AUDIO UPDATE

Psychoacoustics and Stereo Imagery

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FIG. 1

IN MY LAST TWO COLUMNS I DIScussed the technologies and purposes of signal processors. I indicated that the major trouble areas in audio reproduction are noise, dynamic-range limitations, frequency balance, and spatial imaging. I covered the first three problems in past columns; now let's take a brief look at the theory of stereo perception and the way that certain products can affect and enhance the stereo illusion.

Auditory localization

The human ear/brain's ability to localize sound sources is important for at least two reasons: It enabled our remote ancestors to determine the precise direction from which the saber-tooth tiger was coming (as a guide to the direction in which *they* should be going), and today it provides the ability to construct a stereo image psychoacoustically from two or more sound sources.

There are two differences between the sounds reaching our ears that we use to achieve localization: time-of-arrival differences and sound-pressure-level differences. In addition, there is some evidence that frequency-response differences between the ears due to head diffraction assist the localization process, but the present view is that the contribution is small, no matter how large the head. In general, differences in arrival times are used to localize lower-frequency sound sources, and differences in level are used for the higher frequencies; the brain's crossover point between the two is about 1200 Hz.

There's a good reason why your ear/brain mechanism uses (actually, needs) two different cuing mechanisms for localization. For wavelengths in the mid- to high-frequency ranges, your head is an acoustic barrier that partially blocks the sound reaching the ear most distant from the sound source. The difference between the ears is about 16 dB at 5,000 Hz, falling to about 7 dB at 1,000 Hz. When the frequency is low enough (i. e., the wavelengths long enough), the head ceases to be an adequate baffle and essentially the same signal *level* is heard by both ears.

However, your brain still senses

the differences in arrival time (*phase*) between the signals reaching your two ears—which is about 0.6 millisecond from a source located fully on one side of the head or the other—and that information provides the data needed for localization. Below 200 Hz or so, where wavelengths are very long, arrival-time differences begin to disappear and directionality begins to be lost. That, by the way, explains why the sound from subwoofers is non-directional.

Unnatural stereo

What I've just described is the way the ear localizes the source of *natural* sounds. Although stereo reproduction makes use of the same perceptual mechanisms to generate a spatial image, the process of stereo reproduction provides different and somewhat problematic raw material for the ear/brain to work with. Problems arise because part of the sound produced by each musical instrument and performer in a recording almost always appears in *both* channels and is reproduced by *two* widely spaced speakers.

So if you hear a centered soloist, both right and left speakers are contributing in equal measure to the illusion. But when a vocalist or musical instrument appears more to the left or to the right, the loudness/phase differences in the *two* signals reaching your ears have tilted your perception in one direction or another.

For example, when you are listening to a well-recorded jazz group, each performer (plus whatever reverberant hall sound might be captured) is represented by two signals, one in each channel. It should be obvious that stereo reproduction is a totally artificial (and, as you can see, surprisingly complex) process that works by manipulating—and misleading—the ear's normal sound-localization procedures.

Improving the image

An appreciation of the ear/brain's stereo spatial perception mechanism is helpful in understanding the techniques used by the various stereo enhancers, imagers, and synthesizers. Here are some commonly used techniques.

- In a normal stereo recording in which *two* speakers are used to reproduce each performer and instrument, there is a large amount of "inter-aural crosstalk." In other words, too much of the left-channel sound intended only for the listener's left ear reaches his right ear, and vice versa. Polk's SDA speakers, shown in Fig. 1, and Carver's electronic "Holographic" circuits achieve their effects by acoustically (Polk) or electronically (Carver) nulling the sound that reaches each ear from the opposite, unwanted channel. The enhancement that results from that procedure has to be heard to be believed. The sound stage is no longer confined to a narrowly defined space between the right and left speakers; depending upon the program material, it can form an arc of almost 180-degrees in front of the listener.
- Some imaging devices manipulate the phase of the two channels. Others extract the left-minus-right signal (which represents the difference between the two channels) and use it to enhance the "rightness" and the "leftness" of each channel. That technique, which has been used in several receivers, can substantially broaden the stereo sound stage.
- Mono-to-stereo synthesizers "comb-filter" the audio spectrum into three or more segments (the more, the better), putting alternate bands in each channel, and/or phase shifting each of the newly generated channels in opposite directions. Those circuits are found in some audio/video products; their intention is to provide a stereo effect from mono sound tracks and broadcasts.
- Several loudspeaker manufacturers have rearranged the sound-field propagation of their products (by the use of acoustical and electrical delays) to offset some of the spatial constrictions and artificialities introduced by normal stereo reproduction. AR's *Magic Speaker* and dbx's speaker systems embody that approach.
- Time-delay devices electronically delay a portion of both right and left channel signals separately and feed them into strategically placed rear speakers as a means of emulating the acoustic time delays found in large concert halls.

I've probably neglected a few special techniques during my once-over-lightly treatment, but my purpose was to remove some of the technical mystery from the various products, not to create a catalog.

Four-channel revisited

A new breed of audio processor has come into prominence recently. To the audio old-timers among us, they may seem somewhat reminiscent of the quad decoders of the early seventies. To distinguish the new products from their multichannel predecessors, these new products are referred to as Sound Field or Surround Sound Processors, Home Theatre Sound Systems, or simply Dolby Surround Decoders. The processing in the more complex units is done mostly by digital means. We'll look at those units next month along with some of the reasons why stereo doesn't work right. **R-E**