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Features and News

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Extremely Low Frequency Electromagnetic Radiation Biological Research

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The Department of the Navy has been developing Extremely Low Frequency (ELF) communications concepts. The program, known as Project SANGUINE, has been in the research and development stage for several years. Early research was naturally oriented toward determining whether Extremely Low Frequency communication is physically possible. Initial research was successful and ELF communication was proven feasible as early as 1963.

Continuing research emphasized definition of natural parameters and electronics techniques that are associated with ELF communications concepts. For example, the natural "background noise" in the ELF portion of the electromagnetic spectrum had to be characterized both in terms of content, seasonal and daily variability, and nominal amplitude; the electrical conductivity of potential transmission sites were largely matters of conjecture at ELF; propagation path losses had to be determined; necessary transmission frequencies and bandwidths had to be defined.

As parameters were identified, research was expanded to include study of the side effects of ELF transmissions. The experiences of the public utilities in inductive coordination over the past half century showed that Project SANGUINE engineers needed to look into electrical interference effects on very long electrical systems such as power distribution systems and telephone lines if the promise of ELF communications was to be attained.

The electrical interference research, which was initiated in 1967, was not so much an exercise in formulation of new engineering methods as it was an exercise in application of existing techniques to Project SANGUINE. The original concept of ELF communications was based on a transmitting antenna that was a relatively large loop antenna. The current loop was formed by a wire antenna grounded to earth at either end in an area of low conductivity with the return current flowing deep underground. The induction field of such an antenna is much wider than the induction field of antennae operating at higher frequencies. This feature reduced the Project SANGUINE problem to applying the most economical and practical techniques for mitigating electrical and electronic intereference rather than developing new methods. The research has been successful, and Project SANGUINE can now select various methods of controlling interference between an ELF transmitting antenna and other electrical systems.

The Department of the Navy realized that the number of potential sites for an ELF transmitter was limited. The system would have to share the land with the local biota. An environmental program was clearly necessary to assure compatible existence.

To assure this compatibility, a biological research program was initiated in 1968. The first question that had to be answered was what previous work has been done in ELF research. A survey of hundreds of articles, reports and books showed that very little effort was associated with ELF. Most of the biological effects work in the past was concentrated either in the microwave region of the electromagnetic spectrum or within the very narrow confines between zero and about 10 Hz. Project SANGUINE's interests are principally in the 40-100 Hz region. The parameters of prime interest are 45 and 75 Hz with experimental exposure at 1 and 10 v/m and 0.5 gauss. Most of the applicable work involved very intense fields, (thousands of gauss, hundreds of thousands of v/m) many orders of magnitude above the levels anticipated from a conceptual SANGUINE transmitter. It was also evident that one of the real difficulties involved in performing biological experiments was in generating the electromagnetic fields and establishing the appropriate test protocols.

A pilot research program was initiated by the Department of the Navy in early 1969 to determine problems associated with laboratory studies at ELF frequencies. Two of the research objectives were to develop the necessary research techniques and to define electric and magnetic field levels that would not produce obvious biological reactions. This initial series of investigations is nearing completion. Preliminary investigations on small population samples suggest some possible biological effects at electromagnetic parameters of relatively high intensity (20 v/m and 2 gauss).

Although Project SANGUINE is still in the conceptual stage, the results of several years of research have narrowed the formerly wide range in essential parameters associated with potential ELF communications systems and environmental compatibility.

The most likely transmitting antenna would be an array of long buried wires excited by a series of generators and grounded at either end. Since the ELF wavelength is about 4000 miles, the antennae should be many miles long in order to be at all efficient. The depth of burial of the insulated cable would be about 6 ft. or greater. The terminal

The author is chairman of the Biological/Ecological Subcommittee of the Environmental Compatability Assurance Group (ECAG).

grounds at either end would consist of many vertical ground rods connected together by a buried horizontal wire. The length of these distributed grounds would be only several thousand feet. This type of ground system is similar to that used near commercial radio and television stations and near power generating stations. A distributed ground provides the required very low electrical impedance (several ohms) and distributes the current to prevent heating, corrosion, excessive power losses, and eliminate safety hazards.

The transmitting antenna would consist of a series of radiating elements. Both the length and number of individual elements will depend upon the communications coverage that is desired. At the present time it is likely that the transmitting antenna would be constructed in a gridlike pattern to provide desired coverage. The number of elements could be only several or as many as 20 in each direction. The distance between adjacent elements is likely to be between 5 and 20 miles.

The electromagnetic fields predicted for a present conceptual ELF communications systems would be very low. The fields would be characterized quite differently near the distributed grounds than near the antennae. For example, the field intensities near an antenna cable vary according to the table shown below if the antenna current is 100 amp:

Distance from Antenna Cable	*E*	*B*
Surface of cable insulation	0.07 v/m	8 gauss
Surface of earth (about 6 ft. about cable)	0.04 v/m	0.13 gauss

Measurements made near distributed grounds at an experimental test site in Wisconsin averaged only about 1.5 v/m for a 100 amp antenna current.

Several interesting comparisons can be made regarding Project SANGUINE electromagnetic field levels. Many home appliances develop higher field than the conceptual ELF system. The magnetic flux density measured near a woman's hair dryer was 24 gauss—three times the level expected at the surface of an antenna cable. Measurements of electric field gradients near home 60 Hz electric power system grounding rods were in the range of 0.014 to 0.33 v/m with an average of 0.05 v/m. Electric field strengths near commercial radio and television transmitting antennae are orders of magnitude higher than SANGUINE levels.

A group of biologists, physicians, and ecologists from government and industry forming the Biological/Ecological Subcommittee of the Environmental Compatibility Assurance Group (ECAG) has been reviewing the research and progress of Project SANGUINE for the past 10 months. Even though all evidence to date indicates that biological reactions at the very low ELF field intensities associated with SANGUINE are unlikely, the Subcommittee has advised the Department of the Navy that further research should be conducted. It is realized that it would be wholly impractical to study low-powered ELF effects on every living creature that might be exposed to these conditions. A research matrix (see illustration) was developed to indicate the areas in which additional research is desirable to determine environmental compatibility. In the opinion of the Subcommittee, good scientific investigations in the problem areas, as indicated in the matrix, should yield information upon which sound guidelines to ensure environmental compatibility could be based.

Since little is known about the perception of ELF electromagnetic fields by animals, three representative species of mammals (markedly different with respect to size) should be studied in regard to various physiological rhythms and behavioral aspects. In addition, experiments on representative native or laboratory lower animals should be conducted to determine if there are any effects on growth, developmental, genetic and reproductive factors. Behavioral studies (which might include migratory patterns) should be conducted on representative species from this group. It is also considered that field studies should be conducted on isolated ecological systems exposed to electromagnetic fields analogous to those proposed for Project SANGUINE. Food cycles of representative fresh water organisms, soil organisms, and land forms should be investigated similarly. In addition, scientific and clinical studies on humans working in such fields or similar would be undertaken by the Department of the Navy.

The scientific community is invited to submit appropriate research proposals to cover scientific aspects of any of the problems outlined in the matrix. Submission (original plus 14 copies) should be made to the Biological Sciences Division of the Office of Naval Research, Arlington, Virginia, 22217 prior to 1 February 1971. Proposed research will be reviewed in the spring of 1971 by an AIBS scientific panel. Selection for support will be based on scientific merit, relevance and the availability of funds. Questions regarding the proposed research program or laboratory simulator design should be addressed to:

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Research Areas

Humans	Mammals	Lower Animals	Plants	Interactions Organisms	
Navy Department Responsibility	Small Medium Large	Fish Amphibia Birds Invertebrate Cellular		Aquatic	Terrestrial

Research Activities

I. Laboratory Studies[1]
  A. Physiological
    1. Rhythms
    2. Systemic
      a. Reproduction
      b. Other
  B. Genetic
  C. Growth and Development
    1. Organogenesis
    2. Hatchability
  D. Behavioral
    1. Perception
    2. Preference
    3. Reaction Time
    4. Learning
    5. Migratory
    6. Activity
II. Field Studies
  A. Health Surveys
    1. Clinical
    2. Epidemiological
  B. Ecological Impact
  C. Migratory Patterns

[1]The parameters of prime interest are 45 and 75 Hz with exposures at 1 and 10 v/m, 0.5 gauss.