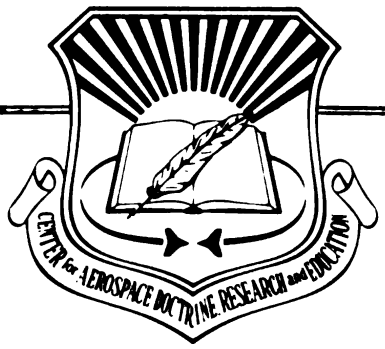

Low-Intensity Conflict and Modern Technology

LT COL DAVID J. DEAN, USAF
Editor

With a Foreword by
CONGRESSMAN NEWT GINGRICH

Air University Press
Center for Aerospace Doctrine, Research, and Education
Maxwell Air Force Base, Alabama

June 1986

Library of Congress Cataloguing in Publication Data

Low-intensity conflict and modern technology.

Papers presented at a workshop conducted by Air University Center for Aerospace Doctrine, Research, and Education (CADRE), March 1984.

Includes bibliographies.

1. Low-intensity conflicts—Congresses. 2. Munitions—Congresses. I. Dean, David J. II. Air University (U.S.). Center for Aerospace Doctrine, Research, and Education.

U104.L69 1986 355'.0218 86-3537

CONTENTS

THE ELECTROMAGNETIC SPECTRUM IN LOW-INTENSITY CONFLICT

by

Capt Paul E. Tyler, MC, USN

Although electromagnetic radiation is familiar to everyone, the prototype being visible light, and although some magnetic and "electrical" properties have been observed for centuries (the lodestone, for example), not until late in the eighteenth century did scientists identify electromagnetism for what it really is, explore its physics, and develop rational theories for its practical use. Major contributions to this field include the experiments and studies of Harvey, Helmholtz, Faraday, and Maxwell. Maxwell finally formulated the basic theory of the electromagnetic field, which Hertz later verified. Today, research on electromagnetic fields is moving in directions far different from what these pioneer scientists envisoned or attempted.

The results of many studies that have been published in the last few years indicate that specific biological effects can be achieved by controlling the various parameters of the electromagnetic (EM) field. A few of the more important EM factors that can be manipulated are frequency, wave shape, rate of pulse onset, pulse duration, pulse amplitude, repetition rate, secondary modulation, and symmetry and asymmetry of the pulse. Many of the clinical effects of electromagnetic radiation were first noticed using direct current applied directly to the skin. Later the same effects were obtained by applying external fields. Electromagnetic radiation has been reported in the literature to induce or enhance the following effects:

1. Stimulation of bone regeneration in fractures.
2. Healing of normal fractures.
3. Treatment of congenital pseudarthrosis.
4. Healing of wounds.

5. Electroanesthesia.
6. Electroconvulsive therapy.
7. Behavior modification in animals.
8. Altered electroencephalograms in animals and humans.
9. Altered brain morphology in animals.
10. Effects of acupuncture.
11. Treatment of drug addiction.
12. Electrostimulation for relief of pain.
13. Altered firing of neuronal cells.

These are but a few of the many biological effects and uses that have been reported over the past decade. They are not exhaustive and do not include many of the effects reported in the Soviet and East European literature.

As with most human endeavors, these applications of electromagnetic radiation have the potential for being a double-edged sword. They can produce significant benefits, yet at the same time can be exploited and used in a controlled manner for military or covert applications. This paper focuses on the potential uses of electromagnetic radiation in future low-intensity conflicts.

POTENTIAL MILITARY APPLICATIONS OF EMR

The exploitation of this technology for military uses is still in its infancy and only recently has been recognized by the United States as a feasible option. A 1982 Air Force review of biotechnology had this to say:

> Currently available data allow the projection that specially generated radiofrequency radiation (RFR) fields may pose powerful and revolutionary antipersonnel military threats. Electroshock therapy indicates the ability of induced electric current to completely interrupt mental functioning for short periods of time, to obtain cognition for longer periods and to restructure emotional response over prolonged intervals.
>
> Experience with electroshock therapy, RFR experiments and the increasing understanding of the brain as an electrically mediated organ suggested the serious probability that impressed electromagnetic fields can be disruptive to purposeful behavior and may be capable of directing and/or interrogating such behavior. Further, the passage of approximately 100 milliamperes through the myocardium can lead to cardiac standstill and death, again pointing to a speed-of-light weapons effect.
>
> A rapidly scanning RFR system could provide an effective stun or kill capability over a large area. System effectiveness will be a function of wave form, field intensity, pulse widths, repetition frequency, and carrier frequency. The system can be developed using tissue and whole animal experimental studies, coupled with mechanisms and waveform effects research.
>
> Using relatively low-level RFR, it may be possible to sensitize large military groups to extremely dispersed amounts of biological or chemical agents to which the unirradiated population would be immune.[1]

The potential applications of artificial electromagnetic fields are wide ranging and can be used in many military or quasi-military situations.

Some of these potential uses include dealing with terrorist groups, crowd control, controlling breeches of security at military installations, and antipersonnel techniques in tactical warfare. In all of these cases the EM systems would be used to produce mild to severe physiological disruption or perceptual distortion or disorientation. In addition the ability of individuals to function could be degraded to such a point that they would be combat ineffective. Another advantage of electromagnetic systems is that they can provide coverage over large areas with a single system. They are silent and countermeasures to them may be difficult to develop. Assuming that electromagnetic radiation can be controlled to produce a specific adverse biological effect, the equal possibility exists that one can produce a beneficial effect such as enhancing the performance of individuals. This development would provide personnel with enhanced capabilities in time of need. For example, if a small force is required to operate in isolation for an extended period of time, then local exposure to the right parameters of electromagnetic radiation may give this force the ability to do so with minimal rest and still maintain peak performance. One last area where electromagnetic radiation may prove to be of some value is in enhancing abilities of individuals for anomalous phenomena.

CLASSICAL THEORY VERSUS RECENT THEORETICAL RESEARCH

Even though the body is basically an electrochemical system, modern science has almost exclusively studied the chemical aspects of the body and to date has largely neglected the electrical aspects. However, over the past decade researchers have devised many mathematical models to approximate the internal fields in animals and humans. Some of the later models have shown general agreement with experimental measurements made with phantom models and animals. Presently most scientists in the field use the concept of specific absorption rate for dosimetry of electromagnetic radiation. Specific absorption rate is the intensity of the internal electric field or quantity of energy absorbed per unit time per unit mass. The latest edition of the *Dosimetry Handbook* discusses specific absorption rate in detail.[2] Tables 2-4 and 2-5 present the depth of penetration of various frequencies of electromagnetic radiation in biological tissues according to current electromagnetic theory. However, the use of these classical concepts of electrodynamics does not explain some experimental and clinical findings. For example, according to classical physics, the frequency of visible light would indicate that it is reflected or totally absorbed within the first few millimeters of tissue and thus no light should pass through significant amounts of tissue. But it does. Also, classical theory indicates that the body should be completely invisible to extremely low frequencies of light where a single wave length is thousands of miles long. However, visible

light has been used in clinical medicine to transilluminate various body tissues. The technique is particularly useful in observing the skulls of infants and the various sinus cavities.

A second area where classical theory fails to provide an adequate explanation for observed effects is in the clinical use of extremely low frequency (ELF) electromagnetic fields. Researchers have found that pulsed external magnetic fields at frequencies below 100 hertz will stimulate the healing of nonunion fractures, congenital pseudarthroses, and failed arthroses.[3] The effects of these pulsed magnetic fields have been extremely impressive and their use in orthopedic conditions has been approved by the Food and Drug Administration.

Recently, pulsed electromagnetic fields have been reported to induce cellular transcription.[4] At the other end of the nonionizing spectrum, research reports are also showing biological effects that are not predicted by classical theories. For example, Kremer and others have published several papers showing that low-intensity millimeter waves produce biological effects. They have also shown that not only are the effects seen at very low power, but they are also frequency specific.[5]

TABLE 2-4

Characteristics of Electromagnetic Wave Propagation in Tissues of High Water Content Represented by Muscles and Skin at Various Frequencies

Frequency MHz	Wavelength Air/Tissue cm	Depth of Penetration cm	Dielectric Constant	Conductivity mho/cm	Reflection Coefficient at Interface	
					Air/Muscle	Muscle/Fat
100	300/27	6.66	71.7	0.889	0.881 +175	0.650 −7.96
200	150/16.6	4.79	56.5	1.28	0.844 +175	0.612 −8.06
300	100/11.0	3.89	54	1.37	0.825 +175	0.592 −8.14
433	69.3/8.76	3.57	53	1.43	0.803 +175	0.562 −7.06
750	40/5.34	3.18	52	1.54	0.779 +176	0.532 −5.69
915	32.8/4.46	3.04	51	1.60	0.772 +177	0.519 −4.32
1,500	20/2.81	2.42	49	1.77	0.761 +177	0.506 −3.66
2,450	12.2/1.76	1.70	47	2.21	0.754 +177	0.500 −3.88
3,000	10/1.45	1.61	46	2.26	0.751 +178	0.495 −3.20
5,000	6/0.89	0.788	44	3.92	0.749 +177	0.502 −4.95
5,800	5.17/0.775	0.720	43.3	4.73	0.746 +177	0.502 −4.29
8,000	3.75/0.578	0.413	40	7.65	0.744 +176	0.513 −6.65
10,000	3/0.464	0.343	39.9	10.3	0.743 +176	0.518 −5.95

Source: S. Baranski and P. Czerski, *Biological Effects of Microwaves* (Stroudsburg, Pa.: Dowden, Hutchinson, and Ross, 1976).

TABLE 2-5

Characteristics of Electromagnetic Wave Propagation in Tissues of Low Content Represented by Fat and Bone at Various Frequencies

Frequency MHz	Wavelength Air/Tissue in cm	Depth of Penetration cm	Dielectric Constant	Conductivity mho/cm	Reflection Coefficient at Interface	
					Air/Fat	Fat/Muscle
100	300/10.6	60.4	7.45	19.1-75.0	0.511 +168	0.650 +172
200	150/59.7	39.2	5.95	25.8-94.2	0.458 +168	0.612 +172
300	100/41	31.1	5.7	31.6-107	0.438 +169	0.592 +172
433	69.3/28.8	26.2	5.6	37.9-118	0.427 +170	0.562 +173
750	40/16.8	23	5.6	49.8-138	0.415 +173	0.532 +174
915	32.8/13.7	17.7	5.6	55.6-147	0.417 +173	0.519 +176
1,500	20/8.41	13.0	5.6	70.8-171	0.412 +174	0.506 +176
2,450	12.2/5.21	11.2	5.5	96.4-213	0.406 +176	0.500 +176
3,000	10/4.25	9.74	5.5	110-234	0.406 +176	0.495 +177
5,000	6/2.63	6.67	5.5	162-309	0.393 +176	0.502 +175
5,900	5.17/2.29	5.24	5.05	186-338	0.388 +176	0.503 +176
8,000	3.75/1.73	4.61	4.7	255-431	0.371 +176	0.513 +173
10,000	3/1.41	3.39	4.5	324-549	0.363 +175	0.518 +174

Source: S. Baranski and P. Czerski, *Biological Effects*

As a result of these and other studies, several groups of scientists have been reevaluating their concepts and looking for new solutions. Some of the newer approaches have included the recognition that biological systems are nonlinear and rather than apply simple linear functions to the interaction of electromagnetic fields and biologicals systems, one must use nonlinear wave mechanics.[6] Some researchers have even incorporated the mathematics of chaos dynamics.[7]

The result of this rethinking has been the acceptance by many scientists that intrinsic electromagnetic fields play a key role in a wide range of biological functions, including embyrogenesis,[8] bone repair,[9] and information transfer and storage, particularly in the central nervous system.[10] In addition, many scientists and researchers have speculated as to the adverse effects of EM fields on biological systems. Some recent work using the concepts of chaos dynamics may have a major impact upon how one looks at external systems interactions with biological systems. Scientists have known for some time that chaotic behavior of systems exists in physics and chemistry. More recently its mathematics of nonlinear differential equations has been applied to biology.[11]

In simple terms, systems will behave "normally" over a wide range of conditions then suddenly shift into a chaotic mode when a single parameter (among many) moves through a critical value. Thus a tiny change in one parameter can result in drastic alterations in the behavior of a system. Dr Rapp of the Medical College of Pennsylvania has suggested that epileptic behavior and other convulsions may be the result of chaotic behavior within the central nervous system. He cites theoretical evidence that suggests that neurons and neural networks are capable of shifting into chaotic behavior. Guerara and others have recently reported the onset

of chaotic behavior in chicken heart cells when stimulated by electrical signals at specific frequencies and amplitudes.[12] It has also been shown that normal breathing takes place at certain frequencies and amplitudes, but not at others. Animals forced to breathe at certain unnatural frequencies develop severe respiratory distress.

This past year, Dr Adey has evaluated a Soviet LIDA medical instrument that has been claimed to induce sleep. The instrument can produce pulsed sound, light, heat, and electromagnetic energy. The four modalities can be used all together, singly, or in any combination of the four. Soviet medical literature contains claims that the use of the instrument will benefit "inorganically caused neuropsychic and somatic disorders, such as neuroses, psychoses, insomnia and hypertension." Their concept of what is "inorganic" is questionable and why they seem to relate hypertension with neuroses and psychoses is unknown.

According to Dr Adey's report, electromagnetic fields may induce a slower rate of state transitions in cats. The electromagnetic field alone was capable of prolonging particular sleep states. The efficacy of the EM field alone to prolong a sleep state was less than when combined with either visual or auditory stimuli. The use of visual and auditory stimuli without the electromagnetic field also shifted sleep patterns to deeper levels, but did not alter rates of state transitions. Dr Adey felt that there may be a synergistic action between the electromagnetic field and the rhythmic sensory stimuli to achieve sustained states at one sleep level—a condition that was not present when any single stimulus was delivered alone.[13]

The instrument used in the Soviet experiments was considered to be of 1950s technology, using a self-excited oscillator and vacuum tubes. The center frequency was 40 megahertz, but harmonic and spurious radiations in excess of 1 gigahertz were noted. The pulse duration was 0.3 seconds with a repetition rate of 10 to 100 pulses per minute. Reports in the literature state that many newer and more effective models have been developed.

In a recent paper, Ubeda, Delgado, and others reported that the pulse shape of a pulsed magnetic field has an influence upon the development of chick embryos.[14] They reported that using four different-shaped pulses resulted in differing effects on the embryos. The first signal had a rise time of 100 microseconds with a declining plateau. The second signal was basically a square wave with a rise time of 2 microseconds. The third had a rise time of 42 microseconds with a secondary modulation throughout the signal. The fourth signal also had a rise time of 42 microseconds without the superimposed modulation. All pulses had a 500-microsecond duration and a repetition rate of 100 hertz. The results showed that some wave forms interfered with embryogenesis while others did not. A windowing effect was also noted with the exposure intensities; some effects were noted at low intensities but not at higher intensities.

Windowing of both frequency and power amplitude have also been reported by other investigators.[15] This phenomenon was first reported by Adey and his coworkers in the early seventies, but until recently has not been widely accepted as an important parameter. The specific wave form and windowing of both the

frequency and amplitude may have very specific biological targets and effects. Bassett has reported that in his laboratory recent studies have shown that the voltage wave form induced by a given pulse appears characteristically different in various tissues and organs. He goes on to state that it is possible to identify the tissue type by an analysis of the frequency response pattern, using fast Fourier transforms.[16]

Most scientists in the United States have discounted many of the Soviet reports that exposure to low levels of electromagnetic radiation causes these types of biological effects. Until recently many scientists believed both that thermal heating was the only mechanism which could produce biological effects and that levels reported in the Soviet and East European literature could not induce a significant thermal burden in the human body and thus could not produce any biological effects. The second major reason for disbelief was the attempt by early researchers to duplicate some of the Soviet research and their failure to find similar results. These failures to replicate the Soviet work were the result of several factors, which included the lack of sufficient details in the Soviet reports as to their exact protocols; lack of similar equipment; use of different frequencies; and use of higher power levels and finding no effects, and so assuming—without checking—that lower levels would also show no effects. And in some cases the reports were not valid in the first place. Even in the Soviet literature one finds many contradictions and so must read and evaluate it with a critical eye.

Current research in chaotic behavior has shown that the alternation of only one parameter to a critical phase can induce chaotic behavior with drastic outcomes. It is not too difficult to envision that electromagnetic systems could interact with the electrical signal in cardiac muscle. If the proper parameters were utilized, several possible results could be produced. These include auricular or ventricular fibrillation, or complete asystole with a resultant fatal outcome.

Past research has shown both altered behavior in animals and altered electroencephalograms (EEG) in both humans and animals. What these EEG changes mean in practical terms to humans at the present time is difficult to say, since we still lack a great deal of knowledge and there is much controversy about what a "normal" EEG means. It is currently impossible to understand and to predict how an altered EEG can influence behavior and the cognitive processes of an individual. Some current research provides a few clues that altering brain waves can have a major impact on a person's cognitive and overt behavior. In this regard, some people have even speculated that electromagnetism has already been used for this purpose.[17]

Some recent theoretical research has looked at the classical neuronal synapse and proposed that the size of the synaptic space is so small that rather than a pure chemical event taking place, it must be a quantum mechanical event. Classically it has been assumed that an action potential transverses down the axion and directly stimulates the vesicules to release their chemical neurotransmitters, which then cross the synapse and trigger the second neuron to fire its action potential. If it is true that the event is quantum mechanical in nature then the following events may

be taking place rather than events envisioned in the classical chemical concept: The action potential descends down the axion and produces a bias across the synaptic junction, which then induces electron tunneling in the reverse direction, which in turn causes a confirmational change in the vesicules. This confirmational change causes the vesicules to release their neurotransmitter. This mechanism also involves leakage currents from nearby neurons and perineuronal cells. The cells are "talking" to each other so that the system is far more complex than once thought. These quantum mechanical events, being statistical in nature and depending upon crosstalk from other cells instead of a pure internal electrical conductance within the single cell, infer that the complex system will be susceptible to external nonlinear electromagnetic influences. The disruption of neural pathways can lead to a multitude of effects. With today's sophisticated weapon systems, one does not have to totally disable individuals to render them ineffective for combat. For example, if their timing is altered or their cognitive processes are degraded these individuals may be unable to operate their equipment (fly their aircraft, make the proper decision with computer-operated systems, or successfully complete related action).

Because of the many parameters involved and the apparent specificity of each parameter, one can tailor a specific response. The ability to have this kind of flexibility provides an enormous range of options to the user. It opens the door for providing an appropriate response in warfare, be it conventional or unconventional. There are still many unanswered questions concerning this technology. To date, the vast majority of research done in this country has focused on using single frequency sources with standard parameters. No one has used multiple frequencies during a single exposure, nor has anyone tried to manipulate the parameters to produce biological effects. Up to the present time the majority of scientists in the United States have assumed that a "microwave is a microwave," and research done at one frequency would be applicable to any frequency in the same region. We now know that the experiment must be frequency specific, but how specific? Does this change for various portions of the electromagnetic spectrum? There are unconfirmed reports that a change of .01 hertz can make a difference. Most scientists still do not believe that this small a change in frequency will make a difference. Yet, Rapp has shown that a frequency-encoded signal can act as a trigger for the release of amylase from the salivary glands of the blowfly (Calliphora exythocephalla). The variation in the frequency that modified the release of the enzyme was from 0.00 hertz to 0.056 hertz. In this study the stimulus was the chemical 5-hydroxytryptaime. What is of particular interest is that the original chemical interaction was converted to a digital frequency oscillation. The general reaction was analog to digital and back to analog.[18] A fundamental question is, could the same response be obtained by bypassing the initial chemical (analog) input and stimulate the cell directly with and electromagnetic signal at these same frequencies. The results of this experiment certainly indicate that a narrow specific frequency may be required to obtain specific results.

Contrary to the Soviets' materialistic approach to this area and their utilization of electromagnetic radiation as an explanation for all such events, it is doubtful that

most such events can be attributed to electromagnetic fields. Nevertheless, the evidence does indicate that certain functions and capabilities in the area can be enhanced with the proper use of electromagnetic fields. But, again this area has received very little attention. Certainly adequate research by competent scientists has not been done.

A large portion of this paper may read like Buck Rogers and the twenty-first century. Many readers will say that some of the ideas and concepts do not fit with their current concepts and theories of physics and biology. This may be true in part, but then most of the medical science I learned in medical school more than 25 years ago is not valid today. Certainly the concepts in this paper will not fit with classical physics. One is reminded of the trite saying that the science fiction of today is the scientific facts of tomorrow. I think this philosophy was elegantly stated by Werner Eisenberg in a speech given in 1934.

> Now that we know all our journeying can only bring us back to our starting point, we realize that we are unable to reach full understanding no matter how far we travel. The infinity of the universe lies outside this path. In quite a similar way modern physics has shown that the structure of classical physics—as that of modern physics—is complete in itself. Classical physics extends just as far as the conceptions which form its basis can be applied. But these conceptions already fail us when applied to the processes of nuclear physics, and much more so in the case of all fields of science which are even further removed from classical physics. Thus the hope of understanding all aspects of intellectual life on the principles of classical physics is no more justified than the hope of the traveler who believes he will have obtained the answer to all problems once he has journeyed to the end of the world.
>
> Yet the misunderstanding, that the transformations in exact science have brought to light certain limits to the application of rational thinking, must immediately be countered. A narrower field of application is given to certain ways of thought only, and not to rational thought in general. The discovery that the earth is not the world, but only a small and discrete part of the world, has enabled us to relegate to its proper position the illusory "end of the world" concept, and instead to map the whole surface of the earth accurately. In a similar way modern physics has purged classical physics of its arbitrary belief in its unlimited application. It has shown that some parts of our science, e.g., mechanics, electricity, and quantum theory, present scientific systems complete in themselves, rational and capable of complete investigation. They state their respective natural laws, probably correctly, for all time. The essence of this statement is given by the phrase "completeness in itself" (Abgeschlossenheit). The most important new result of nuclear physics was the recognition of the possibility of applying quite different types of natural laws, without contradiction, to one and the same physical event. This is due to the fact that within a system of laws which are based on certain fundamental ideas only certain quite definite ways of asking questions make sense, and thus, that such a system is separated from others which allow different questions to be put. Thus, the transition in science from previously investigated fields of experience to new ones will never consist simply of the application of already known laws to these new fields. On the contrary, a really new field of experience will always lead to the crystallization of a new system of scientific concepts and laws. They will be no less capable of rational analysis than the old ones, but their nature will be fundamentally different. It is for this reason that modern physics adopt an attitude very different from classical physics toward all those fields not yet included in its investigations. Let us, for example, consider the problems concerned with the existence of living organisms. From the standpoint of modern physics, according to Bohr, we should expect the laws characteristic of these organisms to be separated from the purely physical laws in a rational and accurately comprehensive manner, just as, say quantum theory is

separated from classical mechanics. A similar solution will, on a smaller scale, apply to the investigation into the properties of the atomic nucleus, which occupies the center of interest in contemporary physics. The edifice of exact science can hardly be looked upon as a consistent and coherent unit in the naive way we had hoped. Simply following the prescribed route from any given point will not lead us to all other rooms of this building; for it consists of specific parts, and though each of these is connected to the others by many passageways and each may encompass some others or be encompassed by others, nevertheless each is a unit complete in itself. The advance from the parts already completed to the newly discovered, or to be newly erected, demands each time an intellectual jump, which cannot be achieved through the simple development of already existing knowledge.[19]

NOTES

1. *Final Report on Biotechnology Research Requirements for Aeronautical Systems Through the Year 2000*, AFOSR-TR-82-0643, vol. 1 and vol. 2, 30 July 1982.

2. C. E. Durney, M. F. Iskander, H. Massoudi, S. J. Allen, and J. C. Mitchell, *Radiofrequency Radiation Dosimetry Handbook*, 3d ed., SAM-TR-80-32, Brooks AFB, Texas (1980), 136.

3. For detailed discussions of this research, see C. A. L. Bassett, A. A. Pilla et al., "A Nonoperative Salvage of Surgically Resistant Pseudarthroses and Nonunions by Pulsing Electromagnetic Fields," *Clinical Orthopaedics* 124 (1977), 128–43; C. A. L. Bassett, N. Caulo et al., "Congenital 'Pseudarthroses' of the Tibia—Treatment with Pulsating Electromagnetic Fields," *Clinical Orthopaedics* 154 (1981), 136–49; C. A. L. Bassett, S. N. Mitchell et al., "Treatment of Ununified Tibial Diaphyseal Fractures with Pulsating Electromagnetic Fields," *Journal of Bone Joint Surgery* 63:A (1981), 511–23; C. A. L. Bassett, S. N. Mitchell et al., "Pulsing Electromagnetic Field Treatment in Ununited Fractures and Failed Arthroses," *Journal of American Medical Association* 247 (1982), 623–28; C. A. L. Bassett, "Biomedical Implications of Pulsing Electromagnetic Fields," *Surgical Rounds* (January 1983), 22–31; J. S. Kort et al., "Congenital Pseudarthrosis of the Tibia: Treatment with Pulsing Electromagnetic Fields, The International Experience," *Clinical Orthopaedics* 165 (1982), 124–37; L. Sedel, P. Christel et al., "Resultants de le stimulation par champ electromagnetique de la consolidation des psuedarthroses, apropos de 37 cas," *Review of Chiropractic Orthopaedics* 67 (1981), 11–23; W. J. Sharrard, M. L. Sutcliffe et al., "The Treatment of Fibrous Nonunion or Fractures by Pulsing Electromagnetic Stimulation," *Journal of Bone Joint Surgery* 64:B (1982), 189–93; and M. L. Sutcliffe and A. A. J. Goldberg, "The Treatment of Congenital Psuedarthrosis of the Tibia with Pulsating Electromagnetic Fields, A Survey of 52 Cases," *Clinical Orthopaedics* 166 (1982), 45–57.

4. R. Goodman, C. A. L. Bassett, and A. S. Henderson, "Pulsing Electromagnetic Fields Induce Cellular Transcription," *Science* 220 (17 June 1983): 1283–85.

5. F. Kremer, C. Koschnitzke, L. Santo, P. Quick, and A. Paglitsch, "The Nonthermal Effect of Millimeter Wave Radiation on the Puffing of Giant Chromosomes," in H. Frohlich and F. Kremer, eds., *Coherent Excitations in Biological Systems* (Berlin: Spinger-Verlag, 1983).

6. A. F. Lawrence and W. R. Adey, "Nonlinear Wave Mechanisms in Interactions Between Excitable Tissue and Electromagnetic Fields," *Neurological Research* 4:1/2 (1982), 115–53.

7. P. E. Rapp, A. I. Mees, and C. T. Sparrow, "Frequency Encoded Biochemical Regulation Is More Accurate Than Amplitude Dependent Control," *Theoretical Biology* 90 (1981), 531–44.

8. J. M. R. Delgado, J. Leal, J. L. Monteaguo, and M. G. Garcia, "Embryological Changes Induced by Weak, Extremely Low Frequency Electromagnetic Fields," *Journal of Anatomy* 134 (1982), 533–51.

9. Bassett, Pilla et al., "Nonoperative Salvage"; Bassett, Caulo et al., "Cogenital 'Pseudarthroses' "; Bassett, Mitchell et al., "Treatment"; Bassett, Mitchell et al., "Pulsing Electromagnetic Field Treatment"; and Bassett, "Biomedical Implications."

10. Kort et al., "Cogenital Psuedarthroses."

11. M. R. Guerara, L. Glass, and A. Shrier, "Phase Lacking, Period-Doubling Bifurcations and Irregular Dynamics in Periodically Stimulated Cardiac Cells," *Science* 214 (1981), 1350–53.

12. Ibid.

13. W. R. Adey, "Possible Behavioral Effects Produced by Pulsed RF Fields from Soviet 'LIDA' Medical Therapy Instrument," contract report N60921, NSWC, October 1983.

14. A. Ubeda, J. Leal, M. A. Trillo, M. A. Jimanez, and J. M. R. Delgado, "Pulse Shape of Magnetic Fields Influence Chick Ebryogenesis," *Journal of Anatomy*, in press.

15. W. R. Adey, "Tissue Interactions with Nonionizing Electromagnetic Fields," *Physiology Review* 61 (1981), 435–514; S. M. Bawin, W. R. Adey, and I. M. Sabbot, "Ionic Factors in Release of ^{45}Ca from Chicken Cerebral Tissue by Electromagnetic Fields," *Proceedings of National Academy of Science (USA)* 75 (1978), 6314–18; S. M. Bawin, L. K. Kaczmarek, and W. R. Adey, "Effects of Modulated VHF Fields on the Central Nervous System," *Annals of NY Academy of Science* 247 (1975), 74–81; C. S. Blackman, J. A. Elder, C. M. Weil, S. G. Beunane, D. C. Eichinger, and D. E. Hause, "Induction of Calcium Ion Efflux from Brain Tissue by Radiofrequency Radiation: Effects of Modulation Frequency and Field Strength," *Radio Science* 14 (1979), 93–98.

16. Bassett, "Biomedical Implications."

17. M. Ebon, *Psychio Warfare* (New York: McGraw-Hill, 1983), 118–20.

18. Rapp, Mees, and Sparrow, "Frequency Encoded Biochemical Regulation."

19. Werner Eisenberg, speech to the first general session on the occasion of the general meeting of the Gesellschaft duetscher Naturforscher and Aserzte, Hanover, 17 September 1934. Originally published in Naturwissenschaften 1934, 22 Jabrg., Heft 40.

OTHER REFERENCES

E. Aarholt, E. A. Flinn, and L. W. Smith, "Magnetic Fields Affect the Lac Operon System," *Physics, Medicine, and Biology* 27 (1982), 606–10.

W. R. Adey, "Models of Membranes of Cerebral Cells as Substrates for Information Storage," *Biosystems* 8 (1977), 163–78.

S. M. Bawin, A. R. Sheppard, and W. R. Adey, "Possible Mechanism of Weak Electromagnetic Field Complexing in Brain Tissues," *Bioelectrochemistry. Biogenetics* 5 (1978), 67–76.

G. Collaccio and A. A. Pilla, "Electromagnetic Modulatran of Biological Processes: Chemical, Physical, and Biological Correlates in the Ca- Uptake by Embyronal Chick Tibia *in vitro*," *Bioelectrochemistry. Biogenetics* 10 (1983), 119–31.

Dixie R. Rein G., "Noradrenaline Release Potentiated in a Cloral Nerve Cell Line by Low-Intensity Pulsed Magnetic Fields," *Nature* 196 (1982), 253–56.

K. Gary, A. A. Dilla, and C. Mayand, "Induced Pulsating Currents Affect Membrane Bound Enzyme Kinetics: Applications of Na+K+ATPase Using New Flow System," *Journal of Electrochemistry Society* 130 (1983), 120c.

R. A. Luben, C. D. Cain, D. M. Rose, and W. R. Adey, "Effects of Electromagnetic Stimuli on Bone and Bone Cells *in vitro:* Inhibitions of Responses to Parathyroid Hormone by Low-Energy, Low-Frequency Fields," *Proceedings of National Academy of Science (USA)* 79 (1982), 4180–84.

L. A. Nortan, A. Shteyer, and G. A. Rodon, "Electromagnetic Field Effects on DNA Synthesis in Bone Cells," *Journal of Electrochemistry* 127 (1980), 129c.

A. A. Pilla, "The Rate of Modulation of Cell and Tissue Function via Electrochemical Information Transfer," in R. O. Becker, ed., *Mechanism of Growth Control* (Springfield, Ill.: C. C. Thomas Press, 1982), 211–36.