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CUES FOR DIRECTION DETECTION IN THE EAR OF THE RABBIT.

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The mammalian external ear brings about a free field to eardrum sound pressure level (SPL) transformation of received sound. The transformation varies with the direction of the sound source and consequently interaural intensity differences (I.I.D.s) are generated (see e.g. Shaw 1974).

We have obtained free field to eardrum SPL transformation functions from the heads of New Zealand White rabbits using a microphone (Bruel and Kjaer type 4138) inserted into the base of the external auditory meatus. The heads were mounted centrally in an anechoic chamber (2.5 x 2.5 x 2.0 m) on a pedestal about which a vertical steel arc (1 m radius) could be rotated through 360° azimuth. Broad band sound was delivered from a loudspeaker clamped to the steel arc. The vertical position of the loudspeaker could be varied by clamping it at different heights on the arc.

Frequency/intensity spectra (0 - 20 kHz) were obtained for the free field and then for the external ear using a high resolution signal analyser (Bruel and Kjaer type 2033). Free field to eardrum SPL transformation functions were then derived by taking the amplitude ratio between the external ear spectrum and the free field spectrum. Transformation functions were obtained for every 10° azimuth, for every 15° elevation (between -15° elevation and +75° elevation). 0° elevation was defined as the horizontal plane grazing the top of the skull; 0° azimuth was taken as the mid sagittal (anterior) plane. Some typical transformation functions are shown (Fig. 1. a to c).

Interaural intensity difference (I.I.D.) spectra were also obtained for every 10° azimuth at 15° intervals of elevation by taking the amplitude ratio between the relevant ipsilateral external ear spectrum and the relevant contralateral one. Thus, for example, the I.I.D. spectrum at 90° azimuth was obtained by taking the ratio between the spectrum at 90° and the spectrum at 270° (Fig. 1. (d)).

In a complementary series of experiments, I.I.D. spectra were obtained using the cochlear microphonic (C.M.) from 13 anaesthetized (urethane) rabbits. Both sets of I.I.D. spectra consistently showed maxima in the low and mid frequency bands and a variable number of maxima at higher frequencies. The low and mid frequency maxima changed predictably in magnitude with angle of azimuth (Figs. 2 and 3). The magnitudes of I.I.D. spectrum maxima, particularly in the sector of space faced by the ear under investigation, thus provide good potential cues for assessing the angle of azimuth of the sound source.

I.I.D. values also change with elevation and therefore their usefulness as cues for azimuth depends on the animal's ability to assess the angle of elevation of the sound source. A potential cue for elevation is, however, also available in each I.I.D. spectrum: the higher the elevation of the sound source, the higher the frequencies at which maxima occur (Figs. 5 and 6). I.I.D. spectrum maxima also shift 'up-frequency' with increasing elevation of the sound source in the guinea-pig (Gower and Palmer, in preparation) and probably also in humans (Shaw 1974) and may well be a generally available cue for elevation in the mammals.

It is important for animals such as the rabbit to be able to localize unidentified sound sources rapidly. Naturally occurring sounds are typically broad band, are often of very brief duration and may occur anywhere in three-dimensional space. The I.I.D. spectrum provides sufficient cues for the directional assessment of such sounds, without recourse to head or pinna movements.

Reference:

1. E.A.G. SHAW 1974 in Handbook of Sensory Physiology Vol. V/1, 455–490. Eds W.D. KEIDEL and W.D. Neff. Springer-Verlag, Berlin, Heidelberg, New York. Chapter 14: The external ear.

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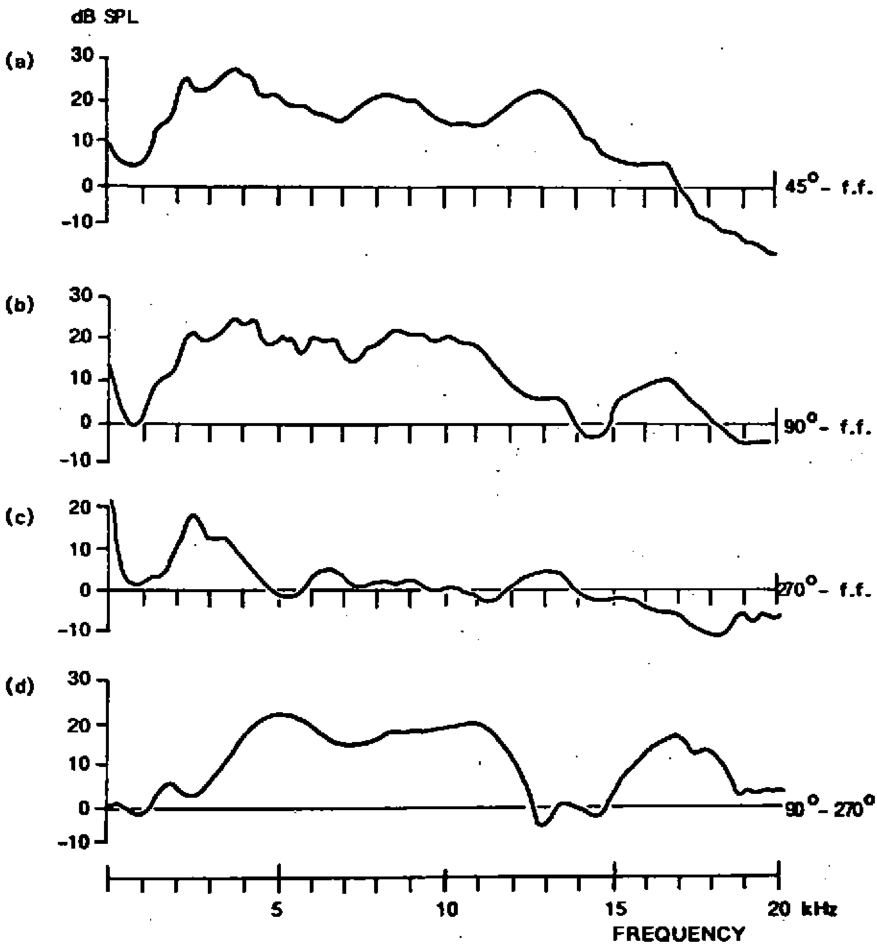

Figure 1. Free field to eardrum transformation functions at (a) 45° azimuth, (b) 90° azimuth, (c) 270° azimuth and (d) the derived I.I.D. spectrum (b - c). All at 0° elevation. (RX, pinna opening normal to 25° azimuth).

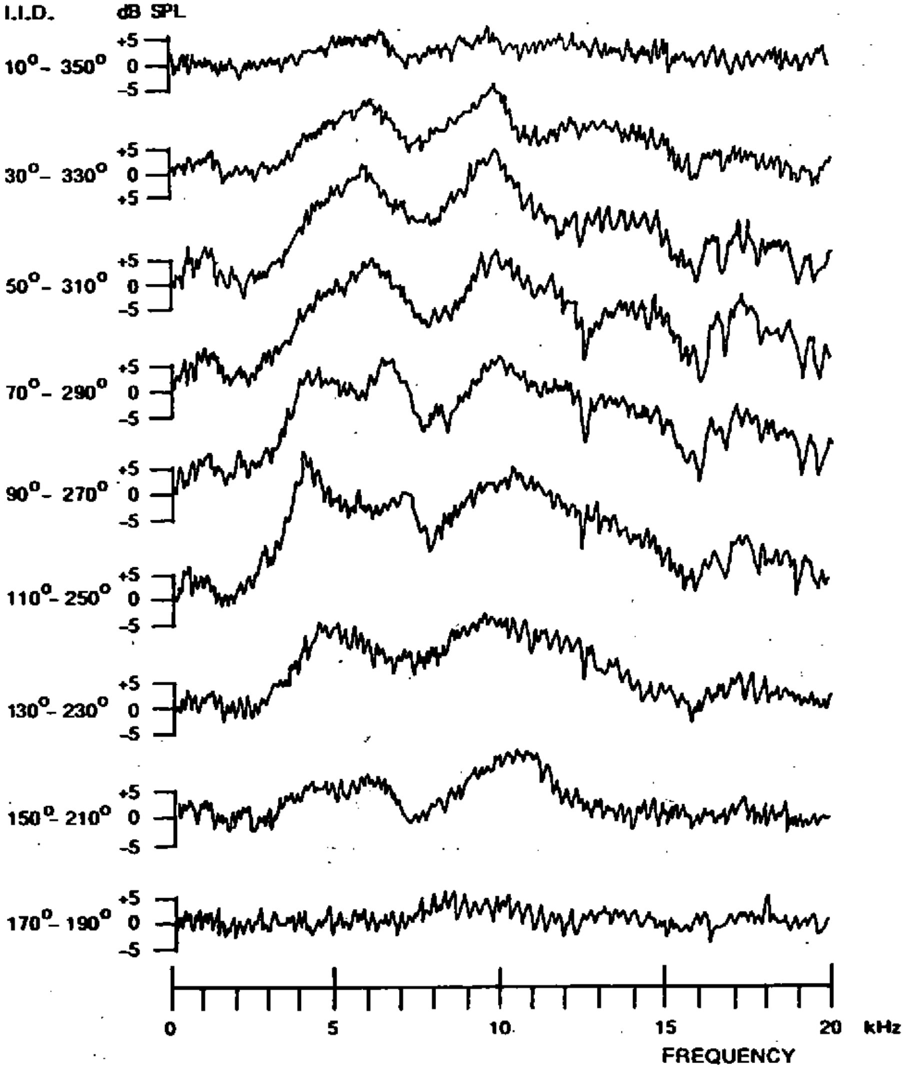

Figure 2. Examples of I.I.D. spectra obtained from the cochlear microphonic; 0° elevation. (R9; pinna opening normal to 24° azimuth).

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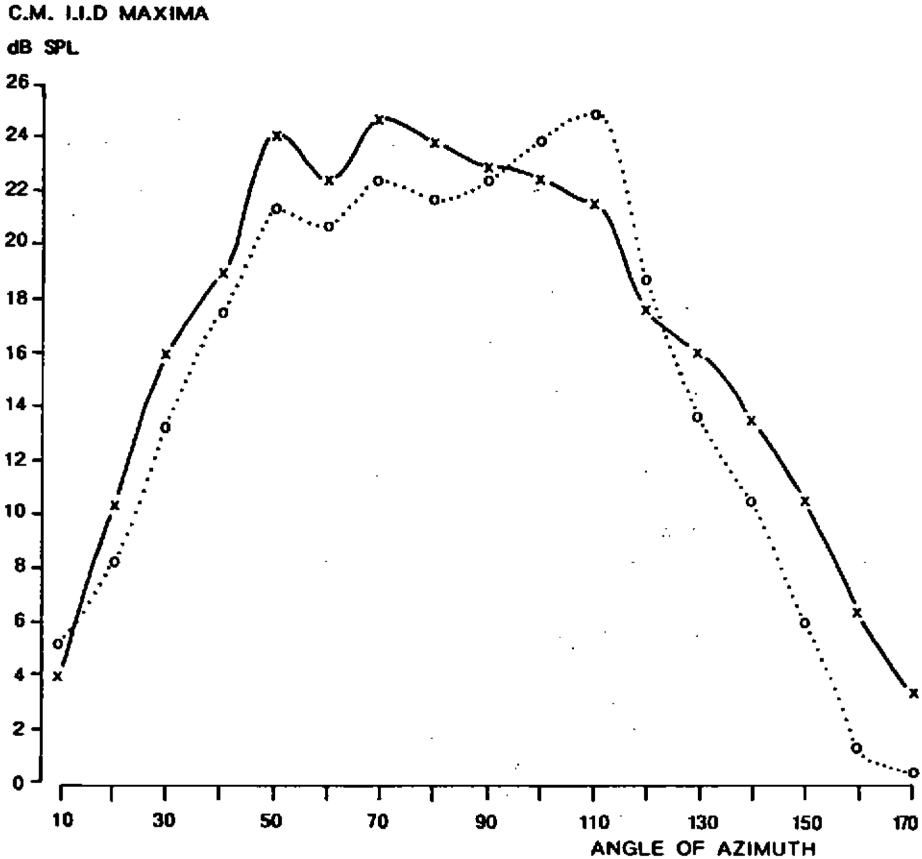

Figure 3. C.M. I.I.D. spectrum maxima values plotted as functions of angle of azimuth; 0^{o} elevation (R9; pinna opening normal to 24^{o} azimuth). o······o - low frequency maxima x——x - mid frequency maxima.

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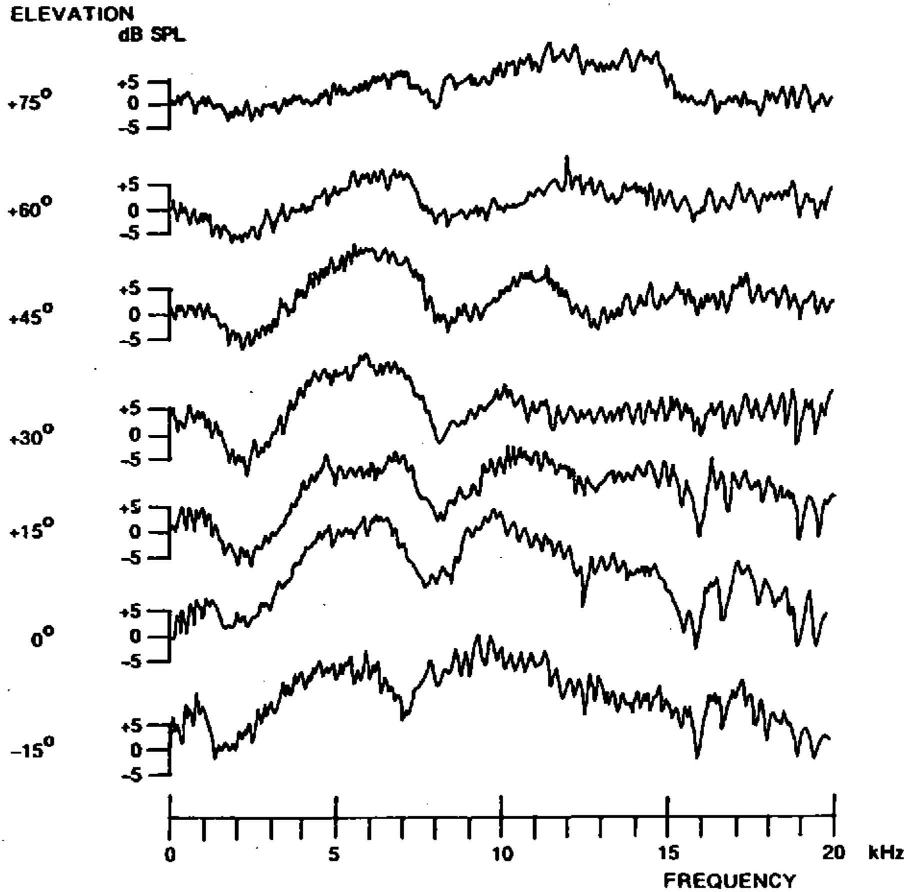

Figure 4. Examples of C.M. I.I.D. spectra at various elevations; 80° azimuth. (R9; pinna normal to 24° azimuth).

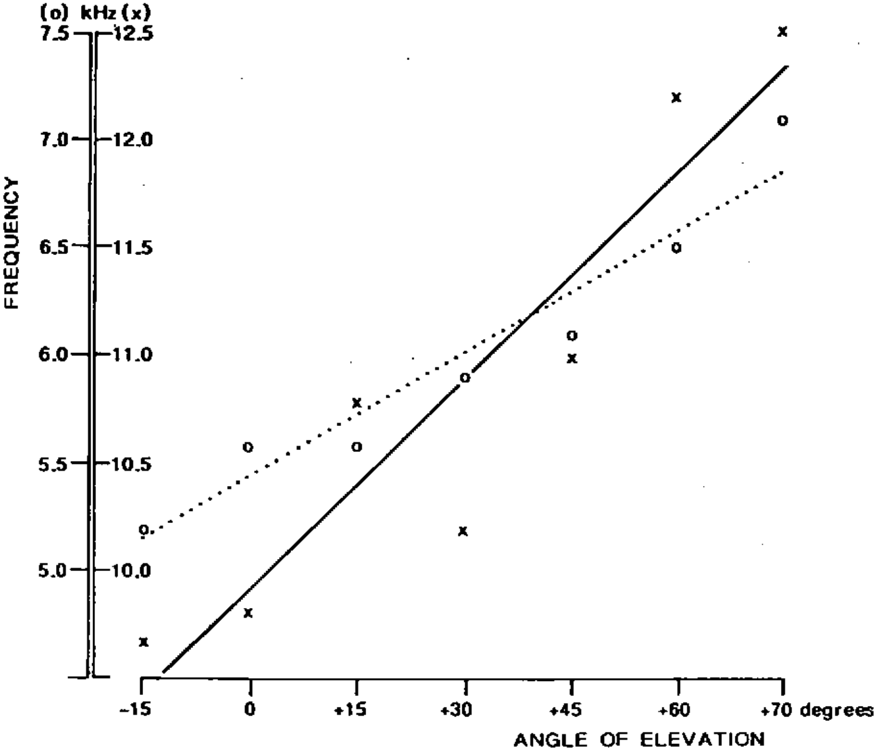

Figure 5. The frequencies at which C.M. I.I.D. spectra are maximal, plotted as functions of angle of elevation; 80° azimuth. (R9; pinna opening normal to 24° azimuth). o·······o low frequency maxima; x——x mid frequency maxima.