PETER SCHEIBER

360° Space in Two Channels

Perhaps too much attention has been given to four channel sound. The author views quadriphonics in a different way.

WHO NEEDS four channels? That is a question I asked myself back in the late '60s. What audio needs is *space*; total, 360 degree space can be communicated through control of phase in two channels.

Even the most conservative audiophile won't quibble with the statement that two channels are here to stay; it's not going to be "back to mono." What are these two channels for? Is it better to replace the old mono "hole in the wall" with two holes in the wall? Is it better to have the audio program reach the listener through two channels rather than through one?

Obviously, talking about channels simply misses the point. Stereo is not sound coming from two point sources instead of one—two "holes in the wall"—stereo is *space*. Stereo is an improvement over mono because it takes the "no space" point source of mono, and stretches it into the now-familiar "stereo stage"—really, a left-right wall of space.

But, walls are flat, and the world (including the world of sound) is round. The step from mono to stereo was a step in the right direction, but only a first step.

At this point, let's move one step back ourselves, and take the long view of what the art of sound reproduction is all about. All those microphones, recording consoles, 2, 4, 8, 16, 24-track tape machines, all the disc cutting lathes, the phonograph pickups putting out signals measured in billionths of a watt, as well as the amplifiers to bring these tiny signals up to hundreds of watts to drive speakers, all the f.m. transmitters and, at the other end, tuners, are simply some of the links in a chain whose single purpose is to carry information—audible information, that is, but coded into more "shippable" electrical form—from point of origin to each of millions of "output terminals"—the listeners' loudspeakers. The whole progress of the audio art is the story of progress in bringing the human ear more and more audible information.

AUDIBLE INFORMATION: FREQUENCY AND INTENSITY

The first sound recording and reproducing equipment was "flat" from a few hundred Hertz to a couple of thou-

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sand—well, not flat, really, with tremendous peaks and dips even in this narrow range. The audio art still had a long way to go in conveying complete frequency information: we are capable of hearing about from 20 to 20,000 Hertz.

Today, state-of-the-art recording and reproduction can bring us this whole audible frequency range. And, even everyday home reproduction equipment is able to bring at least 60 dB of dynamic range—covering a range of audible intensities ranging from quite soft to quite loud. Distortions, adding *unwanted* information in the form of error signals generated by the equipment itself, are now routinely kept below one per cent.

Frequency and intensity information—doesn't this include all the audible information that we have set out to communicate? Think about it: if we can reproduce every overtone of any sound properly, with minimal distortion, and with a full range of intensities, then aren't we giving the ear all the information it needs for a perfect electronic re-creation of any conceivable sound that can be heard? Isn't this all that is needed to reproduce an audibly perfect singing voice, gunshot, acoustic guitar, synthesizer—any sound we can hear?

The answer is yes but—

Now we are able to re-create all sounds taking place in the "sound world" in which we all live—but not the sound world itself. We live in 360 degrees of sonic space, and stereo gives us, at best, a 60-to-90-degree segment of this space. We can reproduce nearly perfectly *what* any sound is, but not *where* it is. Today, in the "age of stereo," the audio art is bringing us nearly all the frequency and intensity information, but losing most of the spatial information.

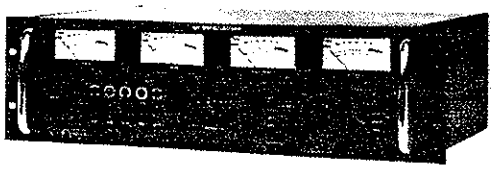
FINDING THE SPACE FOR THE SPACE

We are looking for a way to convey a 360 degree sound world; conventional stereo gives us only a flat, left-right wall of sound. What is missing, clearly, is the front-back dimension, which, in combination with the existing left-right dimension, can make possible the re-creation of the full 360 degrees of space.

But before figuring out how to get where we are going, it often helps to review how we got where we now are. In doing this, we are essentially following the same path of reasoning that I took in the late '60s on the way to my well-publicized demonstrations of the encoded quadriphonic disc.

Stereo "codes" the left-right position of sound sources by controlling *amplitude* ratio in the stereo pair of channels. For example, in the recording studio mixdown process, we want to place a rhythm guitar at left center in the stereo mix. To do this, we turn the pan pot carrying this guitar until we are feeding, say, 2x volts of the guitar's signal into the left channel, and x volts into the right channel. In playback through the stereo pair of speakers, the rhythm guitar will be heard from a position left of stereo center. Now, the guitar can play louder or softer, changing the *absolute* signal voltage (x) fed by the pan pot into the stereo channels; or we can even replace the guitar with an entirely different instrument—say, a synthesizer—but the 2:1 *ratio* of amplitudes set by the pan pot, feeding the two stereo channels, will not change, and the sound—rhythm guitar, synthesizer, etc.—will not budge from left center position. The important thing here is that position on the "stereo stage" is determined by controlling the proportions (*ratio*) of signal applied to the left and right channels. Stereo mixdown is a *coding* of left-right position in terms of *amplitude ratio*.

This is where stereo is now. We are looking to keep this left-right dimension, and add the front-back one, because



The Scheiber 360° Spatial Decoder

if we can do this, we will be in a position to carry in our "stereo" pair of channels not just the usual flat, left-right "wall of sound," but a full 360 degrees of space.

It turns out to be mathematically demonstrable that there is a close analogy between the parameter of *amplitude ratio* in two channels, which is generally controlled in order to place sounds along the left-right dimension of the stereo "wall of sound," and the parameter of *phase difference*, which, in conventional stereo, is not used in a controlled way at all. If we control the amplitude parameter to get left-right placement, and the phase parameter to get front-back placement, then, between the two, we can place sounds anywhere in 360 degrees of space. The mathematical theory behind this phase-amplitude analogy was published in the *Journal of the Audio Engineering Society* in 1971 under the title, "Analyzing Phase-Amplitude Matrices." Essentially, this paper showed that by controlling amplitude in two channels, we get a single left-right spatial dimension, while by controlling amplitude *and* phase, we get a spatial "phase-amplitude sphere."

The upshot is that with stereo, we've become accustomed to using only half the spatial-information-carrying capacity of our "stereo" channel pair. The audio-bandwith pair of channels present on disc and on f.m. broadcast, and probably soon to be on a.m. as well, is capable of carrying 360 degrees of spatial (or directional) information. [Through phase difference/amplitude ratio coding, each of the various signals in a program (not necessarily four) may be assigned a specific position on the phase-amplitude sphere, remaining electrically separated from all other signals in the channel pair to the extent that its spherical co-ordinates (latitude and longitude) differs from the others.] The major challenge—which we're just beginning to meet with success—has been related to making this theoretical surround-space capability of the "stereo" channel pair into the most effective acoustical reality.

The 360° Spatial Decoder was designed on the basis of some quite new positional recovery techniques with the aim of demonstrating a high order of 360 degree localization from two-channel surround-coded program sources, including, notably, disc and f.m. broadcast.

Success of the 360° Spatial Decoder in generating an effective acoustical reality is gauged by the reactions of major audio reviewers, substantially all saying that the unit's audible performance in reproducing SQ-coded program equalled or surpassed what they had previously heard from discrete four-channel sources. However, this represents a misinterpretation of the design goals of the 360° Spatial Decoder. The device was *not* designed to make obsolete the use of four discrete channels for surround sound reproduction. Remember, we are interested in auditory *space*, not in channels. The design aim of the 360° Spatial Decoder is to show how successfully *two* channels (the commonly available stereo pair) may be used to carry the total, 360 degree audible environment.

ADVANTAGES OF CODING 360° SPACE IN TWO CHANNELS

Encoding 360 degree sound space in two channels has many practical advantages from the viewpoint of a spatial medium for the stereo music market. It can be broadcast now, without changes in FCC regulations. And, it doesn't reduce radio audience coverage, as any discrete four-channel system must as a result of the shunting off of a portion of the station's power into additional subcarriers not demodulated by the mono and stereo audiences. When a.m. stereo broadcast is approved by the FCC, which seems more and more inevitable, the coding method will be the only way possible to put surround (left-right/front-back) program on a.m. radio. The encoded quad record is somewhat more rugged than the one existing discrete quad disc, since it contains no extremely fine, ultrasonic modulations, and the dynamic range of the encoded disc is appreciably wider, frequency range slightly wider, and distortion much lower.

A single decoder circuit suffices for both records and surround broadcasts, while the discrete quad system must use a separate circuit for each. In fact, whenever we have a "stereo" pair of channels, we can use it not just for left-right stereo, as we usually do, but for left-right *plus* front-back stereo—that is, 360 degree spatial stereo—through control of phase. This is phase-amplitude coding.

THE CLINCHER

Study of encoding-decoding problems revealed that more spatial information was going on to encoded surround records than we were, so far, able to get off again. Decoding equipment simply did not exist that was capable of retrieving all the positional information being put on the coded records. Audible separation obtainable in playing *existing* surround-coded records would be a function of ongoing improvements in *decoding* technology.

This rather exciting conclusion was soon corroborated by demonstrations of three "super-decoders:" CBS Technology Center's "Paramatrix," the Tate, and the author's 360° Spatial Decoder, the only one of the three so far available. All three demonstrated audible separation in reproducing existing SQ-coded records of a level previously believed by many to be impossible. Technically, all three are based on "parametric" or "cancellation" principles new to the art, and their order-of-magnitude audible performance improvement is in part attributable to the fact that they can achieve full separation without the use of "gain-riding," or turning off of channels.

Priorities in the design of the 360° Spatial Decoder included lower distortion and wider dynamic range than achieved in any other device for the reproduction of surround program from disc; 360-degree positional accuracy and stability, and "smoothness," a term used by my colleagues at the CBS Technology Center to mean that the space and separation appear to be "just there," without any sense of the electronics used to get them. Some circuit features of the device are:

1) Precision components are used as a matter of course —not because a 1 per cent resistor or capacitor sounds different from a 5 per cent resistor or capacitor, but because the 360° Spatial Decoder's design specifications required that the performance of the actual unit exactly conform to mathematical calculations.

For example, the phase shifter networks which form the foundation of the entire device employ 1 per cent capacitors custom-built to values calculated by the author. Only with precise phase control over the entire audio band, can the Spatial Decoder do precisely what the equations call for—with especial reference to accuracy and stability of sound source placement.

2) Positional sensing is by the precise axis-crossing (phase comparator) method.

3) Phase detection is based on a modified Fletcher-Munson curve instead of the simple high pass that is quite satisfactory in consumer-grade devices.

(4) The basic SQ matrix used in the 360° Spatial Decoder has been re-calculated for sharper side image localization. An additional benefit of this is that there is a more in-phase relationship among the sounds radiated by the four loudspeakers, resulting in a subtle, but perceptible quality of "smoothness" or "fullness" of bass characteristic of the instrument.

5) The 0.05 per cent distortion specified for the Spatial Decoder refers to intermodulation, and is a conservative rating (most units test around 0.02 per cent). Unlike any other decoding equipment, this figure is contributed almost entirely by class A, f.e.t. circuitry which determines the basic sound quality of the unit; conventional (bipolar) transistors account for less than 0.1 per cent.

6) The Spatial Decoder achieves a 90+ dB dynamic range. This is the widest range of any genuinely functioning quadriphonic disc or broadcast reproducing equipment. In my own record listening, I use an audiophile phono preamplifier known for exceptionally low noise. With no record playing, listening through the Spatial Decoder, it is possible to hear a faint hiss in a quiet room. But if the volume control on the preamp is turned down, the hiss level reduces considerably, even though the Decoder is still wide open. Most of the audible noise is generated by this preamplifier known for its quietness, and not by the Decoder!

7) Perhaps the most important difference in the audible output of the 360° Spatial Decoder is the most difficult to explain because it deals with a technological challenge new in the audio art: every decoder must recognize genuine positional information among the welter of random-phase relationships of musical program material. In comparison with other "super-decoder," the Spatial Decoder has a fuller array of mechanisms for discriminating against phase error information. The audible result has been described as a "smoothness"—a sense that spaciousness and 360 degree sound source localization are "just there," without any awareness of the electronic means used in achieving them.

WHAT NEXT?

One of the most rewarding aspects of studying the ability of two audio-bandwidth channels to carry 360 degrees of spatial information with audible success is that each performance advance has started out from a level generally believed to be incapable of being exceeded. And, that *existing* 360 degree spatial programs phase-amplitude coded in two channels can be reproduced with ever-improving spatial precision as decoding techniques continue to be refined. Programmable digital filtering and multiplexing techniques suggest the possibility of independent decoding of substantially every Fourier (frequency) component of every directional signal in a coded surround program. The 360° Spatial Decoder exemplifies what we can do today.

Who needs four channels? I've heard some great spatial sound reproduced via four discrete channels; my own preference has been to investigate the potential inherent in phase-amplitude coding 360 degrees of auditory space in the two channels that we already have. Through control of phase information, the "stereo" pair of channels can carry not only a flat, left-right wall of space, but a full 360 degrees of surround space. We've been wasting half the spatial information capacity of our pair of channels. Let's put it all to use. ■