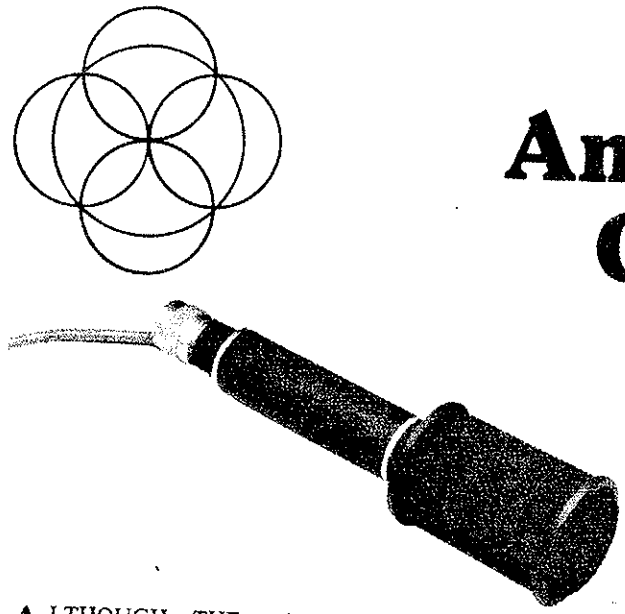


Ambisonics-The Calrec Soundfield Microphone

J Howard Smith, Calrec Audio Ltd

While much theory has been devoted to Surround Sound and Ambisonics, to date Calrec Audio Ltd is the only company that has developed a product using this theory, the *Soundfield* microphone.

ALTHOUGH THE original concept of the *Soundfield* microphone was to produce a coherent 3-dimensional signal suitable for replaying full surround sound, the most immediate advantage offered to the recording and broadcasting industry is a stereo microphone with several unique and quite revolutionary advantages.

1. The stereo output is truly coincident over most of the audio spectrum, ie the two outputs originate from capsules that apparently occupy the same point in space, thus greatly reducing the phase errors introduced by conventional microphones and their inevitable effect on the frequency response.

2. The microphone may be electronically rotated through 360° horizontally from a remote position.

3. The microphone may be electronically tilted vertically ±45° from a remote position.

4. The angle between the apparent capsules may be varied from 0° (ie mono) to 180° electronically from a remote position.

5. The microphone may be 'apparently' moved either forwards/backwards or up/down from its real position.

6. The polar pattern may be adjusted to any first order characteristic (ie omni to figure-of-eight via cardioid).

7. Functions 2 to 6 may be performed *post-session off tape* provided that the 4-channel B-format signal has been recorded.

8. The B-format master tape allows the recording to be re-issued in the future in whatever form of surround sound may eventually be adopted, up to a maximum of full periphony, ie 'with height'.

In order to understand the seemingly impossible task of moving and steering a microphone that was de-rigged three weeks ago, it is necessary to examine the construction of the B-format signal referred to earlier, but first a reminder of conventional microphone parameters.

The need for Soundfield

Nearly all microphones available today operate in either one of two modes or a mixture of both. They are either omnidirectional, figure-of-eight or some mixture of these two, a 50/50 mix giving cardioid.

Unfortunately it is impossible to design capsules with optimal omni (pressure) and figure-of-eight (gradient) responses as parameters which improve the performance of one system adversely affect the other, and as these two signals are normally generated either by one diaphragm or by two driving one circuit, they are inseparably mixed. It is tribute indeed to the makers art that modern microphones sound as well as they do when faced with this basic fact.

B-format construction

The Calrec *Soundfield* microphone has four very accurately matched cardioid capsules arranged in a regular tetrahedron. Both these facts are of vital importance to the correct operation of the microphone.

Fig 1 shows the capsule array with the front looking out from the paper. If the output of right front (RF) is subtracted from that of left back (LB) then the two pressure components cancel, being out of phase, and the gradient components add to form a figure-of-eight response. It is at this stage that the accurate matching of the capsules is important for provided that the capsules match perfectly, when added anti-phase any errors due to imperfect design are equal and opposite, and therefore cancel each other out. In practice the cancellation is not perfect, but is of a very high order. Consequently a figure-of-eight characteristic is generated whose purity is considerably better than the two cardioids from which it was formed.

The axis of the 'eight' is right/front, ie 45°, left/back, ie 225° and is horizontal; see fig 2. The fact that the original capsules were angled simply reduces the sensitivity of the resultant 'eight'.

44 ▶

FIG.1

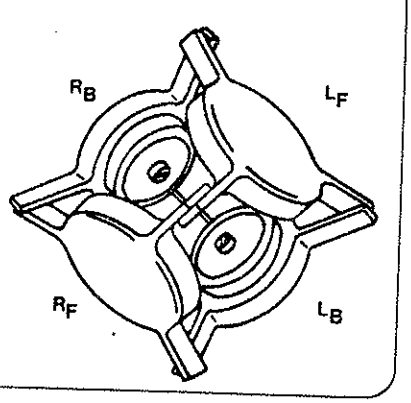


FIG. 2

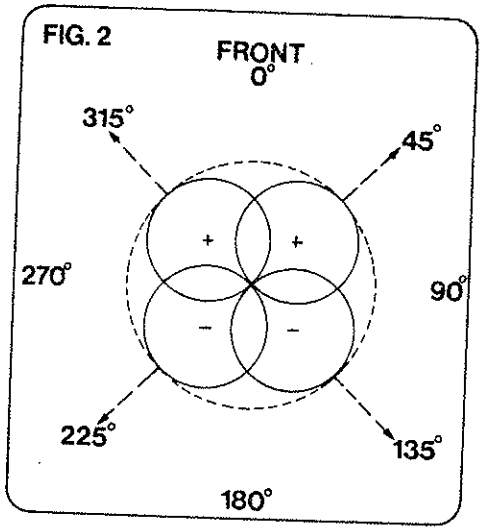
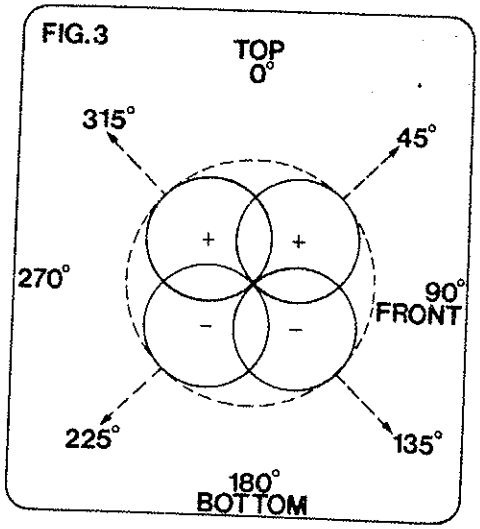


FIG.3



Ambisonics-The Calrec Soundfield Microphone

The same operation with left front (LF) and right back (RB) produces a gradient signal on the 315°-135° axis, ie at 90° to the first, and a similar sum for vertical information using RF — RB and LF — LB produces two more gradients both on the 0°-180° horizontal axis but inclined in the vertical at 45° and 315° respectively (**fig 3**). If the two horizontal figure-of-eight patterns are now added in phase, the result is a gradient signal whose prime axis is 0°-180° and is termed 'X'. The same signals added out-of-phase, produce a 270°-90° gradient, termed 'Y' and adding the two 45° vertical signals produce a figure-of-eight at 90° to the horizontal, termed 'Z'.

We now have signals representing the gradient component of the sound in the three prime directions. Left-right, front-back and up-down and all that is now required to complete the characterisation, is a pressure signal, termed 'W'; this is produced by adding all the capsule outputs in-phase.

Let us now quote the component parts of the four B-format signals.

$X = LF + RF - LB - RB$
$W = LF + RF + LB + RB$
$Y = LF - RF + LB - RB$
$Z = LF - RF - LB + RB$

It can be seen that each B-format signal is made up of 25% of each of the original capsule signals and it is this fact together with the regular tetrahedral array that make it possible, for the first time ever, to correct for the physical spacing of the capsules and produce a truly coincident B-format master signal.

Examination of the frequency response of the B-format before equalisation reveals that while the three gradient signals XYZ sensibly follow each other, they all have a response that rises with frequency above about 1kHz whereas the pressure signal 'W' falls with rising frequency, the difference being up to 10dB (**fig 4**).

It must be stressed that this situation applies to all cardioid microphones, but can only be examined *and corrected* in the *Soundfield* system. As Gerzon remarked in his paper to the 50th AES Convention: "This should convince sceptics of the fallacy of assuming that 'nearly coincident' is good enough".

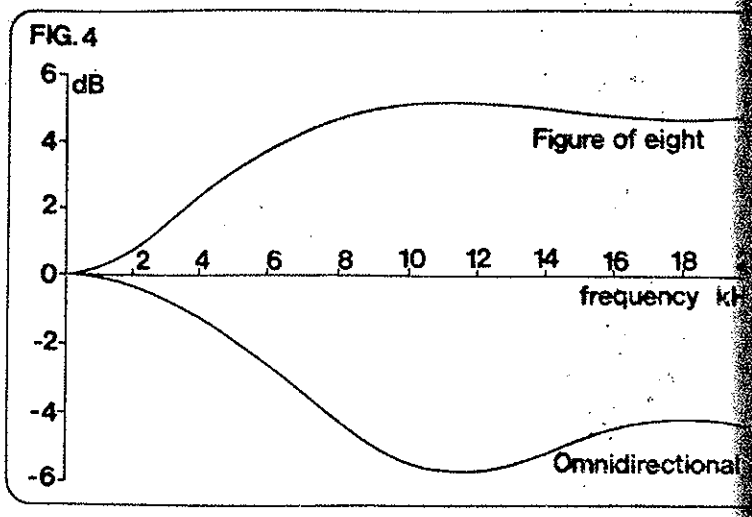
To use B-format to produce a stereo output it is necessary to recombine the signals in the correct proportions. For instance to produce a 90° crossed pair of figure-of-eights pointing to the front and horizontal, the formulae would be:

$L = \frac{1}{2}X + \frac{1}{2}Y$
$R = \frac{1}{2}X - \frac{1}{2}Y$

As X and Y are themselves 'eights' no other signals are required. If cardioids are required then the 'W' pressure signal must be half of the total energy:

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

FIG. 4



The system can generate any first order characteristic, that is any pattern from omni to figure-of-eight through all the cardioids and these may be adjusted during programme. Up to four such virtual microphones may be generated, two forwards and two backwards and the angle between each pair may be altered from 0° (mono to the front, mono to the back) to 180° (mono to the left, mono to the right) in a scissoring motion. The 'rig' may then be rotated through 360° horizontally and tilted ±45° vertically.

The last control facility to be described is proving in practice to be the most interesting. Dominance allows the ratio of direct to reverberant sound to be altered in either a forwards/backwards or upwards/downwards direction. This is achieved by acting on the appropriate part of the B-format signal, 'X' for F — B and 'Z' for U — D, without affecting any of the other parameters. The result of this is to apparently move the microphone in the direction indicated.

In addition to the above-mentioned features, the microphone control unit has 0dB line sending capable outputs for both B-format and stereo and can therefore be considered as a complete recording channel for a one microphone recording.

The *Soundfield* system, therefore, not only provides the world's first 'coincident' microphone for stereo, but also a signal storage format that allows recall of *total* directional information for future use. ■