Site Visit to Naval Medical Research Institute
15 October 1984

Present: M. Marron (NY State), E. Postow (Naval Medical R & D Command), J. Thomas (NaMRI), and A. Liboff (NaMRI)

Summary: Thomas and Liboff have discovered a new effect of weak 60 Hz magnetic fields on the behavior of rats that appears ***only if the earth's static magnetic field is partially shielded.*** This stunning demonstration that an animal's response to an *alternating* magnetic field depends on the presence of *static* magnetic of appropriate intensity is consistent with several other studies reported earlier this year. Their work, when taken together with earlier studies by other groups, provides strong support for the hypothesis that static magnetic fields, similar in strength to the earth's own magnetic field, can dramatically alter the response of a living organism to alternating electromagnetic fields.

Experimental: Thomas and Liboff use a behavioral paradigm that has been successfully used before by Thomas to demonstrate subtle interactions between microwave exposure and drug effects in rats. A rat is exposed for 0.5 hr to a 60 Hz linearly-polarized magnetic field of approximately 1/2 Gauss, oriented in a plane parallel to the earth's surface. Immediately after exposure the rat is placed in an operant conditioning test box and his bar-pressing activity is monitored. The rats are rewarded with a food pellet when the bar is pressed twice at an interval of 20 s. The rats learn quite rapidly to separate most of their bar presses by 20 s and thereby minimize the number of times they must press the bar to eat.

If, for example, trained rats are given a small amount of amphetamine before being placed in the test boxes, they lose their ability to judge a 20 second interval and their bar pressing record shows and increased number of randomly spaced presses. Exposure of rats for 30 minutes to 60 Hz magnetic fields produces no discernible change in their behavior. However if the ambient earth's magnetic field present in the laboratory is reduced by about half (0.5 to 0.27 Gauss), a 30 min exposure to 60 Hz magnetic fiels causes the rats to lose their ability to judge 20 s intervals just like they do when given amphetamines. Exposure of rats to the reduced static magnetic fields without the application of 60 Hz alternating fields produces no change in behavior.

Rationale: Even more startling than the experimental results themselves is the rationale these investigators used to design an experiment involving reducing the strength of the earth's magnetic field. In July at the Bioelectromagnetic Society meeting Carl Blackman from EPA reported a suprising extension of his previously reported studies that showed calcium efflux from chick brain tissue was enhanced when the tissue was exposed to very weak electromagnetic fields at only a few specific frequencies in the range 15 to 105 Hz. Blackman reported that the specific frequencies producing a change in calcium efflux depended quite critically on the strength of the static magnetic field present at the sample during exposure to the ac fields.

Liboff noticed that the frequency and static magnetic field configurations producing a change in efflux were exactly those satisfying the cyclotron resonance condition equation:

$$w = (q/m) * B$$

when the ratio (q/m) corresponded to either Na^{+} or K^{+}. In this equation w is angular frequency, B is the magnetic field strength, q is charge, and m is mass. The cyclotron resonance frequency is the frequency a charged particle in free space will loop about a circular orbit when a magnetic field is applied perpendicular to its velocity; the force causing the particle to execute this orbit is sometimes referred to as the Lorentz force.

Liboff reasoned that if this relationship holds for Blackman's experiments it might also hold for the behavioral experiment he and Thomas were performing. He computed the magnetic field strength necessary to produce a 60 Hz resonance condition for either K^{+} or Na^{+} but found that he did not have a sufficient range on his current apparatus to reduce the ambient field enough. He did however have enough oomph to reduce the earth's field to produce a 60 Hz resonance condition for Li^{+} ions. The results stated in the experimental paragraph above were obtained with this condition.

Discussion: The biological significance of the cyclotron resonance relation is far from clear at this point. It is difficult to imagine a biological mechanism in which the Lorentz force could play a significant role beacuse of the small size of the force. For example, for a particle with a mass of Li^{+} executing a 60 Hz orbit of radius 1 micron, the energy imparted to the particle is over 12 orders of magnitude smaller than kT. Put another way, in order to impart an energy on the order kT to a Li^{+} at 60 Hz it would have orbital motion on a circle almost one meter in diameter. Of course small forces affecting lots of particles (Avogadro's number, say) can certainly produce macroscopic effects. Electrolytic conduction is an example.

What is clear is that the cyclotron resonance equation is satisfied in the case of several of Blackman's Ca^{+2} efflux experiments and one of Thomas'. This would seem to be more than coincidence. How much more remains to be seen.

M. Marron

M. Marron
16 Oct 84