

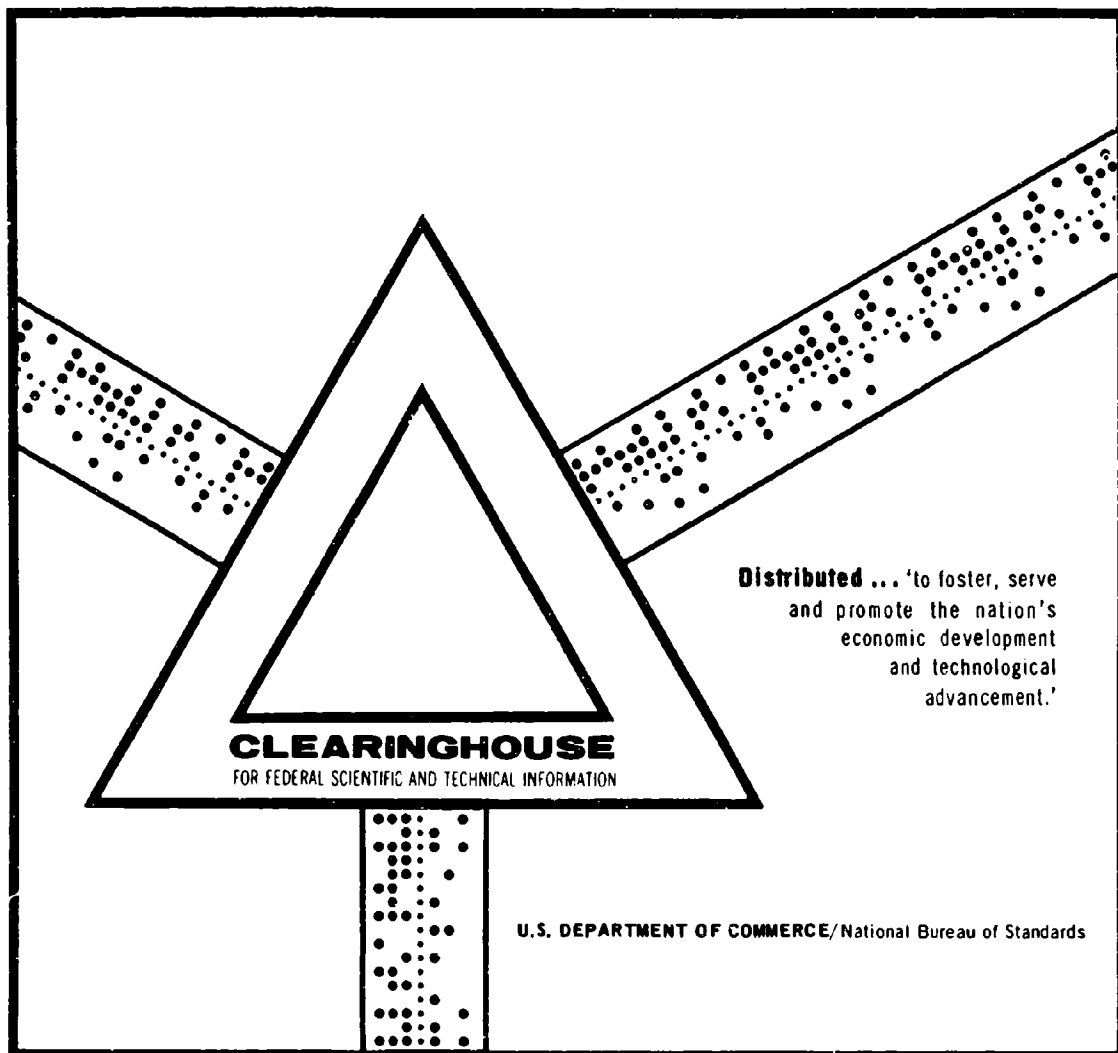
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EFFECTS OF MICROWAVES AND RADIO FREQUENCY  
ENERGY ON THE CENTRAL NERVOUS SYSTEM

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17 September 1969



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EFFECTS OF MICROWAVES AND RADIO FREQUENCY

ENERGY ON THE CENTRAL NERVOUS SYSTEM\*

ALLAN H. FREY

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OLD YORK AND MORELAND ROADS  
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THIS SYMPOSIUM WAS ORGANIZED FOR SEVERAL REASONS. ONE WAS TO BRING TOGETHER ACTIVE INVESTIGATORS IN ORDER TO SEE WHERE WE STAND IN THE STATE OF THE ART. ANOTHER REASON WAS TO PROVIDE A TUTORIAL SITUATION FOR INVESTIGATORS WHO HAVE INTEREST IN EMBARKING UPON EXPERIMENTATION IN THIS AREA. FOR THEM THE ORGANIZERS WISHED TO PROVIDE AN UNDERSTANDING OF WHAT HAS BEEN DONE ALREADY, WHY CERTAIN LINES HAVE OR HAVE NOT BEEN PURSUED, AND THE PROBLEMS ENCOUNTERED OR THAT CAN BE EXPECTED. IT IS TO MEET THESE OBJECTIVES THAT I SHALL ADDRESS MYSELF. THUS, I SHALL BRIEFLY SKETCH SOME OF THE HISTORY OF THIS AREA OF RESEARCH, OUTLINE BRIEFLY THE EXPERIMENTATION THAT I HAVE CARRIED OUT, AND STATE STRONGLY WHAT I BELIEVE TO BE CRITICAL MATTERS THAT AN INVESTIGATOR MUST RECOGNIZE.

THE LAST SUBSTANTIAL GROUP OF EXPERIMENTS IN THIS AREA WERE CARRIED OUT IN THE MIDDLE AND LATE 1950'S. THE RESULTS OF THESE EXPERIMENTS WERE BROUGHT TOGETHER AND DETAILED JUST BEFORE AND AFTER 1960; IN THE FOUR ANNUAL CONFERENCES THAT WERE CALLED TRI-SERVICE CONFERENCES. THIS AFTERNOON'S SESSION IS IN A SENSE UNIQUE. THERE WAS NO SESSION ON THE NERVOUS SYSTEM IN THOSE CONFERENCES. TODAY INVESTIGATION OF THE NEURAL EFFECTS OF RF ENERGY IS RECOGNIZED AS A LEGITIMATE AREA OF INVESTIGATION. BUT EXISTING WITH THIS RECOGNITION IS ALSO A GOOD DEAL OF CONFUSION AND MISUNDERSTANDING. SUCH CONFUSION AND MISUNDERSTANDING IS CHARACTERISTIC IN SCIENTIFIC AREAS IN WHICH THERE IS A GREAT DEAL OF TALK AND VERY LITTLE DATA COLLECTION.

WHY IS THERE SO MUCH MISUNDERSTANDING AND CONFUSION AND SO LITTLE DATA COLLECTION IN THIS AREA? THERE ARE FOUR SOURCES THAT HAVE CONTRIBUTED TO THE DEVELOPMENT OF THIS SITUATION. WE SHOULD RECOGNIZE THEM FOR WHAT THEY ARE. THEN WE CAN MOVE ON TO MORE USEFUL PURSUITS SUCH AS MEANINGFUL EXPERIMENTATION.

FIRST, WHEN THE TRI-SERVICE RESEARCH PROGRAM WAS ORGANIZED IT WAS ASSUMED THAT THE ONLY POSSIBLE EFFECT WAS THE "HEATING" OF TISSUE. SOME PEOPLE INVOLVED IN THAT PROGRAM QUITE CONFIDENTLY SHOWED BY MEANS OF EQUATIONS THAT NEURAL FUNCTION COULD NOT BE

\*TEXT OF AN EXTEMPORANEOUS PRESENTATION AT THE U.S. PUBLIC HEALTH SERVICE SPONSORED "SYMPOSIUM ON THE BIOLOGICAL EFFECTS AND HEALTH IMPLICATIONS OF MICROWAVE RADIATION". THE SYMPOSIUM WAS HELD UNDER THE AUSPICES OF THE MEDICAL COLLEGE OF VIRGINIA AT RICHMOND, VIRGINIA ON SEPTEMBER 17 THROUGH 19, 1969.

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AFFECTED BY RF ENERGY. ABOUT THE TIME OF THE LAST TRI-SERVICE RESEARCH CONFERENCE, WHEN I FIRST BECAME INTERESTED IN THIS AREA, I CAN RECALL BEING SHOWN ON A CHALK BOARD THE CALCULATIONS THAT "PROVED" THAT NERVES CAN NOT BE AFFECTED BY RF ENERGY.

THERE WAS, HOWEVER, ONE BASIC FAULT IN THIS LINE OF REASONING. THE FAULT WAS THE ASSUMPTION THAT WE HAVE A GOOD UNDERSTANDING OF NERVOUS SYSTEM FUNCTION. THIS ASSUMPTION IS WRONG. OUR UNDERSTANDING OF HOW INFORMATION IS CODED, TRANSFERRED AND STORED IN THE NERVOUS SYSTEM IS VIRTUALLY NIL. IN FACT, THERE IS INCREASING EVIDENCE TO INDICATE THAT EVEN THE EXISTING HYPOTHESES, SUCH AS THE ONE THAT THE ELECTRICAL SPIKES RECORDED FROM NERVES ARE THE INFORMATION CARRIERS, ARE INCORRECT. INSTEAD IT APPEARS THAT WE MUST LOOK AT NEURAL FUNCTION FROM THE STANDPOINT OF SOLID STATE PHYSICS. LOOKED AT IN THIS WAY, MANY POSSIBILITIES FOR RF ENERGY INTERACTIONS WITH THE MECHANISM OF INFORMATION TRANSFER AND STORAGE IN THE NERVOUS SYSTEM ARE APPARENT. IN THIS NEW CONTEXT, FACTORS ALMOST TOTALLY IGNORED IN THE TRI-SERVICE PROGRAM, FACTORS SUCH AS MODULATION, THE DELIBERATE USE OF LOW POWER DENSITIES, AND THE CAREFUL CHOICE OF SPECIFIC CARRIER FREQUENCIES ARE CLEARLY OF IMPORTANCE.

THUS, THROUGH THE ACCEPTANCE OF A FALSE ASSUMPTION, THE ONLY NERVOUS SYSTEM INVESTIGATION IN THE TRI-SERVICE PROGRAM CONSISTED OF A SMALL STUDY IN WHICH THE INVESTIGATORS WERE GIVEN AN X BAND TRANSMITTER AS AN RF SOURCE. THE LOGIC IN ASSIGNING A GROUP OF INVESTIGATORS RESPONSIBILITY FOR PROVIDING INFORMATION ON THE EFFECTS OF RF ENERGY ON THE NERVOUS SYSTEM, AND THEN GIVING THEM AN X BAND TRANSMITTER, ESCAPES ME. ALTHOUGH THESE INVESTIGATORS WORKED QUITE DILIGENTLY, ONE CAN NOT PENETRATE VERY DEEPLY INTO THE BODY WITH X BAND ENERGY. IN FACT, THE ENERGY IS LARGELY DEPOSITED IN THE FIRST FEW MILLIMETERS OF SKIN. THE BEST THAT COULD BE DONE WERE MARGINAL STUDIES ON STIMULATION OF PERIPHERAL NERVE ENDINGS.

THE SECOND SOURCE OF MISUNDERSTANDING CAN BE TRACED TO THE CONTROVERSY ON THERMAL VS NON-THERMAL EFFECTS. A VERY HEATED CONTROVERSY DEVELOPED BETWEEN THOSE WHO THOUGHT THAT ONLY THERMAL EFFECTS COULD OCCUR AND THOSE WHO THOUGHT NON-THERMAL EFFECTS COULD ALSO OCCUR. THIS CONTROVERSY INVOLVED A GOOD BIT OF EMOTION AND INVESTIGATORS POLARIZED INTO TWO OPPOSING CAMPS. OF COURSE, THOSE WHO HELD THE THERMAL POSITION AND WERE DOMINANT, CONSIDERED ANY DISCUSSION OF OR EXPERIMENTATION WITH NEURAL FUNCTION AS A PART OF THE NON-THERMAL CAMP AND THUS DESERVING OF CENSURE. THE TRAGEDY IN THIS IS THAT THE THERMAL VS NON-THERMAL CONTROVERSY IS ONE OF SEMANTICS, NOT SCIENCE. IN GENERAL, THE INVESTIGATORS WERE TALKING PAST EACH OTHER. FOR EXAMPLE, ONE INVESTIGATOR OBVIOUSLY DEFINED THERMAL IN HIS MIND AS RISE IN CORE TEMPERATURE. ANOTHER DEFINED IT IN HIS MIND AS INCREASE IN MOLECULAR VIBRATION. THERE NEVER WAS A COMMON DEFINITION OF THE WORDS THERMAL AND NON-THERMAL.

THE THIRD FACTOR THAT UNFORTUNATELY CONTRIBUTED TO THE MISUNDERSTANDING AND CONFUSION IS A SCIENTIFICALLY IRRELEVANT ONE. THERE WERE JURISDICTIONAL BATTLES AMONG SOME GROUPS AS TO WHO

WOULD CONTROL AND BE RESPONSIBLE FOR RF RESEARCH. THIS RESULTED IN POSITIONS BEING TAKEN AND ENERGETICALLY SUPPORTED ON THE THERMAL VS NON-THERMAL CONTROVERSY, THE POSSIBILITY OF NERVOUS SYSTEM EFFECTS, ETC. THE MISINFORMATION THAT THIS GENERATED IS PHENOMENAL. FOR EXAMPLE, IT WAS SO BAD THAT I FINALLY FELT COMPELLED TO INCLUDE IN PAPERS THAT I HAD PUBLISHED IN THIS AREA A STATEMENT SUCH AS "... CONCLUSIONS OR INFERENCES BEYOND THIS (STATED IN THE FOREGOING SENTENCE) ARE ABSOLUTELY NOT WARRANTED BY THE DATA". I HAD HOPES THAT THIS WOULD DISCOURAGE TO SOME EXTENT THE DRAWING OF UNWARRANTED CONCLUSIONS, AT LEAST FROM MY DATA, BY PEOPLE IN THE VARIOUS CAMPS WHO THEN NEGLECTED TO INDICATE CLEARLY WHOSE CONCLUSIONS THEY WERE.

A FOURTH SOURCE OF THIS MISUNDERSTANDING STEMS FROM THE EXISTENCE OF A GOOD BIT OF RUSSIAN WORK ON RF ENERGY EFFECTS ON NERVOUS SYSTEM FUNCTION. IN GENERAL, THIS RUSSIAN WORK WAS REJECTED BY AMERICAN INVESTIGATORS FOR VARIOUS GOOD AND BAD REASONS.

ONE REASON WAS DUE TO THE DIFFERENCES IN TRADITION IN U.S. AND U.S.S.R. BIOLOGY. AMERICAN INVESTIGATORS ARE ORIENTED TO LOOKING FOR EFFECTS THROUGH A MICROSCOPE. INVESTIGATORS IN THE SOVIET UNION HAVE A SOMEWHAT DIFFERENT TRADITION. THEY TEND TO LOOK FOR EFFECTS IN THE MODIFICATION OF NERVOUS SYSTEM FUNCTION. SINCE THERE WAS NO ONE IN THE BEHAVIORAL AREA SUBSTANTIALLY INVOLVED IN THE AMERICAN PROGRAM, THERE WAS NO ONE WHO HAD THE BACKGROUND TO EVALUATE AND INTERPRET THE SIGNIFICANCE OF THE RUSSIAN WORK. INSTEAD, IT TENDED TO BE DISMISSED AS ALIEN AND UNINTERPRETABLE.

ANOTHER FACTOR INVOLVED IN THE REJECTION OF THE RUSSIAN WORK WAS THE FACT THAT MANY OF THE TRANSLATIONS OF THE RUSSIAN WORK WERE SIMPLY ATROCIOUS. MANY OF THESE TRANSLATIONS WERE COMPLETELY MISLEADING. FOR EXAMPLE, IN ONE THE WORD FOR HYPOTHALMUS WAS TRANSLATED AS CEREBELLUM. THIS MISTRANSLATION IN THE CONTEXT OF THE REST OF THE REPORT MADE THE EXPERIMENT APPEAR TO BE POORLY DONE. ONE CAN EASILY UNDERSTAND THE NEGATIVE VIEW OF AMERICAN INVESTIGATORS WHO EVALUATED THE WORK THROUGH THESE TRANSLATIONS. I PERSONALLY FOUND IT NECESSARY TO HAVE MANY OF MY OWN TRANSLATIONS MADE OF REPRINTS THAT I RECEIVED FROM RUSSIAN INVESTIGATORS. IN THIS WAY, I CHECKED ON THE ACCURACY OF TRANSLATIONS THAT WERE DISTRIBUTED BY VARIOUS TRANSLATION GROUPS

AN ADDITIONAL REASON FOR THE NEGATIVE VIEW OF AMERICAN INVESTIGATORS WAS THE FACT THAT THE RUSSIANS OFTEN DID NOT GIVE INFORMATION IN THEIR PAPERS WHICH WE FEEL IS NECESSARY TO EVALUATE THE QUALITY OF THE RESEARCH. RUSSIANS WORKING IN OTHER AREAS ALSO DO NOT GIVE SUFFICIENT INFORMATION. ONE SOMETIMES GETS THE IMPRESSION THAT MANY OF THE RUSSIAN INVESTIGATORS DO NOT LIKE TO HAVE THEIR FRIENDS DOWN THE HALL OR IN ANOTHER INSTITUTE KNOW TOO MUCH ABOUT WHAT THEY ARE CURRENTLY DOING.

ANOTHER REASON WAS THAT SOME OF THE WORK WAS OF POOR QUALITY. THUS, THERE WERE GOOD AND BAD REASONS FOR REJECTING PORTIONS OF THE RUSSIAN WORK. IN LOOKING AT THIS HISTORY, I THINK IT BECOMES CLEARER WHY THERE IS SO MUCH ARGUMENT, CONFUSION, AND MISUNDERSTANDING IN THIS AREA OF RESEARCH.

THERE WAS THE ASSUMPTION THAT WE HAD A COMPLETE UNDERSTANDING OF NERVOUS SYSTEM FUNCTION. THIS FALSE ASSUMPTION PROVIDED THE UNDERPINNING FOR CALCULATIONS THAT WERE GLIBLY OFFERED AS PROOF THAT NEURAL FUNCTION COULD NOT BE EFFECTED BY RF ENERGY. THUS, THERE WAS LITTLE RESEARCH ON NERVOUS SYSTEM FUNCTION AND LITTLE EVALUATION OF FACTORS SUCH AS MODULATION.

THERE WAS ALSO THE POLARIZATION OF INVESTIGATORS INTO THE THERMAL AND NON-THERMAL CAMPS WITH THE EMOTION AND NARROWING OF VIEWS THAT THIS INVOLVED. THERE WAS THE JURISDICTIONAL BATTLES BETWEEN CERTAIN GROUPS FOR CONTROL OVER RF RESEARCH. AND THERE WAS ALSO THE SUBSTANTIAL AMOUNT OF RUSSIAN WORK ON THE NERVOUS SYSTEM THAT WAS NOT TO OUR LIKING BECAUSE; IT WAS ALIEN TO OUR TRADITION, THEY OFTEN OMITTED INFORMATION THAT WE REGARD AS IMPORTANT IN EVALUATING THE QUALITY OF RESEARCH, MANY OF OUR TRANSLATIONS WERE MISLEADING, AND SOME OF THE WORK WAS OF POOR QUALITY.

WITH THIS RECOGNITION OF THE SOURCES OF CONFUSION AND MISUNDERSTANDING, POSSIBLY WE CAN NOW MOVE FORWARD IN OUR IGNORANCE OF THE FUNCTION OF THE NERVOUS SYSTEM TO DEVELOP AN UNDERSTANDING OF THE EFFECTS AND HAZARDS OF RF ENERGY AND TO DEVELOP THE USE OF RF ENERGY AS A TOOL TO HELP US OBTAIN AN UNDERSTANDING OF NERVOUS SYSTEM FUNCTION.

SO MUCH FOR GENERAL HISTORY. I SHALL NOW SKETCH THE NATURE AND RESULTS OF THE EXPERIMENTATION I HAVE CARRIED OUT IN THIS AREA.

I HAVE DONE A FAIR AMOUNT OF RESEARCH WITH THIS ENERGY AT CARRIER FREQUENCIES IN THE VLF, VHF AND UHF BANDS. THIS ENCOMPASSES MANY OF THE FREQUENCIES USED IN RADAR, TELEVISION, INDUSTRIAL PROCESSES, AND INCLUDES SOME OF THE RADIO BROADCAST FREQUENCIES. THE WORK HAS INVOLVED NERVOUS SYSTEM FUNCTION, HEART FUNCTION, ENDOCRINE GLAND FUNCTION, AND MATHEMATICAL MODELING OF EFFECTS. MUCH OF THE DATA IS AVAILABLE IN VARIOUS JOURNALS. THERE IS A SUBSTANTIAL AMOUNT THOUGH THAT I HAVE NOT HAD TIME TO PREPARE FOR PUBLICATION. THIS LATER I SHALL EMPHASIZE.

MY INTEREST IN THIS AREA BEGAN WHEN I MET A MAN WHOSE WORK INVOLVED HIM IN MEASURING THE FIELDS OF NEW RADARS. HE MENTIONED TO ME THAT CERTAIN RADARS INDUCE THE PERCEPTION OF SOUND. AFTER A DISCUSSION WHICH SEEMED TO ELIMINATE THE OBVIOUS SOURCES OF THE SOUND, SUCH AS FILLINGS IN THE TEETH, I ARRANGED TO VISIT A RADAR SITE AT WHICH HE COULD HEAR THIS SOUND. SUCH BEGAN MY EXPERIMENTATION WITH RF ENERGY.

LET ME NOTE HERE THAT I WAS NOT THE FIRST TO PUBLISH A REPORT ON THE PERCEPTION OF SOUND IN A RADAR FIELD. CREDIT SHOULD BE GIVEN TO A GROUP OF ENGINEERS AT AIL WHO PUBLISHED A ONE PAGE REPORT ON IT ABOUT THIRTEEN YEARS BEFORE MY FIRST REPORT. UNFORTUNATELY THEY DID NOT PURSUE THE MATTER. I LEARNED FROM ONE OF THEM LATER THAT WHEN THEY BROUGHT THE PHENOMENON TO THE ATTENTION OF AN EXPERT ON HEARING, HE TOLD THEM THAT THERE WAS NOTHING TO IT; JUST TEETH RATTLING. SHOULD I EVER BECOME AN EXPERT IN SOME AREA, I HOPE THAT I SHALL RECOGNIZE THE BOUNDS OF MY OWN WISDOM.

MY WORK IN THIS AREA BEGAN WITH THE STUDY OF HUMAN PERCEPTION OF THE RF INDUCED SOUND. THIS HUMAN WORK HAS BEEN FULLY REPORTED AND INDEPENDENTLY VERIFIED BY SEVERAL PEOPLE WHO HAVE ADHERED TO THE PARAMETERS THAT I HAVE SPECIFIED AS NECESSARY TO INDUCE THE EFFECT; PARAMETERS SUCH AS A SPECIFIC BAND OF CARRIER FREQUENCIES.

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INSERT FIGURE 1 ABOUT HERE

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IN FIGURE 1, THIS BAND OF FREQUENCIES IS SPECIFIED.

EARLY IN THE WORK, I EXPLORED THE POSSIBILITY OF EXPLAINING THE RADAR INDUCED HEARING EFFECT AS THE ELECTROPHONIC EFFECT. THE ELECTROPHONIC EFFECT INVOLVED PUTTING THE HEAD BETWEEN ELECTRODES ON WHICH THERE IS A HIGH POTENTIAL AND THEREBY INDUCE A SOUND THRU SKIN VIBRATION. KNOWLEDGE OF THE PHENOMENON GOES BACK TO THE TIME OF VOLTA. MORE RECENTLY, STEVENS, FLOTORP AND ALSO SOMMER AND VON GIERKE EXPERIMENTED WITH THE ELECTROPHONIC EFFECT. I EXPERIMENTED WITH THE ELECTROPHONIC EFFECT AND ALSO USED RADAR ENERGY TO COMPARE SPECIFIC FINDINGS WITH THE TWO EFFECTS TO SEE IF THEY WERE THE SAME. THIS RESULTED IN THE FINDING THAT THE RADAR EFFECT COULD NOT BE EXPLAINED WITH THE ELECTROPHONIC MODEL.

I THEREFORE WENT ON INTO ANIMAL EXPERIMENTATION IN ORDER TO DETERMINE THE LOCUS AND NATURE OF THE RF HEARING EFFECT. I SEARCHED FOR COCHLEAR MICROPHONICS IN GUINEA PIGS AND ALSO IN CATS EXPOSED TO RADAR ENERGY. WE FOUND THAT THERE WERE NO COCHLEAR MICROPHONICS IN EITHER SPECIES. CONTROL TESTS WITH ACOUSTIC ENERGY OF COMPARABLE WAVEFORM AND LOUDNESS, INCLUDING THE ALTERATION OF ACOUSTIC AND RADAR ENERGY, INDICATED THAT A MICROPHONIC DOES NOT OCCUR WITH THE RADAR ENERGY. THE POWER DENSITIES WE USED WERE FAR ABOVE THAT NEEDED TO INDUCE THE EFFECT IN CATS.

I CARRIED THE QUEST FURTHER BY FIRST CONDITIONING CATS TO RESPOND TO RADAR ENERGY CUES AND SIMILAR ACOUSTIC CUES. I THEN DESTROYED THE COCHLEAS SURGICALLY IN SOME CATS AND WITH NEOMYCIN IN OTHER CATS. UNFORTUNATELY, THE RESULTS OF THIS STUDY ARE NOT COMPLETE. I HAD BORROWED THE USE OF A TRANSMITTER WHOSE CHARACTERISTICS WERE OF PARTICULAR INTEREST TO ME AND USED IT AS THE RADAR SOURCE. JUST AS I REACHED THE FINAL STAGE OF THE EXPERIMENT, THE TRANSMITTER WAS TAKEN AWAY ON TWO DAYS NOTICE TO BE USED IN SOUTH-EAST ASIA. WE FOUND THOUGH, IN A CRASH EFFORT, THAT THE RESPONSE TO ACOUSTIC ENERGY WAS LOST. IN SOME CATS, THE RESPONSE TO RADAR SEEMED TO BE THERE. WE DID A LIMITED AMOUNT OF COCHLEAR HISTOLOGY AND FOUND THE INTENDED DAMAGE. NO CONCLUSIONS, HOWEVER, SHOULD BE DRAWN. BEHAVIORAL RESEARCH WITH DEAFENED CATS IS DIFFICULT AT BEST. I WISH TO ONLY POINT OUT THAT SUCH WORK WITH RADAR CAN BE DONE AND THAT I SHALL COMPLETE IT.

CONCURRENTLY WITH THE FOREGOING WORK, WE PURSUED ANOTHER LINE TO OBTAIN SUGGESTIONS AS TO THE LOCUS OF THE RF HEARING SENSING MECHANISM. USING ENERGY THRESHOLD LEVELS OBTAINED FOR

THE HEARING EFFECT IN HUMANS, WE MATHEMATICALLY TRACED THE RF ENERGY THROUGH A MATHEMATICAL MODEL FOR FOREHEAD TISSUE LAYERS. WE FELT THAT KNOWING WHERE THE SIGNAL STRENGTHS CROSSED IN OUR MATHEMATICAL MODEL WOULD ENABLE US TO MAKE A REASONABLE JUDGMENT AS TO WHERE TO LOOK IN THE ANIMAL FOR THE SENSING MECHANISM. IN CONSTRUCTING OUR MODEL, WE PICKED ALL TISSUE ELECTRICAL VALUES IN ADVANCE, USED STANDARD VALUES FOR TISSUE THICKNESS, AND TOOK INTO CONSIDERATION ONLY FIRST REFLECTIONS. OUR CALCULATIONS INDICATE THAT THE FIRST RF ENERGY CROSSING IS IN THE BRAIN. IT IS

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INSERT FIGURE 2 ABOUT HERE.

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EMPHASIZED THAT THIS SHOULD NOT BE CONSTRUED AS PROOF. IT IS ONLY A SUGGESTION TO GUIDE RESEARCH. AS ONE OF THIS AFTERNOON'S SPEAKERS CAN PROVE, THE RESULT OF SUCH CALCULATIONS CAN AT BEST BE CONSIDERED A RESEARCH SUGGESTION.

AS AN ASIDE AND INCIDENTAL TO THE FOREGOING WORK, I NOTICED THAT HEADACHES APPEARED TO BE INDUCED AT SOME FREQUENCIES AT LOW POWER LEVELS. A LIMITED AMOUNT OF EXPLORATION LEADS ME TO BELIEVE THAT THE HEADACHE EFFECT IS PROBABLY REAL, BUT IT REQUIRES VERIFICATION. THUS, IT IS MENTIONED HERE ONLY AS A HYPOTHESES FOR RESEARCH.

I SHALL NOW LEAVE THE RF AUDITORY EFFECT AND MENTION SOME OTHER EXPERIMENTATION WE HAVE DONE. WE HAVE CARRIED OUT EXPERIMENTATION WITH CATS IN WHICH WE ESTABLISHED AVOIDANCE CONDITIONING. CATS CAN USE THE RF ENERGY AS A CUE IN AVOIDANCE CONDITIONING. WE HAVE ALSO ESTABLISHED RF THRESHOLDS FOR THIS IN CATS. I HAVE ALSO SEEN INDICATIONS OF AVOIDANCE BEHAVIOR IN MONKEYS THOUGH AT RELATIVELY HIGH POWER DENSITIES.

SINCE THERE WERE SUGGESTIONS IN SOME OF THE EXPERIMENTS THAT WE MIGHT BE MODIFYING LEVEL OF CONSCIOUSNESS, WE CARRIED OUT LIMITED EXPERIMENTATION WITH MONKEYS TO DETERMINE IF RF ENERGY CAN MODIFY LEVEL OF CONSCIOUSNESS. WE FOUND, AT THE FREQUENCY USED, NO DRASTIC CHANGES IN LEVEL OF CONSCIOUSNESS AS MEASURED BY A STANDARD BEHAVIORAL TECHNIQUE.

WE ALSO EMBARKED UPON A PROGRAM TO DEVELOP A RECORDING ELECTRODE SYSTEM THAT COULD BE USED IN AN RF FIELD AND WOULD NOT ITSELF INTRODUCE ARTIFACTS. WE FOUND THAT CONVENTIONAL ELECTRODE SYSTEMS TEND TO GIVE INTERESTING BUT QUESTIONABLE RESULTS. THIS ENDEAVOR WAS SUCCESSFUL AND WE HAVE A PATENT PENDING ON THE ELECTRODE SYSTEM.

WITH THIS ELECTRODE SYSTEM, WE WERE ABLE TO STUDY BRAIN ACTIVITY IN INTACT CATS UNDER RF STIMULATION. AS MAY BE SEEN IN FIGURES 3 AND 4, EVOKED RESPONSES CAN BE INDUCED IN THE BRAIN STEM AT AVERAGE POWER DENSITIES OF  $30 \mu\text{w}/\text{cm}^2$ . THEIR CHARACTERISTICS IN THE RETICULAR FORMATION AND HYPOTHALMIC AREAS ARE AS ONE



MIGHT EXPECT FROM WHAT WE KNOW ABOUT EVOKED RESPONSES IN GENERAL. THE DETAILS OF TECHNIQUE AND EXPERIMENTAL CONTROLS ARE PUBLISHED.

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INSERT FIGURES 3 AND 4 ABOUT HERE

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WITH AN ELECTRODE SYSTEM AND THE EVOKED RESPONSE AS A DEPENDENT VARIABLE, WE WERE ABLE TO DO PARAMETRIC STUDIES. WE FOUND THAT THE HEAD MUST BE EXPOSED TO RF ENERGY FOR THE EFFECT TO OCCUR. IT WAS OBSERVED THAT WITHIN THE CARRIER FREQUENCY RANGE USED, THERE APPEARED TO BE A REDUCTION IN EFFECT AT THE HIGHEST FREQUENCY USED. VARYING POWER DENSITY HAD A DISTINCT EFFECT. CHANGES IN POLARIZATION OF THE ENERGY DID NOT SEEM TO HAVE MUCH EFFECT. CHANGING PULSE REPETITION FREQUENCY DOES NOT SEEM TO MATTER UNTIL THE PRF IS GREATER THAN 50 PPS.

LEAVING THE EVOKED BRAIN POTENTIAL WORK, I WILL MENTION BRIEFLY SEVERAL LIMITED STUDIES WE HAVE DONE. IN LIMITED EXPERIMENTATION WITH HUMANS, A. VLF, WE HAVE FOUND THAT THERE IS NO AUDITORY EFFECT, EVEN AT VERY HIGH FIELD STRENGTHS. THERE IS, HOWEVER, STIMULATION OF SKIN RECEPTORS. THERE IS ALSO AN INDICATION OF THE HEADACHE PHENOMENON AGAIN.

WE HAVE CARRIED OUT EXPLORATORY WORK IN BRAIN CHEMISTRY UNDER RF ENERGY AS WELL AS LOOKED AT THE EFFECT OF RF ENERGY ON ISOLATED LOBSTER GANGLIA. THERE IS INSUFFICIENT DATA, HOWEVER, TO DISCUSS ANY EFFECT.

SO MUCH FOR A MENTION OF OUR SEVERAL MORE RECENT EXPLORATORY EXPERIMENTS. OUR WORK WITH THE HEART HAS BEEN MORE EXTENSIVE. I SHALL NOW BRIEFLY SKETCH THE NATURE OF OUR HEART EXPERIMENTATION. INITIALLY, WE ILLUMINATED ISOLATED FROG HEARTS WITH PULSE MODULATED RF ENERGY. THE PULSES WERE SYNCHRONIZED WITH THE ELECTROCARDIOGRAM IN AN ATTEMPT TO INDUCE A POSITIVE FEEDBACK CONDITION. WE FOUND THAT SYNCHRONIZING THE RF PULSES WITH THE R WAVE RESULTED IN TACHYCARDIA AND FREQUENTLY ARRHYTHMIA AND CESSATION OF THE HEART. SYNCHRONIZING IT WITH EARLIER PORTIONS OF THE ECG RESULTED IN LITTLE EFFECT ON THE ECG.

WE HAVE EXTENDED THIS HEART WORK ALONG SEVERAL LINES. WE HAVE SYNCHRONIZED THE RF ENERGY WITH THE LATER PORTIONS OF THE ECG. WE FIND A TACHYCARDIA EFFECT WHEN WE SYNCHRONIZE WITH THE T WAVE BUT THE EFFECT IS GREATER WHEN WE HIT THE HEART AT THE R WAVE. HERE, AGAIN, WE SEE A DISTINCTION BETWEEN THE EFFECT OF ELECTRICAL SHOCK AND THE EFFECT OF RF ENERGY. STUDIES WITH ELECTRICAL SHOCK SHOW THAT THE APPLICATION OF THE STIMULUS AT THE RISE OF THE T WAVE YIELDS THE GREATER EFFECT. THIS IS NOT THE POINT OF GREATEST RF EFFECT.

WE HAVE ALSO EXTENDED THE HEART WORK TO INCLUDE ILLUMINATING THE ANIMAL WITH THE HEART INTACT AND WITHIN THE BODY. WE FIND

THAT TACHYCARDIA AND ARRHYTHMIA STILL OCCUR. THE EFFECT IS NOT AS GREAT HOWEVER. WE ARE CURRENTLY TRYING TO DETERMINE IF THIS IS DUE TO INCREASED FIELD DISTORTION OR ONE OF THE BODY'S BUFFERING SYSTEMS.

WE ARE ALSO EVALUATING THE NATURE OF THE CHANGE IN THE ELECTROCARDIOGRAM. WE OBSERVE SHIFTS IN THE TIME RELATIONSHIPS AMONG VARIOUS PORTIONS OF THE ECG, BUT HAVE NOT HAD TIME TO ANALYZE THE NATURE OF THE SHIFTS.

I SHALL CLOSE BY CALLING ATTENTION TO SEVERAL POINTS THAT I BELIEVE TO BE OF IMPORTANCE.

FIRST, LET US IGNORE THE THERMAL VS NON-THERMAL CONTROVERSY. IF IT WOULD BE IN MY POWER, I WOULD BANISH THE WORDS THERMAL AND NON-THERMAL FROM THIS AREA OF RESEARCH. WE HAVE HAD ENOUGH OF SEMANTIC CONFUSION. IF ONE FEELS A REAL NEED TO USE THE WORD THERMAL, THEN ONE HAS THE OBLIGATION TO MAKE VERY CLEAR HOW HE IS DEFINING THERMAL. THEN, WHEN THE INEVITABLE ARGUMENT STARTS, HIS OPPONENT IS OBLIGATED TO PROVIDE A DEFINITION.

SECOND, WE SHOULD RECOGNIZE EXPLICITLY THAT WE KNOW VERY LITTLE ABOUT THE FUNCTION OF THE NERVOUS SYSTEM. WE KNOW EVEN LESS ABOUT THE POSSIBLE INTERACTION OF RF ENERGY WITH NEURAL FUNCTION. WE SHOULD KEEP CLEARLY IN MIND THAT WE DO NOT KNOW HOW INFORMATION IS CODED IN THE NERVOUS SYSTEM. WE DO NOT KNOW HOW INFORMATION IS TRANSFERRED IN THE NERVOUS SYSTEM. WE DO NOT KNOW HOW INFORMATION IS STORED IN THE NERVOUS SYSTEM. THUS, WE CAN NOT CONCLUDE FROM CALCULATIONS BASED UPON SOME SET OF ASSUMPTIONS WHAT EFFECT RF ENERGY WILL HAVE ON NEURAL FUNCTION. NOR CAN WE DRAW CONCLUSIONS ON THE FUNCTION OF SYSTEMS SUCH AS THE CARDIOVASCULAR AND ENDOCRINE WHICH INVOLVE A MEASURE OF NEURAL CONTROL. HYPOTHESES CAN AND SHOULD BE GENERATED, BUT NO CONCLUSIONS DRAWN. THESE HYPOTHESES MUST THEN BE SUBJECTED TO EXPERIMENTAL TEST.

THIRD, PARAMETRIC STUDIES MUST BE CARRIED OUT AND EXPERIMENTAL CONTROLS MUST BE RECOGNIZED AND USED. MOST OF MY EXPERIMENTAL WORK HAS NOT BEEN IN THE RF AREA. ON THE BASIS OF MY EXPERIENCES, I HAVE CONCLUDED THAT BIOLOGICAL EXPERIMENTS WITH RF ENERGY HAVE AN UNUSUALLY GREAT NUMBER OF PITFALLS. MANY PARAMETRIC STUDIES ARE NEEDED AND EXTRAORDINARY (FOR BIOLOGY) EXPERIMENTAL CONTROLS ARE NEEDED.

FOURTH, LET US RECOGNIZE, AT LEAST IN WORKING WITH THE NERVOUS SYSTEM AND HEART, THAT RF ENERGY IS NOT "RF" ENERGY AND MICROWAVES ARE NOT "MICROWAVES". ONE SHOULD NOT GENERALIZE CONCLUSIONS BASED UPON DATA AT ONE FREQUENCY BY REFERRING TO "MICROWAVE EFFECTS". WE MUST DEFINE THE SPECIFIC FREQUENCY. FOR EXAMPLE, I'VE FOUND THAT ONE DOES NOT OBTAIN AT 9 GHZ THE SAME EFFECTS THAT OCCUR AT 1 GHZ. AND THERE ARE OTHER EFFECTS AT 21 KHZ.

FIFTH, IT SHOULD BE EXPLICITLY RECOGNIZED THAT THERE IS NOT A CATEGORY OF RF EFFECTS AND A CATEGORY OF RF HAZARDS. ONE CAN ONLY HAVE BIOLOGICAL EFFECTS OF RF. WHETHER OR NOT THESE ARE A

HAZARD IS A MATTER OF INTERPRETING THE INFLUENCE OF THE EFFECTS IN A PARTICULAR SET OF CIRCUMSTANCES.

SIXTH, WE MUST ESTABLISH THE MINIMUM INFORMATION ON EXPERIMENTAL METHOD AND TECHNIQUE THAT MUST BE REPORTED. SOME OF THE MOST BASIC INFORMATION, EVEN IN AMERICAN REPORTS, IS LACKING. I HAVE EXPERIENCED GREAT FRUSTRATION IN WRITING THE ANALYTICAL REVIEWS THAT I HAVE DONE IN THIS AREA BECAUSE OF THIS. FOR EXAMPLE, CARRIER FREQUENCY IS OFTEN SPECIFIED AS SIMPLY X BAND OR SHF. THERE IS OFTEN NO INDICATION AS TO WHETHER THE ENERGY WAS MODULATED OR NOT. RF MEASUREMENT TECHNIQUE IS OFTEN NOT SPELLED OUT. IT MUST BE SPELLED OUT IF ONE IS TO EVALUATE THE REPORT. EVEN WITH THE BEST EQUIPMENT AND TECHNIQUE, THE CONFIDENCE LIMITS FOR A MEASUREMENT ARE WIDE; AN ORDER OF MAGNITUDE.

THIS IS COMPOUNDED BY INVESTIGATORS USING DISSIMILAR TECHNIQUES. FOR EXAMPLE, ONE INVESTIGATOR MEASURES THE TEMPERATURE OF A GLASS OF WATER WHILE ANOTHER INVESTIGATOR MEASURES THERMISTER RESPONSE AS SEEN BY A POWER METER. IN THEORY, SOME COMPARISONS CAN BE MADE AND CONCLUSIONS DRAWN; IN FACT, SUCH COMPARISONS ARE STRAINED AND TENUOUS. WE MUST ESTABLISH STANDARD MEASUREMENT TECHNIQUES AND STANDARDIZE ON THE UNITS IN WHICH THEY ARE REPORTED.

THE FOREGOING HAS BEEN A LIMITED HISTORY OF THE AREA, A BRIEF SKETCH OF MY EXPERIMENTATION, AND SOME POINTS THAT I BELIEVE TO BE WORTHY OF ATTENTION.

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