EMR Spectrum Principle

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Abstract:

The electromagnetic spectrum has a very wide range of frequencies. Understanding how these various frequencies interact with human bodies is very important for appreciating how these signals and fields can cause biological effects when tissues or whole bodies are exposed. Biophysics is a very important scientific discipline for understanding how the natural body electromagnetic and biological systems work and how external signals from extremely low-frequency fields and radiofrequency and microwave radiation enter into and interact with the body systems and cells. The basic physics principles involved are resonance interaction and absorbance, and energy conversion and conservation. The failure to understand these principles leads to errors in the setting of standards and the inappropriate interpretation of epidemiological results.

1. Introduction:

The electromagnetic spectrum starts from a 0Hz frequency, a static field, and with increased frequencies it goes through a sequence of frequency bands, Table 1.

TABLE 1: Frequency Bands of the Electromagnetic Spectrum, Gandhi (1990).

Frequency range	Band	Abbreviation
0-30 Hz	Ultra low frequency	ULF
30-300 Hz	Extremely low frequency	ELF
0.3-3 kHz	Voice frequency	VF
3-30 kHz	Very low frequency	VLF
30-300 kHz	Low frequency	LF
0.3-3 MHz	Medium frequency	MF
3-30 MHz	High frequency	HF
30-300 MHz	Very high frequency	VHF
0.3-3 GHz	Ultra-high frequency	UHF
3-30 GHz	Super-high frequency	SHF
30-300 GHz	Extremely high frequency	EHF

The common usage of the spectrum is shown in Figure 1.

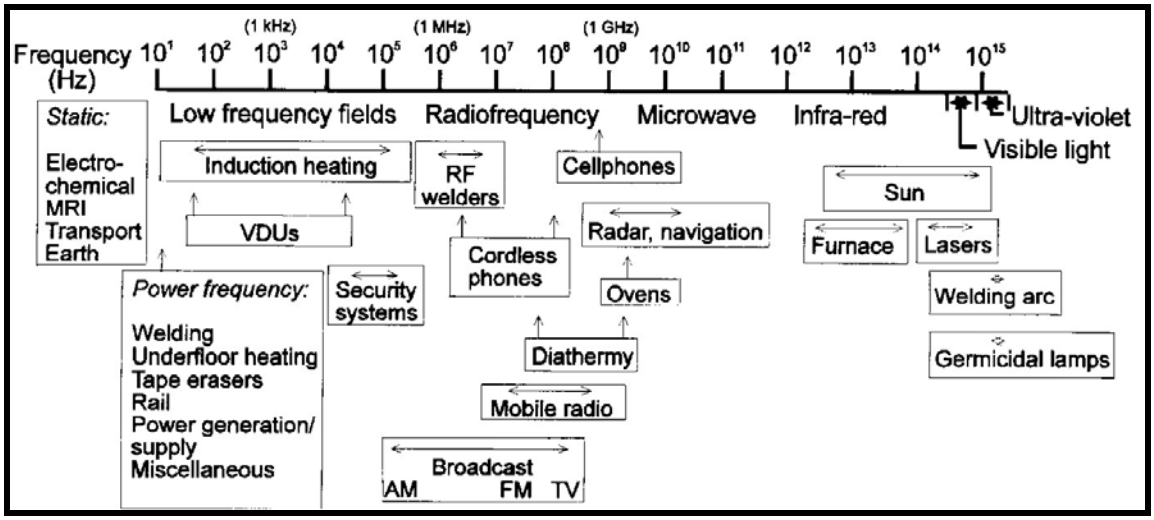

Figure 1: Regions of the electromagnetic spectrum and their relationship to occupation and environment, RSNZ (1998).

Electromagnetic radiation is an oscillating electric field with a proportional magnetic field at right angles to it, Figure 2. The energy is contained in the oscillating E and H signals that are traveling through the air at the speed of "light".

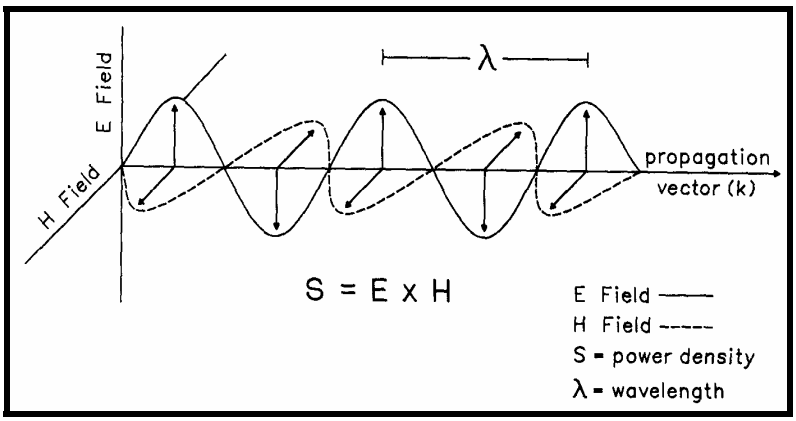

Figure 2: The propagation of energy by time-varying electric and magnetic fields is electromagnetic radiation, with the power flux density (S) = E x H where E is the electric field strength and H is the magnetic field strength.

An electromagnetic radiating wave is a combination of an oscillating electric field and magnetic field at right angles to each other, Figure 2. The oscillation rate is the frequency (f). The wave travels through space at the speed of light, $c = 3 \times 10^8$ m/s in a vacuum. In other media the speed is slower but the frequency remains the same, resulting in a shorter wavelength. In air the speed is close to the vacuum speed. The relationship between the speed, the frequency and the wavelength is: $c = f \lambda$, where c is in m/s, f in cycles/second (Hertz, Hz) and the wavelength is in m.

When propagating radiation enters air, fluid or tissue the radiation velocity decreases in proportion to the density and the frequency, a parameter called a refraction index. An

example of this is a rainbow. The white sunlight passing through water droplets of the rain and the shorter wavelength (violet and blue), and bending more than the longer wavelength (lower frequency) red and yellow. This puts violet and blue on the inside of the primary rainbow with yellow and red on the outside.

When propagating radio-frequency or microwave radiation penetrates a body it slows down, reducing the wavelength but not altering the frequency which is at right angles to the propagation direction.

The power density or exposure level (S) is the product of the electric field (E, V/m) and the magnetic field (H, A/m), S = E H. Since the ratio of E/H = 377Ω, where 377Ω is the impedance of space.

Hence for electric fields: $S = E^2/377\ W/m^2 = E^2/3.77\ \mu W/cm^2$ (1)

For magnetic fields: $S = 377\ H^2\ W/m^2 = 37700\ H^2\ \mu W/cm^2$ (2)

Hence an electric field of 0.6 V/m gives $S = 0.095 \mu W/cm^2$. A magnetic field of 0.1mA/m gives $S = 0.0004 \mu W/cm^2 = 0.4\ nW/cm^2$, where ($\mu$ = micro = 10^{-6}) and (n = nano = 10^{-9}).

2. Resonance:

Resonance is a fundamental classic physics process that music and telecommunication relies on, Figure 3.

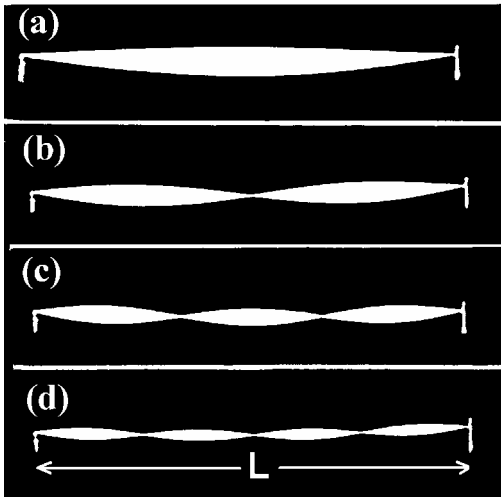

Figure 3: Standing waves on a stretched string with the nodes (zero amplitude) spaced at $\lambda/2$ where λ is the wavelength. In (a) $\lambda = 2L$; (b) $\lambda = L$; (c) $\lambda = 2L/3$ and (d) $\lambda = L/2$. The corresponding frequencies are (a) 1 f / 2 ; (b) 2 f /2 ; (c) 3 f / 2 and (d) 4 f / 2.

In physics and music the harmonics of standing waves on a string can illustrate the ways that different frequencies and wavelengths in proportion to the length of the string or the antenna are natural resonant signals for a particular length (L), Figure 3. All musical

instruments' design and usage is based on resonance of the length of the string or tube and the diameter of the drum.

Resonance is a process used by both the transmitter antenna and the receiver aerial. Their size is related to the wavelength of the transmitted signal. Both the transmitter antennas and the receiver aerials have a length that has a natural oscillation frequency that proportionately matches the frequency of the transmitted signal. Transmitting antennas are used to convert oscillating electric currents and voltage generated by the transmitter circuit into electromagnetic fields radiating through space. In the absence of material boundaries that reflect or scatter the waves, the fields propagate in the form of spherical waves, whose amplitude varies inversely with the distance from the antenna,

The physics principles such as resonance are fundamental parts of the brain's electromagnetic system for thinking and intelligence that has been used to understand the brain and to design and create electronically advanced telecommunication systems that also rely on resonance for its operations.

3. EMR Spectrum Principle:

It is observed that both biological effects and epidemiological effects appear to be the same or very similar from ELF exposure and from RF/MW exposures, including calcium ion efflux, melatonin reduction, DNA strand breakage, chromosome aberrations, leukaemia, brain cancer, breast cancer, miscarriage and neurological effects. Adey (1988) shows that a 56V/m ELF field induces a tissue gradient of 10^{-7}V/cm, whereas a 56V/m 147MHz signal induces a tissue gradient of 10^{-1}V/cm, a million times higher. This is close to the factor given by Figure 4 between 16Hz and 147MHz.

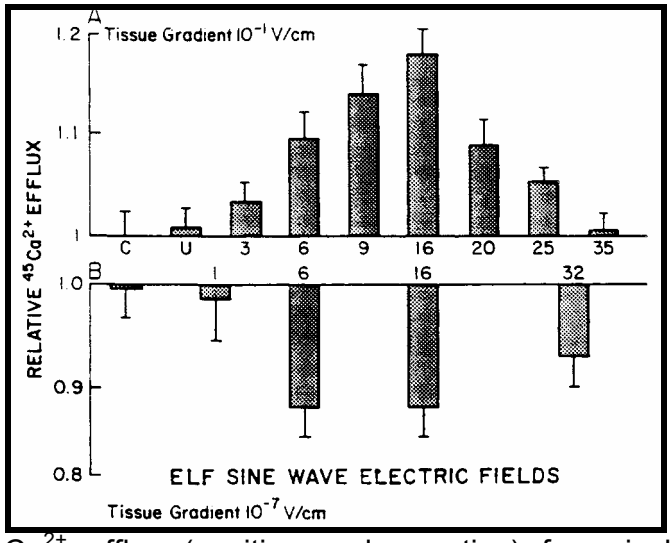

Figure 4: Relative Ca^{2+} efflux (positive and negative) from isolated chick cerebral hemisphere exposed to (A) weak RF field (147 MHz, 0.8 mW/cm^2, 56 V/m in air), amplitude modulated at low frequencies (abscissa) (Bawin et al. (1975) and (B) ELF electric field (56 V/m in air) over the same modulation frequency range, Adey (1988). The tissue gradients differ by 10^6 between A and B.

The dielectric constant is approximately the AC equivalent of the DC Resistance. As the dielectric constant decreases the conductivity increases. The dielectric properties of biological tissue depend on the water content because of the interaction of the RF/MW signal with the tissues. Two types of effects control the dielectric behaviour. One is the oscillation of the free charges or ions and the other the rotation of the molecules at the frequency of the applied electromagnetic signal, Johnson and Guy (1972), Tables 2 and 3. This results in a progressive reduction in the dielectric constant with rising frequency of the electromagnetic signal, Figure 5.

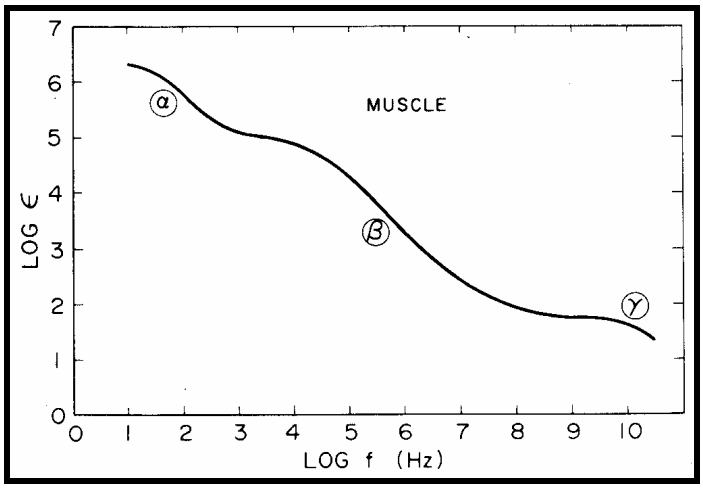

Figure 5: The dielectric constant of muscle as a function of frequency, Schwan and Foster (1980).

The significant drop in dielectric constant with increasing frequency shows a linked process across the spectrum with increasing conductivity and higher induced currents as the frequency rises. The frequency dependence of the induced current in muscle tissue, exposed to a unit external field, was modeled by Vignati and Giuliani (1998), Figure 6.

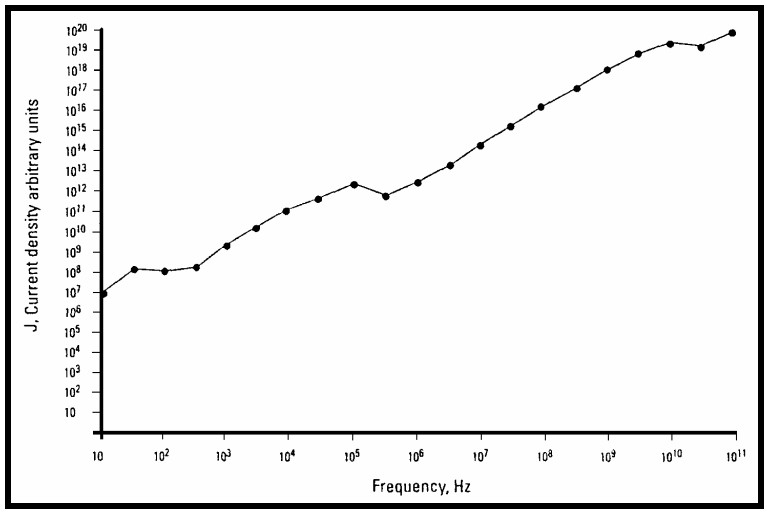

Figure 6: Capacitive current density in a toroid of human muscle tissue of unitary radius, to a unitary magnetic induction, Vignati and Giuliani (1997).

PROPERTIES OF ELECTROMAGNETIC WAVES IN BIOLOGICAL MEDIA (Johnson and Guy (1972))

TABLE 2: Muscle, Skin, and Tissues with High Water Content

Frequency (MHz)	Wavelength in Air (cm)	Dielectric Constant ε_H	Conductivity σ_H (mho/m)	Wavelength λ_H (cm)	Depth of Penetration* (cm)
1	30000	2000	0.40	436	91.3
10	3000	160	0.63	118	21.6
27.12	1106	113	0.61	68.1	14.3
40.68	738	97.3	0.69	51.3	11.2
100	300	71.7	0.89	27.0	6.66
200	150	56.5	1.28	16.6	4.79
300	100	54	1.37	11.9	3.89
433	69.3	53	1.43	8.76	3.57
750	40	52	1.54	5.34	3.18
915	32.8	51	1.60	4.46	3.04
1500	20	49	1.77	2.81	2.42
2450	12.2	47	2.21	1.76	1.70
3000	10	46	2.26	1.45	1.61
5000	6	44	3.92	0.89	0.79
5800	5.17	43.3	4.73	0.78	0.72
8000	3.75	40	7.65	0.58	0.41
10000	3	39.9	10.30	0.46	0.34

λ_H : The wavelength inside the high water content tissue; * Depth of penetration is based on the depth at which the intensity drops to the level of 1/e, i.e. about 36.8%.

TABLE 3: Fat, Bone, and Tissues with Low Water Content

Frequency (MHz)	Wavelength in Air (cm)	Dielectric Constant ε_L	Conductivity σ_L (mmho/m)	Wavelength λ_L (cm)	Depth of Penetration (cm)
1	30000				
10	3000				
27.12	1106	20	10.9-43.2	241	159
40.68	738	14.6	12.6-52.8	187	118
100	300	7.45	19.1-75.9	106	60.4
200	150	5.95	25.8-94.2	59.7	39.2
300	100	5.7	31.6-107	41.0	32.1
433	69.3	5.6	37.9-118	29.8	26.2
750	40	5.6	49.8-138	16.8	23.0
915	32.8	5.6	55.6-147	13.7	17.7
1500	20	5.6	70.8-171	8.41	13.9
2450	12.2	5.5	96.4-213	5.21	11.2
3000	10	5.5	110-234	4.25	9.7
5000	6	5.5	162-309	2.63	6.7
5900	5.17	5.05	186-338	2.29	5.2
8000	3.75	4.7	255-431	1.73	4.6
10000	3	4.5	324-549	1.41	3.4

λ_L : The wavelength inside the low water content tissue;

In a book edited by Prof Om Gandhi in 1990, Prof Gandhi presents several chapters on the biological and biophysical parameters of human tissue's relationship to the absorption of electromagnetic radiation. One of the main differences of various organs is the water content which makes a difference of the way the radiation interacts with that tissue, Tables 4 and 5.

TABLE 4: Dielectric Constant at 37°C of Various Tissues at Radio and Microwave Frequencies, Gandhi (1990).

	Frequency					
Tissue	100 kHz	1 MHz	10 MHz	100 MHz	1 GHz	10 GHz
Skeletal muscle	(14.4-24.8) x 10^3	(1.9-2.5) x 10^3	162-204	64-90	57-59	43-45
Liver	(9.8-13.7) x 10^3	1.97 x 103	251-338	65-82	47-49	35
Spleen	3.3 x 103	1.45 x 10^3	321-410	69-101	50-55	41
Kidney	(10. 9-12.5) x 10^3	(2.39-2.69) x 10^3	190-204	66-95	42-50	40
Brain	(1.96-3.8) x 10^3	(0.54-1.25) x 10^3	163-352	57-90	37-55	38-44
Bone	280	87	37	23		

TABLE 5: Conductivity at 37°C of Various Tissues at Radio and Microwave Frequencies in Siemens per Metre, Gandhi (1990).

	Frequency					
Tissue	100 kHz	1 MHz	10 MHz	100 MHz	1 GHz	10 GHz
Skeletal muscle	0.38-0.59	0.58-0.85	0.69-0.96	0.75-1.05	1.38-1.45	11.5
Liver	0.15-0.16	0.27-0.3	0.42-0.47	0.6-0.72	0.95-1.1	8.9
Spleen	0.62	0.63	0.5-0.84	0.73-1.05	1.09-11.3	10.1
Kidney	0.24-0.25	0.36-0.37	0.50-0.68	0.66-1.05	0.95-1.0	9.7
Brain	0.12-0.17	0.14-0.21	0.21-0.63	0.48-0.95	0.81-1.2	8-10.8
Bone	0.014	0.017	0.024	0.057		

These two tables confirm the well-established relationships between the dielectric constant declining and the conductivity rising with increasing carrier frequency.

4. Epidemiological evidence supports the spectrum principle:

There is robust and extensive data supporting the EMR Spectrum Principle. While this paper is primarily about RF/MW exposures, confirmation of adverse effects is given by studies that involve mixed and ELF exposures. Astrocytomas are a subgroup of Gliomas (Brain Cancers). A group that was chronically exposed to high ELF fields in electrical utility occupations developed a high rate of Astrocytomas, Theriault et al. (1994).

OR = 28.48 (1.76-461.3)

In a 15-year data set of childhood cancer in the vicinity of the Sutro Tower, a powerful radio and TV tower in San Francisco, there were 2 brain cancers within a population of about 114 children. This gives:

RR = 80.4 (16.4-394), p=0.00046

Out to a distance of 1 km the mean exposures are smaller and 5 brain cancers occurred in a population of about 736 children. This gives:

RR = 31.1 (9.5-101.7), p=0.0000048

This data is derived from Selvin et al. (1992).

In terms of latency, of the 123 childhood cancer cases, 21 (17%) were in 0-2 year olds and 19 (15.5%) in 2-5 year olds, showing that the cancer latency is less than 2 years for some cases with RF exposure. The early childhood ALL peak associated with ELF fields in homes peaks between 3-4 years whereas this RF exposure associated peak is in 0-2 years.

Zaret (1977) reports that in a group of 18 workers who were servicing microwave communication equipment there were 2 with Astrocytoma. Allowing for a 10-year exposure and cancer development period, this gives an incidence rate of 1111 per 100,000p-yrs and a relative risk of:

RR = 1634 (385-6939), p<0.0000009

This shows that RF/MW radiation exposure produces very high increased rates of brain cancer. It is higher even for residential exposure levels for childhood brain cancer than compared to electrical occupational ELF exposures.

The EMR Spectrum and the data supporting it gives robust support for the *a priori* hypothesis that electromagnetic radiation and ELF fields are a Universal Genotoxic Carcinogen.

5. EMR spectrum principle:

The EMR spectrum principle is that the higher the carrier frequency the higher are the biological impacts on exposed tissues because the higher frequency fields interact more strongly with tissues inducing higher electric field gradients, lower dielectric constant, higher electrical conductivity and higher induced electric currents.

This means that biological and epidemiological effects found from ELF fields will be found from radiofrequency and microwave radiation exposure at much lower field intensities. Because the fields are genotoxic across the spectrum they all have a safe exposure level of zero. The EMR Spectrum Principle indicates that dose-response of Relative Risks will

have far higher gradients from radiofrequency microwave exposure compared to ELF exposure.

6. Implications of the failure to appreciate the Spectrum Principle:

There is strong evidence of consistent effects across the spectrum and strong support for the biophysical evidence and principles of higher and higher induced currents and induced tissue fields with the higher carrier frequencies. Hence effects found from ELF fields are much more likely to occur at much lower mean intensities with exposure to RF/MW fields.

The failure to understand and appreciate this has led to a strong bias among health assessment authorities. In 1990 an internal U.S. E.P.A. staff review, that was peer-reviewed, proposed to classify ELF fields as a probable (Class 2A) human carcinogen and RF/MW fields as a possible (Class 2B) human carcinogen, Sibbison (1990). Even though the evidence is far stronger, in June 1998 a working group of the U.S. National Institute of Environmental Health Sciences (NIEHS) declared that power frequency ELF fields are possible (Class 2B) human carcinogens. In June 2001, when the evidence is much stronger, the International Agency for Research on Cancer (IARC), a WHO sub-group, classified ELF fields as a possible (Class 2B) human carcinogen.

These authorities have not reviewed the literature summarized in reviews on my web site, www.neilcherry.com. Nor do they understand the biophysics implications of EMR spectrum principle.

In some cases a deliberately dismissive approach is taken by limiting consideration of evidence to a small range of intensities, frequency range and modulation type. An integrative and open approach is more consistent with the modern systems approach and is much more appropriate for public health protection approaches.

It is established in toxicology that a genotoxic substance has no safe threshold level because the damage occurs cell-by-cell. The UK Royal Commission on Environmental Pollution, Report No. 23, Setting Environmental Standards, UKRCEP (1998), Section 2.36 states:

> **"For some types of effect a threshold dose cannot be determined with confidence and it is questionable whether a threshold exists. An important type of effect in this category is *genotoxic carcinogenicity* (change of the genetic material). Any exposure of a cell to a substance which is a genotoxic carcinogen could potentially produce a mutation which might lead to cancer (if in somatic cells) or (if in germ cells) to effects that could be inherited. Equally, there may well be a threshold dose below which such effects do not occur because physiological processes rapidly detoxify the organism or repair the damage before it becomes established in genetic material."**

The brain does not contain germ cells for reproductive purposes. The very slow or no replacement of brain cells requires a very strong repair mechanism in brain cells but

genotoxic damage leads to cell death and cancer. I have already cited sufficient evidence to classify RF/MW as a Universal Genotoxic carcinogen that causes brain cancer.

For genotoxic carcinogenic substances the safe threshold is zero and the approach that should be taken with genotoxic carcinogens is the *de minimis* approach.

Cell phones produce high exposure of the users' head. Hence, evidence that RF/MW radiation and cell phone type radiation is genotoxic and carcinogenic gives strong evidence that cell phone usage increases the risk of brain cancer. Heavy cell phone usage significantly increases the risk of brain cancer. A much larger body of published research is cited below to confirm and strengthen the hypothesis and my conclusions. The latest Swedish research, Hardell et al. (2002) shows a significant 9-fold increase in Astrocytoma from analogue cellphone usage, OR = 9.00, 95%CI: 1.15-71.0, n=12. This is consistent with applying the EMR Spectrum Principle to the very large body of published research showing that extremely low frequency fields enhance brain cancer in electrical and electronic workers, and adults and children residents living in very low intensity ELF fields.

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