Electronics World

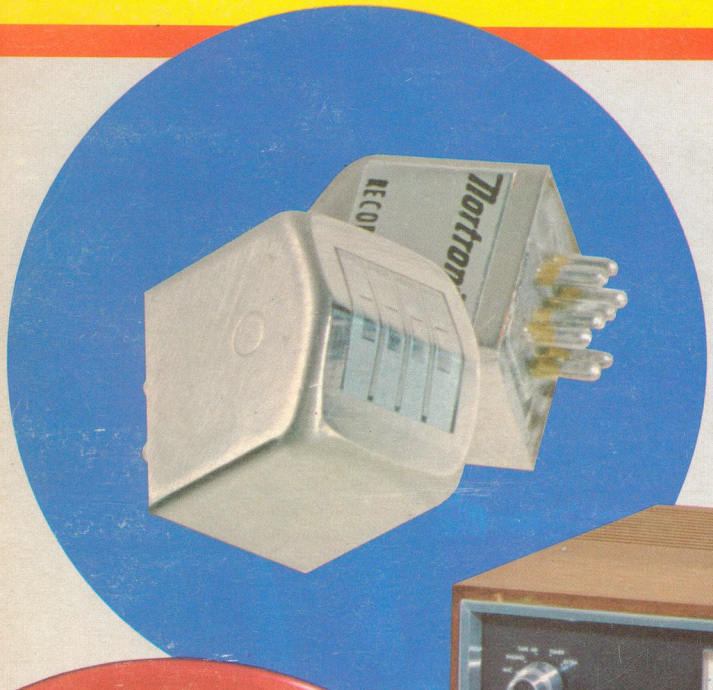
FEBRUARY, 1970
60 CENTS

NEW CIRCUIT DESIGNS IN 1970 COLOR-TV SETS

REGULATED POWER SUPPLIES: Design and Construction

ELECTRONICS AND THE HEART

ELECTRONIC DICE—For Games of Chance



4-CHANNEL STEREO

The New Surround Sound

A ZIFF-DAVIS PUBLICATION

Four-Channel Stereo
—the New Surround Sound

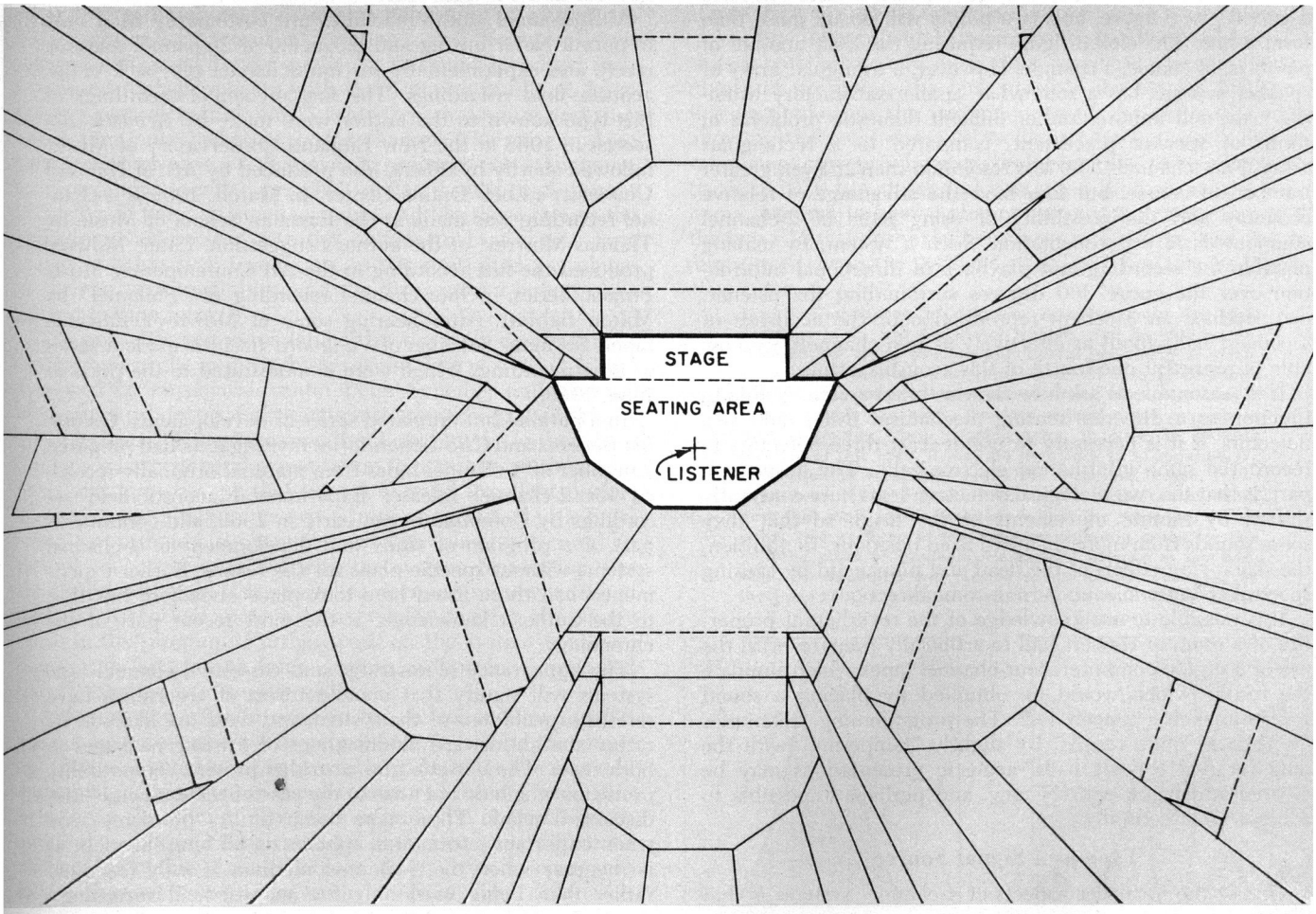
By ROBERT BERKOVITZ / Acoustic Research, Inc.

If you want to be immersed and surrounded by sound or reproduce the ambiance of a concert hall, try 4-channel stereo. Here are the principles and techniques used for a system that is causing much excitement in the high-fidelity industry.

FOUR-CHANNEL stereo, an exciting new feature of the recent Los Angeles Hi-Fi Show, is a technique of recording, broadcasting, and playback which permits sounds to be presented to the listener from any direction in the horizontal plane. Although the resulting reproduction cannot match the resolution of which the ear and brain are capable and is not independent of the acoustics of the listening room, the system works well and creates an interesting illusion. The number of channels and the present state of electronic technology make possible 4-channel professional and amateur recording systems, as well as home-playback components which are within economic reach of many music listeners. Since multichannel recording is not new, it is the possibility of its availability to home listeners, and not the system itself, which is causing all the excitement.

The importance of 4-channel systems can best be realized by considering the essential nature of high-fidelity recording and playback. Properly made 2-channel stereo recordings are capable of satisfying even critical listeners, as long as the recording engineer wishes to produce the effect, upon playback, that the instruments are in the same room as the listener. The success of this illusion, however, involves eliminating from the recording the acoustics of the recording hall. Otherwise, the presence of this reverberation, superimposed upon that of the listening room, would quickly betray to the listener the artificiality of the presentation. The apparent source of sound is limited, of course, to a location (or locations) between the two speaker systems. But, since it is usually easy to separate these adequately in most listening rooms, the distance between speakers is

Fig. 1. Sound-image map for Jordan Hall at New England Conservatory of Music (Boston), where AR first made 4-channel music recordings. The dashed line represents the front edge of the stage. The various images of the hall experienced by a listener at the position shown are the result of sound reflections from the walls. Clearly no two microphones could record all the positional information in such a case, nor could any number of loudspeakers arranged in one straight line reproduce it.



rarely a limitation in 2-channel stereo.

Limitations arise if we want to record or reproduce an *acoustic field*, that is, to recreate for the listener the sensations produced by hearing the real performance in the acoustic setting of the concert hall. The acoustic properties of any room or hall are really the total effect of the time delays, amplitudes, directions, and frequency spectra of the reflections of the original sound as they come to the listener from the walls of the room (Fig. 1). The acoustic field at the concert-goer's seat is a region in which not only the sound level but the direction of the source of sound is constantly changing. Just as monophonic recording is able to produce only a linear array of sources, one behind the other, 2-channel stereo can only represent a plane with the edge closest to the listener formed by a line between the two speakers (Fig. 2).

Bethany Beardslee, soprano, is shown here during the preparations for the 4-channel recording by AR of "Philomel" by Milton Babbitt. Eight widely spaced microphones were used in chapel of General Theological Seminary, New York.

Sounds originating outside this sector may be recorded by using additional or omnidirectional microphones to mix this sound with that from the primary area being recorded. However, this additional sound cannot be recorded in a way which will permit it to be recovered correctly, as to direction, by the listener; nor can any types or combinations of speaker systems or other components regenerate it from a 2-channel recording.

To represent sound sources or their images in *any* direction with respect to the listener, more than two elements (microphones, loudspeakers) are needed, because we need to surround the listener. We need a set of points which will form a closed-plane figure, and two points will do no more than form a line. The closed figure requiring the least number of points is, of course, a triangle. However, a triangular array of speaker systems has a somewhat smaller satisfactory listening area, and imposes rather difficult domestic problems in terms of speaker placement, compared to a rectangular array. Four channels offer less resolution than an even greater number, of course, but four have the advantage of relative economy and the possibility of using pairs of 2-channel components in experimentation. Such a system, by making possible the recording and playback of directional information over the entire 360 degrees surrounding the listener, can produce an excellent reproduction of the acoustics of a concert hall, about as effectively as two channels are now able to represent one-fourth of this acoustic setting.

It is reasonable to ask how the ear/brain system is able to function as a direction-sensing mechanism using only two detectors, if it is necessary to use at least three detectors to record the same information electronically. The answer, in part, is that the two biological detectors (ears) are constantly shifted by minute movements of the head, so that they sense sounds from more than two fixed positions. In addition, the shadowing effects of the head and pinnae aid by causing spectral changes in sounds from some directions.

It is possible to use knowledge of the reverberant properties of a room or concert hall to artificially prepare, with the use of a digital computer, four-channel tapes which simulate the results which would be obtained by placing a sound source in such a concert hall. The programming techniques for this are quite simple. By slightly "tampering" with the data for real concert halls, acoustic presentations may be created which are entirely new, and perhaps impossible to achieve architecturally.

Tape as a Signal Source

One of the fortunate aspects of 4-channel systems is that all of the components needed for experimentation are readily available, and have been for many years. Foremost among these is the multitrack tape recorder, available in many professional recording studios in 3-, 4-, and up to 24-channel versions. Lower cost reel-to-reel machines for home use are also now available, requiring only the added amplifier and pair of speakers for a full 4-channel record/play system. An informal standard already exists for pre-recorded tapes for this use, in which channel 1 is left front, 3 is right front, 2 is left rear and 4 is right rear.

Multichannel studio machines are customarily used only to permit easier mixing and balancing of 2-channel releases, rarely and experimentally for multichannel playback or for acoustic-field recordings. The first 4-channel recordings of this type known to the author were made by *Acoustic Research* in 1968 at the New England Conservatory of Music, followed shortly by others, also produced by *AR*, at Harvard University's Loeb Drama Center. In March, 1969, a 4-channel recording was made at the Eastman School of Music by Thomas Mowrey, at the author's suggestion. Later, Mowrey produced the first recording in the *AR* Contemporary Music Project Series: a four-channel recording of "Philomel" by Milton Babbitt. After hearing some of Mowrey's Eastman tapes, Seymour Solomon of *Vanguard Records* made a series of tape recordings which were demonstrated to the press in June, 1969.

In a parallel but unrelated series of developments, *Columbia Records* and *CBS Laboratories* investigators had prepared a number of 4-channel tapes from material originally recorded for 2-channel release. Experimental acoustic-field recordings by *Columbia* began early in 1969, and continue as part of a program of study and development of 4-channel systems without specific plans for the future. Earlier experiments than those listed here took place elsewhere but this, to the author's knowledge, is the most recent part of the chronology.

The appearance of cartridge and cassette 4-channel tape systems will signify that manufacturers of recordings have serious expectations of the system, and these are likely to be rather straightforward modifications of existing packages in both cases. The cassette and cartridge present compatibility problems which do not arise in the case of the 4-channel disc discussed below. These tape compatibility problems arise when important information appears on all four channels, as is the case when the 4-channel medium is fully exploited rather than being used only for acoustic-field recordings.

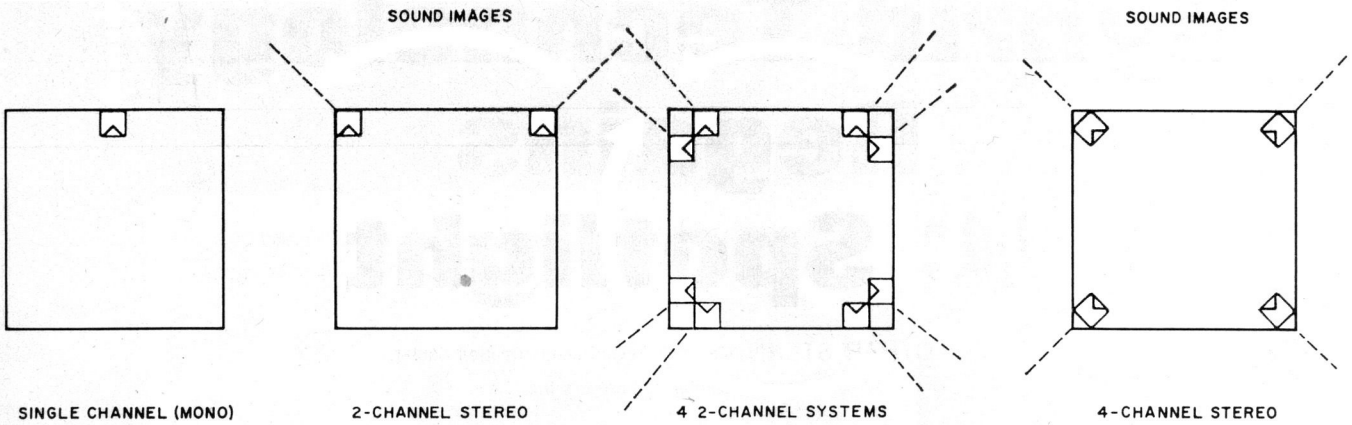


Fig. 2. A one-speaker system reproduces all sounds as if they were located somewhere on a line extending behind the speaker. Two speakers are able to give the effect of a sound field in the space behind and between the speakers. Four sets of two speakers each, one on each wall of a rectangular room, can cover a 360° plane field. In practice, four loudspeakers are used.

Playing only the front two channels in such cases gives the listener only half the information in the recording. It is desirable to mix the information from the rear channels into those in front so that it will not be lost when the tapes are played by a listener with a 2-channel system. To do so, the information must be recorded and played with a double matrixing system, similar to that now used for FM multiplex broadcasting. This will allow present owners of 2-channel machines to play 4-channel tapes when they appear. Alternatively, the two additional signals may be routed through a switch which mixes them with the other two signals.

Four-Channel Discs

Disc systems are the potential basis for widespread use of 4-channel recorded material. This is both because of their compatibility (a recently demonstrated 4-channel disc can be played immediately on 2-channel systems with no changes in equipment and no loss of information), and because of their low cost compared to tape media. To this must be added their continued high popularity with the listening public. A long-playing record costs about 25 cents to manufacture and runs about 45 minutes, whether 2- or 4-channel. The same playing time on ¼-inch tape, at 3¾ inches per second, costs the manufacturer about a dollar, or a half dollar if an 8-track format is used—still twice as much as a disc. Add to these factors the need for even present recorder owners to buy a new tape player of some sort, in contrast to the continued usefulness of their present turntables, and the disc seems a potent competitor to tape formats.

The only disc system which has been widely demonstrated to members of the audio industry at the time of writing is that proposed by musician-inventor Peter Scheiber and Thomas Mowrey, a producer of classical music recordings well-known in the industry. The system was first heard by the author some time prior to its general presentation to members of the audio press and industry. At that time it showed excellent performance in reproducing one voice from one channel at a time, using an ordinary 2-channel cartridge playing through a special "decoder" required with the system. Separation was very good, although it appeared to decrease somewhat when complex 4-channel material was substituted for the single voice in the program. Further work on the system has been done, and listeners at later demonstrations have reported that the system works quite well.

Although the method used in the Scheiber-Mowrey disc has not been revealed by its proponents, it is clear that some sacrifice in channel capacity must be made, since the encoded 4-channel information on the disc is stored in only two channels. Since the storage capability of an audio channel—whatever the medium—is restricted, it is likely that some difference will be detectable if the Scheiber-Mowrey disc is compared to a 4-channel tape of the same program. The difference, however, may be unimportant, or even less than would be heard were another disc system employed.

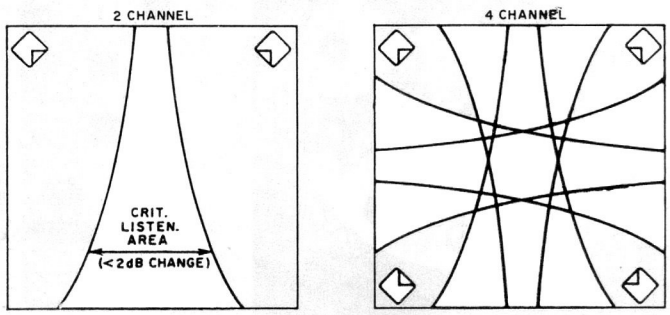
(*Editor's Note: Scheiber and Mowrey have applied for patents on their system and have formed the* Audiodata Co. *to exploit their technique. It is claimed that neither frequency response nor a dynamic range has been compromised in their disc. Nor is a subcarrier technique employed for the two additional channels.*)

FM Broadcasts

Apart from the public demonstrations which are presented at the *Acoustic Research* Music Rooms in New York and Cambridge, the largest number of listeners have heard 4-channel stereo through the medium of FM broadcasts in the Boston area. There, every Saturday night, *AR* is presenting the entire Boston Symphony season live in 4-channel stereo, transmitted on two FM stations, WCRB and WGBH.

Various experimental microphone locations have been tested, both before and during the broadcast season, with the object of providing the best possible service for 2-channel listeners, who are the vast majority of the audience, while allowing the most effective 4-channel transmission. The arrangement currently favored, and scheduled to be adopted in the first 1970 broadcast and continued thereafter, will allow home listeners to hear 4-channel stereo or to tune in one of the two FM stations for either a near or medium "seat" in the reproduced acoustic setting of (*Continued on page* 58)

Fig. 3. Comparison of optimum listening areas for ideal speakers in 2- and 4-channel systems. The boundaries enclose critical areas within which lateral movement of listener will not produce more than 2 dB of imbalance. Since other factors also operate, actual areas are larger. When four channels are used, the four critical areas overlap to form a smaller ideal listening zone. In order to increase the size of this area, it may be necessary to exaggerate the separation of recordings made for 4-channel stereo. However, even if the listener is not in this ideal central area, note that most of the locations within the room are within either two or three of the optimum listening areas for two or three pairs of speakers. Hence, the listener at the back wall, for example, will receive sound images produced by the front two speakers as well as by the rear two speakers.



Four-Channel Stereo

(*Continued from page* 41)

Symphony Hall, long-considered one of the world's finest concert halls. Optionally, listeners may add one more channel to their 2-channel systems by tuning in WGBH on a monophonic radio and placing it at the back of the room. Those with no stereo equipment at all can enjoy a reverberant effect by listening to WCRB on a monophonic AM radio and WGBH on a monophonic FM set. In addition, regular 2-channel stereo reception has been improved as a direct result of the work undertaken in the 4-channel experiments.

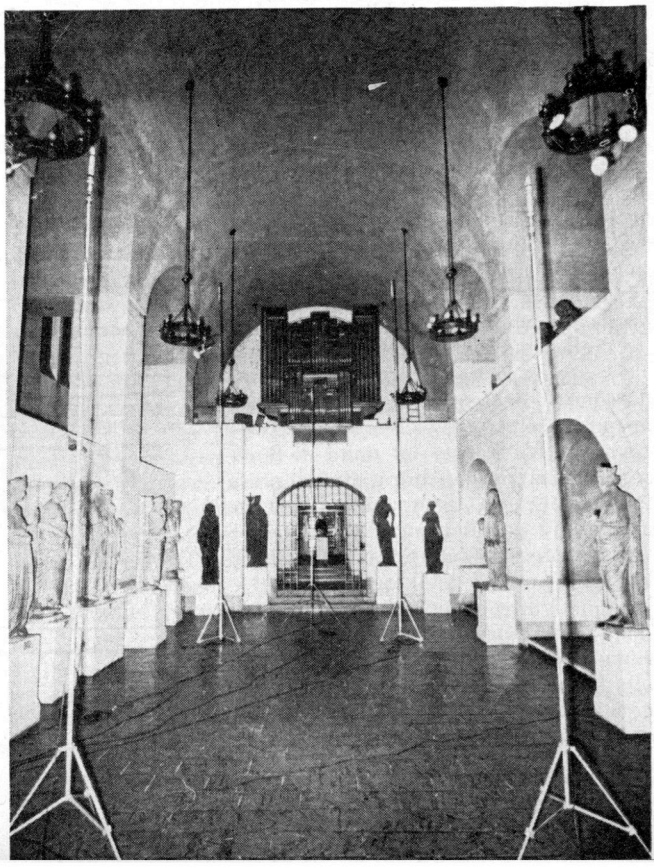
(*In New York City, WNYC-FM and WKCR have transmitted a number of programs using 4-channel tape.*—Editor)

The only multiplex FM system thus far proposed publicly has been that of William Halstead, using additional subcarriers for compatible transmission of the necessary four channels. A compatible multiplex system would be superior to the two-station approach for the reasons outlined in the discussion of tape above, since the listener with only one stereo system would then hear all the information presented.

Amplifiers and Speaker Systems

Since a 4-channel stereo system can be thought of as four 2-channel systems, one on each wall of a room, it is not surprising that the same criteria as apply to the 2-channel technique should also influence setting up a 4-channel system. However, the need to provide optimum results from all four directions simultaneously does make somewhat more care necessary in choosing and placing speaker systems, while some types of speaker systems may not lend themselves to 4-channel use. If audio systems which employ a "center-fill" speaker are used, then eight speaker systems, rather than four, will be needed. Reflecting-type speakers, which create images which are intense additional sound sources, cause "sound effects" which do not result from reverberant information in the recording.

Microphone setup in Busch-Reisinger Museum at Harvard during Columbia recording of organ music performed by E. Power Biggs. Five microphones were used; front center information from fifth mike was mixed into front left and right.



The optimum listening area is that which includes the region in which the optimum areas for the four "pairs" of speakers overlap (Fig. 3). A simple computer program was used to prepare the diagram showing ideal locations for listening to acoustic-field recordings with minimum balance error. The arrangement giving the largest effective listening area for such recordings is a square, as large as can be arranged in a given room, preferably with the speaker systems near the corners, for best channel separation and directional accuracy.

All rooms, including concert halls, tend to absorb high frequencies more than middle or low frequencies. As a result, the recording of a piano in a concert hall will contain an over-all deficiency of high frequencies when compared to a recording of the piano made, say, outdoors at the same volume level. This is because the sound in the concert hall is the total of direct sound (correct high-frequency balance) and reflected sound (attenuated high frequencies), while an anechoic recording contains only the direct sound of the instrument.

In reproducing the concert-hall recording, we wish to hear the balance as it is in the concert hall, that is, with slightly attenuated high frequencies. However, the room in which such a recording is played is also somewhat reverberant and therefore dilutes high-frequency content slightly further. It is therefore desirable to apply slight treble boost to compensate for listening-room losses when playing acoustic-field recordings made in the concert hall. If 2-channel recordings of the "presence" type are played, the treble boost should be removed, and listening room acoustics allowed to play their normal part.

Acoustic-field recordings are not the only kind which can be made with 4-channel recorders, however. The least critical recordings, from the home listener's viewpoint, are those in which each channel carries its own unique signal. In these cases, there is little or no restriction on the type of speaker system which may be used, except for the usual requirement that the speaker display some semblance of accuracy if the playback is to reflect the intention of the recording's producer.

Naturally, all the speakers used will have to be in phase with one another. To achieve this is a slightly more time-consuming activity than is the case when only two speaker systems need to be matched with each other.

Multichannel systems have been available before this time, and several different formats have been proposed in the past. Usually, even when three or four channels were used, these have been proposed to cover only the front one-fourth of the listening field. Whether the most recent series of experiments will lead to any more substantial development than the earlier proposals will undoubtedly depend to some extent upon the public's reaction to the 4-channel presentations it is able to hear and upon the outcome of experiments made both by professionals and amateurs.

Audio is a field which owes a great deal of its vitality and progress to individual efforts at exploration and development, of which the Scheiber-Mowrey 4-channel disc is only a recent example. Perhaps other individual investigators, spurred by industry interest, will now support and develop techniques of 4-channel stereo just as they aided in the development of 2-channel stereo a decade ago. ▲

EDITOR'S NOTE: *Last month we promised our readers we would keep them abreast of developments on 4-channel stereo. Bob Berkovitz' article in this issue is such an all-inclusive presentation that it's rather difficult to say any more at this time. We had hoped to include an article by Russ Molloy of* The Telex Corp. *also, giving his opinions on 4-channel stereo, but due to business commitments, his article has not materialized. In line with keeping our readers up-to-date, however, we have planned a rather extensive story on 4-channel stereo by Daniel von Recklinghausen of* H. H. Scott, Inc., *which will appear next month.*