DESIGNERNOTEBOOK

Technology By Any Other Name...

New DSP concepts shape the EAW NT Series

By David Gunness

This Designer Notebook was submitted by EAW. Live Sound *makes every effort to eliminate any use of marketing inspired hyperbole.*

Earlier this year, the company I've worked with over the past decade – Eastern Acoustic Works (EAW) – unveiled a new series of lightweight, self-powered PA loudspeakers. What's so "revolutionary" about that? After all, we're a loudspeaker company – aren't we supposed to develop new (and improved) models?

Fair enough. But the unique facet of these loudspeakers, called the NT Series, is a new digital signal processing technology that I've been refining for several years, and it makes for an interesting discussion.

In fact, the marketing gurus at the company figured it would be a good idea to name the DSP after me, so that's why it's called "Gunness Focusing." Just keep in mind that a group of dedicated product design engineers worked very hard as a team on this technology and the loudspeakers.

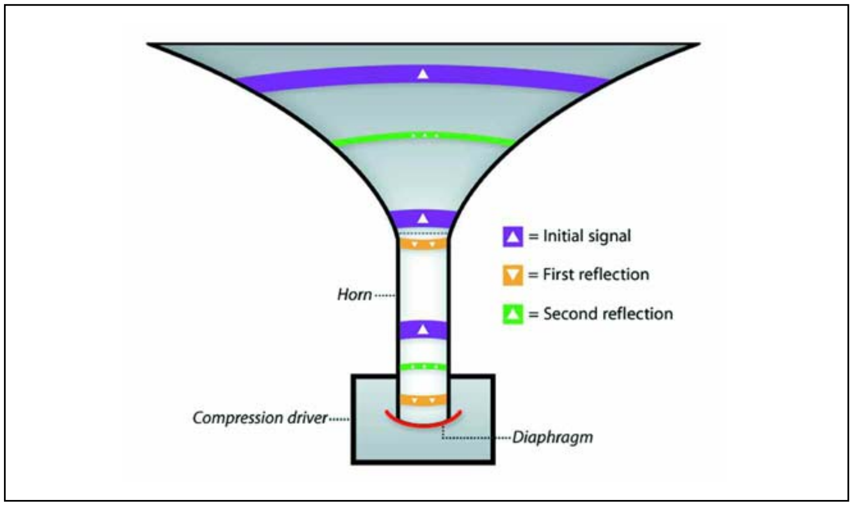
Regardless of what it's called, the point is what the technology is designed to do: in a nutshell, eliminate the traditional high-frequency characteristics of "honk" and "splashiness" that have always bugged me. (Watch out or I'll really start throwing around the techno-jargon!) We set out to find a way to minimize these, and best case, render them completely inaudible.

Let's start with an overview. There are generally three requirements for professional loudspeakers. The first is rather obvious: quality audio reproduction.

The other two: a loudspeaker must get loud in order to provide the projection needed to cover large spaces, and this projection should be delivered with a well-controlled pattern. Horn loading is generally seen as the most efficient method of achieving these results, and is therefore commonly used in the smallest to the largest loudspeakers.

Compact two-way design is the most frequent direction, because events with smaller audiences are the most frequently encountered applications, both portable and installed. This includes outdoor gatherings and concerts, corporate events, meetings, and regional tours on the portable side; and clubs, theaters, churches, auditoriums, hotel

The new NT Series includes four self-powered two-way models and a dual-12-loaded subwoofer. All two-way enclosures incorporate an angle that also make them suitable for stage monitoring applications.



An exiting wavefront reflected back into a horn as it encounters a discontinuity along the expanding walls can cause "honk."

ballrooms, and so on, for install.

These types of loudspeakers normally incorporate a horn-loaded, HF compression driver and horn as well as a direct radiating cone driver. However, achieving the output and projection pattern goals often comes at a heavy price in reproduction quality – even very well designed horn/driver combinations face inherent limitations that invariably lead to the "honk" and "splashiness" adjectives.

Now let's get a little more specific.

OBSCURING DETAIL

The "honk" of a horn is normally heard in the lower frequencies of its band pass, while "splashiness" is usually heard at the highest frequencies and obscures the fine detail in instruments such as cymbals.

Likewise, cone drivers have inherent resonances in their upper frequency range that result in "muddiness" in the middle of the vocal range. These high-frequency (HF) and low-frequency (LF) behaviors combine to produce a sonic signature we all commonly refer to as "coloration."

Splashiness is produced by the phase plugs found in compression drivers. Phase plug openings are arranged so that the path from any point on the driver's diaphragm to an opening is relatively short. The intent is that all of the driver's sound power leaves via the "nearest exit" in the phase plug.

However, some fraction of the sound arriving at any particular phase plug opening will continue past and arrive at a second opening where this sound is divided again, ad infinitum. Thus, rather than a single acoustical impulse, transient energy leaves the phase plug and reaches the listener as a decaying sequence of impulses. The decaying impulses from one signal invariably overlap and mask details in subsequent HF signals.

The result is the masking of transient attacks and a lack of HF detail and subtleties normally and cleanly reproduced by direct radiating, but low output, HF drivers.

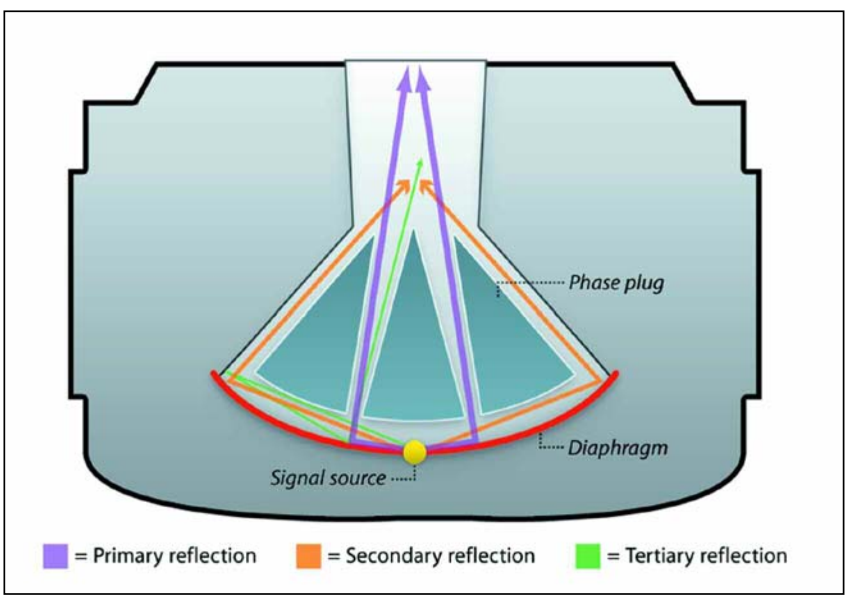
Honk, better defined as horn resonance, happens when a wavefront encounters a discontinuity along a horn's expanding walls, producing a sound reflection. All horns have such a discontinuity at their mouths.

Likewise, diffraction slots, used to achieve wide HF patterns in constant directivity horns, present a severe discontinuity at their exits. These discontinuities cause a portion of the sound energy to be reflected back to the compression driver where it is both partially absorbed and partially re-emitted, often several milliseconds late. For a transient signal, this repetitious process results in a resonance that produces a decaying sequence of impulses at the listener rather than a well-defined impulse.

Because low frequencies tend to be reflected more strongly than high frequencies, the most problematic reflections are in the lowest octaves of the horn's usable range. The excess energy from these reflections builds up and results in distinct colorations at frequencies related to the path length of the reflections.

DICTATING CROSSOVER

In compact, two-way loudspeakers, physical limitations result in an HF horn size that virtually dictates the crossover frequency be set above the



Depiction of HF reflections that cause "splashiness" in a horn-loaded loudspeaker.

LF driver's optimum upper frequency limit. This problem is especially troublesome with 15-inch LF drivers, because their usable frequency upper limits are at even lower frequencies than typical 12-inch drivers.

The result is that the LF driver must reproduce frequencies where its transient response is sloppy and its sonic character is muddy. The crispness of the horn-loaded HF system only accentuates this character.

A major source of the LF driver problems is the physical vibrations that travel from the voice coil through the cone material to the edge surround. Here they are only partially absorbed, meaning a portion of their energy is reflected back through the cone to the voice coil.

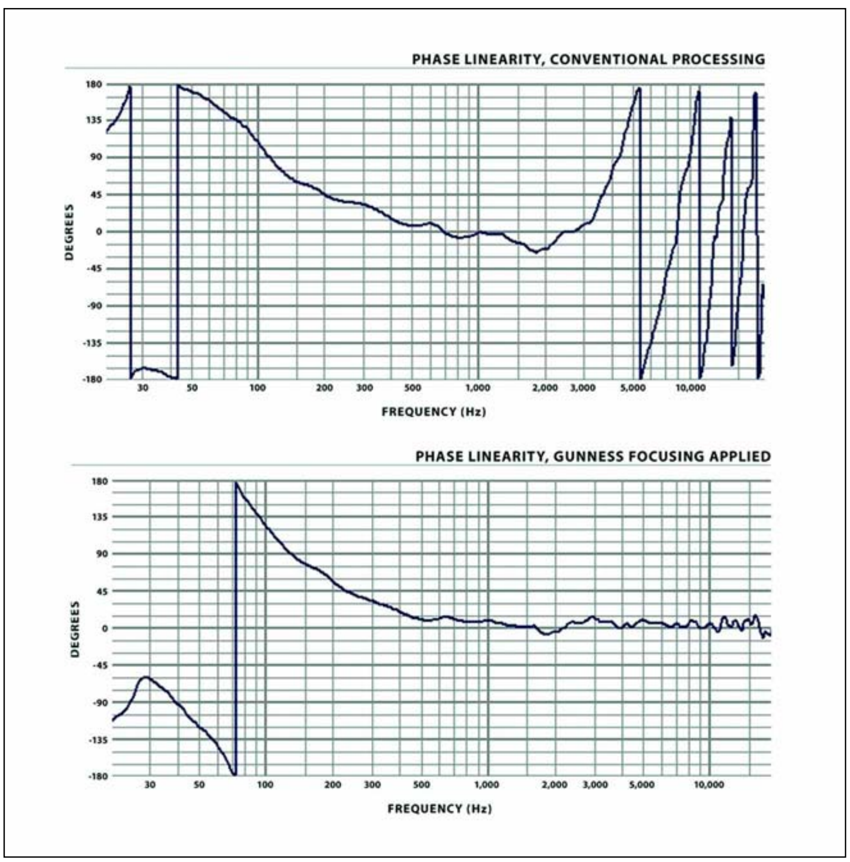
Some of this energy is then reflected back up through the cone. This repetitious process results in resonances. Unlike a horn, these reflections tend to be strongest at the upper end of the woofer's usable range.

While poor transient response and coloration are a ubiquitous plague for any high-output PA loudspeaker, our engineering team suspected there was a cure. What we sought was reproduction quality equal that found in direct radiating, near-field studio monitors, while still producing output levels necessary for sound reinforcement.

EASILY APPLIED, ADAPTED

Rather than working with any of our existing loudspeaker models, it was decided early in the R&D process that we'd start with a clean sheet of paper, a new compact series of self-powered loudspeakers. If this worked, the technology could then be easily applied and adapted to other designs. (The resulting NT Series line offers five models, with choice of 12- or 15-inch cone drivers, two coverage patterns, and a companion dual-12-inch subwoofer.)

The primary tool available for dealing with loudspeaker anomalies is DSP (digital signal processing). However, it's generally assumed that certain loudspeaker problems cannot be corrected using DSP, or that the correction would mean unacceptable compromises in other key performance areas. These assumptions are based on the use of the standard digital processing algorithms found in virtually all digital processors and on their usual method of application.



Demonstration of phase linearity between the input signal and the output signal. (Perfection would be a line at 0 degrees.)

Understanding the trade-offs of traditional DSP implementations is key in understanding how our approach is different. The usual method for employing DSP begins with the measurement of a loudspeaker's frequency response. This response is then inverted to generate a complementary "preconditioning" set of filters. These filters should theoretically correct the performance anomalies in question.

The problem is that the measured response includes two kinds of anomalous behaviors. The first are linear, time invariant, and spatially consistent anomalies, meaning behaviors that don't vary with the loudspeaker's operating conditions or the ambient environment. These are correctable behaviors.

The second are non-linear, time variant, and spatially variant anomalies, meaning behaviors that vary with the loudspeaker's operating conditions or the ambient environment. These are uncorrectable behaviors.

Because both types of behaviors are lumped together in the measured response, the preconditioning filters end up including filtering for the uncorrectable anomalies. This condition actually makes the response worse in some directions and at output levels that differ from the original measured response.

To further complicate matters, certain of these behaviors can permanently change with use. This means such filtering would not only cease to be helpful over time, but likely detrimental to reproduction accuracy. As a result, DSP has not provided the illusive cures for very specific and quite obvious anomalies: honk, splashiness, and cone resonances.

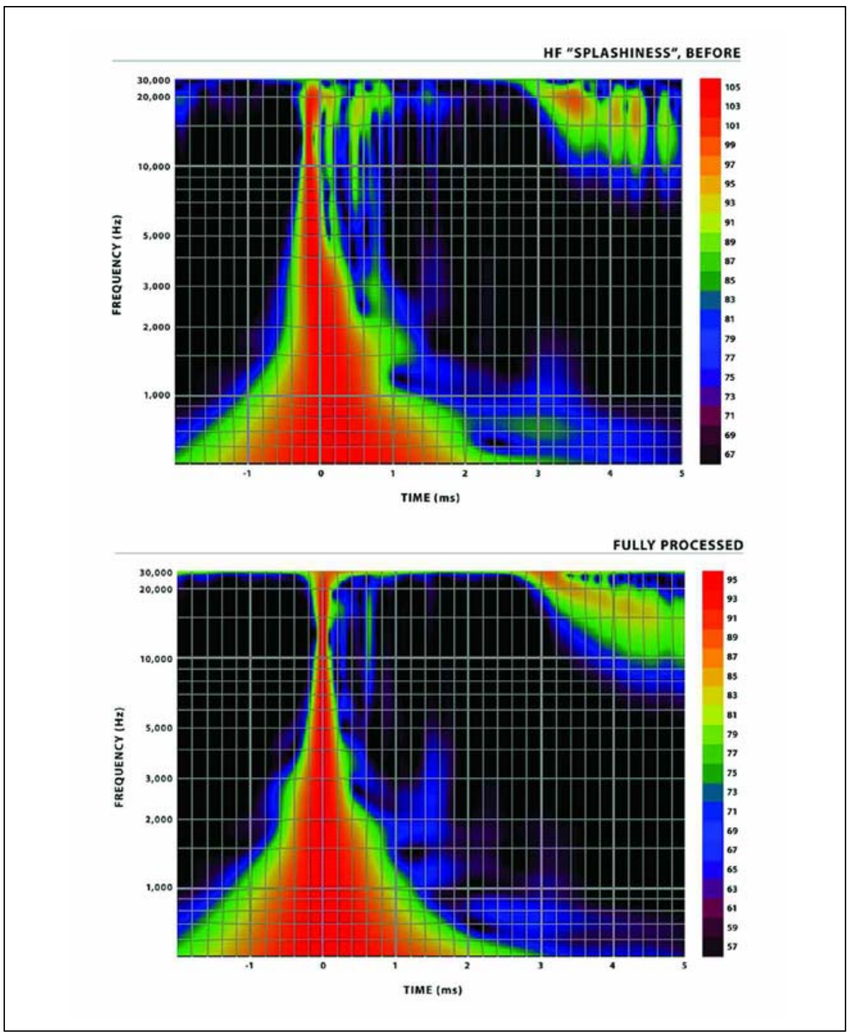
ENGINEERING TACTICS

The first target was development of a proprietary, software-based, spectrograph for the acoustical analysis. This spectrograph, along with other analysis tools, was used to investigate the unprocessed responses of the loudspeakers' HF and LF subsystems in various directions and at various levels.

The analysis allowed various performance anomalies to be isolated from each other. In this way, those anomalies that were linear, time invariant, spatially consistent, and therefore correctable, could be distinguished from anomalies without those characteristics, and which were therefore not correctable.

The next step was to apply appropriate DSP to the correctable anomalies. Another analysis was performed on the standard, universally used DSP algorithms. This test proved that these standard algorithms simply did not produce filters with response shapes, temporal behaviors, or resolutions with anywhere near the required precisions or accuracies necessary to correct those anomalies to which they were being applied. To solve this dilemma, the engineering team undertook development of custom (and rather radical if I do say so myself) DSP algorithms specifically engineered to provide the required filters for correcting loudspeaker anomalies. The resulting filters had to possess the required precision and accuracy in both the frequency and time domain. At the same time, any uncorrectable anomalies would have to be ignored by the filters.

This advanced processing cannot be applied "as is" to just any loudspeaker, let alone be something that even the most astute of users can set up. The anomalies and resonance problems it cures are very specific to each loudspeaker design. Thus, the internal physical details must be known, the anomalies must be carefully analyzed, and appropriate filters must be custom designed.



"Before and after" spectrograph images that show the difference in sonic characteristics that cause horn honk and splashiness with Gunness Focusing applied.

CUSTOM PLATFORM

EAW's sister company, Acuma Labs, designed a custom DSP and microprocessor hardware platform able to implement the processing along with the requisite driver protection and analog-to-digital conversion.

In addition, this module has specialized memory capabilities where the different signal processing set-ups for all NT models are stored. This means any NT electronic assembly can be quickly configured for use with any NT model using on-board dip switches – beneficial for quick and easy field service

The final ingredients in the NT Series' recipe takes the portable nature of the loudspeakers into account. The goal was products that weigh less than many similarly sized, un-powered loudspeakers. To this end, a proprietary design called Orbital Magnet Arrays is applied, and its purpose is to significantly improve the output to weight ratio of the magnetic structure.

It's also interesting to note that the choice of power amplification focused as much on weight requirements as it did on sound quality and reliability. And while the cabinets are constructed of the usual EAW multi-ply Baltic Birch ply, several ways were discovered to eliminate some of the usual weight.

The result of this engineering effort is the NT Series. While Gunness Focusing is integral to these loudspeakers, note that it can also be implemented in a stand-alone, digital processor with the appropriate hardware design.

This means we can proliferate the technology to existing and coming new products appropriate for a wide variety of configurations and applications. ■

Dave Gunness *is director of research and development for EAW and holds several patents for loudspeaker and related designs.*