NEAR-FIELD MONITORS

In recording control rooms, it is common to place small loudspeakers on the meter bridge at the rear of the recording console. These are called near-field or close-field monitors because they are not far from the listeners. As shown in Figure 18.1c, the near field of a small two-way loudspeaker (the midrange and tweeter of the example system) extends to somewhere in the range 21 in. to almost 6 ft (0.53 to 1.8 m). Including the reflection from the console under the loudspeaker greatly extends that distance. There is no doubt, then, that the recording engineer is listening in the acoustical near field, and that what is heard will depend on where the ears are located in distance, as well as laterally and in height. The propagating wavefront has not stabilized, and as a result this is not a desirable sound field in which to do precision listening, but as they say, perhaps it is “good enough for rock-and-roll.”

Some of these far-field distances are much greater than the 1 m distance universally used for specifying loudspeaker sensitivity (e.g., 89 dB @ 2.83 v @ 1 m). There is no problem here because in the standards that specify the rituals of loudspeaker measurements, it is stated that the measurement should be made in the far field, whatever that may be, and then the sound level that would be expected from a point source at 1 m should be calculated. For example, if a measurement is made at 2 m, 6 dB should be added to arrive at the sound level at the reference distance, even though 1 m may be within the near field of that particular loudspeaker. The 1 m standard distance is therefore a convenience, not a directive that a microphone should be placed at that distance. *Many* people have misunderstood the intent of the standard distance, including some major players in the loudspeaker business.

If it is necessary to make measurements within the near field, useful data can still be obtained by spatial averaging: making several measurements at the same distance but at several different angular orientations with respect to the loudspeaker and averaging them. This is another of those uncertainty principle situations. By spatial averaging we have a better idea of the true frequency response, but we don’t know the axis to which it applies. If we measure at a single point within the near field, we know the axis precisely, but we don’t have a good measure of the frequency response.

18.1.2 Line Sources: Cylindrical Spreading

Figure 18.2 shows another extreme—the “infinite” line source—that , if it could be realized, would radiate a perfectly cylindrical sound wave, the area of which expands linearly with the radius. As a result, the sound level falls at the lower rate of –3 dB per double-distance. Practical line sources have finite lengths, so the critical issue becomes one of keeping listeners within the near field of the line, where the desirable –3 dB/dd (dd = double distance) relationship holds and out of the far field where even line sources revert to –6 dB/dd.

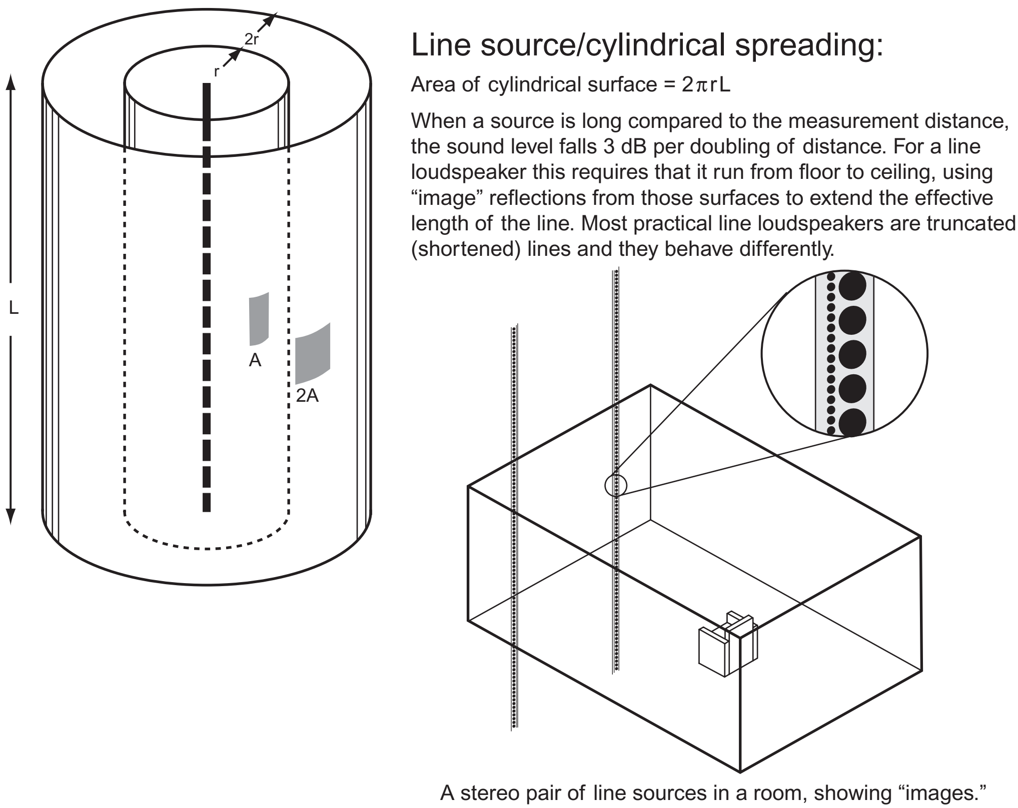

FIGURE 18.2 *An illustration of a theoretical infinite line source and of a practical approximation.*

Obviously the distance at which the near- far-field transition occurs is a function of frequency and the length of the line. Figure 18.2 shows a stereo pair of full-height lines, taking advantage of the ceiling and floor reflected images to make them appear to be even longer. A portion of one line has been expanded to show that it is a two-way system using conventional cone and/or dome loudspeaker drivers, densely packed (ideally spaced by less than about 1/2 wavelength of the highest reproduced frequency) to simulate a continuous sound source.

It is possible to use less than a full-height floor-to-ceiling array if one understands the variables and how they can be traded off. Lipshitz and Vanderkooy (1986) provide a thorough theoretical background to the behavior of "finite length" (not full height), truncated, line sources and they point out a number of problems, ultimately concluding that "there is little to recommend the use of line sources as acoustic radiators." They did grant that full-height lines had potential if the –3 dB/octave tilt in the frequency response is corrected.

There are advantages to collections of drivers: They share the workload and therefore can play loud without distress. However, most of the products casually referred to as "line sources" or "truncated line sources" in the industry are simply vertical arrangements of drivers that are too short to be useful even as truncated lines and with the drivers too far apart to be any kind of line. These loudspeaker systems obey the rules of collected point sources, with the disadvantage that, due to their size, the far field is a long distance away.

Griffin (2003) gives a comprehensive and comprehensible presentation of what is involved in designing practical line sources that approach the performance of full-height lines using less hardware. Smith (1997) describes a commercial realization and explains why it does what it does. Keele culminates a series of papers on constant-beamwidth transducers (CBTs) in a collaboration with Button, in which they examine the performance of several variations of truncated lines: straight and curved, "shaded" (drive power reduced toward the end), and unshaded (all transducers driven equally), all standing on a plane-reflecting surface (Keele and Button, 2005). It is a masterpiece of predictions and measurements that provide many answers and suggest many more possibilities. Figure 18.3 shows a small sample of the informative sound field simulations in the paper.

It is rare to see such clear illustrations of what is right and wrong with certain aspects of sound reproduction. In Chapter 12, we looked at adjacent boundary interactions, pointing out that the immediate surroundings of loudspeakers affect how they function and that some of the effects are not subtle. Figure 18.3a shows how just a single reflecting surface, the floor, disrupts an omnidirectional point source. Instead of tidy expanding circular contour plots, we see an example of gross acoustical interference with alternating lobes of high and low sound levels. The constant directivity of the source, indicated on the right, means that this problem exists at all frequencies, but the patterns will be different because of differing wavelengths. Additional boundaries—ceiling, side walls—add more of the same, of course, and the merged combination usually ends up being more satisfactory than this single-dimensional perspective suggests. This is, after all, another perspective on comb filtering, discussed in Chapter 9.

Chapter 12 finished with examples of loudspeakers designed to interface with room boundaries. Illustration 18.3b and those that follow show how much better things can be if a boundary is considered as part of the loudspeaker design. Figure 18.3b shows that a simple truncated line seems to be an improvement over the elevated point source, but note that uniform directivity has been sacrificed. The directivity index has a sharply rising character, indicating high-frequency beaming.

Figure 18.3c shows that shading the output, reducing the drive delivered to the transducers closer to the top of the line according to a Hann contour, greatly simplifies the pattern, but it still beams at high frequencies. We are not there yet.

Curving the line, as shown in (d), seems to be a step in the right direction. The contour lines are not yet smooth, but there is an underlying desirable order

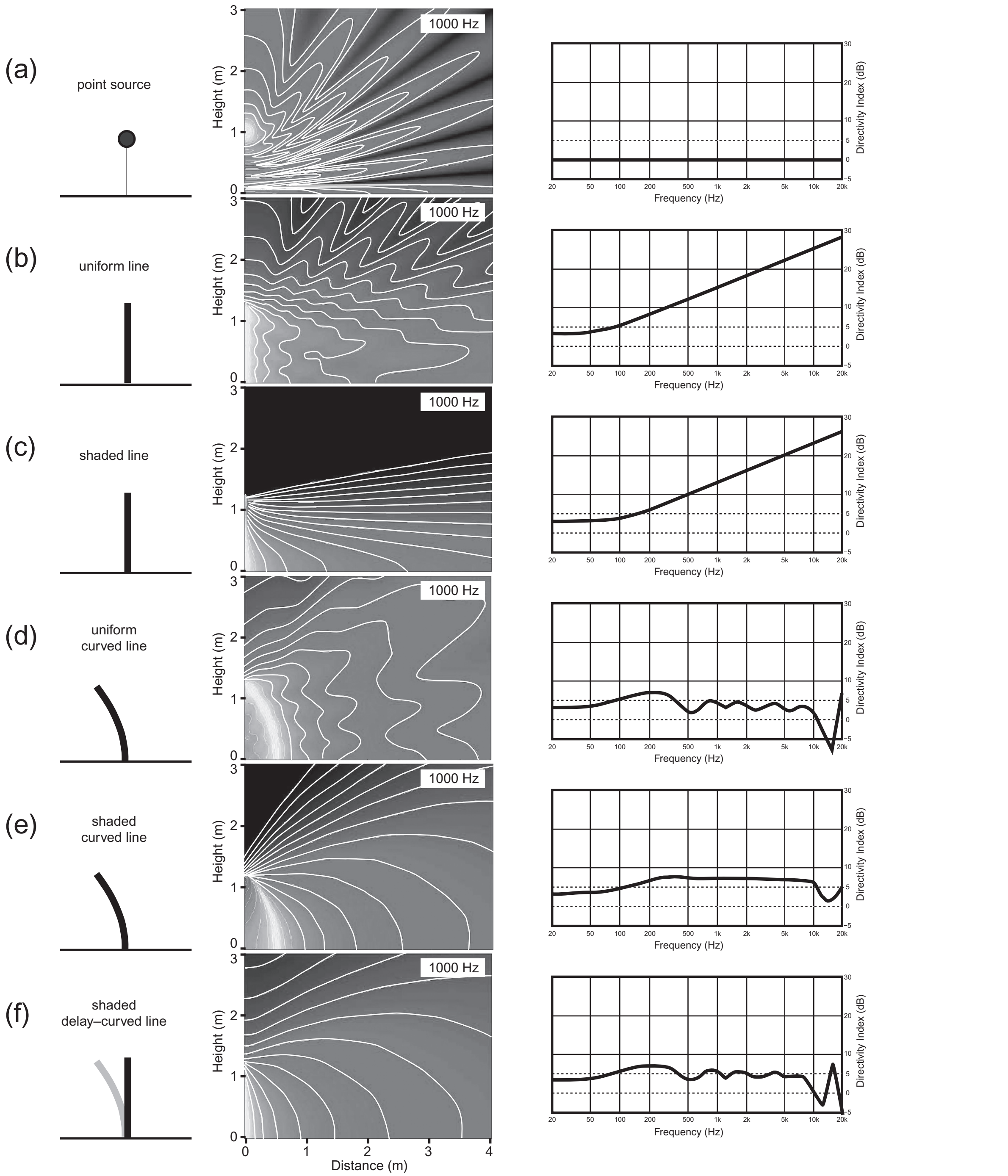

FIGURE 18.3 *Illustrations of the near-sound fields generated above a ground plane by several sound sources. The shading gets darker as sound levels drop; adjacent contour lines represent sound levels that differ by 3 dB. The original paper displays results for several frequencies; all of those shown are for 1 kHz. The words and graphics on the left explain the sources. On the right are far-field directivity indexes. Data from Keele and Button (2005).*

to them. The constancy of the directivity index tells us that it applies over a wide bandwidth.

Shading the curved line using the Legendre contour yields a set of plots that have a sense of order and beauty, (e). The constant directivity index indicates that it will be similar at most frequencies. This is the kind of thing we like to see.

If the marketing department thinks that the customers might prefer a straight line, applying the right delays to the drive signals can, in effect, contour the line (f). When shaded, the result is very similar to (e)—and good.

Scanning from (a) to (e) and (f), it is easy to see that there are improvements that can be made in the delivery of sounds from loudspeakers, through rooms, to listeners. This is a two-dimensional example of what is possible. Interfacing the source with the floor benevolently uses that reflection, and directivity control reduces the effect of the ceiling reflection. Line sources, by their nature, have a narrow frontal aspect, so horizontal dispersion can be wide and uniform.

How did (e) and (f) sound? Excellent—at least that is the author's opinion from a biased, sighted test. It was distinctive in how little the sound level and timbre appeared to change with location in the room and how the loudspeaker did not get "loud" as one walked up to it. Note that the sound level contours around ear height (just under 2 m) are only gently sloped.

Any of these line radiators can be positioned at the ceiling interface—for example, as surround loudspeakers—or positioned between floor and ceiling. In the latter situation, they lose the boundary reflection and will need to be physically lengthened to regain comparable radiation performance. The shaded versions would have the lower half inverted so the acoustical output would decline toward both ends, top and bottom. So as we move into the detailed characterization of loudspeaker performance, it is important to keep in mind that directivity and propagation characteristics are important parts of the data set.

18.2 MEASURING THE ESSENTIAL PROPERTIES OF LOUDSPEAKERS

Frequency response is the single most important aspect of the performance of any audio device. If it is wrong, nothing else matters. That is a statement without proof at this point in the book, but that will come. It is interesting to consider that for as long as anyone in audio can remember, all electronic devices had basically flat frequency responses. No manufacturer of an amplifying device, a storage device, or a music or film distribution medium would even momentarily consider a frequency response specification that was far from what could be drawn with a ruler from some very low frequency to some very high frequency. Yet, when we come to loudspeakers, it is as though we threw away the rule book and suddenly tolerances of ±3 dB or more are considered acceptable. The measurements in Figures 17.2 and 17.3 show a few loudspeakers from the 1960s.