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AGARD Lecture Series on the Impact of Proposed Radio
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19 ABSTRACT (Continue on reverse if necessary and identify by block number) During April 1985, the North Atlantic Treaty Organization's Advisory Group for Aerospace Research and Development (AGARD) held a lecture series dealing with the impact of proposed and existing radio-frequency (RF) radiation standards on military operations. This report discusses presentations on specific absorption rate and RF energy, biological effects of RF energy, long-term exposure, accidental exposure, epidemiological studies, power-line frequencies, very low frequency to medium frequency hazards, exposure standards, and measurement problems. The appendix provides background on AGARD and its lecture series.				
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AGARD LECTURE SERIES ON THE IMPACT OF PROPOSED RADIO FREQUENCY RADIATION STANDARDS ON MILITARY OPERATIONS

During April 1985, the North Atlantic Treaty Organization's (NATO) Advisory Group for Aerospace Research and Development (AGARD) held a lecture series dealing with the impact of proposed and existing radio frequency (RF) radiation standards on military operations. Three sets of lectures were held: in Rome, Lisbon, and Paris. Each series lasted 2 days, and the lectures were given by the same set of speakers at each. In this report I attempt a distillation of the lectures given in Lisbon. (For those not familiar with AGARD, I have discussed its background and organization in the appendix.)

Reprints of the lectures are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

The Lisbon Series

AGARD Lecture Series No. 138, entitled "The Impact of Proposed Radiofrequency Radiation Standards on Military Operations," was opened by the series director, Mr. John C. Mitchell. Mitchell, who is Chief, Radiation Physics Branch, Radiation Sciences Division, US Air Force (USAF) School of Aerospace Medicine, Brooks Air Force Base, Texas, gave an overview of the use of RF energy by the military as well as by civilian industries. He reviewed not only the many types of RF emitters in general use, but also some of the possible levels to which personnel might be potentially exposed.

The lectures in this series included presentations on: (1) the physical interactions of RF radiation fields with biological systems, (2) the biological effects of RF radiation exposures, (3) the procedures for measuring RF radiation fields in military operations, and (4) the development and operational impact of new RF radiation safety guidelines.

Besides Mitchell, the speakers and their affiliations were: (1) Dr. Carl H.

Durney (Electrical Engineering Department, University of Utah); (2) COL Roger B. Graham (USAF Occupational Environmental Health Laboratory); (3) Dr. A.W. Guy (Department of Rehabilitation Medicine and Center for Bioengineering, University of Washington); (4) Dr. Jerome H. Krupp (Radiation Sciences Division, USAF School of Aerospace Medicine); (5) Dr. Norbert J. Roberts (University of Rochester Medical Center); and (6) Dr. Jürgen H. Bernhardt (Institut für Strahlenhygiene des Bundesgesundheitsamtes, West Germany).

The "kickoff" speaker was Professor Durney, who set the stage for understanding much of what was presented in later lectures by introducing the physical concepts of the interaction of RF energy with biological systems, particularly with humans. Durney presented a very good tutorial on dosimetry and its underlying concepts as well as the numerical and analytical techniques used for estimating specific absorption rate (SAR) of RF energy that impinges on animals and phantom models for humans. He pointed out the differences and problems associated with measurements in the near field as opposed to the far field of an RF antenna, and the differences arising due to orientation and configuration of the subject with respect to the field. Finally, he outlined what needs to be done in terms of calculations and measurements of SAR in both the near and the far field of an antenna.

SAR and RF Energy

Guy presented a great quantity of data, most from his own very active laboratory, to illustrate the distribution of heating patterns and the consequences of localized SAR due to exposure to RF energy. He stressed the need to know the relationship between the absorbed energy, the tissue cooling mechanisms, and the temperature if one is going to understand the thermally induced biological effects. He discussed the complexity that arises in the human body due to the different types of tissues, with differing water content, and the many interfaces encountered by the RF energy.

effects will remain. The difficulty of assessment implied that very subtle effects, without a distinguishing lesion or disease entity, will continue to fertilize the blossoming of anecdotal epidemiology data. In the meantime, rational review of the existing data provides no reason to predict adverse consequences from lifespan exposure to currently allowable levels of RF radiation.

Accidental Exposure

There have been a number of real and imaginary accidental exposures to high levels of RF energy, both in military and industrial situations. This is inevitable, given human fallibility. COL R.B. Graham reviewed several cases with which the USAF has been involved. He reviewed the procedures that have been developed to investigate accidents and to evaluate the health aspects of the person who was overexposed. In every case where the people exposed are employees, according to Graham, they are kept under medical surveillance throughout their lives in order to detect any harmful effects that might develop.

Graham provided a good summary of the results of the USAF's medical evaluations. According to him, medical evaluations have been done on many, but not all of the personnel involved in RF radiation overexposures at USAF bases since 1972. Not all of the personnel involved have been USAF employees. There have been incidents on USAF bases that involved civilian contractors, foreign nationals, US Army, and US Marine Corps personnel.

In many cases the medical data obtained from the evaluations of the accidental RF radiation overexposures are incomplete in several respects, primarily due to a lack of standardization of the clinical examinations. Nevertheless, these case files can and do provide important anecdotal information concerning human exposure to RF radiation fields. This repository of the case files is the only one of its kind known to exist.

Of the more than 330 (as of 1 August 1984) suspected individual overex-

posure files in the repository, only 58 were positively confirmed to have exceeded the permissible exposure limit (PEL). Of those 58, 26 individuals reported that they clearly felt a warming sensation at the time of the overexposure, 20 felt no warmth, and 12 were not sure. It can therefore be concluded that 45 percent of those overexposed felt the energy, and probably as a consequence of that feeling terminated the exposure. Of the approximately 240 alleged overexposures that were later positively confirmed as not exceeding the PEL, 26 felt a warming sensation and terminated the exposure before the PEL could be exceeded, 173 individuals felt no sensation and 39 were not sure. In the remaining cases, no determination could be made about whether exposure occurred.

Tables 1 through 6 summarize the accidental RF radiation exposures as a function of frequency, average power density, and exposure time.

Graham revealed that medical examinations conducted on persons who were overexposed to RF energy have shown few, if any, consistent clinical patterns. This contradicts several reports in the popular media. In a few cases there was edema or erythema or both, or even minor imperfections in the lens of the eyes. However, these all either disappeared or caused no ill health. According to Graham, psychological and neurological examinations have also been uncharacteristic, except for anxiety in several cases where the individuals were so concerned about the possible consequences of the exposure that they exhibited such symptoms.

Epidemiological Studies

There have been several attempts to conduct epidemiological studies of human exposures to RF energy. To date, none has been fully accepted because of a number of complications attendant to such studies with RF energy. Roberts reviewed several such attempts and went on to discuss the requirements for good epidemiological investigations, how these general principles might be

applied to RF energy studies, and why some of them can never be achieved. There are many pitfalls when one attempts to look back at a population that may have been exposed to RF energy, and Roberts cautioned the course attendees about these pitfalls. One of the most critical bits of information that is always lacking is the level to which the sample population was exposed. Since there is no such thing as an RF personnel dosimeter, people who work in occupations where they are likely to be exposed have no way to keep a record of that exposure. This then, as Roberts pointed out, is one of the most severe limitations to epidemiological studies in this field.

It is interesting to note, as an aside, that a prominent Polish scientist, Dr. Stan Szmigielski of the Center for Radiobiology and Radioprotection, Warsaw, has just reported in an informal communication the results of an epidemiological study carried out on a group of military workers in Poland that were exposed to heavy doses of microwaves. Szmigielski claims to have found "a definite increased risk of neoplasms resulting from the exposure."

Although only 3 percent of the Polish soldiers received heavy doses of microwaves, that group suffered 8.8 percent of the cancers found among the soldiers in the study.

Exposed soldiers were six to seven times more likely to contract cancer of the lymphatic system and the blood-forming organs, and four to five times more likely to suffer thyroid cancer. The rate of lung cancer, the commonest type of cancer among Polish soldiers, was virtually the same regardless of the extent of exposure. Smoking may have evened this out.

The increase in cancer rates varied with age. Soldiers in their twenties who received high doses of microwaves were five to six times more likely to get cancer than their compatriots of the same age. Those in their fifties were only one to two times more at risk.

It is not certain how many people were included in the populations stud-

ied. This information has not been released by the Polish authorities. Szmigielski plans to present further details of this study at a major meeting in 1985 and to submit results of the study for publication.

Power-Line Frequencies

Most of these lecturers dealt with RF energy in the frequency range above 2 MHz. However, Bernhardt addressed the portion of the spectrum below 100 kHz, with particular emphasis on power-line frequencies of 50 to 60 Hz.

There is very little theoretical or experimental data available on the specific field strengths that humans can tolerate without ill effects in the frequency range between 0 and 100 kHz, with the exception of power-line frequencies. There are several industrial operations, other than in the power industry, where people are likely to be exposed to substantial field intensities at frequencies below 100 kHz. Sources such as RF sealers and heating units are examples of these types of equipment. Here magnetic fields are of particular interest because they can penetrate deeply into the human body. However, biological effects, should they occur, are likely to be due primarily to induced electric fields within the body. Examples of some effects that have been reported are movement of hair on the body, generation of magnetophosphenes, and subjective complaints such as fatigue or headaches. In medicine, the effects of magnetic fields are being used both for diagnosis (nuclear magnetic resonance) and therapy (bone stimulation by induction and magnetotherapy).

There is much uncertainty in the determination of personnel health limits for frequencies below 100 kHz--largely because so far a good model has not been developed for estimating the risk in the frequency range involved here. Such a concept, however, is necessary as one cannot expect that the full frequency range can be studied by experiments with results similar to those obtained in power engineering fields. Bernhardt's lecture described a simple concept that

in nerve and muscle tissue. The values were summarized in current density/frequency diagrams. Using extensive data found in the literature, Bernhardt derived threshold values for the electric current densities for stimulation of neurons or muscle cells and, where possible, correlated these with frequency.

VLF to MF Hazards

Moving up somewhat in frequency, Guy discussed the biological hazards to humans exposed to the very low frequency (VLF) to medium frequency (MF) bands extending from 3 kHz to 3 MHz. He pointed out that these hazards may result from any one of several phenomena: (1) electric shock, (2) spark discharge, (3) elevation of tissue temperature, (4) burns, (5) pacemaker interference, or (6) the so-called neuroasthenic syndrome reported widely in the Soviet and East European literature.

As Guy pointed out, most of these have been well studied and documented. However, there is considerable controversy about the neuroasthenic syndrome, which produces a number of subjective responses such as fatigue, loss of memory, decreased sex drive, and inattentiveness. The fact is that there have not been a large number of really good studies of the subtle and long-term biological effects due to electromagnetic energy in the VLF-MF range.

Guy has compiled a summary of the published literature reporting biological effects due to VLF-MF fields in both Western and Eastern-bloc countries. Most of the studies in the Western world have been carried out on animals, while more than half of the Soviet studies were done on human workers. While most of the effects reported were on the central nervous system and cardiovascular system, there seems to be an inconsistency between reported effects in animals and humans in terms of the same calculated SAR.

On the issue of the difference between the Eastern and Western research, Guy pointed out that the literature on biological effects of VLF to MF electro-

magnetic fields indicates that the current status of research is essentially at the stage that microwave research was in the early 1960s. As mentioned, there is great inconsistency between the Soviet and Western literatures. The Soviet scientists seem to be further ahead in research activity, especially in hygienic studies. However, their reports are sadly lacking in details of their experiments. In many cases, they do not include the field intensity and frequency. Details are not given of the methodology in either the human or animal studies, making the results difficult, if not impossible, to evaluate. In addition, as Guy pointed out, there is a major deficiency in the area of dosimetry in both Soviet and Western reports. The biological effects of EM fields are related to the amount of current, field strength, or energy in the biological objects. The distribution of current, field, or energy in the exposed objects is determined by the frequency and intensity of the field, and the dielectric properties, size, and geometry of the exposed tissue, as well as by the exposure conditions. The reporting of only the frequency and field intensity of the electric or magnetic field does not give enough dosimetry information about the exposure. Therefore, it is difficult to compare experimental results from various laboratories. Extrapolation from animal research to humans cannot be done without the essential dosimetric information. It would be ideal to be able to estimate the induced current density, electric field intensity, or SAR in tissues for all the reported data. However, it is impossible to give a close estimate because of the lack of essential information on the exposure conditions in most of the papers.

Soviet human studies indicate that the central nervous system, the autonomic nervous system, and the cardiovascular system are affected by VLF-MF radiation. The effects are very similar to those reported for the microwave exposure. There is no Western research to confirm or deny the Soviet findings.

public in the frequency range of 10 to 30 MHz. Mitchell showed Figure 2 to illustrate the differences in the principal guidelines and standards. The Canadian and UK standards are not shown on the figure. The differences between these and the ANSI standard are small.

The new human exposure guidelines have a number of safety features that are seldom considered. However, since

the general public often perceives all forms of radiation as hazardous, regardless of level, Mitchell went on to highlight some of the inherent safety features associated with the new generation of standards.

Measurement Problems

As might be imagined, there are a number of practical operational problems

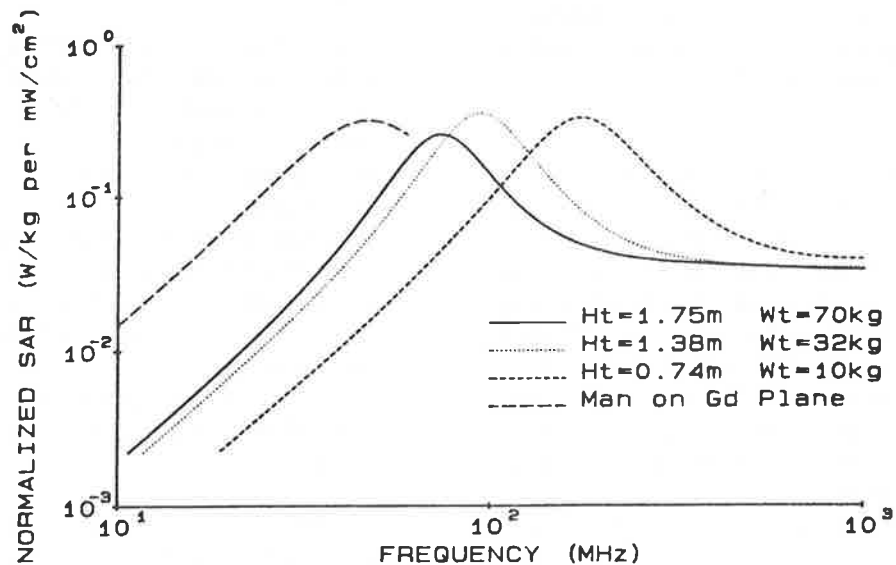


Figure 1. Specific absorption rate for different size humans.

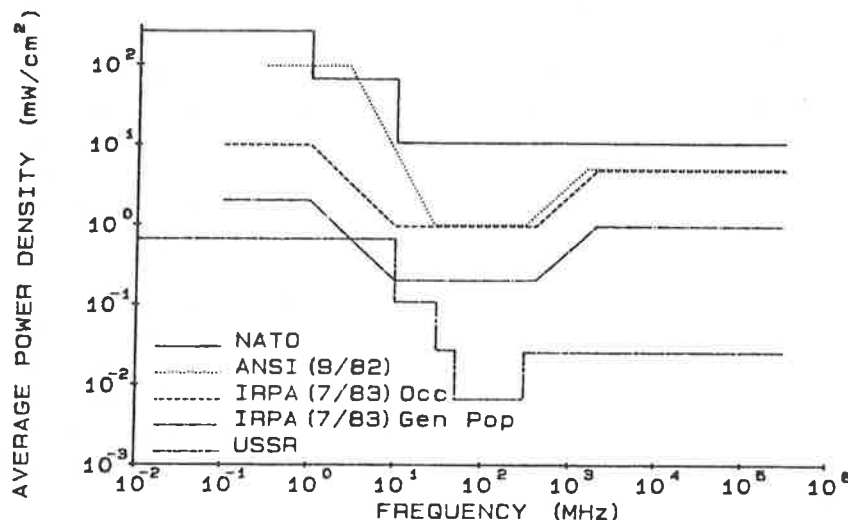


Figure 2. Comparison of RFR safety guidelines.

Denmark, France, West Germany, Greece, Italy, The Netherlands, Norway, Portugal, Turkey, the UK, and the US. Iceland and Luxembourg are not represented on the National Delegates Board, but do receive copies of AGARD publications. Each government appoints one, two, or three members of the board, as it wishes, but each country has only one vote.

The National Delegates Board meets twice a year, in the spring and on the occasion of the AGARD Annual Meeting in the fall. (The original AGARD annual meetings, between 1952 and 1965, were known as general assemblies; they were held each year in a different NATO country and brought together as many AGARD personalities as possible in a variety of scientific and business meetings. After 1965, these general assemblies were replaced by smaller annual meetings, which continue to rotate among NATO nations and thus provide an opportunity for each country in turn to inform the other NATO nations of its aerospace research and development programs.)

Each spring the National Delegates Board reviews the technical program and budget for the following year and receives the director's report for the previous year. Each fall, the board takes the opportunity offered by attendance at the AGARD Annual Meeting to review progress and provide general scientific and administrative guidance. The steering committee normally convenes once a year. Meetings of the panel chairmen take place at the time of each National Delegates Board meeting.

AGARD Panels

There are nine AGARD panels composed of a total of about 400 members, who are experts actively engaged in research, development, or management in academic institutions, government establishments, or industrial enterprises related to the aerospace field. Panel members are appointed by their respective National Delegates, normally for a term of 3 years. Reappointment is permissible, but National Delegates review panel memberships regularly to ensure that the

composition of the panels continues to reflect current activity and interests in the scientific speciality concerned.

Each panel defines a program of meetings and publications in its own speciality, within the general constraints of AGARD policy as determined by the National Delegates Board. Panel members are responsible for enlisting the necessary support and participation from their own countries. In all these activities, panels can call upon the resources of the AGARD staff; in particular, each panel is supported by a full-time panel executive, who acts at the AGARD director's representative.

Missions of the Panels

The detailed areas of interest of each panel vary fairly rapidly as the field of aerospace science and technology expands and as interactions between specialist areas become more or less relevant. In very general terms, the goal of each panel is to fulfill the AGARD mission within its own area of scientific and technical interest and competence. One mechanism for achieving this goal is the sponsorship of lecture series.

Basically, the Aerospace Medical Panel, which sponsored the lecture series discussed in this report, is concerned with the effects of aerospace environment factors on pilot performance. The panel has stimulated research activities in the field of air-crew medical standards, human factors related to accident prevention, and anthropo-technical assistance in bioengineering research and development. The Aerospace Medical Panel keeps abreast of the scientific and technological progress in aeronautics and astronautics and is a measure of the achievements of all other AGARD technical panels. The panel has subcommittees concerned with the specific problems of behavioral sciences, biodynamics, special clinical and physiological problems in military aviation, and special senses.

The other panels are as follows:

(1) Avionics Panel, (2) Electromagnetic Wave Propagation Panel, (3) Flight