Testing *New Audio*

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What do the Digital Video Disc, 3D Audio for PCs, voice+data modems and Dolby AC-3 surround sound have in common? They're all examples of *new audio* testing problems that recently emerged for both design and production testers.

What is *new audio*? Audio frequency testing requirements are now moving far beyond the core products such as stereos, sound-reinforcement systems, intercoms, and recorders. Even in the personal computer area, audio testing has expanded beyond basic PC sound to new functions such as 3-D audio.

New audio represents a group of computer, communications and entertainment product-related applications that are just now creating demand for new approaches and techniques for audio testing. Emerging standards, for example in the areas of PC audio and simultaneous voice/data communications are one factor driving the new applications. In other areas such as PCS and cellular phones, strong competition is producing a need to differentiate products by adding more audio features such as internal answering and messaging functions.

Although the new products as a group tend to fall into the general classification of communications and multimedia, the individual test solutions are dissimilar and specific to the products and technologies involved. One of the more unusual examples in the multimedia area is 3-D audio, also called positional audio.

Testing 3-D Audio

Like holograms and other attempts to produce three dimensional *visual* fields, 3-D audio attempts to create a three dimensional *soundspace*. Spatial localization of sound by the brain is an interesting mechanism. With only a few cues, the brain analyzes the different sound inputs from our two ears and tells us from what direction a sound emanated.

Successful positional 3-D audio uses audio processors to produce aural cues which fool our auditory sense into believing that a sound is located in a particular point in space—or even to believe it has just moved behind us from one point to another! The entire technology is based on relatively recent pyschoacoustic research that previously had been mostly of academic interest.

But video and computer game developers quickly learned that by positioning and moving sound effects in a virtual 3-D soundspace

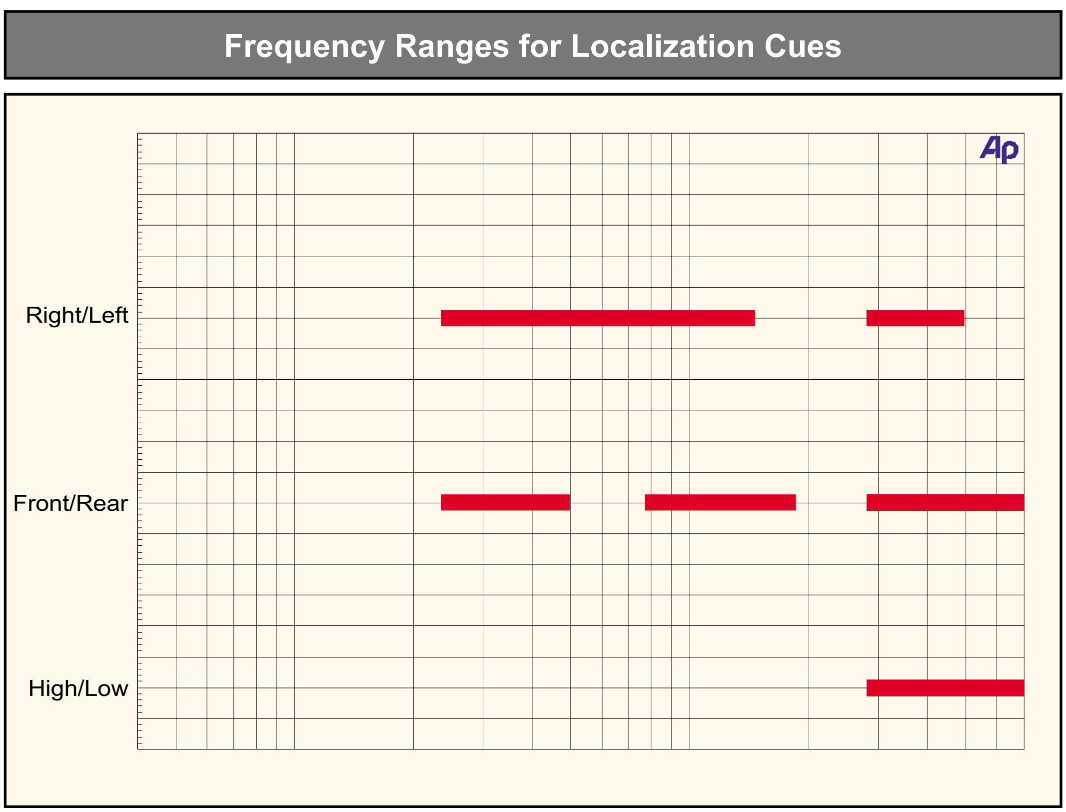

Figure 1.

Audio Switching System

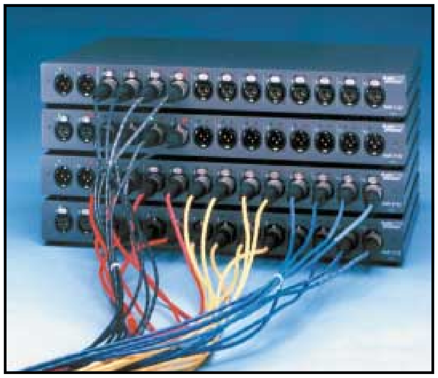

Figure 2.

dramatically increased the overall entertainment factor. Faster main processors and special-purpose digital sound processing hardware literally have now accelerated the trend to include both software and hardware 3-D audio functions to be compatible with today's standard processor chips. Although currently driven almost exclusively by game applications, general acceptance of positional audio, along with the availability of accelerator hardware for processing, opens up the possibility that conventional music and sound for video also could be positioned and moved in real time as you listen.

Because localization effects in hearing have been studied for years, it was understood that intensity as well as timing differences, or first arrival, between the left and right ears were responsible for most of our perceived left-right soundfield placement. More recent research determined that the frequency-response variations caused by the pinna, the folds of the outer ear, also contributed allowing us to differentiate between sounds in front and sounds from the rear.

The surface and shape of the outer ear act as a filter, changing the frequency response of sounds from the rear as compared to sounds arriving from the front. An even more complex arrangement of reflections from the folds of the ear creates different combinations of high-frequency response deviations at different vertical angles. In most cases, this allows us to sense whether a sound comes from above or below. So aural cues for left/right, front/rear and up/down all depend on frequency response changes within certain bands (**Figure 1**).

Frequency Response of Multiple Audio Channels of a DVD Player

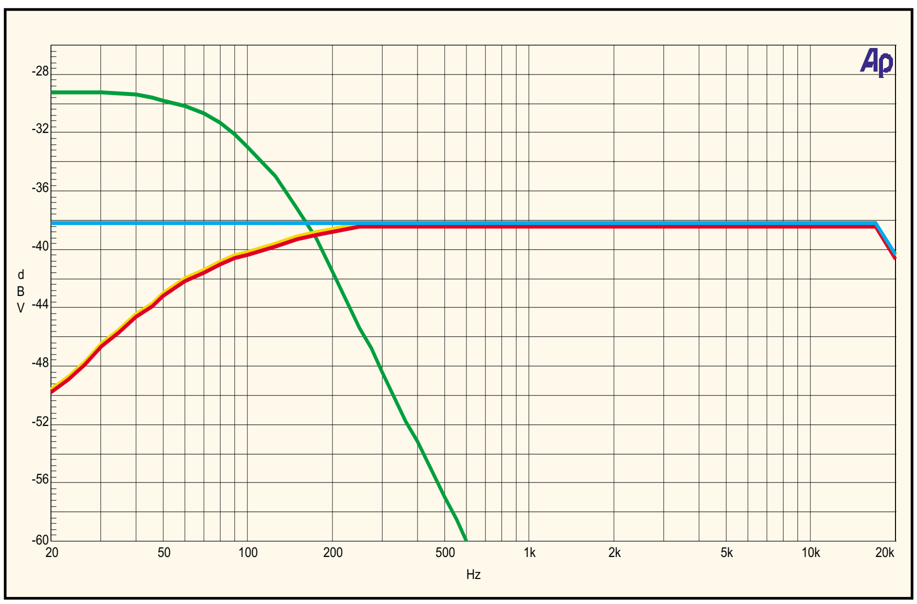

Figure 3.

To make matters slightly more complicated, synthetic 3-D positioning is most easily created for binaural listening through headphones but most listeners use two loudspeakers instead. A head response transfer function (HRTF) is a model of how these factors are interpreted by the brain/ear combination to localize a given sound.

Three dimensional audio systems use the HRTF-based rules to manipulate relative audio amplitude, frequency, time delay and phase and frequency shifting, creating a dynamically altered audio channel response. It is this audio channel response which in turn must be measured to determine if the 3-D system is operating according to plan.

When a 3-D audio software or hardware product is tested, two problems exist. First, since the 3-D processing alters normal non-3-D linear frequency and phase response, there must be an internal soft or hard bypass to defeat it. Then the PC sound system may be checked in the usual manner for flat frequency response, low distortion, and noise.

The second problem—that of verifying 3-D functionality—is more difficult. When a sound consisting of wideband frequency information is moved in the created sound field by dynamically altering its overall magnitude in the left and right outputs, the relative amplitude of different portions of its frequency spectrum, and other parameters. These other parameters could include signal phase and first arrival time.

Think of the 3-D audio system as a special encoder, and our ears and brain as the decoder. But for audio testing we want to use a multifunction general purpose audio analyzer without benefit of an intervening human ear/brain decoder.

Because of the complexity of the processing for positional audio, it is not practical nor necessary to dynamically test the 3-D positioning. The audio test solution is to pick a certain number of fixed spatial positions in the three axis

Plot of Frequency and Phase Response of a Line-Isolation Transformer for a Modem

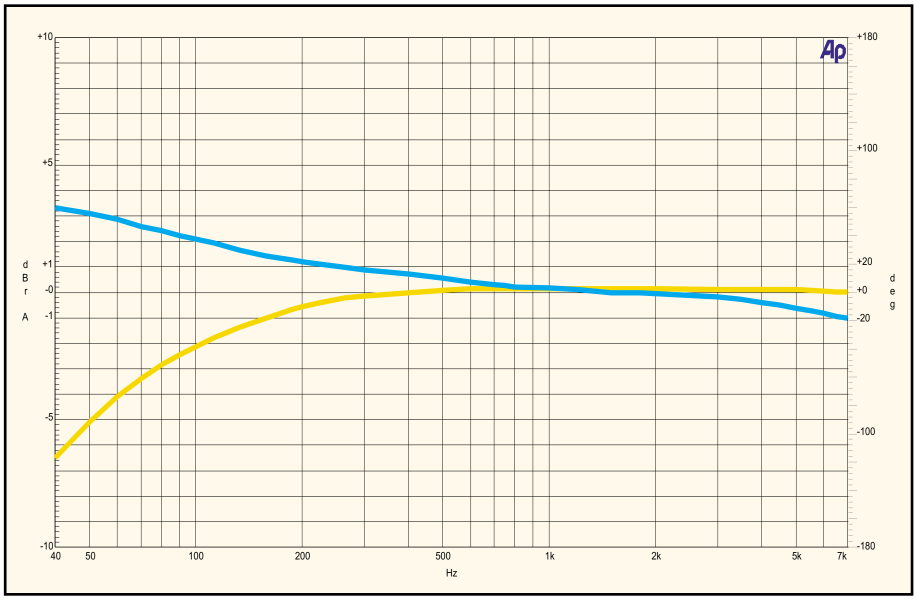

Figure 4.

space (left/right - front/rear - up/down) and then measure the net overall response of sound placed in this position with a frequency response test.

A stepped sine sweep or sinemultitone signal that originally flat will show a different frequency response for each position. Limit files or templates of the expected characteristic at that soundfield position may be used for pass-fail evaluations.

The response curve for each position should match the predicted aggregate frequency response for that sound position as defined by the HRTF in use. Various 3-D audio systems differ from each other, and most systems also include proprietary methods which further alter the sound to be positioned or moved. So it is necessary to compare the test result with the specified and predicted curve for each spatial position on that particular 3-D system.

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One interesting extended application for these two channel, 3-D audio systems could be to create a virtual surround-sound environment for original multichannel content such as film soundtracks. Positional signal processing can be applied to previously decoded multichannel sound in order to generate a pseudosurround-sound field using only the two speakers on a PC. But quality issues require a true multichannel sound environment for high visual and aural fidelity uses, such as home theater and auditorium presentation.

DVD

The digital video disc, a.k.a. digital versatile disc or DVD, is the leading candidate to replace the current video laser disc and various video cassette playback systems. It offers digital image quality, smaller size, lower cost, enhanced features, and multichannel surround sound.

Although an open format aspect of the DVD specification allows for more than one audio standard, discs and players produced for the U.S. market as well as some other parts of the world include the Dolby AC-3 digital multichannel surround-sound system for DVD audio. The system delivers five full frequency range channels (left front, center, right front, left rear, and right rear) and a limited-frequency-range, low-frequency enhancement channel for a total of six channels to be tested.

Since necessary audio testing requires arbitrary access to one or more of the six channels, software-controlled audio switchers may be used in conjunction with a two channel audio analyzer to access one or more of the six channels for any given test. (**Figure 2**). But since the DVD provides wide dynamic-range audio, the switching device must have residual noise low enough to be compatible with commercially available converters with dynamic ranges exceeding 100 dB. Even a passive switching device is unlikely to meet these numbers unless properly engineered with respect to PCB trace layoutand powering and shielding considerations.

Dolby AC-3 Testing

For product-design acceptance or production testing, in addition to simply verifying the presence of audio from all six outputs, various audio tests are needed to guarantee quality. These tests typically include harmonic distortion (THD+N), level/flatness, noise, channel separation, and converter linearity.

Figure 3 shows a multichannel audio frequency response from channels of a DVD player. Also required are other, more specialized tests relating to multichannel decoders, such as system gain calibration, decode mode selection, and dialogue normalization. In the specific case of Dolby AC-3, the entire technology is a licensed, and design samples produced worldwide must pass precise audio quality licensing tests in order to wear the Dolby badge.

Other *New Audio*

Perhaps a little less glamorous but just as significant in terms of worldwide use are the new classes of data modems, some also operating with simultaneous voice and data. As higher data rates and more features have been standardized, the remaining near-constant is the phone line, called the local subscriber loop, to which the typical mass market modem will be connected. Although the quality of the local loop telephone lines generally has not increased very much in recent times, increasing data rates rely on ever more complex encoding standards which still must operate within the very restricted (about 3.5 kHz) bandwidth available through the analog local loop.

This means that analog nonlinearities in frequency and phase response must be minimized within the line interface portion of the modem itself. Even the most advanced modems still are subject to analog performance limitations.

In the past, with less demanding frequency encoding schemes, parameters such as frequency response of the telephone line isolation transformer were not very important. A severe rolloff or extreme phase nonlinearity caused by poor design or production of this necessarily low cost component might not have been a problem. However, newer designs require flatter response of this and other components, for example a voice audio line input section.

Figure 4 shows the frequency response of a better quality isolation transformer stage. The frequency response of the sample extends beyond the necessary line bandwidth but, as a consequence, the phase response in-band is well behaved.

Conclusion

These examples of products and technologies are only a sample of *new audio* testing applications and methodologies. As audio and video are ever more tightly wound together in new standards and devices, more and more products previously devoid of any audio frequency must now handle audio in some manner. Whether in the design phase or production, these *new audio* channels must be tested.

About the Author

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This article originally appeared in EE-Evaluation Engineering, November 1997