TECTONIC – MODEL OF THE IN-ROOM ACOUSTIC FIELD FROM A DML   28th March 2013

OUTLINE

The distribution of the acoustic field from a DML class radiator in real room environments has not been fully described to a satisfactory level.

Anecdotal evidence (often from experienced listeners) and some limited experimental evidence suggests that the acoustic field radiated by DMLs into rooms does not experience as noticeable a drop-off with distance as is commonly observed with conventional piston class radiators. Listeners have also commented that DMLs appear to provide a more natural and less fatiguing acoustic experience.

This document presents the initial ideas of a model that attempts to describe the acoustic radiation from DML class radiators within real room environments. The proposed model aims to provide an explanation consistent with the observed and measured evidence.

Much of the thinking behind this model was inspired by the book `Sound Reproduction_by Floyd E. Toole, kindly gifted by Marcelo Vercelli.

BACKGROUND

The dichotomy between live performances and sound reproduction can be greatly simplified by the following statements (Toole, 2008, p. 28 & 29):

In live performances:

- ***The sound sources are multidirectional, radiating sound in all directions, most of it away from individual listeners in the audience.***
- ***Perceptions of timbre, space, and envelopment created by reflections within the room are essential parts of the performance.***

In sound reproduction:

- ***Most loudspeakers have significant directivity and are aimed at listeners.***
- ***Ideally, perceptions of timbre, direction, distance, space, and envelopment should be conveyed by multichannel audio systems delivering specific kinds of sounds to loudspeakers in specific locations.***
- ***Ideally, what listeners should hear should be independent of the room around them. In practice it is the required degree of independence that is under investigation.***

One of the key aspects to understanding how sound sources and rooms interact is the relationship between the direct and the reverberant sound fields.

In a large performance space (e.g. classic concert hall) the absorption is minimised to conserve the acoustic energy produced by instruments and voices. An active reflected sound field ensures a wide distribution of energy throughout the hall. However, one of the main challenges in the design of these spaces is to preserve the sound energy in the reflections without obscuring the temporal details in the structure of music and speech.

Consider figure 1 (reproduced from Toole, figure 4.2). An omnidirectional sound source located well away from room boundaries radiates into the room. The level of the direct sound falls with the inverse square of distance until it encounters the reverberant sound field

The distance from the source at which the direct sound level equals the reverberant sound level is known as the critical distance.

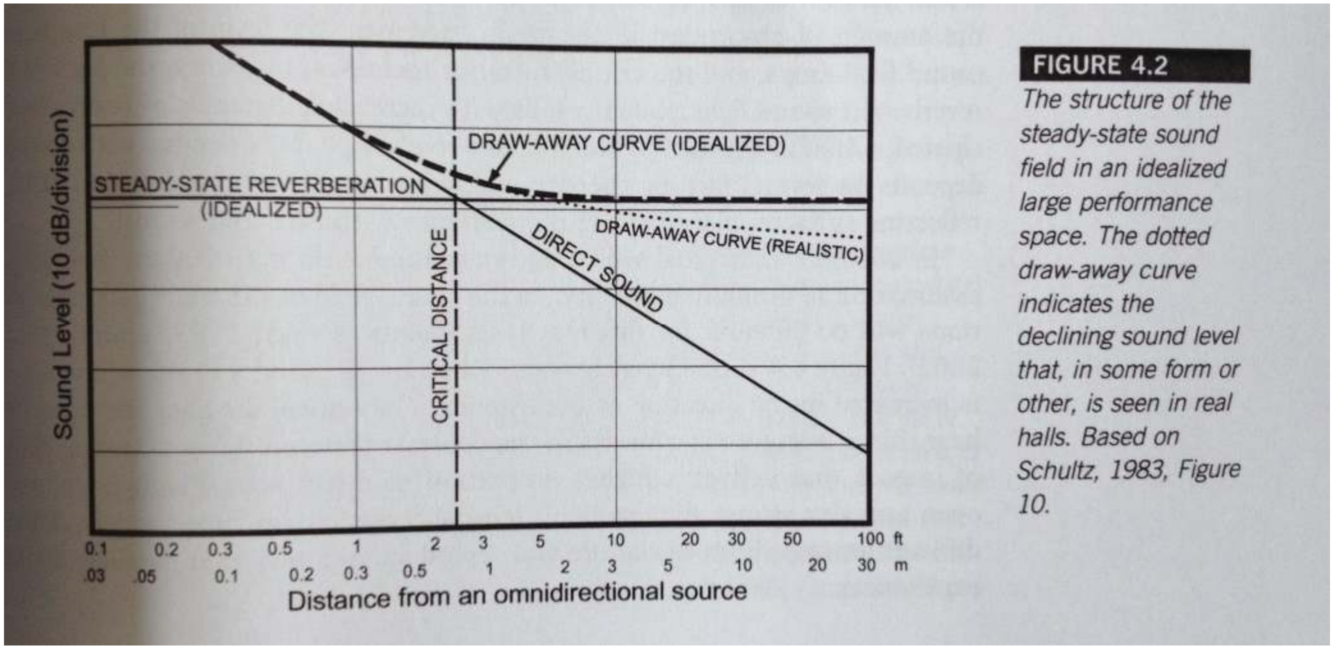

Figure 1. See annotation in figure.

Note that to generate the curves shown in figure 1 an omnidirectional source was employed. Very few loudspeakers used for reproduction in large spaces can be considered omnidirectional. In fact in most cases it is considered important to have control of the directivity.

Quoting again from Toole (Toole, 2008, p. 47):

Directional control is critical in designing sound reinforcement systems, the purpose of which is to deliver sound to the audience without exciting excessive reflections and reverberation within the room itself. The challenge is to put more of the audience in a predominantly direct sound field, precisely the opposite of a live concert hall experience.

In analysing this statement it is fair to ask; why are sound reinforcement systems designed to create sound fields that directly contradict with the natural response of a live concert hall?

The wave fronts from boundary reflections produced by pistonic class radiators are strongly phase correlated with the wave fronts from the direct radiation. This creates strong interference effects. Such effects can lead to loss of intelligibility and are a source of auditory confusion ¯ particularly if they arrive within 100 ¯ 200ms of the original sound set (the precedence effect).

This leads to an unfortunate conclusion when using narrow directivity, phase coherent sources:

Therefore when using pistonic class radiators for sound reinforcement systems it is necessary to immerse the audience in a predominantly direct sound field to ensure intelligibility and a cohesive interpretation of the sound event.

This creates two main problems for the audience:

1. As the level of the direct sound field follows the inverse square law (doubling of distance causes a drop of 6dB) to ensure good sound reproduction for audience members at the rear of the seating area, it is often necessary to create a substantially higher sound level for those members at the front seating area, which can be unpleasant and fatiguing.

2. The audience is immersed in a highly artificial sound field, very different from the natural sound field produced by live instruments in a concert hall or any other natural environmental listening space where the reverberant field contributes significantly more energy to the auditory experience.

As the directivity index of the sound reinforcement system is increased, either through intended design of the reinforcement system engineer as discussed above or due to the inherent directivity of the loudspeakers used for the reinforcement, the critical distance is increased. This effect is shown in figure 2 (reproduced from Toole, figure 4.4).

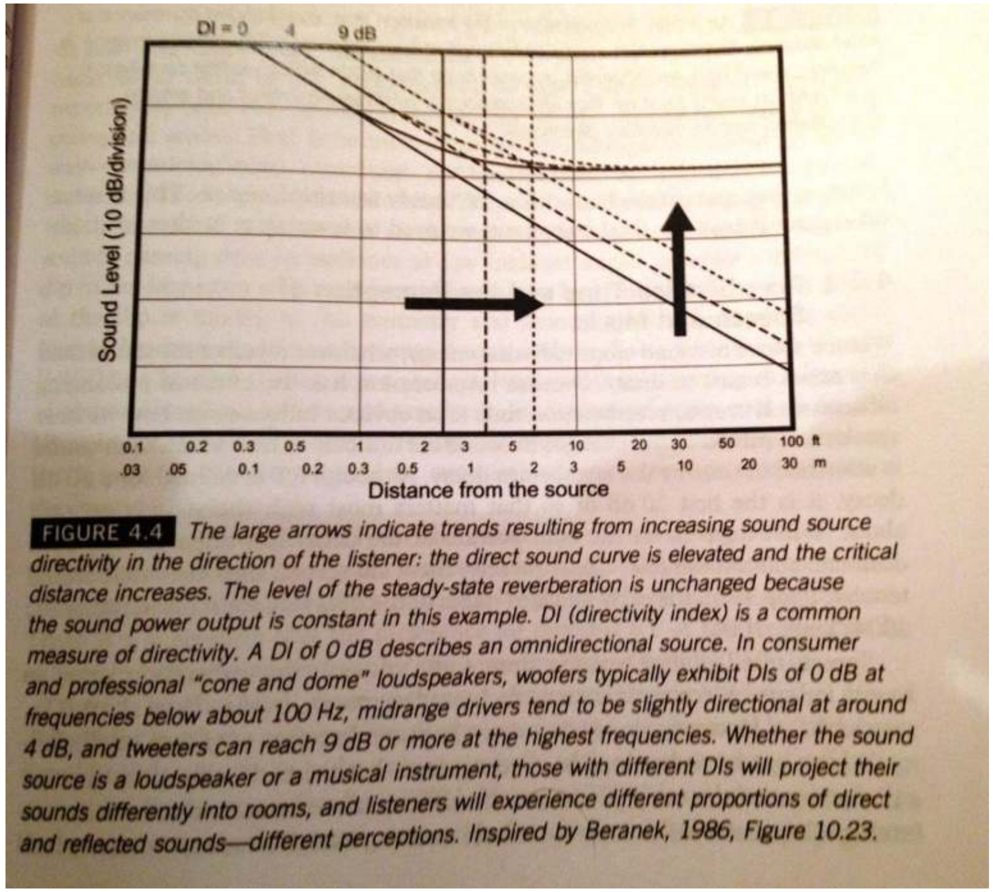

FIGURE 4.4 *The large arrows indicate trends resulting from increasing sound source directivity in the direction of the listener: the direct sound curve is elevated and the critical distance increases. The level of the steady-state reverberation is unchanged because the sound power output is constant in this example. DI (directivity index) is a common measure of directivity. A DI of 0 dB describes an omnidirectional source. In consumer and professional "cone and dome" loudspeakers, woofers typically exhibit DIs of 0 dB at frequencies below about 100 Hz, midrange drivers tend to be slightly directional at around 4 dB, and tweeters can reach 9 dB or more at the highest frequencies. Whether the sound source is a loudspeaker or a musical instrument, those with different DIs will project their sounds differently into rooms, and listeners will experience different proportions of direct and reflected sounds—different perceptions. Inspired by Beranek, 1986, Figure 10.23.*

Figure 2. See annotation in figure.

An increase in the critical distance places more of the audience in the direct sound field, subjecting the closest members to much higher sound levels than those seated further back.

Sound reinforcement systems with higher directivity indices will give increased critical distances in rooms, and as discussed above the total sound field in the room becomes further removed from the real, live acoustic experience.

THE DML CLASS OF RADIATIOR

The radiation from a DML can be characterised by two key attributes:

1. Wide directivity.
2. Diffuse radiation.

The radiation from a DML can be, to a degree, separated into two, overlapping regions; the initial pistonic transient followed by a diffuse tail. The region of the panel that radiates the initial pistonic transient decreases in dimension with increasing frequency in such a way that the typical ka=2 limit is not seen for a DML (at least not until much higher in frequency than would be expected for the size of the radiator). This implies wide directivity even at higher frequencies regardless of the panel size.

The output that drives the diffuse tail predominantly comes from radiation by the panel modes. In modally dense panels the radiation sources consist of a large number of regions radiating in a highly complex, pseudo-random way. In effect each region is like a tiny piston speaker (with its own amplitude and phase) and the sum of these over the panel generates a diffuse acoustic output with wide directivity.

As seen in figure 2 a loudspeaker source with wide directivity (low directivity index) exhibits a reduced critical distance. Over the critical distance the sound level is seen to fall with the expected 6dB per doubling of distance. Beyond the critical distance the fall off rate is much reduced due to the influence of the reverberant sound field.

Therefore by using a wide directivity source, such as a DML, the critical distance is reduced so that none of the audience is located within the direct sound field.

This would not be particularly useful for an omnidirectional pistonic type speaker as the reverberant sound field the audience is now immersed in will be full of correlated reflections creating interference, reduced intelligibility and auditory discomfort.

However, as discussed earlier a diffuse source would not have these issues

With a diffuse source there is a significantly reduced correlation between the directly radiated and reflected wave fronts. Therefore the output from a DML that contributes to the reverberant field does not do so in a way that obscures intelligibility (as is the case for a coherent source).

Reproducing the earlier cited quote from Toole (Toole, 2008, p. 47):

Directional control is critical in designing sound reinforcement systems, the purpose of which is to deliver sound to the audience without exciting excessive reflections and reverberation within the room itself. The challenge is to put more of the audience in a predominantly direct sound field, precisely the opposite of a live concert hall experience.

As has just been outlined, the DML contributes to the reverberant field but in a much more sympathetic way than non-diffuse sources. This reduces the need to place the audience in a predominantly direct sound field ¯ an unnatural auditory environment.

Thus though the use of DMLs in sound reinforcement systems the audience can be placed within a more natural acoustic field, akin to that of a live concert hall experience.

As the audience is now immersed in the reverberant field, the level drop with distance is closer to a linear fall-off and the difference in level between the front and back rows is reduced.