The Basics of High Fidelity
Part 4: The Ideal Loudspeaker, Reflections and Resonances

Part 1 dealt with the problem of transparency, Part 2 and 3 with the problem of applying this idea to the transduction of audio into sound allowing to construct an ideal loudspeaker on the basis of the “there and then” illusion (virtual reality). In part 4 I will further elaborate on the role of reflections and resonances.

Reflections and resonances are closely related, reflections cause standing waves in a room leading to unwanted resonances. Part 3 explained that reflections are a core element in HiFi loudspeaker reproduction. In essence, we must not try to eliminate reflections striving towards an “dead” reproduction room, but we have to exploit reflections in such a manner that they are of benefit to the reproduction. Reflections should create a sense of immersion with a diffuse field that is similar to a concert hall. There are loudspeakers on the market that follow this strategy, but as I already pointed out in Part 3, none of the available commercial solutions fulfill the equalized diffuse field requirement.

When we try to exploit reverberations for the diffuse field, we run into the problem of standing waves which cause degrading resonances. While musical instruments benefit from resonances, they add a specific “color” to the instruments, a reproduction room and a loudspeaker should never add any color to any sound. The main goal of a production room, be it a concert hall or a recording studio, is to provide acoustic integration of the different radiation patterns as found in acoustical instruments. They should not add any color to the acoustical instruments that are being recorded. Furthermore a concert hall also provides a sense of immersion that often is missing in loudspeaker reproduction.

To deal with the problem of resonances with loudspeaker reproduction, we have to start with a well-designed driver but unfortunately we also need an enclosure that prevents low frequency short-circuiting. This enclosure is an acoustic nightmare, the air inside the enclosure and all the panels used in the enclosure cause sound coloration by resonances. Can we design an enclosure that is free of any resonances?

Based on the insight that reflections that interfere with themselves are the root cause of resonances we can prevent them by using non-parallel surfaces. If we use parallel surfaces all reflections lead to identical resonances while non-parallel surfaces lead to waves for which it is more difficult to have self-interference (see Figures 1 and 2). In fact there is a mathematical formulation that relates the symmetry of a system with the distribution of the resonances (“eigenvalues”), the more asymmetric the system the wider distributed the resonances and the less peaked the resonance characteristic. This leads us to the following theorem: “The ideal loudspeaker enclosure has no point, line or surface symmetry with regards to the enclosed volume as well as its boundary surfaces”. Figure 3 provides an example of such an enclosure and I have to admit, it’s not easy to produce and also the left and right enclosure should be constructed enantiomorphic in order to have a visual acceptable design.

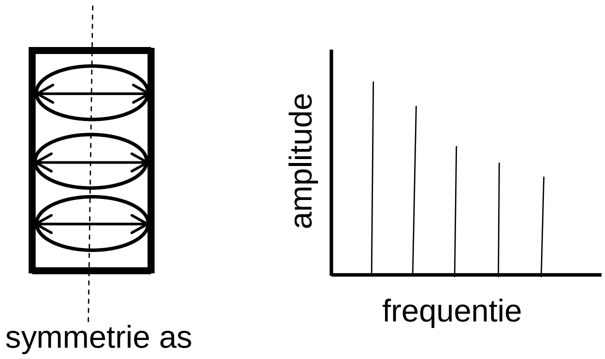

Figure 1. Schematic impression of how resonances are generated by parallel boundaries. The symmetry causes coinciding eigenvalues, a limited number of resonant frequencies are generated with large amplitudes.

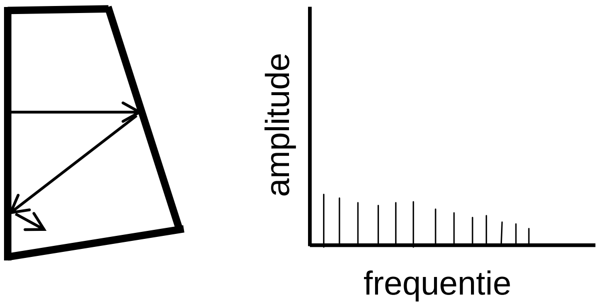

Figure 2. Schematic impression of how resonances are generated by non-parallel boundaries. The asymmetry makes self-interference more difficult causing less coinciding eigenvalues, a large number of different resonant frequencies are generated with low amplitudes.

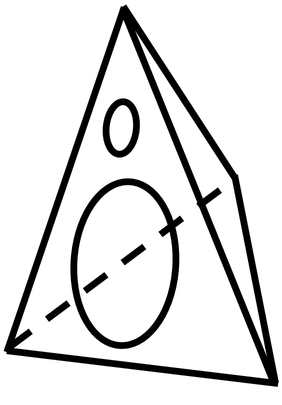

Figure 3. The ideal, tetraëder shaped, loudspeaker enclosure*: there is no point, line or surface symmetry with regard to the enclosed volume as well as its boundary surfaces". There are no parallel surfaces leading to less pronounced resonances.*

The same argument can of course also be applied to our reproduction room, hard parallel surfaces are a disaster in sound reproduction, the problem however is "who wants to live in a tetraëder?" An acceptable, more practical solution is to place large symmetry braking objects in the reproduction room and apply damping to parallel surfaces. In the professional world one often uses Quadratic Residue Diffusors (QRD's) which exploit the basic idea of asymmetry to enhance the diffuse field as well as reduce room resonances, leading to an increased feeling of immersion.

Resonances in the reproduction room caused by objects in that room can lead to severe degradations, especially in the case of sharp (high Q) resonances. Listen to a sine sweep over a set of loudspeakers in a living room and you will be shocked by the audibility of many resonances. The sharper the resonance the more objectionable, but also the less likely that the resonance will be triggered by a music fragment. This makes the perceived quality of any loudspeaker system dependent on the extent to which these resonances are triggered by the music fragments used in the subjective assessment.

And what about the wonderful concert halls like the Amsterdam Concertgebouw and the Wiener Musik Verein Halle, these are not tetraëders? That's right, and may be an asymmetric tetraëder concert hall would sound perfect, creating the ultimate feeling of immersion in an ideal diffuse field.

Go to Part 5: Audio Compression.

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