MASKING, A PERIPHERAL EFFECT!

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INTRODUCTION

Masking is one of the most important properties of the ear. Tone-on-tone masking of continuous tones was systematically studied as early as 1924 by Wegel and Lane. In "classical" masking experiments narrow band noises are often used as maskers, in order to avoid beats. These masking patterns (see for example Zwicker 1963) illustrate best the ear's frequency selectivity if masked threshold is plotted as a function of the critical-band rate. These patterns exhibit strong nonlinearities, especially in the frequency region above that of the masker. The ear's combination of frequency selectivity and nonlinearity raises the question: "is masking produced peripherally in the cochlea or more centrally through neural interactions?" (question a).

There are, however, additional aspects to the masking properties of the ear. Strong temporal effects have been measured in the cases of pre-, simultaneous, and post-masking (Fastl, 1977, 1979). Masking-period patterns (Zwicker, 1976a) have provided additional information, especially concerning the masking of periodic sounds such as very-low- and low-frequency tones, i.e. tones with frequencies below 1 kHz. Excitation-critical band rate patterns are an important aid to the understanding of many of the psychoacoustical properties of continuous sounds (see for example Zwicker 1970). These patterns are based on masking patterns measured with continuous test tones. An awareness of the importance of temporal effects leads to a second question (b): "How much influence do temporal effects have on the masking or excitation patterns produced by maskers with frequencies below 1 kHz?"

RESULTS

An attempt was made to answer both question (a) and question (b) using classical and temporal masking patterns on the one hand and so-called suppression-period patterns (Zwicker, 1981, Zwicker and Manley 1981) of delayed oto-acoustic emissions on the other.

The author, served as subject for all measurements. The methods and apparatus used are described in detail in the above-mentioned literature.

The top part (a) of Fig. 1 shows the stimulus configuration for the measurement of a masking-period pattern, with a 20 Hz-111 dB tone as masker and a tone burst composed of 1.5 ms-1350 Hz impulses as test sound. The threshold of the burst was measured as a function of its temporal position Δt within the period T of the masker. The masking-period pattern obtained in this way is drawn in Fig. 1b using open circles. The threshold in quiet for the test tone burst was measured before and after the series of measurements and is indicated by closed circles to the left and to the right of Fig. 1b. The thresholds of the continuous 1350-Hz tone in quiet (closed rhombus) and masked by the 20-Hz tone (open rhombus) are also indicated.

The sound pressure p_{OAE} of the delayed oto-acoustic emissions evoked by the same test tone burst with a sensation level SL = 20 dB is plotted in Fig. 1c. At left and right, the p_{OAE} without the suppressing 20-Hz tone is given, while the inner curves belong to conditions for which p_{OAE} is suppressed by the 20-Hz tone at the corresponding temporal position Δt within its period. The effective value of p_{OAE} measured for the window within the two indicated dashed lines is given in Fig. 1d on a logarithmic scale (normalized to an arbitrary value p_n) as a function of Δt. The curves in Fig. 1b and Fig. 1d are virtually exact mirror images of each other.

More data of the same kind are given in Fig. 2 but for masker frequencies of 40 Hz, 80 Hz, and 160 Hz, as indicated. Masker levels are chosen so that an L_T^* of about 40 dB is reached in the masking pattern's maximum. In Fig. 1 (for 20 Hz masker frequency), the temporal resolution was chosen corresponding to 1/8 of the period, while it was reduced to 1/4 of the period in Fig. 2 for all three masker frequencies. Thresholds of the continuous test tone in quiet, as well as masked by the low-frequency tones, are again indicated as open and closed rhombi respectively. Fig. 2 shows that the masking-period patterns become shallower with increasing

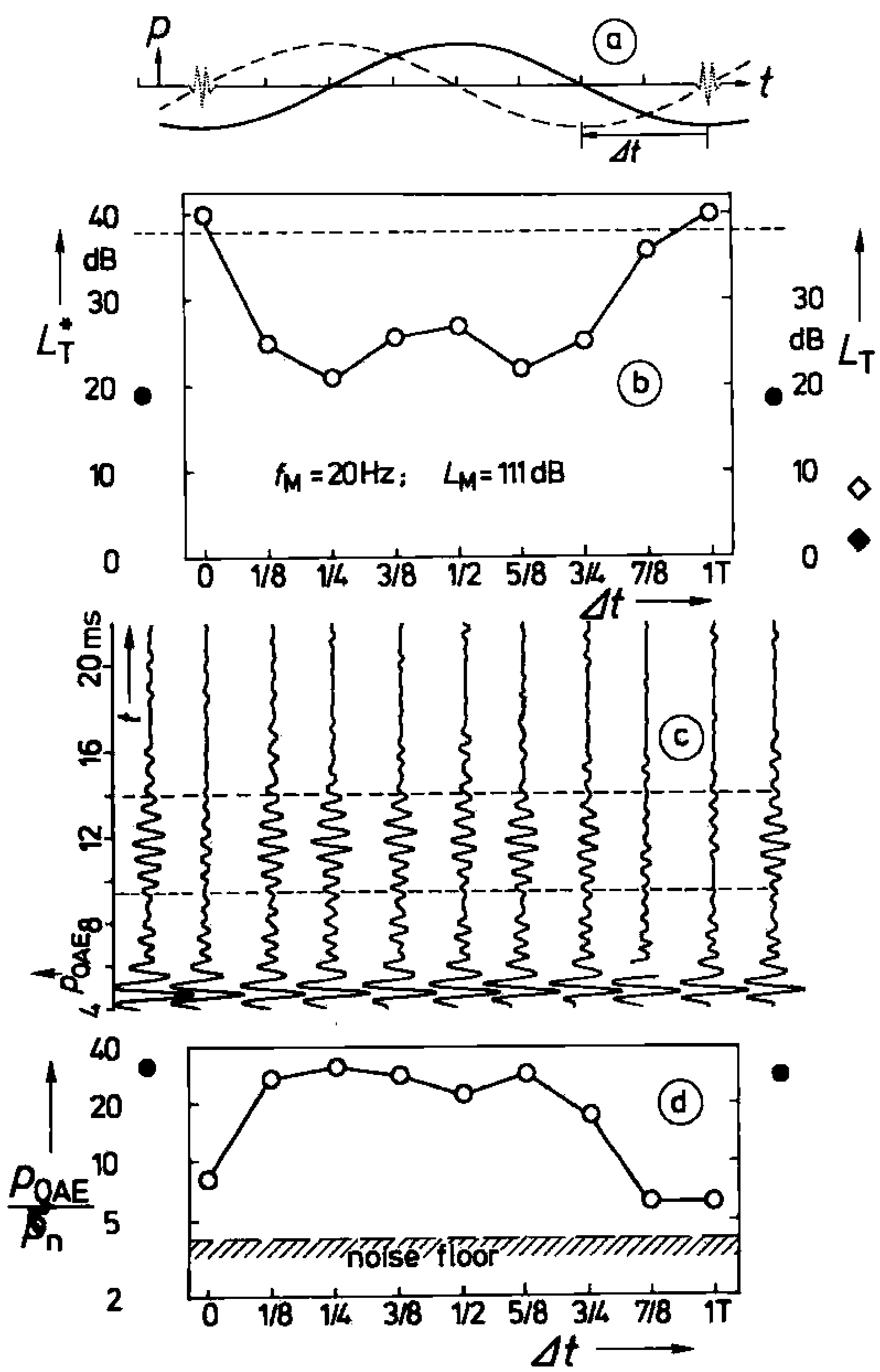

Fig. 1. Masking-period pattern (b) produced by a 20-Hz masker and measured with a 1350-Hz tone burst as indicated in (a). Suppression-period pattern (d) extracted from the corresponding sound pressure-time function (c) of delayed oto-acoustic emissions, evoked by the same test-signal as indicated in (a) but with SL = 20 dB.

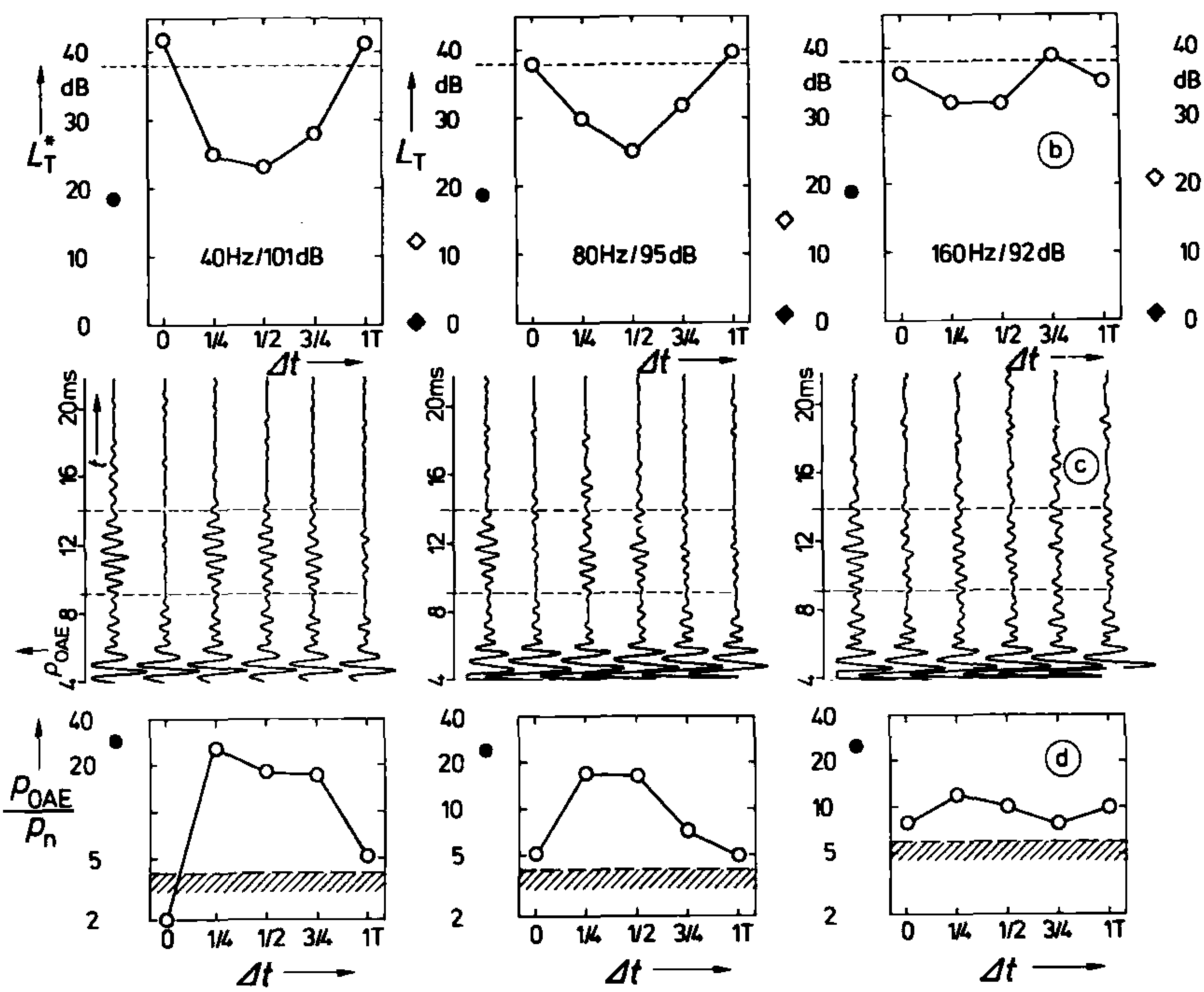

Fig. 2. Masking-period patterns (b), sound pressure-time functions of delayed evoked oto-acoustic emissions (c) and corresponding suppression-period patterns (d) for 40 Hz (left), 80 Hz (center), and 160 Hz masker (right).

masker frequency. The same holds for the suppression-period patterns.

DISCUSSION AND CONCLUSIONS

The very close mirror relationship between curves (a) and (d) in Fig. 1 for 20-Hz masker frequency is found also for 40, 80,and 160 Hz masker frequency, as shown in Fig. 2. This relationship confirms the assumption expressed earlier (Zwicker 1979,1983) that masking is produced peripherally, i.e. within the cochlea, at least for threshold shifts up to about 20 dB, the upper limit of linear rise of oto-acoustic emissions.

Masking produced by low-frequency maskers is not a steady state effect but varies with the period of the masker. Masking is most effective at the point of minimum pressure, i.e. maximum rarefaction, as indicated in the masking-period pattern (for example Fig. 1b). The differences between the maxima and the minima of the masking-period patterns decrease with increasing masker frequency from 19, to 19, 15 and finally 6 dB for frequencies of 20, 40, 80 and 160 Hz, respectively.