J. HOWARD SMITH

The Sound Field Microphone

Four cardioid condenser capsules arranged on the faces of a tetrahedon, through in-phase and out-of-phase matching, reflect true ambience.

THE CALREC TYPE CM 4050 Sound Field Microphone is based on an application of the mathematical theory of *Sampling,* in which a closely-spaced array of capacitor capsules and associated matching electronic circuitry completely characterize the first-order directivity of the sound reaching the microphone. (The term, "first-order" refers to the mathematical derivation of various polar pattern formulae. Most practical microphones exhibit first-order polar patterns. Ed.)

The Sound Field Microphone's output may be mono, stereo, quadriphonic or Ambisonic, and can be rotated continuously through 360 degrees horizontally, and tilted ± 45 degrees vertically.

CARDIOID OPERATING PRINCIPLES

Before explaining the operating principles of the Sound Field Microphone, let us examine the principle factors governing the operation of a standard cardioid microphone. It may be worth noting that the earliest cardioid microphones (c. 1933) contained two transducers whose outputs were combined within the microphone housing; one was omni-directional (usually a moving coil)—the other, bi-directional (typically, a ribbon element).

In fact, today a "theoretically perfect" cardioid microphone may be thought of as operating in these two modes simultaneously: first, as a pure pressure-sensitive device with an omni-directional polar response, producing a positive-going signal for an increase in pressure level, irrespective of direction (FIGURE 1). At the same time, it functions as a pressure-gradient (i.e., sensitive to the direction of pressure flow) device, with a figure-8 polar response producing a positive-going signal for pressure flow from 0 degrees (front), no signal at all for pressure flows from 90 degrees or 270 degrees (sides), and a negative-going signal for pressure flow from 180 degrees (back). (FIGURE 2)

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As these signals are produced around a single diaphragm, the resultant output of the microphone is a 50-50 mix of the two which, with addition of the in-phase information (from the front) and cancellation of out-of-phase information (from the rear), gives the familiar first-order cardioid polar pattern. (FIGURE 3).

Unfortunately, in real life the two apparent systems vary both from each other and/or from theoretical norms of frequency response, sensitivity and polar pattern. Consequently, their summation does not produce the perfect cardioid pattern, or a level frequency response over the entire audio spectrum.

By skillful design and scrupulous manufacture, it is possible—particularly in capacitor capsules—to keep these variations to a minimum, and so produce the excellent performance specifications of the modern condenser microphone. But even these are some way below theoretical perfection, and must always be so, because corrections that improve the performance of one system will adversely affect the other.

THE SOUND FIELD PRINCIPLE

The Sound Field microphone monitors the three-dimensional sound field around itself, using four very high quality, well-matched cardioid condenser capsules on the faces of a regular tetrahedron (FIGURE 4). The technique allows the component parts to be isolated, individually corrected, and re-combined to produce an output (or outputs) that its designers consider to be as close to the theoretical ideal as it is likely to achieve, for some time to come.

FIGURE 5 is a graphic representation of the four-capsule array, with the nominal front looking straight out from the paper. FIGURE 6 shows the Sound Field Microphone suspended in the middle of a room. The faces of the tetrahedron have been "exploded" to clarify their relative orientations, which are:

Capsule 1—Left-front, up (L_f)
Capsule 2—Right-back, up (R_b)
Capsule 3—Right-front, down (R_f)
Capsule 4—Left-back, down (L_b)

If the cardioid outputs of capsules 1 and 2 are combined out-of-phase, the result is a figure-8 which is free of any distortion caused by the addition of the original omni-directional and figure-8 components within the capsules,

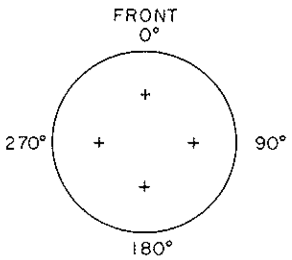


Figure 1. An ideal omni-directional polar pattern.

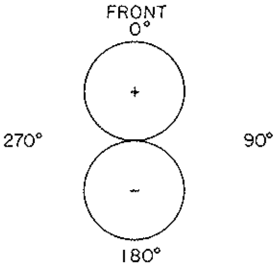


Figure 2. An ideal bi-directional polar pattern.

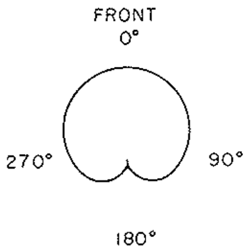


Figure 3. Cardioid polar pattern, produced by combining the polar responses seen in Figures 1 and 2.

as these are equal and, combined out-of-phase, will cancel out. The axis of the resultant pattern is 45 degrees to 225 degrees along the horizontal. The same procedure with capsules 3 and 4 produces 315 degrees to 135 degrees horizontal. Both combinations are shown in FIGURE 7.

Repeating the process with capsules 1 and 3, and 2 and 4, gives patterns at 315 degrees to 135 degrees (1 and 3) and, 45 degrees to 225 degrees (2 and 4) vertical, as shown in FIGURE 8. Note that, at this stage, the positive lobes of each of these patterns is angled either forward or upward.

FURTHER COMBINATIONS

The next stage of the process is to add the forward-oriented horizontal patterns in-phase, to produce one figure-8 pattern on a horizontal (front-to-back) axis of 0 degrees to 180 degrees. The same patterns are combined out-of-phase, to produce another figure-8 at 90 degrees to 270 degrees (i.e., left-to-right). A similar single in-phase treatment of the two vertical components produces one vertical figure-8 pattern.

Throughout all combinational processing stages, great care must be taken to maintain the relative gains accurately, in order to guarantee optimum pattern shapes.

There now exists three pressure-gradient (bi-directional) signals, representing the three basic components of direction; front-back, left-right, and up-down. Finally, it is only necessary to add the outputs of all four capsules in-phase, producing a single omni-directional pressure signal.

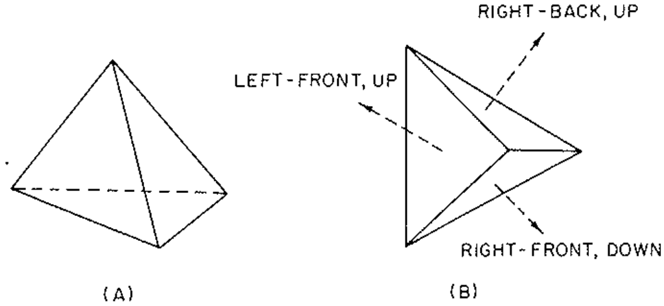


Figure 4 (A) A regular tetrahedron (in effect, a three-sided pyramid.) (B) The same tetrahedron, oriented so that its sides face in the directions shown by the dashed lines. (The fourth side faces right-back, down).

We now have the four signals required to construct any first-order characteristic—from figure-8 through cardioid, to omni-directional—looking in any direction through 360 degrees horizontally and vertically. At this stage, phase correction is applied in order that any two or more microphone patterns so constructed are truly coincident. That is, they apparently occupy the same point in space.

THE "B" FORMAT

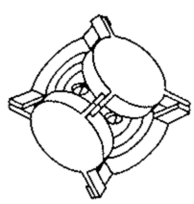
These four signals, known as "B" Format, and designated W (omni-directional), X (front-back), Y (left-right), and Z (up-down), may be directly recorded on tape for processing later on. This allows experimentation with capsule angle, pattern, pan, and tilt, without in any way affecting the actual recorded "B" Format signals. Naturally, in a live broadcast situation this facility would not be practicable, but would create unprecedented freedom for experimentation during pre-broadcast rehearsals.

THE SOUND FIELD CONTROL SYSTEM

Since the European debut of the Sound Field Microphone at the 59th convention of the Audio Engineering Society (Hamburg, Germany, February 28 to March 3, 1978), additional development work has taken place, and the complete system now comprises two units—the actual microphone, and the Sound Field Control Unit. The Control Unit provides the following facilities:

1. Input gain switching, over a 50 dB range.
2. Capsule mute switching (test purposes only).
3. Microphone normal/inverted switching.
4. Master fader (rotary).
5. Metering (PPM or VU) switchable to W, X, Y or Z.
6. Rotate—360 degrees of continuous horizontal rotation.
7. Tilt—± 45 degrees of continuous vertical rotation.
8. Vertical Dominance. If the sound field is imagined as a sphere, the Vertical Dominance function will

Figure 5. The four capsules of the Sound Field Microphone.



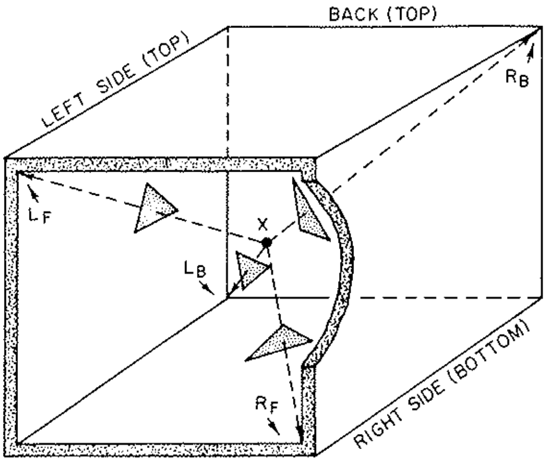


Figure 6. "X" marks the spot where the Sound Field Microphone is suspended in the middle of a room. The faces of its tetrahedronal shape have been "exploded" to clarify the relative orientation of the four capsules on the single tetrahedron.

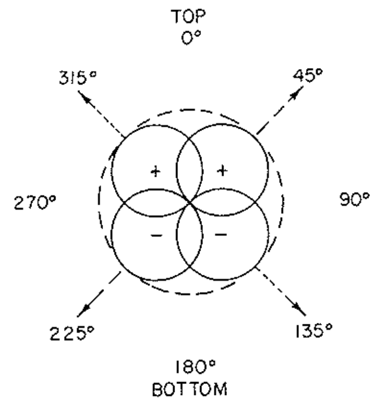
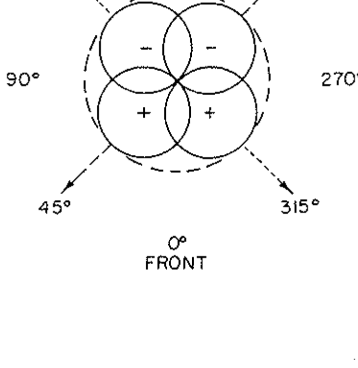


Figure 8. Dashed line: combination of capsules 1 & 3. Dotted line: combination of capsules 2 & 4.

extract a cone of information, the apex of which is at the center of the sphere, and whose angle is determined by the rotary potentiometer (45 degrees maximum, up or down). The feature is useful for getting rid of the unwanted sounds of ventilating systems or audience reactions, while maintaining an otherwise-spherical sound field.

9. Output Mode Selector—mono, stereo, quadriphonic or Ambisonic.
10. Angle. In the stereo mode, this function controls the capsule angle of a virtual pair, ranging from 0 degrees (mono) to 180 degrees. Similarly, in the quadriphonic mode, the virtual four capsules may be scissored between 0 degrees (both pairs on a 0 degree to 180 degree axis), and 180 degrees (both pairs on a 90 degree to 270 degree axis). In the Ambisonic mode, the control relates to loudspeaker position; it should be adjusted to the angle subtended by the left-front and right-front speakers at the central listening position.
11. Polar Patterns—Variable through all first-order characteristics, from figure-8 through cardioid, to omni-directional.
12. Gain—Acts as master monitor gain during "B" Format recording.

Figure 7. Dashed line: combination of capsules 1 & 2. Dotted line: combination of capsules 3 & 4.



The Calrec Sound Microphone, and the NRDC (National Research and Development Corporation) Ambisonic System are the subject of United Kingdom Patent No. 1494751 and United States of America Patent Nos. 3997725 and 4042779, together with all corresponding patents in other countries, and all other patents pending. ■

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This bibliograph makes no attempt to be complete and the author apologizes to those kindred spirits not mentioned.