48541 Signal Theory — Digital Room Correction Project

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Digital Room Correction (DRC) is the term used in hifi circles for signal processing that is used to compensate for or counteract the (detrimental) effects of the listening room upon the music signal. DRC is related to audio processing that is used in "pro-sound" installations such as concert halls, theaters, and stadiums, but focussed specifically on domestic audio listening. In this project, you will design and implement, in Matlab, a basic DRC system.

1 Background

Figure 1 illustrates a naive view of how an audio signal reaches the ears of the listener from the loudspeakers. If the loudspeakers perfectly reproduce the recorded signal, then the listener hears a perfect reproduction of the left and right signals from the loudspeakers. (Note: this situation is not actually ideal, as will be discussed below.)

Figure 2 illustrates what happens in actuality. The walls (as well as the floor and ceiling) of the listening room act as reflective surfaces, and the sound wave from the loudspeaker reflects of all of these surfaces multiple times. Depending on the material on the walls and on the frequency of the audio signal, these waves will be reflected multiple times, in different amounts. There are basically two types of behavior associated with repeated reflections in a listening rooms:

- Reverberant sound. Above a certain frequency (typically, around 250 Hz), the sound reflects off the walls in many directions, resulting in a decay of the sound over a period of time—up to several seconds in a highly reverberant room, such as, say, a tiled bathroom. You can hear this effect by clapping your hands once and listening.

- Room modes. Below roughly the same frequency, sound waves reflect off opposite pairs of walls and create *modes*. At certain frequencies, modes reinforce the reflected waves to increase the amount of that frequency in the room; at other frequencies, reflected waves cancel each other to create a "null" in the room.

A certain amount of reverberant field is necessary for natural-sounding music playback. If no sound at all was reflected, a listening room would sound very "dead" and be unpleasant to be in. (This type of room is called *anechoic*, meaning "no echos.")

Room modes are not desired, though. Although physical remedies such as absorbers are used in environments such as recording studios, these remedies are expensive and often not acceptable for size or aesthetic reasons in a domestic living room. Advances in digital technology make it feasible to address at least some of these problems digitally, using signal processing.

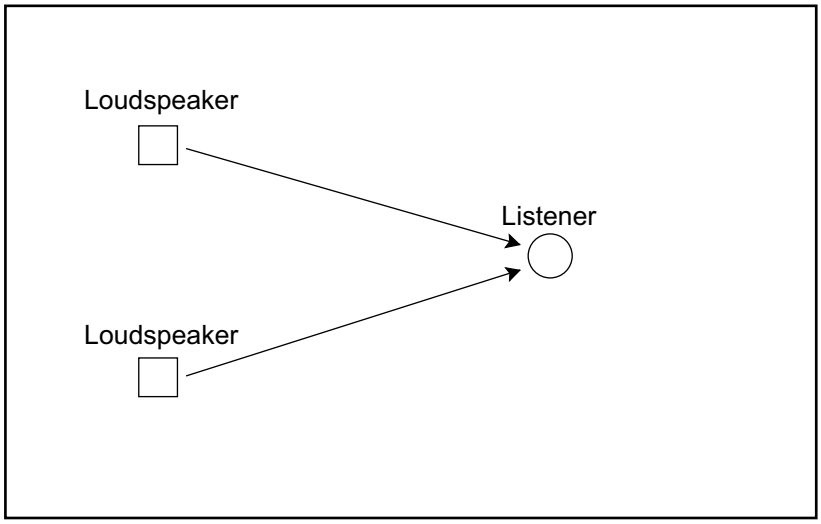

Figure 1: A listening room with no reflections

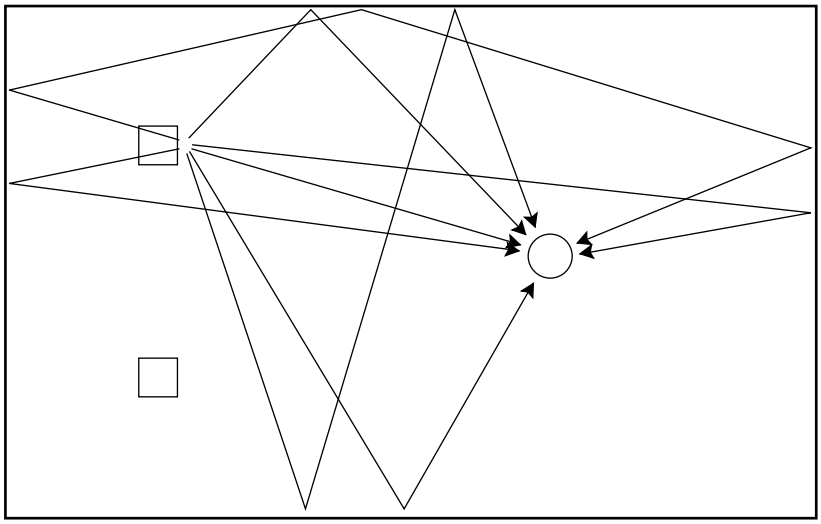

Figure 2: A listening room with reflections

2 The project

There are three steps when using a DRC system:

1. Firstly, the room is measured to determine its response. A test signal is played through the loudspeaker, and a signal is picked up by a microphone at the listening position. This signal is analyzed to determine the room response.

   (In a real room, this is quite complicated, as the response varies according to the location of the loudspeaker and the microphone. Often, multiple measurements are made in different locations.)

2. Secondly, the desired response is specified, and a correction curve determined. The desired response is known as a "target curve." No DRC system can compensate completely for the room—the goal is to reduce the negative effects of the room, not to eliminate the room.

3. Finally, music is played through the DRC system, which applies the correction curve to the signal. The resulting sound at the listening position will be closer to an "ideal" sound than it would be without the DRC.

Your goal is to implement all three steps in Matlab. For the purposes of this subject, you will not be performing measurements on a real room, but on a simulation. The simulation will be provided to you. (The reason for not using a real room is twofold: first, it is quite time-consuming to measure a real room, and second, we don't have suitable equipment to enable a full class to do room measurements.)

During the course of the semester, you will be exploring the concept of digital room correction with an aim to learning about Signal Theory. To begin with, you won't fully understand how DRC works, nor will you have the knowledge to realize the system. But, you will begin with an overall block diagram, and fill in the theory and the functionality of the blocks as the semester progresses.