Basic Stereo Microphone Perspectives—A Review*

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This paper is a review of the methods used for creating illusions in stereo, with common configurations utilizing two, three, and four microphones. It presents the placement and type of microphones used for each configuration, and discusses their basic characteristics, advantages, and disadvantages. All of the techniques discussed have produced satisfying results. The use of a particular technique will depend on circumstances: the sound source, the recording environment, the desired effect, and the release format.

0 INTRODUCTION

Early acoustical recordings were made using a single-point pickup system. Later, electrical recording made multiple-microphone pickup techniques possible, and eventually encouraged the development of multichannel sound.

During the 1930s, researchers, such as Alan Blumlein in the United Kingdom and Arthur Keller and Harvey Fletcher of Bell Laboratories in the United States, independently experimented with stereo disk recording. The first commercial use of multichannel sound was the Disney Studio's production of "Fantasia" in 1940. Unfortunately for theaters that invested in this interlocked dual-system format, "Fantasia" was the only product released.

Various multichannel sound formats reappeared in the 1950s. Cinema was the first, followed soon by home consumer formats in tape, disk, and radio broadcast.

Initially, the 45/45 stereo disk was perceived as such a wonderful advance—and the corresponding product was in such short supply—that *anything* would sell. As more product became available, and as listeners and their equipment became more sophisticated, the quality of these recordings came to be a factor influencing long-term sales.

Classical music is most often identified as being a long-term money maker. However, a wide range of music from acoustical folk to Pink Floyd also fits that category. Sheffield Records' reintroduction of the direct-to-disk recording technique, and Mobile Fidelity's "Original Master" series have shown that there is an enduring market for quality product. The discreet use of simple microphone techniques is often found among these long-term best-selling recordings.

Accurate stereo imaging is the foundation for the art of stereo recording. Experience with the basic techniques and knowledge of their attributes are essential for anyone working in stereo formats.

The *art* of recording lies in manipulating illusions. The *science* of recording involves the tools and techniques used to create these illusions.

This paper is a review of the "how" of creating illusions in stereo. It describes the common stereo con-

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figurations which utilize two, three, and four microphones. It presents the placement and type of microphones used for each configuration, and discusses their basic characteristics, advantages, and disadvantages. All of the techniques discussed here have produced satisfying results. The use of a particular technique will depend on circumstances: the sound source, the recording environment, the desired effect, and the release format.

Some formats, for example stereo cinema and broadcast, impose constraints, such as the need for a predictable mono/stereo relationship. Other formats have their own particular demands. The important thing is that the perspective be appropriate to the format—whether it be track building on a record album or the transience of a live broadcast. Creative use of the appropriate technique is the hallmark of the master of a craft.

1 TWO-MICROPHONE TECHNIQUES

1.1 Coincident Techniques

Coincident or "intensity stereo" techniques are achieved with a pair of directional microphones, most often vertically aligned on a common axis, and set at an angle to each other in the horizontal plane (Fig. 1). Thus there is minimum time (phase) difference between the two capsules for sound sources on the horizontal plane. Properly done, this style relies solely on intensity differences between the two signals for directional cues. The choice of the microphone pair's polar pattern can vary from subcardioid to bidirectional, depending on the specific technique being implemented. The angles formed by the microphone pair are typically symmetrical about the centerline of the sound source, and the included angles discussed in this paper are the total angles between the axes of the microphones.

An advantage of intensity stereo is that the angular accuracy of the stereo imaging is unaffected by the distance of the microphone pair from the sound source. A disadvantage is that without the interchannel time delay common to some other miking techniques, the stereo image sometimes seems lacking a "sense of space."

1.1.1 *XY* Cardioids and Hypercardioids

The microphone pair is typically set at an included angle of between 60 and 120°. The specific angle chosen determines the "apparent width" of the stereo image, and the choice of this angle is subjective, with consideration given to the distance of the microphone pair from the sound source, the actual width of that source, and the polar pattern of the microphones. A critical factor to consider when using these techniques is this polar response. As the individual microphones are oriented at an angle to most of the sound source, considerable off-axis coloration is possible. As with any stereo technique, the microphones comprising the pair should have as good a polar response as possible. Further, they should be closely matched with regard to polar and frequency response, since any differences will cause the image to wander with changes in pitch.

1) *Cardioid microphone*. Use of cardioid microphones is common in coincident techniques, typically with an included angle of 90–120°, and placed fairly close to the sound source (Fig. 2). Often the axes of the microphones are aimed at a point near the extremes of the sound source. As the direct-to-reverberant-sound ratio of this approach is high, this can offer some rejection of unwanted sound from the rear of the pair. Sometimes a distant pickup with a large reverberation component is desired. In such circumstances, included angles as large as 180° may be employed.

2) *Hypercardioid microphone*. Using a hypercardioid pair is similar to using cardioids, except that the included angle is typically narrower to preserve a solid center image (Fig. 3). The increased reach of the hypercardioid allows a more distant placement for a given direct-to-reverberant-sound ratio. With their small reverse-polarity lobes, using hypercardioids is a good compromise between implementing *XY* with cardioids and the Blumlein technique.

1.1.2 Blumlein

The "crossed pair of figure of eights" is the earliest of the *XY* techniques, and is configured with two bidirectional microphones, oriented at an included angle of 90° (Fig. 4). It was developed in the early 1930s by British scientist Alan Blumlein and was presented in his seminal patent [1].

One attribute of this technique is that the rear lobes of these microphones record the rear 90° quadrant in

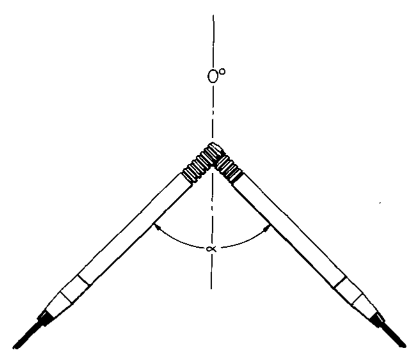

Fig. 1. Coincident *XY* microphone pair.

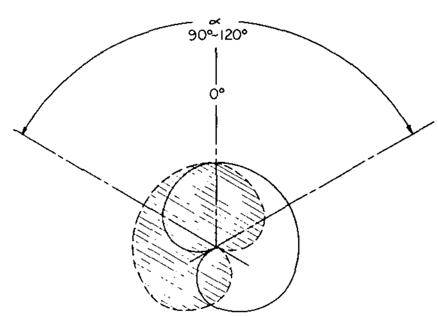

Fig. 2. *XY* cardioid pair.

phase but out of polarity, and place this into the stereo image (cross channeled) together with the front quadrant. Signals from the two side quadrants are picked up out of phase. Placement is therefore critical in order to maintain a proper direct-to-reverberant-sound ratio and to avoid strong out-of-phase components. Typically, this technique works very well in a wide room or one with minimal side-wall reflections, where strong signals are not presented to the side quadrants of the stereo pair. It is often commented that this configuration produces a very natural sound.

1.1.3 MS Stereo

This form of intensity stereo—one variation of which is detailed by Blumlein in his patent [1]—uses one microphone (the M or midcomponent) aimed directly at the centerline of the sound source and another, a bidirectional microphone (the S or side component), oriented laterally (Fig. 5). Their outputs are processed by a sum and difference matrix network, which resolves them into conventional *XY* stereo signals, (M + S) and (M − S). The left/right orientation is determined by the direction of the positive lobe of the S microphone.

An advantage of this system is that it provides absolute monaural predictability: when the left and right signals are combined, the sum is solely the output of the M component: (M + S) + (M − S) = 2M. By judicious choice of polar pattern and placement of the M microphone, the monaural signal can be optimized. Conveniently this pickup is by definition on axis to the midline of the sound source and suffers minimally from off-axis coloration. The S component (the bidirectional microphone), with its null plane bisecting the sound source, provides more reverberant information than the M component. As it is generally desirable that there be less reverberation in a monaural signal than in stereo, there is a built-in advantage to MS in that it automatically has a less reverberant character when summed to mono than in its stereo image.

Finally the MS technique offers the mixing engineer greater control of the stereo image from the mixing desk than is available with any other technique. By changing the pattern of the M pickup (using a remote-pattern microphone), the apparent distance from the sound source—and the amount of ambience inherent in the M signal—can be adjusted. Further, by varying the M-to-S ratio in the sum and difference matrix, the apparent width of the stereo stage can also be adjusted (Fig. 6). This adjustment can be made either during the original recording session or later, during a post-production session [2].

1.1.4 Coincident Omnidirectional Microphones

This technique was developed by Ron Streicher for use as a soloist pickup. Since most omnidirectional microphones exhibit directionality at higher frequencies, configuring a pair of omnidirectionals at an included angle of 60–90° provides a stable, coherent center image combined with a sense of stereo space. Further, there will be little sense of image shift as the soloist moves, as is the case with directional microphones. The use of pressure capsules also eliminates the proximity effect and breath blasting problems associated with gradient microphones.

1.2 Near Coincident Techniques

This term is used by Wes Dooley to describe that class of techniques where a microphone pair is placed close enough together to be substantially coincident for low frequencies, yet is far enough apart to have an appreciable time delay between channels for sound sources located to the far right and left. These techniques otherwise differ little from coincident microphone configurations, except that the stereo imaging results from differences in both intensity and time (phase).

The value of these techniques is that they exhibit good localization combined with a sense of depth. Close miking is not recommended using these techniques, since small movements of the sound source can produce

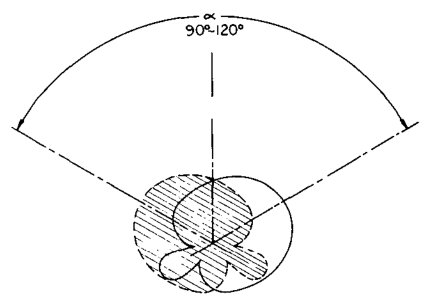

Fig. 3. *XY* Hypercardioid pair.

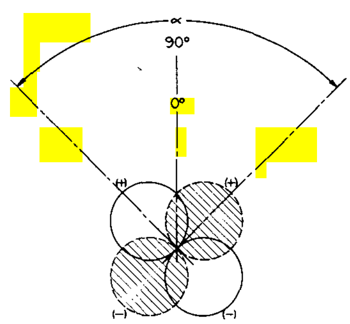

Fig. 4. *XY* crossed figure of eights (Blumlein).

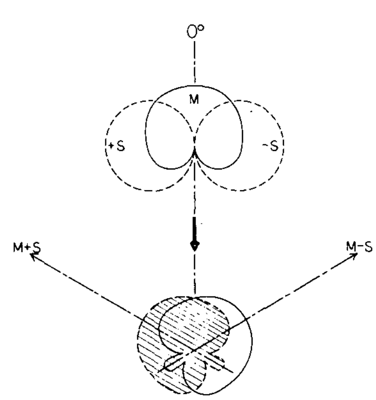

Fig. 5. MS conversion to *XY*.

large image shifts. Sounds arriving from the far left or far right can also create problems for disk cutting or monaural summation due to interchannel time delay.

1.2.1 O.R.T.F.

Named for the French National Broadcasting Organization (Office de Radiodiffusion-Télévision Française), this configuration consists of two cardioid microphones, oriented outward from the centerline of the sound source with an included angle of 110° and with a capsule spacing of 17 cm (Fig. 7).

1.2.2 N.O.S.

Adopted by the Dutch Broadcasting Organization (Nederlandsche Omroep Stichting), this standard consists of two cardioid microphones, oriented outward from the centerline with an included angle of 90° and a capsule spacing of 30 cm (Fig. 8).

(*Note*: A variety of people and organizations have their own proprietary variations on these techniques. Choices of pickup pattern, spacing, or included angle have all been altered. Be willing to experiment with variations, as did Tony Faulkner.)

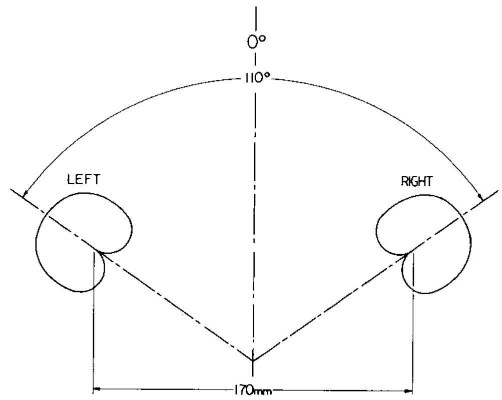

Fig. 7. O.R.T.F. configuration.

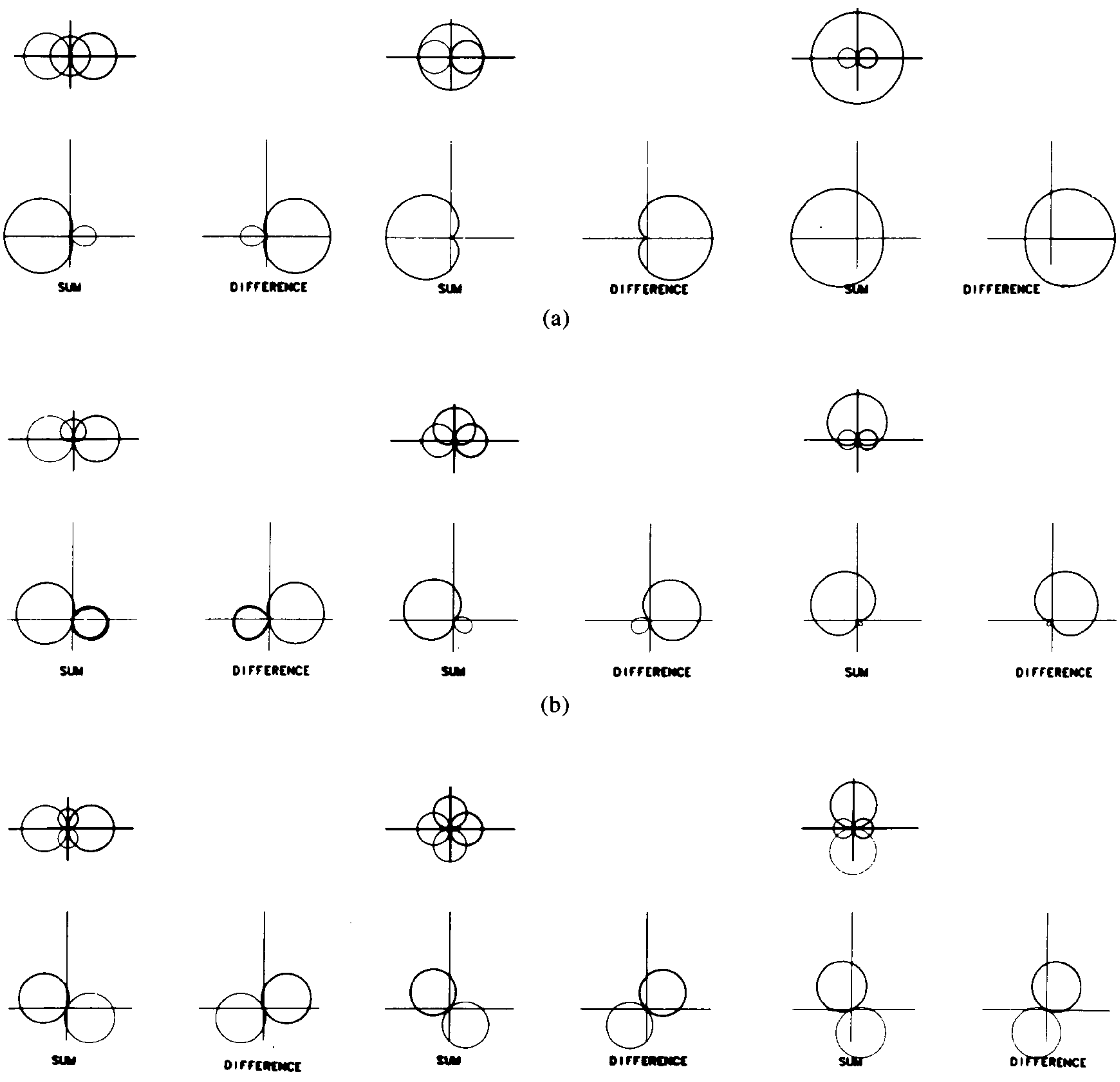

Fig. 6. MS to equivalent *XY* transformations for M-to-S ratios of 30:70, 50:50, and 70:30. (a) Omnidirectional M component. (b) Cardioid M component. (c) Bidirectional M component. (From [2].)

1.2.3 Faulkner

Developed by British recording engineer Tony Faulkner [3], this configuration uses two bidirectional microphones facing directly forward toward the sound source, spaced 20 cm apart (Fig. 9). This technique combines much of the coherence of the Blumlein technique with the "openness" afforded by the time (phase) differences resulting from the spacing between the microphones. In addition, his recommendation that the microphone pair be placed farther back from the sound source than is common with other coincident techniques provides a more natural balance between the near and more distant elements within that sound source.

1.2.4 Binaural

This technique is intended specifically for playback via headphones. It is often configured with two omnidirectional microphones placed into the ears of a dummy head to simulate the sound received at the ears of a listener. This technique can be quite realistic, providing a good illusion in both the horizontal and the vertical planes. (Unfortunately these illusions do not translate as well to loudspeaker playback.)

Similar techniques have been configured with two omnidirectional (or even bidirectional) microphones placed approximately 3–4 in (75–100 mm) on either side of a sound-absorptive baffle (Fig. 10). This results in a pickup similar to the binaural method, and it provides sufficient cross-channeling information to allow for reproduction over loudspeakers as well.

1.3 Spaced Techniques

Spaced microphones were the first configuration known to relate a stereo image [4]. Generally these techniques employ two (or more) microphones set symmetrically along a line that is perpendicular to, and bisected by, the midline of the sound source. The polar pattern of the stereo pair, their spacing, and their distance from the sound source are all variables within this style. Stereo information in these configurations is created by the differences in both amplitude and time of arrival of the sound wave. A characteristic of this approach is that positional information will radically change as the distance to the sound source varies. Extremely distant sounds can present negligible directional cues to the listener.

When using spaced microphone configurations, special attention must be given to the following potential problems: 1) low-frequency comb filter effects on sound sources to the extreme left or right of the sound stage, 2) vague center imaging, and 3) erratic monaural compatibility.

With these techniques placement and aiming are the essential elements of the art, and as with all stereo recording, a stereo phase-monitor oscilloscope is a very useful setup and monitoring tool. Formulas for spaced microphone layouts have been widely published, and variations on these recommendations are often employed, necessitated by the physical or aesthetic needs of the recording environment [5].

1.3.1 Spaced Omnidirectional Microphones

Typically this style is realized with two (or three) microphones. Common spacings are from 2 to 10 ft (0.6–1 m) on either side of the centerline. The spacing is determined by the the width of the sound source and the distance of the microphone pair from it. A general rule is that the microphones should be placed one-third to one-half the distance from the centerline to the outer edge of the sound stage (Fig. 11).

When omnidirectional microphones are used, there is a good general sense of the acoustic space, coupled with the pressure pickup's outstanding—if sometimes overpowering—low-frequency response. Wind noise problems are generally eliminated, although very-low-

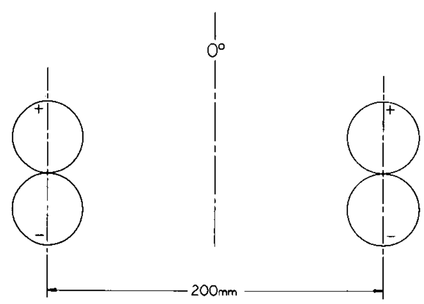

Fig. 9. Faulkner configuration.

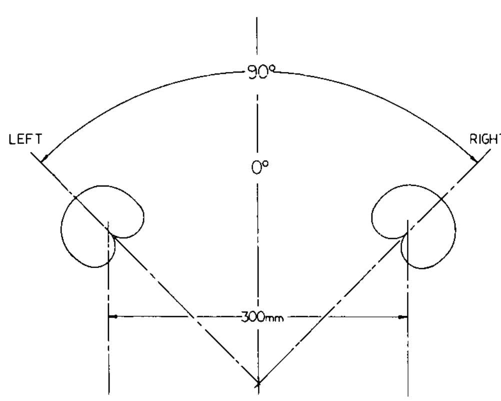

Fig. 8. N.O.S. configuration.

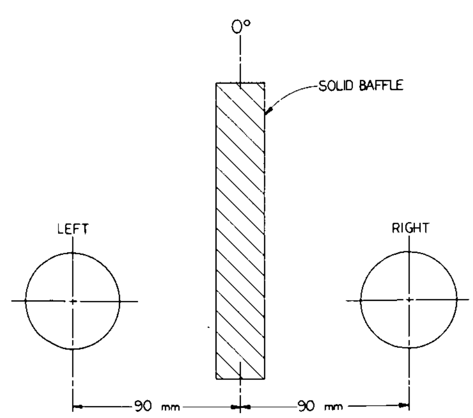

Fig. 10. "Quasibinaural" configuration.

frequency sounds, such as air conditioning or traffic noise, are well recorded.

Omnidirectional microphones are designed to be either flat to an on-axis sound source (free field) or flat to a reverberant sound field (random incidence). In the latter case, the on-axis frequency response will be tipped up at the high end. Experimentation with their axial orientation to the sound field can therefore be productive. Omnidirectional microphones require the closest placement to the sound source for a given direct-to-reverberant-sound ratio of any polar pattern, and have the maximum potential for pickup of undesirable sounds from the environment. Under the best circumstances, their sound can indeed be very open and sensual.

1.3.2 Pressure Boundary Microphones

Ed Long's experiments with boundary-surface mounted transducers, and the subsequent commercial success of this work, have given rise to several "new" microphones, the most widely used of these being the "Pressure Zone Microphone"[1] (PZM) [6].

Use of these microphones for stereo recording is similar to using spaced omnidirectional microphones in that their polar pattern is hemispherical about the boundary surface. When baffles are employed to shape this pattern, they may then be treated similarly to spaced cardioid microphones.

Experiments have been done simulating some of the conventional coincident and near-coincident techniques utilizing such microphones [7].

1.3.3 Spaced Cardioid Microphones

This style is similar to spaced omnidirectional microphones, as described above. Since these microphones are directional, they will tend to favor that segment of the sound source which is more on axis. For reverberation, audience response, and other very off-axis sources, they will exhibit the effects of off-axis coloration. Thus their orientation and placement can sometimes be more critical than with omnidirectional microphones.

1.3.4 Spaced Bidirectional Microphones

Bidirectional microphones have more "reach" to the front than do cardioids, but they also have an equal—though reverse-polarity—pickup lobe to the rear. Thus they must be placed farther back from the sound source than either omnidirectionals or cardioid microphones in order to achieve the same coverage. The rear lobe provides that the reverberation components and audience response will have the same sonic characteristics as the front lobe (that is, there will be little off-axis coloration of these sounds).

One advantage of this technique is provided by the null plane of these microphones. Proper orientation of this plane can reduce the pickup of unwanted sounds quite effectively. However, care must be taken that the most desired sound not be placed in the out-of-polarity rear lobes, since it is becoming increasingly evident that absolute polarity is a perceivable element in a good recording chain.

1.3.5 Spaced Hypercardioid Microphones

This polar pattern is midway between cardioid and bidirectional. The front lobe has more "reach" (that is, narrower) than that of a cardioid, while the small rear lobe has the reverse-polarity aspect of the bidirectional microphone. The null area is generally a cone, somewhere between the 90° null plane of the bidirectional and the 180° null point of the cardioid. The exact null cone angle, the amount of rear lobe pickup, and the coloration of sounds arriving from off axis will depend on the particular design of the microphone being used. Considerations involved in using such a spaced pair would be an amalgam of those for spaced cardioid and spaced bidirectional microphones.

2 THREE- OR FOUR-MICROPHONE TECHNIQUES

These techniques are generally an extension of the two-microphone configurations discussed. Most of the same qualities, advantages, and disadvantages therefore apply [8].

2.1 Three Spaced Microphones

This technique was developed by researchers at Bell Laboratories during their experiments into stereo in the 1930s [9]. It employs a center microphone added to the two-microphone array discussed earlier. This will fill the "hole in the middle," which results from the wide spacing of the two outer microphones, and can also be used to "tighten" the center imaging of the configuration.

One problem arising from this additional microphone is that it compounds the effects of the phase anomalies between the microphones in the array, thus increasing the comb filtering and raising the frequencies affected into the more noticeable middle and upper ranges of the spectrum.

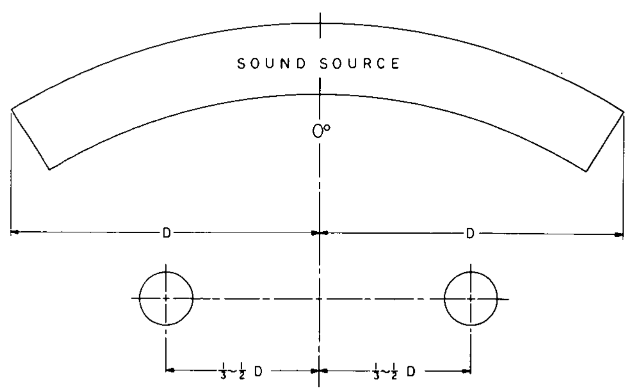

Fig. 11. Spaced omnidirectional pair.

[1] Registered trademark of Crown International, Inc.

2.2 Two-Microphone Techniques with Accent Microphone

Commonly an accent microphone is added to the basic two- or three-microphone technique to give special emphasis to a soloist within the overall sound stage. When more than one accent microphone is used, this leads into the realm of multimicrophone techniques and is outside the subject of this paper.

When an accent microphone is used, care must be given to the placement and type employed (as well as the amount of its signal introduced into the mix), so that it contributes only a proper representation of that soloist and does not color or change the balance of the surrounding elements of the sound stage.

With intensity stereo techniques this accent microphone can often sound "out of context" with the overall sound, since it is being introduced into the mix ahead in time of the basic pickup. One means of compensating for this is to delay the signal from that microphone (via a digital delay device) such that it "arrives" into the mix at the same time or slightly later (10–15 ms) than the signal from the basic pickup. This temporal manipulation may be obviated by careful addition of this signal into the mix such that it only adds presence to the sound of the soloist, but is not perceived as a separate pickup in and of itself.

Likewise, the proper panning of this pickup into the overall stereo sound stage is critical to eliminate a "wandering" image with changes in the intensity of the soloist.

2.3 The Sound Field Microphone

Following theoretical developoment by Michael Gerzon, under the auspices of the National Research Development Council in England, this special microphone system was commercially produced by Calrec Audio Ltd. It employs four transducer elements in a single housing, and via electronic manipulation, the signals from these are converted into "ambisonic" surround-sound signals as well as conventional left and right stereo signals.

In their original form, the four signals are derived from four transducers arrayed in a near-coincident tetrahedron. Their outputs (the A-format signals) are electronically matrixed to produce 1) an omnidirectional component, relating the pressure of the sound wave at the microphone; 2) a pressure-gradient component, relating the vertical (up–down) information of the sound wave; 3) a pressure-gradient component relating the lateral (left–right) information; and 4) a pressure-gradient component, relating the spatial (fore/aft) information. These signals are virtually coincident, due to the electronic manipulation, and are known as the B format, containing the overall horizontal, vertical, and pressure information.

These B-format signals can be stored on four-channel tape for postproduction, or they may be immediately processed again to resolve into quadraphonic, ambisonic, or conventional stereo signals—but with an important difference. The electronic controls of the microphone system further allow the mixing engineer the facility to steer, pan, tilt, vary the included angle, alter the directional pattern, and otherwise change the overall stereo perspective and imaging to suit his taste—all electronically and without ever touching the microphone itself.

3 OBSERVATIONS

Numerous factors must be carefully considered when planning a stereo recording. The sonic and technical characteristics of the microphones are important, and so are the visual aesthetics of their placement. During a recording session without audience, there are few concerns other than the obvious rules of safety for both the microphones and the performers. When an audience will view the performance, the mixing engineer must also consider appearance. Live, telecast, or filmed performances all demand compromises to be made between conflicting requirements of sight lines and microphone placement. This is particularly true with staged performances such as opera, musicals, or dramatic theater.

The discrete use of single-point coincident stereo microphones flown from above can often prove beneficial. In addition the use of boundary surface techniques will provide a good, clear pickup of stage activity, and still be quite invisible to the audience.

The use of a single-point remote-control stereo microphone (such as the AKG C-422 or the Neumann SM-69) can also offer the engineer the added flexibility of making alterations in the stereo perspective if or when the performance or sound source dictates, without the need for changing the physical position of the microphone. The ultimate example of this is the Calrec sound-field microphone previously discussed.

The final consideration in any miking situation is, of course, the sound: does it adequately represent the original sound source (if, indeed, it is supposed to)? Such aspects as localization, depth, presence, clarity of individual components, and lack of unnatural coloration are primary things to consider. Equally important: does the pickup adequately avoid the unwanted sounds in the environment?

There is no magic answer, no one "right way" to accomplish the task. What works well today may not suffice tomorrow. Thus it is imperative that mixing engineers learn as many approaches as they can, so that when that "impossible situation" does present itself, the relevant knowledge and the tools will be at hand to meet the situation.

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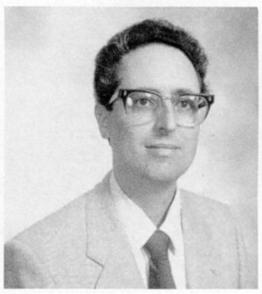
THE AUTHORS



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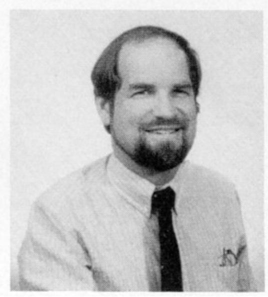

W. Dooley

Ron Streicher has had a lifelong involvement with music, first as a pianist and percussionist, and then as a choral conductor. He earned his B.A. degree in composition and theory from UCLA, and then a Master of Arts in communications arts from Loyola University in Los Angeles.

His interest in recording, which subsequently evolved into a career, developed while serving as a volunteer for the music department of a public radio station in LA. His many projects for public radio include numerous radio plays and the national broadcasts of the Los Angeles Philharmonic Orchestra, the California Chamber Symphony, the Monday Evening Concert series, and several other Southern California chamber music series. His work has been heard over the National Public Radio, American Public Radio, and California Radio Music networks.

Still involved with live music production, Mr. Streicher began his company Pacific Audio-Visual Enterprises in 1972. He has designed and supervised sound reinforcement for the Philadelphia Orchestra, the Metropolitan Opera, and the New York City Opera productions at the Mann Music Center in Philadelphia, where he has been the audio consultant since 1977; he is also audio consultant to the Monday Evening Concert series of the Los Angeles County Museum of Art.

Among the record companies he has worked for are Angel, CMS Desto, Discovery, and SAZ Records. He traveled to Pakistan for SAZ to make the first digital recording of Moslem religious music.

Mr. Streicher is actively involved with the educational activities of the AES, having given numerous presentations at local and national meetings. He has served on the executive committee of the Los Angeles Section almost since he became a member (as a committeeman, vice-chairman, and now in his eighth term as section secretary) and was the vice-chairman of the 78th AES Convention in Anaheim. He is also a member of the SBE, USITT, NARAS, SPERDVAC, Pacific Pioneer Broadcasters, and the Sapphire Group.

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Wes Dooley, president of Audio Engineering Associates, attended Pomona College and Pacific Oaks College where he received his B.S. degree. He began his audio career in broadcasting at KSPC-FM in 1963. A year later his work in remote recording led to his employment by Wally Heider. In 1965 he joined Custom Fidelity Company, where he was chief engineer, responsible for designing and constructing disk mastering facilities and several of the first 8-track studios in Los Angeles. As recording supervisor for Custom Fidelity, he was responsible for remote recording operations throughout the Western United States. In 1975 Mr. Dooley formed Audio Engineering Associates which specializes in audio system design and fabrication. In the past two years, Audio Engineering Associates has undertaken design projects for the Mann Music Center in Philadelphia, Stevie Wonder, the members of Earth Wind and Fire, and Kansas. He has researched M/S stereo techniques, the results of which were presented at the 69th convention of the AES and published, with coauthor Ron Streicher, in the *Journal*. As an independent recording engineer, he has completed projects for commercial albums in Europe, Africa, and New Zealand.

Mr. Dooley is vice president of the Western Region of the AES. He is a member of the Hollywood Sapphire Group, the Society of Broadcast and Communications Engineers, and NARAS.