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2000 October 5

Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
The Portals TW-A325
445 12th Street, SW
Washington, DC 20554

Dear Ms. Salas:

I am enclosing a document which I would like to submit as a response to the recent NOI concerning possible revision of Part 15 on UltraWide Band transmissions (Docket Number ET-98-153; DA No. 00-2255).

Yours truly,

(jwill@AstraGate.net)

Encl.: "Comments on Thermal and Nonthermal Mechanisms", dated 2000-09-19.

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Comments on Thermal and Nonthermal Mechanisms

by John Michael Williams

Some Comments on Kenneth Foster's paper, "Thermal and Nonthermal Mechanisms of Interaction of Radio-Frequency Energy with Biological Systems", *IEEE Transactions on Plasma Science*, 2000, vol. 28 (1), pp. 15 - 23 (February issue). This paper will be referred to as KF2000 in the following.

I would like to spend considerable discussion on the overall method of analysis of the problem, as shown in KF2000 Figure 1. I think the approach, even for expository or didactic purposes, is wrong and may be seriously misleading. As will be shown, the underlying problem is the use of engineering technique to quantify or formulate new understanding: Understanding, as opposed to proper application, represents a function of science, not of engineering.

I also have comments on numerous specific points in the paper. Although most of my comments express disagreement with findings or opinions cited in KF2000, I do in general think the paper provides a good basis of review of the literature, with a balanced openness to future improvements in knowledge of the subject.

The Model of Analysis Should be Changed

To begin, I do not think a paper addressed to an audience of engineers need be cast in a familiar engineering stereotype. Engineers in general may be assumed to be intelligent and well-educated and therefore capable of understanding new approaches. All electrical or electronic engineers will have a very firm basis in electricity and magnetism. They won't need filters or antennas to understand the body. However, the KF2000 method of analysis seems to model a biological response as somewhat like a message from a radio receiver; so, it looks for an antenna isolated or decoupled from a set of RF amplifiers perhaps themselves decoupled from audio amplifiers finally triggering a bio-servo response.

This becomes an error when it leads the author to an emphasis on the electronics of the electromagnetic radiation (EMR), and not on the fundamental reasons for those electronics. Filters are for radios or servo systems. There are no filters in the body, so analysis by filter stages <u>necessarily</u> will be wrong. For example, on p. 18 the author says,

> "The electric field induced inside the body by an external electric or magnetic field [or EMR--jmw] depends strongly on frequency and the geometry of the system. Because of the conductivity of body tissues, it is difficult to couple low

frequency fields into the body through air, and DC fields are excluded entirely."

This is wrong. The penetration of a field is attenuated at least exponentially with depth by any uniform body tissue, as shown in KF2000 Fig. 4 and documented in papers cited throughout Section II of KF2000. For example, a typical equation relating the field intensity at depth d in tissue to the applied intensity in air would take the form, for some tissue- and unit-dependent constant k, and frequency f in Hz,

$$I_{\text{tissue}}(d,f) = I_{\text{air}} \cdot \exp\left(-k \cdot d \cdot f^{1/2}\right). \tag{1}$$

The tissue depth for a given intensity becomes <u>less</u>, the higher the frequency, not greater. Penetration increases with decreasing frequency. In the quote above, the author apparently is generalizing from metallic reflection to a biological response: A DC voltage applied across the body, whether by EMR, a static field in air, or wires from a battery, will cause current to flow by ionic conduction in the body fluids. The more conductive the body, the greater the current. When the coupling is through air, the current flow will stop because of the resistivity of air, but displaced charges will remain displaced to cancel the field applied.

In the quote above, the author is thinking of reflection of EMR from a (very conductive) metal: There, the penetration is small; and, for DC, the internal field is close to zero. However, the <u>reason</u> the penetration, or the DC field, in a metal is small is that the charge carriers in the metal, electrons, are responding so actively that they cancel the field by their motion (in the case of microwaves) or by their static relocation (in the case of DC).

When oscillating electrical (or magnetic) fields are applied to the body in air, the reason the penetration is limited is because the biological effect, an oscillating flow of ions, is large near the surface, declines exponentially with depth, and is absorptive. Deeper, the field is weaker, so motion will be less whether the deep tissue be conductive or not. So the quote above is misdirective if not completely wrong.

Returning specifically to the issue of describing serial filter stages as in KF2000 Figure 1, to accept the KF2000 model, one has to abandon the idea that the EMR applied to the organism might interact anywhere it can penetrate. KF2000 Figure 1, and nearby text, presumes that EMR has sequential effects at stages separate enough to be considered isolated (or, shielded) from one another except for connecting filters. Such nice sequencing can be achieved by good engineering design, but one should not insist on discovering it in a nonengineered organism.

The problem implied by KF2000 Figure 1 may be seen by considering an analogy of two containers of 250 ml of water, one a 6-cm diameter paper cup, and the other a 50-cm diameter paper plate: Which one would warm more rapidly in a microwave

oven? Both are "high-pass" to the ~2 GHz microwave oven excitation because of the ~30 GHz (~1 cm wavelength) first *E*-dipole harmonic of liquid water.

The problem also may be seen by trying to diagram not the signal flow, but the geometry of an organism that would allow such an analysis to be valid. A two-dimensional representation of this geometry might be as follows:

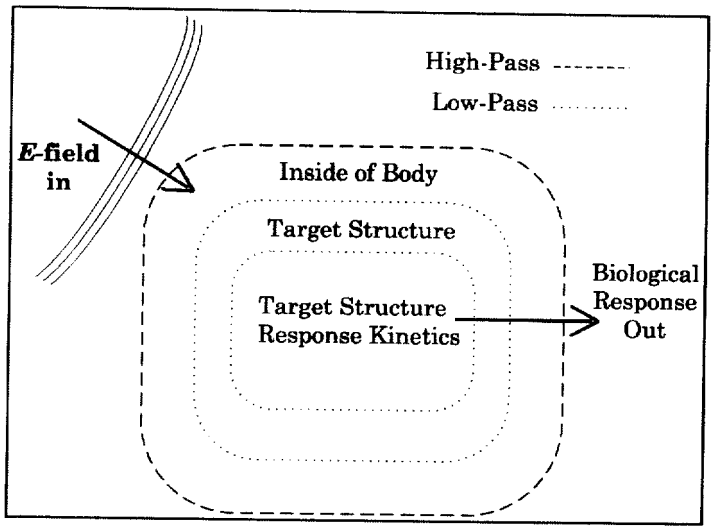

Figure 1. Organism geometry implied by the KF2000, Fig. 1, filter system.

The problem now becomes obvious: There is a contradiction in separating KF2000's "Target Structure" from "Inside of Body". Merely because the human body might have a certain geometry does not mean that interaction of EMR with the target structure depends upon that geometry. Counterexamples to KF2000 Figure 1 are easy to construct:

Suppose, for example, that the target structure were a set of metal fillings in the teeth and the EMR were in the broadcast TV or GHz range. Clearly, a fraction of the current induced in the fillings by EMR beamed at the body would be independent of the height of the person.

Now, true, the body can act as an "antenna", but any small component of the EMR "high-passed" by the body merely would be superposed on the EMR directly interacting with the fillings. The EMR directly acting would depend on shielding, reflection, and refraction by the teeth and lips, not by any generality representable by "Inside of Body". It would be incorrect in this example to describe the body (actually, the mouth) as a high-pass filter: In fact, if anything, the circumference of the open mouth would define a bandpass for EMR capable of exciting the fillings.

The same argument might be applied anywhere in the body--for any "target structure". The skull, for example, bandpasses EMR finally interacting in the scalp and the flesh of the face. Both geometrical resonance and the microwave "skin effect" (no pun intended) would channel microwave energy from the skull into the

flesh outside the skull. KF2000 Figure 1 would imply that the interaction with the skull could be filtered only to the brain and other organs inside the skull.

We suggest that analysis of the effect of EMR on human biological response should focus on tissue and organ boundaries as they exist in the body, not on "the body" as a radio chassis in any general sense. This idea will be expanded immediately below.

We also point out that the belief that microwaves do not produce tissue effects other than heat seems to be a prejudice based on history more than science, as may be seen by the review in Chapter 7 of Durney, *et al* (1999). The history seems based on attempts to discover how the body "was engineered". KF2000 and others rightly have reserved final judgement on this belief.

The belief that heat might exclude other responses seems connected to inaccurate usage of the term, "biological mechanisms". "Biological mechanisms" has no meaning in terms of the living body; actually, "biological mechanisms" merely refers to measurements or theory typically made by people studying biology. The real, physical mechanisms driving life involve the same atomic coulomb fields--valence and conduction electrons--and the same molecular dipoles that change in the picosecond scale of the fastest optical instruments. It is an error unknowingly to avoid this level of analysis, or to claim that life at this level is as random as an ideal gas, in trying to understand the interactions of microwaves with living tissue. If the microwaves are well-ordered at this level, and if the tissue is well-ordered (alive) at this level, then well-ordered interactions <u>must</u> be taking place before the end-result of heat.

The difficult question is <u>how to apply the microwaves</u> so they are amplified by the living organism at a level easily observable by persons studying the biology. Thus, the question is not how to postulate a "design" for the organism but rather how to seek empirically to use what is there, whatever science reveals of it, as an effective interface to our instruments.

EMR Interaction Can Not All Be Heat

Consider a tissue boundary such as the mucous membrane of the stomach wall or the endothelium of a large blood vessel. Such a boundary will be enclosed in cell membranes with a regular coulomb structure, the structure being organ dependent when relaxed in the absence of EMR.

For example, without much loss of generality, let us take a structure consisting of electric dipoles which happened to be aligned with positive pole locally pointing into some polar fluid such as water. This is shown in Figure 2:

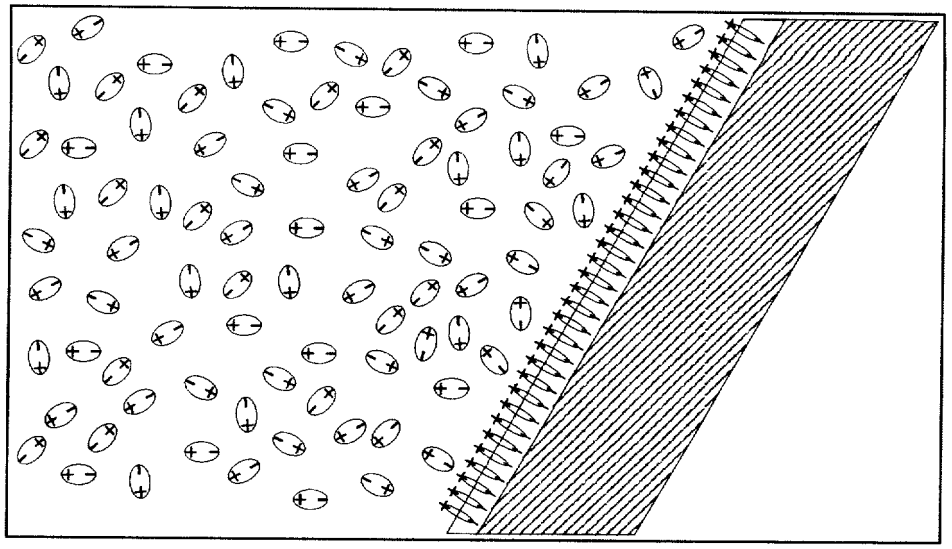

Figure 2. Unaligned electric dipoles in a fluid (left) bounded by solid tissue with a membrane layer of aligned dipoles.

Now, how would microwave EMR raise the temperature of the fluid? More generally, how can one understand the effect of microwave EMR on the structures in Figure 2? Especially, how could a coherent, regularly structured beam create increased disorder (heat) in the fluid?

The effect within the bulk of the fluid is easy to understand: The dipoles initially may be assumed arranged at random with respect to one another. When they are rotated (torqued) together, all magnitudes in phase with the EMR, they interact at random distances and phases with respect to one another. Thus, the EMR-induced motions contribute random momentum and therefore random energy. This is shown in Figure 3. In that figure, the Poynting vector $\vec{\mathbf{J}}$ is shown for EMR propagating as a plane wave from left to right, with a few illustrative EMR torque angles shown. The Poynting vector is given to define the direction of the incident EMR as the direction of $\mathbf{E} \times \mathbf{H}$, were the medium removed and replaced by vacuum.

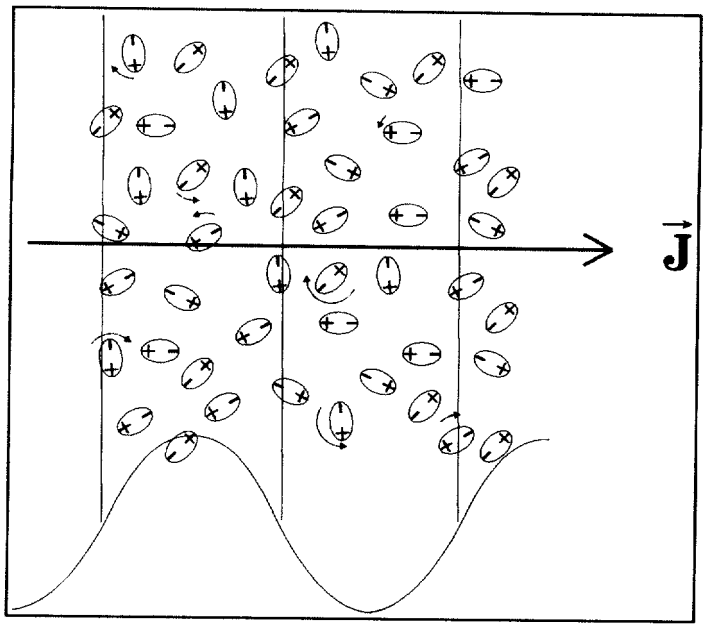

Figure 3. Sketch of the effect of a plane EMR beam propagating in a bulk fluid of polar elements, with a net result of increasing the temperature. The *E*-vector magnitude and polarity (+ up) is shown on an arbitrary vertical scale. The EMR torque on a few illustrative polar elements is shown as a vectorial angle.

So, the net effect of the EMR is to deposit energy in the fluid. This energy macroscopically is completely disordered and therefore is heat energy.

Now consider the same EMR near the fluid boundary: The boundary is more ordered than the bulk of the fluid, so some EMR energy will be delivered to the membrane as free energy, not heat. It is not physically possible that no free energy would be delivered. As it happens, in the absence of EMR, the fluid dipoles will tend to be somewhat ordered (correlated) close to the membrane anyway, so as to tend to line up with the membrane dipoles. This means that random motion because of heat is screened from the membrane dipoles to some extent by the dipoles in the immediately adjacent fluid. The heat in the fluid immediately adjacent to the membrane is represented by lower-amplitude, less random velocities of larger, more correlated ionic elements. All this is sketched in Figure 4, where, for variety, a gaussian-tapered beam envelope is assumed.

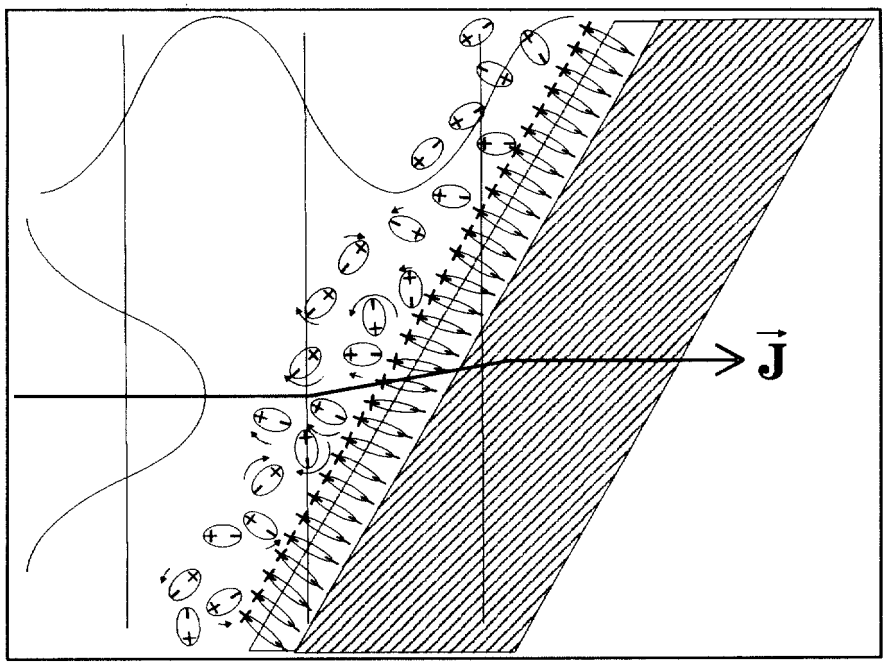

Figure 4. Effect of a gaussian EMR beam propagating from a polar fluid across an organ boundary with a polarized membrane. Necessarily, some EMR energy will be transferred to the boundary as free energy, not as heat.

If we assume in general that the Poynting vector $\vec{J}$ will not be perfectly perpendicular to the boundary, then the interaction in Figure 4 will deliver some linear momentum transverse to $\vec{J}$; the EMR beam will be refracted. The angle of refraction will be proportional to the amount of free energy delivered to the boundary dipoles. The momentum transferred to the membrane will correspond entirely to free energy; no heat will be involved. We ignore here the dielectric and other properties quantifying the direction and amount of refraction. For now, we also ignore diffraction and reflections (which would set up standing wave modulations in the incident beam).

So, we may see that an ordering effect will occur in the direction of propagation, and also in general transverse to it. Because all body tissue is ordered at organ boundaries, and also is ordered in bulk (except maybe fat, and fluid such as blood, lymph, or a digestive juice), all body tissue will receive free energy from EMR.

We therefore assert that the burden of proof should be on the claim that microwaves act like microwave ovens and do nothing but cause heat to be transferred to living tissue. Based on the *prima facie* argument of this section, EMR should be assumed have nonthermal effects on living tissue unless explicitly provable otherwise.

We move to one, final point in this initial, overall discussion of KF2000 with the observation that the body cells, especially the individual nerves and sensory receptors, function as ordered systems of boundaries in fluid. The temperature of

the body always causes disorder in the ubiquitous body fluids; nevertheless, nerves and muscles do perform orderly functions, which of course require free energy.

The mechanism of action of nerves, muscles, and systems of them, has been described in terms of membrane depolarization. This depolarization occurs because membranes are not only populated by structure-related dipoles as in the figures above, but also are more sparsely populated by specialized channels which can open or close to regulate exchange of ions, primarily sodium (Na+) and potassium (K+), but also calcium and perhaps other ions.

Living cells generally internally are more negative than their local environment, thereby storing some free energy in an electric potential across their bounding membranes. This potential difference is electrochemical and depends on continuous expenditure of energy to maintain higher intracellular K+ concentrations and lower intracellular Na+ concentrations than would be so during chemical (osmotic) equilibrium. The ion gradients are controlled by enzyme action which does its work using the adenosine triphosphate (ATP) energy store available to cells throughout the body.

Specifically, resting neurons typically expend energy to operate a Na-K "pump" which keeps the potential inside the cell about 70 mV more negative than the outside (Regan, 1972, p. 7). The membrane can liberate energy very locally by allowing some extracellular Na+ to flow in and some intracellular K+ to flow out. An additional osmotic potential also exists. Dendritic depolarization (e. g., "C" nerve fiber sensory response) may cause the -70 mV potential to drop close to 0 V immediately adjacent to the depolarized areas of the cell membrane.

When the originally resting electric field across a nerve membrane develops a steep enough spatial gradient, the specialized closed channels are forced to open, causing a spread of depolarization, which may become a nerve action potential under proper circumstances. The sudden depolarization during an axonal action potential may cause the resting potential of -70 mV to swing past 0 to perhaps +10 mV. This action probably is what KF2000 describes as having the relatively slow time constant on the order of milliseconds. For example, see the review of "membrane excitation" in KF2000, p. 20.

We note, aside, that diffusion permits the approximate equation of locally <u>steep</u> spatial gradients with locally <u>sudden</u> temporal ones and is essential in the Hodgkin-Huxley and similar approaches: For ion species j in concentration $u_j(x,t)$,

$$D\frac{\partial u(x,t)}{\partial x} - \rho u(x,t) = \frac{\partial u(x,t)}{\partial t}; \quad \text{so,} \quad \frac{\partial u}{\partial x} - (\text{loss}) \propto \frac{\partial u}{\partial t} - (\text{system input}). \tag{2}$$

Here, the hypothetical "Na-K pump" would function to keep (loss) = (system input) when averaged over long times.

The membrane channels in a neuron originally are held closed by polar molecules (PM) which open for depolarization because of smaller-scale, faster coulombic

(electrical) response. At some level, the time-constants of processes seen as a nerve action potential will be on microsecond and nanosecond scales. It may be convenient to describe the response in terms of a single characteristic time constant, but arbitrary time constants control the response at arbitrary levels of analysis.

Comments on KF2000 Specific Points

p. 16, Figure 4. The field penetration vs. frequency curves tend to fall on straight lines, except between about 10^8 and 10^{10} Hz (wavelength between a couple of cm and a few m), where they seem to level off somewhat before starting a steeper descent. The attenuation in muscle is greater than in fat at all frequencies, probably reflecting the greater water (polar) fraction of muscle, but perhaps also related to the more regular organization (larger membrane fraction in the hierarchical fascicle structures) of muscle tissue than fat.

Some data have shown a loss of frequency dependence of electrical properties in all soft tissue for very high frequencies around 20 GHz (see Durney *et al*, 1999). Presumably, at high enough frequencies significantly water-distinct tissues would converge to somewhat distinct levels of absorbance.

p. 17, Eq. 4: The terminology of the interpretation seems ambiguous. What is being referred to as "dipole"? The magnetic permeability even of blood is insignificantly different from that of vacuum. However, in nearby text, the result for typical human flesh in the quasistatic limit is said to be that the magnetic dipole D_M contributes about 15 x the electric dipole D_E to the induced electric field E_i. Also, the $|E_i|$ (same as $|\vec{D}|$?) is the sum of the electrically and magnetically induced contributions; so, is it correct to write, for some constant k, $|E_i| \cong k(|D_M| + |D_E|)$? Presumably D_M and D_E are the (orthogonal) components of the incident EMR, if plane wave? Would we have, $|D_M| = |\vec{B}_i|$, and $|D_E| = |\vec{P}_i|$?

p. 17, IIIB, the Resonance Region. It would not be unreasonable consider this somewhere between wavelengths of about 5x the height of a human to 1/5 the length of the smallest bone, organ, or opening in the body--say, 10 m to 0.1 mm; this would imply free space microwave frequencies of perhaps 30 MHz to 1000 GHz. Again, just because the math gets complicated here doesn't mean that organ, tissue, or cellular response has to be determined here. However, in this region, the local geometry of body structures can concentrate fields by factors of ten or more.

pp. 17-18, cites Chen & Gandhi, in 1991, with simulation results for a half-cycle of 40 MHz at 1 kV/m peak found about 1 to 4 A, depending on target organ geometry; the conclusion was that the internal field was about 1/3 the incident field in air. Both in this and the quasi-static regime, an approximation is maybe 10 mV induced for every incident V/m, assuming a grounded human in a vertically polarized E field and pulses lasting some tens of ns. This is an interesting and useful generality.

p. 18, IV: The Laplace representation, using a "cell" of two concentric spheres, seems completely divorced from reality and merely a choice based on available computer programs. Applied to a cell (rather than to the nucleus of a cell), the reasoning thus resembles the assumption that microwaves induce only heat because heat can be calculated and measured easily.

Spherical symmetry implies field cancellations unwarranted in living, multicellular organisms. In fact, even unicellular organisms almost never are spherical in geometry: Why? Because they need asymmetry to locomote or to sense chemical or other field differences necessary to survival. Otherwise, the cell would have to wait at random for life to come to it--a survival strategy good enough for the nucleus (or a virus) to survive inside a cell, but a strategy as random as heat for the cell as such!

The only spherical cells in the human body are fat cells or perhaps some kinds of blood cell. Modelled as ellipsoids, sensory or motor nerve cells would have eccentricities on the order of 10^6 or more.

The spherical model in this section must be assumed irrelevant to the question of nonthermal interaction. However, perhaps it might be corrected for geometry, and organized to match the observed data on actual living cells:

For example, allow a cell diameter of 10^{-5} m and length of 10^{-1} m. Many human nerve cells would fit this. So, the eccentricity would be something like 10^4. Therefore, allowing for living organization, one might approximate the living cell by a chain of 10^4 of the objectionable spherical cells, each of twice the spherical radius to correct for surface vector cancellation because of spherical symmetry. Because of series addition of resistance, the capacitivity to conductivity ratio in KF2000 Eq. (12) would be increased lengthwise by a factor of about 10^4; but, radially it would be decreased by a factor of $2/2^2 \cong 1/2$. Using KF2000 Eq. (12), the result would be a time-constant of maybe 0.1 μs locally (in a plane perpendicular to the long direction), but one of about $0.1 \cdot 10^4 \mu s \cong 1\,\text{ms}$ globally, in a direction exactly on the longest dimension of the cell. The projection of an incident EMR Poynting vector thus would interact by the time-constant of the living cell, but depending on the angle of incidence, over a range of something like 10^4:1. The membrane potentials in KF2000 Figure 5 then would have to be corrected by some factor between 1 and 10^4, depending on angle of incidence of the EMR on the elongated, living cell.

To continue the example of the living cell just described, the preceding reasoning would lead one to expect a membrane potential somewhere between 10^{-6} and 10^{-2} V for a 1 V/m incident E field. Because pulsed UWB fields may be expected to reach several kV/m, EMR-induced membrane potentials on the order of several times the normal neuronal resting levels of -70 mV should be anticipated. Thus, in this case, the assumption of heat was based clearly on an invalid spherical simulation.

p. 19, IV discussion of time-domain response. One must recognize that standing wave components will be found everywhere near organ boundaries, especially where

muscle and either bone or skin are close. The medium always being absorptive, the reflected wave amplitude will be smaller than the incident, creating an oscillating, standing field with a net DC component, the polarity depending on local phases. The geometry of the resultant DC field essentially will be unrelated to incident frequency, except for being multiple half-wavelengths in size, but it will be fairly closely related to the geometry and tissue properties of the organism. If the incident field or organism is moving, the standing wave patterns will be transitory, persisting perhaps for milliseconds or seconds. The time-change of the DC component then should be expected to impose cm-scale, changing, DC spatial patterns on nerve cell receptive processes, which should cause sensory responses.

It seems reasonable that this would be the theoretical basis for use of UWB or other pulsed radar transmitters to harass living humans and animals.

p. 20, VA 2, Rate of temperature increase. Rapid thermal expansion of tissue water caused by 5 μs, 1-10 GHz, $\sim 10^4 W/m$ pulses is said to explain "microwave hearing" of radar. At 1 GHz, the wavelength would be about 30 cm; at 10 GHz, 3 cm. Presumably, different tissues would cause a temporal transient proportional in intensity to their differential absorbance. However, a more efficient mechanism would be differential spatial amplitude over the skull, because of refraction, diffraction, and reflection of the EMR pulse, and possibly because of occurrence of briefly existing standing modes.

p. 21, VC, Field-charge interactions. The conclusion here was that random thermal motion of ions in solution would be some 8 or 9 orders of magnitude greater than the velocity to an ion added by a (steady) field of 1kV/m; therefore, field-charge interactions would be drowned out in thermal noise. However, there are three serious flaws in this conclusion:

First, the extracellular fluids are not filled with small ions, but rather with macromolecular assemblages (Regan, 1972, p. 1) with far greater organization (correlation) than the "ideal gas" on which the use of Boltzmann's formula is based. At a given temperature, then, the thermal velocities will be far less than the ones presented in KF2000. Much of the fluid thermal energy will be internal to the assemblages and will not be available to add noise to EMR-membrane interactions.

Second, the conclusion refers to the distant fluid extracellular medium, not to the partially screening region near the membrane of a living cell.

Third, as is well known, small drift displacements in general may correspond to very large measured values of electrical current. These displacements are superposed on the average random thermal motion and are independent of it because they are not random.

For example, a coaxial-plate capacitor with properties similar to a 1-cm long unmyelinated "C" nerve fiber, 0.5 μm in diameter, and with 100 Å -thick membrane, at 1 GHz (KF2000, Fig. 3) would have capacitance,

$$C = \frac{2\pi\varepsilon d}{\ln(r_{outer}/r_{inner})} = \frac{2\pi(20\cdot 8.85\cdot 10^{-12})10^{-2}}{\ln((0.5\cdot 10^{-6}+100\cdot 10^{-10})/0.5\cdot 10^{-6})} \cong \frac{10^{-11}}{0.02} \cong 500\,\text{pF}. \tag{3}$$

Now, charging a 500 pF capacitor to 1 kV means that $5\cdot 10^{-7}$ coulomb of charge must be moved between the plates. That amounts to over 10^{12} charge carriers (ions of unit charge); so, doing 9 orders of magnitude less still amounts to a displacement across the membrane of maybe 10^3 ions of the kind described in KF2000! Thermal activity on these scales averages out to zero and should be ignored when describing the drift movement of so many hundreds or thousands of ions. KF2000's comments about random thermal motion must be rethought.

p. 21, VC, Field-permanent-dipole interactions. KF2000 provides an expression for torque on a membrane dipole from an electric field E, as $|torque| = E\mu\cos\theta$, with μ a dipole moment and θ the angle between the field and dipole. Then, Eq. (20) is supposed to give the response time constant τ for dipole alignment by Stokes's law as,

$$\tau = \frac{4\pi\eta a^3}{kT}, \tag{4}$$

in which a is the dipole element radius (membrane half-width), kT is Boltzmann's constant times the absolute temperature, and η is a fluid-dynamic viscosity causing the interaction to be inelastic.

The reasoning is that if the time-constant in (4) is too low, it implies that the dipole moment must be small, so very little torque can be applied, and the interaction of the field with the membrane will be small. KF2000 Table II gives data for various cell elements, showing that very large field strengths are required for significant energy transfer to the membrane.

However, the dependence on one time parameter to interface all elements of the implied system again seems to be in error: It assumes that the only membrane interaction, above some thermal threshold, must be thermal! This is an incredible assumption: If any significant heat could be stored in the membrane, it would lose structural integrity. What is the reason that energy transferred to the membrane would not be transferred to the hypothetical "Na-K pump", to a subset of the PM gating system, or simply to geometric displacement (local compression or dilation) of the membrane in some phase-related way? And why should not each conceivable channel for momentum or energy be associated with its own, arbitrary time constant?

p. 22, final paragraph of V. KF2000 states that "The mechanisms described above are well-established and noncontroversial". Yes, heat is noncontroversial as the end-product of any interaction. It is definitely a safe haven. However, the errors of concept explained in detail at the start of these comments suggest that the

use of heat by KF2000, as well as by many others in the long history cited in KF2000, must be in error. Errors of agreement can add nonlinearly with errors of understanding to produce unwarranted noncontroversy.

The present list of comments, as well as the final "paradox" discussion in KF2000, seems to show that the problem of microwave-tissue interaction, especially for UWB microwaves, is not well understood by the majority of researchers or writers who have been publishing papers in this field. Therefore, the lack of controversy claimed by KF2000 should be replaced by serious questioning of the assumptions underlying the reportedly widespread agreement.

In closing, it is interesting that KF2000 does not cite Lu *et al* (1999), who have found that UWB microwaves can cause a drop in blood pressure in rats. Speculation as to the apparently nonthermal mechanism of the Lu *et al* findings might have been interesting.

References

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