Experimental Tetrahedral Recording: Part One

By Michael Gerzon

IN the September 1970 *Studio Sound*, the author proposed a new system of four-channel recording using the skew tetrahedral loudspeaker layout shown in **fig. 1**, which is essentially a conventional square four-speaker layout with the front left (LF) and rear right (RR) speakers raised to the ceiling, and the front right (RF) and rear left (LR) speakers lowered to the floor. By this means it was hoped to capture the original directional effect of all sounds around the listener, both horizontally and vertically.

Recently, an experimental live relay and recording was arranged using this system. Considerations governing the design of the experiment will be described next month. The following confines itself to a description of the experimental set-up and an account of some impressions obtained by listeners.

The relay and recording was of a rehearsal and public concert given by the Schola Cantorum of Oxford, conducted by Andrew Parrott, of unaccompanied and accompanied choral music, in the chapel of Merton College, Oxford, on May 8. This location has a distinctive 'church acoustic'

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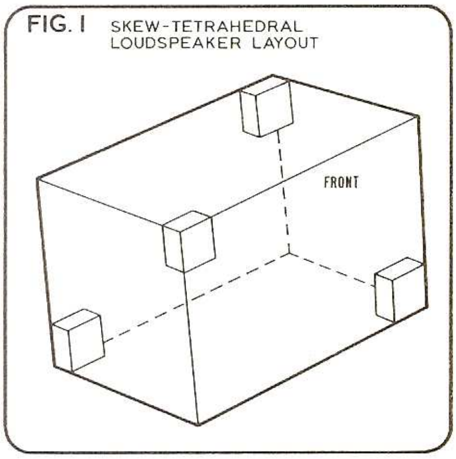
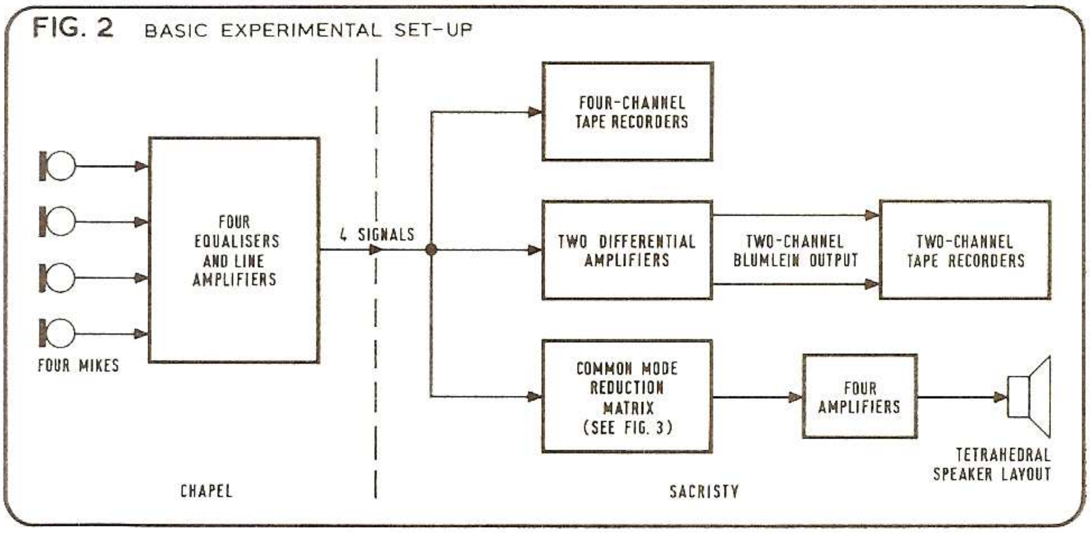
and the experimental aim was to determine how realistically this could be reproduced.



The following set-up was used for the experiment (see also **fig. 2**). Four coincident Calrec 652 cardioid microphones, pointing along the four axes of the chosen tetrahedron of fig. 1, were placed in the middle of the audience in the chapel at just above ear level so as to provide an accurate comparison between the sound as heard live and as reproduced. These were fed into a four channel equaliser/line amplifier and this fed cable to the Sacristy adjacent to the chapel. In the Sacristy, the signal was split to feed two four-channel tape recorders, a 6.25 mm *Crown* loaned by Carston Electronics and brought by Bob Arthurton, and a 12.5 mm *Scully* loaned by Granada Recordings and brought by David Martin. The four signals were also fed via Quad valve amps



into a tetrahedral monitoring set-up consisting of two floor level Quad electrostatic speakers and two Spendor *BC1* monitors placed 2.5m up on the top of stepladders. The floorplan of the speakers was about 3m square. The four channel signals were fed to the monitoring amps via a matrix circuit which allowed the cardioid microphone outputs to be converted into hypercardioids at the turn of a knob.

The four-channel signal was also taken to a pair of differential amplifiers which produced a crossed figure-of-eight Blumlein stereo output for simultaneous two-channel recording.

A relatively small speaker layout was used to simulate domestic conditions and to minimise the effect of the acoustics of the rather large Sacristy. As only four people could be seated comfortably within the tetrahedron, only a small number of people were able to take part in the experiment. Among these were Sid O'Connell and Granville Cooper, whose previous experience of other tetrahedral systems proved invaluable in pinpointing strengths and weaknesses of this system. It was possible to compare the reproduced sound with the real thing by passing through the door to the chapel.

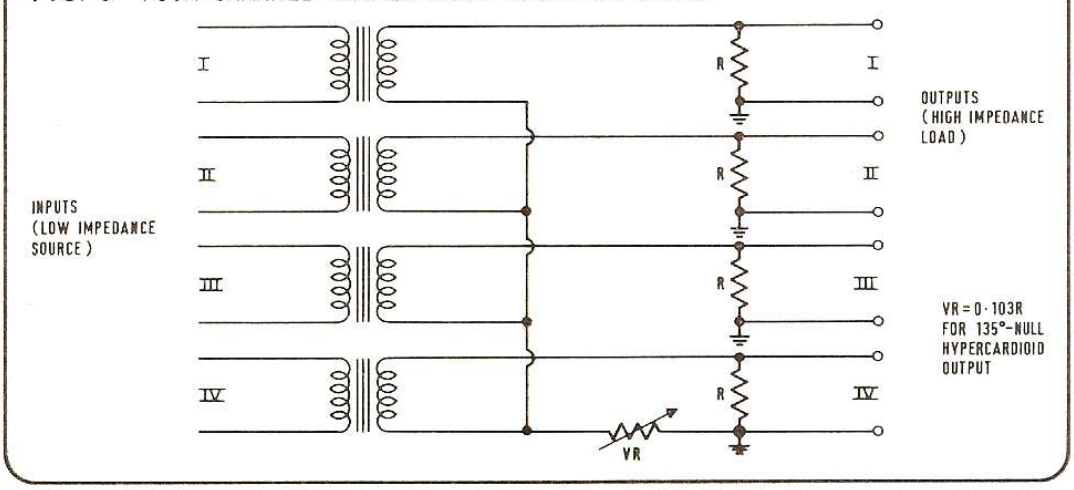
The initial setting up of speaker phasing and levels was found to be somewhat difficult and small errors in the channel gains were found to have a considerable effect on the reproduced sounds. When these were correctly adjusted, the basic stereo image was found to be reasonably correct in its directional effect, and sounds arriving at the microphones from above, below, the sides, the front and the back of the microphones were reproduced from these positions also.

When the skew tetrahedron of fig. 1 was first proposed, the author and others were worried that the front stereo image might not appear flat, but would instead tilt downwards from left to right. It was in fact found that a good horizontal stereo image was obtained in all sensible listening positions once levels had been adjusted. The general three dimensional sound picture was judged to be about the most accurate yet heard, and considerably superior to the stereo picture obtained with other systems.

There were two really important flaws heard. The first defect, given the name 'overlap' by Rex Baldock at the time, is the effect obtained when the sound corresponding to one direction emerges to some degree even from speakers in the opposite direction. Overlap is familiar to those who have tried Hafler reproduction with the rear speakers turned up a little too high. Just as a mono sound gains in richness from being reproduced from two speakers, so does a sound gain even more richness if it is reproduced from all four speakers. This extra quality was described as 'openness' by the one listener who liked it but other listeners felt that the richness caused by the overlap was rather unnatural and some found that sounds seemed to be coming from both in front and behind at the same time.

Calculations show that a sound arriving from the front at the cardioid microphones will be picked up by the rear microphones only 11.4 dB down relative to the front microphones. This degree of overlap can be reduced by using hypercardioid microphones. In the experiment, hypercardioids were simulated by using a common mode reduction circuit to reduce the common mode (i.e. omnidirectional) component of the four cardioid signals. The circuit used is illustrated in **fig. 3**, and a setting of the variable resistor VR at about 0.1R was found to give a considerable reduction of overlap; this setting corresponds to using hypercardioid microphones whose nulls are 135^{o} off-axis, and increases the front-back separation from 11.4 dB to around 20 dB. The pick-up of front sounds by the rear channels can theoretically be eliminated by putting VR=0.183 R, corresponding to 125.3^{o} null hypercardioids, but this is found to cause a lot of out-of-phase overlap for sounds coming from the sides of the orchestra. It was found subjectively that the least overlap corresponded to VR=0.1R very approximately. The result of these preliminary tests was that cardioids give too much overlap, and 135^{o} null hypercardioids, obtained by matrixing, give a much better effect.

FIG. 3 FOUR-CHANNEL COMMON MODE REDUCTION CIRCUIT



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The other important flaw in the tetrahedral reproduction is far more difficult to rectify. As readers of this journal are aware, the *ELS* and *BC1* speakers used are among the most uncoloured available. They were chosen for precisely this reason, as fidelity to the live sound was the most important consideration. Unfortunately, it was considered impractical to mount *ELS*s on stepladders, and only two Spendors were available. As an *ELS* and a Spendor have been found to work well as a stereo pair, being surprisingly similar in sound, it was decided to use two of each as described earlier. However, it was found difficult to match their outputs for the tetrahedral reproduction.

Even when the levels were set optimally, it was found that the coloration from the four speakers caused a very disturbing side-effect. Although the basic stereo image was distributed horizontally, the four loudspeakers were heard as separate and very distracting sources of coloration. The coloration from the Spendors tended to pull LF and RR sounds upwards, and the *ELS* coloration tended to pull the RF and LR sounds downwards. These sources of coloration greatly disturbed the overall impression of a homogeneous sound field around the listener, and this is certainly the most serious problem to be solved with this system. Its seriousness is indicated by the observation that the *ELS* is probably the least coloured loudspeaker available and that the *BC1* is generally regarded as approaching it; yet the tetrahedral system made the Spendors seem tremendously prominent as a separate source of coloration and even the Quads were shown up to a lesser extent. If this experiment is anything to go by, tetrahedral reproduction as in fig. 1 is an ideal way for loudspeaker designers to assess so-called 'subtle' colorations — there is clearly an enormous amount of progress yet to be made in loudspeaker design.

The energetic members of Oxford University Tape Recording Society who had done all the hard work of the experiment decided that a mixed Spendor/Quad system was unsatisfactory. The next day they set up a tetrahedral playback system in a domestic room consisting of four *ELS*s, two placed on the floor, and two strapped precariously at ceiling level on stepladders, angled downwards towards the listener to avoid the loss of treble up top (literally!). This set-up gave much better results. The channel levels were found to be less critical, although the bass output of the ceiling *ELS*s had to be reduced to obtain a balance. With this system, the speaker coloration was found to be less disturbing, although its effects were still noticeable. The high degree of overlap given by cardioids was found to be more objectionable than with the earlier system.

The acoustics of the Sacristy had to some extent obscured the subtleties of the Spendor/Quad tetrahedral playback and it was found that, with the all-Quad system in the domestic room, the original acoustics of the chapel were audible with great clarity, even though the sound was being played back from a rather hissy tape. It was possible to analyse the acoustics in the same detail as if one were there live; with careful listening, one could pick out the precise position of a lectern which had obstructed some of the reverberant sound near the microphones. The separate effects of various parts of the ceiling and walls of the chapel were clearly distinguishable, and the whole experience strongly argued against those who claim that four channels need only pick up a generalised reverberant richness and nothing more.

There are many who regard the height effect as an altogether unnecessary luxury and, at first sight, our choice of music with virtually no vertical spread seems to suggest they are right. Yet the listening tests showed quite the opposite – the height effect on the reverberation added very considerably to the realism. Indeed, several listeners standing *outside* the tetrahedron still found the spaciousness of the recording to be superior to that obtained from most conventional four-channel recordings *within* the square of speakers. Another index of the improved realism is that listeners outside the playback room heard a sound that gave a quite uncanny imitation of emerging from a chapel.

Some of the orchestral playing in the concert had been rather scrappy and this was found to be very disturbing musically on two-speaker stereo playback. It was interesting to note that such flaws were far less noticeable on tetrahedral playback which, like the live sound, made it easier to listen though such performance errors to the music. The purely musical value of tetrahedral reproduction should not be underestimated.

This catalogue of enthusiastic initial impressions indicates the tremendous potential of tetrahedral reproduction but it must not disguise the serious problems that remain. When set up carefully, the overall impression is that of a basically realistic sound with a lot of spurious distractions added. Speaker coloration is the most serious and perhaps the tetrahedral system needs to wait until loudspeakers have attained the required standards. Alternatively, coloration might be rendered less disturbing by sharing it out among more loudspeakers, say a cube. The requirement that the amount of overlap must be kept down means that the choice of microphone arrangement is more critical than with other systems, although this problem would not exist with pan-pot multimike recordings.

It seems that the relative balance between the four channels must be accurately maintained right from the live sound to the playback speakers, as a small imbalance can shift a sound farther that with the narrowly angled speakers of two-speaker stereo. It is important to point the microphones accurately, as a 5° or 10° rotation of the image can make the sound seem terribly lopsided. This is especially important since the speakers become more prominent as distinct sources of sound when one's head is not pointing forward.

Another problem is that there is a partial 'hole in the middle' effect at the front, two sides and back (and, one presumes, above and below, although this was not evident in the absence of such direct sounds). The stereo image is certainly there, but it is less rigidly locked in place between the speakers than in the corners. The overall stereo effect does vary with listening position, although the orchestra tilts only near the corners, or if there is a channel imbalance. When one rotates one's head, one has an impression that the sound rotates with it, although the sound tends to lock into a position not far from its original one a little while after the head rotation stops. This rotation was less pronounced for hypercardioids than cardioids, and no rotation occurred when direct sounds surrounded the listener, as with audience applause.

When channel balance was out, it could be quite difficult to determine the precise relative positions of sounds, especially when there was too much overlap. It was also difficult to obtain a good distance effect, and the sound seemed to stop short at the loudspeaker distance, even when the live sound was closer. This disappointing distance effect is puzzling, as I have heard generally inferior systems reproduce all distances, both close and distant, with great fidelity.

These have been some initial reactions to skew-tetrahedral reproduction. It offers a tantalising glimpse into what audio could be like, and one becomes depressingly aware of the overwhelming deficiencies of even the best conventional four-channel stereo. It, or something like it, is clearly the system of the future, but how far in the future is anyone's guess as the practical problems still seem formidable. What is now needed is much more experimental investigation of this and related systems. It is only by patient research, by trial and error, that many of the difficulties can be resolved.

Meanwhile, it seems desirable for commercial recordings to be made containing height information where possible. Tetrahedral recordings made for the skew-tetrahedral layout of fig. 1 are directly suitable for playback over the conventional square loudspeaker layout, although the height effect is then lost. The situation seems to be that tetrahedral recordings can be issued in any genuine four-channel medium, but cannot be played back properly as yet. It should be observed that, if necessary, it will always be possible to rematrix a recording made for one tetrahedral system for playback via another.

A four-channel 12.5 mm tape has been recorded in the above experiment. This tape is available for copying or playback by anyone interested, although deficiencies in the recording set-up have given it rather a dull treble.

Tetrahedral systems can be varied in so many ways that it is essential for experimenters to understand the principles before they start. A naive outlook can render experiments fruitless. For this reason, the second part of this article will deal with the principles, setting-up procedures and uses of tetrahedral recording.

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