being located more in the auditorium, may produce curves like the solid lines in the left parts of the figures.

Such a difference, in fact, may even be attractive up to a certain point, so that experienced listeners just notice it, but others in the audience perceive it as a 'special' but undefined quality.

There have been occasional attempts to compensate for a too-short reverberation time in the auditorium by allowing the audience to hear the longer reverberation time of the stage house; but we have learned in this section that the decay process thus achieved is quite different from that which a longer reverberation time in the auditorium would give.

II.3.5 Electroacoustical Coupling between Rooms

Any consideration of coupled rooms would be incomplete today if we took into account only the 'natural' coupling, discussed up to this point, without also accounting for the possibility of 'artificial' coupling by means of microphones, amplifiers and loudspeakers.

The most frequently used applications of the latter occur with radio or television broadcasts and in cinema theaters. The sound is picked up by a microphone in one room and is transmitted, either 'live' or recorded, into another room (a living room or a cinema theater), where it is re-radiated by loudspeakers.

This kind of coupling exhibits two essential differences from natural coupling. First, the coupling is uni-directional; that is, with respect to our energy balance, room 1 transfers into room 2 an amount of power P_{21} that is proportional to E_1:

$$P_{21} = K_{21} E_1 \tag{3.53}$$

but room 2 transmits no power back to room 1 at all.

The second difference is that the power radiated into room 2 is not subtracted from the power P_1 radiated into room 1; that is, the electroacoustical equipment does not absorb sound energy in room 1 and thus has no influence on the value of A_1. (This is not as self-evident as it appears. At least we will discuss later an arrangement by which the electroacoustical equipment actually adds to P_1 and thereby reduces the value of A_1.)

The power P_{21} is taken from an independent power source, which is 'piloted' by the time-varying E_1; only in this manner is the uni-directional coupling possible. The constant K_{21}, which contains the gain of the amplifier chain, can be given any value we choose; therefore, the amount of power radiated into room 2 is independent of the amount of power produced in room 1.

The lack of any energy feedback from room 2 leads to a power balance equation for room 1 in which E_2 does not appear:

$$P_1 = \frac{c}{4} A_1 E_1 + V_1 \frac{\mathrm{d}E_1}{\mathrm{d}t} \tag{3.54}$$

After the sound source is stopped, we have only a single exponential decay with the damping constant:

$$\delta_1 = \frac{cA_1}{4V_1} \tag{3.55}$$

The initial energy density after long excitation is:

$$E_{01} = \frac{4P_1}{cA_1} \tag{3.56}$$

For impulsive excitation, we get (as above, in eqn. (3.52)):

$$E_{01}' = \frac{P_1 \Delta t}{V_1} \tag{3.57}$$

In the playback room, in both cases, the reverberation in room 1 appears as continuing but decreasing excitation. For steady-state excitation in room 1, we get the equation:

$$K_{21} E_{01} e^{-2\delta_1 t} = \frac{c}{4} A_2 E_2 + V_2 \frac{\mathrm{d}E_2}{\mathrm{d}t} \tag{3.58}$$

This reverberation forces a single decay process in room 2 with the same exponent:

$$E_{21} = E_{021} e^{-2\delta_1 t} \tag{3.59}$$

or, according to (3.58):

$$E_{21} = \frac{4K_{21}E_{01}}{cA_2} \frac{\delta_2}{\delta_2 - \delta_1} e^{-2\delta_1 t} \tag{3.60}$$

where we have again introduced δ_2 for the damping constant of room 2:

$$\delta_2 = \frac{cA_2}{8V_2} \tag{3.61}$$

But the initial energy density that appears in eqn. (3.60) is, in general, not that which exists at $t=0$ in room 2. If the reverberation follows steady-state excitation, we must expect there the energy density:

$$E_{02}=\frac{4K_{21}E_{01}}{cA_2} \tag{3.62}$$

If the decay follows an impulsive excitation, we have

$$E_{02}'=0 \tag{3.63}$$

In both cases, we must supplement eqn. (3.60) with a term that decays with the damping constant δ_2, in order to fulfil the initial conditions. Physically expressed, we must add to the 'forced-reverberation' term a 'free-reverberation' term.

Thus, we get a solution for steady-state excitation as follows:

$$E_2=\frac{4K_{21}E_{01}}{cA_2}\left[\frac{\delta_2}{\delta_2-\delta_1}e^{-2\delta_1 t}-\frac{\delta_1}{\delta_2-\delta_1}e^{-2\delta_2 t}\right] \tag{3.64}$$

In the case of impulsive excitation we get:

$$E_2'=\frac{4K_{21}E_{01}'}{cA_2}\,\frac{\delta_2}{\delta_2-\delta_1}\left[e^{-2\delta_1 t}-e^{-2\delta_2 t}\right] \tag{3.65}$$

(The expressions in brackets are the same as those in eqns. (3.48) and (3.50), showing that in those equations we have already neglected the feedback from the neighboring room.)

Note that eqns. (3.64) and (3.65), taking into account eqns. (3.56) and (3.57), obey the general condition of eqn. (1.18).

We distinguish again between the two possibilities, that room 1 or room 2 is the more reverberant. Figure 3.6 shows the curves of level versus time for these two cases (left and right): the situation with steady-state excitation is shown at the top, that with impulsive excitation at the bottom. The solid lines refer to the recording room, the dashed lines to the playback room, 2.

The case of $\delta_1<\delta_2$ (i.e. $T_1>T_2$, left) is the normal situation for the playback of concerts in living rooms. The reverberation heard there corresponds to the reverberation in the recording room (since the short time delay in room 2 is hardly noticeable). For the other case, $\delta_1>\delta_2$ (i.e. the reproduction of 'dry' music in a reverberant space, right), the short reverberation time of the recording room is not observable in room 2. For this reason, the changes in recorded reverberation that are some-

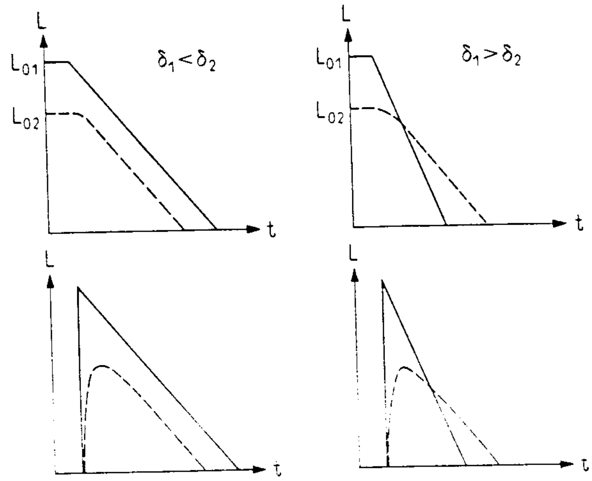

Fig. 3.6. Reverberation processes (level versus time) for unidirectional coupling between rooms. Left: source room more reverberant. Right: playback room more reverberant. Top: steady-state excitation. Bottom: impulsive excitation.

times introduced in an attempt to replace the missing visual scenery with 'acoustical scenery', are not heard, because they are swamped by the reverberation of the playback room.

Since such artificial manipulation of the recorded acoustics was regarded as a legitimate tool of the movie industry, it was assumed in the early days that it was necessary to make the acoustics of cinema theaters as 'dead' as possible. But this extreme practice was quickly given up, not only because cinema theaters are sometimes used for other purposes, but also because it was found that the loudspeaker sound is unnatural when the reflections from the walls and ceiling are missing. All the sound tends to be localized at the front, so that even when the reproduced sound contains reverberation, the listener never feels that he is in a reverberant space, nor even that he is looking into a reverberant space.

Certainly, a reverberant cinema theater would be unsuitable, because the speech would be unintelligible; so nowadays the acoustical requirements for a cinema theater are considered to be the same as for a lecture room or drama theater.

It is not always possible, on the stage, to adjust the acoustical impression to match the visual scene: sometimes, in fact, there is an obvious contradiction. The more-or-less absorptive painted canvas stage