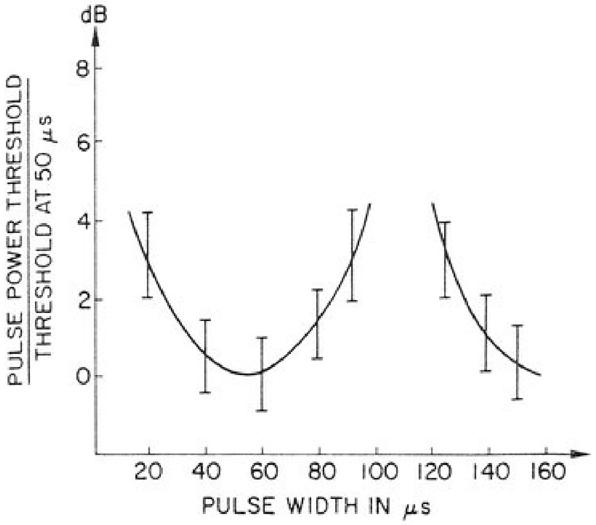

Fig. 2. Dependence of threshold of RF hearing on duration of pulse width at a PRR of 8000 pps. (Based on observers who were not perceptive of low-pitch sounds at pulse widths longer than 50 μs).

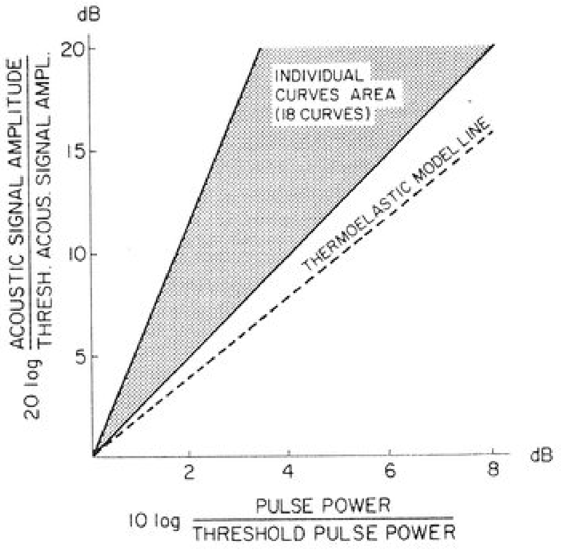

Fig. 3. Area of perceived loudness of RF pulses by 18 observers who matched AF to RF signals; audio signal = 10 kHz; RF signal = 10,000 pps. The dotted line indicates the relation predicted by the thermoacoustic model.

3.4. *Equivalence of audio and RF sounds.*

After *O*s matched the pitch and timbre of a sine-wave sound at 2 kHz to that of a train of RF pulses at 2000 pps, they were asked, first, to match the loudness of the auditory signal with that of the train of RF pulses as pulse width was varied between 5 and 150 μs; and second, to provide responses that were used to determine absolute thresholds of perception of RF pulses. Peak power was maintained at the same level in both series of measurements. The complex relation between pulse width and loudness referred to earlier was clearly evident (Figure 3).

Some of the *O*s described a new sensation when the pulse widths were increased toward 100 μs. The pitch shifted downward and the RF sound was referred externally to the head. Two *O*s with HFALs below 10 kHz could not perceive shorter RF pulses but were able to sense distinctly the longer pulses. For other *O*s, when pulses were successively shortened from 100 toward 50 μs, both the higher- and lower-pitched sounds were reported; at pulse widths less than 50 μs, the lower-pitched sound was never heard.

3.4. *Beat frequencies.*

When sinusoidal sound waves above 8 kHz were simultaneously presented with 10- to 30-μs microwave pulses that recurred at PRRs slightly above or below 8000 s^{-1}, a beat-frequency note was heard distinctly. Further, when exact matching of RF and AF frequencies was accomplished, and *O* was allowed to adjust phase of the AF signal until it opposed that of the train of microwave pulses, cancellation and loss of sensation occurred. Observers with HFALs below 15 kHz could obtain the same cancellation when a 5000-pps train of pulses was properly phased with a 10-kHz AF signal. Similarly, when the PRR was set at 800 pps, beat frequencies were obtained when the AF signal was slightly above or below harmonic frequencies of the fundamental microwave PRR.

3.5. *Water immersion.*

All of the qualitative sensory characteristics (pitch and timbre) evoked by microwave pulses of widths less than 50 μs persisted when *O*s' heads were lowered into water. Loudness, however, diminished roughly in proportion to the depth of immersion. Upon complete immersion, auditory sensations disappeared. For pulse durations longer than 50 μs, even partial immersion resulted in loss of sensation.

4. DISCUSSION

The auditory sensations evoked by trains of shorter (≤ 50 μs) microwave pulses are believed to be due to limited perception of pulsed waves at PRRs above 8000 pps. This explanation was offered earlier by *Frey* [1961], who suggested an even lower cut-off frequency of 5000 pps. Fourier analysis of the dependence of harmonic amplitude on pulse duration, if conjoined with the assumption that loudness of