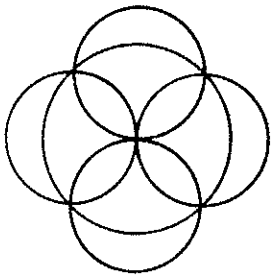
Ambisonics - The Theory and Patents



Adrian Hope

In the field of Ambisonics and Surround Sound, there are a dedicated group of researchers who have produced a large number of patents covering many different aspects of their research. Adrian Hope here attempts to unravel some of the more important patents.

WHEN the National Research Development Corporation, a quasi official body which backs a limited number of British inventions, announced a complicated cross licensing agreement or 'pool' with Duane Cooper of the USA and Nippon Columbia of Japan on surround sound patents the wholly predictable reaction was one big yawn. Hadn't some kind of agreement with Japan already been signed? What in Heaven's name is a patents pool? And I thought quadraphonics was dead anyway.

In fact the NRDC-Cooper-Nippon agreement could have very far-reaching consequences for the recording and broadcasting industry. Certainly 'quadraphonics', as the trade, press, record industry and public have grown to know and distrust it, is dead. But there is a good chance that a whole new generation of surround sound technology will reach the commercial market over the next few years. Indeed if anything now delays commercialisation of surround sound it will be our all too strong memories of the quadraphonic *debacle*. But until recently there was a risk that the second coming of surround sound would be delayed by a chaotic patent situation that was developing behind the scenes. The recent NRDC signing, which followed an informal agreement of a few years ago, was the end result of a considerable amount of often heated behind the scenes negotiations between the owners of a large number of key patents on future trends in surround sound technology. It became clear, early on in the development of Ambisonics technology, that there was a very real conflict of patent interest between Duane Cooper of the University of Illinois, USA, Nippon-Columbia of Japan and the British Ambisonics team including Michael Gerzon of the Mathematics Institute, Oxford University and Professor Peter Fellgett of the University of Reading.

Without the recently announced agreement, virtually all commercial development of Ambisonics style surround sound could well have been stifled. In effect and in simplified terms what NRDC, Cooper and Nippon have created is a patent pool, a collection of patent rights into which authorised parties can dip without fear of provoking a patent infringement action from any of the others. In this respect the NRDC pool resembles that created in late 1919 with the birth of the Radio Corporation of America, or RCA as the company subsequently became known. The early days of radio, just like the early days of surround sound and 'quadraphonics', saw a mass of patents granted to different inventors on different circuits and techniques. By the end of the Great War decade it had become almost impossible for anyone to make a radio set without infringing literally dozens, possibly hundreds, of other people's patents. The RCA patent pool was intended to rationalise the situation. The scheme never really worked as intended but without it there would probably never have been the radio boom that followed in the Twenties. The NRDC patent pool is far smaller than the radio pool, because it contains none of the patents granted to pioneering workers in the field and to companies such as Sansui and CBS on their QS and SQ systems. The pool contains nothing from Japanese Victor. Also outside the pool are crucial patents on multi-channel radio transmission techniques, for instance the broadcast of a third information channel by phase quadrature modulation of the conventional FM stereo difference channel as probably first patented by Dorren in 1970 (US Patent 3708623). But the pool does contain some potentially very valuable patent rights.

If, as now seems increasingly likely, the Ambisonics approach to surround sound is adopted commercially by broadcasting and record companies, the potential value increases. To understand the true value of the patent pool, and the problems which still remain unresolved, it's necessary to look very briefly at the lynchpins of Ambisonics surround sound technology. The patents themselves then offer some useful nuts-and-bolts detail on the techniques adopted in practice. It is also interesting to look at a few milestone patents in surround sound development which are not pooled. It should, however, be noted that this article is not intended as a legal opinion on the value or validity of any patent mentioned and the relevance or otherwise of any patents to competitors' activities. Such issues can only be decided by a court of law. But, frankly, Heaven help any court of law that has to decide the issues involved. And Heaven help the bank balance of any firm or individual who goes to court on a surround sound dispute. The technology involved is now so high and complex that any court action centring on a surround sound patent folio and alleged infringement is likely to be very long and very expensive for all concerned. In short, only the patent lawyers can hope to gain from any disputes that aren't resolved by out of court negotiations.

The essence of quadraphonics was to record or transmit a quartet of speaker-feed signals in as discrete a fashion as possible, ie with a minimum of crosstalk. The ultimate aim was to transmit or record the four speaker feeds as four separate signals, amplify them separately and feed them to four separate speakers arranged in the corners of the room. Matrix encoding techniques, whereby the four speaker feeds were mixed down into a stereo pair for recording or transmission, and then 'unmixed' for amplification and reproduction, was one of various compromises adopted. Multiplexing by frequency separation was another approach. There exist hundreds, if not thousands, of patents on variations of these basic themes. The basic concept of mixing or matrixing signals together and then recovering them, was first investigated by Bell Labs in the USA and patented by Alan Dower Blumlein of EMI in the early Thirties. Blumlein's British Patent 394325 of 1931—and arguably the most famous electronic patent ever granted—is to be found cited by name and number at the end of almost every technical paper on surround sound innovation. And Blumlein's ideas were certainly not just armchair dreams. Every stereo disc currently pressed and sold matrixes the stereo left and right channel signals by 45° double modulation of a 90° groove exactly as described by Blumlein.

Incidentally, even before the Bell and Blumlein patents, proposals for recording 2-channel

signals by vertical and horizontal modulation of the groove had been proposed and patented. Also before Blumlein, Bell Labs in New York had developed in 1929 and patented (USA patent 1910254) a clear forerunner of the so-called 'discrete' multichannel signal recording and transmission systems. Separate sound channels were displaced in the frequency scale 'to form a progressive series of bands separated by suitable intervals', ie the multiple channels were frequency-multiplexed. The frequency-multiplex approach was refined by William Livy of EMI in 1946. Livy's British patent 612163 proposes that a high frequency carrier should be recorded on the disc along with the programme and used on replay to lock an oscillator to actual disc speed. In 1954 an American inventor, Kenneth Hamman of Ohio, patented (US ...nt 2849540) a further development of the frequency-multiplex idea. This specifically described the use of a 30kHz carrier tone.

All patents have a limited legal life (for practical purposes 20 years can be safely taken as the maximum) and once a patent is dead, what it contains is public property. Everything so far mentioned is thus now public property.

The matrixing approach was probably first taken up again by David Hafler in the USA, who in 1965 patented a simple derived sum centre channel system (US 3417203). In 1971 Hafler went on to patent a derived difference rear channel system (BP 1356843). But it is generally acknowledged that much of what this patent claims is legally invalid because Hafler had already published his idea in an article which appeared in the August 1970 issue of *Hi-Fi News & Record Review*. (As a general ...e a patent is invalid if it covers ideas already disclosed to the public.) The year before Hafler published his derived channel ideas, New York musician Peter Scheiber had lodged a series of patent applications which almost certainly represent the first legal claims to what became known as quadraphonics. A licensing deal was struck between Scheiber and CBS, so that Scheiber patents are now effectively pooled with the large number of CBS patents on SQ and derivative systems, mostly originating from Ben Bauer. The most important early Scheiber patents are BP 1328141 and 1328142. Broadly speaking the SQ folio relates to a wide variety of recording and transmission techniques intended, in one way and another, to preserve the integrity of separate speaker feed signals. Although this approach is eschewed by the Ambisonics team, it remains to be seen whether the extensive folio of CBS patents presents any legal obstacle to the NRDC Nippon pool covering Ambisonics and related technology. Without doubt the recent and untimely death of Ben Bauer will affect this whole issue. It is unlikely that anyone at CBS will now push SQ, and watch for possible patent infringement, with anything matching the enthusiasm of Ben Bauer. Another important string of patents under the CBS wing are those covering the Tate decoder (now being used by Dolby Labs for film surround sound decoding). British patent 1514162 and US patent 3944735 describe and protect the circuitry devised by Martin Willcocks of Huntingdon, England to enhance the directional decoding of any matrixed signal.

The Ambisonics team eschew the speaker feed approach with persuasive arguments in favour of recording and transmitting a handful of information channels, from which speaker feed signals are derived on reception or replay, ie the signals transmitted are *not* suitable for amplification and direct feed to a loudspeaker. This approach enables the speaker feeds to be matched to the number of loudspeakers and their layout in a room. Ambisonics also eschews the adaptation of stereo pair-wise blending techniques to surround sound. According to conventional stereo reproduction; as first patented by Blumlein pairwise blended signals are fed to two loudspeakers angled at about 60°. This presents a good illusion of a sound spread between the loudspeakers, but only for a listener facing the loudspeaker pair. The illusion breaks down if the speaker pair is behind or, worse still, to the side of the listener. But of course if four loudspeakers are spaced around a listener, only one pair can at any one time be to the listener's front. Also if four loudspeakers are spaced around a listener, each pair subtends an angle of 90°, which is too wide for a good stereo image even to the front. This is the obvious fallacy on which so much quadraphonic development has been based!

According to Ambisonics research the speaker feed signals necessary to create a reasonable illusion of sound from four, or ideally more, loudspeakers around the listener can be derived from two transmission channels. But a better illusion can be obtained if the speaker feeds are derived from signals carried by three transmission channels. As a compromise measure the third channel can be bandwidth limited, ie a so-called half-channel. If a fourth transmission channel (in this context 'transmission' includes 'recording') is used for such a simple speaker system, there will be quality degradation because the loudspeaker positions will be emphasised and the phantom images between them will be pulled towards speakers. Remember that any loudspeaker listening must rely on an illusion. When we hear sound naturally we hear it arriving from an infinite number of directions. The trick in loudspeaker listening is to disguise the fact that the sound is issuing from a very limited number of loudspeakers, each resembling a point source. If four transmission channels are used then speaker feed signals for six or preferably seven loudspeakers must be derived to prevent 'speaker emphasis'. Alternatively the fourth channel can be used to provide height information, ie to derive feed signals for speakers positioned above and below the listener. Ambisonics technology therefore involved (a) production in the studio of a clutch of four signals which contain all the necessary sound and height information, (b) encoding these studio or so-called 'B-format' signals into a clutch of signals suitable for recording or transmission with the facilities available, ie two signals for a stereo disc or stereo radio transmission, or two-and-a-half or three or four signals where extra channels are available, and (c) deriving from the arriving 2- 2½- 3- or 4-channel signals, a number of speaker feed signals tailored to the number and layout of loudspeakers in use (fig 1). An important aspect of the system is that it is hierarchical in approach; the total information available in the recording studio in the four B-format channels can be disseminated by recording or radio transmission in a manner tailored to the facilities available and reproduced in a manner tailored to the reproduction facilities available, ie mono, stereo or surround. Patents in the Nippon-NRDC folio now cover crucial aspects of all three stages in this hierarchical chain.

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FIG.1 UHJ HIERARCHICAL ENCODING AND DECODING USING AMBISONIC TECHNOLOGY

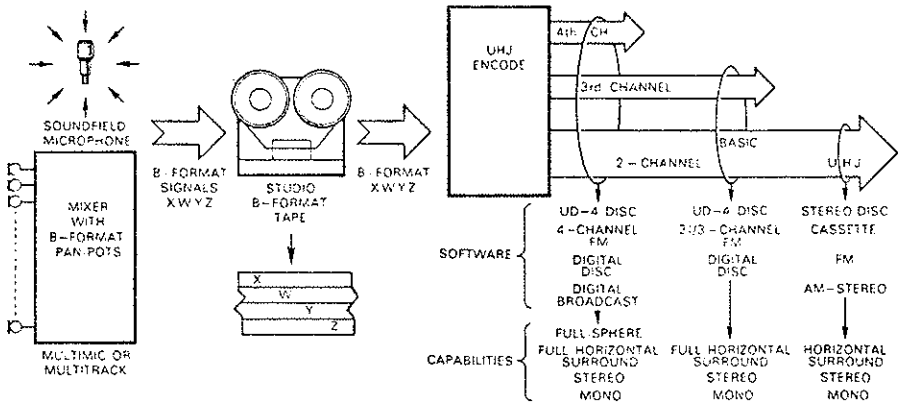
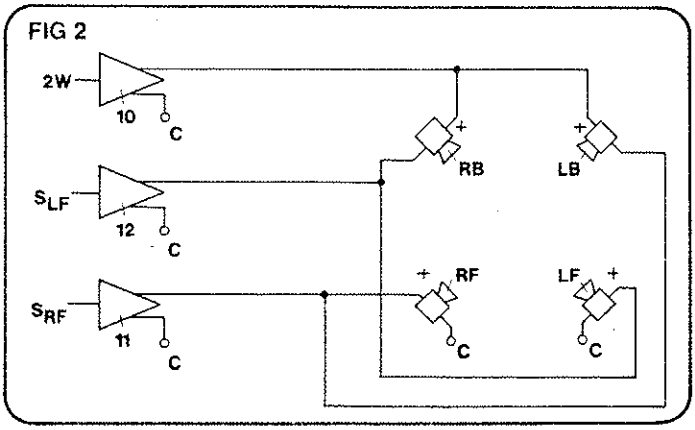


FIG 2



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To begin at the beginning of the sound chain, the *Soundfield* microphone manufactured and sold by Calrec is covered by NRDC British patent 1512514. In this patent the inventors Peter Craven and Michael Gerzon re-iterate the problem that when an attempt is made to sample the sound in a studio at a single point in space, it is physically impossible to have two separate microphones, let alone four, located at *precisely* one and the same point. This means that the output signal from a multi capsule microphone array will inevitably contain anomalous information, especially at high frequencies where the wavelength resembles the capsule size and spacing. The aim of the patent is to provide a multi-capsule microphone assembly which delivers a series of outputs which are doctored to resemble the outputs of notionally 'truly coincident' microphone capsules. The patented proposal is a 4-capsule assembly, with the capsules mounted as if one is on each face of an invisible tetrahedron. Each capsule has a cardioid or hypercardioid response pattern and the tetrahedron is positioned so that the maximum response directions are left back down, right front up, left front down and right back up. The four capsule outputs are separately amplified and fed to a matrix which delivers four equalised outputs. One of these outputs is the zero order harmonic and therefore an omnidirectional signal. The remaining three are first order spherical harmonics corresponding to the signals which would be produced by figure-of-eight microphones pointing front-to-back, left-to right, and up-and-down. The patent gives the necessary matrix equations along with the formula for equalising the frequency characteristics of the capsule outputs over the full audio range. The object of the exercise is to obtain identical frequency response of the *Soundfield* microphone to sounds arising from all directions. Essentially the frequency characteristic of the matrix at low frequencies follows one pattern and pivots at higher frequencies to a different pattern. Moreover a different equalisation pattern is applied to the omni signal than to the figure-of-eight signals and different pivot frequencies are used.

The four outputs from the matrix (equalised omni and equalised front-to-back, left-to-right and up-and-down figure-of-eight signals) are the B-format signals. As previously explained they can be recorded or transmitted in 2-, 2½-, 3- or 4-channel format. The method of hierarchical encoding is covered by a variety of patents. British NRDC patent 1369813 stems from the work of Peter Fellgett and dates back to 1871. The patent claims a method of encoding azimuth information in two transmission channels. One channel carries omnidirectional signal components which contain sound from all directions with equal gain; the other channel carries azimuth or phaser signal components with sounds from all horizontal directions of unity gain but with a phase shift relative to the corresponding omnidirectional signal component. A pair of patents from Duane Cooper (British patents 1411944 and 1411995) also date back to 1971 and in more detail cover the basic matrix theory (now referred to as BMX) proposed by Fellgett. Both Fellgett and Cooper were of course working independently, in ignorance of each others' activities. The BBC coincidentally filed a patent application in 1972 which was issued as British Patent 1414166 and virtually restated Fellgett's ideas in different words but with additional mention of a third channel. It is also known that around this time CBS looked at, but took a considered decision against, the use of 'New Orleans', a matrix which is closer to BMX than SQ. The Cooper patents are by far the most mathematical of the bunch and are most definitely not recommended as light bedside reading. But in essence they describe an encode/decode matrix which is directionally symmetrical. Source signals representative of sound from different bearing angles, measured with respect to a reference direction, are matrixed according to co-efficients corresponding to functions of those angles. The price paid for BMX symmetry was of course extreme phasiness in some sectors of the reproduced sound field. The manner in which the priority dates of the NRDC, and Cooper patents overlap is extremely complicated, some aspects of each invention being pre-dated by the other and so on. All concerned in the current patent pool agreement should give daily thanks that they no longer have to worry about arguing the issue of who dreamed up which equation first in front of a bemused high court judge who still listens in mono on an old *Quad* valve amp and had always thought *quad*raphonics was somehow related to Acoustical of Huntingdon.

It is now fairly widely appreciated that an answer to the phasiness inherent in 2-channel matrix compromises is the use of an additional channel or channels of information. The foundation for this hierarchical approach, or universal matrix UMX, was laid by Cooper's British patents 1411994/5 (followed by USA patent 3970788) and further developed in subsequent work by all parties to the patent pool. The recently agreed UHJ encoding format (or more accurately agreed range of formats including HJ) is not (yet) specifically referred to in any published patents, but a recent US patent by Gerzon (4095049) contains incomprehensible maths which should cover not only the current UHJ hierarchy but any future developments.

The extra channel (or channels) of information used in addition to the base band pair is transmitted by radio multiplexing techniques (such as the previously mentioned phase quadrature modulation of the stereo difference carrier) and recorded by disc multiplex techniques as used by Nippon Columbia for their previous releases in the *UD4* quadraphonic system and by JVC for their apparently now defunct *CD4* system. The techniques developed by Nippon and used for *UD4* are equally well suited to UHJ recording.

For instance in British patent 1473533 Cooper, along with inventors Toshihiko Takagi and Yoshihisa Kamo, describe a means of angle modulating the high frequency carrier with sum and difference signals to reduce clipping distortion, crosstalk and up-talk from the base band caused by tracking and tracing distortion in a disc reproduction system. Two more patents from Cooper were issued alongside this joint Cooper-Nippon UMX improvement. British patent 1473531, for instance, originates the concept of cutting a disc with the carrier channel signal reversely compensated by an anticipated amount of tracing distortion, so that up-talk from the baseband into the carrier is negated. Likewise Cooper's British patent 1473532 originates the idea of matching the recording pre-emphasis characteristic of the base band signals with the phase modulation index of the phase modulated carrier channel signals. This drastically reduces the FM beat distortion which can be produced when the modulated carrier channel signals are mixed with the main channel signals during recording on the walls of the disc groove. As anyone who has heard any of the relatively few Denon *UD4* discs pressed and released a few years ago by Nippon-Columbia will doubtless recognise, this trio of patents protects valuable advances in carrier cutting technology. It seems likely therefore that any record company outside the NRDC pool and serious about cutting carrier discs will need to look very closely at what those patents describe and what they legally monopolise.

Likewise, designers outside the pool might also be well advised to look closely at Nippon Columbia USA patent number 4070552. This patent, which dates back to 1975, describes an interesting cutting technique intended to reduce noise on carrier discs. Essentially the angle modulated carrier is recorded by constant acceleration cutting techniques. Another, related, Nippon patent 4075425 concerns reproduction systems and uses a level detection means to squash to the carrier if the signals recovered from the disc fall below an acceptable level and the signal-to-noise ratio degrades. Noise is of course a perennial bugbear with carrier disc cuts.

We now arrive in the home, as it were, at the decoding stage with derivation of speaker feed signals. NRDC British patents 1494751 and 1494752 originate from Michael Gerzon's work in 1974 and claim lynchpin aspects of the process for reproducing sound from signals delivered to the 'consumer', either from a disc or tape recording or from a radio transmission. This pair of patents protects important aspects of the decode process for converting the arriving signals into speaker feed signals tailor-made for the reproduction system used. The first concerns a layout control system to 'tune' the speaker feed output to the speaker layout adopted. The UHJ Consumer or C-format signals arriving from disc, tape or radio are decoded by an amplitude-phase matrix into signals which originated in the recording studio. Thus for a 3-channel UHJ input, the decoder matrix produces an omni or pressure signal, a forward velocity or front-back difference signal and a leftward velocity or left-right difference signal. If the UHJ input contains height information then a fourth, up-down difference signal is also produced by the matrix. These decoded signals are now doctored prior to amplification and fed to the loudspeakers. Signals decoded from other formats are similarly doctored. The nature of doctoring is in direct dependence on the number of loudspeakers used, their angle around the listener and their distance from the listener. Doctoring is not simply an alteration in gain between the signals fed to the various loudspeakers. For example in a simple four loudspeaker azimuth or horizontal-only situation, when the angle between the front speaker pair is narrowed

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from the not ideal 90° to the ideal 60°, the speaker layout is inevitably asymmetrical. In this case the gain for the front-back difference signal is reduced to compensate for increased front-back speaker width, and the gain for the left-right signal is increased to compensate for the decreased side-to-side loudspeaker width. Additionally the decoded signals are frequency filtered to compensate for the effect at the listening position of the distance between the loudspeakers and the listener. Any finite loudspeaker distance will of course inevitably produce some degree of bass boost and phase shift in the directional lower frequency components of the reproduced sound at the listener's position. This can degrade image quality and sometimes cause locational errors. Inverse highpass filtering is thus used to compensate for distance at the same time as the decoder outputs are balanced to compensate for loudspeaker layout.

The second patent is concerned with Gerzon's theories on sound localisation. Assuming a perfectly adjusted loudspeaker layout, there is still the very real problem of how to generate from those loudspeakers the audible clues which will fool a listener's ears and brain into believing that the sound field is originating from an infinite number of sources around the listener rather than a few point sources of sound. In the patent, Gerzon recaps on the now 100-year-old theory that human beings locate the source of a sound by complex evaluation of the relative amplitude and phase relationships as it arrives almost, but not quite, simultaneously at each of the listener's two ears. For low frequency, long wavelength sounds, a human head offers virtually no obstacle. So sound arrives at each ear with virtually the same amplitude. But there is a difference in phase between the sound arriving at each ear, because of the extra distance travelled. Thus at low frequencies the ear-brain combination uses phase as a directional clue. At higher frequencies, with wavelengths comparable to the size of a human head (which is the extra distance which the sound must travel) phase relationships become meaningless. But the head acts at high frequencies as a baffle and this creates a difference in amplitude across the head. So for high frequencies our ears and brain use amplitude as a directional cue. Traditionally the transitional frequency is put at around 700Hz. But the transition is of course gradual and Gerzon suggests in the patent that for surround sound reproduction purposes the turnover point should be taken as around 320Hz. This, he suggests, makes the listener's position with respect to the loudspeakers far less critical. So according to the patent, when reproducing programme material the listener's ears should be provided with amplitude clues to direction for frequencies above the transition frequency and with phase clues to direction for frequencies below the transition frequency. This calls for the design of a frequency dependent matrix which approximates to ideal low frequency design at low frequencies and ideal high frequency design at high frequencies. Most important of all is the band around the transition frequency where there has to be a suitably designed transition performance.

The patented solution is to provide identical shelf filters in the two difference signal paths and a third filter of different characteristic in the omni signal path. Each filter has identical phase response and each has one gain at low frequency (below the transition frequency) and another at high frequency (above the transition frequency). Most important, each shelf filter makes a transition from low frequency gain to high frequency gain across the frequency band spread round the transition frequency band. Incidentally, note that just as the layout control system operates in advance of the circuitry which derives and amplifies the speaker feed signals, so the frequency dependent circuitry operates in advance of speaker feed derivation. On most conventional quadraphonic decoders, any layout control or frequency doctoring is likely to be on signals which have already been decoded and designated to feed individual loudspeakers.

Gradually it becomes clear how the NRDC-Nippon pool could well have considerable long-term value. Although patents on disc cutting technology have a potentially limited life (because before too long the recorded and transmitted signals will simply be slotted into a digital stream without any need for disc or radio carrier modulation) the patented techniques for deriving B-format studio signals, for encoding and decoding them for recording or transmission and for deriving speaker feed signals from the decoded signals are an essential and immutable part of the system.

More patents, most it seems from Gerzon and the NRDC, are in the legal pipeline and issuing on a regular basis to protect sophistications of the basic system. USA patent 4139729 (and recently also British patent 1548674), for instance, describes Gerzon's scheme for using three power amplifiers to drive four loudspeakers, or four amplifiers to drive five loudspeakers, and so on, without unwanted information spill over. Fig 2 of the patent shows the basic three amplifier/four loudspeaker layout. Such a technique clearly offers useful economies for the manufacturer of surround sound reproduction equipment. USA patent 4081606 (soon to issue as British patent 1550627) protects Gerzon's ideas for a variable decoder (christened the 'Variable Directional Preference' or VDP decoder. This employs logic circuitry similar to that used in quadraphonic systems to enhance directional decoding in continually varying dependence on the signals being decoded, but varies the width of individual images rather than the signal direction. This is achieved by reducing the phasiness of the most important signal at the expense of phasiness in less important signals. For instance, where the decoded signal is front orientated, the front signal phasiness is reduced at the expense of extra phasiness at the rear, where it is psycho-acoustically less important. In other words the preferred sound direction is made to sound sharper at the expense of others which become less sharp but remain unchanged in direction. USA patent 4151369 proposes the use of a time delay in the decoder speaker feed outputs, with the delay in each speaker feed being related to the distance between the speakers and a listener. As well as covering the UHJ hierarchy mathematics, USA patent 4095049 (soon to issue as British patent 1550628) covers an interesting idea for adding a third channel of information to a basic 2-channel system in such a way that the third channel can be reduced in amplitude, or restricted in frequency, without noticeably affecting important localisation criteria. This is achieved by the use of extra phase amplitude matrices. It apparently took Gerzon two full years to work out the maths involved. The advantages, especially for broadcasters, are, however, obvious. When a third channel of information is transmitted along with the stereo base band signal any third channel degradation, for instance due to poor reception conditions, produces a gradual changeover to 2-channel operation with the reproduced image positions remaining predominantly unchanged, but less precise.

Currently the IBA and BBC and the FCC are all looking at various aspects of surround sound broadcasting, so is Dutch radio, eg with regular Concertgebouw broadcasts. Sadly neither the BBC nor the IBA have made much public noise in surround sound of late. Although one might reasonably expect that these two quasi-official British broadcasting authorities would either co-operate with each other and the quasi-official NRDC *or* work completely separately and regard the other's progress as a challenge, it often seems to an outsider as if the IBA warms to surround sound as the BBC cools off and vice versa! There are, however, more practical reasons for the current cool-off. Happily the few senior bureaucrats who for years occupied seats of power in Broadcasting House and laid a dead hand of restraint on the small but enthusiastic band of BBC engineers devoted to the cause of surround sound broadcasting, are now out to pasture. But almost coincident with the bureaucrats' exit, some BBC engineers took to hampering their own progress by embarking on industrial action. Essentially the beef is that more loudspeakers at the monitoring stage warrant commensurately more pounds in the pay packet. However justifiable the extent of the claim may (or may not) be there is little likelihood at the moment of the impoverished BBC radio coffers coughing up the kind of rises sought. So, for the time being at least, there is unlikely to be any surround sound broadcasting from the BBC. Nevertheless the Calrec *Soundfield* microphone is being extensively used, for instance for the Proms, and informal surround sound, tapes are often made for research and evaluation purposes.

In the 1979 Proms season there was one concert in particular which it would be fascinating to hear in surround sound. *Star Child* (by the aptly named George Crumb, and with every bit as much artistic content as the Tate Gallery's now famous pile of bricks) embodies some impressive surround sound spacing effects. So spread is the orchestra, in fact, that six conductors were needed for the Albert Hall performance. At one point in the pretentious proceedings a string of muted trumpets play from balcony boxes spaced full circle around the hall. Most interesting of all a string section performs from the hall balcony high at rear dead centre. One of the most difficult tricks in surround sound matrixing is to encode rear dead centre, for accurate reproduction in surround and no significant loss of level in stereo and mono. Some matrices would lose the *Star Child* rear centre strings altogether in

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it is this fact together with the regular tetrahedral array that make

of half of the total energy:

$$L = \tfrac{1}{4}X + \tfrac{1}{4}Y + \tfrac{1}{2}W$$
$$R = \tfrac{1}{4}X - \tfrac{1}{4}Y + \tfrac{1}{2}W$$

allows the ratio of direct to reverberant sound to be altered in either a forwards/backwards or upwards/

'coincident' microphone for stereo, but also a signal storage format that allows recall of *total* directional information for future use. ■

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mono. Mono and stereo compatibility are not just a technical exercise. Although Crumb's opus may not be everyone's musical cup of tea, there will doubtless be surround sound drama performances where important dialogue comes from the rear of the listener. It just isn't acceptable for a matrix to lose this in mono.

The IBA tests have ground to a halt after clearly suggesting that although 2½-channel transmission of UHJ signals can give very good surround results (comparable in fact to those obtainable from three channels), the stereo and mono compatibility of 2½ just isn't good enough for critical listening. And until extensive on-air 3-channel tests have been run, no one will really know whether this format is acceptable to stereo and mono listeners with existing equipment (from the standpoint of interference, such as birdies etc) and whether it will be acceptable to surround listeners on the fringe of the reception area. What is needed is more work on these issues on a European or world scale. The IBA are stymied because their radio stations are all local-only. Hopefully some of this work will be done by the FCC who are currently considering various issues relating to surround sound in preparation for a decision expected some time in, or after, 1981. Be patient. Speed in this context is not the essence. Any decision now taken on surround sound will be with us for decades to come. It *must* therefore be a carefully considered decision. It is also easy for Europeans to overlook the fact that although the BBC, IBA and other broadcasting organisations in Europe, such as Dutch Radio, are now fairly firmly committed to Ambisonics, the FCC has so far shown most enthusiasm for SQ. Thus the FCC has both inter- and intra-system choices to make. Little activity can reasonably be expected on the disc front until the broadcasters have made some positive moves and the listening public has been offered a real incentive to buy suitable decoding equipment. But already Nippon-Columbia is known to be pressing UHJ carrier discs (albeit mainly for test purposes) and the British record company Nimbus has a dozen or more classical issues in 2-channel UHJ. Occasional one-off issues are also available, for instance *The Organ at York Minster* is a 2-channel HJ recording which is available from Banks and Son (Music) Ltd, Stonegate, York. Incidentally, anyone interested in comparing HJ with the original BBC matrix-H format should try and obtain a copy of the BBC Records disc *40 Years of Television—Norrie Paramor Remembers* which was reputedly cut from an H-Matrix tape (remember that Matrix-H was the original BBC format, HJ is the new BBC format and Ambisonics UHJ is the hierarchy which incorporates HJ).

Currently all the signs are that future commercial contests will be between SQ on the one hand and Ambisonics UHJ on the other. For the reasons already explained, it is unlikely that there will be much conflict between the patent folio held by CBS on the one hand and the NRDC Nippon pool on the other. It also seems likely that with the death of Ben Bauer the drive for SQ will lose momentum. Certainly CBS Records are showing no interest in the system. Japanese Victor and Sansui appear already to have lost all enthusiasm for surround sound, and again it seems unlikely that the patents held by those companies will be of much significance to future development of Ambisonics and UHJ technology. So apart from some negotiations in the area of phase quadrature carrier modulation (patent monopoly on this basic idea is amost certainly owned by American interests) it seems unlikely now that patent litigation will seriously hamper progress of surround sound. Anyone hopeful that surround sound will eventually become available as a recording, broadcast and reproduction option should therefore be thankful that the NRDC pool has been negotiated. ■