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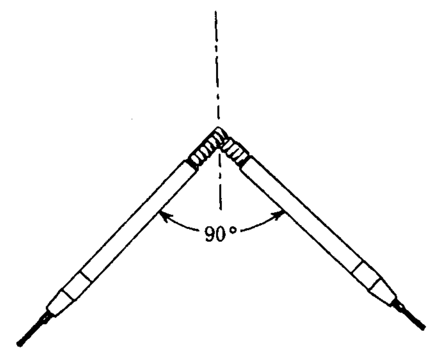
Coincident-microphone techniques

CHAPTER 3 EXAMINED WHY INTERAURAL INCOHERENCE IS IMPORTANT for proper perception of stereo imaging. When considering stereo microphone configurations, however, the term *coherence* has a different connotation. In this context phase coherence results from preserving only intensity cues and excluding any phase, or time of arrival, cues between the two microphones of the stereo pair. To avoid confusion that might result from using these different meanings for the word *coherence*, the term *phase integrity* is used in this chapter.

Intensity stereo

If the microphones of a basic stereo pair are placed as close together as possible—so any differences in the time of arrival of sounds are kept to a minimum—the pickup is called a *coincident pair*. Such a stereo pickup could be configured using two directional microphones, as shown in Fig. 7-1. The microphones are placed one immediately above the other, so their diaphragms are essentially coincident with respect to the horizontal plane. (As discussed in chapter 5, conventional two-channel stereo is concerned only with lateral perspective. Although some minor phase errors will be introduced between the two channels from sound arriving along this vertical displacement, these errors are not significant and could generally be ignored, provided this vertical spacing is kept small.) The microphones are angled symmetrically on either side of the midpoint of the stereo soundstage, so that each microphone emphasizes half, or one side, for example, of the stereo image. Because the acoustical input of the two microphones differs only in intensity, as determined by the direction of arrival of the sound, these coincident microphone techniques often are called *intensity stereo.*



7-1 Arrangement of microphones for a coincident pair, also known as ***intensity stereo.*** The microphones are crossed, so the right microphone records the left audio channel, and the left microphone records the right audio channel.

Monophonic compatibility

With intensity stereo there are virtually no comb-filtering effects due to phase cancellation if the signals between the two microphones are subsequently combined to produce a monophonic signal (see chapter 8).

Mono compatibility is an important consideration for any program that will be broadcast over radio or television. Since the beginning of stereo media, a concern for *backward* compatibility with monophonic reproduction systems has existed. Music stores in the late 1950s had to stock two different versions of each record: one monophonic and one stereo. Early stereo radio broadcasts were carried via two different stations—one for each channel—until the compatible FM multiplex system currently in use was developed.

Broadcasters still need to maintain monophonic compatibility, because even today the majority of people who listen to radio do so via monophonic sets. Similarly with television audio, the vast majority of receivers only produce mono sound. Despite the proliferation of multiplex movie houses in almost every community, most of the motion picture audiences are still listening to a monophonic sound reproduction system.

Thus, any producer wishing to present a quality-sounding program to the entire audience must pay attention to mono compatibility. Failure to do so results in degradation of the stereo image, the mono timbre, or both.

The choice of the polar pattern, the angle between the principal axes, and the position of the two microphones relative to the sound source determines the character of the stereo image.

XY stereo techniques

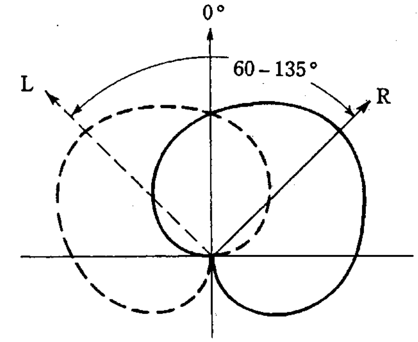
In Fig. 7-1, two directional microphones are arranged as a stereo pickup. This arrangement is sometimes referred to as an *XY* stereo configuration.

When the microphones are cardioids, the response is primarily to the front half of the soundfield (Fig. 7-14). By eliminating the rear lobes of the bidirectional microphones, the pickup of unwanted sound from the rear—ambience, reverberation, a noisy audience, etc.—is greatly reduced. This reduction not only benefits the clarity of the stereo image, but it is crucial for the derived monophonic signal, where excess reverberation or noise easily complicates or confuses the sonic texture.

As with the Blumlein technique of crossed bidirectional patterns, crossed cardioids provide a strong sense of lateral spread across the stereo soundstage. Because this technique also results solely from differences in intensity between the microphones, the two signals have phase integrity—resulting in a highly accurate and stable image for the listener. Because the microphones pick up little from the rear, they can be located further from the sound source and still maintain a good direct-to-reverberant ratio. This is advantageous when the ensemble is large or sightlines are critical—such as live performances or video presentations.

Although other polar patterns could be used for *XY* pickups, the most common configuration uses cardioid microphones, angled between 60° and 135°,

shown in Fig. 7-14. The angle determines the ***width*** of the stereo image, and is suggested by the actual width of the soundstage relative to the placement of the microphones. Because the polar pattern of a good cardioid microphone provides uniform frequency response to about 90° off-axis, the resulting stereo image can encompass a broad span.



7-14 An *XY Stereo* pair of crossed cardioid microphones. The choice of angle between the two microphones is determined by the size of the sound source and the placement of the microphone pair.

A major benefit of all coincident techniques is that the angular fidelity of the pickup closely matches the original source. Lateral position within the reproduced sound stage is independent of the distance the sound subject is from the microphones, because the intensity differences between the two signals are determined primarily by the polar pattern of the microphones. Thus, a person talking at a position 45° off the centerline will reproduce a sonic image at that angle, whether the speaker is 2 feet or 20 feet away from the microphones.

Criticisms of coincident stereo

Much has been written concerning the sonic advantages—and disadvantages—of coincident microphone techniques. The most frequent criticism of coincident microphone techniques is that the sound produced is ***dry*** or ***analytical***, lacking a sense of spaciousness achieved by other techniques. Sometimes coincident techniques also are chastised for having a too ***narrow*** image, that is ***confined*** between the two loudspeakers (References 7-2, 7-3, and 7-4).

9
Spaced microphone stereo techniques

IN THE EARLY DAYS OF THE DEVELOPMENT OF STEREOPHONIC TECHNIQUES, researchers experimented with two different approaches. Alan Blumlein focused on coincident microphone techniques in England. At the same time, in the United States, spaced microphones were used for experimental recordings of the Philadelphia Orchestra by Arthur Keller, Harvey Fletcher, William Snow, and others at Bell Laboratories (Reference 9-1).

Time-of-arrival (phase) effects are important in the preservation of directional cues for accurate stereo imaging. The research work done at Bell Laboratories cannot be slighted, however, because it has led to contemporary mixing engineers at well-respected recording companies such as Telarc, Delos, RCA, and London regularly using spaced microphone techniques.

Near-coincident microphone arrays

The natural spacing between the two ears on the human head has engendered several stereophonic experiments. Binaural pickup, in it simplest manifestation, specifically requires that headphones be used for reproduction (see chapter 6). Most other microphone techniques, however, are intended for loudspeaker playback.

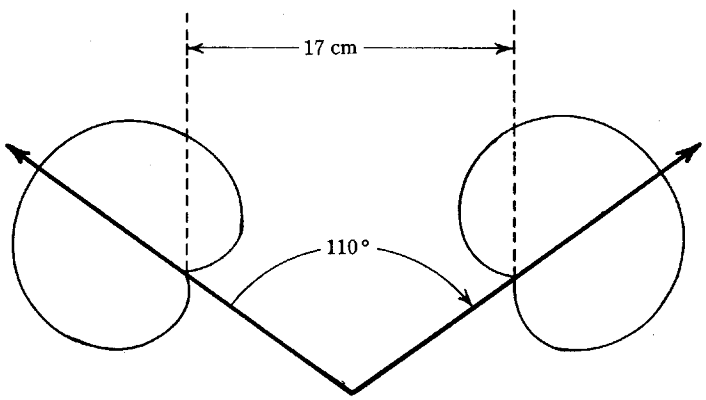
By placing the two microphones relatively close together, much of the phase integrity discussed in earlier chapters can be preserved; therefore, these *near-coincident* configurations are still largely dependent on intensity differences for their stereophonic information. The spacing between the microphones, however, introduces phase differences that can be significant to the sound produced from the system.

When compared to the truly coincident pickups discussed in chapter 7, near-coincident techniques provide an increased sense of *space* around the performers; this is similar to adding *air* or providing a more open sound. This effect is due solely to the phase anomalies (i.e., comb filters) introduced by the time-of-arrival differences between the two microphones. This phasiness often is considered pleasing and a favorable improvement over the more analytical, dry sound produced by coincident techniques. When creating the audio illusion, however, there can be no gains without realizing corresponding losses. In this case, the losses involve a compromise of the solidity and stability of the central region of the stereo image, accompanied by a decrease in monophonic compatibility due to the comb filter effects discussed in chapter 8. Because in near-coincident techniques the spacing between microphones is relatively small, only the upper frequencies (generally above 1,000 Hz) are affected, and sonic degradation due to these phase-related effects is minimal. These upper-frequency phase anomalies create the *airiness* frequently praised when these techniques are used.

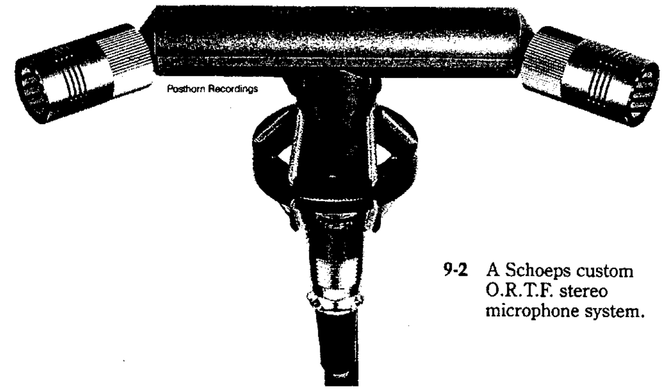
The O.R.T.F. technique

This microphone configuration, named for the French national broadcasting agency, *Office de Radiodiffusion-Tèlèvision Française*, was developed for producing pleasing stereo while maintaining adequate monophonic compatibility. The principal axes of the two cardioid microphones in this configuration are angled away from each other at an included angle of 110°, with capsules separated by 17 cm. (Fig. 9-1). This array closely resembles the interaural spacing and angular reception of the ears on an average adult human head.

Because two directional microphones such as cardioids are used at this angle and spacing, the O.R.T.F. technique still provides intensity differences between the stereo channels. At low frequencies, the signals from the two microphones are virtually phase coherent. With minimal phase differences becoming apparent only at higher frequencies, the comb filter effects are tolerable, producing a pleasing *air*



9-1 The O.R.T.F. (Office de Radiodiffusion Tèlèvision Française) stereo microphone array. Configured with two cardioid microphones, spaced 17 cm, and angled outward at 110°.

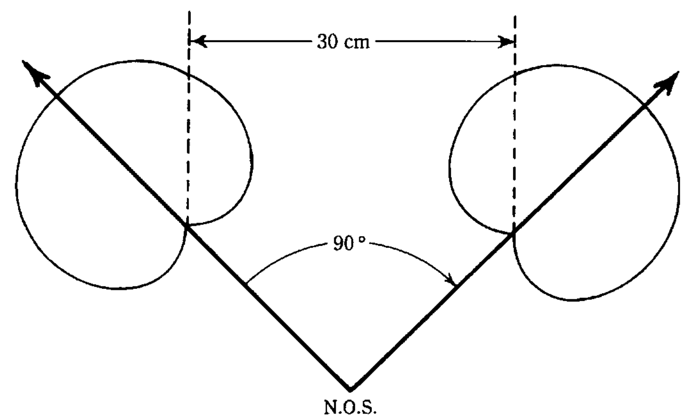


9-2 A Schoeps custom O.R.T.F. stereo microphone system.

around the subject. It is this sense of openness that makes O.R.T.F. one of the most widely used microphone pickups in Europe (Fig. 9-2).

The N.O.S. technique

Developed by engineers at Netherlands Radio, the N.O.S. array (*Nederlandsche Omroep Stitching*) also uses two cardioid microphones set at an angle of 90°, with a capsule spacing of 30 cm (Fig. 9-3). The narrower angle still provides intensity

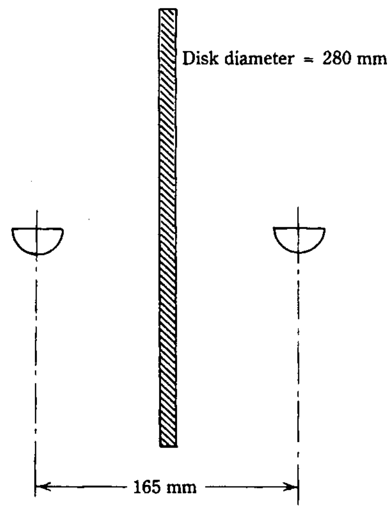


9-3 The N.O.S. (*Nederlandsche Omroep Stitching*) stereo microphone array. Configured with two cardioid microphones, spaced 30 cm apart, and angled outward at 90°.

cues primarily, although the wider spacing produces phase differences that become evident at lower frequencies, beginning at approximately 250 Hz, or around Middle C. This point differs from the O.R.T.F. technique, where audible comb filter effects occur two octaves higher, around 1,000 Hz. Due to comb-filter effects, monophonic compatibility is much more noticeably affected, although it is not as evident when heard in stereo.

The O.S.S. technique

The *Optimal Stereo Signal* technique was proposed first by Jürg Jecklin of the Swiss Broadcasting Corporation (Reference 9-2). Also called the Jecklin Disk, this system uses a pair of omnidirectional microphones separated by an acoustically opaque baffle (Fig. 9-4). The spacing between the microphones is 16.5 cm; the diameter of the disc is 28 cm. Again, this spacing is an approximation of an average adult human head, with the baffle providing some acoustical separation between the two omnidirectional pickups.



9-4 The Jecklin Disk uses two omnidirectional microphones spaced 8.25 cm on either side of a 28-cm acoustical baffle treated with absorptive material.

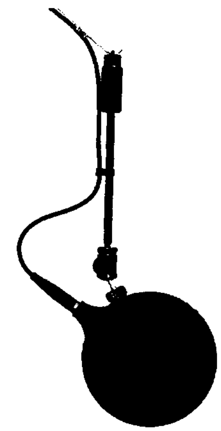
According to the inventor: This combination has the following properties:

1) In the frequency range below 200 Hz, the disk has no influence. Both microphones receive the same signal.

2) With increasing frequency, diffraction occurs at the edge of the disk with an increasing effect of separation of the two microphones.

3) The polar response of the OSS microphone is omnidirectional, which is satisfactory for rooms with either r.. minal or too short a reverberation time." (Reference 9-2)

This approach is an attempt to bridge the gap, between binaural and stereo techniques. i.e., between headphone and loudspeaker reproduction. It works fairly well for both, but it also presents some compromises that prevent it from being technically correct for either technique. Due to the recent interest in personal stereo portables, however, this microphone technique has inspired further research to develop stereo microphone systems that will serve successfully both headphone and loudspeaker listening (Fig. 9-5 and Reference 9-3).



9-5 The Schoeps model KFM-6U stereo microphone, based on the theories of Gunther Thiele. Posthorn Recordings

The Stereo Ambient Sampling System

The S.A.S.S. array was developed by Michael Billingsley for Crown International, Inc. (Reference 9-4). The product was designed to give highly localized stereo imaging for loudspeaker reproduction. The monocompatible, near-coincident array allots an omnidirectional microphone capsule for each channel, mounted near, or flush with, a boundary approximately 12.7 cm square. The two boundaries are angled left and right of center. The sound diffraction of each boundary creates a directional polar pattern aimed left and right of the center, much like a coincident or near-coincident array. The capsules are *ear-spaced* 170 mm apart (Fig. 6-14), separated by an acoustical baffle. The polar patterns of the boundaries and the spacing between capsules were chosen to provide natural perceived stereo imaging. As a near-coincident array, the S.A.S.S. array forms stereo images by a combination of spacing, isolating, and shaping of the directional pattern of otherwise omnidirectional capsules used to create time and spectral differences between channels (Reference 9-5).

This product was a unique implementation of the boundary effect achieved by placing a pressure-responsive (omnidirectional) pickup within a pressure boundary surface. With the S.A.S.S., two pressure-zone microphones are employed to produce the stereo array. Because the pressure boundary surfaces are relatively small, a 6 dB increase results only in the mid- and high-frequency directional, or hemispheric, response of the pickup due to the buildup of pressure at the reflecting boundary surfaces. At the same time, the pickup retains the generally even polar response and extended low-frequency response inherent to the omnidirectional microphones used.

Arrangement of microphones

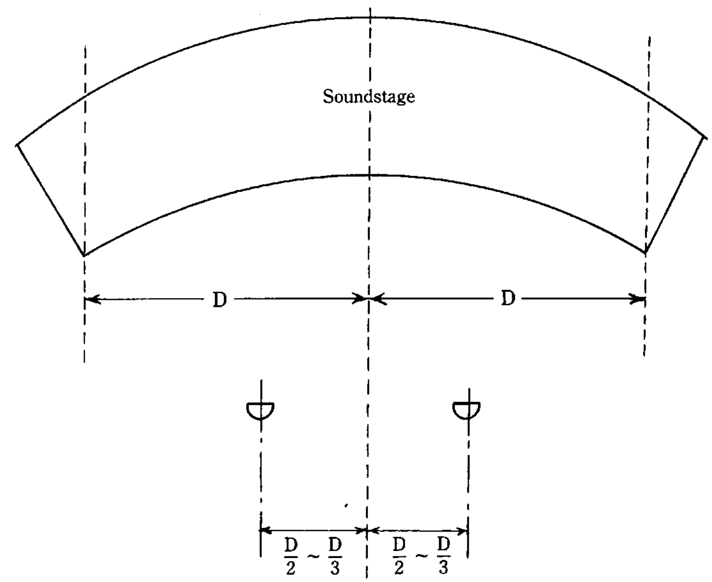
The specific arrangement of microphones is always a matter of taste, which is determined by the specific application at hand. Therefore, restricting oneself to a strictly defined angle or spacing is a self-defeating exercise. The generic category of near-coincident techniques can encompass any configuration of two microphones spaced a short distance apart; the choice of polar pattern and included angle is determined by the situation. If reasonable care is given to the configuration and placement of a near-coincident array, the resulting sound quality of the pickup most often will be satisfactory. Therefore, this is a generally safe approach to producing a stereo recording. If setup time is short or no sound check is possible, a near-coincident microphone pickup will almost always produce a good balance and perspective; it might not be spectacular, but it should not be bad either.

Widely spaced microphones

The experiments at Bell Laboratories in the 1930s led first to the *wall of sound* approach discussed in chapter 1, which for practicality was reduced to two or three widely spaced microphones. Spaced microphone techniques are sometimes called A-B stereo, as opposed to the term XY associated with coincident techniques. Because omnidirectional microphones supposedly receive sound equally well from all directions, they were the ideal choice for implementing spaced techniques (Fig. 9-6). With this arrangement, the inverse square law is important when determining the left-right stereo image. Sounds originating closer to each microphone are reproduced louder than those further away; and tend to *cluster around* the respective loudspeakers when played back. Time-of-arrival effects also play an important role, contributing to both the determination of the lateral placement of the elements within the stereo image and the production of other phase-related phenomena. Once the microphones are separated by an appreciable distance, (more than 25 feet), discrete echoes possibly could be perceived as the soundwave travels between the two pickups.

Lateral imaging

Chapter 2 discussed the effects of level and time-of-arrival differences on the perception of lateral imaging. A common signal emanating more loudly from one loudspeaker of a stereo pair tends to sound like it is coming primarily from that loudspeaker. Similarly, the law of the first wavefront dictates that when a signal



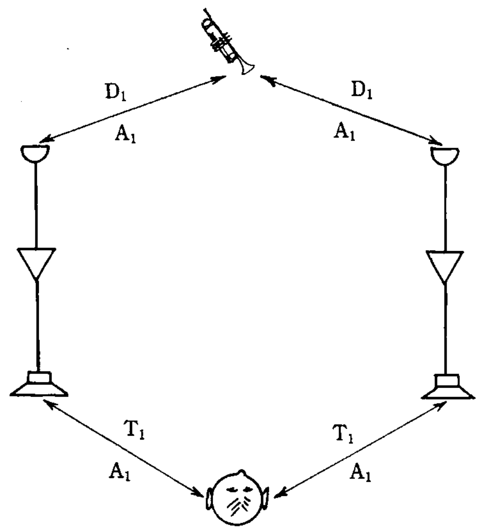
9-6 General arrangement for spaced omnidirectional microphones, showing that the spacing between the two microphones is 1/3 to 1/2 the width of the sound stage.

arrives at a listener from two different directions separated slightly in time, the signal that arrives first will determine the direction of the perceived source.

If a trumpet player is centered between two microphones, the distance (D_1) and amplitude (A_1) between the trumpet and each of the microphones is equal, resulting in signals with equal time-of-arrival (T_1) and amplitude (A_1) at the ears of the listener (Fig. 9-7). This produces a phantom image of the trumpet in the center, between the two loudspeakers.

If the trumpet player moves away from the center position, toward one of the two microphones, the situation changes considerably (Fig. 9-8). Due to the inverse square law, the trumpet will be significantly louder at the right microphone (A_4), moving its image toward the right loudspeaker. Because it is also closer to the right microphone, the sound is reproduced slightly sooner from the right loudspeaker, and the law of the first wavefront causes it to be heard from that speaker. Thus, these two effects combine to determine the lateral imaging of sounds placed between the two microphones of a spaced pair.

Only sounds originating exactly on the centerline between the microphones will sound like they are centered between the loudspeakers. Chapter 2 demon-

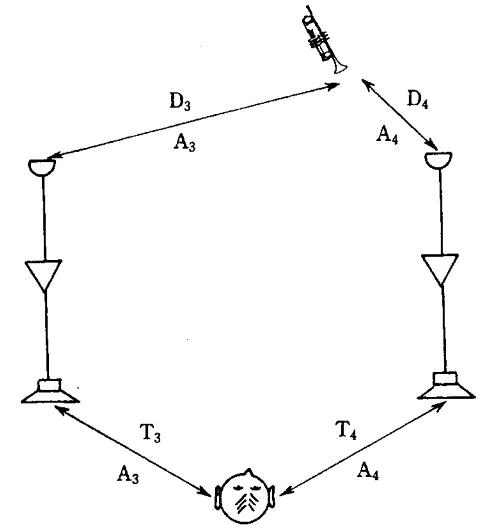


9-7 If a trumpet is centered between the two microphones, the time of arrival and amplitude of its reproduced signal will be equal for the listener.

strated that it takes as little as a one or two millisecond of time difference to move a signal almost completely to one loudspeaker or the other. Thus, even slight movement away from that centerline causes significant shifts in the reproduced imaging. Coupled with the change in intensity and timbre of the sound as it is closer to one microphone than the other, this time difference causes stereo imaging with spaced microphones to degrade rapidly, and collapse around the two loudspeakers, with little or no sound coming from the center of the soundstage. For this reason, a third microphone often is added to the array (Fig. 9-9). Placed at the midpoint between the left and right microphones and mixed equally into each channel, this microphone fills in the hole in the middle and creates a more stable center image.

Phase-related problems

Chapter 8 discussed the problems encountered when a signal is picked up and reproduced via two different path lengths and the comb filter effects that result. This is the case with widely spaced microphones. Elements of the sound source that are not exactly located along the centerline are reproduced with varying amounts of time delay between the two channels—resulting in comb filtering when reproduced via two loudspeakers. These effects are more pronounced when the two stereo channels are combined into a monophonic signal, because phase cancellations are always more audible when the summations are electrical rather than acoustical.

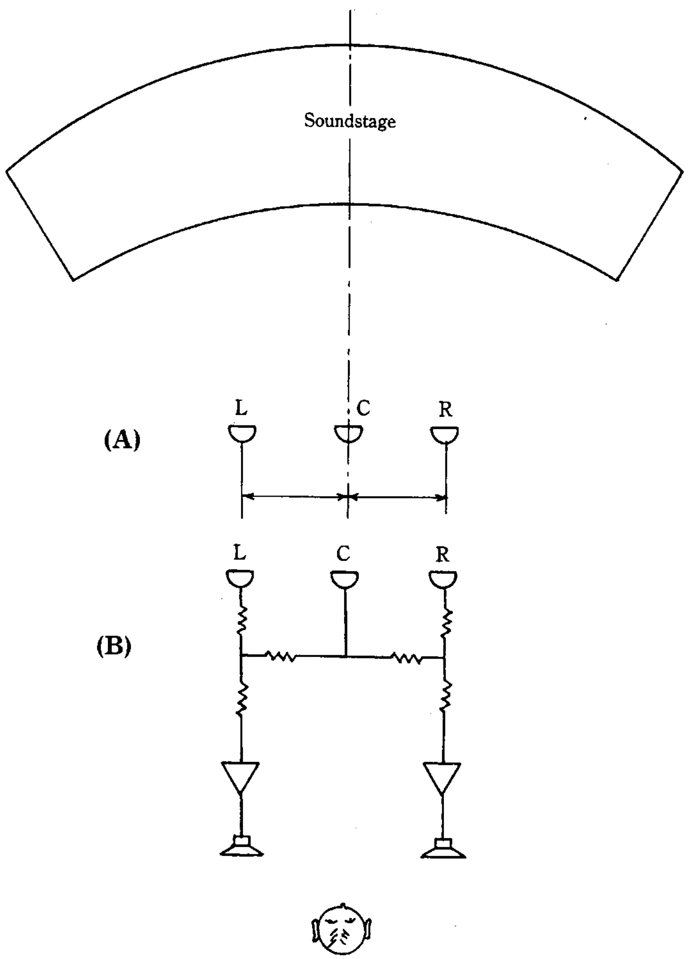


9-8 If the trumpet is closer to the right-channel microphones, the inverse square law will produce unequal levels at the ears of the listener. This, together with the shorter time of arrival, will cause the sound of the trumpet to appear to come from the right loudspeaker.

Besides the spectral anomalies of comb filtering, other phase-related effects can result from spaced microphones. Some listeners consider these detrimental, but others find them beneficial. The most prominent of these *split personality* effects is an increase in the spaciousness of the sound. The general lack of precise imaging resulting from spaced microphones is another characteristic that some listeners find offensive; however, the slight increase in the overall loudness of the signal is an effect produced by phase anomalies that some listeners enjoy.

This dichotomy of listener preferences gives rise to numerous techniques for stereo recording. Referring back to chapter 4, there is no *right* way to record anything. The ultimate criterion is whether the illusion desired by the creative team (producer, performer, and engineer) is achieved and conveyed to the listener (Reference 9-7).

From the foregoing, it is evident that spaced microphones should be implemented with extreme caution. Instances occur when they are appropriate, however, like those with generally uncorrelated sound sources, such as pipe organ or outdoor ambiences. (They also can be advantageous when recording the surround channels of a multichannel recording, discussed in chapter 13.) When accurate stereo imaging is required, however, other techniques are better employed.



9-9 A center microphone is sometimes added to a spaced pair. Mixed equally into both channels, this will tend to fill-in the hole in the middle sometimes encountered when just two microphones are used.

Spaced omnidirectional microphones

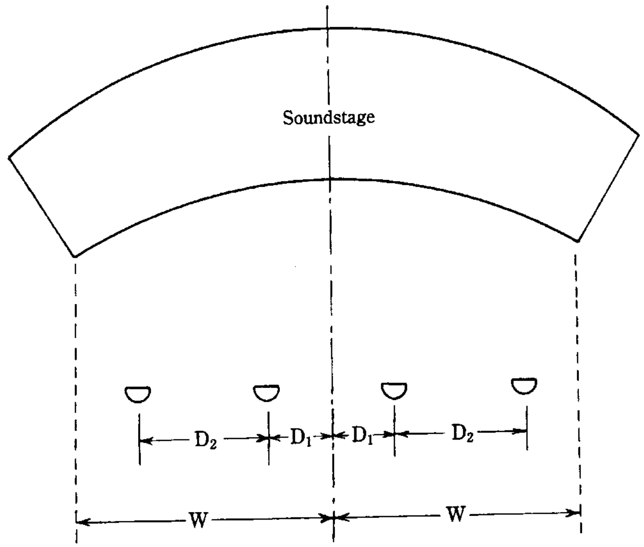
Omnidirectional microphones are most often used to configure a spaced pair, because their pickup is theoretically unaffected by the angle of sound arrival. Careful examination of the polar response diagrams of actual microphones, however, reveals that most of these microphones become directional at higher frequencies. Therefore, when placing the microphones—whether on stands or suspended from above—it is best to aim their pickup axis toward the sound source instead of just letting them hang. Optimum response will result from this precaution.

Because the pickup of sound is equal from all directions, placement of a spaced pair of omnidirectional microphones is critical for maintaining a proper direct-to-ambient sound balance. It is generally best to position them high, in front of the soundstage. The separation between the microphones is determined by the width of the soundstage (Figs. 9-6 and 9-10). The actual distance in front of the soundstage, as with most microphone placement, is determined by critical distance (see chapter 5); the more ambient the space, the closer the microphones need to be. By placing the microphones high above the front of the sound source, the differential distance between them and the front and back of the stage will be minimized. This helps reduce acoustical imbalance between the nearer and more distant elements.

The extended low-frequency response inherent with omnidirectional microphones offers both advantages and disadvantages—all of which should be considered. Sounds with ample low-frequency information are reproduced well—often better than with any other microphone type. This is advantageous for pipe organ and orchestral music, as well as some environmental or sound effect recordings.

The omnidirectional microphone's extended response, however, also can have negative effects when excessive undesirable low-frequency noise is present from such sources as air conditioning systems, traffic, etc. Responsive only to pressure, omnidirectional microphones are relatively undisturbed by wind, which is primarily air motion or velocity energy. Thus, they are not as susceptible to the mechanical effects of wind noise as their directional counterparts. The excellent low-frequency response and lack of discrimination against off-axis sounds, however, allow omnidirectional microphones to pick up the low rumbling effects of wind, air conditioning systems, etc.

A final benefit of omnidirectional microphones is their complete lack of *proximity effect* (i.e., the artificial boosting of low frequencies when the microphone is placed close to the source of sound). Proximity effect, or *bass tip up* as it is known in the United Kingdom, is a common artifact with all directional microphones. Although a spaced microphone pair is not usually close enough to the sound source to encounter the proximity effect, situations might arise when this could occur, such as a system set relatively close to a piano or other musical instrument. In this case, the lack of proximity effect preserves the natural timbral balance of the instrument, without the need for external equalization.



$$D_1 \cong \frac{W}{4}$$

$$D_2 \cong \frac{W}{2}$$

9-10 A stereo array using four directional microphones to pick up a large ensemble. The center microphone pair provides the principal stereo pickup, and the outer microphones help to cover the extremes.

Spaced directional microphones

If the recording environment is too noisy to allow the use of omnidirectional microphones, or when the microphones must be placed further from the sound source for visual reasons, directional microphones such as cardioids or hypercardioids must be used. In these situations, the spacing between the microphones still could be similar to the placement in Figs. 9-6 and 9-9, although they probably will need to be closer together. Frequently, two microphones are used on either side of center, as shown in Fig. 9-10. The distance factor of the microphones, together with the critical distance of the sound source in the environment, will dictate their placement to the sound source (see Fig. 7-13).

The aiming of directional microphones is more critical than with omnidirectionals, because all desired sound must be kept within the acceptable regions of the microphones' polar response patterns. The off-axis response of the microphones also must be considered, because it determines how they *color* the sound of the environment around them.

The effects of wind noise must be considered. Appropriate wind screening might be needed if the microphones are used outdoors or near air conditioning supply ducts.

More about interference problems

When a third or fourth microphone is added to the array, the amount of comb filtering is compounded; three microphones produce three sets of combs (Fig. 9-11), that combine to produce a complex set of response aberrations. Similarly, four microphones produce six sets of combs (Fig. 9-12).

Another problem with spaced microphones is the *duality of time cues* that results from two sets of lateral time cues presented to the listener (Fig. 9-13). Because the distance between the sound source and the microphones is generally different than the distance between the loudspeakers and the listener, the time cues are distorted on playback. For sounds equidistant from the microphones, this distortion could be minimized if the spacing between the loudspeakers is made the same as the spacing between the microphones; it would not, however, eliminate the problem for sounds not situated equidistant from the microphones. Trying to maintain such an equal spacing for microphones and loudspeakers is not practical. This is another reason why accurate stereo imaging is difficult to achieve with spaced microphone techniques.

The Decca Tree

Developed by the recording engineers of Decca Records, the *Decca Tree* was configured using three omnidirectional condenser microphones positioned at the ends of a T-shaped fixture. The spacing between the left and right microphones was approximately 2 m and the center microphone was in front of these by approximately 1.5 m (Fig. 9-14). The relatively close spacing provides sufficient intensity cues for good stereo imaging and sufficient phase information to produce an *open* sound. The middle microphone ensures a solid center for the stereo soundstage. (The use of Neumann M-50 microphones for the original Decca Tree provided it with its characteristic warm and enveloping sound—one still cherished by the London/Decca label, as well as many other recording engineers around the world.)

This technique is also favored by film scoring mixers, because of its ability to produce good stable stereo imaging, which will hold up through the application of the Dolby Surround Sound matrix system.