Whither Four Channels?

Michael Gerzon* examines the history and philosophy of quadraphony

No one used to the splendour and subtlety of live music can doubt how unnatural even the best recorded stereo sound is. Yet for the last seventy years advertisers have been assuring audio enthusiasts that theirs was the best of all possible worlds, and that perfection had arrived. Also for seventy years advertisers have pronounced that their latest breakthroughs were so superior to anything heard before that all previous efforts at sound production were thereby rendered totally obsolete.

It is thus natural that the confused hi-fi enthusiast, his last penny spent on the 'ultimate' stereo, should be somewhat less than enthusiastic about the advent of four-channel stereo. Using the cynical words of one long-established loudspeaker manufacturer, "Ho-hum, another major breakthrough". One can't help wondering if the main point of four channels is to sell more loudspeakers and amplifiers, rather than to give more realistic sound. In fact, is four-channel stereo anything more than a gimmick?

For the benefit of those who have been too busy listening to music to notice the fuss, it is as well to state just what four-channel stereo *is*. In its simplest form, four separate channels of sound are recorded on special four-channel tapes or discs, and are fed to four loudspeakers placed around the listener, two to the front and two to the rear. The two front loudspeakers reproduce the usual stereo orchestral sound, and the two rear ones reproduce the recorded reverberation, reflected sound, and audience noises of the concert hall. By this means the listener should gain the impression that he is placed in the middle of the original hall, and should hear exactly the same sound that he would hear if he were there 'live'.

There are some who seem to think that the object of four-channel stereo is to put one in the middle of the orchestra. Doing this might indeed be a very impressive gimmick, but it clearly would not give one realistic reproduction of the music. It is true that the conductor hears the orchestra spread most of the way around him, but any good conductor aims to produce a musical blend of sound not for himself, but for those listeners sitting in good seats in the body of the concert hall. The result is that the sound heard by the conductor or the orchestral players is grossly unbalanced musically, and is not what the listener is meant to hear.

If the four speakers are not meant to put the listener in the middle of the orchestra, what are they supposed to do? At first sight, if the orchestra is meant to appear to be only in front of the listener, then the rear speakers seem to be superfluous as no direct sound need come from them. The flaw in this argument is the false assumption that only sound arriving direct from the orchestra is important.

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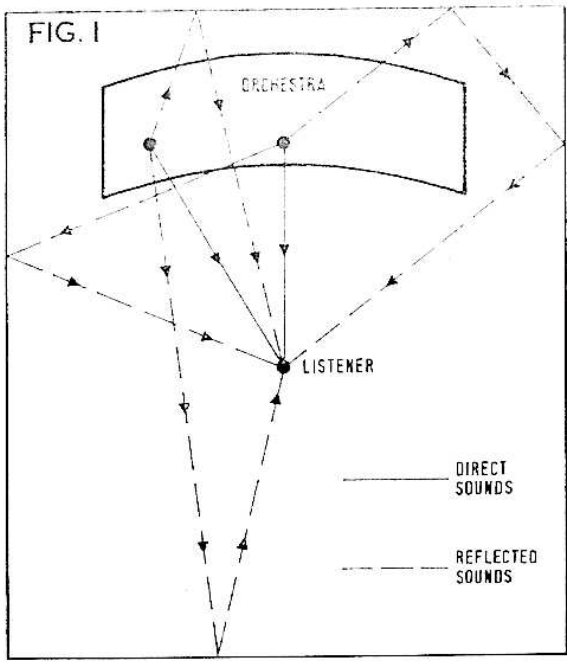
In most listening positions in a good concert hall, more than half the total sound energy reaches the listener after being reflected form the walls, ceiling or floor, rather than direct from the orchestra (see **fig.1**). The importance of this reflected sound is clear from the great care and skill required to design concert halls. If a concert hall has too little reflected sound (i.e. reverberation), then the orchestra sounds thin and shrill, and lacks depth and body. On the other hand, if the hall has too much reverberation, then the orchestral sound is muddy and thick and lacks detail.

When listening in a good concert hall, one is consciously only aware of the sound as arriving direct from the orchestra, the effect of the reverberation being to add a full, spacious quality to that sound. Although one may not actually notice the reverberation as coming from directions all around, this 'all-round sound' is responsible for the convincing sense of depth and distance obtained with live sounds. It is this remarkable, but poorly understood ability of the ears to interpret reverberation, that enables blind people to avoid bumping into even quite small objects, using merely the reflections of the noise of their footsteps or of a tapping stick.



If one reproduces the concert hall reverberation via only the usual two stereo speakers, the music certainly sounds as though extra reverberation is present, but one misses the sense of depth that live all-round reverberation adds. Different people describe this deficiency in different ways, but the effect is that ordinary stereo sound often seems to lie between the speakers, not behind them. The result is what I like to describe as a 'cardboard cut-out orchestra'. In the concert hall, even with one's eyes shut, one is aware that the orchestra is, say, ten or twenty metres away, and that the rear of the orchestra is further away than the front. Much of this sense of depth, this ability to gauge distance, disappears in stereo recordings, even when concert hall reverberation is recorded in adequate amounts. This deficiency is due to the fact that the reverberation does not surround the listener.

Economic and domestic considerations mean that one cannot completely surround the listener with loudspeakers, and in practice only four speakers are used for all-round sound reproduction. The impression of sounds coming from directions other

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than that of one of the loudspeakers is obtained by feeding signals to adjacent pairs of speakers, so that the sound appears to come from between them.

It is at this point that we arrive at a strange paradox. Although a good system of 4-channel stereo should be *capable* of reproducing sound appearing to come from any direction around the listener, in a good recording one should not actually be *aware* of sounds coming from behind. As we have seen, the main effect of concert hall reverberation coming from all round is to make the orchestra appear to be at a natural distance from the listener, and to give the sound depth and fullness. It is only in a poor and badly designed concert hall that one is aware of reverberation coming from behind one. Such back-reflections are one of the worst and most distracting forms of bad concert-hall acoustic.

Thus a good four-channel orchestral recording should have plenty of depth and fullness, but should not draw attention to the fact that sounds are arriving from behind. It is a sad fact that most commercial classical four-channel recordings to date suffer from precisely this fault; the listener has the uncomfortable sense of being sandwiched between two walls of sound – a stereo orchestra in front, and a back-reflection from behind. It is a common misconception, even among some audio experts, that the object of 4-channel stereo is to reproduce sound from *behind* the listener, as well as from in front. In fact sounds should be made to come from *all round* the listener, from both sides as well as front and back.

There are many different qualities present in live sound, but absent in normal 2-speaker stereo reproduction. The 4-channel systems that have been demonstrated possess some, but not all, of the qualities absent in ordinary stereo. Those additional qualities that have been captured are often impressive, but there is a danger that, because of the improvement over ordinary stereo, the listener will fail to observe those deficiencies that remain. In order to be able to judge intelligently how good a 4-channel system is, it is necessary to examine in detail the various qualities of live sound that are absent in 2-speaker reproduction.

The first quality is the sense of *fullness* or *richness* which is given by reverberation coming from all around one. This reverberation appears to be unlocalised, i.e. does not appear to come from anywhere in particular. This effect is often gained to some extent when listening through headphones, or when seated between a stereo pair of loudspeakers; however, in such circumstance one loses the ability to localise the musicians in front of oneself. Many people confuse this richness with the presence of plenty of bass, and it is common for inexperienced listeners to think that good 4-speaker stereo has a lot of bass, even when it is actually quite poor.

A second quality present in live sound is that the orchestra appears to be placed at a *distance* of many metres from the listener. In much ordinary

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stereo, the sound appears to lie between the speakers, and unfortunately most commercial 4-channel recordings do not place the orchestra at a convincing distance, despite the additional richness of the sound. A related, and even more subtle, quality of live sound is the ability to hear the *different distances* of the front and the back of the orchestra, and this dimension of depth is only partially captured in recordings. It is no good for the recording engineer merely to 'add' reverberation to create a sense of distance, as the ears seem to rely on the quality and directional characteristics of the reverberation, as well as its intensity, to deduce distance.

A third quality of live sound is that of *sounds coming from all around one*. In the concert hall, there are continuous small audience noises all around one, even during the performance. This audience reaction is usually only noticed consciously when there is a cougher, whisperer or sweet-eater in the audience, but when such distractions are absent there is no doubt that this 'atmosphere' can help in the enjoyment of the music. All this is largely lost in ordinary 2-speaker stereo, and good 4-speaker reproduction is capable of vividly recreating the atmosphere of a live concert to a remarkable degree.

A fourth quality of live sound is the *accurate sense of direction* that is often absent even with good 2-channel stereo. It is true that the ears are rather poor at determining the precise direction of a sound, but they are extraordinarily good at sorting out two sounds which are very close to one another. It is this ability to hear closely spaced sounds as being clearly separated spatially that is lost in most stereo reproduction, even though the superficial stereo effect might seem quite good. This precise location ability seems to involve the reverberant sound as well as the direct sound.

A fifth quality of live sound is that of *height*. In live music, much of the concert hall ambience arrives at one's ears after being reflected from the ceiling. Also, it is quite common for the rear of an orchestra to be higher than the front, or for the orchestra to subtend a vertical angle at one's ears (see **fig. 2**). In addition, organs usually have their pipes placed at a great height. The result of all this is that many sounds appear to come from non-horizontal directions. In ordinary stereo, this vertical spread of sound is completely lost. While height information helps to make all music sound more realistic, it is of special musical importance in works involving organs, in which the majestic sound of the organ floating above all other sounds greatly adds to the impact.

A sixth quality of live sound is the *wide apparent dynamic range*. Even in the recordings made with no alterations made in the recording level, 2-channel stereo seems to have a restricted dynamic range, with the loud passages seeming insufficiently loud, and the quiet passages lacking the correct hushed quality. Good 4-speaker reproduction seems capable of

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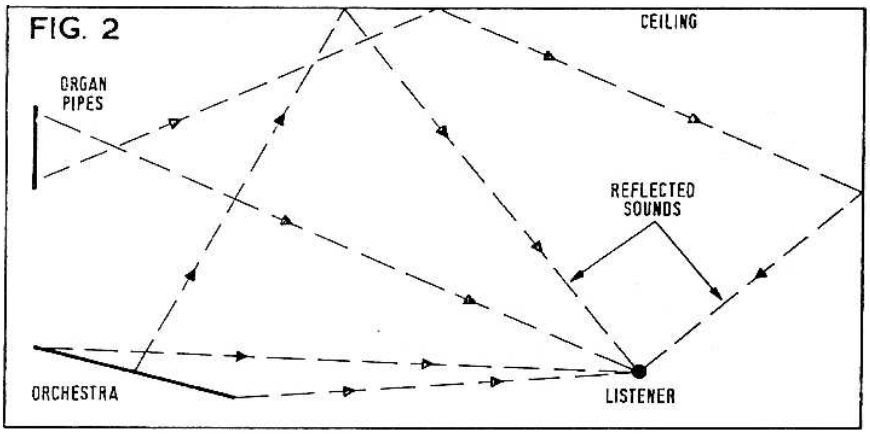

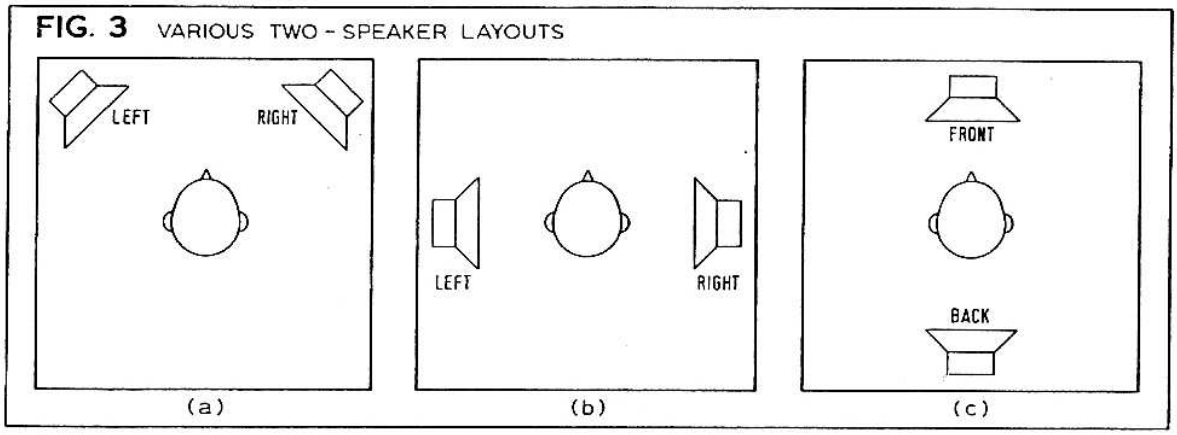

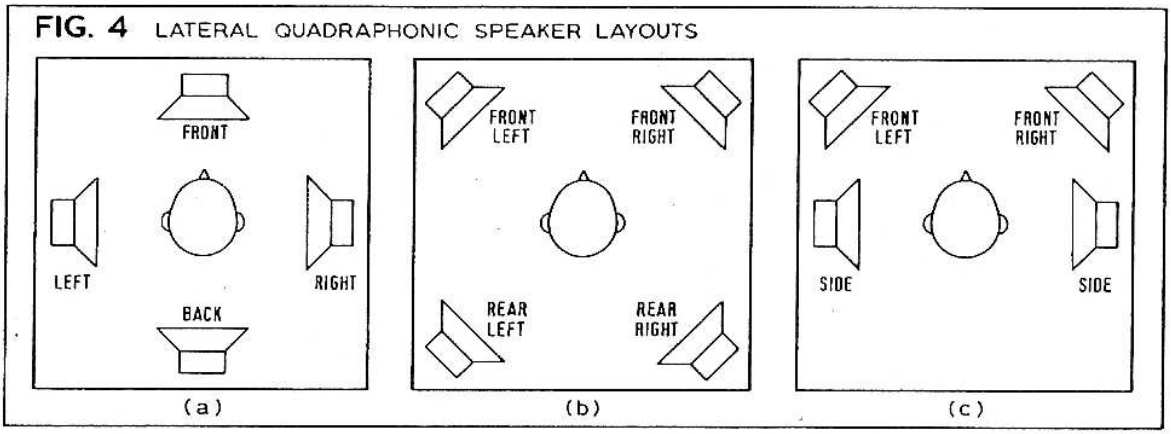

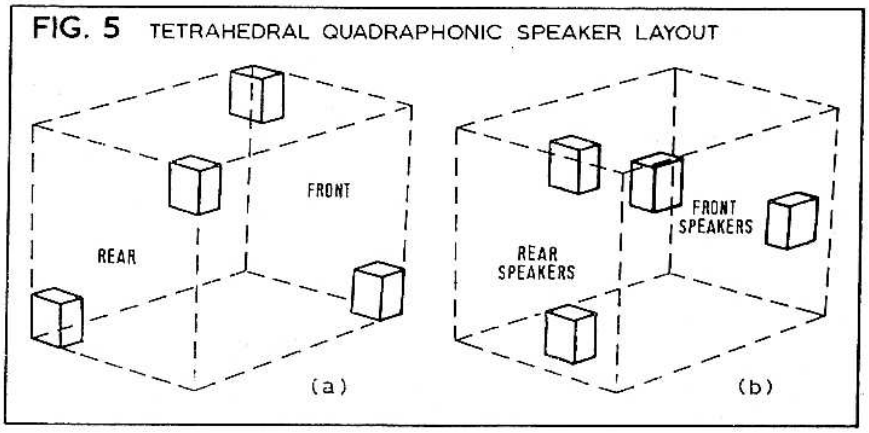

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removing most of this effect, and the 'electric' quality of live fortissimo music is largely recaptured. However, I have not heard any recording that is completely natural in this respect, and most American recordings sound almost as restricted as ordinary stereo in this quality.

A seventh quality of live sound is one's *awareness of the shape* and size of the concert hall around one. An experienced listener can often describe much of the character and extent of a concert hall merely from the character of its 'sound'. Even inexperienced listeners are usually aware of the 'setting' in which the music takes place, and this information is rarely adequately captured in recordings.

The above list of qualities absent from even the best 2-speaker stereo is not exhaustive, and has not even mentioned the usual 'technical' deficiencies such as distortion, noise, dynamic compression, or poor frequency and transient response. Even technically perfect 2-channel stereo would lack the listed qualities, and it therefore seems rather surprising that anyone could believe that ordinary stereo had achieved almost perfect sound reproduction.

The aim of 4-channel stereo is (or should be) to recapture as many as possible of these missing qualities of live sound in the home. It is evident to anyone who has heard commercial 4-channel recordings that only a few of these qualities have been captured, and that some new deficiencies have been introduced which are absent in ordinary stereo. Among the faults that I have noted with many 4-channel recordings are: an excessive quantity of reverberation compared to the real thing, a lack of precise directional information, a lack of any sound from the sides of listener, the absence of height information, distracting echoes from behind the listener, and the lack of that sense of perspective which makes the orchestra appear to be at a natural distance from the listener. Much of the 4-channel sound heard is generally muddy and confused, and is less satisfying than ordinary old-fashioned stereo.

For some years there have been experiments which have attempted to recreate the sound of the concert hall by playing ordinary stereo through a front pair of loudspeakers, and by playing a synthetically-produced reverberation through the rear speakers. In these experiments, the rear channels' sound is derived by passing the stereo signals into a reverberation unit, which uses springs or tape-delays to conjure up an artificially reverberated version of the original sound, so as to simulate concert hall reverberation. One of the most successful of these synthetic systems has been marketed by Grampian, whose 'ambiophonic' reverberation unit has been available for this purpose for several years.

However, by examining the above list of missing qualities in reproduced sound, one soon realizes that synthetic 4-channel systems cannot be the final answer. Synthetic reverberation can

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add an extra fullness to the stereo sound, and it can place the orchestra a little behind the front loudspeakers. What it cannot do is to recreate a concert hall around one; it cannot give the orchestra genuine depth so that the rear is more distant than the front, and it cannot replace the other missing qualities listed earlier. Good musicians always adapt their performances to suit the most subtle qualities of the concert hall in which they are performing. This can be proved by making recordings of the same musicians performing the same works in different halls; such a comparison reveals that there are important subtleties of performance which depend on the acoustics. These subtleties are completely lost if a synthetic reverberation is added afterwards.

This warning is necessary, as there has been a spate of synthetic 4-channel systems recently, produced by manufacturers jumping on to the 4-channel bandwagon. Another alarming development is the report that some record companies are experimenting with using artificial reverberation to convert their old stereo recordings into 4-channels ones. It should be said, however, that many 'genuine' 4-channel recordings are so bad that one seasoned American commentator has opined that many of the synthetic systems are still preferable to the majority of commercial 4-channel recordings.

Despite the poor quality of most current 4-channel recordings, we have seen that the deficiencies of ordinary stereo are such that some new multi-speaker system of sound reproduction is required. The musical importance of realistic reproduction is now widely recognised, and so there should be no need to argue the desirability of achieving true reproduction of the original sound in the concert hall. However, 4-channel reproduction should also be capable of handling the simpler requirements of light music recording. This is something that even current 4-channel recording techniques can cope with, and it would be a dull soul who fails to be enchanted by the effect of synthesised sound coming from all around one in *Switched-on Bach* – not that Bach is normally regarded as a light music composer!

The arrangers of light music are only just beginning to realise that 4-channel sound can mean much more than merely placing instruments in various directions about the listener. One of the new effects now being exploited is overhead sound, in which a sound can be made to hover over the listener by feeding it equally to all four channels. Another interesting effect is *quadruple tracking*, in which an instrument is made to seem to be performing all around you without being anywhere in particular; this is achieved by recording the instrument playing the same thing four times over, putting one of the recordings on each of the four tracks. The arranger of light music has to treat such new effects with great taste and skill in order not to turn them into tiresome gimmicks, but the possibilities

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of 4-channels in light music seem very worthwhile.

In the world of serious music, this type of spatial effect has already been extensively exploited. Especially notable is *Poème Electronique* by Edgard Varèse, who in his seventies composed one of the very few masterpieces of electronic music. This work was composed for reproduction in Corbusier's Philips Pavilion at the 1958 Brussels Exhibition, and its electronic sounds dart to and fro from points all around the listener. Other electronic or live works involving sounds coming from all round the listener have been written by such modern composers as Iannis Xenakis, Pierre Boulez and Karlheinz Stockhausen.

In much modern music, spatial effects are as important as, say, rhythm or dynamics. Even in earlier music, all-round sound has been of musical importance. Well known examples are the *Berlioz Requiem*, and the many 'echo-music' compositions of the baroque era.

Another possibility of 4-speaker reproduction is in the presentation of recorded drama and poetry, in which surround-sound effects provide endless possibilities. Not everyone may wish to have a battle fought around them, but many less spectacular items might be dramatically effective, such as placing narrators or off-stage events behind or to one side of the listener.

Apart from such special effects, the primary purpose of 4-speaker stereo is to get as close to the original sound as possible. It is unfortunate that there are so many different qualities of live sound to be captured, as most simple-minded ideas of how to record or reproduce 4-speaker stereo will fail to achieve some of these qualities. However, at this stage a large number of proposals have already emerged, and some of these will now be examined.

The simplest type of stereophonic system involves only two speakers, and the three main 2-speaker formats will be discussed first. The standard 2-speaker format is that of **fig. 3a**, which produces a good directional effect, but conveys little of the spacious feeling of a live concert hall. It is in fact possible, under ideal conditions, to achieve surround sound *using only the usual two stereo speakers as* in fig. 3a. In some 'dead' listening rooms, out-of-phase sounds in the two-channel recording can actually appear to come from behind the listener's head, even though only frontal loudspeakers are used. The reason for this is poorly understood, and the effect is largely lost in most listening rooms. However, even in these circumstances stereo recordings having a large amount of out-of-phase reverberation seem to have a depth and a 3-dimensional quality lacking in ordinary stereo. For this reason, stereo recordings made for the Hafler reproduction system described later should enable a more spacious effect to be obtained from ordinary stereo.

Another 2-speaker format is illustrated in **fig. 3b**, with one speaker placed at each side of the listener. With suitable recordings, this system gives

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an excellent sense of space and depth, but is quite hopeless at conveying a good directional effect. A 2-speaker format that has received some attention is that of **fig. 3c**, with one speaker at the front and one at the back. With suitable special 2-channel recordings, this system is capable of conveying a fair degree of spaciousness, and places the orchestra firmly in front of the listener, but lacks a proper lateral stereo effect. Front-and-back stereo is an excellent means for recordists to find out about the problems involved in using rear speakers, without the extra complications of four channels. Experimental recordings using this technique show that the ears are very much more sensitive to echoes (i.e. time-delayed signals) from behind than to echoes from the narrowly-angled speakers of conventional stereo. It is thus unadvisable to use microphones placed well back to pick up the rear reverberation, as this causes unpleasant echo effects of the type heard on many commercial 4-channel recordings.

Several years ago Granville Cooper demonstrated successful front-and-rear 2-speaker recordings made using coincident microphones, which did not suffer from an echo effect and which had a large listening area in which good results were obtained.

The advantages of all three 2-speaker systems can be obtained by using four loudspeakers. Three such 'quadraphonic' loudspeaker arrangements have been widely used, and are illustrated in **fig. 4**. The system of **fig. 4a** was proposed independently by David Hafler and the author, and has a speaker at each side, one at the front, and one at the back. The presence of loudspeakers at each side of the head makes the reproduction particularly spacious, and a great depth is still obtained even if the rear speaker is disconnected.

The format of fig. 4a has been suggested mainly for use with special 2-channel stereo recordings, whose *sum* signal L + R is fed to the front loudspeaker, whose left signal L is fed to the left speaker, whose right signal R is fed to the right speaker, and whose *difference* signal L – R is fed to the back speaker. Full details can be found in the August 1970 *Hi-Fi News*, but a little thought will show that, not only is an ordinary stereo signal reproduced in front of the listener, but also any out-of-phase signal in the two channels will be reproduced from behind the listener. Such special stereo recordings can be made by the Hafler technique, which adds an out-of-phase reverberation signal to an ordinary stereo recording, or by recording using the coincident Blumlein technique with figure-of-eight microphones, which automatically picks up out-of-phase reverberation. The type of system described here in which the signals for four speakers are obtained from two channels by adding and subtracting signals is known as a *matrixing system.*

The most realistic 4-speaker reproduction so far heard by the author has used a matrixing system with 2-channel Blumlein recordings, and conveys a sense of spaciousness,

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natural dynamics, sounds from all around one, and the distances of the different sounds. Indeed, sounds recorded close to the microphones actually sound closer to the listener than the loudspeakers! Few other methods of recording surround-sound can convey the distance effect so well. Nevertheless, there is no reason to doubt that a genuine 4-channel system could do even better, but this requires current recording techniques to improve a great deal.

The most popular 4-speaker format is that of **fig. 4b**, which effectively consists of a 2-channel stereo system in front, and another behind. Most genuine 4-channel commercial recordings have been designed for this loudspeaker layout, which covers a larger listening area than that of fig. 4a. It should prove possible to use this layout with a 2-channel matrixing system, and a 3-channel matrixing system is capable of conveying all the information required for this loudspeaker arrangement. By raising all four speakers above the listener's head, it is possible to convey some degree of height information, although the full subtleties of the height dimension cannot be convincingly captured by this means.

Another 4-speaker format is that of **fig. 4c**, using two speakers in front, and one at each side of the listener. Some of the advantages of 4-speaker stereo are lost as no sounds can come from the back, but the presence of speakers at each side of the head increases the sense of spaciousness. The system of fig. 4c works quite well with conventional 4-channels recordings, but can also be used for the spacious reproduction of 2-channel material. One system proposed by David Hafler in the U.S.A and Rorbaek Madsen in Denmark reproduces the left and right stereo channels over the front speakers in the usual way, and the *difference* L – R of the two channels over the side loudspeakers. If the recordings has out-of-phase reverberation information incorporated, this should make the sound more spacious, although other surround-sound qualities will not be fully captured.

Another method of adding spaciousness had been proposed by Madsen, which works with both mono and stereo. He suggests feeding the front speakers of fig. 4c in the usual way, but feeding the side speakers with the *sum* signal L + R via a 5 to 10 millisecond delay line. Madsen claims that this enables the ears to recover the reverberation hidden in the original recording while still making the direct sound appear to come from in front. This uses the Haas effect, which asserts that the apparent direction of a sound is not affected by subsequent sounds arriving at the ears 5 to 30 milliseconds later. (It will be seen that if a tape recorder is used to provide the delay for the side speakers, then the delay will be far too long for the Haas effect to work successfully.)

A defect of all the systems so far discussed is that they cannot convey the *height* of all sounds correctly. To overcome this problem, Granville

Cooper* and the present author have proposed the use of *tetrahedral* systems, in which the four loudspeakers are placed at the four corners of a tetrahedron. (A tetrahedron is a solid shaped like a pyramid with a triangular base.) The author's proposal is that the four speakers should be placed at the four corners of the room as in the conventional system of fig. 4b, except that the front left and rear right speakers should be at ceiling level, and the rear left and front right speakers should be at floor level (see **fig. 5a**). This particular tetrahedral arrangement should give a larger listening area than any other, and enables sounds to be reproduced from any direction, whether horizontal or vertical. For example, a sound can be made to appear to come from below by being reproduced via the rear left and the front right loudspeakers.

Another tetrahedral system has been proposed by Granville Cooper which uses two conventional stereo speakers in front, and two rear speakers placed one above the other at floor and ceiling level, as illustrated in **fig. 5b**. It is possible to convert recordings made for one tetrahedral system to the other by means of special matrixing circuitry. A number of experimental tetrahedral four-channel recordings have been made for Cooper's system, using four coincident cardioid microphones pointing, during recording, in the directions of the loudspeakers during playback. Initial results have been encouraging.

There have been a number of attempts to code 4-channel recordings into two channels, so that they reproduce well as conventional stereo while enabling a full 4-channel sound to be recovered using special electronic decoding apparatus. The best known of these systems is that devised by Peter Scheiber, which appears to be a matrixing system in which the decoder increases the effective separation between the four output channels by automatically turning down the gain of those output channels containing crosstalk. Such a system is capable of recovering the original directional effect, but is unlikely to capture subtleties of reverberation that convey a sense of distance and perspective. Despite the claim that such systems allow four independent channels to be conveyed via only two, they cannot in fact convey some quite important types of 4-channel information at all. For example, such a system cannot convey a sound on, say, both the front left and the rear right channels without conveying sounds on the other two channels as well. This deficiency prevents such systems from being used with tetrahedral reproduction, as the matrixing used throws away the height information.

At the present time, it seems that results almost as good as, and sometimes better than, commercial 4-channel sound can be obtained from ordinary 2-channel stereo material by reproducing them via one of the Hafler

* See 'Tetrahedral Ambiophony', Studio Sound, June 1970

techniques. The simplest method is to use the speaker layouts of figs 4 b or 4c, in which the front loudspeakers are connected to the stereo amplifier in the usual way, and the rear speakers are connected, in opposite phases from one another, between the *live* loudspeaker terminals of the same stereo amplifier. This ensures that the rear speakers reproduce the difference signal L – R, and the ambient effect obtained from them can be optimised by trying them connected in series and in parallel, and by careful rear speaker placement. While the effect obtained is not equal to the best surround stereo, this simple technique can nevertheless effect a considerable improvement over ordinary stereo.

Whatever system is used, experience with top-quality material shows that the best results can only be obtained if the sounds from all four speakers are of equal technical quality. It has been widely suggested that the reverberation from the rear can be of much lower quality than the direct sound from the front without having much effect on the overall quality. This appears to be untrue, and the overall reproduction becomes quite fatiguing if the rear sound is more distorted or coloured than the front. If the rear speakers only reproduce reverberation, then it is permissible to reduce the power of the rear channels, but this cannot be skimped too much as many realistic recordings convey a rear power only about 6 dB less than the front power. Initially, the extra richness of 4-speaker sound allows one to use rear speakers with little bass, but it is not long before the bass is missed.

Although it is often stated that reverberation has little treble, on good recordings realism is lost if the rear treble response is poorer than the front. On bad recordings, a reduction in the rear treble can prove very effective at suppressing objectionable back-echo effects. A tolerable sound, with good richness, can be obtained from commercial 4-channel recordings by placing the rear speakers high up, at the back of a projecting shelf. This prevents the rear sound becoming obtrusive, and the shelf helps to obstruct the treble and hence cut it down for listeners near the back of the room.

However, the full sense of distance, dynamics, extent, direction and surround-sound cannot be obtained without first-rate equipment, first-rate recordings, and a no-compromise loudspeaker placement. The extra realism of the best experimental 4-speaker stereo forces one to judge the sound by comparison with the real thing, rather than by comparison with other hi-fi, and this makes the normal small technical deficiencies become far more noticeable.

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