Building a Minimally Baffled Dipole Loudspeaker

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# Voicing the Dipole Loudspeaker

The final stage of crossover development is often called “voicing.” The voicing EQ correction is applied to correct the loudspeaker’s tonal balance. A flat on-axis response from a dipole system will often sound too bright. Research reviewed by Toole [[[1]](#endnote-2)] and performed by Olive [[[2]](#endnote-3)] suggests that a down-trending power response over most of the audio band is preferred by both trained and untrained listeners and my own listening tests confirm this. Toole and Olive have published their findings as plots of the steady-state room curves for a variety of highly rated loudspeakers. The in-room steady-state response is similar to the power response of the loudspeaker, which may be estimated by inverting the loudspeaker’s directivity index.

One source of data regarding the directivity index of loudspeakers can be found online from published Klippel analyses [[[3]](#endnote-4)]. For many well-regarded loudspeakers the same trend is observed: the directivity index begins to rise above 0dB between 100Hz and 300Hz, reaching 10dB or more by 10kHz. Since the loudspeaker’s power response can be estimated from the inverse of this curve, the power response is undergoing a 10dB decrease over this frequency range.

Often, a loudspeaker with a dipole radiation pattern and a flat on-axis FR is perceived simultaneously both as bass anemic and too bright. The reason for this lies in the difference in its power response. A conventional “boxed” loudspeaker with a near flat FR has a DI that increases from 0dB at low frequencies to 10dB or more at high frequencies. In contrast, a loudspeaker with a dipole radiation pattern a flat FR has a constant DI value of about 4.75dB.

Because the PR can be approximated by the inverse of the DI curve, the dipole with deliver 4dB to 5dB less acoustic power at low frequencies (anemic bass) and 4dB to 5dB more acoustic power at high frequencies (brightness) when both systems have flat on-axis FR. In addition, a dipole cannot pressurize the room and will not benefit from room gain at very low frequencies. For these reasons, a dipole must be voiced in such a way as to offset these differences in PR, even though this will also change the dipole’s on-axis FR.

When I first developed the prototype loudspeaker in 2021, I experimented over a long period of time, using more and less amounts of the down-tilting EQ and changing the range of frequencies in which the voicing EQ was applied. I arrived at a spectral tilt of approximately 4dB to 5dB per decade provided the most accurate and satisfying tonal balance. This is similar to, but steeper than, a “pinkening filter” used to convert white noise to pink noise. The down-tilt is used between 100Hz and 10kHz, typically amounting to 8dB to 10dB of correction in total. At the highest frequencies, the rising directivity of the tweeter will continue the trend without requiring EQ. [[[4]](#endnote-5), Figure 4.20] One way to implement this type of correction in DSP is via a filter bank consisting of multiple first order shelf filters, each applying only 1-2 dB of correction. Design of similar analog active pinkening filters is discussed by Self in reference [[5]](#endnote-6), section. 11.14 “equalizers with non-6 dB Slopes.”

More recently, I have modified my voicing approach. I now use a -3dB/decade trend line as a guide for voicing and adjust around this for the best tonal balance. Listening trials resulted in a voicing EQ curve that spans 8dB and is very similar to the steady-state listener-preferred curve reported by Olive [ii]. This curve is shown in the following figure. The modified voicing EQ shows -3dB/decade trend line (dashed green) and voicing EQ (blue).

Anytime a trial crossover is undergoing evaluation, several listening sessions should ensue using program material that is familiar to the designer. An iterative process of listening, tweaking and adjusting of the voicing EQ correction should be used. At this point the system should be very close to being well balanced tonally, and only very minor adjustments should be necessary. There are many small clues to listen for, but it is important to keep in mind that the tonal balance in the recording was set during the mix, and this was judged using loudspeakers with their own tonal balance. This creates what is known as the circle of confusion, a term coined by Floyd Toole [[[6]](#endnote-7), pp.18-24]. Because there is no established standard it is often left to chance that the monitors at the mixing console and the immediate acoustic environment were tonally neutral and did not imprint their own sound upon the recording. Therefore, listening to a range of high-quality music from various sources and styles is essential during the evaluation. An astute and experienced listener can often detect whether the entire recording is tonally off-balance and make judgements accordingly. It helps if the critical listening is spread out over several days and lasts only a couple hours at a time, with several hours or more of downtime to give the ears a rest. Repeat the listening evaluation in the morning and you will be rewarded with a fresh perspective. In the nude wireframe dipole loudspeaker, the voicing process is relatively straightforward because it consists only of optimizing the voicing equalization curve and choosing the subwoofer level.

The development of a minimally-baffled nude dipole loudspeaker, when executed as described above, has a similar feel each time. This may be the result of several factors. Because the size of the midrange falls within a narrow range its passband always spans between approximately 350Hz and 2kHz. The response of the midrange is similar from driver to driver, and each is distinguished more by the off-axis performance above 1kHz and the distortion performance overall. The choice of driver used in the woofer panel is more liberal, and primarily the distortion below 200Hz and ability to operate cleanly up to and above the midrange crossover point are the characteristics that differentiate one implementation from another. The crossover and voicing equalization are similar from system to system, and this familiarity streamlines the crafting of the loudspeaker as the designer gains experience.

**References**

1. F. Toole, “The Measurement and Calibration of Sound Reproducing Systems”, JAES vol. 63 Issue 7/8 pp. 512-541; July 2015. [↑](#endnote-ref-2)
2. S.E. Olive, T. Welti, E. McMullin, “Listener Preferences for In-Room Loudspeaker and Headphone Target Responses,” presented at the 135th Convention of the Audio Engineering Society (2013 Oct.), convention paper 8994. [↑](#endnote-ref-3)
3. E. Hardison “Erin’s Audio Corner”, various loudspeaker measurements, http://erinsaudiocorner.com [↑](#endnote-ref-4)
4. L. L. Beranek, “Acoustics,” McGraw-Hill, New York, 1954. [↑](#endnote-ref-5)
5. D. Self, *The Design of Active Crossovers*, Oxford: Focal Press, 2011. [↑](#endnote-ref-6)
6. F.E. Toole, *Sound Reproduction: The Acoustics and Psychoacoustics of Loudspeakers and Rooms*, Focal press (July 2008). [↑](#endnote-ref-7)