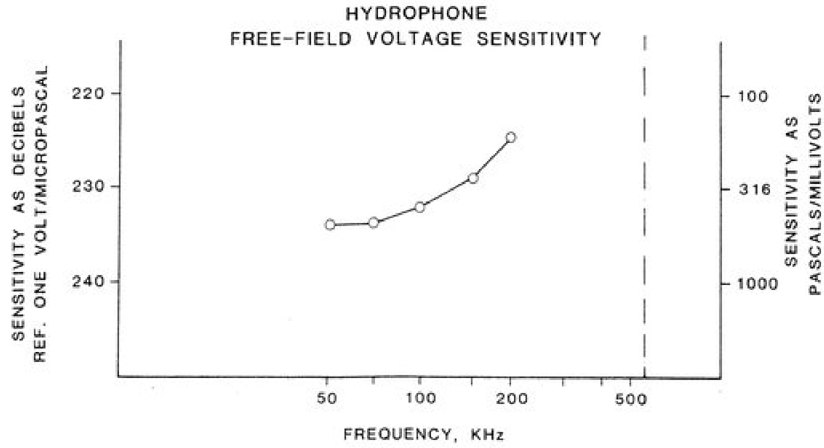

Fig. 2. Calibration graph of the free-field voltage sensitivity typical of the implanted hydrophone transducers. Reference device was a Navy Type E-27 hydrophone obtained from the Underwater Sound Reference Division, Naval Research Laboratory, Orlando, FL.

Following brainstem potential measurements, the hydrophone output cable was connected to the oscilloscope, and the animal was again subjected to a series of 5.655 GHz microwave pulses during which photographs were made of the oscilloscope trace. The animal was then removed from the chamber and placed on a bench surface adjacent to the pulsed 2.45 GHz source. Hydrophone signals, induced by absorption of the 2.45 GHz pulses, were recorded from the oscilloscope for various orientations of the Elmed Model 15 surface applicator. For one cat preparation, three-pulse bursts of 2.45 GHz energy were applied such that the interpulse spacing of the burst was varied over a range of frequencies centered on the apparent "ringing" frequency of the brain observed in the single-pulse irradiation. In so doing, a "tuning curve" for the fundamental mode of brain vibration was obtained [17], [18]. The animals were euthanized by barbiturate overdose following the 2.45 GHz experiments.

In the case of rats, brainstem potentials were obtained before surgical implantation of the transducer. Anesthetized rats were first instrumented with short needle electrodes and placed in the 5.655 GHz chamber and in front of the speaker for comparison of brainstem potentials. The hydrophone transducer was then surgically implanted in the same general location as before at a depth of about 8 mm. The rat was again positioned in front of the 5.655 GHz horn for recording the hydrophone output signal. Simultaneously, the signal was fed to the spectrum analyzer such that both time-domain and frequency-domain measurements could be obtained from a single series of microwave pulses. Photographs were taken of both oscilloscope traces. The animal was then removed from the chamber and, as before, was placed near the 2.450 GHz generator where the applicator or waveguide was used to apply pulsed microwave energy to the head. Photographs were again made of the hydrophone output signal and of the simultaneously analyzed spectrum of that signal. Each rat was euthanized by an overdose of anesthetics at the end of the experiment. The response of the implanted hydrophone transducer without acoustic or microwave stimulation clearly showed the absence of endogenious acoustic signals inside the brain tissue.

To assess the microwave-induced artifact in the disk hydrophone element, the bare transducer was irradiated in the 5.655 GHz chamber at the location occupied by the animal's head with the coaxial cable oriented parallel to the magnetic vector. A photograph of the output signal was then made. At 2.450 GHz, observation of the microwave artifact was not possible because it was physically impossible to situate only the small transducer in front of the applicator because the applicator was not designed to operate into air.

III. Results

A. *Hydrophone Calibration and Artifact Control*

From the physical properties of the piezoelectric material comprising the active element, a self-resonance is expected to occur between 500 and 600 kHz [19]. The calibration data shown in Fig. 2 appear to indicate this trend.

When the device alone was placed in front of the 5.655 GHz aperture, the transducer output waveform showed a large and slow spike with a small high-frequency, "ringing" signal superimposed. The frequency of the "ringing" signal was approximately 550 kHz and was thus close to the theoretically predicted self-resonance of the transducer.

B. *Microwave-Induced Pressure Waves in the Brain*

Fig. 3 shows hydrophone output waveforms for one cat and one guinea pig irradiated as described. The shorter, 5.655 GHz pulses appeared to stimulate more high-frequency vibrational activity than did the 2.450 GHz pulses, but in each instance a complex envelope of various modes was evident.

Hydrophone output waveforms, together with their spectra, are shown in Fig. 4 for the six rat experiments at 5.655 GHz. Fig. 5 shows the same type of data obtained at 2.450 GHz. The spectral traces clearly indicate more high-frequency response to the shorter, 5.655 GHz pulses, and although the waveforms are not identical, most records show a distinct vibration near 60 kHz, the computed fundamental mode of the brain.

Results of the "tuning-curve" irradiation experiments using