to Fig. 4.15 it will be seen that the radiation resistance of a vibrating surface decreases as the ratio of the dimensions to the wavelength decreases.

Considering the size of the double bass, the sound output of the instrument is relatively low. Nevertheless, the double bass plays an important role in reinforcing the bass portion of an orchestra which, under any condition, is usually weak.

c. Piano. The piano is the outstanding example of a struck-string musical instrument (Sec. 5.3*C*1). The acoustic spectrums of three notes of a piano are shown in Fig. 6.16. As in other string instruments, all the components in the harmonic series are present in the piano (Sec. 4.5). The overtone structure depends to some extent upon the velocity with which the hammer strikes the string. The velocity of the hammer depends upon the velocity of the key at the moment that it "throws off" the hammer. The pianist can produce different tone qualities but only as a function of the intensity. In the high-frequency range, the amplitude of the harmonics decreases rapidly with frequency. The piano has a very uniform quality in going from one tone to the next. On the other hand, there is a marked difference between the tones in the low registers and the high registers. The low tones are richest in harmonics, because

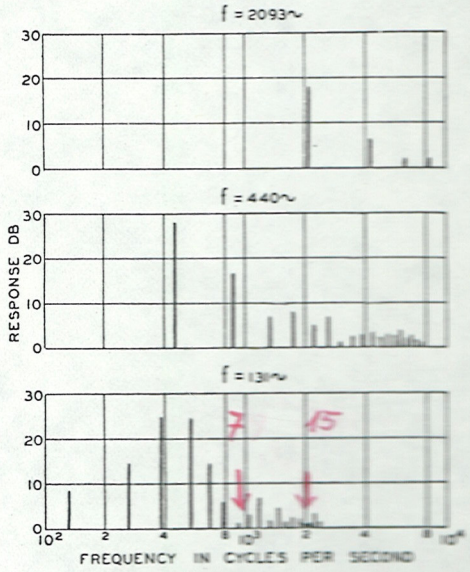

FIG. 6.16. The acoustic spectrums of three tones of a piano.

the low tones are not produced with the same efficiency as the higher tones. This is caused by the decreased coupling between the soundboard and the air in the low-frequency range due to the relatively small acoustical-radiation resistance. Referring to Fig. 4.15, it will be seen that the acoustical-radiation resistance of a vibrating surface decreases as the ratio of the dimensions to the wavelength decreases. It also follows that, in the larger grand pianos with correspondingly larger soundboards, the low tones will be reproduced with greater efficiency, because as the soundboard is made larger the coupling between the strings and the air is improved, owing to the larger acoustical radiation resistance.

The sound-output characteristic of a piano tone consists of growth and decay, but no steady-state condition. There is considerable variation in the frequency spectrum during the growth and decay intervals. The acoustic spectrum shown in Fig. 6.16 represents the frequency components in the output during a short interval of time in the decay period.

d. Guitar. The guitar is an example of a plucked-string instrument. The acoustic spectrums of two open strings of the guitar are shown in Fig. 6.17. As in other string instruments, all the components in the harmonic series are present in the guitar (Sec. 4.5). As in the piano, the complexion of the overtone structure depends upon the intensity with which the instrument is plucked, that is, the deflection of the string from the normal repose position when it is released. The sound-output characteristic of a guitar tone consists of a growth and decay, but no steady-state condition. There is considerable variation in the acoustic spectrum

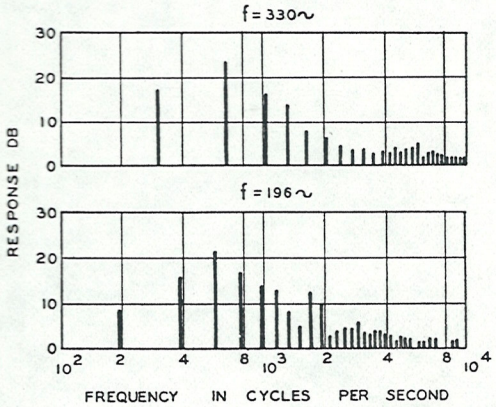

FIG. 6.17. The acoustic spectrums of two tones of a guitar.