Article By Alvin Foster
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In 1991 (*BASS* v18n1) I wrote that "the best stereo speaker is one that fulfills the requirements of the human auditory system for optimum localization, imaging, and clarity." I felt that an accurate loudspeaker would likely have a dispersion pattern that would be more directional than conventional box designs; increasing a speaker's directivity would improve its fidelity at the listening chair. These conclusions came at the end of a long article on the Carver Amazing Mark IV speaker. I pledged to continue my research into the causes of the "box" sound, and why planar line-source speakers sound different from conventional cone loudspeakers.

I have more recently concluded that there is no one speaker type or dispersion pattern that best fulfills the requirements of the human auditory system in all playback environments. For home stereo, however, I believe that the tall planar dipole line-source speaker offers the best compromise among the important variables of imaging, clarity, and envelopment.

Dispersion Types

In my article, I defined the typical multi-way cone speaker system as having a wide dispersion pattern. In contrast, I mistakenly claimed that the Carver Amazing dipole speaker had a narrower (beamier) dispersion pattern, stating "the narrow dispersion pattern of the line-source driver more closely fulfilled the auditory requirements of the ear" [the Carver's narrow ribbon has the wide horizontal radiation that would be expected for its size — DRM]. The difficulty with mistakenly applying my 1991 definition of narrow dispersion to the Amazing loudspeaker has come when I try to reconcile why I do not prefer speakers with narrower dispersion even though they typically produce more pinpoint imaging. I am not alone in this finding. In the December 1997 *Audio* review of the JBL SVA1600 horn speaker, Don Keele Jr. concluded that although the imaging and clarity of the JBL were superior to his B&W 801s (a multiway cone loudspeaker), he preferred the "laid-back, staid sound" of the 801s on balance [but also affecting one's preference would be overall in-room response or tonal balance and familiarity with a given radiation pattern — DRM.]

The Major Comparison Factors —
Frequency Response and Dispersion Pattern(s)

Based on my library and laboratory research, I have concluded, as have others, that the best measures of speaker quality are frequency response and dispersion pattern.

I have not found any credible research showing that most of the differences we hear among loudspeakers cannot be explained by examining these two variables. In fact, controlled listening tests have consistently shown that speakers sound the same if they have the same frequency response and dispersion pattern and are operated within their linear range. Finally, the speakers must occupy the same space.

The Role of Distortions

My 1991 conclusion on the minor role distortions of all types play in determining playback quality still stands. Harmonic and IM distortion, phase response/time lag, transient response, squarewave reproduction, decay time, etc., measured in my tests and others', have proven to be unreliable indicators of a loudspeaker's playback quality. I cited, among others, the definitive research of Salmi and Wickstrom, Toole, and at Bose, all of which concluded that such distortions pale in significance to frequency response and dispersion pattern. Tomlinson Holman, during his November 1997 Boston-AES/BAS presentation, reported on German research that similarly concluded there was no hint of a relationship between such distortions and perceived playback quality, based on a study of 45 different speakers in three different rooms.

But even if not a major factor, distortion is somewhat important. My research with multiple listeners indicates that harmonic distortion above 1.2% on 20- 60Hz tones is audible, and above 0.3% at higher frequencies is audible. On complex music, about 10% distortion is considered the requirement for audibility.

In my study with tones, I used two sinewave generators. One fed the main tone while the second generator was set to the second harmonic; in other words, if 16Hz were under study, the first generator was set for 90dBspl at 16Hz and the second was set to 32Hz (second harmonic) and its level raised from -100dB (0.001% HD) to a level at which the listener in a real room could detect a difference when the second tone was switched on or off by a second party, singleblind.

A regular feature of Keele's reviews in *Audio* is maximum peak power tests. Using his custom tones, he has reported that audible distortion in loudspeakers does not occur until extremely high levels are reached. Similarly, Tom Nousaine, in his *Stereo Review* subwoofer reviews, has demonstrated that of more than 10% for audibility.

Wide Dispersion:
Planar Dipole Line-Source Loudspeakers

An extremely large radiation surface, such as a long ribbon, characterizes the planar dipole speaker. The Sound Lab A-1, an electrostatic design, and the Wisdom Adrenaline, a ribbon design, are excellent examples. Each is about 6' high. When stereo-only playback is desired, they and similar speakers have the dispersion pattern most closely fulfilling the auditory requirements of the human ear: wide and uniform.

How much direct and indirect energy does such a dipole generate? It presents a more diffuse overall soundfield to the listener because 50% of the energy generated is projected out the back of the speaker toward the front wall, away from the listener; thus at least half of the speaker's output is reflected at least once before being heard [in a listening with typical placement, though, this is true of all speakers over a wide, non-treble frequency range, because of the integrating time of the ear — DRM]. Because the soundfield is diffuse in this way, it imparts a greater sense of envelopment — a feeling of being there and of being involved in the music.

Kommentar [OP1]: wide but not wide enough.

Kommentar [OP2]: Envelopment is a property of multi channel reproduction, not stereo.
I prefer the term "early spatial impression" as used by Griesinger in this context.

How tall does such a speaker have to be to perform like a line source? There are at least two answers to this question, according to David L. Smith (formerly of McIntosh, now at Snell) in a 1995 AES convention paper. One rule of thumb is that the far field begins at distances equal to three times the source's largest dimension. In the case of the Wisdom ribbon, this means a listener distance greater than 18'. Another definition of the far field is that point where the line source's SPL falls off at the same rate as a point source: -6dB with a doubling of distance (the linesource level begins its dropoff with 3dB per doubling of distance) [this may not always be precisely the case in listening rooms — DRM]. At higher frequencies the far field is even farther away. Smith concludes, "When long arrays are used for home loudspeakers, the listener is very likely to be in the near field."

When you sit within one foot of any speaker, the direct sound is much stronger and louder than the room reflections. This, too, is sometimes referred to as near-field listening. As you move away from the speaker, you start to hear more of the room. Typically, after about three feet, you hear more of the room than you do the speaker. In my 1991 Amazing article, I quoted Daniel Queen's assertion that a "typical wide-dispersion loudspeaker permits only about14% of the direct energy to reach the listener."

Dipole line-source designs address the shortcomings of other driver designs: (1) acoustic resonances inside the cabinet, (2) different acoustic impedances on the dynamic driver between the inside and outside of the cabinet, (3) stronger ceiling and floor and sometimes wall reflections, and (4) less consistency in vertical, and sometimes horizontal, dispersion. Well-designed cone or horn loudspeakers can reduce these limitations, however.

Power Response

The power response of a loudspeaker, the sum of all the energy radiated from the system, is difficult to measure, and this probably accounts for its receiving insufficient attention in speaker evaluation [plus the mania for impulse-based measurement gear — DRM]. Ideally to measure power response, one must employ an anechoic chamber (or simulate an anechoic environment) plus multiple microphones positioned around the speaker (or a single mike placed at multiple points), and then sum the total. A comparison of the power response with the direct sound defines a speaker's directivity.

A dipole's bidirectional radiation often means it will have a flatter power response than a monopole loudspeaker. Flatness is important because in a room we listen chiefly to a speaker's power response, as Roy Allison and some others point out.

Kommentar [OP3]: **Updated 23-Mar-2012**
Flatness **cannot** mean "constancy" in this context but the absence of dips and peaks (although dips are more benign than peaks).

A major fault sometimes alleged for dipole speakers is the 'unnatural' reflection created by the strong rearward radiation toward the front wall [this is chiefly a treble effect compared with conventional forward-facing speakers, and some find it highly pleasant — DRM]. It arrives at the listener well after the initial sound. I maintain that since all speakers generate both useful and unwanted reflections within a room, the real questions to settle for the listener should be: (1) the amount of frequency response alteration, (2) the composition of the delayed sound, i.e., how many early and late reflections are included, and (3) the percentage of direct and indirect sound.

Kommentar [OP4]: Red emphasis added 01-Jun-2012

A dipole should be placed at least 7.5' from the front wall — an adequate distance according to the BBC information provided by Holman during his recent presentation. Holman stated that a reflection is of negligible importance if it occurs at least 15ms after the initial arrival and its energy is at least 15dB lower. Such reflections do not affect either timbre or localization. And longer delays can augment the listening experience.

Floor and Ceiling Reflections

Having vertical dispersion restricted means planar speakers send less energy to the floor and ceiling, so a listener encounters fewer early reflections. What further distinguishes planars from other designs that aim for partly reduced vertical dispersion, such as midrange-tweeter-midrange, is that planar speakers maintain a more consistent response with different head heights. In some MTM speaker designs, vertical dispersion is limited only over an octave; above that range the speaker is beamy and below it the dispersion is broad.

Boundary augmentation affects planar dipoles like any speaker, but less so because of the height of the source driver, its restricted vertical radiation pattern, and the effective multiple distances to the floor and ceiling, which distribute the Allison effect over a broader frequency range, tempering its severity. As a test, I placed a cone speaker 18" off the floor, and there was a dip around 188Hz, just as Allison's work predicts. The dip caused noticeable voice coloration, a tonal or timbral change that was a clear result of the floor, front wall, and side wall reflections. To introduce a similar 200Hz dip into the output of my Amazing speaker, I used a 1/3-octave equalizer, and the bottom-of-the-barrel sound that I had associated exclusively with box speakers was now being exhibited by the Carvers, pushing the voice from front stage.

By judicious placement, such boundary-augmentation problems can be minimized for any design, including box speakers, along with other early reflections that color the sound.

Dips to the Side

Another advantage of planar dipole loudspeakers is the sideways cancellation that results when the potentially annoying early side-wall reflections are reduced.

Multiple-Speaker Interactions

According to Keith R. Holland and Philip R. Newell (September 1997 AES preprint), using "loudspeakers in pairs for the reproduction of two-channel stereo give rise to mutual coupling [multiple speaker interaction] effects, which compound the usual loudspeaker/room interface problems."

There are two primary effects, and one historical reason, that have instigated the requirement for a separate center channel speaker in home theaters. Any pair of speakers radiating the same information creates a phantom image between them. If one speaker is louder, or if the listener is closer to one speaker, this phantom image will shift toward that speaker. If the pair of speakers is the left and right channels, this shift of the phantom center image will skew, or distort, the front proscenium of sound. Compared with a signal coming only from a single center channel speaker, the interaction of two speakers radiating the same signal causes a frequency response notch at around 2kHz at the listener's ears.

This obviously results in a change in timbre. response changing with position.

The movie industry puts dialog in the center channel, since dialog is of primary importance in most films.

As a result of two speakers radiating the same signal, the frequency response balance at the listener's ears is also gradually boosted in the lower midrange and bass, due to mutual coupling. Having two speakers radiate the same signal at the same level, midrange and highs increase 3dB compared with either speaker alone. As the frequency drops and the wavelengths get longer than twice the distance between the speakers, the coupling gets stronger, ultimately reaching +6dB in the bass [this gradual reinforcement is shown in several real-world in-room measurements graphed in *BASS* v17n6 — DRM]. The impact of these effects is affected by the reverberant nature of the room and the speaker dispersion patterns, with

According to Holland and Newell, "Dipole loudspeakers, such as most electrostatics, behave in a different manner. The dipole radiation pattern means that little or no sound is radiated toward the other loudspeaker, thus rendering them immune to mutual coupling effects…. Some room-related mutual coupling will still occur, however, although to a lesser extent than for monopole loudspeakers."

If tall dipole planar speakers can be so good in these criteria, why isn't the design more popular? The likely reasons are space limitations, cost, size, visual appearance (spouse-acceptance factor), and the distance required from the front wall.

Medium Dispersion: A Cone Loudspeaker

Depending on its size and the frequency range it is asked to reproduce, a cone loudspeaker can have dispersion wider than a planar driver or a narrower directivity that rivals the horn. As Allison explains it, "Directionality is, with rare exceptions, a function of the wavelength of the frequency being generated in relation to the size of the driver (or the dimension of the mouth of the horn) normal to the plane of interest" [this holds for all drivers, planar as well as cone — DRM]. For a 10" woofer, the transition point to less than omni output is about 500Hz and above; for a 4" driver it is about 1.4kHz and above; and for a 1" dome tweeter it is the 4-8kHz octave. When drivers are called upon to deliver sound higher than these points, their output becomes increasingly concentrated on axis and their off-axis response falls.

Power Response, Reflections And Horizontal Dispersion

Allison: "If the power response of the system is well-dispersed and free of abrupt changes throughout most of the audible frequency spectrum, then our ears will interpret the reverberant field as smooth and natural. [Presuming a relatively flat on-axis frequency response,] if the power response of the system varies significantly with frequency, we will hear an uneven response." With too many cone/box speakers, the power response of the system falls until the crossover network brings in a smaller driver, at which frequency the output is again more omnidirectional. At this crossover point the dispersion broadens and the power response jumps up again. Sawtooth power response curves like this can easily be heard even when the axial output from the system is flat.

A typical two-way cone loudspeaker, such as the Paradigm Phantom, has no rear-facing drivers. The 8" and the 3/4" drivers are asked to deliver the entire audible bandwidth. The result often is a power response that does not equal the planar driver in smoothness. James Moir states, "At first thought it would appear that the reduction in the horizontal offaxis output at high frequencies would be of little consequence to a listener seated on axis, but experience shows that the effects on sound quality are indeed obvious to a moderately experienced listener."

The effect of a speaker's distribution of sound is often discussed in audiophile literature, as in comments like the "cymbals and trumpets sound better on horn loudspeakers" or "they sound too laid-back." What is not often discussed is the cause, or how the speaker's characteristics — directivity, and frequency response as a function of angle (both of which affect the ratio of direct and indirect energy as a function of frequency, at the listening position) — are most likely the cause of the perception.

Since wide and consistent horizontal dispersion is impossible for a single forward-facing cone driver to produce, it is better when multiple drivers of different widths are used to cover the audio band. And even then, both the reflections that influence imaging, and the total in-room power response, sometimes will be ragged.

Narrower Dispersion: A Horn-Loaded Speaker

A speaker with narrow dispersion directs more sound forward than to the sides and rear and thus is less affected by the room. This characteristic translates into excellent imaging but, of the three major speaker dispersion types, with the least sense of envelopment and spaciousness. Controlled-directivity horn speakers are known for their clarity and imaging. You can pinpoint the horns; in fact, horns and cymbals sometimes appear to stand out or sound more forward than the other orchestral instruments.

Some people believe that a stereo loudspeaker *should* have a narrow radiation pattern, like a horn's. It produces less of a reverberant field and some feel it thus is ideal for pop music. It simulates more "they are here" than "you are there." It is the opposite of, say, the Bose 901.

The good news is that there typically are fewer early reflections than from a cone loudspeaker — behavior more like that of planar loudspeakers. The downside is that a horn's limited dispersion can mean it is less suited to being used as a lone pair in a stereo system [depending on your goal and taste — DRM]. Wide-dispersion proponents argue that in any case, since pinpoint imaging is not that important a part of the concert experience, it also is not that important for playback.

Kommentar [OP5]: It's an excuse. Ideally there should be both. Early spatial impressions and good imaging.

Power Response

The dispersion pattern of a typical horn-loaded driver, such as the JBL SVA1600, might be quite narrow especially in the treble, meaning the overall balance at our ears will probably have too much bass and too little highs and will contain the least amount of reverberant energy [also depending on how close one sits and on the liveliness of the room surfaces — DRM]. This imbalance might happen even if the axis response is flat.

Kommentar [OP6]: I think horn/big waveguide speakers work better when listening from a greater distance; greater than what can be achieved in a typical small listening room.

Kommentar [OP7]:
Updated 01-Jun-2012
There are several relations that create imbalances:
1. The narrowing of the sound power response
2.The change of the initial time delay gap between the woofer and the horn tweeter.
3.The change of the critical distance between the woofer and the horn tweeter.
All this in combination makes a small sweet spot, a the "blown into your face" impression and the perception as if you would listen into the auditory scene through a rectagular window.

Floor and Ceiling Reflections

Early vertical reflections are typically minimized because horn-loaded drivers often have restricted vertical output.

Horizontal Dispersion

Although constant-directivity horns can be designed to have wide and even horizontal dispersion, the equal of [and sometimes better than] many other speaker types, most often the radiation pattern is restricted to a defined listening area, which is great for theaters. The result is minimized side-wall interference and extremely tight imaging — about the best.

Kommentar [OP8]: Or other places that require sound reinforcement systems.

Why All This Is Important?

The effect of the sound distribution of a loudspeaker — its dispersion pattern or patterns — is rarely correlated in audiophile writing with what we actually hear in a room.

Kommentar [OP9]: Even today, 12 years later !

Correcting my 1991 definition of the narrow-driver planar dipole speaker to that of a speaker having wide dispersion, for example, fits better with the conclusions reached by the authors listed in that article: Moir, Queen, Kates, et al. According to Moir, "The soundfield in a room does not become increasingly diffuse with the passage of time as is generally thought, but instead becomes increasingly ordered, with the sound energy concentrated in well-defined spatial patterns even at the lower frequencies." Thus, reverberation is not the decay of a diffuse soundfield but the decay of well-defined patterns of energy. The resulting sound is composed of short and long reflections and imperfect frequency response(s). Hence, listening to a narrow-dispersion speaker will be a very different experience from listening to a that many audiophiles crave. Such a reverberant field provides the blending of orchestral voices and the feeling of spaciousness that are the essence of the concert hall experience. [Some listeners feel not just large-force/large-space classical — DRM.]

Multichannel Sound Requirements

Kommentar [OP10]: I think I prefer stereo over multichannel because the brain gets just enough food to start working and building my own auditory scene or imaginary venue.
Maybe stereo vs. multichannel is like a book vs. the corresponding movie. Often times the book is more absorbing or even haunting. You have the freedom to make your own picture compared to what the movie maker feels is important to show.

There is considerable debate in the home multichannel playback arena about how many speakers are needed and what constitutes the ideal dispersion pattern when the music source is a stereo CD. Signal processors have been manufactured to convert existing stereo CD output into surround signals that their manufacturers claim provide the best of both worlds: discrete, localized effects that image to the left, center, right, and sides and rear. They also claim to have effects that wrap all the way around the listener. The Yamaha DSP-1, the Citation 7.0, and the Lexicon processors are among the many units available. The goal of these devices is to place the listener in a 3D soundfield. To do this most successfully, each speaker's dispersion pattern, the number of speakers, and location requirements will be different from a system set up in accordance with the THX guidelines for video soundtracks.

The home speaker setup for the playback of movies was largely copied from the THX movie theater standards, established after considerable research. However, the playback requirements are not the same if reproducing music is the main criterion. In the theater, many people sit off-center in a very large room. To keep dialog centered, a center channel was incorporated in the standard, along with directional front left and right speakers. The THX criteria have a frontal bias; the intent is not to enclose you in a musical soundfield.

To prevent the listener from localizing sound to the side speakers, dipole speakers were specified. An added reason for a diffuse soundfield on the side was to reduce the audibility of film dropouts, clicks, random noises, etc., that enter during the moviemaking process, and leakage from the Dolby Surround matrix decoding of some front-channel sounds.

In the home music system, however, spaciousness and envelopment are key for many listeners. Stereo means three-dimensional; only minimum localization cues are required.

The sense of being enclosed or having the music all around you requires a different emphasis, not narrow directionality, especially if you are limited to 5.1 playback channels. According to Holman, for maximum envelopment in a 5.1-channel system, the front two loudspeakers should be at ±36 degrees, the two side channels at ±108 degrees, and the remaining speaker at 180 degrees, behind the listener [the points of a regular pentagon — DJW].

Conclusion

All speakers in a room generate a total soundfield that plays the key role in fidelity. The main concerns should be to dissect the composition of the sound, my categories being: (a) potentially annoying early reflections, (b) the more benign late reflections, (c) a frequency response altered by boundary augmentation and then by room dimensions and (d) the proportions of direct and reflected energy.

Kommentar [OP11]: Benign ? Desired !

The latest studies on the need for envelopment and its causes are right-on. All speakers, whatever their dispersion, generate a reverberant field in a room, and for maximum high-fidelity envelopment with music I submit that we want a soundfield that most closely maintains the balance of the information on the disc [those who feel that most recordings are made too close to the sound source probably will not want their playback to be chiefly direct sound, though — DRM]. As audiophiles, we have paid too much attention to reports on the various other distortions generated by loudspeakers. We need more emphasis on correlating the speaker's frequency response and dispersion pattern(s) with what we hear. [And the room is an equal partner; not even horns can be divorced from the room — DJW.]

Kommentar [OP12]: Red emphasis added 23-Mar-2012

This situation can improve if audio reviewers would categorize speaker system dispersion into my three main groups of wide, medium, and narrow, and note dispersion uniformity as a function of frequency. By correctly typing speakers, reviewers will give their readers a better idea of how a given system fits their both playback requirements and their environment.