"M-S" Stereophony and Compatibility

GERHART BORE* and STEPHEN F. TEMMER**

Anyone who has ever heard either track of a stereo tape by itself realizes that it is not a good substitute for a well-recorded monaural tape. The author describes a system which will eliminate this trouble, not only on stereo tapes, but also on stereodiscs and in broadcasting—with particular emphasis on its value in combinations of FM and FM-multiplex.

OUR EARS ENABLE US not only to appreciate sounds according to their intensities and duration, but to pin-point their origin in terms of direction and distance. To determine the direction of sound we utilize several faculties: the ability to calculate the difference in time of arrival of the two initial transient components of a sound at the two ears; the sensitivity to intensity and sound-color differences at the two ears; and, in the case of one ear alone, the perception of the curvature of the wavefront, which for point sources decreases with distance. As a means of measuring, the ear makes use of the phase difference between pressure and velocity, particularly in the low-frequency components and in low-frequency transients, which amounts to 90 deg. at the point of origin, and 0 deg. for plane-wave propagation. In the diffused sound field of enclosed spaces, it is also possible to estimate the distance of the sound source by means of the *intensity difference* between the direct sound and its subsequent reflections from the boundary surfaces.

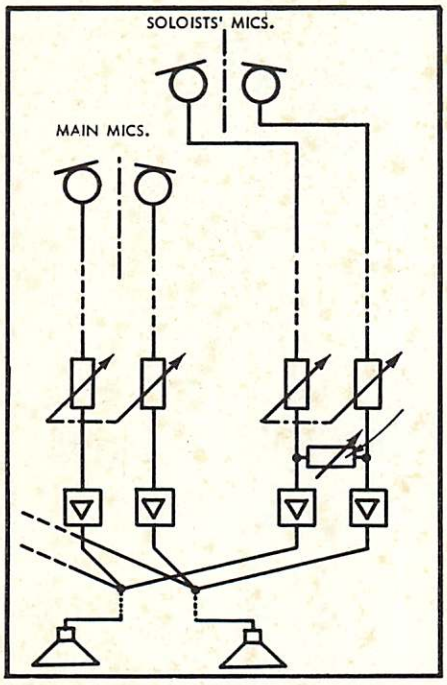

Fig. 1. Block schematic of a normal two-channel transmission system.

Practical Stereophonic Sound Transmission

Normal Classical Two-channel Transmission. In the "classical" method, pick-up is carried out by two microphones accurately matched as to frequency response and polar characteristic. In practice, adequate matching is only attainable in the case of high-grade condenser microphones, free from subsidiary resonances within the transmission band. Cardioid microphones, which have proved particularly satisfactory in stereophonic sound-film systems, are preferred. Thanks to their single-sided directional pattern, the direct sound, so important for localization, can be picked out of the general sound picture from a greater distance. However, microphones with other polar characteristics can be used, according to the nature of the room and method of reproduction. The microphones are used side by side at a spacing of 12 to 48 inches, depending on the size of the working arc desired. If, as is not always necessary in stereophonic pick-up, additional soloists' microphones are employed, these should consist of pairs of microphones placed closer together. A variable attenuator D (*Fig.* 1) in the cross-connection between the soloists' microphones permits a shortening of the "base" along which the soloist appears to move to and fro, so that a small sideways movement of the soloist does not cause an apparent leap from one loudspeaker to the other. The use of a single microphone, the output of which, after amplification by separate amplifiers is arbitrarily mixed into the two channels by hand, is subjectively much less pleasing.

In order to enhance the left-right impression by additional intensity and tone-color differences, a small baffle can be placed between the microphones, or they can be mounted on opposite sides of a sphere, a so-called "dummy head" of 4 to 12 inches diameter. For laterally displaced sound sources, this causes a shadowing of the further microphone leading to a more uniform representation of the sound scene on the reproducing side; the farther a sound source is displaced laterally, the less the incremental difference of path length to the microphones for further displacement. In this region the intensity differences carry the effect and the above-mentioned apparent crowding of sound sources toward the loudspeakers is avoided. In addition, the diffraction of the sound waves around the dummy head or baffle causes an attenuation of the higher frequencies on the far side.

"Intensity" Stereophony. Now let us look at the possibilities of locating sound source directions entirely by intensity difference in the two loudspeakers. In order to do that, we must locate the two

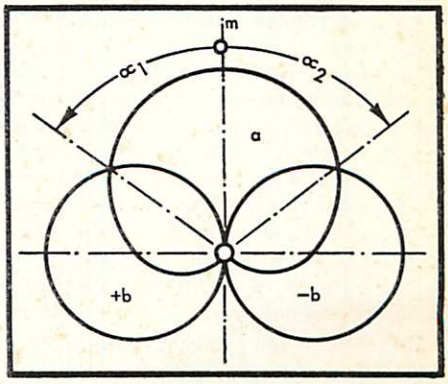

Fig. 2. Polar diagram of a microphone combination for M-S stereophony.

* *George Neumann Laboratories, Berlin, Germany.*
** *President, Gotham Audio Development Corporation, 2 W. 46th St., New York 36, N. Y.*

Reprinted from AUDIO - April 1958

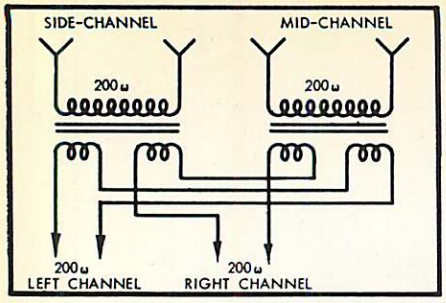

Fig. 3. Electrical sum and difference formation.

microphones at the same point in order to avoid differences of transmission time. They can be arranged very closely one above the other without disadvantage. Microphones with very well-defined polar characteristics must be used. They are rotated in different directions, so that each favors one half of the sound stage. This type of intensity stereophony, however, has no practical value, since the discovery by Lauridsen of "M-S stereophony" achieves a substantially more elegant solution at about the same cost. M-S stereophony means mid-side stereophony. One microphone with cardioid characteristic handles the whole sound picture, exactly as does the principal microphone in a single-channel pick-up. A second microphone having a cosine or figure 8 characteristic is placed closely above or below the first and turned so that its null plane contains the principal axis of reception of the cardioid microphone (*Fig.* 2). If the two microphone outputs a and b are interconnected so that the sum $a+b$ and the difference $a-b$ are formed, as shown diagrammatically in *Fig.* 3, two channels result, in each of which one half of the pick-up area is preferentially received. The arrangement relies on the fact that the two principal axes of a pressure gradient microphone correspond to voltages of opposite polarity. The combining can, for example, be done in the manner shown, by using differential transformers.

If we assume that the instantaneous value of a sound from the left produces a positive voltage b in the cosine microphone, sound sources on the central axis m will give rise to the voltage a in the cardioid microphone only, thus producing a central impression. Sources making an angle α_1, with the central axis, give rise to a voltage $a+b$ in the left loudspeaker and $a-b$ in the right loudspeaker. With $a=b$ only the left loudspeaker is energized, the source appears to the listener to lie in that direction. Similarly, sound sources at an angle α_2 appear to come from the right loudspeaker.

Smaller angles in the transmitting studio correspond to apparent directions between the loudspeakers in the reproducing room. The size of the angle $\alpha_1+\alpha_2$ can be varied, within limits, by changes in relative gain of the microphone channels.

Sources which lie outside the included angle $\alpha_1+\alpha_2$, will be localized more centrally. In this region the output from the cosine microphone predominates causing the loudspeakers to be driven in opposite phase and resulting in indefinite impressions of direction for a centrally situated listener. In this region no sound source should be set up. In this case too, as experience shows, if the quality is to be pleasant, soloists' microphones are necessary, consisting of double microphones arranged as in *Fig.* 4.

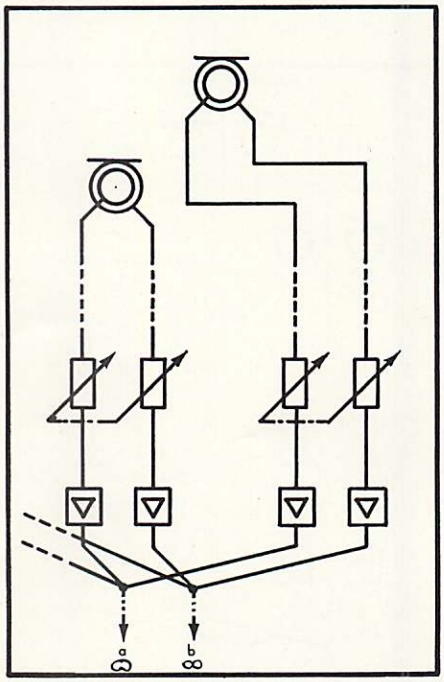

Fig. 4. Method of mixing in additional microphones.

A significant advantage of MS-stereophony lies in the fact that one channel —namely the mid-channel—carries a satisfactory single-channel transmission. The decision as to whether a two-channel transmission shall be produced monaurally or stereophonically may thus be decided at the reproducing end. This advantage is not obtained with classical stereophony; with this, two channels are always necessary for the achievement of good reproduction. Mixing of the two channels is not successful, firstly because the combination of two microphones into a "doublet" gives an undesirable highly frequency-dependent polar characteristic, and secondly the microphones will not have been placed suitably for a single-channel pick-up.

If no value is placed on "compatibility" of intensity stereophony with single-channel transmission, a pair of crossed gradient microphones with accurate cosine characteristics may be used for transmission with good results (*Fig.* 5). After double electrical addition and subtraction (according to *Fig.* 3) similarly proportioned voltages result as for MS-stereophony. The microphone output voltages permit a good transmission of directional impressions only for sectors 90 deg. wide to the front and back, and care is, therefore, necessary in placement. For sources lying outside this range of angles the directions will appear indefinite, because the loudspeakers will be driven by voltages wholly, or partially, in antiphase.

Microphones for Stereophonic Transmission

Microphones for use in stereophonic pick-up must satisfy several additional requirements. Over and above the known requirements for single-channel transmission with respect to flat frequency characteristic and low harmonic distortion, together with a wide dynamic range, classical stereophony demands equality of frequency and phase characteristic in the transmission channels; otherwise, the transmitted directional impressions will be frequency dependent. It is not easy to find matched samples from types of microphones in which the frequency response is achieved by a series of resonances spread throughout the transmission band, even if these microphones are quite satisfactory for single-channel transmission.

Condenser microphones have been found particularly suitable for the purpose. (Their accurate matching is, of course, only fully effective if, on the reproducing side, accurately matched loudspeakers are used.)

For stereophonic pick-up using classical principles, Neumann condenser microphones, specially selected for uniform frequency response, can be used. Transmission by means of the intensity stereophony principle requires microphones with strongly directional characteristics. In addition, they must have small physical dimensions so that they do not distort

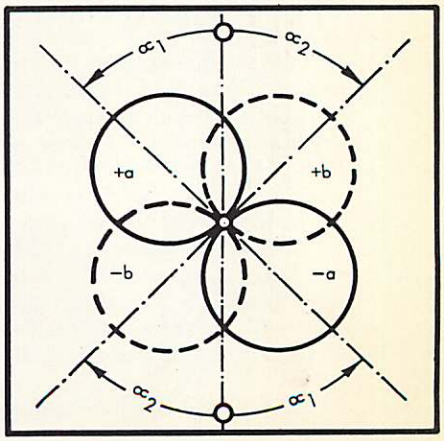

Fig. 5. Polar diagram and working angles for two cosine (velocity actuated) microphones.

the sound field when mounted in close proximity.

These stringent requirements can only be met in practice by the use of condenser microphone capsules as pick-up elements. Since it is barely possible to put two single microphones sufficiently close together without some disadvantage, the Neumann[1] stereo-microphone model SM 2, (*Fig.* 6), was developed for these applications.

This double microphone contains two similar, closely adjacent, microphone capsules. Their principal axes can be turned away from each other. The capsules are pressure-gradient operated with two diaphragms. Each system is capable of independent remote adjustment by variation of the polarizing voltage, continuously from spherical through cardioid to cosine characteristic, so that with this microphone many different arrangements may be tried. The frequency response and polar characteristics of this microphone are, of course, of prime importance in stereophony of the "classical" type, but are even more important for the M-S Intensity stereophony here described. *Figure* 7 shows the frequency response curves at each polar pattern position, and the polar characteristics of each microphone capsule at key frequencies

[1] The firm of Georg Neumann, Berlin, Germany, is the manufacturer of the U-47, M-49, and KM series of microphones sold in the United States under the "Telefunken" label.

Fig. 6. The Neuman SM-2 stereo microphone.

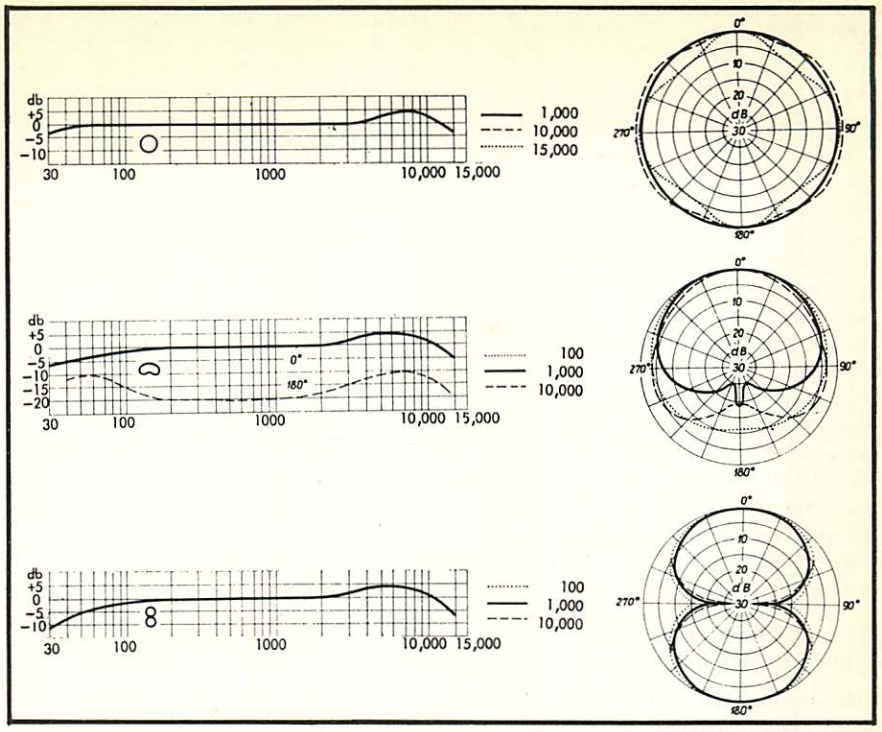

Fig. 7. Frequency response and polar characteristics of the Neuman SM-2 stereo microphone.

Application of the M-S Stereo Principle to Compatible Stereophonic Broadcasting

For some time now, stereo broadcasting through use of AM-FM or FM-FM means has been carried on. This means that radio stations broadcasting simultaneously on AM and FM have been splitting their outlets, feeding the left signal to one and the right signal to the other transmitter. The obvious fault with this form of two-channel transmission is the difference in quality between AM and FM, and, therefore, the uneven reproduction of the two stereo signals. In some localities, two FM stations have gotten together and have each carried one side of the stereo signal. This solves the quality problem but still leaves unsolved the main objection to either of these systems: the fact that a monaural listener (that means the vast majority) hears only one side *or* the other of the stereo broadcast. This presents a sound of complete unbalance, with the melody predominant at some times and the accompaniment at other times. An effort to reduce the distance between the microphones in the original pick-up will help this situation, but at the same time will reduce the stereo effect for the stereo listener.

Now let us examine the imminent start of FM Multiplex Stereo. In this method, one of the stereo signals is broadcast on one of the multiplex subcarriers of an FM station. (As many as three such subcarriers have successfully been used, primarily for point-to-point and in the background-music field for restaurants and supermarkets.) Recent tests have shown that such a subcarrier channel can be endowed with the same 50–15,000 cps response as the main FM signal. This is, of course, essential. A small adapter is required to extract this sub-carrier signal from existing FM tuners. Crosby Laboratories, Inc., of Hicksville, Long Island, have a patent designed to make such broadcasting more compatible. It does this by means of a sum-and-difference system; i.e., the two signals are electrically added and broadcast on the main FM channel, while the electrical subtraction of the two signals is broadcast on the multiplex channel. (Since there are no listeners tuned solely to the multiplex channel, the listening value of this subtractive signal is of no importance.) This is only a partial solution to the problem of compatibility; partial because, as pointed out earlier, mixing of the left and right channels of a classical left-right stereo system is undesirable from several viewpoints. Here is where the M-S Intensity Stereophony once again proves to be a solution. The "M" channel is fed to the FM Main Channel, while the "S" channel is fed to the Multiplex Channel. At the receiving end, the Main-Channel *only* listener will get the centrally placed monaural microphone output. Using the same sum-and-difference converter (*Fig.* 3) as shown previously will resolve these two signals into left and right stereo channels. The same converter, inciden-

tally, is needed for the Crosby sum-and-difference system.

The M-S Stereo Principle Applied to Stereo Tapes

It is interesting to note that after the "M" and "S" channels have been converted into Left and Right channels, the insertion of another identical converter (*Fig.* 3) will reproduce the original "M" and "S" signals. This is in sharp contrast to recordings made in the Left-Right or classical system. A stereo-tape, whose left and right tracks were derived from a recording made with the Neumann SM-2 Intensity-Stereo Microphone, may be played back with a full-track playback head, which, in essence, acts as a converter and adds the two signals and restores the "M" channel; the *true mid-channel* of the cardioid element.

The M-S Stereo Principle Applied to Stereo Discs

Again here the Intensity Stereophony shows definite advantages. Indeed, these advantages are such that the M-S principle can be applied without the necessity of the previously described converter. We can actually use the geometry of the groove as a converter. The stereo-disc principle which has recently been adopted is based on playback with a cartridge sensitive to signals placed in the groove at an angle of 45 deg. to the vertical. There is no compulsion placed on the record manufacturer for using a 45-45 cutterhead to achieve this groove. The 45-deg. modulation can be assumed to be a vector resulting from lateral and vertical signal. Let us use a cutter capable of recording a vertical and lateral signal on a disc, and modulate the lateral channel with "M" output of the SM-2 Microphone, and the vertical channel with the "S" output. A 45-45 stereo cartridge will effectively act as our converter (*Fig.* 3) in playback, providing the sum of M and S on one side of the groove and the difference on the other. At the same time, this groove played back with a monaural lateral playback cartridge will reproduce the "M" or *true mid-channel* alone. (It must be pointed out that the damage to the vertical groove component by cartridges with low vertical compliance will be exactly the same as in stereo discs cut from left-right stereo tapes using a 45-45 degree cutting head.)

Conclusions

Much research has been done in the field of stereophonics from the standpoint of reproduction through earphones, loudspeakers, two-channel, three-channel, or multichannel systems. Judgment in the use of different recording techniques has been on the basis of many and varied criteria. These have included attempts to startle the listener; tries at spreading the orchestra out to many times its actual concert width; arbitrary assignment of instrumental sections and vocalists to left and right channels, without regard to representation of realism; and many more. We believe that with the advent of stereo-disc and stereo multiplex FM, a tremendous interest in sound reproduction will be generated; an interest many times that of recent years. And after we have settled down to real *enjoyment* of our newly-discovered dimension, rather than the open-mouthed, startled look one sees nowadays on the faces of people when first confronted with *stereo,* then I believe we will go back and re-examine some of the basic truths of stereo recording with perhaps a view toward a return to realism and a true third dimension. The writers firmly believe that the Intensity-Stereophony principle represents reproduction of a true third dimension. Æ