Human auditory system response to modulated electromagnetic energy

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FREY, ALLAN H. *Human auditory system response to modulated electromagnetic energy.* J. Appl. Physiol. 17(4): 689–692. 1962.—The intent of this paper is to bring a new phenomenon to the attention of physiologists. Using extremely low average power densities of electromagnetic energy, the perception of sounds was induced in normal and deaf humans. The effect was induced several hundred feet from the antenna the instant the transmitter was turned on, and is a function of carrier frequency and modulation. Attempts were made to match the sounds induced by electromagnetic energy and acoustic energy. The closest match occurred when the acoustic amplifier was driven by the rf transmitter's modulator. Peak power density is a critical factor and, with acoustic noise of approximately 80 db, a peak power density of approximately 275 mw/cm² is needed to induce the perception at carrier frequencies of 425 mc and 1,310 mc. The average power density can be at least as low as 400 μw/cm². The evidence for the various possible sites of the electromagnetic energy sensor are discussed and locations peripheral to the cochlea are ruled out.

A SIGNIFICANT AMOUNT OF RESEARCH has been concerned with the effects of radio-frequency (rf) energy on organisms (electromagnetic energy between 1 kc and 100 Gc). Typically, this work has been concerned with determining damage resulting from body temperature increase. The average power densities used have been on the order of 0.1–1 w/cm² used over many minutes to several hours.

In contrast, using average power densities measured in microwatts per square centimeter, we have found that other effects, which are transient, can be induced with this energy. Further, these effects occur the instant the transmitter is turned on. With appropriate modulation, the perception of various sounds can be induced in clinically deaf, as well as normal, human subjects at a distance of inches up to thousands of feet from the transmitter. With somewhat different transmitter parameters, we can induce the perception of severe buffeting of the head, without such apparent vestibular symptoms as dizziness or nausea. Changing transmitter parameters again, one can induce a "pins-and-needles" sensation.

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Experimental work with these phenomena may yield information on auditory system functioning and, more generally, information on nervous system function. For example, this energy could possibly be used as a tool to explore nervous system coding, possibly using Neider and Neff's procedures (1), and for stimulating the nervous system without the damage caused by electrodes.

Since most of our data have been obtained on the "rf sound" and only the visual system has previously been shown to respond to electromagnetic energy, this paper will be concerned only with the auditory effects data. As a further restriction, only data from human subjects will be reported, since only these data can be discussed meaningfully at the present time. The long series of studies we performed to ascertain that we were dealing with a biologically significant phenomenon (rather than broadcasts from sources such as loose fillings in the teeth) are summarized in another paper (2), which also reports on the measuring instruments used in this work.

The intent of this paper is to bring this new phenomenon to the attention of physiologists. The data reported are intended to suggest numerous lines of experimentation and indicate necessary experimental controls.

Since we were dealing with a significant phenomenon, we decided to explore the effects of a wide range of transmitter parameters to build up a body of knowledge which would allow us to generate hypotheses and determine what experimental controls would be necessary. Thus, the numbers given are conservative; they should not be considered precise, since the transmitters were never located in ideal laboratory environments. Within the limits of our measurement, the orientation of the subject in the rf field was of little consequence.

Most of the transmitters used to date in the experimentation have been pulse modulated with no information placed on the signal. The rf sound has been described as being a buzz, clicking, hiss, or knocking, depending on several transmitter parameters, i.e., pulse width and pulse-repetition rate (PRF). The apparent source of these sounds is localized by the subjects as being within, or immediately behind, the head. The sound always seems to come from within or immediately behind