WHAT CANNOT BE RECORDED WITH THE CBS "SQ" FOUR-CHANNEL SYSTEM

by: Michael A. Gerzon

One of the main aims in designing the CBS "SQ" matrix 4-2-4 system was that the effect of the original 4-channel mastertape should be preserved as far as is possible within two channels. In practice, this has meant that sounds in the four corners and straight in front have had their positions preserved reasonably well. However, there are a wide variety of other effects of interest to producers of both classical and "pop" recordings that are incapable of being reproduced well, or even at all, via the "SQ" system, although certain of the competing 4-2-4 systems are well able to handle them. The following describes the permanent limitations producers will be subjected to if the "SQ" system is adopted as an industry standard.

1. POSITIONS AT WHICH RECORDING IS INADVISABLE

1(a). CBS point out that sounds recorded straight behind the listener will not be reproduced in monophonic reproduction. Therefore sounds must not be recorded straight behind the listener.

1(b). Sounds recorded at the right side of the listener will be attenuated by 8.3 dB relative to front-centre sounds when played in mono. Therefore, sounds important to the musical balance should not be recorded at the right side, although no such deficiency occurs for sounds recorded at the left side.

1(c). Sounds recorded at the left side have a strong tendency to be pulled forward,if a "variable-gain" playback decoder is used, when even fairly moderate levels of sound are recorded simultaneously at the front centre. If this effect is to be avoided, producers should not allow the musical texture at any time to consist mainly of sounds at the left side and at front centre. For similar reasons, the musical texture should never be allowed to consist of simultaneous right-side and back-centre sounds.

1(d). One useful 4-channel effect available to producers is to place a small group of musicians clustered around and to either side of a loudspeaker. This effect should not be used with the "SQ" system at the front left and back right speaker positions, as the system is incapable of distinguishing between sounds immediately clockwise and immediately anticlockwise of these corners. This is inherent in the system, and would hold even if the playback decoder incorporated an on-line computer.

1(e). With practical playback media, if sounds which are mainly treble (e.g. cymbals, singer sibilants) are recorded at front centre, then phase errors appear between the two channels due to imperfect cutterheads and pick-ups, or due to tape--weave or skew-aligned tape heads. This will cause a variable gain decoder to stop assigning such sounds to the front speakers only, and instead to reproduce them with more-or-less equal intensity through all four speakers. The mechanism of human hearing can often assign sounds from behind the listener erroneously to the front, but the converse happens more rarely. Thus the effect of mainly-treble front sounds moving towards the back is particularly disconcerting. This effect occured even during CBS's own carefully-prepared demonstrations, and so it is not advisable to record mainly-treble sounds at front centre, if the effect is to be avoided.

2. OVERHEAD SOUND

2(a). One useful effect in recording light and pop music is to make all four speakers reproduce the same sound. This gives an 'in-the-head' or 'overhead' effect. This is reproduced via the CBS "SQ" system as a sound emerging mainly from the front right and rear left speakers, which tends to give the effect of a sound emerging from slightly to the right of front. In 2-speaker stereo reproduction, such a sound will come from the right side of the image. Therefore, straightforward overhead sound cannot be used with the "SQ" system. CBS have recently introduced an alternative encoding matrix in an attempt to solve this problem, which gives overhead sounds an image position which varies randomly with frequency. Unfortunately, such randomisation also affects the positions of side--quadrant and diagonal sounds (see 2(b)) adversely, and in any case does not work on nearly pure tones of electronic origin.

2(b). Another useful effect is that in which a sound is pan-potted across a diagonal pair of speakers. When roughly overhead, a sound pan-potted between front left and rear right will be reproduced via the "SQ" system attenuated by 5 dB, and will emerge predominantly from the speakers on the other diagonal. Thus it is not advisable to pan-pot sounds between the front-left and rear-right speakers. Sounds pan-potted overhead on the front-right/rear-left diagonal will be reproduced via "SQ" mainly from the desired pair of speakers and boosted by an acceptable 2dB. In 2-speaker playback, all types of overhead sound emerge from the right side of the image.

3. REVERBERATION AND AMBIENCE

3(a). Unpublished research (but see references 1 & 2) by the author suggests that an important criterion for a good sense of depth in non-mono recordings is that the apparent amount of reverberation energy coming from different directions around the listener should not vary with direction. Certain recording techniques and reverberation devices (e.g. later samples of the EMT stereo

plate) fulfill this requirement well for 2-speaker stereo. As remarked in item 1(d), the CBS "SQ" system suffers from a hiatus in reproducing positions near the front left or rear right corners, and this will prevent the desired uniformity of distribution of reverberation around the listener from being achieved.

3(b). A uniform spread of reverberation is also found (for psychoacoustic reasons not yet understood) to be helpful to the ears in separating and distinguishing between sound images spaced apart by only a narrow angle. The CBS "SQ" system is thus not good at resolving individual sounds within a group. This holds particularly at the corners, as the simple matrix decoder blurs a corner image to a width of about 25°, and the variable-gain type decoder has the effect described in item 1(d).

3(c). When played through a variable-gain decoder, recordings having a fair sense of reverberant space (e.g. the CBS recording of Gabrielli in St. Marks) are made to sound like four monophonic sounds emerging from the four speakers. This suggests that very spacious recordings should not be played through the variable gain decoder, as this tends to overdo the effect of assigning sounds to their respective speakers in such recordings. As the sense of being behind is almost completely absent from centre back sounds played through the simple matrix decoder (all four speakers producing equal intensities), such recordings should not incorporate centre-back sounds even if monophonic compatibility (item 1(a)) is unimportant.

4. MICROPHONE TECHNIQUES

No coincident microphone technique is possible using the available technology* that will make recordings that give the correct directional effect via the "SQ" system. Four-channel recordings made using such techniques will not matrix correctly via the "SQ" encoder. Thus, although coincident microphone techniques are the most convenient for applications such as live and conference recording or for sound effects, and also for establishing a basic stereo image, they are incompatible with the "SQ" system. These techniques are the only ones available that consistently give a uniform spread of ambience round the listener (see items 3(a) and 3(b)).

---

* 4th-order gradient microphones are ideally required, although with some loss of precision (especially via variable-gain decoders) wide-range 2nd-order gradient microphones (which are not available) could be used.

5. ADDING HEIGHT

It is possible to design so-called 'periphonic' systems of sound recording that reproduce all directions about the listener, both vertical and horizontal. All the simpler such systems are inherently incompatible with "SQ", notably the 2-channel system described by Scheiber (ref. 3). The author has used very general theoretical methods to discover all possible periphonic systems that have sufficient flexibility to fit into a domestic environment. It can be shown that a minimum of seven extra channels need to be added to the "SQ" system to record a full height effect, although the loss of precision of location thus caused means that adding 23 extra channels would be much more satisfactorary. Both proposals are clearly impractical.

The height effect is potentially useful as an important extra dimension in popular music, as any producer will quickly see. In classical music it seems to add very considerably to the ears' ability to use ambience information to recreate a concert hall setting, and is also useful in placing organs and the like in their correct vertical perspective. While recording systems have been classified, the ideal playback system for convenient and effective domestic use is still the subject of research, but this technical problem is likely to be solved at a commercial level in the forseeable future. The possibilities of such periphonic systems will be forever unattainable, or cause an expensive conflict between incompatible systems at some future time, if the record industry adopts CBS "SQ" as a standard system.

6. OTHER SYSTEMS

The reader may well suspect that, while these defects may exist in the CBS system, they might also exist in all other systems, or else other equally serious defects might then take their place. It is true that a number of alternative systems are equally deficient, or more so, but there is a class of 4-2-4 systems which suffer from none of the above-listed faults. These systems (called 'phasor' systems) have been discovered independently by at least four people, and are in the process of commercial exploitation with solid commercial and financial backing by at least two.

The phasor systems record two items of information, one (called the omnidirectional signal) being the sum of all the sounds in the recording, and the other (called the phasor signal) being the sum of all the recorded signals once each signal has been phase shifted by an angle equal to its horizontal angle around the listener. Examples of phasor systems are the "UMX" system of Duane H. Cooper and Takeo Shiga, which has been taken up by Nippon Columbia, and a system backed

by the British National Research and Development Corporation.

Because they contain the same information, all phasor systems will give the same surround-sound effect. Unlike the CBS "SQ" system, phasor systems allow the option of using loudspeaker layouts involving more than four speakers to give an improved image stability. Such layouts used with the "SQ" system cause some sounds (e.g. side-left sounds) to become mis-located. The "SQ" system was designed only to handle the 4 corner sounds well, and is thus the only system with an almost total inflexibility in permissable speaker layouts.

The recorded information of the Sansui QS, Dynaco/Gately and old Electro-Voice systems is essentially the same as that in a phasor system. The only point of contention between phasor systems of recording is the problem of finding the best way of incorporating the omni and phasor signals within the 2 channels. The UMX method has excellent monophonic compatibility, but in 2-speaker stereo reproduction, sounds are reproduced with a 90° phase error between speakers. (There is a division of opinion about whether this is harmful, due to slightly vaguer images, or helpful, due to improved stereo image width). The Sansui/Dynaco/old-E-V systems have poorer monophonic compatibility,but in-phase 2-speaker stereo images. A compromise system involving 45° phase errors beteeen the channels may offer the most acceptable compatibility.

Because the information contained in UMX, Sansui QS, Dynaco and old E-V system recordings is essentially the same, any 4-speaker results obtained by any particular manufacturer's decoding circuit may also be obtained via a suitably modified decoder from any of the other systems listed here. The choice between phasor systems is therefore conditioned by compatibility and the possible simplicity of the decoder. Most of the "SQ" system's defects also apply (to a slightly lesser degree) to the new Electro-Voice system. The main (& possibly only) advantage of the "SQ" system over phasor systems is its property of so-called "omnidirectional fidelity", which means that a sound pan-potted around a listener using a conventional quadraphonic pan-pot with sine-cosine law will not vary in volume. With a phasor system, such a sound will vary by $\pm$ 0.9 dB. This effect is only of importance when a sound circles the listener rapidly, and can in any case be eliminated by using a quadraphonic pan-pot of the type invented by Duane H. Cooper.

7. CONCLUSIONS

The CBS "SQ" system imposes severe constraints on the creative use of quadraphony, and many effects of interest to the producer are reproduced very imperfectly. It is inconsistent with certain major future developments (the addition of the full vertical dimension, and also the use of speaker layouts using more than 4 speakers), and may thus cause a very expensive battle between mutually inconsistent systems incorporating these developments at some future time. There exist several competitive systems (in which the author has no commercial interests) which are free from these constraints.

REFERENCES

1. M.A. Gerzon, "Recording Techniques for Multichannel Stereo", British Kinematograph, Sound, and Television Journal, June 1971.

2. B.B. Bauer, "Some Techniques Towards Better Stereophonic Perspective", I.R.E. Transactions on Audio, vol.11 , pages 88-92 (1963).

3. P. Scheiber, "Analysing Phase-Amplitude Matrices", Journal of the Audio Engineering Soc., vol. 19 (November 1971).