5 Pitch and Pitch Strength

In this chapter the pitch of pure tones, complex tones and noise bands is addressed, and models for spectral pitch and virtual pitch are developed. In addition, the pitch strength of various sounds is assessed.

5.1 Pitch of Pure Tones

5.1.1 Ratio Pitch

The pitch of pure tones can be measured by different procedures. One possibility is that the subject is presented with a pure tone of frequency $f_1$ and has to adjust the frequency $f_{1/2}$ of a second tone in such a manner that the second tone produces half the pitch of the first tone. If, for instance, a pure tone of 440 Hz is used as sound 1 and a pure tone of variable frequency as sound 2, and the subject listening alternately to sounds 1 and 2, adjusts sound 2 to produce half the pitch elicited by sound 1, the average setting for the second tone is a frequency of 220 Hz. This means that at low frequencies, the halving of the pitch sensation corresponds to a ratio of 2 : 1 in frequency. This result at low frequencies is expected particularly from musically trained subjects. At high frequencies, however, some unexpected effects occur. If a frequency of 8 kHz is chosen for $f_1$, subjects produce for the sensation of “half pitch” not a frequency of 4 kHz, but a frequency of about 1300 Hz. Although there exist large individual differences, the value of 1300 Hz, on average, could be confirmed in many experiments. Measurements at other frequencies above 1 kHz confirm the tendency observed: for the perception of “half pitch”, a ratio of the corresponding frequencies larger than 2 : 1 is necessary. This relation is shown in Fig. 5.1 by the solid curve. The frequency $f_1$ is given at the upper abscissa, the frequency $f_{1/2}$ at the left ordinate. The broken curve indicates the ratio of 2 : 1 between frequency $f_1$ and frequency $f_{1/2}$. Up to a frequency of about 1 kHz, the broken line and the solid line coincide; significant deviations occur at higher frequencies. The example that 1300 Hz represents “half pitch” of 8 kHz is indicated in Fig. 5.1 by arrows and the thin broken lines. In the same way that the sensation “half pitch” is determined, the sensation “double pitch” can be measured. For both types of experiments, a method of constant stimuli is frequently used. Moreover, at high frequencies, narrow
Fig. 5.1. Frequency and ratio pitch. The relationship between the frequency $f_1$ and the frequency $f_{1/2}$ producing “half pitch” (solid). Ratio pitch as a function of frequency (dotted). Cross: reference 125 Hz = 125 mel. Dashed lines with arrows: indication that 1300 Hz corresponds to the “half pitch” of 8 kHz

Ratios can be determined from experiments with halving and doubling of sensations, but not absolute values. To get absolute values it is necessary to define a reference point for the sensation “ratio pitch” as function of frequency. For the results plotted in Fig. 5.1, it is advisable to choose the reference point at low frequencies where the frequencies $f_1$ and $f_{1/2}$ are proportional, and to assume as the constant of proportionality the factor 1. In this way, the dotted line in Fig. 5.1 in the frequency region below 500 Hz, is produced by shifting the solid line by a factor of 2 towards the left. As a reference frequency, 125 Hz is chosen and marked in Fig. 5.1 by a cross. The dotted line in Fig. 5.1 then indicates that the numerical value of the frequency is identical to the numerical value of the ratio pitch at low frequencies. Because ratio pitch determined this way is related to our sensation of melodies, it was assigned the unit “mel”. Therefore, a pure tone of 125 Hz has a ratio pitch of 125 mel, and the tuning standard, 440 Hz, shows a ratio pitch with almost the same numerical value. However, at high frequencies, the numerical value of frequency and that of ratio pitch deviate substantially from another. As indicated by the dotted line in Fig. 5.1, a frequency of 8 kHz corresponds to a ratio pitch of 2100 mel, and a frequency of 1300 Hz corresponds to a ratio pitch of 1050 mel. Thus the experimental finding that a tone