile services Switching Center
MSISDN	Mobile Station ISDN number
MSRN	Mobile Station Roaming Number

NADC	North American Digital Cellular
NMT	Nordic Mobile Telephone
NSS	Network and Switching Subsystem
OAM	Operation, Administration and Maintenance
OSS	Operation and Support Subsystem
PAD	Packet Assembler Disassembler
PCH	Paging CHannel