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An analysis of the military services protective measures, both physical and administrative, is made.

Investigation reveals that there are several areas in which the individual services could improve their protective measures by adopting measures in use in other services.

Recommendations as to corrective measures are suggested.

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Protecting Military Personnel and The Public
from the Hazards of Electromagnetic Radiation
from Military Communications and Radar Systems

Stephen A. Oliva, MAJ, USA
U.S. Army Command and General Staff College
Fort Leavenworth, Kansas 66027

Final Report 8 June 1979

Approved for Public Release; Distribution Unlimited

A Master of Military Art and Science thesis presented to the faculty of the U.S. Army Command and General Staff College, Fort Leavenworth, Kansas 66027

PROTECTING MILITARY PERSONNEL AND THE PUBLIC FROM THE HAZARDS OF ELECTROMAGNETIC RADIATION FROM MILITARY COMMUNICATIONS AND RADAR SYSTEMS

A thesis presented to the Faculty of the U.S. Army Command and General Staff College in partial fulfillment of the requirements for the

MASTER OF MILITARY ART AND SCIENCE

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Accepted this 8th day of June 1979 by

Philip J. Brookes, Director, Graduate Degree Programs.

The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

PROTECTING MILITARY PERSONNEL AND THE PUBLIC FROM THE HAZARDS OF ELECTROMAGNETIC RADIATION FROM MILITARY COMMUNICATIONS AND RADAR SYSTEMS, by Major Stephen A. Oliva, USA, 114 pages.

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CHAPTER I

INTRODUCTION

The research in this thesis has as its objective the improvement of the protection provided by the military services to military personnel and members of the general public from the hazards of electromagnetic radiation (EMR) of military communications and radar systems. Hazards from EMR emitted by systems not used for communications or as radar, but operating in the same frequency range, will be considered.

All EMR emitters with output levels of sufficient strength may be potentially hazardous, providing safety criteria are not observed. Communications and radar systems are the most numerous emitters of EMR in use by the military services. These systems are limited to a frequency range from 30 Hertz(Hz) to 300 Gigahertz(GHz). Therefore, this research will concentrate on only that subdivision of EMR, and not be concerned with EMR above 300 GHz, such as infrared, visible, and ultraviolet radiation.

An examination of the protection provided by the military services from the possible hazards of EMR is necessary at this time because of recent questioning of the adequacy of existing safety criteria. Concern over the possibility of physical damage to humans has led to the recent publication of a book that alleges that the government and the electronics industry are deliberately covering up the hazards of EMR. The book graphically states:

> Microwave radiation is more than kitchen ovens. It is radar, television, telephone and satellite communications. It is diathermy machines, burglar alarms, and garage-door openers. Microwave and radio-frequency heating is used in the manufacture of shoes, for bonding plywood, for roasting coffee beans, for killing weeds and insects, and in hundreds of other industrial and agricultural processes. Microwaves provide a vast arsenal of weapons for total electronic warfare.
>
> Microwave radiation can blind you, affect your behavior, cause genetic damage, even kill you. The risks you run have been hidden from you by the Pentagon, the State Department, and the electronics industry. With this book, the microwave cover-up is ended.[1]

Brodeur, in writing this conception of the hazards of EMR, has succeeded in affecting public attitudes and perceptions concerning EMR. This was shown by the reaction in New York following the publishing of his book. New York City has instituted a moratorium on the construction of microwave transmission towers. The city has also proposed an amendment to their health code setting a maximum exposure level for public areas of $50 mW/cm^2$ from 10MHz to 300GHz. This level is 1/200 of today's standard.[2]

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[1] Paul Brodeur, The Zapping of America: Microwaves, Their Deadly Risk, and the Cover-Up, (1977), preface.

[2] H. Sobel, "President's Message," IEEE Society on Microwave Theory and Techniques Newsletter, 91 (Fall 1978), 1.

Recent newspaper articles have shown that many segments of society in the United States are concerned with the effects of EMR. Protestors have used vandalism and shooting in an attempt to stop the installation of high voltage power lines, which emit EMR in the extremely low frequency range.[3] Other articles have shown concern over the effects of EMR on the part of the United States General Accounting Office,[4] and the Retail Clerks International Union.[5]

Actual cases of physical injury attributed to EMR have reached the courts. Veterans have filed claims alleging that cataracts and other eye defects are the result of chronic exposure to low level EMR while in the service. Several claims have been settled and involved payments in excess of $100,000.[6]

The military services are deeply involved in the operation of devices which emit EMR. Many military communications and radar systems, as well as other types of systems

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[3] "Power Line Sparks Strong Protest," The Kansas City Star, November 27, 1978, 30.

[4] "Microwave Safety Rules Hit," The Kansas City Star, December 12, 1978, 6.

[5] "Microwave Hazard in Stores Claimed by Retail Union," Electronic Engineering Times, December 25, 1978, 1-2.

[6] "Proposed Program for Biomedical Research of Electromagnetic Radiation Effects, June 1975," enclosure to Memorandum for: Assistant Director for Environment and Life Sciences, Office of the Director of Defense Research and Engineering (June 11, 1975), section IIB (pages unnumbered).

which operate in the same frequency range, may emit potentially hazardous levels of EMR. The services are constantly adding systems which emit EMR to the equipment they acquire and operate.

The military services have many regulations, instructions, guidance, and standards concerned with protection of personnel from the hazards of EMR. This paper seeks to answer the question "How can the military services improve the EMR hazard protection provided to military personnel and the public?" To answer this question, the nature of EMR must be considered along with the extent of the actual hazard created by EMR. The military involvement with EMR emitting systems and research into the hazards of EMR must be known. Then, a review of protective measures of the services may be accomplished in an attempt to answer the above question.

In Chapter II, the nature of electromagnetic radiation with respect to its interactions with biological matter is briefly reviewed to form the basis for examining the problem of the EMR hazard.

In Chapter III, the importance of protection from the EMR hazard is examined by means of reviewing the extent of the hazard at various frequencies. The extent of this hazard is established by examining the observed effects of EMR on biological systems, factors which contribute to the enhancement or lessening of these effects, and the present standards of safety in the United States. Also examined are standards of safety in other countries, and the reasons for the differences in standards among countries. The purpose of this chapter will be to determine the extent to which protection must be provided by the military services.

In Chapter IV, the degree of involvement of the military services with systems that emit EMR and with research into the hazards of EMR is examined.

The military services utilize large portions of the electromagnetic spectrum. Submarine communications, long and short distance voice and code communications, aircraft and space communications, radio relayed telephone communications, radio navigation radar, and meteorological aids form the majority of applications. In addition, the Navy is interested in the Extremely Low Frequency portion of the spectrum, and has established experimental systems, for submarine communications. All services use microwave food processing devices which are potentially hazardous if not properly controlled. The military use of certain frequency bands overlaps the civilian use of these bands in some areas, such as FM broadcasting and television. The military use of these frequency bands involves systems ranging in power output from a few milliwatts to many megawatts. Types of existing and proposed systems and systems in development are examined to determine types of military systems for which protection is required.

In Chapter V, the present protective measures in use in the military services are reviewed. The overall effectiveness of the military services' effort to provide protection is analyzed by conducting a comparison of various protective measures in use. Instances where one or more military service is not utilizing a protective measure used by one of the other services are noted.

In Chapter VI, the conclusions and recommendations are presented.

CHAPTER II

ELECTROMAGNETIC RADIATION

In this chapter, the nature of electromagnetic radiation and its interaction with matter, including biological matter, is examined, and common terms concerning the electromagnetic spectrum are explained.

PHYSICAL CHARACTERISTICS OF ELECTROMAGNETIC RADIATION

About 1860, James C. Maxwell showed the relationship between moving electric charges in a wire and the creation of magnetic and electric fields in space around the wire. If the charges in the wire were made to flow in alternate directions at a given rate, or frequency, the changes of electric and magnetic field intensities would be propagated through space as electromagnetic waves. Maxwell's theories established the electromagnetic nature of light, which explained how light could travel through a vacuum. Based on his theories, Maxwell predicted the existance of radio waves in 1864. Twenty years later, Hertz confirmed Maxwell's theories by producing and detecting radio waves experimentally. Radio waves were shown to propagate at the speed of light, and radio waves and light were shown to be essentially the same.

The frequency and the wavelength of an electromagnetic wave traveling through a given material was determined to be related by the formula:

$$C = F\lambda$$

where C = the speed of light in the material

F = the frequency of the electromagnetic wave

λ = the wavelength of the electromagnetic wave

Although the mechanisms for creating radio waves had been observed, the mechanisms for creating light, and the even higher frequency waves of ultraviolet, x-rays, and gamma rays, were not known until after 1900, when Planck's quantum hypothesis became accepted. The hypothesis predicted the manner in which energy is transferred from a radiating body into a "beam" of radiation, or electromagnetic wave. Planck assumed that radiation is emitted only in discreet amounts called <u>quanta</u>, and that at a given frequency <u>quanta</u> all possess the same amount of energy. Thus, the amount of energy contained in electromagnetic waves, or electromagnetic radiation (EMR) depends on the frequency of the radiation. When considering the direct interaction of EMR with matter, the radiation is considered to have the properties of a particle, called a photon, which has a certain amount of energy and travels with a speed C (defined above).

Thus, EMR may be considered to be a wave or a particle, depending on whether it is traveling through space or interacting directly with matter. When speaking of the energy contained in EMR, it has become customary to use the quantity of energy known as the electron volt (ev), which is defined as the amount of energy an electron will acquire if it is moved by electric forces through a potential differences of one volt.

For radiation for which the photon energy is high enough, direct interactions with matter which displace electrons from the atoms of the matter are possible. The energy needed to displace an electron from an atom varies from a low of 3.87ev for Cesium to a high of 24.46ev for Helium.[1] At 300 GHz, the highest frequency with which this paper is concerned, the photon energy is .00124ev, three orders of magnitude too low to interact directly with atoms.[2]

Thus, below 300 GHz, the wave nature of EMR is all that need be considered when determining interactions with matter. Although this may seem obvious, the fact the electromagnetic radiation is called "radiation" could cause it to be confused with nuclear radiation. The fact is that EMR in the frequency range discussed in this paper is "non-ionizing radiation" as opposed to nuclear or "ionizing" radiation, and thus interacts with matter in a different manner than nuclear radiation.

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[1]Reference Data for Radio Engineers (1973), pp. 4-2 through 4-5.

[2]Reference Data for Radio Engineers (1973), p. 37-2.

To determine the physical effects of EMR when it interacts with matter, the characteristics of electromagnetic radiation in non-conducting (dielectric) and conducting media must be considered. In general all media through which an electromagnetic wave may travel have the physical characteristics of permittivity (ε), permeability (μ) and conductivity (σ).

An electromagnetic wave, upon striking an interface between two media of dissimilar characteristics will be partially reflected and will partially penetrate the new media. If the media is a conductor, an electromagnetic wave in traveling through it will give up some of its energy, creating currents, resulting in heating of the conducting media. This relationship is shown in Figure 1, for an electromagnetic wave leaving a non-conducting media (such as air) and entering a conducting medium.

The strength of the transmitted wave upon first entering the conducting media, and the distance into the media which the wave travels before being absorbed and having its energy transformed to heat is dependent primarily on the conductivity of the material.

Another important consideration in determining the behavior of EMR in a given material is the frequency of the EMR, since the physical characteristics of many materials change with frequency. An example is sea water, which acts like a conductor below approximately 10MHz, but acts like a

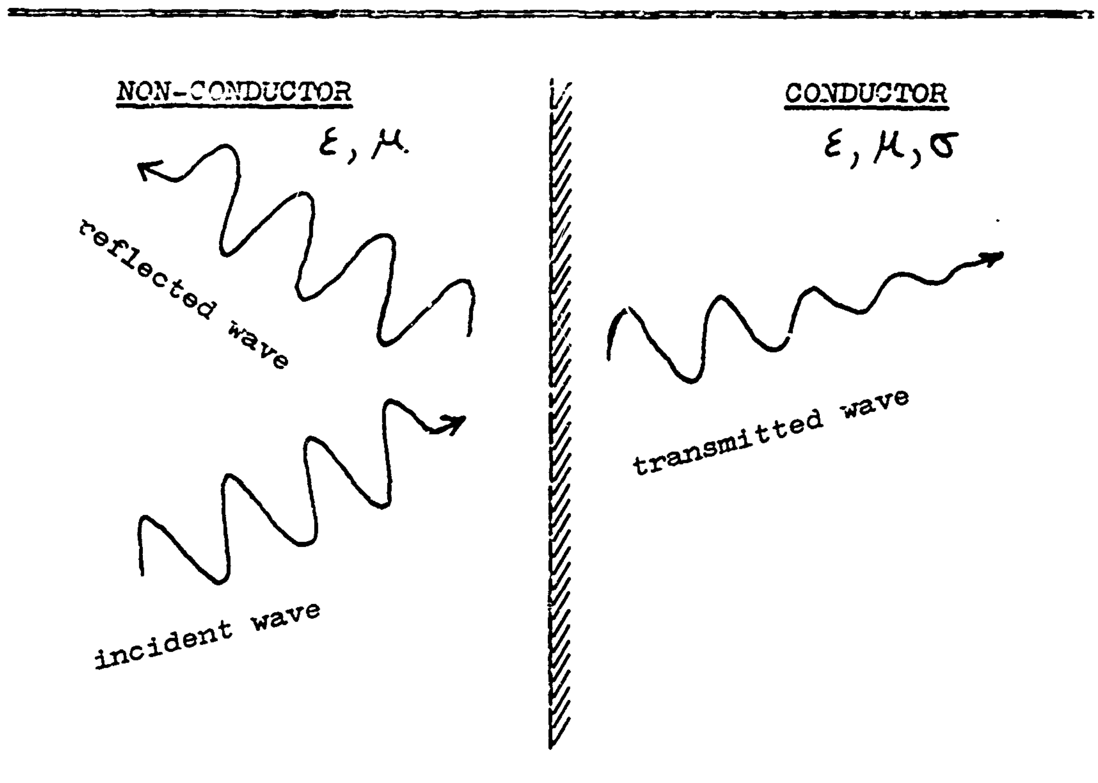

Figure 1. Electronicmagnetic Wave incident on a conducting plane.

dielectric above 100 GHz.[3] This simply means that at different frequencies EMR of the same power density will be reflected from and transmitted through a given material in different manners. Thus, the energy absorbed in biological material will chiefly be dependent on the frequency of the EMR. Other factors, such as the size and shape of the organism, and its orientation with respect to the incident EMR, will also affect the total energy absorbed.

Another method of transferring energy from an electromagnetic field to a partially or non-conducting media is through the interaction of a field with a polar molecule (for example, water). Polar molecules tend to align themselves with an electric field. If the field is rapidly oscillating, polar molecules will also oscillate, if given the freedom to do so by the physical structure in which they are constrained. This oscillation of polar molecules results in the transformation of electrical field energy into kinetic energy, creating heat. This effect is also highly frequency dependent, as given polar molecules can only oscillate to certain frequencies, based on physical constraints.

THE ELECTROMAGNETIC SPECTRUM

The Electromagnetic Spectrum is usually broken down into several sub-regions, based on frequency, as shown in

[3] J. W. Kraus, Electromagnetics (1953), 391-394.

Figure 2.

In addition, sections of the spectrum have received common names, also shown.

Since the physical characteristics of biological matter are different in different frequency ranges, any possible hazard to members of the military and the general public will be dependent on the frequency range of the system being considered. The possible hazards of EMR at various frequencies will be discussed in Chapter III.

	BAND NUMBER	FREQUENCY RANGE	COMMON NAME
	1	3 - 30 Hertz	Un-named
	2	30 - 300 Hertz	Extremely Low Frequency (ELF)
	3	300 - 3000 Hertz	Voice Frequency (VF)
Radio Frequencies	4	3 - 30 Kilohertz	Very-low Frequency (VLF)
	5	30 - 300 Kilohertz	Low Frequency (LF)
	6	300 - 3000 Kilohertz	Medium Frequency (MF)
	7	3 - 30 Megahertz	High Frequency (HF)
	8	30 - 300 Megahertz	Very-high Frequency (VHF)
Microwaves	9	300 - 3000 Megahertz	Ultra-high Frequency (UHF)
	10	3 - 30 Gigahertz	Super-high Frequency (SHF)
	11	30 - 300 Gigahertz	Extremely High Frequency (EHF)
	12	300 - 3000 Gigahertz	Un-named

Figure 2. The Electromagnetic Spectrum

CHAPTER III

THE ELECTROMAGNETIC RADIATION HAZARD

An indicator of the total growth of devices and systems which emit electromagnetic radiation (EMR) is the increase in commercial radio and TV stations from 936 in 1945 to over 8,000 at the present time. The proliferation of Citizens Band Radio sets to an estimated 15 million units, the vast increases in civilian and military communications systems, radars, air traffic control systems, and even microwave ovens,[1] also show the usefulness of EMR emitting devices to modern society.

Although science fiction writers postulated the possibility as early as 1951,[2] the fact that EMR may pose hazards to the health of man at other than extremely high levels has only been known for a relatively short time. Only since the late 1950's has much research been accomplished, and standards of safe exposure been established.

In addition to Brodeur, who attacks present safety standards and demands more research, as shown in Chapter I,

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[1] Paul Brodeur, The Zapping of America: Microwaves, Their Deadly Risk, and the Cover Up (1977), 7-12.

[2] Robert A. Heinlein, Three by Heinlein: The Puppet Masters; Waldo; Magic, Incorporated (1951), 226-227 and 233-234.

professional scientists have also found reason to doubt the adequacy of the standards.[3] The following sections will discuss the hazards and existing safety standards.

DEFINING THE HAZARD

The energy from EMR which strikes any material (including biological organisms such as animals, plants and man) may be affected by being reflected from the material, transmitted through the material, or absorbed. It is possible to have all three things happen simultaneously, i.e., some of the energy from the EMR may be absorbed, while some is being reflected and some transmitted. The behavior of EMR below a photon energy level of approximately three electron volts is said to be non-ionizing, since the photon energy of the EMR is so small that there is no ionization of component atoms and molecules when the energy is absorbed in biological material. There is, therefore, no necessary relation between the effects of ionizing (nuclear) radiation and non-ionizing radiation.

Thermal Effects

When EMR energy is absorbed by a biological organism, the energy is converted to heat. Effects caused by the heating of biological material exposed to EMR are called

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[3]Richard A. Tell, "Broadcast Radiation: How Safe is Safe?" IEEE Spectrum, 9 (August 1972), 43-51.

Thermal effects.[4] The heat thus produced may affect the composition or functioning of biological systems in many possible ways and is generally manifested by a rise in temperature. The thermal effects are a function of the actual average power absorbed by a particular material, and are not directly due to the field intensity to which the material is exposed, since some of the energy will not be absorbed, as discussed above. The field intensity or the power density (or power flux density)[5] of the EMR is thus only one of the factors contributing to total absorbed energy of a given organism, and thus to thermal effects.

Factors Contributing to Absorption of EMR

Effects on biological systems caused by EMR are due to a combination of many factors in addition to the field strength or power density of the field to which the system is exposed. These additional factors include:

a. The depth of penetration of the EMR, which is a function of permittivity (ε) and conductance (σ) of the biologic material, depending on the frequency of the EMR.[6]

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[4]Joseph H. Vogelman, "Physical Characteristics of Microwave and other Radio Frequency Radiation," in Biological Effects and Health Implication of Microwave Radiation, BRH/DBE 70 - 2 (June 1972), 7-12.

[5]For a discussion of the definitions of field intensity and power density, see Appendix A.

[6]Herman P. Schwan, "Interaction of Microwave and Radio Frequency Radiation with Biological Systems," IEEE Transactions on Microwave Theory and Techniques, MTT - 19 (1971), 147.

b. The size and orientation of the biological subject with respect to the wavelength and incident direction of the EMR.[7]

c. Reflection characteristics of surrounding environment in regard to the biological material receiving reflected energy from several directions, thus contributing to a higher total energy absorption than might be expected from the incident EMR.

d. The location of the biological subject in relation to being in the near field or the far field of the radiating antenna. (See Appendix A for definitions).

Factors Contributing to the Thermal Hazard

The effects on biological systems due to absorption of EMR, as discussed above, may be hazardous to living biological organisms providing the absorbed energy is sufficient to raise the organism's temperature to a hazardous level, either overall, or in selected areas. Normal heat transfer processes of living organisms will serve to dissipate low levels of absorbed energy without hazard.

Factors which inhibit the dissipation of thermal energy by a living organism, thus increasing the hazard,

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[7]Om P. Gandhi, "Frequency and Orientation Effects on Whole Animal Absorption of Electromagnetic Waves" IEEE Transactions on Biomedical Engineering, BME - 22 (1975), 536-542.

include:

a. long duration of exposure

b. high temperature

c. high humidity

d. lack of air motion

Any or all of these factors may affect the levels of EMR which may be endured without damage.[8]

Non-Thermal Effects

Non-thermal effects are effects which cannot be directly explained by the heat created by the absorption of EMR energy. At the present time, there is considerable controversy in this country over the significance of non-thermal effects and even over the actual existence of such effects. The primary source of evidence for the existence of non-thermal effects has been research in the Soviet Union and other Eastern European countries,[9,10] although a few

[8] William W. Mumford, "Heat Stress due to RF Radiation," in Biological Effects and Health Implications of Microwave Radiation, BRH/DBE 70 - 2 (June 1970), 21-34.

[9] Z. V. Gordon, et al., "Main Directions and Results of Research Conducted in the USSR on the Biologic Effects of Microwaves," in Biologic Effects and Health Implications of Microwave Radiation: Proceedings of an International Symposium, Warsaw, 15-18 October 1973, (1974), 23.

[10] Klimkova-Deutschova, "Newrologic Findings in Persons Exposed to Microwaves," in Biologic Effects and Health Implications of Microwave Radiation: Proceedings of an International Symposium, Warsaw, 15-18 October 1973, (1974), 271.

researchers in the United States have reported non-thermal effects[11,12] of various types in the UHF and SHF frequency regions. Additionally, experiments in the ELF frequency regions were accomplished at non-thermal levels, also with controversial results. Most scientists in the United States, however, have either taken the position that non-thermal effects are possible, but not proven, and are recommending further examination of the Eastern European work, or are taking the position that evidence for non-thermal effects is only suggestive.[13] Other authors have stated that Soviet non-thermal effects have exposure levels and methods of exposure that are suspect, or the clinical results are hearsay,[14] or ambiguous.[15] In developing the reasons for the uncertainties of non-thermal effects in the HF through SHF

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[11] Joseph C. Sharp, et al., "Generation of Acoustic Signals by Pulsed Microwave Energy," IEEE Transactions on Microwave Theory and Techniques, MTT - 22 (1974), 583-584.

[12] G. A. Lindaur, et al., "Further Experiments Seeking Evidence of Non-thermal Biological Effects of Microwave Radiation," IEEE Transactions on Microwave Theory and Techniques, MTT - 22 (1974), 790-793.

[13] William C. Milroy and S. M. Michaelson, "Biological Effects of Microwave Radiation," Health Physics, 20 (1971), 568.

[14] Vogelman, "Physical Characteristics," 7-8.

[15] B. D. McLees and E. D. Finch, "Analysis of Reported Physiologic Effects of Microwave Radiation," Advances in Biological and Medical Physics, Vol. 14.

frequency regions Cleary[16] determined that the cause could be thermal effects that were not grossly detectable. Other U.S. scientists, in attempting to repeat certain Soviet experiments, have not obtained the same reported results.[17]

Biological Effects of EMR

Figures 3 and 4 are a partial listing of reported microwave and radio frequency (RF) effects in biological systems, both above and below the existing safety levels. Those effects marked with an asterisk are suggested as non-thermal responses, i.e., are reported to occur below the level of the present U.S. Safety Standard.[18] Reported effects at ELF frequencies are non-thermal. They are, however, contradictory, with a few investigators reporting effects, and a large majority reporting no results, except for reports from the USSR.[19]

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[16] Stephen F. Cleary, "Uncertainties in the Evaluation of the Biological Effects of Microwave and Radio-frequency Radiation," Health Physics, 25 (1973), 403.

[17] Ira T. Kaplan, et al., "Absence of Heart Rate Effects in Rabbits during Low-level Microwave Irradiation," IEEE Transactions on Microwave Theory and Techniques, MTT-19 (1971), 168-173.

[18] Cleary, "Uncertainties," 388.

[19] Morton W. Miller, "High Voltage Overhead," Environment, 20 (January-February 1978), 10-12.

IN HUMANS	IN EXPERIMENTAL ANIMALS
hyperthermia	mutations*
cataracts and lenticular opacities	hemoconcentration
auditory nerve effects*	hemodilution
neurological effects*	pupillary dilation
fatigability*	hyperthermia
headache*	burns
sleepiness*	vascular hypertension
irritability*	hemorrhage
loss of appetite*	testicular effects
memory difficulties*	chromosomal abberations
cardiovascular effects	neurological (CNS) effects*
heart enlargement	
EEG changes	
increased thyroid activity	
alterations in serum proteins	
decrease in olfactory sensation*	*Possible non-thermal effects, unconfirmed by United States scientists.
hair loss*	
disruption of sexual potency	
unstable mood*	
hypochondriasis*	
anxiety*	
respiratory changes	
histamine elevations in serum	
reduction in auditory sensitivity*	

Figure 3. *In Vivo* effects of EMR

mitotic arrest (cell cultures)
resonance absorption in methyl palmitate*
pearl chain formation (blood cells and bacteria)
neuronal interactions
enzyme inactivation
orientational effects in microorganisms
bactericidal effects
alteration of plant growth
chromosonal aberations
dielectric dispersion of cells and biomolecules
plant tumor growth arrest
excitation of frog muscle and heart preparations

*Possible non-thermal effects, unconfirmed by United States scientists.

Figure 4. In Vitro effects of EMP

U.S. Standards of Safety

The Radiation Control for Health and Safety Act of 1968, Public Law 90-602, places the responsibility for setting performance standards to control EMR from electronic products manufactured in or imported to the United States on the Department of Health, Education and Welfare (HEW). HEW has delegated to the Bureau of Radiological Health (BRH) the actual administration of the Act.

In addition, the Departments of Labor and HEW were given authority by the Occupational Safety and Health Act (OSHA) of 1970, Public Law 91-596, to establish health and safety standards for protection of workers exposed to possible hazards. EMR standards that have been adopted are usually those developed by the American National Standards Institute (ANSI), or the American Conference of Governmental Industrial Hygienists (ACGIH). The U.S. standard for microwave and RF radiation was originally developed in the early 1950's based on the amount of EMR created heat the body could tolerate and dissipate without a significant rise in body temperature. The tolerance level was determined to be ten milliwatts per square centimeter ($10mW/cm^2$), average for continuous exposure in the frequency range from 10 MHz to 100 GHz. The Department of Defense, in the early 1950's also investigated the effects of microwaves and RF radiation and determined that there was no evidence for biological effects at average levels below

100mW/cm^2. Thus, while the level for continuous exposure is 10 mW/cm^2, individuals are permitted to occupy areas where levels are above 10mW/cm^2 for short periods of time.[20]

At frequencies below 10 MHz, the United States has not set safety standards. This has probably resulted from the fact that very little energy is absorbed by biological organisms in these lower frequency bands, and the fact that, except for unusual circumstances, the levels from U.S. broadcast stations in the frequency range below 10 MHz do not exceed any limits or standards in effect anywhere in the world.[21] The exception to this is in the ELF area, where exposure to fields sometimes exceeds the maximum permissible values set by the Soviet Union and other Eastern European countries.

It should be emphasized at this point that the standards for maximum permissible values of exposure to EMR are for whole body irradiation, and that certain medical techniques, such as diathermy, are not controlled by these standards, since only small areas of the body are exposed to EMR.

The standards set by BRH for microwave ovens, since they are to be operated among the general public where certain

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[20]Sol M. Michaelson, "Standards of Protection of Personnel Against Nonionizing Radiation," American Industrial Hygiene Association Journal, 35 (December 1974), 778-790.

[21]Tell, "Broadcast Radiation," 48.

individuals may be more susceptible to the effects of EMR than the members of select groups such as communications workers or the military, are even stricter than the ANSI standards. The BRH standards went into effect in 1971. Radiation from new microwave ovens was restricted to 1mW/cm^2 measured 5cm from the ovens outside surface. After purchase, the limit is no more than 5mW/cm^2 over the lifetime of the oven.[22]

STANDARDS OF SAFETY IN OTHER COUNTRIES

Most other Western industrialized countries have adopted safety standards in the upper RF and microwave portions of the electromagnetic spectrum that are basically similar to those in the United States, with Canada, United Kingdom, Federal Republic of Germany, Netherlands, France and Sweden almost exactly duplicating the ANSI and ACGIH standards. As in the United States, virtually no Western nation has safety standards in the HF band and below, although some nations have informal standards. In Great Britain, for instance, 1000V/m is considered to be the maximum permissible exposure in the ELF band (once again due to high voltage transmission lines). In the Soviet Union and other Eastern European countries, the safety standards for continuous

[22] D. Mennie, "Microwave Ovens: What's Cooking?", IEEE Spectrum, 12 (March 1975). 36.

exposure in the RF and microwave bands are significantly lower, being 10 $\mu W/cm^2$ in most of these countries, with maximum exposures on the order of $10 mW/cm^2$ and $1 mW/cm^2$ for short periods of time.

The Eastern European approach has been one of insuring against any possibility of long term effects, based on the philosophy that the selected maximum allowable exposure values must not only guarantee protection from direct damage to biological organisms but must also exclude adverse subjective effects such as fatigue, irritability, headache, etc., under long-duration exposure to EMR.[23]

Below the RF and microwave bands, the Eastern European and Soviet philosophy of insuring against the possibility of long term low level effects has also influenced their safety standards. Soviet Standards,[24] for instance, set the following limits for working in ELF electric field near transmission lines:

Electric Field	Time Limit/Day
0 - 5 kV/m	no limit
5 - 10kV/m	3 hours
10 - 15kV/m	1½ hours
15 - 20 kV/m	10 minutes
20 - 25kV/m	5 minutes
25kV/m and up	not permitted

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[23] Karel Marha, "Microwave Radiation Safety Standards in Eastern Europe," IEEE Transactions on Microwave Theory and Techniques, MTT - 19 (1971), 166.

[24] Miller, "High Voltage Overhead," 14-15.

DIFFERENCE BETWEEN STANDARDS

A comparison of standards for RF and microwave exposure in various countries is shown as Figure 5. No comparison can be made between Western and Eastern standards for EMR exposure below 10 MHz, since the Western countries have no exposure standards in this region. The differences between Western and Eastern standards of protection appear to be due to a fundamental difference of philosophy as stated by Miller:

> In general, the Russian philosophy of standard setting is somewhat different from that in the U.S. in that standards normally represent an ideal to be striven for rather than an absolute limit never to be exceeded. Generally, the levels set in Russian standards are based on the minimum level observed to have caused any effect whatsoever, even if the effect is not necessarily harmful, and the standards do not take into account any practical considerations, such as the practicality of achieving the standards. . . Whether or not the electric field standards are strictly enforced is not known.[25]

Insight as to enforcement of standards in the Soviet Union was provided by Czechoslovakia's Karel Marha during a 1969 HEW sponsored meeting, who indicated that the Soviet safety level is qualified in various ways - for example, the military is exempt.[26]

Since the Eastern European countries lower maximum levels are based on the existence of non-thermal effects, the

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[25] Miller, "High Voltage Overhead," 15.

[26] D. R. Justesen and C. Susskind, "Book Review - The Zapping of America," IEEE Spectrum, 15 (1978), 61.

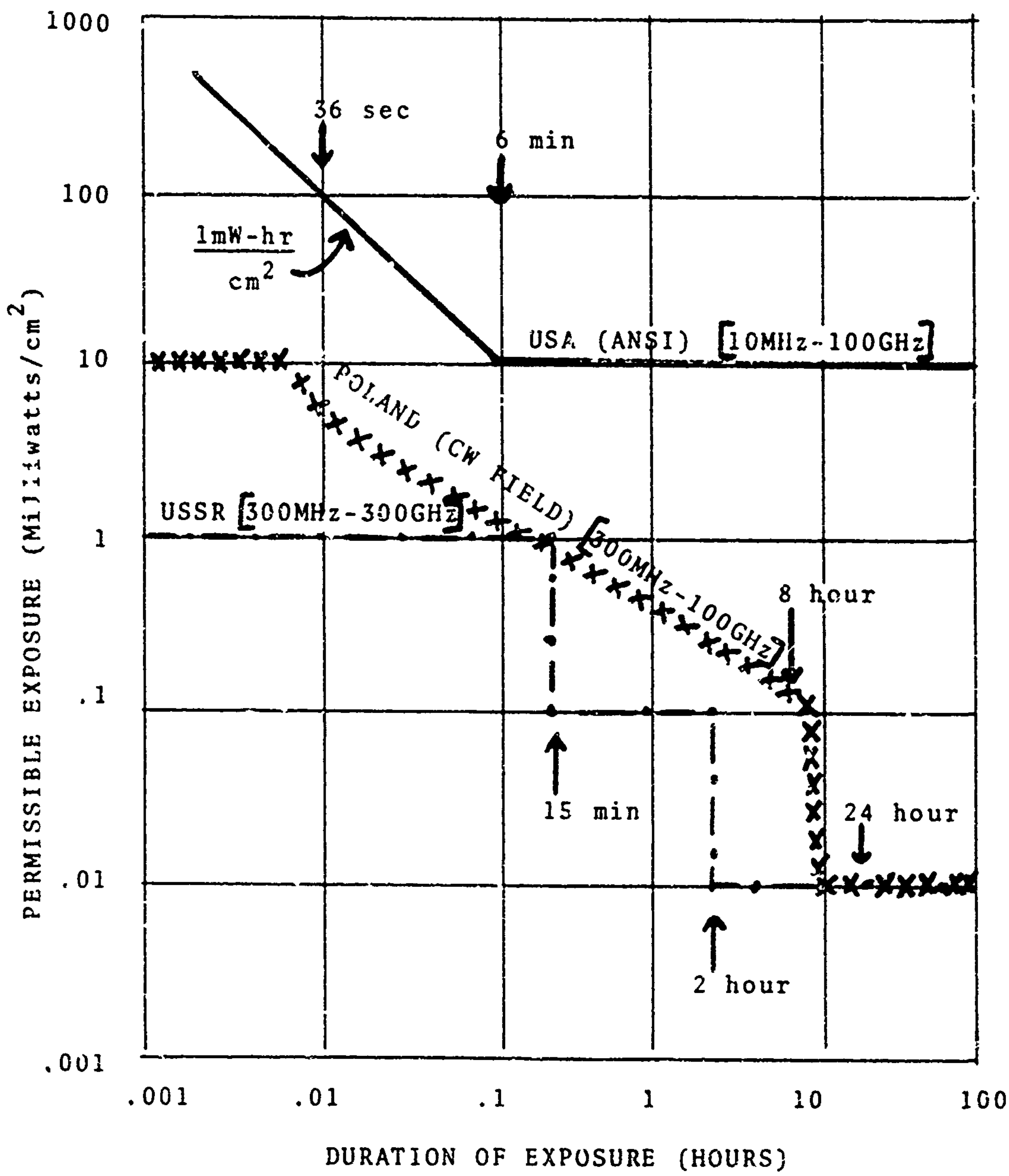

Figure 5. Whole body exposure standards for USA, USSR and Poland.

scientific opinions mentioned earlier apply to any evaluation of the differences in safety standards.

The difference between Western and Eastern standards, and the cost of implementing new standards with lower permissible maximum exposure levels in the United States, has led Brodeur[27] to postulate a vast coverup and lack of interest in investigating the more subtle effects of EMR. However, scientists in the United States generally regard Brodeur's views to be unsupportable on a scientific basis, as well as non-objective.[28]

Thus, it is unlikely that there will be any near term resolution of the problem of differences between standards, since the differences are based primarily on the controversy concerning the existence of non-thermal effects. Most Western scientists remain unconvinced of the existence of these effects or that such a hazard exists.

IMPLICATIONS FOR THE MILITARY SERVICES

The military services are only required to insure that the ANSI standards of protection, as described earlier in this chapter, and shown in Figure 1, are met. However, the controversy concerning possible non-thermal effects, along with increased public awareness of the hazards

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[27] Brodeur, "Zapping," 35-38 and 232.

[28] Justesen and Susskind, "Review of Zapping," 60-[illegible].

of EMR, imply that the military services must be more than usually aware of the hazards involved, and insure that the best possible protective measures be employed, so as to ensure the maximum protection is provided to members of the military and the public.

The next chapter examines the extent of the military involvement with systems that produce EMR, and the present military research effort into the hazards of EMR.

CHAPTER IV

THE MILITARY INVOLVEMENT WITH EMR

Virtually every weapons system, surveillance system, communications device or system, or air traffic control system in use by the military emits EMR. Emitters range in size from small hand held or back packed radios to giant satellite communications systems and phased array tracking radars emitting megawatts of power. The military operates facilities that routinely employ Electromagnetic Pulse (EMP) and has constructed test facilities for ELF band communications systems. The Department of Defense spends millions of dollars annually on research into the effects of EMR on biological systems. The following sections will examine all of these aspects of the military involvement with EMR.

MAJOR SYSTEMS USING EMR

Satellite Communications Systems

Satellite communications are currently being developed and are in use by all military services, for use as both tactical and strategic communications. Such systems most frequently operate in the UHF and SHF frequency bands and are utilized in many sizes, from man-packed and vehicular mounted systems to large fixed ground terminals which emit many gigawatts of equivalent power. Satellite communications systems are the most powerful continuous wave (cw) sources of environmental microwave radiation. These systems have the greatest potential for emitting hazardous levels of EMR because significant power densities may exist at much greater distances from the antenna than would be possible for other radiating systems of lesser average power output.[1] The narrow beam width of the antennas, as well as the fact that the antennas may remain relatively fixed in location while tracking geostationary (synchronous) satellites contribute to the possible hazard. Most high power military satellite systems are part of the Defense Satellite Communications System (DSCS).

Radar Systems

Radar systems were developed for military use during World War II, and now cover a multitude of uses in the military EMR spectrum. These include ground mounted target acquisition and ground surveillance, air traffic control and navigation, air defense, airborne target identification, warning, and acquisition, space vehicle and missile tracking, shipboard target tracking and acquisition, weather warning, missile control, and many other uses.

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[1] Norbert N. Hankin, An Evaluation of Selected Satellite Communications Systems as Sources of Environmental Microwave Radiation. EPA-520/2-74-008 (December 1974), 1-2.

Although radar systems emit EMR at peak powers approaching those used in satellite communications, the fact that radar uses pulsed energy rather than continuous energy means that the average power density will be less for the same peak power. The fact that many radar systems are continuously rotating their energy beams also lessens the average power density at a given point.

Most of the above applications of EMR are common to both military and civilian uses. However, there are several military systems which are unique, and are thus worthy of separate mention. These systems are:

a. AN/FPS-85 spacetrack radar is a fully operational phased array system which operates at 450 MHz with a peak power of 32 MW. Although details of the phased array system are classified, a comparison with the 8 KW peak power of the AN/MSC-60 satellite communications system which creates a 5 GW effective radiated power shows that this system could possibly be hazardous at great distances.

b. The Continental United States (CONUS) Over-the-Horizon Backscatter (OTH-B) Radar system, currently under development, will consist of two radars oriented seaward, one each in the northeast and northwest United States. The high power transmitter will operate in the 3-30 MHz band and is expected to produce 10mW/cm^2 at 2,200 feet from the antenna.

c. The Airborne Warning and Control System (AWACS) radar has a unique rotating phased array antenna system which transmits a high power pulsed signal (details classified) while in flight. Although shielded somewhat by the aircraft itself, the crew is in the near field of this radar.

The above systems represent systems which are unique to the military at the present time, and therefore require an even more intensive review as to the possible EMR hazards.[2]

Constant upgrading of military radars is occurring all the time. In addition to the unique systems mentioned above, recent deliveries of new AN/BPS-1000 Air Defense/Air Traffic Control Search Radar with 2 Megawatts of peak power in the 1250-1350 MHz frequency range[3] indicate that military standard systems are also biologically significant if not properly protected.

RF and Microwave Communications Systems

The military services have many communications systems (other than satellite) in this range. For the most part, single channel, point-to-point voice and teletype communications are carried out in the MF and HF frequency band (although some long range maritime communications occur in the LF and VLF bands) while multiple channel, radio relay voice

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[2] "Proposed Program for Biomedical Research of Electromagnetic Radiation Effects, June 1975," enclosure to Memorandum for: Assistant Director for Environment and Life Sciences, Office of the Director of Defense Research and Engineering (June 11, 1975), pages unnumbered.

[3] James E. Dalmas, "An Advanced Long Range Radar," Signal, 31 (October 1976), p. 77.

and data communications occur in the microwave bands. Although power outputs of military equipment in the ranges above 30 MHz is relatively low, there is still possible legal hazard associated with these systems even under the present safety standards. For example, recent tests at 150 MHz with a hand held civilian FM transceiver with 6 watt power output to a whip antenna held .2 inches in front of the nose of a model of a human head, showed a power density of 168mW/cm^2 at the surface of the head.[4] Although the author, through thermal tests, concluded that this was not dangerous, the exposure level was in excess of the presently existing safety level.

Evaluation of the radio frequency and microwave radiation hazards to personnel on naval ships has been necessary due to high-powered communications and radar equipment carried aboard. It was determined that for a given class of ship there are many areas where hazardous levels of radiation exist and that measures were required to protect ships personnel while allowing continued operation of critical equipment. Due to the limited space available, providing adequate protection is difficult.[5]

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[4] J. E. Kearman, "How Dangerous is RF Radiation?" QST LXII (September 1978), 31.

[5] Zorach R. Glaser and Glen M. Heimer, "Determination of Hazardous Microwave Fields Aboard Naval Ships," IEEE Transactions on Microwave Theory and Techniques, MTT - 19 (1971), 232-238.

ELF Communications Systems

In recent years, the Navy has become interested in ELF as a means of communications with submarines. Currently, messages are sent at VLF by using high powered transmitters with large complex antennas mounted on towers. The ELF communications system, originally known as SANGUINE, and later as SEAFARER, would provide one-way communications to submerged submarines from a single transmitter site, around which the antenna would be buried. ELF signals, when radiated into the free space cavity formed between the earth's surface and the bottom of the ionosphere, will penetrate great depths of the ocean without being attenuated significantly.[6] Questions of environmental impact and biological safety have delayed the implementation of the system. The Navy feels that: "It is in the best interest of the Department of Defense and important to our national security to pursue research and development on attainment and use of an ELF capability."[7]

It is therefore probable that research in the ELF area will continue, and that some sort of ELF submarine communications system will eventually be fielded.

Electromagnetic Pulse (EMP) Simulators

A significant part of energy released during a nuclear

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[6] James R. Wait, "Project Sanguine," Science, 178 (20 October 1977), 272-273.

[7] Gordon R. Nagler, "Seafarer," Signal, 31 (January 1977), 14.

explosion can appear as EMP. EMP has, as component parts of the total pulse, frequencies which correspond to the frequencies used by many commercial and military systems. Since EMP has been shown to be capable of disrupting or destroying components of electrical systems at distances of many thousands of miles,[8] the military services have constructed EMP simulators which are used to test the effects of EMP on various systems. Additionally, EMP simulators are used in testing new systems which have been "hardened" to the effects of EMP. Since EMP contains frequency components which are known to be hazardous to biological organisms, the question of safety for personnel conducting tests in an EMP simulator has become one of interest to the military.

Microwave Food Processing Systems

EMR in the microwave frequency bands has been used in cooking applications because of its ability to transfer energy, in the form of heat, to biological material. Personnel hazards from ovens using EMR may occur whenever EMR leakage levels become excessive. The military services use microwave food processing systems in cafeterias, food vending areas, dining facilities, kitchens, and hospitals on bases, posts and camps throughout the country, as well as on military ships and aircraft.

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[8]U.S. Department of Defense, Defense Nuclear Agency, DNA EMP Awareness Course Notes, DNA 2772T (August 1973), 3.

EMR Diathermy

The heating effect of microwave and RF energy has been used as physical therapy. This use of EMR is generally applied to limited areas of the body by qualified physicians or medical personnel. The military services utilize diathermy devices at many military hospitals.

MILITARY RESEARCH INTO HAZARDS OF EMR

During the 1950's, the mil[illegible] services were instrumental in establishing research pro[illegible] study the electrical properties of biological org[illegible] ving tissue) and the absorption characteristics of tissu[illegible] EMR, as well as the problem of cataract formation. The Tri-Service program resulted in the establishment of the present 10mW/cm^2 maximum permissible exposure level for continuous exposure, in 1957, and validated it at the last meeting of the Tri-Service Conference in 1960.[9]

A member of the Tri-Service Program, in discussing it in 1971, states:

> Although the Tri-Service Program has been criticized for lack of quantitative data produced, one must not lose sight of the fact that this program was the only large scale coordinated effort in the Western world to elucidate and understand some of the basic mechanisms of microwave bioeffects and to assess the possible health implications of this form of energy . . . . Any thorough and objective review of the proceedings of the Tri-Service

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[9] Sol M. Michaelson, "The Tri-Service Program A Tribute to George M. Knauf, USAF (MC)." IEEE Transactions on Microwave Theory and Techniques, MTT - 19 (1971), 131-132.

Conferences reveals the wealth of information that became available in a short period during which the program was in effect.[10]

An opposing view of the value of the EMR research effort is presented by Brodeur, who states that the military, through the Tri-Service research program, undertook research with the preconceived idea that all effects were thermal, and that all research was conducted to acquire data validating the 10mW/cm^2 standard. He feels that non-thermal effects were completely ignored, and further feels that the Navy specifically was opposed even to the enforcement of that standard because microwave exposure on flight decks were higher and could not be lowered without curtailing operations.[11]

It was not until the 1970's that concern over possible non-thermal effects became evident, and the military services became deeply involved with EMR hazardous research once again. Although small efforts had continued through the 1960's, the levels of money being expended by the three services became significant enough in 1974 to form another Tri-Service organization to coordinate the military research program. The Tri-Service Research Program was formed to: (1) avoid duplicate efforts; (2) maximize use of manpower and facilities; (3) focus collective efforts to solve highest priority problems in the shortest time; and (4) maintain a joint position concerning exposure standards that would unnecessarily hinder

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[10] Michaelson, "The Tri-Service Program," 143.

[11] Brodeur, "Zapping," 32-35.

DOD operations.[12]

A presentation[13] by the Tri-Service Electromagnetic Radiation Panel at the 158th Joint Medical Research Conference showed that the funds being expended for the Tri-Service EMR Research Program were about 6 million dollars in Fiscal Year (FY) 1978. Of this, about 2.5 million dollars were under contract to outside agencies, and about 3.5 million dollars for in-house Department of Defense research. Table I shows the areas in which the funds were expended. The panel estimated that the amounts expended in the program would increase by 650,000 dollars in FY 79. The panel additionally reported that Department of Defense personnel were involved in a wide range of activities concerning EMR, such as the IEEE Committee on Man and Radiation (COMAR), the Electromagnetic Radiation Management Advisory Council (ERMAC), the Office of Science and Technology Policy ad hoc working group reviewing the biological effects of non-ionizing radiation, the International Microwave Power Institute (IMPI), the Microwave Theory and Techniques Section and Biomedical Engineering Section of the IEEE, and the Union of Radio Science International (URSI).

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[12] "Tri-Service EMR Bioeffects Research Program Executive Summary Document," enclosure to Memorandum for: Assistant Director for Environmental and Life Sciences, Office of the Director of Defense Research and Engineering, (June 11, 1975), 1-2.

[13] U.S. Department of Defense. Summary Report on the Tri-Service Electromagnetic Radiation (EMR) Bioeffects Research Program, October 18, 1978, 1-6.

TABLE I

DOD FUNDING OF EMR BIOEFFECTS RESEARCH BY

PRIORITY AREAS

1.	Energy Distribution and Measurement	$1333K	22%
2.	Biophysical Mechanisms	1088K	18%
3.	Nervous System	1105K	18%
4.	Behavior	763K	14%
5.	Hematology/Immunology	767K	13%
6.	General Physiology	752K	12%
7.	Other (Ecology, Epidemiology, Development, Genetic, Ocular, etc.)	200K	3%
		$6000K	

Source: Obtained from 158th Joint Medical Research Conference, 18 October 1978, Washington, D.C.

In citing the interest that the Department of Defense has in EMR bioeffects, the panel compared papers presented by Department of Defense supported investigators as a percentage of total papers presented by all contributers from the United States, at international meetings. This comparison is shown as Table II.

The involvement of the military services is also indicated by the fact that in 1976, 35 percent of all defense agencies' basic research funding was spent on environmental and life sciences, with the remainder being spent on engineering and physical sciences.[14]

[14] U.S. National Science Foundation, National Science Board, Science Indicators, 1976 (1977), 72.

TABLE II

PAPERS PRESENTED AT EMR BIOEFFECTS MEETINGS BY
DOD - SUPPORTED INVESTIGATORS
(AS A FRACTION OF TOTAL U.S. PAPERS)

1975 URSI	(Boulder)	56/98	(57%)
1976 URSI	(Amherst)	44/56	(68%)
1977 URSI	(Airlie)	58/97	(60%)
1978 IMPI/MTT/URSI	(Ottawa)	25/50	(50%)
1978 URSI	(Helsinki)	25/56	(45%)

Source: Obtained from 158th Joint Medical Research Conference, 18 October 1978, Washington, D.C.

CHAPTER V

PROTECTIVE MEASURES AGAINST EMR HAZARDS

In order to prevent hazards to personnel from EMR emitted by communications and radar equipment in use by the military services, it is necessary to prevent excessive power levels from being absorbed by biological organisms. Since the percentage of incident power that is absorbed by or reflected from a given biological organism is dependent primarily on the frequency of the EMR, for any given incident power density level, the frequency is of primary importance when discussing protective measures. Protective measures may be considered in two broad categories, the first, physical protective measures, are the use of physical devices, the design of EMR emitters, or the use of physical laws governing the propagation of EMR to provide protection in areas where hazards are known to exist; and, the second, administrative protective measures, are those regulations, instructions, standards and guidance promulgated by the various military services which implement various protective measures, provide measures for inspection, determination of hazard, and compliance with standards, and require various medical examinations in an effort to protect military personnel and the public from the hazards of EMR.

In this chapter, the known physical protective measures will be described, the administrative protective measures of the three military services will be listed, and by means of a comparison matrix, areas where protective measures are not common to all services will be discovered. Finally, the implications of physical or administrative protective measures in use in some services, but not all, or measures which are implemented differently in the various services will be discussed.

PHYSICAL PROTECTIVE MEASURES

Distance

An electromagnetic wave, in propagating through free space, loses practically no energy. The only decrease in field intensity (or power density) is caused by the spreading out of the wave front. This spreading out of the wave front causes the power density to decrease as the square of the distance between the source of the EMR and the point of measurement. This is known as the inverse square law. When a wave is propagating in an environment where there is loss, or other phenomena which affect propagation, such as upper atmosphere ionization, or in areas where the wave interacts with the ground, the power density at a given point may be even lower than might be expected using the inverse square law. Thus, distance from the antenna can create an effective lessening of hazard potential. As a protective measure, distance is used to create areas where occupancy by personnel is restricted or forbidden. The distance to which a restricted or forbidden zone must extend depends on many variables such as the height of the antenna over an occupied area, the beam width characteristics of the antenna transmitting the EMR, whether the EMR is pulsed or continuous, whether the antenna is rotating, the frequency of the EMR, and of course, the total power emitted by the antenna. As an example, the AN/TPS-25 transportable battlefield surveillance radar set emits a maximum average power density of 15.1mW/cm^2, due to its input power and pulse characteristics and antenna design.[1] The power density does not drop below 10mw/cm^2 until past 40 feet from the center of the antenna. This simply means that an area up to 40 feet out from the antenna may have to be designated a limited occupancy zone (see Figure 6). On the other hand, if the antenna is mounted high enough, no hazardous conditions will exist in front of the antenna. (See Figure 7.) In the first case, distance is used as a protective measure by establishing a limited occupancy zone in the hazardous area. In the second case, sufficient distance between the antenna and the ground eliminates the possible hazard.

Fixed Shielding

In cases where it is impossible to limit access to a

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[1]U.S. Departments of the Army/Air Force, TB Med 270/ AFM 161-7, (December 1965), 22.

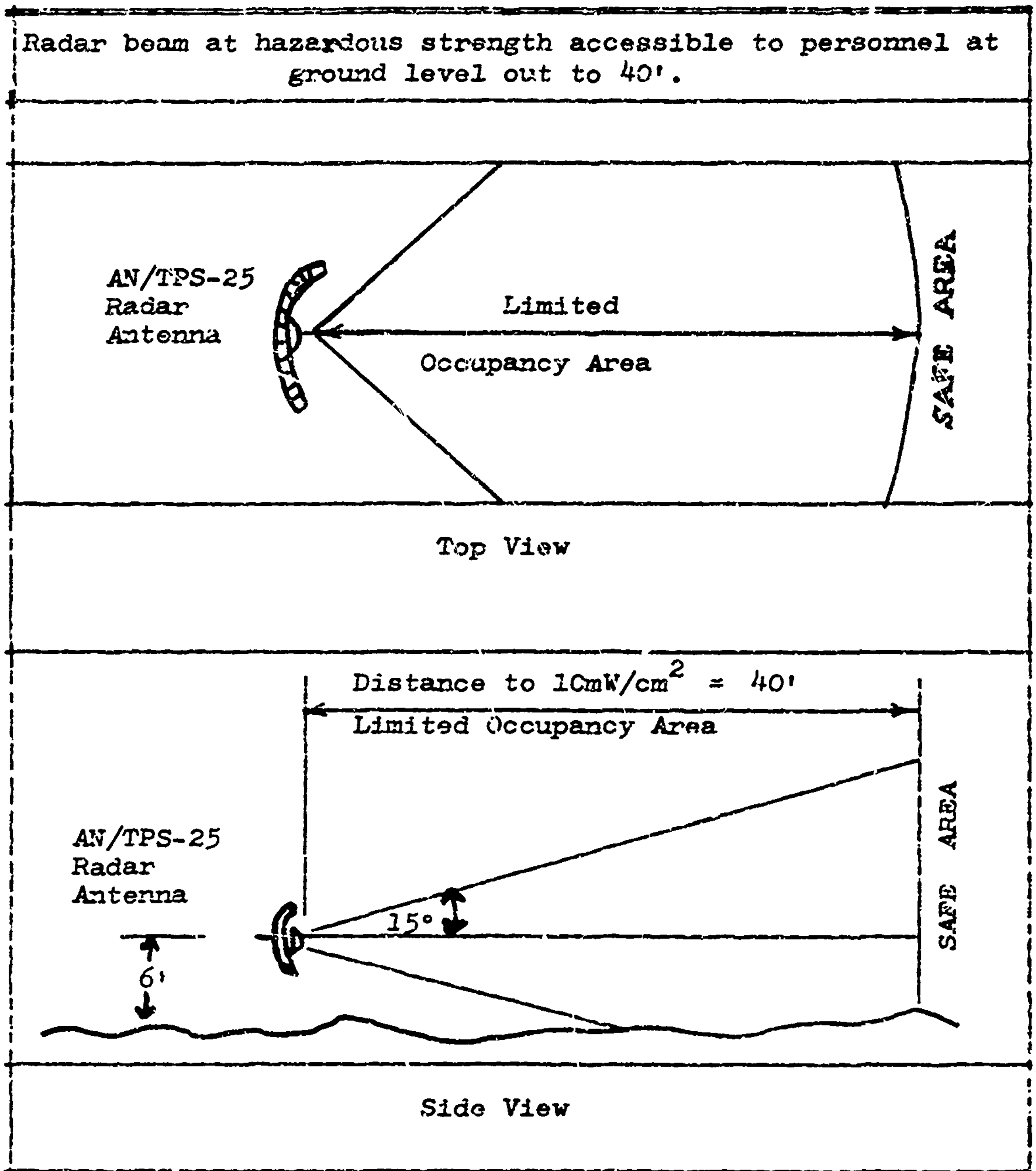

Figure 6. AN/TPS-25--Battlefield Surveillance Radar Set Potentially Hazardous Conditions

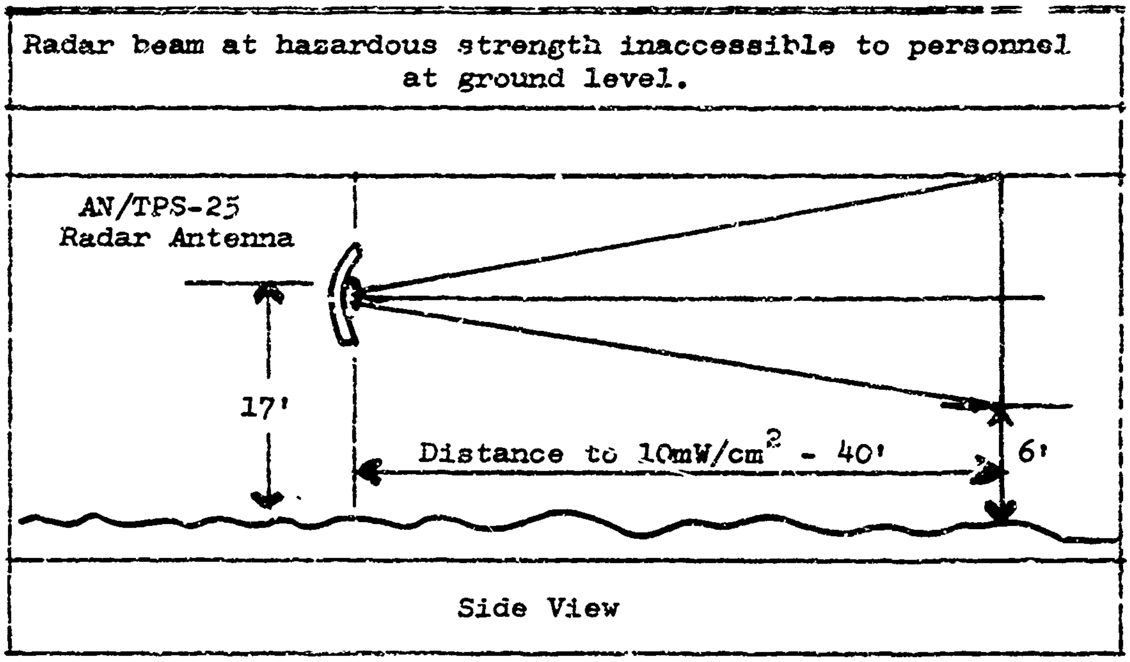

Figure 7. AN/TPS-25--Battlefield Surveillance Radar Set Non-Hazardous Conditions

hazardous area, protection may be provided by placing conducting shields between the antenna and the area which must be occupied. As was discussed in Chapter II, conductors reflect much of the electric field incident upon them, and rapidly attenuate any EMR which does penetrate. Depending on frequency of the EMR, a conducting mesh, rather than a solid shield, is effective in attenuating EMR. Figure 8 shows attenuation factors for various types of shielding material.[2] The attenuation provided by conductors is inversely proportional to the depth of penetration (δ) of EMR into a conductor, and depth of penetration follows the formula:

$$\delta = \frac{1}{\sqrt{f \pi \mu \sigma}}$$

Thus, the attentuation curves are generally constant in the range shown because while frequency is increasing, conductivity is decreasing, as was discussed in Chapter II. At frequencies lower than those shown in Figure 8, the attenuation factor is considerably less than those shown.

Fixed shielding may be used in any situation where it is impossible to establish a limited access or denied occupancy area. Due to the difficulty in denying occupancy to certain areas of ships which may be exposed to hazardous levels of EMR, the Navy has made extensive use of the shielding concept (see Figure 9) on ships.[3]

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[2] U.S. Department of the Army, TB Med 270 (September 1978), 37.

[3] U.S. Department of the Navy, NAVSHIPS 0900-005-8000, (July 1, 1971), 1-10.

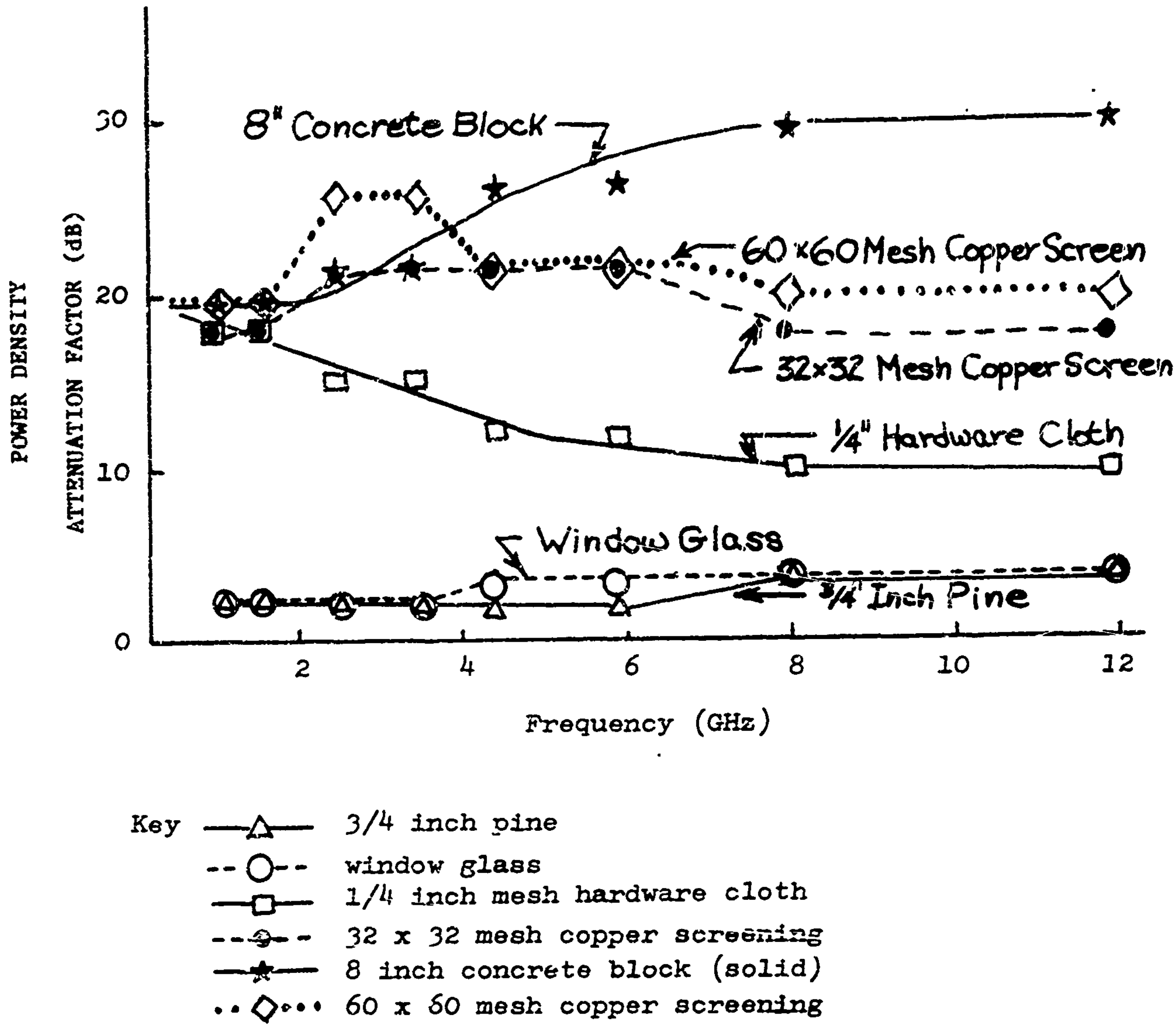

Figure 8. Power Density Attenuation Factors for Various Materials

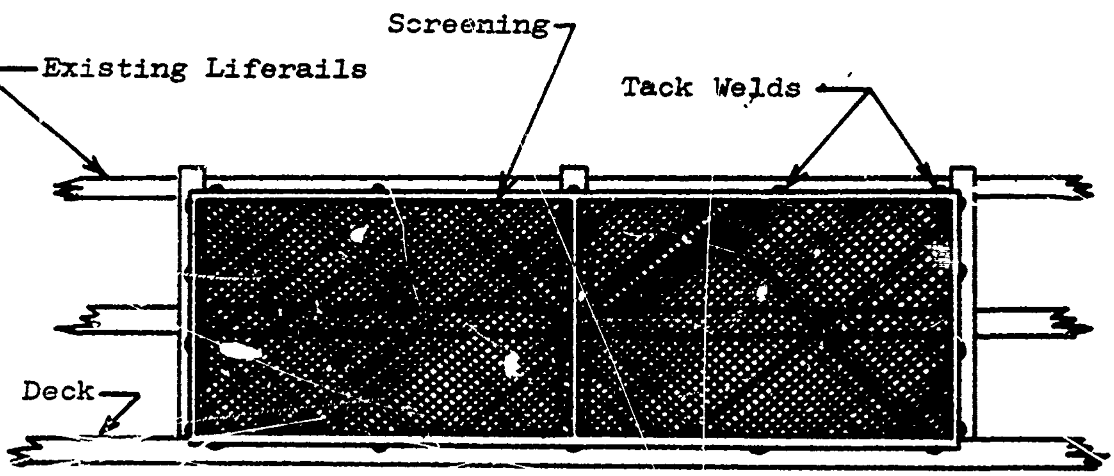

Figure 9. Shipboard EMR Hazard Personnel Safety Screens

Antenna Design and Functions

The type of antenna and its design may be a factor in developing protection for personnel. The type of antenna being utilized determines the pattern of radiation emitted. Thus, a directional antenna may be used to aim radiation away from occupied areas, or to carry dangerous levels of radiation over occupied areas without causing a hazard. An example of this is satellite communications antennas, which have an extremely narrow beamwidth and are generally restricted in vertical azimuth so that the beam cannot be aimed low enough to cause a hazard. Another example would be the mounting of the AN/TPS-25A antenna at such a height that the hazardous levels of EMR were never close enough to the ground to be dangerous to personnel, as was seen in the previous section and shown in Figure 7. Realization of the characteristics of the antennas is needed to ensure proper siting of mobile systems, and to insure optimum planning is accomplished when installing fixed systems.

Antennas which form EMR into a "beam" offer advantages in providing protection because they may be operated in such a way as to avoid occupied or occupiable areas. However, the fact that the energy is being radiated in a narrow beam means that hazardous levels of EMR are being radiated to greater distances than would be the case with less directional antennas. Also, many of these directional antennas have "sidelobes" of radiation which may offer significant hazard if not taken into account. Thus, antenna design may be both a protective measure and a hazard, depending on the employment of the antenna.

The fact that a given antenna may rotate, as is the case for many radar systems, also contributes to lessening the hazard for a given power level and a given antenna. Since average power density is what contributes to the hazard, it must be calculated using the power density at a given distance from the antenna where it is stationary. The stationary power density of the antenna may be used to determine the average power density of a rotating antenna by using the following formula:[4]

$$P = P_o \frac{1.5(BW)}{360}$$

Where: P = average rotating power density at the point of interest; P_o = stationary power density at the point of interest; BW = beamwidth (in degrees) of the half power beam.

It should be noted that even when the average power density of a rotating antenna is used in determining limited or denied occupancy areas, the area in which the power density of the stationary antenna exceeds the maximum short time exposure level must be declared a denied occupancy area. This is required since it is possible for a malfunction to cause the antenna to stop rotating but continue radiating,

[4] U.S. Department of the Army, TB Med 270 (September 1978), 31.

thus causing a hazardous level of radiation in the direction which the malfunctioning antenna is pointed.

Antenna design, as a method of protection, must usually be considered during the design and development of a system. Once a system has been fielded, protective measures required due to its designed operating characteristics must usually be applied by other means.

Protective Clothing

Protective clothing is simply a portable method of shielding personnel from hazardous effects of EMR by providing conductive clothing to reflect the waves. Protective clothing includes methods of protecting the eyes by the use of conductive eyeware which are sufficiently thin or have small mesh screen sufficient to admit light. The Navy has been active in development of protective clothing, since there are many radars on ships which would adversely effect combat operations if shut down for minor repairs. Protective clothing consisting of heavy duty nylon impregnated with silver has been developed for use in the frequency range 200 MHz to 10 GHz in power densities up to $200 mW/cm^2$.[5] Although developed, protective clothing does not seem to have been fielded to any extent, probably because of the limitation in maximum power density, and expense.

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[5] Andrew P. Sosnicky, "Sources and Biological Effects of Non-ionizing EMR" (Masters Thesis, Naval Postgraduate School, 1976), 66.

Emission Cutoff

Emission cutoff, in the context of a protective measure, refers to all measures taken to turn off the EMR transmitter during periods when hazard to personnel may result. Emission cutoff may be a manual or an automatic protective measure.

Manual. A simple method of preventing hazardous exposure is to have the operator turn off the system whenever it is known that personnel will be in the hazardous area or to limit the areas to which the antenna may point, thus avoiding the creation of a hazardous area. This method obviously requires that all areas in which hazardous levels of EMR are present be marked with appropriate warning signs. Training of operators as to the hazards of systems exceeding the maximum permissible exposure levels and where such levels are exceeded is also required, to insure that the operators will take necessary action.

Automatic. Any method which turns off an EMR emitting system without operator intervention would be considered to be automatic. Such methods would include those which shut down the system whenever the EMR from a narrow beam antenna (usually radar) is swept over an area where hazardous exposure may result. Examples are radars on naval ships which have cam cutouts to prevent the equipment from radiating into occupied or possible occupied areas of the ship.[6] Another

[6]Glaser and Heimer, "Determination of Hazardous Microwave Fields," 234.

example, would be a switch which completely shuts down a system whenever a door giving access to a hazardous area is opened. Yet another example is an interlock built into the landing gear of aircraft which prevent the accidental ground operation of radars if there is any weight on the wheels.[7]

Spread Spectrum

Spread Spectrum, a technique for spreading output power over a wide frequency spectrum in order to increase security, reduce signal intercept vulnerability, and increase jamming immunity, is being developed for a wide variety of communications and radar devices.[8] Although this technology is being developed for the above reasons, the technical characteristics involved may yield benefits in providing protection from the hazards of EMR. The technique of spreading a given amount of power over a wide frequency bandwidth means that any given frequency will have less power associated with it. Since absorption of energy from EMR is highly frequency dependent, spreading the power content will result in less total power being absorbed by a given biological organism. The usefulness of considering spread spectrum as a possible protective measure will depend on the development of protection

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[7]Sosnicky, "Sources and Biological Effects," 41.

[8]Gilbert R. Johnson, "Understanding Low Power Spread Spectrum Radars," Electronic Warfare/Defense Electronics, 10 (November 1978), 75-77.

standards which are more frequency dependent than is the case at present. In other words, today's standards, being constant over a wide range of frequencies, cannot take into account the benefits of any system using spread spectrum techniques. Future refinement of the frequency dependence of EMR hazards, and a resultant change in the protective standards, will make consideration of the spread spectrum nature of a possibly hazardous signal one of the considerations necessary in determining overall hazard to personnel.

ADMINISTRATIVE PROTECTIVE MEASURES

The military services, in recognizing the problems associated with the EMR emitted by various communication and radar systems, have promulgated a variety of regulations, instructions, standards and guidance to control the exposure of military personnel and the public to the hazards of EMR.

The following documents are the major administrative measures taken by the three military services. The alphanumeric code following each document will be used in developing a matrix which is a comparison of the various administrative protective measures required by the military services:

U.S. Army

Army Regulation 40-583, "Control of Potential Hazards to Health from Microwave and Radio Frequency Radiation" (AR1).

Army Regulation 40-44, "Control of Potential Hazards to Health from Microwave Cooking Ovens and other Microwave/ Radio Frequency (RF) Food Service Devices" (AR2).

Army Technical Bulletin MED 270, "Control of Hazards to Health from Microwave and Radio Frequency Radiation and Ultrasound" (Approved draft--September 1978) (AR3).

U.S. Navy

BUMED Instruction 6470.13A, "Microwave and Radio Frequency Health Hazards" (NA1).

BUMED Instruction 6470.16, "Microwave Oven; Survey for Hazards" (NA2).

NAVSHIPS Technical Manual, NAVSHIPS 0900-005-8000, "Technical Manual for Radio Frequency Radiation Hazards" (NA3).

U.S. Air Force

Air Force Regulation 127-12, "Air Force Occupational Safety and Health Program" (AF1).

Air Force Occupational Safety and Health Standard 161-9, "Exposure to Radiofrequency Radiation" (AF2).

Note that Air Force Regulation 100-6, "Electromagnetic Interference and Radiation Hazards" is still in effect, but is a virtual duplicate of portions of Air Force Occupational Safety and Health Standard 161-9 (above). AFR 100-6 cites AFR 161-42 as its primary reference on Radio Frequency Hazards, but AFR 161-42 has been superceeded by Air Force Occupational Safety and Health Standard 161-9 (above).

Complete citations for all the above Army, Navy and Air Force manuals, are contained in the bibliography.

The method used in developing the matrix which immediately follows was to review each of the above documents, extract the various protective measures, and compare them one to another to determine which services used a given measure. The codes used in the matrix are as follows:

YES - The given service specifically implements the measure described.

NO - The given service specifically does not implement the measure described.

NM - The measure described is not mentioned in any of the above documents of the given service.

The alpha-numeric code for the publication discussing the given measure in the most detail is contained in parentheses for each measure and service. A detailed discussion of each item in the matrix c. administrative protective measures will be contained in the Comparison and Discussion section immediately following the matrix.

ITEM	ARMY	NAVY	AIR FORCE
1. Establishes EMR exposure standards and criteria:	YES (AR1)	YES (NA1)	YES (AF2)
2. Frequency coverage of standards:			
0-10KHz	NO	NO	NO
10KHz-10MHz	NO	NO	YES
10MHz-100GHz	YES	YES	YES
100GHz-300GHz	YES (AR1)	NO (NA1)	YES (AF2)
3. Permissible exposure levels (PEL):			
a. Frequency range 10KHz-10MHz			
$50mW/cm^2$ (continuous exposure)	NO	NO	YES
$18000mW\text{-}sec/cm^2$ (6 minute period)	NO	NO	YES
b. Frequency range 10MHz-300GHz			
$10mW/cm^2$ (continuous exposure)	YES	YES*	YES
$3600mW\text{-}sec/cm^2$ (6 minute period)	YES**	YES*	YES
*Navy standard only covers frequencies up to 100GHz.			
**Army has a maximum limit of $50mW/cm^2$.			
4. "Unnecessary" exposures above $10mW/cm^2$ prohibited:	YES (AR3)	NM	NO (AF2)
5. Protective clothing developed and allowed for use:	NM	YES (NA1)	NO (AF2)
6. Specific physical protective measures discussed:	YES (AR3)	YES (NA3)	YES (AF2)
7. Establishes comprehensive continuing monitoring program to insure compliance with exposure standards:	YES (AR1)	NO*	YES (AF2)
*See discussion			

ITEM	ARMY	NAVY	AIR FORCE
8. Plans, programs and budgets for research into the hazards of EMR. Conducts research programs.	NM	NM	YES (AF2)
9. Ensures that consideration is given to personnel EMR exposure potential in the Research, Development, Testing and Evaluation (RDTE) phases of new equipment procurement. * See discussion	YES (AR1)	YES*	YES (AF2)
10. Has an established agency to conduct biological effects and suspected personnel overexposure consultations, and provide advice and guidance to service personnel.	YES (AR3)	YES (NA1)	YES (AF2)
11. Has an established agency specifically responsible for the following:			
a. On site surveys of possible hazards.	YES (AR1)	YES* (NA3)	YES (AF2)
b. Estimating hazard distances for selected systems.	YES (AR3)	YES* (NA3)	YES (AF2)
c. Maintaining data on EMR emitter characteristics.	YES (AR3)	YES* (NA3)	YES (AF2)
d. Assistance in investigation of suspected or actual overexposures.	YES (AR1)	YES* (NA1)	YES (AF2)
e. Loan of selected survey instruments. * See discussion	NM	NM	YES (AF2)
12. The organization performing duties outlined in item 11 is provided travel fund for regular and/or requested surveys/assistance visits. *See discussion.	YES*	NO*	YES*

ITEM	ARMY	NAVY	AIR FORCE
13. Requires EMR protection plans, to include the following:			
a. Inventory of all EMR emitters	YES (AR3)	NM	YES (AF2)
b. Categorization of EMR emitting equipment as to hazard.	YES (AR3)	NM	YES (AF2)
c. Periodic resurvey of emitters and checks to insure warning sign and SOP adequacy.	YES (AR1)	NM	YES (AF2)
d. Dissemination of information on measures required for control of exposures to hazardous levels of EMR.	YES (AR1)	YES (NA1)	YES (AF2)
e. Periodic checks of maintenance facilities that repair or test EMR emitters.	YES (AR1)	NM	YES (AF2)
f. Review required, prior to construction of new facilities, to determine potential hazard from existing EMR emitters.	NM	NM	YES (AF2)
g. Review required when EMR emitter inventory changes.	NM	NM	YES (AF2)
14. Hazard warning signs required at locations where access to power densities in excess of maximum allowable is probable.	YES (AR1)	YES (NA3)	YES (AF2)
15. Hazard warning signs required near microwave ovens: * For portable or mobile ovens only	YES* (AR2)	NO (NA2)	NO (AF2)
16. Hazard warning signs required for possible interference with pacemakers (for equipment other than microwave ovens).	YES (AR3)	NM	NO (AF2)

ITEM	ARMY	NAVY	AIR FORCE
17. Formal medical investigation of incidents and accidents (suspected or actual overexposure to EMR) required.	YES (AR1)	YES (NA1)	YES (AF2)
18. Routine pre-or post-employment medical examinations required for personnel occupationally exposed to EMR.	YES (AR1)	YES (NA1)	NO (AF2)
19. Periodic medical examinations required for personnel occupationally exposed to EMR. * Opthalmologic exam only	YES* (AR1)	YES* (NA1)	NO (AF2)
20. Forbids personnel having eye opacities (indicating cataracts) indistinguishable from those caused by high levels of EMR exposure to be occupationally exposed to microwaves.	NM	YES (NA1)	NM
21. Examination required for personnel exposed to more than $50mW/cm^2$ for any period of time. * Examination required in any case since $50mW/cm^2$ is maximum permissible level in the Army. ** Examination only required if exposure exceeds the maximum allowable time period for levels above $10mW/cm^2$.	YES*	YES (NA1)	NO**
22. Commanders allowed to prescribe conditions under which interlocks, limiting or warning devices may be by-passed or overridden.	YES	NM	NM

COMPARISON AND DISCUSSION

Physical Protective Measures

Each service, in its administrative protective measures, discusses various physical protective measures. Not all services discuss the use of all protective measures. Comparison of the various physical protective measures among the three services reveals the following:

Distance. All three services discuss distance as a protective measure. Each describes methods and formulas for performing calculations to determine hazards of particular equipment based on distance from the antenna, frequency, and average power of the transmitter. All services describe methods of determining the areas in which occupancy by personnel must be limited or prohibited based on hazard evaluation. The Navy[9] lists specific equipment and the distances at which a personnel hazard may occur. The Army and Air Force have in the past listed similar information for specific equipment, however, recent publications have eliminated such lists in favor of maintaining a central information facility, due to the difficulty of keeping such lists updated.[10]

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[9] U.S. Department of the Navy, NAVSHIPS 0900-005-8000, (July 1, 1971), 1-3 through 1-7.

[10] TB Med 270/AFM 161-7 contained such lists of equipment. They have, however, been superseded by AFOSH Standard 161-9, and TB Med 523, which do not.

<u>Fixed Shielding</u>. Fixed shielding is specifically recognized by both the Army[11] and the Navy[12] as a method of reducing hazardous levels of EMR. The Army shows exact shielding characteristics for various materials, while the Navy mentions the specific use of metallic shielding on ships, but does not mention methods for shielding EMR emitters at shore installations. The Air Force does not mention the subject.

<u>Antenna Design and Functions</u>. All three services recognize the contribution of different types of antenna and the functions of the emitters as contributing to differences in hazard potential. The services all consider the different designs and functions of equipment after it is designed in calculating the hazard potential for a given system. The Army takes into account the antenna dimensions, antenna gain, polarization of the transmitted wave, height of the antenna, and reduction in average power density caused by a rotating antenna (such as is the case with some radars).[13] Examples of typical calculations based on these characteristics are given.[14] The Navy also recognizes the difference in antenna design and function as contributing to different levels of

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[11] U.S. Department of the Army, TB Med 270 (September 1978), 37.

[12] U.S. Department of the Navy, NAVSHIPS 099-005-8000, (July 1, 1971), 1-10.

[13] U.S. Department of the Army, TB Med 270 (September 1978), 26, 31.

[14] U.S. Department of the Army, TB Med 270 (September 1978), 39-42.

hazard, and provides examples of calculation of power density for various types of antennas.[15] The Air Force also includes these factors in sample calculations of hazards.[16]

Protective Clothing. The Army does not mention protective clothing in regulations or bulletins, and has not developed such clothing. The Army does recognize the existence of protective clothing (in this case microwave protective eyewear), and has stated that more research in protective eyewear would be desirable.[17] The Navy has developed a complete set of protective clothing (described in this chapter under Physical Protective Measures (Protective Clothing), and has described its use in regulations.[18] The Air Force has not developed such clothing and expressly forbids its use, without specific approval.[19]

Emission Cutoff. Emission cutoff methods and design criteria are not addressed in any regulations, instructions,

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[15] U.S. Department of the Navy, NAVSHIPS 0900-005-8000, (July 1, 1971), Appendix B.

[16] U.S. Department of the Air Force, AFOSH Standard 161-9 (October 10, 1978), 21-23.

[17] U.S. Department of the Army, Environmental Hygiene Agency. Microwave Hazards Course Manual. Aberdeen Proving Ground, Md. (undated), 103.

[18] U.S. Department of the Navy. BUMED Instruction 6470.13A, (January 28, 1977), Enclosure 1.

[19] U.S. Department of the Air Force, AFOSH Standard 161-9, (October 10, 1978), 3.

standards or guidance of the three military services. Other literature, described in this chapter under Physical Protective Measures (Emission Cutoff), and elsewhere[20] describe methods by which emission cutoff is being performed.

Spread Spectrum. Spread spectrum techniques are not addressed as a method of protection from EMR hazards by any of the three services. This is probably due to the relatively new technology used. The lower total power requirement of spread spectrum radars and communications systems may prove advantageous in both accomplishing a given operational mission while at the same time reducing the overall hazard of EMR emission from certain types of systems.

Administrative Protective Measures

The matrix developed in the Administrative Protective Measures of this chapter provides a quick comparison of the administrative measures taken by each service through the services regulations, instructions, and technical documents concerned with protection from EMR hazards. The following is a detailed discussion of each item in the matrix.

Item 1. All three services establish exposure standards and criteria for EMR. All are within the limits of the

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[20] Norbert N. Hankin, An Evaluation of Selected Satellite Communications Systems as Sources of Environmental Microwave Radiation, EPA-520/2-74-008 (December 1974), 30.

ANSI standard (see Chapter III). The Army standard for exposure to EMR is established in AR 40-583 and detailed in the September 1978 draft of TB Med 270. Microwave oven standards are contained in AR 40-44 and detailed in TB Med 270. The Navy establishes exposure limits in BUMED Instruction 6470.13A. The Air Force establishes an occupational safety and health program by AF Regulation 127-12 requiring compliance with Air Force Occupational Safety and Health (AFOSH) Standards. The standards for EMR exposure are contained in AFOSH Standard 161-9. Detailed discussion of the frequency range and permissible exposure levels allowed by the three services are contained in items 2 and 3.

Item 2. For all three services the frequency range of the standards in Item 1 cover the range required by the ANSI standards (10 MHz to 100 GHz). In addition, the Army and the Air Force have established standards in the range 100 GHz to 300 GHz, and the Air Force has established a standard for the range 10 KHz to 10 MHz. None of the services has established standards below 10 KHz, and non has established standards for Electromagnetic Pulses. (See Chapter III.)

Item 3. The permissible exposure levels (PEL) established by the services, along with the frequency ranges described in Item 2, are shown in F   e 10. Note that the Army Standard "levels off" at 50mW cm^2, while the Navy and Air Force PELs follow the ANSI standard, allowing exposures

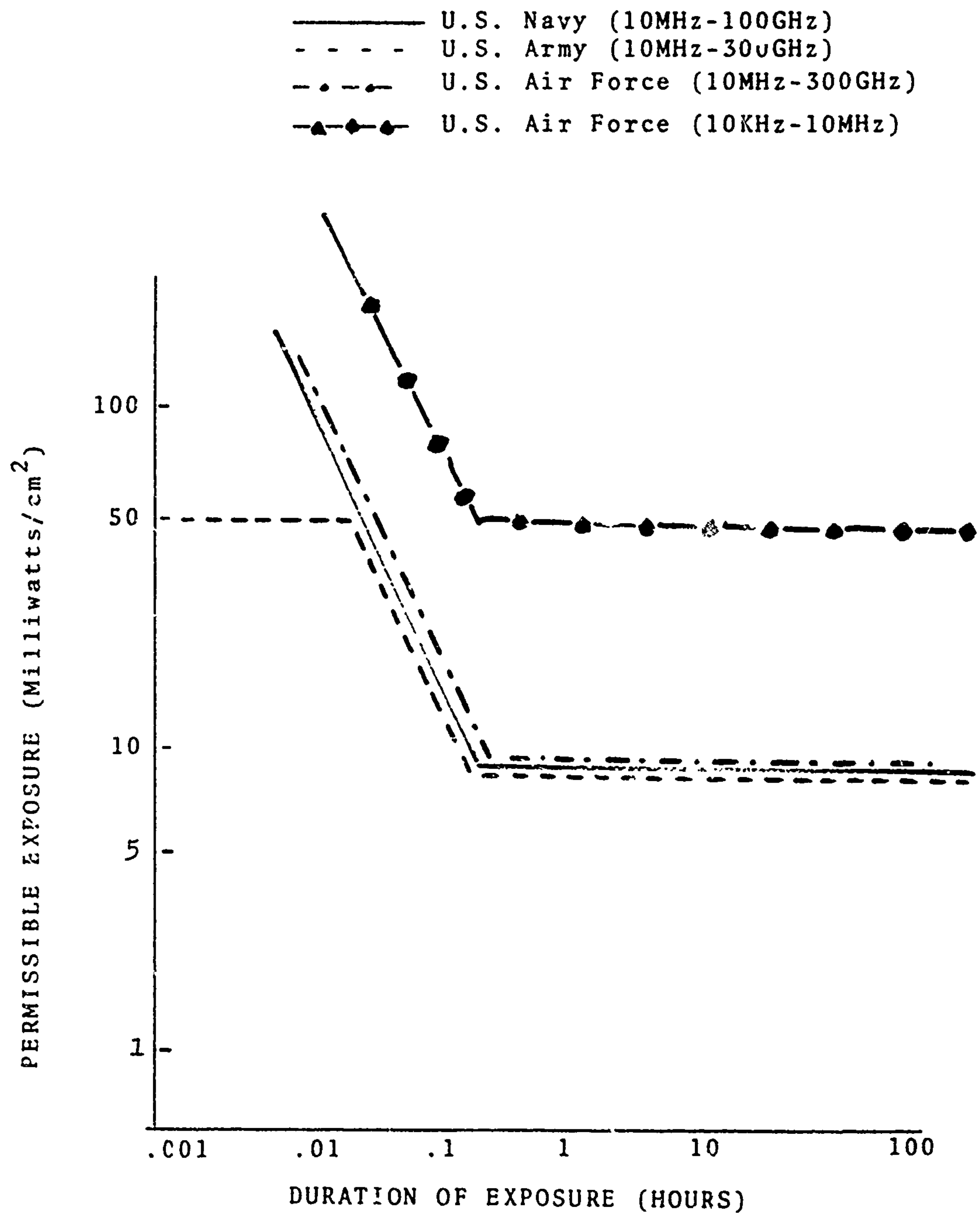

Figure 10. Permissible exposure levels by frequency for the three military services.

greater than 50mW/cm^2 for short periods of time (less than 1.2 minutes). The Air Force PEL for the frequency range 10 KHz to 10 MHz is also shown. The reason given by the Army for limiting exposures of short duration to a maximum of 50mW/cm^2 is "It is not feasible to control limited exposure of less than 1.2 minutes . . . .[21] The Air Force gives no specific reasons for having established a PEL in the 10 KHz to 10 MHz range, stating only that "The PELS listed . . . are based on current knowledge of radio frequency radiation effects."[22]

Item 4. This item is concerned with service policies on exposures above 10mW/cm^2 (the continuous exposure limit for all services in the microwave bands). The Army[23] specifically prohibits "unnecessary" exposures above 10mW/cm^2, while the Air Force states that "It is permissible to allow any personnel exposure that satisfies [the Air Force PELs]."[24] The Navy does not specifically mention "unnecessary" exposures, but does require a medical exam for personnel exposed to more than 50mW/cm^2 of microwave radiation (See Item 20).

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[21]U.S. Department of the Army, TB Med 270 (September 1978), 32.

[22]U.S. Department of the Air Force, AFOSH Standard 161-9, 3.

[23]U.S. Department of the Army, TB Med 270 (September 1978), 32.

[24]U.S. Department of the Air Force, AFOSH Standard 161-9, 3.

Item 5. The development and use of protective clothing (a physical protective measure) is discussed in this chapter under Comparison and Discussion (Physical Protective Measures).

Item 6. All three services discuss physical protective measures to some extent (see Comparison and Discussion (Physical Protective Measures) in this chapter). However, none of the service regulations, instructions, or technical manuals discuss the complete range of physical protective measures available.

Item 7. The Army and Air Force have established comprehensive monitoring programs to insure compliance with exposure standards. The Army's program is centralized, the Air Force's, decentralized.

The Army requires periodic comprehensive surveys of microwave/RF installations, conducted by the U.S. Army Environmental Hygiene Agency (a sub-command of U.S. Army Health Services Command), and the evaluation of plans for installation of microwave and RF equipment and studies of environmental conditions at user sites or test facilities.[25] In addition, the Army requires periodic inspections and surveys of microwave ovens by commanders having possession of them. Reports are maintained at the installation/activity level until

[25] U.S. Department of the Army, AR 40-583, 2.

receipt of the next comparable report.[26]

The Air Force requires base bioenvironmental engineers (BEE) to conduct periodic surveys. In addition, surveys are required when notified of new operations, equipment changes, or equipment modifications which may alter the biological significance of the EMR environment. The BEE also identifies all areas where RF radiation levels exceed USAF permissible exposure levels, and recommends engineering controls as appropriate. The USAF Occupational and Environmental Health Laboratory (OEHL) may be contacted for assistance if necessary. Air Force Communications Service (AFCS) also provides consultation and measurement services.[27] Local bases are also responsible for periodic microwave oven surveys, in a specified format, with copies of reports forwarded to Federal Drug Administration regional offices and the USAF OEHL.[28]

The Navy, although requiring a microwave oven control program[29] similar to the Army, does not have a comprehensive continuing EMR monitoring program. BUMED Instruction 6470.13A requires commanders to be responsible for compliance with the instruction. The instruction calls attention to potential

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[26] U.S. Department of the Army, AR 40-44, 2-2.

[27] U.S. Department of the Air Force, AFOSH Standard 161-9, pages 2-3, and 26-27.

[28] U.S. Department of the Air Force, AFOSH Standard 161-9, 34.

[29] U.S. Department of the Navy, BUMED Instruction 6470.16.

health hazards, specifies maximum exposure levels, provides guidance for medical surveillance and specifies reporting requirements of microwave overexposure incidents. However, the instruction does not establish a formal hazard inspection system, either centralized or decentralized, as is the case in the Army or the Air Force. The functions of personnel hazard evaluation, control and protection is left entirely to the discretion of commanders, although the Navy Bureau of Medicine and Surgery does provide technical assistance through its sub-command, the Navy Environmental Health Center.[30] The Naval Ship Engineering Center is responsible for determining hazardous shipboard areas and insuring that the possibility of biological injury to personnel from RF radiation is minimized or non-existent,[31] however, there is no organization formally responsible for shore installation hazard evaluation.

Item 8. The Air Force specifically assigns responsibility for research into the hazards of EMR in the USAF standards of EMR protection.[32] The Army and Navy do not specifically mention this responsibility in their EMR protection regulations or instructions, although both services

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[30] U.S. Department of the Navy, BUMED Instruction 6470.13A, 3.

[31] U.S. Department of the Navy, NAVSHIPS 0900-004-8000, 1-1.

[32] U.S. Department of the Air Force, AFOSH Standard 161-9, 1.

do conduct such research.[33]

Item 9. The Army specifically requires that agencies responsible for research, development and testing (RDT) of microwave and RF equipment insure that such equipment is evaluated for personnel exposure potential during the RDT phase.[34] The Air Force also requires similar actions in its EMR safety standards.[35] The Navy does not mention such requirements in its instruction on microwave and RF health hazards, although, as mentioned in Item 7, the Naval Ship Engineering Center is responsible for determining hazardous areas on ships. No mention is made of any organizations responsible for determining hazards of EMR emitting equipment being designed for installation at shore activities or in shore-based aircraft.

Item 10. All three services have agencies which conduct consultations in the case of overexposures to EMR, and provide advice and guidance to commanders when requested. These age es are the same as mentioned in Item 7.

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[33]The Walter Reed Army Institute of Research, Washington, D.C., and the Naval Medical Research Institute, Bethesda, MD., conduct research into hazards of EMR. The Army Medical Research and Development Command, Washington, D.C., and the Navy Medical Research and Development Command, Bethesda, MD., fund research by civilian agencies into the hazards of EMR.

[34]U.S. Department of the Army, AR 40-583, 2.

[35]U.S. Departr of the Air Force, AFOSH Standard 161-9, 1.

Item 11. All three services have agencies which are responsible for on-site surveys, estimating hazard distances, maintaining data on EMR emitter charactoristics, and assistance in investigation of suspected or actual overexposures. The Army and the Air Force specifically mention these responsibilities in their regulations/standards concerning EMR hazards (see Item 7); the Navy's instruction on microwave and RF health hazards does not assign specific responsibilities for on-site survoys, estimating hazard distances or maintaining data on EMR emitter characteristics, other than by saying that technical assistance may be requested from the Navy Environmental Health Center. The Navy's Technical Manual for RF Radiation Hazards states that "Requests for the assistance of qualified shipboard survey personnel should be directed to the Naval Ship Engineering Center via the Naval Ship Systems Command."[36] The manual, however, does not specify any regular system of surveys or reports. The manual does contain lists of estimated hazard distances and EMR emitter characteristics for radar systems which could cause hazards to personnel. No mention is made of communications systems. The Air Force specifically states that the USAF OEHL will loan selected survey instruments to assist commanders in resolving RF personnel hazard problems which are beyond the capability of base and

[36] U.S. Department of the Navy, NAVSHIPS 0900-005-8000, 1-2.

major command resources.[37] The Army and the Navy do not mention this capability in their regulations/instructions on EMR hazards.

Item 12. Although the means of providing travel funds is not mentioned in any of the service regulations/instructions/standards on providing protection from EMR hazards, it is the personal knowledge of the author that the Army and Air Force fund the responsible organization directly, while in the Navy, any funding for travel of personnel from either the Navy Environmental Health Center or the Naval Ship Engineering Center must be provided by the requesting command.

Item 13. The Army and the Air Force specifically require inventories of all EMR emitters,[38,39] categorization of EMR emitting equipment as to hazard,[38,39] and periodic resurvey of emitters.[39,40] The Navy does not mention any specific requirements in the above areas in instructions concerning EMR hazards. All three services do require dissemination of information on measures required for control of exposures to

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[37] U.S. Department of the Air Force, AFOSH Standard 161-9, 26-27.

[38] U.S. Department of the Army, TB Med 270 (September 1978), 26.

[39] U.S. Department of the Air Force, AFOSH Standard 161-9, 4-5.

[40] U.S. Department of the Army, AR 40-583, 2.

hazardous levels of EMR.[41,42] (See also Footnote 40.) The Army and Air Force require specific checks and warning for facilities that repair or test EMR emitters. (See Footnote 39 and 40.) The Air Force requires more frequent surveys of such facilities than for other EMR emitters, while the Army does not. The Navy makes no specific reference to test and repair facilities as being any different from any other facility.

Item 14. All three services require hazard warning signs at locations which are hazardous or potentially hazardous to personnel. However, the requirements for posting EMR hazard warnings in such areas are different for each service. The Army requires that "appropriate areas are placarded to the nature of possible hazardous exposure . . . ."[43] The Navy Bureau of Medicine and Surgery requires that "Personnel shall observe 'RF HAZARDS' warning signs which point out the existence of microwave radiation hazards in a specific location or area."[44] The Naval Ship Engineering Center expands

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[41] U.S. Department of the Navy, BUMED Instruction 6470.13A, Enclosure 1.

[42] U.S. Department of the Air Force, AFOSH Standard 161-9, 2.

[43] U.S. Department of the Army, AR 40-583, 2.

[44] U.S. Department of the Navy, BUMED Instruction 6470.13A, Enclosure 1, 2.

on the warning sign requirements, stating "Ensure that radiation hazard warning signs are available and used, not only where required to be permanently posted, but also for temporarily restricting access to certain parts of the ship while radiating."[45] The Air Force states that "RF warning signs are required at any location where access to power density levels in excess of the PEL is probable."[46]

Item 15. Although microwave ovens cannot be continued in use if periodic surveys determine that they leak more than $5mW/cm^2$ (half the permissible exposure level for continuous exposure), the Army requires that "microwave ovens on mobile food carts or ward nourishment stations of medical facilities may require microwave warning signs during operation. Temporary posting of warning signs pertaining to interference to medical electronic devices may be necessary . . . ."[47] The Army also requires that personnel "Conspicously display warning signs identifying potentially harmful generators of EMI [Electromagnetic Interference] such as RF/microwave diathermies, microwave ovens, etc., whenever the devices are in use, so that cardiac pacemaker wearers can avoid the area."[48] The

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[45] U.S. Department of the Navy, NAVSHIPS 0900-005-8000, 1-8.

[46] U.S. Department of the Air Force, AFOSH Standard 161-9, 3.

[47] U.S. Department of the Army, AR 40-44, 2-1.

[48] U.S. Department of the Army, TB Med 270 (September 1978), 49.

Navy and Air Force do not require warning signs near microwave ovens (other than the federally required label on the oven stating that the oven should not be operated when empty, with objects caught in the door, with damaged door, etc.); the Air Force specifically forbids the posting of warning signs around microwave ovens.[49,50]

Item 16. The Army requires warning signs be posted for possible interference with heart pacemakers for any equipment capable of creating EMI (see Item 15). The Air Force specifically prohibits the posting of warning signs at access routes to RF sources because of interference potential to medical prosthetic devices (pacemakers).[51] The Navy does not mention the posting of warning signs for pacemakers in the EMR hazard instructions.

Item 17. All three services require formal medical investigation of incidents and accidents concerning EMR. The Army requires that "Personnel who are known or suspected to have been accidently exposed to levels in excess of applicable protection standards shall be examined as soon as possible following such exposure."[52]

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[49] U.S. Department of the Navy, BUMED Instruction 6470.16.

[50] U.S. Department of the Air Force, AFOSH Standard 161-9, 4.

[51] U.S. Department of the Air Force, AFOSH Standard 161-9, 4.

[52] U.S. Department of the Army, AR 40-583, 2-3.

The Navy requires that "Personnel exposed to power densities above 50mW/cm^2 should be given a complete physical and ophthalmological examination immediately following the incident and at 2-week intervals thereafter for a minimum period of 4 weeks."[53] (See also Item 21.)

The Air Force requires that "In the event of confirmed or likely instance of an overexposure to an individual, a physician will review the individual's medical history and perform such examination as is indicated by clinical symptoms."[54]

Item 18. The Army requires individuals whose assignment may result in significant risk of exposure to potentially hazardous levels of EMR to undergo pre-or post employment medical examinations.[55] The exact requirements of the medical exam are not specified.

The Navy also requires routine pre-and post-employment examinations, and states exactly what such exams should include.[56]

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[53] U.S. Department of the Navy, BUMED Instruction 6470.13A, 4.

[54] U.S. Department of the Air Force, AFOSH Standard 161-9, 7.

[55] U.S. Department of the Army, AR 40-583, 2.

[56] U.S. Department of the Navy, BUMED Instruction 6470.13A, 3.

The Air Force states that pre-or post-employment medical examinations are not required for personnel occupationally exposed to EMR.[57]

Item 19. The Army and the Navy require periodic medical examinations for personnel occupationally exposed to EMR. The specified requirements include periodic opthalmologic examinations only. (See Footnote 55.) The Air Force once again specifically states that medical examinations are not required. (See Footnote 56.)

Item 20. The Navy, in requiring pre-employment examinations, specifically forbids occupationally exposing personnel having eye opacitie which would be indistinguishable on further development from opacities which are caused by microwave exposure.[58] The Army and the Air Force don't address this requirement in their regulations/standards.

Item 21. The Navy has a specific requirement for physical and ophthalmological examinations for personnel exposed to power densities above $50mW/cm^2$, even though the Navy's permissible exposure level allows exposure greater than $50mW/cm^2$ for limited periods of time.[59]

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[57] U.S. Department of the Air Force, AFOSH Standard 161-9, 7.

[58] U.S. Department of the Navy, BUMED Instruction 6470.13A, 4.

[59] U.S. Department of the Navy, BUMED Instruction 6470.13A, 4.

The Army also requires examinations for exposures greater than 50mW/cm^2, but in the Army's case, exposures above 50mW/cm^2 constitute a forbidden exposure level. (See Items 1, 2, and 3.)

The Air Force does not require examinations for exposures above 50mW/cm^2 unless the amount of time the person is exposed exceeds the PEL.

Item 22. The Army allows commanders to prescribe "conditions under which interlocks, limiting or warning devices installed on equipment may be by-passed or overridden during combat alerts, training exercises, and in maintenance or calibration of equipment."[60] The Navy and Air Force make no mention of such a concept in their instruction standards.

This chapter reviewed known physical and administrative protective measures against the hazards of EMR. Comparisons of protectice measures between the services were made and displayed in matrix format. The comparison of physical and administrative protective measures reveals areas of significant differences between the three services. The implications of these differences will be discussed in the next chapter.

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[60] U.S. Department of the Army, AR 40-583, 2.

CHAPTER VI

FINDINGS

A contemporary problem for the military services, as identified in Chapter I, is the attack by various individuals and groups on the measures used to protect members of the military services and the public from hazards of EMR. In order to understand the meaning and adequacy of protective measures employed by the military services, it is necessary to be aware of the nature of EMR, and the extent of the EMR hazard. These subjects have been briefly discussed in Chapters II and III. It is also necessary to understand the extent of the military involvement with equipment and systems capable of causing a biological hazard to man, in order to analyze the protective measures employed by the services. The general classes of EMR emitting systems in use in the military were discussed in Chapter IV.

A problem clouding the issue of the adequacy of the military services EMR protective measures is the controversy surrounding the question of non-thermal effects, described in Chapter III. The scientific questions being discussed concerning non-thermal effects are the driving force behind most serious queries concerning EMR hazard protection. The Eastern European standards of protection, being much lower than those in the United States, continue to be the main source of dissention among members of the U.S. Scientific Community whenever EMR exposure standards are discussed. The military services, being aware of the possibility of hazards due to as yet unproven effects of EMR, continue to fund research designed to discover hazardous effects of EMR as well as the biological mechanisms of such effects. The areas of research and amounts being expended are detailed in Chapter IV.

Although an awareness of the above controversy, and what is being done about it, must certainly concern anyone interested in improving protection from EMR bioeffects, the primary thrust of this paper was not to try and resolve that problem. The fact is that although the military services must certainly be aware of pending problems, in order to not be surprised by new discoveries, if any, in the field of biological hazard protection, they must also provide adequate protection to known hazards on a day-to-day basis. The only recognized and generally accepted EMR hazards, at the present time, are the thermal hazards. To protect against this known hazard, the American National Standards Institute has created a standard setting the safety level of EMR with respect to personnel. The military services are required to conform to this standard. The services may, if they desire, establish stricter standards, and the means of implementing the standard remains the perogative of the individual service. This paper examines the means by which the services presently implement existing protective standards.

The data presented in Chapter V is a compilation of protective measures against EMR hazards in use by the military service. The protective measures in use in each service are shown in comparison with the measures in use in the other services. By means of this comparison, overall protective measures in the military services may be improved by identifying protective measures not in use in all services. The protective measures not in use in all services are indicators of measures which may be implemented, or at least examined, by the non-using service(s) as possible means of improving personnel protection practices. Alternatively, protective measures that are discovered in use, but not by all services, could indicate areas in which protective measures are unduly strict in one or more services. Through the examination and possible elimination of such overly strict measures, funds may be saved which could then be used to improve other areas of EMR hazard protection. Thus, the discussion in the remainder of this chapter will develop conclusions based on the data presented and discussed in Chapter V; will present recommendations intended to improve the EMR hazard protection of the services based on the conclusions; and will present other considerations based on the author's experience with the U.S. Army, with EMR, and with biological research into the hazards of EMR.

CONCLUSIONS

Energy from EMR may be absorbed into biological organisms in various amounts depending on many physical factors. Depending on these physical factors, primarily the intensity of the EMR in relation to its frequency, hazards may be presented to biological organisms, including man. The military services are active users of devices and systems which emit EMR over the entire range from 30 Hz to 300 GHz. The military services, because of their use of devices which emit EMR, and the necessity for conforming with ANSI standards setting the safety level with respect to EMR, have implemented various safety regulations, instructions, guidance and standards.

The services, in their administrative protective measures, describe various physical protective measures. The effects of distance, shielding, protective clothing, and antenna design and function are also discussed in various degrees in service publications.

Protective clothing should either be allowed by all services if it performs adequately, or forbidden by all services if it does not. To have one service implement a policy of protective clothing wear, while another expressly forbids it, while the third service does not mention the subject (other than as a recommendation concerning protective eyewear in a military course on hazards rather than in an official regulation) can only cause doubt as to the adequacy of protection provided. Possible methods of resolving this problem are for the non-using services to state in their regulations that the use of protective clothing in that service is not necessary for whatever reasons apply and to state what alternate methods of protection are to be used, or for the non-using service to actually procure protective clothing similar to that in use in the Navy, and state its use and availability in the appropriate regulation.

Emission cutoff is not specifically discussed as a protective measure in any of the service publications reviewed, although it is mentioned in civilian "open" publications and in publications of other governmental agencies. This information would probably not help base/post/unit commanders in providing better protection, since the technical specifications of emission cutoff devices must usually be established during the design phase. However, since some service regulations require that consideration be given to EMR exposure criteria in the RDTE phases of new equipment procurement, the publication of information on this subject by the Department of Defense would possibly aid in the procurement of safer equipment throughout the military services.

Spread spectrum techniques are not mentioned in the context of being safer than comparable EMR emitting equipment. However, the technical characteristics of spread spectrum devices make them worthy of consideration by all services for possible inclusion in any publication discussing the reduction of hazard of EMR emitters based on technical characteristics.

In the area of administrative protective measures, the differences between the EMR exposure standards (permissible exposure limits) among the three services should be resolved.

The principle that each service should be free to enact more stringent measures than the ANSI standards require certainly could not be argued against; however, a problem exists in that the services do not agree on exactly what frequency range the standards should cover, or what the maximum exposure limit should be. This can only lead to a lessening of credence in the standards, as questions are posed as to what standard is really safe.

Two services, the Army and the Air Force, establish, in regulations and instructions, a comprehensive continuing EMR emitter monitoring program that ensures compliance with their own exposure standards. The Navy does not mention such a program in the appropriate EMR health hazard instruction, other than to require commanders to comply with the instruction. Although further review of Navy manuals concerned with EMR health hazards indicates that specific commands are responsible for various aspects of personnel EMR hazard protection, specifically on ships, the lack of overall guidance in the basic EMR health hazards instruction is notable when contrasted to that of the Army and Air Force. Whether the program is centralized, as is the case in the Army, or decentralized, as is the case in the Air Force, would of course be the choice of the Navy; however, a specific program should be detailed by the Navy to aid in the overall protection of personnel of the military services.

In addition to establishing continuing comprehensive monitoring programs, the Army and the Air Force both maintain central organizations capable of providing technical assistance in the form of on site surveys of possible hazards, estimating hazard distances, maintaining EMR emitter characteristics, etc., as well as providing assistance in investigation of possible overexposures. Although Navy Instructions state that the Naval Environmental Health Laboratory can provide technical assistance, the specific capabilities of this organization are not mentioned. Spelling out the specific capabilities of the assistance organization as is done in the Army and Air Force, as well as delineating its exact responsibilities in regard to personnel protection, could improve the Navy's protection posture as all commands would know exactly what help is available.

Another area in which Army and Air Force techniques could help the Navy is in the funding of the travel of the technical assistance organizations. The Navy does not fund the Naval Environmental Health Laboratory for routine travel in assisting "customers." The major command requesting the assistance must fund the travel. This is a major difference between the Navy and the other services, who provide their assistance organizations with programmed travel funding. This subtle difference in approach could result in commanders in the Navy being more reluctant than commanders in the Army or Air Force to request the assistance of an outside hazard evaluation agency, because of the cost involved to the requesting command. This could tend to reduce overall protection in the Navy as commanders allocate funds to what they consider to be higher priorities.

The many differences in the use of hazard warning signs noted in the data presented in Chapter V is another area in which the services differ. If an item is considered dangerous in a certain environment by one service, and warning signs required, while another specifically states that a sign is not required in the same environment, the overall view of the adequacy of protective measures becomes suspect.

Another area in which the services do not agree is the need for medical investigations or examinations. While all services agree that investigations of incidents or accidents involving overexposure to EMR are required, they do not agree on other medical programs, such as periodic and pre-or-post employment medical exams. If safety requires certain types of examinations in one service, they should be required in all; or if one service can show that a certain type of medical examination is not required for some adequate reason, then there is no logical reason for the other services to retain the requirement.

A final item, the fact that the Army allows commanders to prescribe conditions under which protective devices installed on equipment may be by-passed or overridden, while the other two services do not mention such a concept, is one that should be addressed by all services. The commander, in combat, has always had the responsibility to determine measures to accomplish his mission, and these measures could often be hazardous to personnel under his command. In addition, a realistic training environment is necessary to insure eventual success in any mission. The assumption by the Army that all commanders have the capability of determining the extent of the EMR hazard to sufficient degree to allow them to make a decision concerning the bypassing of safety devices is probably erroneous, given the fact that the Army practices a centralized EMR monitoring program. Reconsideration of this item by all services in light of other service doctrine, with the intent of being more specific as to the latitude allowed commanders in this area, could considerably improve EMR hazard protection.

RECOMMENDATIONS

The following recommendations are offered:

a. That the Secretary of Defense direct the establishment of a committee to discuss the protective measures of the three services, and to coordinate the resolution of the differences between the physical and administrative protective measures of each of the services. The committee's individual service representatives should be empowered to implement changes to service regulations, instructions, standards, and guidance, arrived at by consensus of the group. This committee could be similar in concept to the committee formed at the request of the Director Defense Research and Engineering (now called the Deputy Undersecretary of Defense, Research and Engineering) in 1975 to coordinate the Tri-Service EMR Bioeffects R search Program. That committee is called the Tri-Ser ... Electromagnetic Radiation Panel (TERP). The new committee would concern itself with physical and administrative protective measures, rather than with coordinating the research into biological hazards of EMR. Although the existing TERP has as one of its objectives ". . . to provide guidance for systems development and operations,"[1] this ... ive is accomplished primarily through recommending ...nges to existing permissible exposure levels based on the scientific research the panel coordinates, rather than by actually proposing appropriate physical protective measures or a broad range of administrative protective measures to be implemented by the services. If necessary, due to funding limitations, the charter and panel membership of the TERP could be expanded to include this function.

b. That a tri-service document be published by the Deputy Undersecretary of Defense, Research and Engineering, describing all known physical protective measures and means for implementing the measures. The document would primarily

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[1]U.S. Department of Defense, Summary Report on the Tri-Service Electromagnetic Radiation (EMR) Bioeffects Research Program, presented by the Tri-Service Electromagnetic Radiation Panel (TERP) at the 158th. Joint Medical Research Conference, Washington, D.C., 18 October 1978.

be used in the research, development test and evaluation phases of equipment procurement as a guide in providing appropriate protection prior to the fielding of new EMR emitting equipment.

c. That the three services immediately resolve the differences between their respective EMR exposure standards. That in stating their exposure standards to EMR radiation the services include statements as to why EMR at certain frequencies does not require standards, if that is the case, in the appropriate regulations and instructions.

d. That the Navy establish in its microwave and RF health hazard instructions a comprehensive and continuing EMR emitter monitoring program, similar to either of the other services. The Navy should also either upgrade the capability of the Naval Environmental Health Laboratory to perform EMR health hazard assessments and assistance to other naval commands, or assign these functions to some other agency equipped and manned to handle them.

e. That protective clothing, already in use by the Navy, be examined by the other services for possible use. If a decision not to use protective clothing in the other services is made, that statements concerning the existence of protective clothing and why it is not being used be made in the appropriate regulation, and that statements be made as to what alternate methods of protection are to be used in its place.

f. That at review of the three services' use of hazard warning signs be made to insure conformity of use as a warning near microwave ovens, and near other emitters as possible sources of pacemaker interference.

g. That the services reach agreement as to requirements for periodic, pre-employment, and post-employment medical examinations. That the procedures to be followed in these examinations found to be necessary be established in the appropriate service regulations, instructions and standards on EMR protection. This will enable medical personnel unfamiliar with the symptoms of EMR damage to conduct more meaningful examinations.

h. That all three services better define the latitude of commanders to prescribe conditions under which EMR hazard protective devices may be by-passed or overridden.

OTHER CONSIDERATIONS

Although the concern about a Department of Defense coverup of EMR hazards expressed by Brodeur, as described in Chapter I of this paper, appears to be unfounded, this research has discovered certain areas in which the protection provided to military personnel and the public may be ultimately improved, by better coordinating efforts among the services. That is, of course, but one aspect of the overall problem of EMR hazards. The following represents general observations of the author's twelve years in the U.S. Army, and specifically three years at the Armed Forces Radiobiology Research Institute as an electronics engineer working on projects involving research into the biological hazards of microwave and extremely low frequency radiation, as well as electromagnetic pulse.

a. Non-Thermal Effects. Although this paper did not directly consider the problems posed by the uncertainty surrounding the possibility of non-thermal effects, this is a problem with which the military services are vitally concerned. Ongoing research continues to examine the mechanisms by which EMR may damage biological organisms, as indicated in Chapter IV. The Environmental Protection Agency is considering new guidance for general population exposure to EMR. The military, in at least one service, is addressing the impact of a possible reduction in the maximum permissible exposure level for continuous exposure from $10mW/cm^2$ to $1mW/cm^2$. However, control of RF emitting equipment and/or real estate to restrict levels where personnel may enter or traverse are the only subjects addressed.[2] As is seen in this paper, various other physical and administrative protective measures may need to be considered.

The Navy is the only service that specifically mentions the possibility of non-thermal effects but states that "An association of a biological hazard with the non-thermal effects has not been demonstrated."[3] This appears to be the

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[2]Letter, Department of the Army, Office of the Deputy Chief of Staff for Operations and Plans (DAMO-TCF) to commanders of major army commands, subject: Control of Exposure to Radio Frequency Radiation, Washington, D.C., 12 May 1978.

[3]U.S. Department of the Navy, BUMED Instruction 6470.13A, (January 28, 1977), 2.

opinion of the scientific community in general in the United States, and should probably be acknowledged in the guidance and regulations of all services.

b. <u>Training of Military Personnel</u>. The problem of preventing the hazardous exposure of military personnel actually operating or repairing military communications and radar equipment is one which is not addressed through fully training these personnel in knowledge of the hazards, at least in the Army.

Installation and activity commanders are required to insure that personnel working in the vicinity of microwave or RF radiating equipment are informed of potential health hazards associated with exposures from specific equipment being used. This is usually accomplished through the use of Standing Operating Procedures (SOP's). Although the SOP's exist, and are usually adequate, neither working personnel nor supervisors are fully familiar with the actual hazards of specific equipment. While no one will knowingly walk into an area which is placarded with a hazardous area warning, many personnel in a maintenance environment, for instance, are unaware of the possible hazards of improperly repairing equipment. Even when personnel are knowledgeable of the possible hazards, they have no method of accurately measuring EMR hazard levels, and assume that if something they were doing was dangerous, someone would tell them. The author's experience is that only a small percentage of officers in the Army are familiar with the specific hazards of EMR.

It must be realized that detailed knowledge of the hazards of EMR, which after all, are but one of the hazards with which members of the military are associated on a day-to-day basis, is probably an unrealistic goal. This problem area could probably be improved upon by insuring that appropriate warnings were included in the equipment operating manuals used by military personnel, and by including "awareness" instruction in appropriate training courses at all levels, to include supervisory personnel.

c. Possible Future Protective Measures. Although many physical and administrative protective measures are presently in use, the technology of providing protection from EMR is still an area in which consideration must be given to the development of new techniques. Technology which has as its objective the improvement of the operational capabilities of communications and radar systems may yield benefits in EMR hazard protection. For instance, the development of Offset-Parabolic-Reflector Antenna Systems offer a better compromise between high efficiency and low side lobes than many present antenna systems.[4] This low side lobe characteristics could make systems using such antennas less hazardous to personnel than existing systems.

Another possible protection from the hazards of EMR which could be used by support and maintenance personnel on

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[4] Alan W. Rudge and N.A. Adatia, "Offset-Parabolic-Reflector Antennas: A Review," Proceedings of the IEEE, 66 (1978), 1617.

flight lines and aircraft carrier decks would be the development of simple individual warning devices to be worn with the uniform or carried by one member of a maintenance team. The devices could be similar in concept to the "radar warning" devices sold to motorists, and would warn personnel if they were in the radar beam of an aircraft in which the radar was inadvertently operating. Such a warning device could also be useful in maintenance facilities for use by personnel performing bench repairs on EMR emitting devices.

Soldiers in the field are subject to being exposed to the EMR from a great variety of battlefield surveillance devices. The development of a shield to be included as part of body armor worn by front line troops could result in fewer constraints being placed on the operation of battlefield surveillance and radar devices, as well as increased safety for personnel.

The planners of future satellite communications systems may have to place enough satellites in orbit to insure that ground station elevation angles cannot be low enough to the ground to cause hazards to nearby personnel. This protective function is presently carried out by restraining the antenna so it may not be lowered beyond a specified elevation angle. However, in a field environment this constraint may be unacceptable as troops move to positions where existing satellites may appear low on the horizon.

In the area of administrative protective measures, along with the improvement of regulations, instructions, and standards concerning medical examinations, it may be necessary to develop new techniques of intensively managing and screening medical files to insure that exposure to EMR is permanently maintained as a necessary record and that necessary examinations are accomplished on schedule. This is already done in the field of ionizing radiation, by using a Department of Defense Form 1141, "Record of Occupational Exposure to Ionizing Radiation," which is permanently retained in an individual's medical record. The development of a form for non-ionizing radiation would focus both the individual's and the doctor's attention on the hazards of EMR.

While the present difficulty in quantifying "doses" of non-ionizing radiation in a manner similar to ionizing radiation may limit the utility of such a medical form, the necessity to quantify medical information on periodic updates of medical forms may eventually form a valuable data base on medical problems of individuals occupationally exposed to EMR.

d. Summary. The conclusions and recommendations of this paper open up other aspects of EMR hazard protection which might be considered in the future. The possibility of non-thermal effects being hazardous, however remote this is considered to be at the present time, could increase the need for a tri-service committee to coordinate the implementation of EMR hazard protective measures. The necessity of insuring adequate training of military personnel, and coordinating research and implementation of possible future protective measures, such as suggested above, are subjects which should also be coordinated between all military services, thus improving overall protection.

SUMMARY

In examining the problem of the hazards associated with EMR, this study concludes that there are many areas where differences are apparent in individual service regulations, instructions guidance and standards. Services not implementing protective measures in use in other services may benefit by implementing such measures. Discrepancies between EMR exposure standards among the services may lead to a lessening of credence in the standards. Differences in other areas, such as EMR emitter monitoring programs, use of protective devices, use of hazard warning signs, and medical monitoring programs tend to cast doubt on the adequacy of some service programs when compared to the programs of other services.

In an effort to improve the EMR hazard protection provided by the military services, several recommendations are offered. The recommendations include: establishing a tri-service committee to coordinate the implementation of protective methods among the services; providing specific guidance concerning physical protective measures to be used in the research, development, test and evaluation phases of new equipment procurement; resolving differences between

exposure standards; establishing comprehensive and continuing EMR emitter monitoring programs in the Navy, similar to those in use in the other services; insuring uniformity of the use of hazard warning signs; improving medical monitoring programs and examining the latitude of commanders to prescribe conditions under which EMR hazard protective devices may be bypassed or overridden. These recommendations are attainable at the present time, and will improve EMR hazard protection in the military services.

In addition, this paper discusses other considerations of EMR hazard protection. These include the necessity of planning for the possibility that non-thermal effects may cause a change in present hazard level standards; the necessity of insuring adequate EMR hazard training for military personnel; as well as proposals for the development of future physical and administrative methods of protection.

The use of <u>all</u> available EMR hazard protective measures by <u>all</u> the military services, and continuing programs for the development of new protective measures, will result in better protection for military personnel and members of the general public subject to exposure to potentially hazardous levels of EMR from military communications and radar systems.

APPENDIX

APPENDIX A

DEFINITIONS

Antenna Gain.	The ratio of the power gain of an antenna relative to a standard antenna. The relative gain is usually expressed in decibels. The standard antenna is usually an isotropic antenna.
Conductivity.	A measure of the number of free electrons in a material which could drift in an electric field to create a current.
Decibels (DB).	The unit giving the ratio of two levels of power. The number of decibels is ten times the natural logarithm of the power ratio.
Electron-Volt (e-v)	The unit of energy acquired by an electron in moving through a potential difference of one volt.
Far Field Region.	The region of the radiated field of an antenna where the power density decreases in a manner inversely proportional to the square of the distance from the radiating antenna. This region is also known as the Franhofer region.
Field Intensity.	See Field Strength.
Field Strength.	A measure of the electric field component of electromagnetic radiation. It is defined as the quotient of a force due to a field acting on a test charge divided by the magnitude of the charge. Field strength is measured in newtons per coulomb or in volts per meter, which are equivalent terms. Also known as Field Intensity.
Isotropic.	Having the same radiating characteristics in all directions.

Microwaves.	A common term used to loosely describe electromagnetic radiation in the frequency range from about 300 MHz to 300 GHz.
Near Field Region.	The region of the radiated field of an antenna were the power density is not inversely proportional to the square of the distance from the radiating antenna. This region is also known as the Fresnel region.
Permeability.	A quantity which relates the strength of the magnetic flux density in a material to the strength of the current creating the magnetic flux, or to the strength of the magnetic field.
Permittivity.	A quantity which relates the electric field strength in a non-conducting (dielectric) material to the strength of the electric charge creating the field.
Photon.	A "particle of light" which travels at the speed of light and possesses "quanta" of energy.
Power Density.	The time averaged energy flux of an electromagnetic wave, or the radiated power flowing through a given area. It is usually measured in watts per square meter (W/m^2) or in milliwatts per square centimeter (mW/cm^2). Power density is directly related to the square of the field strength.
Power Gain.	For an antenna, power gain in a given direction is 4π times the ratio of radiation intensity in the given direction to the net power delivered to the antenna.
Quanta.	Energy packets of light produced under the particle theory of light. Under this theory "photons" traveling at the speed of light possess various "quanta" of energy.
Radio Frequency(RF)	A common term used to describe electromagnetic radiation in the frequency range from about 10 KHz to 100 GHz.

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