quadro 1-2-3-4.... or nothing?

The phenomenon of 'quadrophony'* has already been the subject of many publications, but the confusion only seems to increase with every new attempt to clarify the issue. This article may bring a little light into the darkness, by describing and comparing the most important systems that have been proposed so far.

In order to simplify the comparison of the various systems, we shall proceed from a block diagram of the total sound signal path (figure 1).
In this diagram, A represents the recording location (studio, concert hall, etc.) in which a number of microphones are placed. The type and number of microphones used and their position are, of course, significant for the maximum quality of transmission that is attainable. Many fundamental investigations dealing with these aspects are going on at the present time, but they will not be dealt with in this article.
Block B represents the total chain of electronic devices that perform the coding, transmission (via gramophone record, tape or radio) and decoding. One of the possible quadrophonic systems is introduced into this chain.
Block C forms the end of the chain as the living room in which the loudspeakers are usually placed in the four corners. The various systems in block B can now be compared to each other by relating the sound impression reproduced in space C to the original sound impression that was derived (by the recording technican) from the sound event.
First of all, the basic methods of operation of the various systems will be briefly discussed.

Types of system

In general, we can draw a distinction between three different types of system: quasi-quadrophony (or pseudo-quadrophony, similar to pseudo-stereophony), 'discrete' quadrophony with four independent transmission channels and, finally, quadrophony according to matrix systems.
Quasi-quadrophony is based on the experience that a 'spatial impression' enhances the reproduction – regardless of whether or not the reproduced sound actually corresponds to the original as far as the positioning of the various instruments or groups is concerned. Such systems can, for example, reproduce reverberation (or the difference signal from two stereo channels, which usually contains a lot of reverberation) via the two rear loudspeakers. This is sometimes referred to as a '2-2-4' system, in other words a system that uses 2 original sound channels, 2 transmission channels and 4 reproduction channels. It goes under various banners, such as 'Stereo-4', 'Quadro-sound' etc. However, it is not quadrophony in the true sense and will therefore not be discussed any further in this article.
A discrete quadrophonic system contains four different channels that remain separated within section B of figure 1 – from the microphone to the loudspeaker (a '4-4-4' system). An example of this is the CD-4 gramophone record-CD stands for Compatible Discreteness. An experimental radio transmission that used two stereo FM transmitters for one program could also be included in this group.
Finally, matrix systems are based on the mixing of the original information channels. What were previously four channels of the total quadrophonic recording are now combined into two new, specially-coded channels. They can then be conducted over normal stereo systems, divided again into four channels at the destination and reproduced by the four loudspeakers in the listening room. These systems are classed as '4-2-4'.
Since only two equations cannot be solved if they contain four unknowns, the four resulting channels will in the last analysis never be identical with the original four: they must always contain

* Four channel stereo, an accurate but somewhat clumsy phrase, is variously referred to as quadrophony, quadraphony, quadrosonics, quadrasonics, quadrisonics, tetraphony, surround sound, et al. In this article 'quadrophony' is used for the sole reason that it can be abbreviated to 'quadro', which goes with 'mono' and 'stereo'.
After all, 'that which we call quadro by any other name would sound the same' . . . .

crosstalk components. According to the choice of the mixing relationship, however, the spatial sound impression during reproduction can correspond more or less satisfactorily to the original.

CD-4

This system, advocated by Nivico and RCA, is a discrete system.
On a gramophone record, the left 'stereo' channel now contains the sum signal of 'left front plus left rear', and, in addition, a frequency modulated 30 kHz carrier with the difference signal 'left front minus left rear'. The right 'stereo' channel carries the two signals 'right front plus right rear' and 'right front minus right rear' in the same way. For reproduction, the four original channels can (in principle) be regained by simple addition and subtraction of the respective sum and difference channels.
The modulation of the left channel is shown schematically in figure 2. The sum signal with a bandwidth of 15 kHz is cut in the usual way. The difference signal is frequency modulated on a 30 kHz carrier. This modulation is asymmetrical (−10 kHz, +15 kHz), which easily gives rise to amplitude modulation and distortion.
The practical results with this system are discussed in the comparative section.

SQ and QS

SQ (by CBS and Sony) as well as QS (by Sansui) are matrix systems – the abbreviations stand for 'Stereophonic Quadrophonic' and 'Quadrophonic Stereo', respectively. Here the four original channels are mixed into two for transmission and are divided again into four before reproduction.
In the case of SQ the mixing relationship (in amplitude and phase) is set up for optimal channel separation between left and right front, respectively, and between left rear and right rear. The front channels are cut in the same way as normal stereo channels. CBS chose this system because it was expected to produce optimal effects in the case of possible traditional stereo reproduction. From the comparative section, it can be seen to what degree this was achieved. The unavoidable crosstalk takes place between 'front' and 'rear', audibly along both diagonals.
In the case of QS, on the other hand, a mixing relationship that should make acceptable quadrophonic reproduction possible was chosen. A point-like sound source in the recording area is reproduced with an amplitude characteristic that is very close to cardioid. The sketch in figure 3 shows this characteristic for BMX, which will be discussed in the next section. For both QS and BMX this characteristic is always oriented towards the position of the original sound source.
The Japanese 'regular matrix' standard (RM) is based on the QS system.

UMX

UMX is a 'universal matrix system' derived by Professor Cooper (USA) in collaboration with Dr. T. Shiga (Japan).
The practical development followed in cooperation with Nippon Columbia (trade name: Denon). This firm is a member of the Hitachi group.
The point of departure was a thorough scientific investigation of the characteristics of matrix systems. From this the optimal two-channel matrix was derived: BMX. By the addition of a further channel, the three-channel TMX was produced, while QMX works with an extra fourth channel. Of relevance here is the fact that the position of the phantom sound source during reproduction is not altered during transference from two, via three to four channel transmission. The localization does become more precise: with BMX, a solo instrument sounds somewhat 'mushy' (spread over a distance of about 0.5 meters), but with the higher order systems TMX and QMX the sound seems to come from a precisely determinable point.
The characteristics of amplitude and phase, as they arise during the reproduction of a single point source, are shown in figure 3. The amplitude characteristic of BMX is the same as for QS, and is always oriented towards the original position of the sound source. An essential difference from QS lies, however, in the fact that with BMX the phase characteristic also 'rotates': 0° corresponds to the direction of the sound source, while, for example, the sound coming at rightangles to the sound source is phased at ± 45°. This additional information gives a significantly better localization. With the QS-system, 0° phase rotation always corresponds to the sound from the phantom centre front, so that sound sources in the front are drawn towards this point.
In the case of gramophone records in UMX (called UD-4) the two basic channels of BMX are recorded in the same way as for stereo. One basic channel contains the mono signal (sum signal), while the other contains the difference information for the stereo or quadro effect. The third (TMX) and fourth (QMX) channels are frequency modulated on two 30 kHz carriers, similar to those used for CD-4. An essential difference from that system, however, lies in the fact that these two auxiliary channels can be contained in a fairly narrow band. An audio bandwidth of 3 kHz is completely satisfactory, and this can be transmitted as symmetrical frequency modulation with a peak deviation of ± 6 kHz (figure 4).

This limiting of the audio band is possible, because there is hardly any audible difference between BMX and QMX at frequencies above about 3 kHz!
Since the orientation of the various sound sources is the same for all three systems, the transition from QMX to BMX at this cutoff frequency is almost imperceptible.

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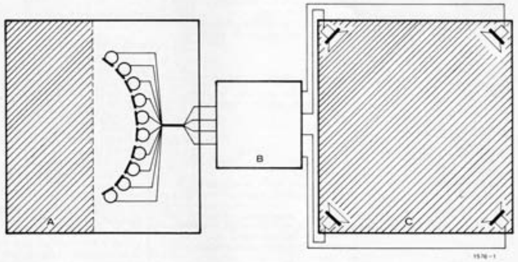

TMX is mainly of interest for radio broadcasting: a third channel can be rather simply provided (for example, by quadrature modulation); however, four channels appear to be an impracticable process — at least in Europe. Greater bandwidths would be required for the transmission of four channels, and these would lead to unacceptable interference on neighbouring channels.

Conclusions

From the comparison of the four systems it is apparent that SQ seems to be based on a different conception of quadrophony: to arrive with 'logic' at four stressed 'corners' (and also 'centre front'). This is succesful to the extent that presentations can be very impressive in spite of the noted shortcomings.
The results of CD-4 and QS are adequate. Since several parameters are not optimal, the peripheral devices for noise reduction and image position stabilization are unnecessarily complicated. In spite of these additional devices, however, the results are not completely satisfactory.
Finally, the UMX system combines the best features of both systems to give the best results. Therefore, from a technical viewpoint, this system is to be preferred.
Unfortunately, the discussion of quadrophony is at present clouded by confusion of language and by commercial considerations. Partly because of this, the UMX system has often been practically ignored.
It is often argued that UMX was developed too late, so that great investments already lie in other systems. Professor Cooper argues strongly against this. In his opinion, the differences from the other systems (especially CD-4) are so slight that possible changeover offers no difficulty.
The number of gramophone records already pressed according to a certain system should not (yet) be decisive either. It would be another matter if a company began to use a particular system for its entire record collection. Fortunately, this has not yet happened.
In view of the rapidly increasing demand for quadrophony especially in the USA and Japan but also in Europe, there is still hope that a definitive choice will be made in the near future. In this event, it is to be hoped that technical arguments will be decisive, and from the technician's standpoint this article could have been entitled: UMX . . . or nothing!

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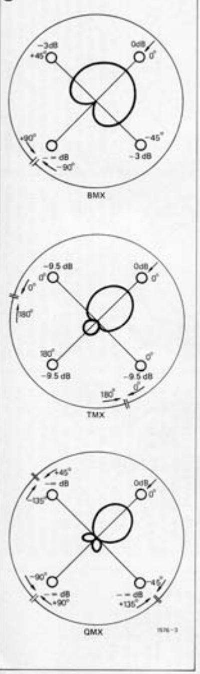

Figure 1. Block diagram of a complete quadrophonic sound chain. A = recording area; B = transmission system, C = reproduction area.

Figure 2. Frequency spectrum on one record groove wall when recording according to the CD-4 system. The sum signal is recorded in the normal way in the base band (0 . . . 15 kHz). A 30 kHz carrier is frequency modulated with the difference signal in the band from 20 to 45 kHz.

Figure 3. Amplitude and phase characteristics of the systems BMX, TMX and QMX. 0 dB of the amplitude characteristic and 0° of the phase characteristic always coincide with the position of the sound source. If several sound sources are reproduced simultaneously, one can imagine the appropriate characteristics as "piled on top of one another".

Figure 4. Frequency spectrum when recording according to the QMX system (one groove wall). The two BMX channels are recorded in the base band (0 . . . 18 kHz). The two auxiliary channels are each modulated on a 30 kHz carrier (FM), in the band from 24 to 36 kHz.

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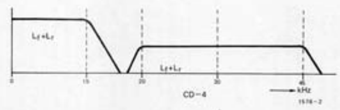

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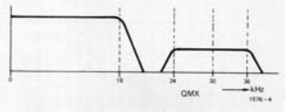

Comparative section	CD-4	SQ	QS	UMX/UD-4
System:	4 discrete channels, of which two are cut in the usual way; the two extra channels are frequency modulated on a 30 kHz carrier. The analogous Dorren system for FM radio is unsuitable for Europe.	Matrix process that in recording produces two pairs of completely separated channels, one for left front/right front, and one for left rear/right rear, respectively. Only intensity stereophony is possible.	Matrix that provides a 'cardioid' amplitude characteristic during reproduction (oriented towards the sound source). The phase characteristic is fixed: 'zero degrees' is always centre front, 180° is centre rear.	Matrix, consisting of two (BMX), three (TMX) or four (QMX) channels. Theoretically, the number of channels could be increased at will. With an increasing number of channels the amplitude characteristic becomes more and more sharply oriented towards the sound source. The phase characteristic rotates in all systems: the 0° point always coincides with the position of the sound source.
Disadvantages:	Wavering amplitude relationships between the channels lead to crosstalk and constant changes in localization. The asymetrical frequency modulation can lead to AM by-products and distortion. The wide information band in the FM auxiliary channels leads to noise problems, so that a noise reduction device is indispensible. For this the ANRS system was developed, which has many similarities to the Dolby system; however, this does not appear to function properly in practice if the carrier level changes (for example, due to record wear), probably because the FM detector is not optimal. Moreover, distortions of the auxiliary channels occur which take the form of distorted crosstalk between the individual channels during reproduction. The pickup cartridge must cope with a frequency range up to 45 kHz.	Strong crosstalk between both pairs of channels is unavoidable. 'Delay time-' or 'phase stereophony' is not possible, because this leads to localization errors. With an automatic gain control ('gain control logic') it is possible to distinctly localize a signal that comes from one of the four corners or from centre front. However, this can only be done for one sound source at a time, namely the strongest, and it influences the position and loudness of the signals from all other sound sources. Without this gain control, everything is drawn by crosstalk to 'right front' or 'left rear'.	Because the phase characteristic is fixed, localization suffers: the apparent position of a sound source is drawn towards centre front or centre rear. With an automatic phase-directed volume and phase control 'variomatrix' the position of the strongest sound source can be accurately localized, regardless of its position.	Apparently none.
Results:	The localization of sound source is good - also in the case of stereo reproduction. The amplitude characteristic as a function of the position of the sound source permits mono reproduction. The system is therefore compatible. However, a distinct 'wavering' of the position arises, because of changes in channel balance. The distorted crosstalk results, for example, in a	With 'logic': 'Ping-pong-pang-peng' effects are produced in quadrophony, but sound sources between the loudspeakers are almost impossible to localize. Without 'logic' the apparent position of sound sources has little in common with the original - both during quadrophonic and stereophonic reproduction. The amplitude characteristic as a function of the	The system gives acceptable quadrophonic reproduction, apart from the fact that the sound sources pile up somewhat in centre front and centre rear. Stereophonic reproduction is also satisfactory; the original sound image (between left front and right front) is, however, reproduced "on a rather narrow stage". Both problems can, of course, be remedied by modi-	Particularly good for quadrophonic, stereophonic and monophonic reproduction. QMX is the obvious choice for gramophone records, while TMX is important for FM radio. A great advantage lies in the fact that cheaper equipment need only detect and decode the two basic channels (as with stereo or QS) to produce good quadrophony (BMX). More expensive equipment,

trumpet blast from one corner being accompanied by distorted sounds from the other corners.

position of the sound sources leads to such a remarkable level pattern that even mono reproduction is unsatisfactory.

fying the recording technique. Mono reproduction is thoroughly acceptable. The only flaw is the fact that sound sources from centre rear are reproduced very weakly or not at all. As long as this is only reverberation, the effect is less noticeable. With certain recordings, however, instruments or other important sounds can be suppressed.

on the other hand, can also detect the third and fourth channel to attain a reproduction with more precise localization. Any crosstalk between the channels causes less precision in the localization of positions, but it does not cause position displacement.

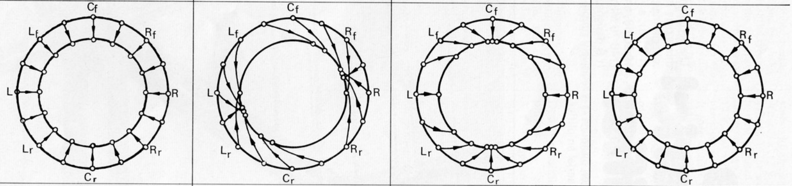

Figure 5. Comparative view of localization during quadrophonic reproduction according to the four systems. The outer circle shows the position of the sound source in the original, while the inner circle shows the position localized during reproduction (derived from the theory of Makita).

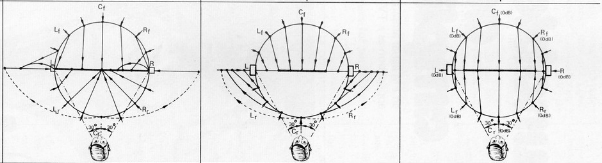

Figure 6. Comparative view of localization in traditional stereo reproduction. The circle shows the original position of the sound source, while the apparent position during reproduction is indicated on the horizontal line (Makita). The loudspeakers are at points L and R.

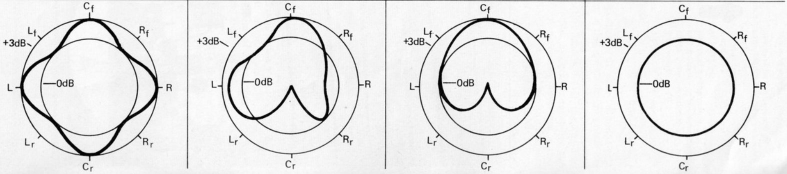

Figure 7. The amplitude characteristics in mono reproduction as a function of the original position of a sound source.