Microwave-Induced Pressure Waves in Mammalian Brains

RICHARD G. OLSEN, SENIOR MEMBER, IEEE, AND JAMES C. LIN, SENIOR MEMBER, IEEE

Abstract—This paper presents direct measurements of acoustic pressure waves in brains of rats, cats, and guinea pigs irradiated with pulsed 2.450 and 5.655 GHz microwaves. A small disk hydrophone transducer was surgically implanted in brains of anesthetized animals. Rectangular pulses (3 kW peak, 2.5 and 5.5 μs wide at 2.450 GHz and 200 kW peak, 0.5 μs wide at 5.655 GHz) were applied through horns, waveguides, and direct contact antennas. The results clearly indicate that pulsed microwaves induce acoustic pressure waves in the brain, confirming earlier theoretical predictions. Furthermore, hydrophone output waveforms and on-line analyzed spectra show that fundamental and second harmonics were nearly identical to those predicted by the thermoelastic theory. However, the hydrophone records show complex sequences of higher order vibrational modes which deviate from predictions based on a homogeneous spherical model of the head.

I. Introduction

One of the most interesting and widely recognized biological effects of microwaves is the pulse-modulated microwave-induced auditory phenomenon [1]. The effect has been described as clicking, buzzing, or chirping sounds [2]-[4] and occurred instantaneously at low average incident power densities. Considerable efforts during the past decade have been devoted to acquiring confirmatory data in lower animals. Consequently, there exists an abundance of literature reporting experimental observation on the electrical events that occur along the auditory pathways in response to pulse-modulated microwave stimulation [5]-[8]. Moreover, several behavioral studies reported successful use of pulsed microwaves as a cue for avoidance conditioning or discriminative control of appetitive behavior of laboratory animals [9], [10]. It is especially noteworthy that these observations were similar to those produced by conventional acoustic stimuli. These reports collectively indicate that the effect involved mechanical displacement of cranial tissue structures that exert influences on the peripheral portion of the auditory system, i.e., the cochlea.

While the precise site and mechanism of interaction have not been clearly identified, most investigators of this phenomenon believe that the response stems from microwave-induced thermoelastic expansion [11]-[13], i.e., when microwave radiation impinges on the head, a portion of the absorbed energy is converted into heat, which produces a small but rapid rise of temperature in cranial tissues. This rise of temperature (10^{-6}°C), occurring in a very short time (10 μs) generates rapid thermoelastic expansion of the brain matter or other tissues in the head, which then launches an acoustic wave of pressure that is detected by the hair cells in the cochlea [11].

A theoretical model based on thermoelastic expansion has been developed for brain spheres that are exposed to pulsed microwave energy [14]-[16]. This theory describes the acoustic waves (i.e., frequency, pressure, and displacement) generated in the head as functions of sizes of brain spheres, and characteristics of impinging and absorbed microwave energies. This thermoelastic theory is applicable to many of the physiological and psychophysical observations [15]. However, direct experimental confirmation for the acoustic pressure waves inside the head has only begun to appear. In a recent paper [17], we presented direct hydrophone measurements of pulsed microwave-induced acoustic signals in various sized spherical head models filled with brain-equivalent materials. It was shown that the measured acoustic frequencies that corresponded to mechanical resonance of the head model agree with those predicted by the thermoelastic theory of interaction. A three-pulse burst applied at appropriate pulse repetition rates could effectively drive the model to respond in such a manner that the microwave-induced pressure amplitude was increased threefold or more. While this lends support for the predicted thermoelastic waves inside the head, it would be extremely desirable to obtain similar confirmation in animal preparations. To this end, we present pressure waves in brains of rats, cats, and guinea pigs irradiated with pulsed 2.450 and 5.655 GHz microwaves.

II. Methods and Materials

A. Subjects

These experiments used three species of animals: six rats, two guinea pigs, and two cats. The male Long-Evans rats (Blue Spruce Farms, Altamont, NY) weighed approximately 475 g. The guinea pigs, *Cavia porcellus* (University of South Alabama, Mobile, AL) were 700 g females of the Hartley strain. Mongrel cats, *Felis catus*, were 4.5 kg males obtained from Wayne Fowler Co., Theodore, AL.

B. Apparatus

Pressure waves were sensed by a small disk hydrophone element composed of lead zirconate-titanate (C-5500) material

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R. G. Olsen is with the Naval Aerospace Medical Research Laboratory, Pensacola, FL 32508.

J. C. Lin is with the Department of Bioengineering, University of Illinois at Chicago, Chicago, IL 60680.

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