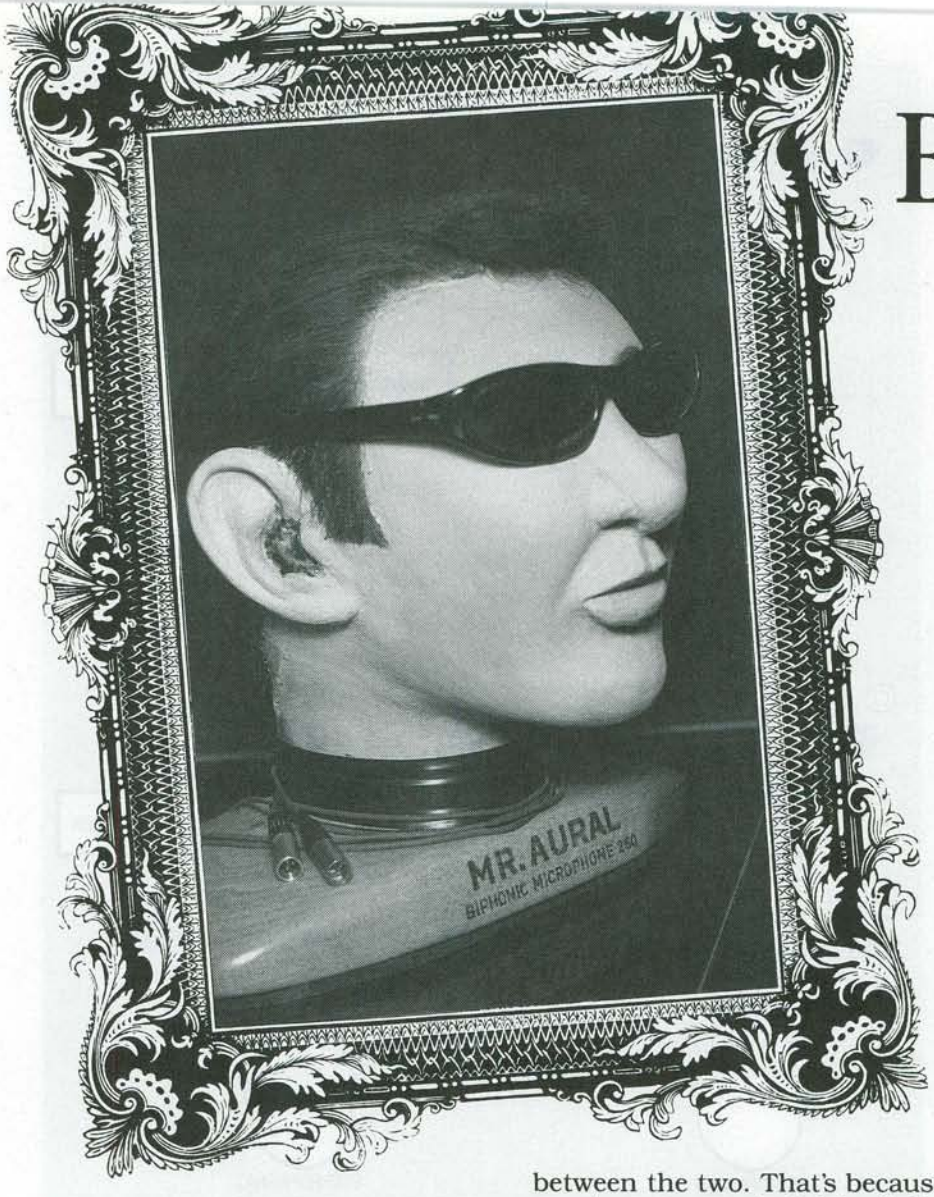

BINAURAL BASICS

Binaural recordings will add a new dimension to your audio world.

JOHN SUNIER

ALTHOUGH MOST AUDIOPHILES ARE familiar with the term binaural, there's still quite a bit of confusion about it. Early in stereo history the terms binaural and stereo were used interchangeably, even though the two recording methods are totally different. Recording pioneer Emory Cook caused some of that confusion by calling his early 50's twin-grooved stereo LP's binaural when they were actually stereo.

Binaural recordings can open up a whole new realm to your listening enjoyment. We'll look at the history behind binaural sound and how it is made as well as present some high-quality binaural products.

The binaural difference

If you listen to a stereo source from stereo headphones compared to the same source listened to from loudspeakers, you'll notice a much different sound between the two. That's because most source material isn't designed for headphone listening. An unnaturally exaggerated effect is created with headphones, as though half an orchestra is on one side of your head and the other half on the other side, with a hole in the middle. Also, the music sounds as if it's happening inside your head rather than out in the room. No serious record producer would ever monitor a recording session solely on headphones; a proper setup of the highest quality monitor loudspeakers is required to get a feeling for proper balance in the mix.

Binaural background

True binaural uses only two microphones, usually small electret condensers either set into the outer ears of an artificial human head, or at least spaced the same distance apart as an average pair of ears, and mounted on either side of a small baffle. The two mikes feed two channels which are kept entirely separated from the source all the way to the final listener, whether live, a recording, or a broadcast. The listener wears stereo headphones and the original left ear signal must be routed properly to the left ear and the right to the right or the effect is compromised. The final result is for the listener to be sonically transported to where the sounds originated, rather than attempting to bring the sounds into the listener's room as with speakers. The left speaker signal is prevented from feeding into the listener's right ear, and vice versa, with binaural playback on stereo headphones. Figure 1-*a–d* shows various types of sound reproductions, including binaural.

With binaural recording, spatial placement within a 360-degree sphere is so realistic that even vertical placement is perceived. Reproduction of the ambience or reflected sounds in a hall is so correct that acoustical engineers can listen to such tapes and identify in which hall they were recorded. The only areas of location that are sometimes problematic are on a line directly in front of and to the rear

of the listener. That is dependent on several factors, including how our hearing mechanism works, differences in headphones, and individual differences as well as learned responses.

Binaural history

The first use of binaural sound occurred in 1881 in Paris. Inventor Clement Ader mounted a series of primitive carbon telephone transmitters along the front of the stage of the Paris Opera House. The transmitters were grouped in pairs the same distance apart as human ears, with several pairs across. The leftmost of each pair were mixed together and fed to one telephone line, which listeners in their homes directed to their left ears using the ordinary phone earpiece. The rightmost of each pair were also mixed together and fed to a second phone line, which each listener had to have installed in their home. The result was that as opera singers moved about the stage, home listeners could "see" their movement while hearing the music with much greater fidelity than a single phone line could possibly provide. The original patent says "This double listening to sound... produces the same effects on the ear that the stereoscope produces on the eye." It's fortunate that a wide frequency response is not the most important parameter for conveying the binaural effect; phase accuracy and correct balance between the two channels is more important.

A similar project was carried out with an improved version of the Ader experiment in Berlin in 1925. During that same year more than one radio station in the U.S. did experimental binaural broadcasts using two different frequencies. Listeners needed two crystal sets, each feeding a separate earphone. The mikes in the studio were kept about seven inches apart, and therefore listeners with only one radio still heard a normal signal.

During the last 40 years there has been sporadic interest in binaural reproduction around the world, centered primarily in Europe and Japan. In 1970, *Stereo Review* issued a binaural demonstration LP of music and sound effects using the "Blue Max" dummy head, which was handmade for the project. Music excerpts from it are still currently available on a pre-recorded cassette. The Sennheiser microphone/headphone people in Germany issued a series of 45-rpm binaural demo recordings (long out of print now), which were well done and designed to promote their open-air phones and special binaural mike system. Diagrams of the placement of musicians and sounds around the listener aided in evaluating how precise the effects were.

One demo in particular was interesting. It featured a woman arriving on a train and being met by a man at the station. Placed among all the sound effects of the train, people, and station environment were the voices of the woman, speaking English, and the man, greeting her in German. Eventually they meet in front of the listener. All the while you can easily focus on either the German or the English and understand perfectly without serious distraction from the other voice, as would occur with stereo sound and certainly with mono reproduction.

This very functional use of binaural is currently being applied to military aircraft communication by researchers at the NASA-Ames Research Center. They use a powerful computer known as the Convolvotron to process mono speech and signals from several sources, such as control

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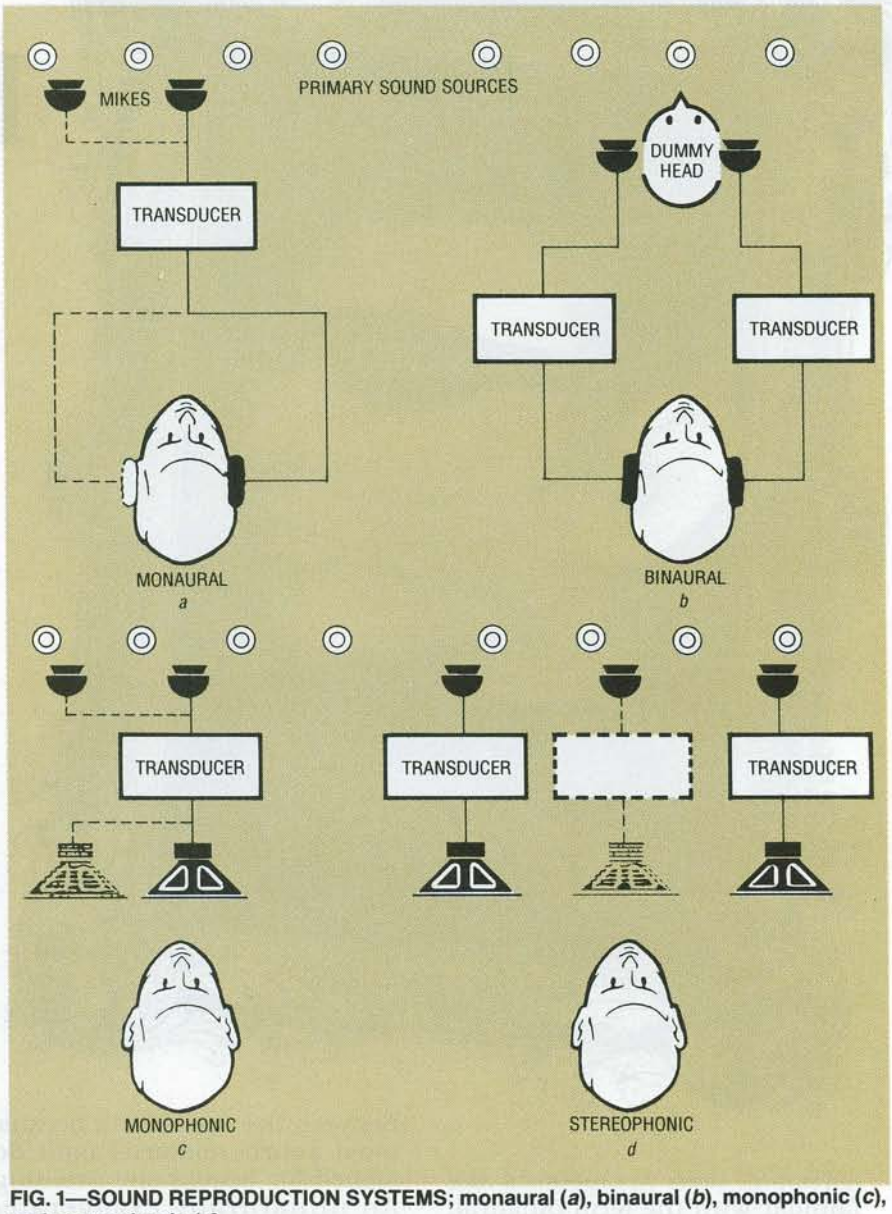

FIG. 1—SOUND REPRODUCTION SYSTEMS; monaural (*a*), binaural (*b*), monophonic (*c*), and stereophonic (*d*).

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towers and other aircraft, and assign them places in a 360-degree sphere so that pilots wearing stereo headphones can "steer" their binaural hearing to the voice they need to hear and ignore the rest. A demo tape mixed those artificial binaural voices into a loud background of helicopter noise and contrasted the very intelligible result with the same signals in both mono and stereo.

Much research is currently being done on the human hearing mechanism and the broad field known as psychoacoustics. Product approaches being promoted, such as Hughes SRS and Q Sound, are an outgrowth of that work. Those systems attempt to offer a binaural-like surround localization with loudspeakers rather than stereo headphones, and only a pair of them at that. With proper source material, mixing, and proper

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placement of the listener in the "sweet spot," those approaches can be quite convincing. When optimum criteria are not met, they can also sound worse than poor mono, and even at their best, they don't equal a good true binaural recording on good headphones.

There is one highly successful speaker approach that can be used with any binaural recording. It is the Binaural Panorama circuit included with the normal ambience, reverb, and Dolby Surround features of the Lexicon CP-1 and CP-3 Digital Audio Environment Processors. Correction of the "trans-aural" signals of the left speaker sounds reaching the right ear and the right speaker sounds reaching the left ear are at the heart of this speaker system. An adjustable delay line sends the properly correlated cancellation signals to each ear, something like Carver's Sonic Holography or Polk's SDS, but is more sophisticated and freer of the "phaseyness" of those approaches. One does have to sit in quite an exact sweet spot. Although it works well with only a pair of speakers, the addition of another matching pair in the rear, being fed a simple L – R signal improves the effect even further. With practice (some of this is a learned response too) the listener can even clearly image sounds to the rear and far sides, as well as vertically.

The crux of the matter is that just as some people have trouble

THE BINAURAL SOURCE

For a free binaural catalog, write to The Binaural Source, Box 1727RE, Ross, CA 94957 (415) 457-9052 PST.

For a schedule, program listings, and station network information on *AUDIOPHILE AUDITION* write to Box 1621, Ross, CA 94957. Enclose a number-10 self-addressed stamped envelope plus $1 or four 20-cent stamps for postage and handling.

If you would like to know more about local radio stations carrying *AUDIOPHILE AUDITION*, call John Sunier at (415) 457-2741 PST.

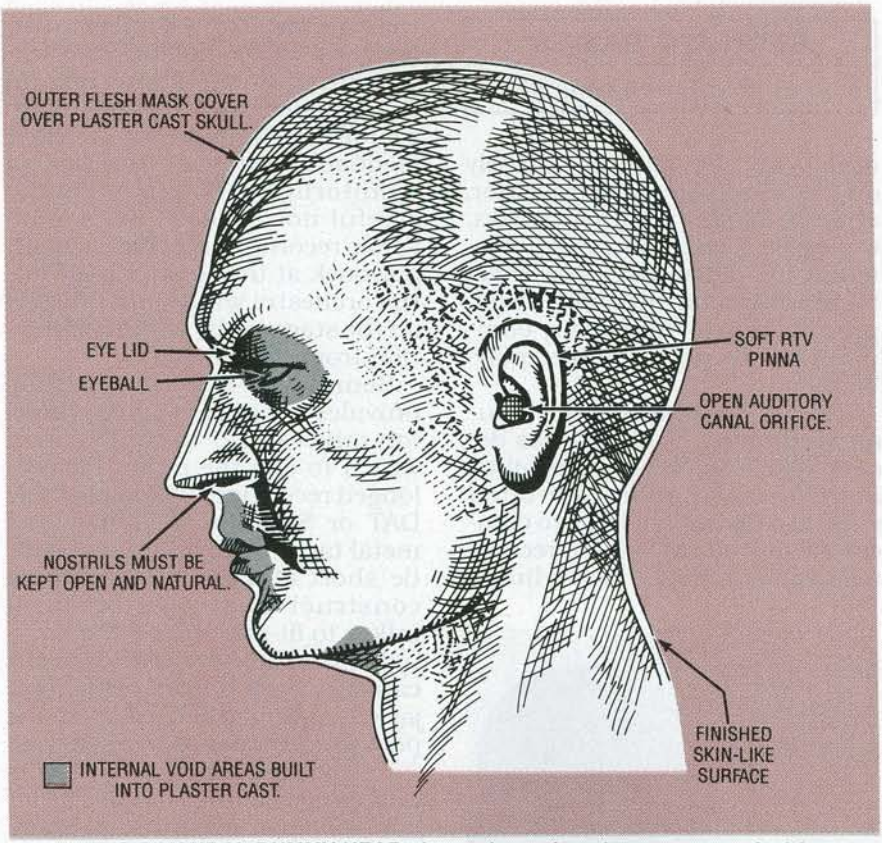

FIG. 2—THIS BINAURAL DUMMY HEAD shows the various human anatomical features that affect sound perception. The mikes are fitted into the auditory canal. All parts shown, including the cranial cavities, ocular structures, nose, skin, and teeth are constructed simulate the human head as closely as possible.

seeing depth when looking at 3D images, some also have trouble experiencing the full binaural effect of being transported to where the sounds originated, rather than attempting to have them brought into your listening room. The pinna, or outer ears, are a vitally important part of the hearing mechanism. A number of researchers have shown how the shapes, bumps, and grooves in the ears control human location of sounds in space.

Binaural dummies

When designing binaural heads for recording, the problem of differing widths between people's ears must be considered. Women's ears, for example, are generally closer together than men's. Therefore, a median distance for the mikes on the dummy head must be chosen and it is not totally accurate for many people. If the mikes are too close together, there will be a reduced binaural realism; if they are too far apart it will be exaggerated or more likely to increase the normal difficulty of imaging sounds directly in front and in back.

One binaural developer, Ron Cole, improved the weak frontal location often experienced with binaural by designing his "Biophonic" dummy heads with exaggerated features on the front of their faces. He also experimented with using real human skulls (obtained from a medical supply house). However, he found that great variations in the shape of real skulls were a problem and switched to plastic and plaster materials. Figure 2 shows one such dummy head, revealing physical characteristics that affect sound reproduction.

There are two professional standard dummy heads used for most commercial binaural recordings available today, and others used primarily in research. The best known is the Neumann KU-81i, which is made of hard dark gray rubber and has condenser mikes sunk into the head. The other is the more complex and even more expensive Aachen Head, also like the Neumann developed in Germany. It comes in two models; one with more detailed features than the

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other—in fact patterned closely on the actual ears of its inventor, and the head of another person. Complex equalization circuits attempt to achieve the most exact binaural localization with headphones while retaining compatibility for loudspeaker playback.

The "i" upgrade of the Neumann dummy head also was designed for speaker compatibility. Both of those mikes are often used in a manner similar to coincident normal mikes for recordings to be released as ordinary

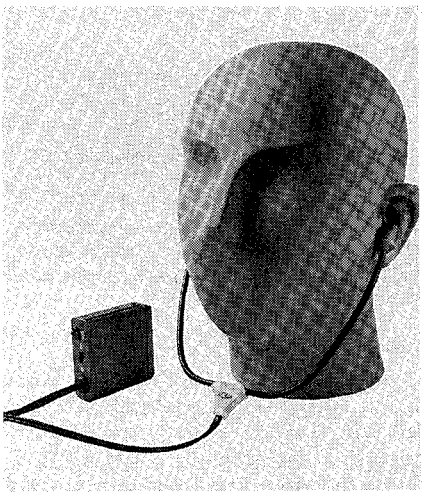

FIG. 3—PHOTO OF THE SENNHEISER MKE 2002 stereo head microphone.

stereo. Sometimes they are used in conjunction with other non-binaural mikes in multi-mike pickups. Of course the speaker playback of compatible binaural recordings will not have the binaural effect (except for the Lexicon circuit mentioned above), but some recording engineers feel that even for stereo playback the Neumann or Aachen heads produce a more natural pickup than any other type of purist mike approach.

Although Sony, JVC, and some other manufacturers have had inexpensive binaural headphone/mike combination units for home recording, those are no longer available. Sennheiser, however, still manufacturers their MKE 2002 binaural mike set, shown in Fig. 3, which sells for about $500. It clips onto the wearer's own ears, similar to airline earphones, and achieves excellent results. There are no headphones, and thus no compromising the bass end to avoid feedback, but also there is no monitoring. One must also be careful not to move one's head when recording a concert, or in playback at that point or the entire orchestra will seem to shuffle off the stage in the opposite direction from the listener!

Sennheiser also thoughtfully provides a simple dummy head for mike stand mounting, on which to clip the mikes for prolonged recording. With a portable DAT or Sony Pro-Walkman and metal tape, the results can be little short of astounding! Others construct their own binaural mikes to fit into their outer ears, using inexpensive mini-electret capsules with a foam and fabric jacket, powered either from the portable recorder or by a separate 9-volt battery. Another option is attaching the mikes to the headband of a pair of earmuffs. There are also two commercially available mike sets that clip to the temples of one's glasses. You should be aware, however, that although these approaches make use of the baffle effect of both the head and even the shoulders, neither includes the effect of the pinna of your ears, so the final results will not have the full binaural realism.

To the problems of individual hearing differences must be added the tremendous variety in specifications of stereo headphones. Headphones that sound fine for stereo will not necessarily achieve the best binaural effect. No headphones on the market at the moment are equalized to perfectly match the average listener's hearing, or for that matter, the equalization of the particular dummy head used for recording or broadcasting. The Stax Lambda Pro and Signature electrostatic headphones have been used by many researchers because their frequency response and phase accuracy is the closest to the ideal available. In fact, an additional optional equalizer box (priced at $800) is offered by Stax, to match even more closely the parameters of the specific headphones to binaural recording reproduction. Stax calls their

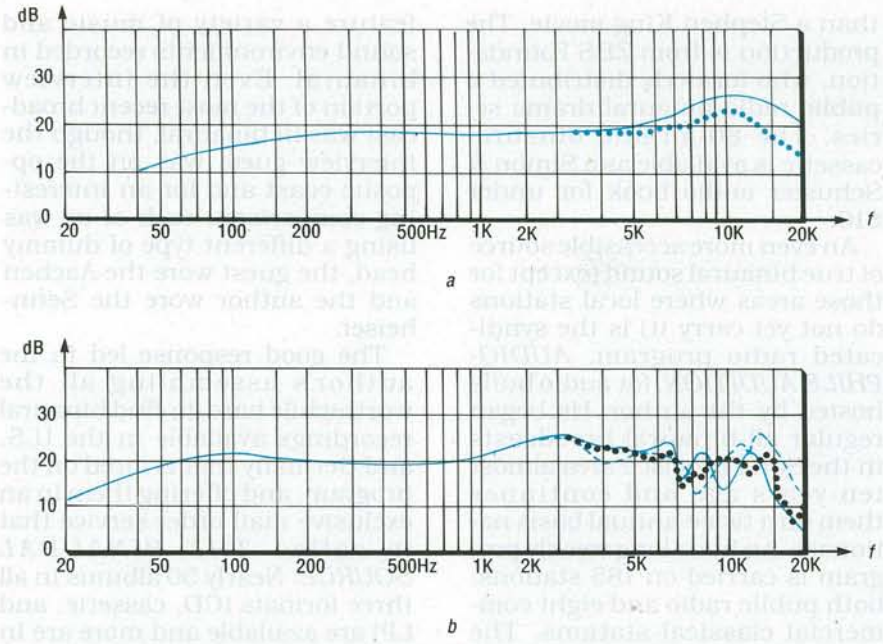

FIG. 4—REPRODUCED SOUND PRESSURE at the ears of various test persons; the MKE 2002 is shown in the free-sound field (*a*), with the open headset HD 424, measured at a reference point with a probe microphone Bruel & Kjaer 4138. Continuous lines indicate a 0-degree reference, dashed lines represent a 90-degree reference.

phones Semi-Panoramic Sound Electrostatic Earspeakers. The idea is to take the sound field out of confinement to the inside of the listener's head and make the sounds appear realistically out in space. Some peoples' ear-brain interface does a better job of this than others, but the headphone design is definitely a factor. Figure 4-*a* shows the frequency response of the Sennheiser MKE 2002 microphone compared to the response of a Bruel & Kjaer 4138 (Fig. 4-*b*). As you can see, the latter microphone produces higher sensitivities in the ears of test persons in the range of 5 Hz to 15 kHz.

Don't think that the electrostatic principle in headphones is inherently superior for binaural listening. Some expensive headphones—both electrostatic and dynamic—compromise the effect. One of the worst is the Consumer Reports-recommended Sony MDR-V6 dynamic. Yet a number of other Sony phones (they are frequently changing models) in the $100 area are excellent for binaural. If you can find a used MDR-M77 you will have a terrific dynamic phone for binaural for about $40.

The earspeaker idea is taken all the way by the headphones from Jecklin and AKG's new K 1000. They position small earspeakers on your head without even touching your ears, and thus make use of the natural pinna so that your own unique direction-locating system can function to its fullest, working on the signals that come in from the headphones.

The Jecklins are available in both electrostatic and dynamic versions. Those two manufacturers considered binaural reproduction seriously in the design of their phones. (Most of the German manufacturers do.) In the author's personal experience, the K 1000's are the most natural-sounding phones for binaural reproduction.

A wonderful side benefit of this is that ordinary stereo's hole-in-the-middle when heard on headphones is seamlessly filled in. Just as with large loudspeakers, some of the delayed left channel signal comes around one's head to the right ear, and vice versa with the left ear receiving the delayed right channel signal. More muscle than a headphone jack provides is needed to power the elements of those phones; a separate power amp should be used and AKG even urges it be a Class A circuit; a bit extreme. The other drawbacks of both the AKG's and Jecklins' is that any-

one else in your vicinity can still hear the sounds.

In more conventional dynamic headphones, the top-of-the-line Sennheiser models HD 560 and 540 are excellent for binaural, as are the top-of-the-line Beyer phones. Joseph Grado has a new handmade high-end Signature headphone, which is also highly successful in preserving accurate binaural localization.

The easiest and least expensive way to get your own startling binaural demo tape is to walk into most any chain bookstore and head for the "talking books" section. Stephen King's *The Mist*, provides one of the most astonishing introductions to binaural that is available anywhere. It features 35 actors and is one of the most detailed radio dramas ever produced. Monsters were created by putting various live animal sounds into a sampling synthesizer and playing them on the keyboard. When heard on headphones in a comfortable chair in the proper setting, such as at night with the lights out, the results can be even scarier than a Stephen King movie. The production is from ZBS Foundation, who formerly distributed a public radio binaural drama series. The 80-minute binaural cassette is available as a Simon & Schuster audio book for under $10.

An even more accessible source of true binaural sound (except for those areas where local stations do not yet carry it) is the syndicated radio program, *AUDIOPHILE AUDITION*, for audio buffs hosted by the author. He began regular all-binaural broadcasts in the San Francisco area almost ten years ago and continues them on a twice-annual basis nationally. An hour-long weekly program is carried on 185 stations, both public radio and eight commercial classical stations. The majority of stations carry its mix of classical, jazz, and interviews with personalities in the audio field "live" directly off the National Public Radio satellite Sundays at 2 PM Eastern Standard Time. (See box on page 86 for details on obtaining more information.)

The author's binaural specials feature a variety of music and sound environments recorded in binaural. Even the interview portion of the most recent broadcast was in binaural, though the interview guest was on the opposite coast and for an interesting comparison, each of us was using a different type of dummy head, the guest wore the Aachen and the author wore the Sennheiser.

The good response led to the author's assembling all the worthwhile hard-to-find binaural recordings available in the U.S. and Germany that is aired on the program, and offering them in an exclusive mail order service that is called *THE BINAURAL SOURCE*. Nearly 50 albums in all three formats (CD, cassette, and LP) are available and more are in production from several different record labels. Radio dramas, sound environment recordings, and a variety of music are featured, including the author's own Binaural Audition one-hour sampler cassette, which provides a useful introduction to this whole new sonic universe. **R-E**