Acoustic Diffraction: Does It Matter?

This author's latest speaker study examines edge diffraction and what you can do to reduce it. **By James Moriyasu**

Cabinet edge diffraction has always been a major design concern for me. It is one thing to look at the sound pressure level (SPL) frequency response chart of a driver on a catalog page and another to measure the same driver in a cabinet. Instead of a smooth response that falls within 1–2dB, the tweeter's response above 1kHz develops multiple peaks and troughs that deviate by up to 2–3dB from flat. Most of these deviations from the "pure" driver response are caused by acoustic diffraction generated by the sharp edge of the cabinet. The edge of the driver mounting plate, the cavity caused by the cone of a midrange or bass driver, and the grille frame also contribute to the problem.

What causes edge diffraction is discussed in detail by D'Appolito.[1] Basically, when a sound wave reaches the edge of the cabinet it is forced to expand into a much larger volume, which causes a pressure drop and the production of a second sound wave. D'Appolito also states that the radius of a rounded edge must be comparable to a wavelength to be effective. For example, he says that a ¾″ radius rounded edge, which corresponds to a frequency of 18kHz, isn't going to help with those diffraction artifacts between 1–18kHz.

Is cabinet diffraction really a problem? According to Dickason there are two points of view regarding cabinet edge diffraction.[2] One view states that it is insignificant because it is swamped by the reverberant field caused by a room and because much listening is done off-axis, which leads to a smoother response. The other point of view holds that image quality is compromised by diffraction.

This study attempts to measure the extent of acoustic edge diffraction and test possible solutions for reducing its levels. It does not make any attempt to determine its effect on the subjective quality of sound produced by a loudspeaker. Nor does it examine asymmetrical driver placement, which tends to smooth the effects of edge diffraction but does not reduce them.

TEST SETUP

I mounted a Morel MDT-29 tweeter and a Vifa P13WH midbass on an enclosure that had front baffle dimensions of 8⅜″ wide by 12″ tall and 6½″ deep. I centered the drivers along the vertical midpoint of the front baffle (*Photo 1*). The tweeter was flush-mounted since it has a 3⁄32″ thick front plate. The midbass opening was rabetted to a depth of ¼″, leaving just enough clearance to cover the woofer with poster board. However, the frame of the driver is ⅛″ below the plane of the baffle, which probably causes some diffraction.

I mounted the enclosure on an IEC baffle (*Photo 2*) and used duct tape to

PHOTO 1: Morel MDT-29 tweeter and Vifa P13WH (covered with poster board) mounted in enclosure.

PHOTO 2: Enclosure with drivers mounted on IEC baffle for measurement.

PHOTO 3: A test enclosure that is 8.875″ wide and 56″ tall.

cover gaps that were between ⅓₂″ to ⅟₁₆″ wide. The IEC baffle was lifted on a manual forklift so that the tweeter was 7′ from the ground. I placed the microphone 1m from the tweeter and made SPL measurements from 500Hz to 20kHz with Loudspeaker Measurement System (LMS) by LinearX.

MEASUREMENTS

I made the first set of measurements, which examines diffraction from the tweeter front plate, with the Vifa P13WH covered with a square of poster board to eliminate diffraction from the midbass cavity. The poster board was ⅟₆₄″ thick and taped into place with duct tape that is ⅟₁₂₈″ thick.

Figure 1 shows what happens when the flush-mounted tweeter is raised ³⁄₃₂″ by loosening the screws and pulling the tweeter forward. This makes the tweeter appear as if it wasn't flush-mounted. The solid line is the tweeter SPL flush-mounted, the dotted line is when it is not flush-mounted, and the dashed line at 60dB is the difference of the non-flush-mounted over the flush-mounted responses.

There are up to 2dB increases between 3kHz and 6kHz and between 12kHz and 15kHz. There is a gradual 1dB dip at 3kHz and almost 2dB of loss between 8–11kHz. I was surprised to see this much diffraction-induced ripple below 5kHz since ³⁄₃₂″ doesn't seem significant compared to the length of the sound waves at these frequencies. So, flush-mounting does significantly minimize diffraction from the edge of the tweeter mounting plate.

The next measurement examines how a midbass driver causes diffraction. In *Fig. 2* you see that after the midbass is uncovered, a 2dB depression oc-

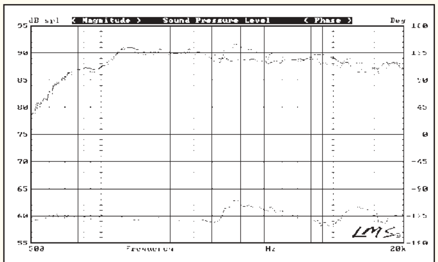

FIGURE 1: SPL of tweeter on IEC baffle with faceplate edge diffraction (dotted line) versus none; difference curve raised by 60dB.

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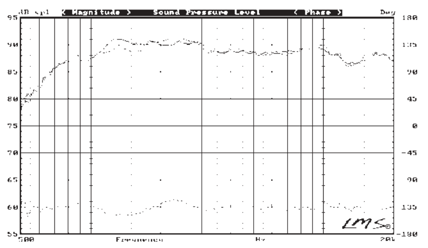

FIGURE 2: SPL of tweeter on IEC baffle with midbass covered (solid line) versus with midbass uncovered; difference curve shows diffraction from midbass cavity.

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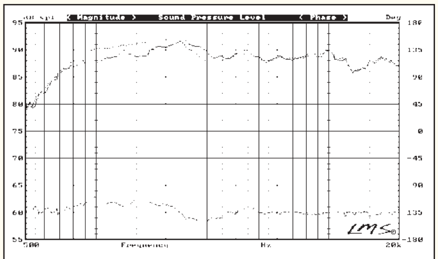

FIGURE 3: SPL of tweeter on IEC baffle with midbass uncovered (solid line) versus enclosure in free air; difference curve shows diffraction from enclosure edges.

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curs between 1200Hz and 1700Hz, while a 1.75dB bump occurs between 2kHz and 2.8kHz. The solid line is the tweeter SPL when it is flush-mounted with the midbass covered, while the dotted line shows the midbass uncovered. There are other ripples of less than a dB above 3kHz, also. So, the cavity from a closely located midbass driver is a source of significant diffraction. Aside from using a flat-faced midrange, which is uncommon, there is nothing that you can do about this source of diffraction.

Of course, in real life no one would want an IEC baffle or two in their living room. So, *Fig. 3* shows what happens when you remove the enclosure from the IEC baffle and measure the tweeter, with the woofer uncovered. The solid line is the response with the IEC baffle with the midbass uncovered, while the dotted line is the enclosure without the IEC baffle. A broad 2dB hump develops between 800Hz and 2.3kHz along with a 2dB depression between 2.3kHz and 3.5kHz due to cabinet edge diffraction. Additional ripples of less than a dB occur above 4kHz, too.

Figure 4 shows the 5″ midbass driver SPL response with and without the IEC baffle. The response without the IEC baffle is the top line. The difference curve is similar to that in *Fig. 3*, with up to a 3dB hump developing between 600Hz and 2kHz. The lack of a dip above 2kHz may be due to the increased directivity of the midbass drive. In other words, there may be less energy at 90° off-axis to generate cabinet edge diffraction.

These humps, dips, and ripples develop because of the additional path length the sound waves must travel from the driver to the cabinet edge. A

PHOTO 4: Test enclosure with 4″ radius shell.

PHOTO 5: Test enclosure with 2″ radius shell.

PHOTO 6: Test enclosure with 1″ radius shell.

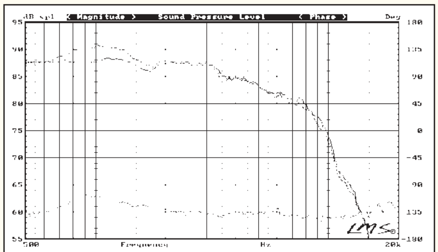

FIGURE 4: SPL of midbass on IEC baffle (solid line) versus enclosure in free air; difference curve shows diffraction from enclosure edges. B-2151-4

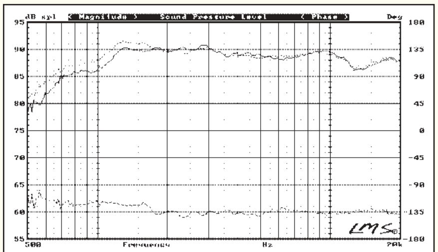

FIGURE 6: SPL of tweeter on enclosure with 4″ radius shell versus on IEC baffle (solid, lower line); difference curve raised 60dB. B-2151-6

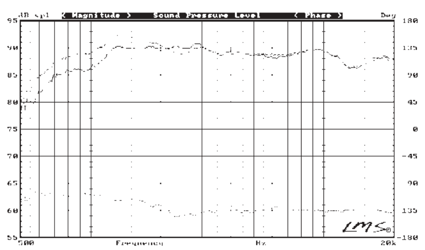

FIGURE 8: SPL of tweeter on enclosure with 1″ radius shell versus on IEC baffle (solid, lower line); difference curve raised 60dB. B-2151-8

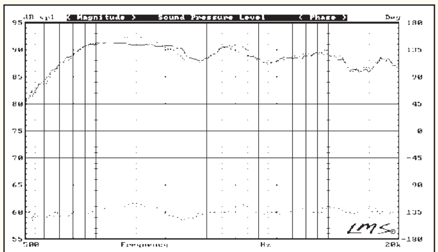

FIGURE 5: SPL of tweeter on 8.875″ × 56″ enclosure. Mounted 4.5″ down (dotted line) versus mounted 9″ down; difference curve raised by 60dB. B-2151-5

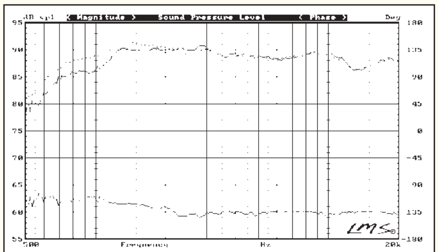

FIGURE 7: SPL of tweeter on enclosure with 2″ radius shell versus on IEC baffle (solid, lower line); difference curve raised 60dB. B-2151-7

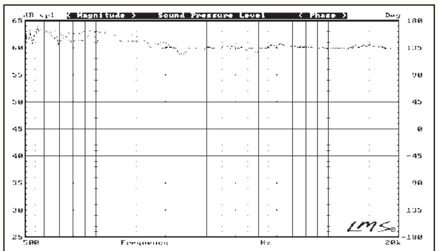

FIGURE 9: Comparison of SPL difference curve of 4″ radius (lower line) versus difference curve of 1″ radius. B-2151-9

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different size front baffle or different driver positions would cause peaks and valleys at different frequencies because of the path length differences.

I also conducted another experiment on a test enclosure that is 8.875″ wide and 56″ tall (*Photo 3*). In this set of measurements, the tweeter was equidistant from the sides and mounted at 4.5″ intervals down from the top. In *Fig. 5* you see that the 4.5″ mounting distance has up to 2dB more peak or depression than the 9″ mounting distance. The 4.5″ mounting distance is the top, dotted line, and the difference curve is at 60dB.

It appears that positioning the tweeter further down from the top of the cabinet lessens diffraction ripple. This is probably because the wavelength paths from the tweeter to the cabinet edges vary more. In other words, when the tweeter is 4.5″ down from the top, it is also about 4.5″ from either side and about 6.4″ from the corners. So the path lengths vary between 4.5″ to 6.4″, a ratio of 1.4 to 1.

When the tweeter is 9.0″ down from the top, it is about 10″ from the corners. So the path lengths vary between 4.5″ to 10″, a ratio of 2.2 to 1, which probably accounts for the smoother response.

I also measured the tweeter 28″ down from the top, and it is up to 1dB smoother compared to the 9.0″ mounting position. These measurements suggest that D'Appolito-type designs—which feature a midrange or midwoofer above and below a tweeter—may have a somewhat smoother response than single mid-driver designs because of the greater spread of the path lengths to the cabinet edge. However, you must take into account the additional diffraction caused by the cavity of the extra driver.

I didn't study diffraction caused by the grille frame because Joe D'Appolito regularly measures and reports on the effect in his reviews of loudspeakers. His measurements show that the typical grille frame causes 2–4dB ripples above 1kHz. "Typical" in this case means a grille frame that protrudes above the front baffle.

PHOTO 7: Test enclosure with 4″, 45° bevel shell.

PHOTO 8: Test enclosure with 2″, 45° bevel shell.

PHOTO 9: Test enclosure with 1″, 45° bevel shell.

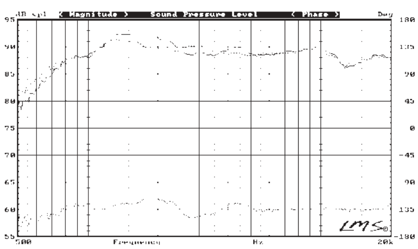

FIGURE 10: SPL of tweeter on enclosure with 4″ radius shell versus enclosure without edge treatment (solid line); difference curve raised 60dB.

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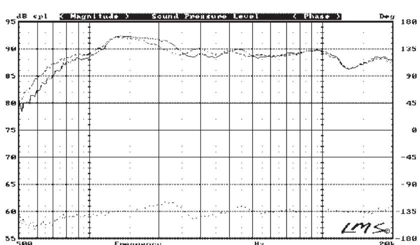

FIGURE 12: SPL of tweeter on enclosure with 1″ radius shell versus enclosure without edge treatment (solid line); difference curve raised 60dB.

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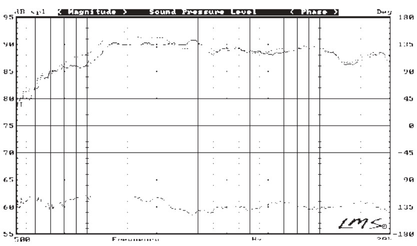

FIGURE 14: SPL of tweeter on enclosure with 4″ beveled shell versus on IEC baffle (solid, lower line); difference curve raised 60dB.

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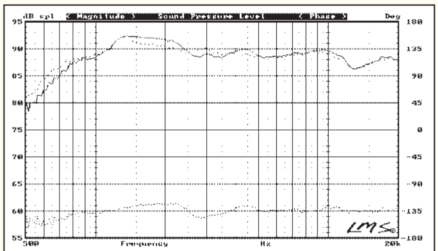

FIGURE 11: SPL of tweeter on enclosure with 2″ radius shell versus enclosure without edge treatment (solid line); difference curve raised 60dB.

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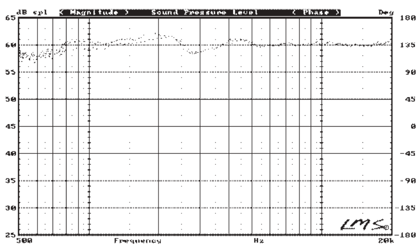

FIGURE 13: Comparison of SPL difference curve of 4″ radius (lower line) versus difference curve of 1″ radius.

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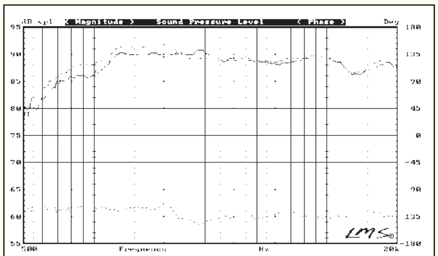

FIGURE 15: SPL of tweeter on enclosure with 2″ beveled shell versus on IEC baffle (solid, lower line); difference curve raised 60dB.

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EDGE RELIEF

I then attempted to reduce cabinet edge diffraction by surrounding the tweeter/midbass enclosure with some sort of edge treatment. For these tests I built "shells" with rounded-over or beveled edges. I then inserted the enclosure with the 12″ × 8⅜″ front baffle into the shell and took tweeter SPL measurements. The rounded-over shells had 4″, 2″, and 1″ radiuses; the shells were built with poster board glued to ¼″ MDF frames (*Photos 4, 5*, and *6*). The beveled shells were built to 4″, 2″, and 1″ thickness with MDF and had a 45° bevel (*Photos 7, 8*, and *9*). I built an additional shell with a dual bevel; its initial bevel was at 22° over 2″ on ¾″ MDF which was then followed by a 45° bevel on ¾″ MDF. See *Photo 10*.

PHOTO 10: Test enclosure with dual bevel, 22°, 45° shell.

To see how much diffraction the edge treatments produced or didn't produce, and what frequencies were affected, I compared their SPL measurements to the ideal response, the IEC baffle. *Figure 6* compares the SPL of the tweeter with a 4″ radius to that of the response on an IEC baffle (solid, lower line). The difference curve is referenced to 60dB. Above 2kHz the diffraction effects are plus or minus a dB or less. However, below 2kHz, diffraction effects increase the SPL output by up to 2dB.

Figure 7 shows that the 2″ radius has similar performance above 2kHz but has more output below that level. *Figure 8* shows the 1″ radius has up to 3dB more output than the IEC baffle below 2kHz. *Figure 9* compares the difference curves for the 4″ radius to the 1″ radius. They are very similar above 2kHz, but below that level the 4″ radius has 1dB less output.

These measurements show that significant levels of diffraction exist below 2kHz despite the edge treatments. However, you could project that by doubling or quadrupling the radius, diffraction could be further reduced and possibly eliminated.

Knowing that some diffraction remains compared to an ideal situation is one thing. How do the edge treatments improve the ubiquitous sharp-edged cabinet? *Figure 10* compares the SPL of the tweeter without edge treatment (top line, solid) to that with the 4″ radius. The difference curve is referenced to 60dB. The radius reduces diffraction by 2dB at 2kHz, 2dB at 2.7kHz, and 1dB at 4.5kHz. Above those frequencies the ripple is less than 0.5dB.

In *Figs. 11* and *12* you see that as the radius decreases, the humps and dips become less pronounced. This means that the smaller radius shells have more diffraction than the 4″ radius shell. *Figure 13* compares the difference curves for the 4″ radius to the 1″ radius. This shows that the 4″ radius has 1dB less output below 2kHz, which is consistent with *Fig. 9*.

EXAMINING BEVELS

This study could have ended at this point, but I've always liked the chiseled look of a beveled edge. Despite their looks, I guessed that the 45° bevels wouldn't work as well as the radiuses. But I thought that the dual bevel might be almost as effective as the radiuses.

Figure 14 compares the SPL of the tweeter with a 4″ bevel to that of the response on an IEC baffle (solid, lower line). The difference curve is referenced to 60dB. Above 2kHz the diffraction effects are plus or minus a little more than a decibel or less. However, below 2.3kHz, diffraction effects increase the SPL output by more than 2dB.

Figure 15 shows the 2″ bevel to have similar performance above 2kHz but, oddly enough, a little less output below that level and a little more output below 900Hz. *Figure 16* shows the 1″ bevel has up to 3dB more output below 2kHz and a fraction of a decibel more diffraction above that by comparison. *Figure 17* shows the dual bevel to have slightly more output below 1kHz, the least output between 1–2kHz, and similar effects above 2.5kHz.

Figure 18 compares the difference curves for the 4″ bevel to the 1″ bevel. They are very similar between 1–2kHz, while the 4″ bevel has 1dB less output between 600Hz to 1000Hz. The 1″ bevel is about 0.5dB better between 2.3kHz and 6kHz.

Figure 19 compares the SPL of the tweeter on an enclosure without edge treatment (top line, solid) to that with the 4″ bevel. The difference curve is referenced to 60dB. The bevel reduces diffraction by 1dB or less at 1.8kHz, 2.7kHz, and 4.5kHz. Above those frequencies the ripple is less than 0.5dB. In *Figs. 20* and *21* you see that as the bevel decreases there isn't any apparent reduction in reducing diffraction. This means that the smaller beveled shells are about as effective as the 4″ beveled shell.

However, the dual bevel was even better at reducing diffraction (*Fig. 22*). The difference curve shows that it reduces diffraction by a little more than a dB at 1.5kHz, 2.7kHz, and 4.7kHz. *Figure 23* compares the difference curves for the dual bevel to the 2″ bevel. This shows that the dual bevel reduces diffraction by 1dB more than the 2″ bevel below 2.7kHz.

It looks as though the 45° bevel really isn't the best choice for reducing edge diffraction. The dual bevel, because it starts with a more gradual 22° slope that transitions to a 45° bevel, is definitely the best of the bevels. It is still not quite as effective as a 4″ radius, however.

CONCLUSION

This study demonstrates the effects of acoustic diffraction from several

PHOTO 11: Example of grille frame integrated with a stepped front baffle.

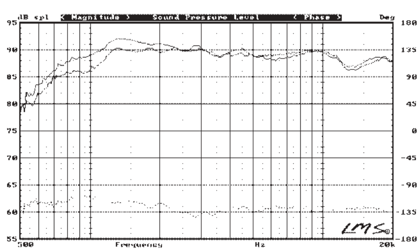

FIGURE 16: SPL of tweeter on enclosure with 1″ beveled shell versus on IEC baffle; difference curve raised 60dB.

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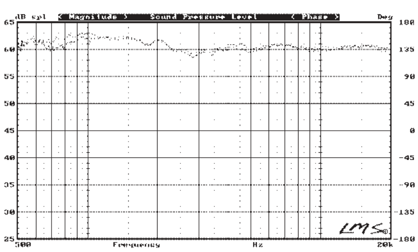

FIGURE 18: Comparison of SPL difference curve of 4″ bevel (lower line) versus difference curve of 1″ bevel.

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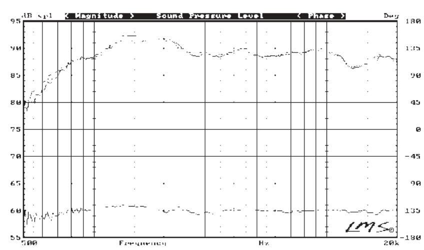

FIGURE 20: SPL of tweeter on enclosure with 2″ beveled shell versus enclosure without edge treatment; difference curve raised 60dB.

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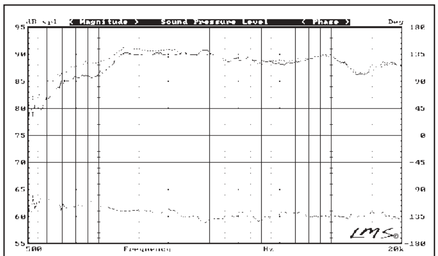

FIGURE 17: SPL of tweeter on enclosure with dual beveled shell versus on IEC baffle (solid, lower line); difference curve raised 60dB.

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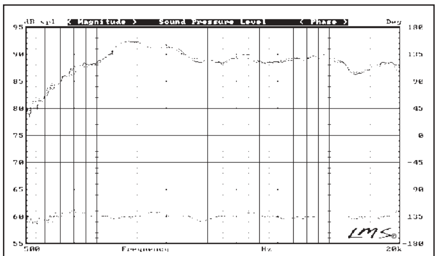

FIGURE 19: SPL of tweeter on enclosure with 4″ beveled shell versus enclosure without edge treatment (solid line); difference curve raised 60dB.

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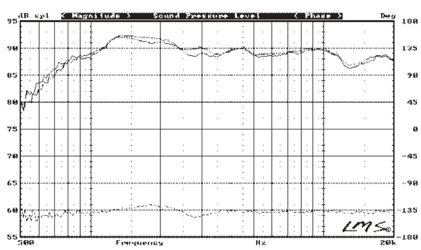

FIGURE 21: SPL of tweeter on enclosure with 1″ beveled shell versus enclosure without edge treatment (solid line); difference curve raised 60dB.

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sources. Edge diffraction from an unrecessed tweeter front plate can cause ripples in the SPL response by up to 4dB, peak to trough. Fortunately, this source of diffraction is easily eliminated by flush-mounting the tweeter.

Diffraction from the edge of the front baffle was the most persistent problem, because it caused response ripples of up to 5dB, peak to trough, between 600Hz and 5kHz. This was demonstrated by measuring a tweeter on an enclosure and comparing that to its response on an IEC baffle.

I evaluated the effectiveness of an edge treatment from two perspectives: how well it compares to an ideal response and how well it works in the real world. Compared to an IEC baffle, all of the edge treatments reduced diffraction ripple to a little over a dB above 2kHz, but below that level even a 4″ radius caused 2dB of additional output. Larger radiuses produced less diffraction than smaller radiuses but did not eliminate diffraction. 45° beveled edges were not as effective as radiuses, but a dual-bevel design was nearly as good as a 4″ radius.

The curious thing about the measurements with the edge treatments is that they don't trail off below 800Hz as in *Fig. 3*, which is the comparison of the enclosure without edge treatment to the IEC baffle. The only factor that could account for this variation is the longer path length from the tweeter to the back of the enclosure.

For example, the 4″ radius has 4.7″ more path length than the 1″ radius. But baffle size appears not to be the cause since the 4″ radius shell has less output than the 1″ shell and the 4″ radius shell is much bigger than the 1″ radius shell. Since these measurements show that diffraction causes 2–3dB of additional output from 2kHz all the way down to 500Hz—the limit of the gated measurement—and don't appear to be diminishing, these measurements imply that diffraction continues below that level.

At these frequencies the wavelengths are long enough not to cause cancellation, so all you see is a 2–3dB "step" response and no ripple. In essence, you can view diffraction as an effect that turns the entire perimeter of the cabinet front edge into a secondary sound source. This might be another reason why mini-monitors or narrow-faced

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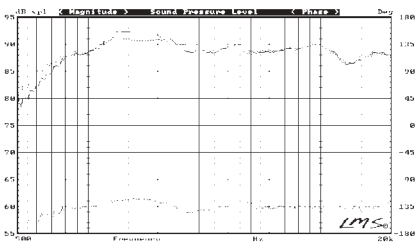

FIGURE 22: SPL of tweeter on enclosure with dual beveled shell versus enclosure without edge treatment (solid line); difference curve raised 60dB.

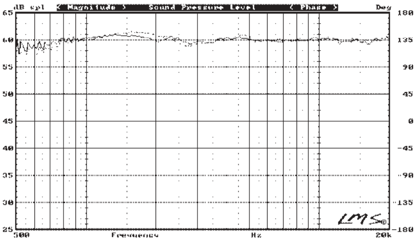

FIGURE 23: Comparison of SPL difference curve of 2″ bevel (lower line) versus difference curve of dual bevel.

Acoustic Diffraction
(from p. 19)

loudspeakers can often image better than larger systems.

Compared to an enclosure with no edge treatment, a 4″ radiused edge reduced diffraction ripples from an untreated enclosure by up to 2dB. These ripples occurred between 1–5kHz. There were variations of less than 0.5dB above 5kHz. Again, 45° beveled edges were not as effective as radiuses, but a dual-bevel design was nearly as good as a 4″ radius.

Earlier, I pointed out that a ¾″ radius isn't going to help reduce diffraction very much. However, a 1″ radius did reduce diffraction by 1–2dB between 2–5kHz. So, there exists some benefit in using a ¾″ radius on a cabinet edge.

Implementing edge treatments into a cabinet design can be challenging, so you must weigh the benefits against the effort required. A ¾″ radius router bit is pretty easy to use if you have a router table. I have a 1½″ radius router bit, but it is a little scary to use. The dual-bevel design isn't that difficult for the average woodworker to build. The 4″ radius could be accomplished with a custom router bit, specialty plywood shapes, laminates, or custom cardboard. This would certainly be the realm of the expert woodworker.

Finally, integrating the grille frame with a stepped front baffle can eliminate diffraction caused by the frame. *Photo 11* shows a recent design that uses a 1½″ radius roundover bit to shape the grille frame and the cabinet front edge. The only modest drawback to this approach is the need to flush-mount the drivers. This tends to limit your choice of tweeters, and there is some additional diffraction caused by the mid-driver being recessed.

I have also built a system that has a grille frame with a 22° bevel that is integrated with a stepped front baffle. The edge of the cabinet sides was beveled with a 45° angle, so the design was very much like the dual-bevel edge that was tested in this study.

This study only scratches the surface of the subject. Could more be done to reduce or minimize cabinet edge diffraction? I limited the edge treatments to what would be considered practical, but perhaps even larger radiuses could be implemented.

Of course, the most important question yet to be answered is how much diffraction takes away from the listening experience. Do loudspeaker systems with less edge diffraction sound better or image better than others? A double-blind study comparing a low-diffraction system versus a high-diffraction version might provide some answers. ❖

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E-MAIL ADDRESS

moriyasuj001@hawaii.rr.com

SOURCES

LinearX
(503)-612-9565
www.linearx.com