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THE GHENT MICROPHONE SYSTEM FOR SQ™ QUADRAPHONIC RECORDING AND BROADCASTING

B. B. Bauer, L. A. Abbagnaro, D. W. Gravereaux & T. J. Marshall
CBS Technology Center, Stamford, USA

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THE GHENT MICROPHONE SYSTEM FOR
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by Benjamin B. Bauer, Louis A. Abbagnaro,
Daniel W. Gravereaux and Trevor J. Marshall
CBS Technology Center, Stamford, Connecticut

Abstract

The Ghent Microphone System is an array of transducers concentrated at a point in space and followed by processing electronics, which receives surrounding directional sounds and delivers a stereo- and mono-compatible SQ-Quadraphonic encoded pair of electrical signals suitable for recording or broadcasting. The Ghent System is adaptable for positioning in a concert hall so that its' front reception area covers the stage while the balance of the microphone perimeter receives the hall ambiance. It also can be used conveniently for picking up surround-sound performances, quartets, rock music, and dramatic presentations with the distance of the performers relative to the microphone being used to balance loudness and signal/reverberation factors, the angular displacement determining the direction of the decoded signal. The code produced by the Ghent Microphone System is equivalent to that of an SQ forward-oriented encoder, the cardinal decoded directions in space being Center Front (0°), Left Front (-50°), Left Back (-130°), Right Front (50°) and Right Back (130°). The Ghent System consists of four limaçon transducers oriented at $\pm 65°$ and $\pm 165°$ responding to the equation $0.30 + 0.70 \cos \theta$ (in practice formed electrically by matrixing the output signals of a standard four-cardioid microphone) and a special encoder which is connected to the 4211 SQ-encoder module. The Ghent System has been tested successfully in the CBS Technology Center anechoic chamber, at Tanglewood (Lenox, Mass., USA) with the Boston Symphony Orchestra, and at the Royal Albert Hall (London, Great Britain) with the BBC Symphony Orchestra, verifying its predicted performance.

SQ is a trademark of CBS Inc.

*Presented at the 55th Convention of the Audio Engineering Society, New York City, Nov. 1, 1976.
+This paper is dedicated to the memory of Georg Neumann.

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Introduction

The Ghent Microphone System* is an array of transducers concentrated at a point in space and followed by processing electronics, which receives surrounding directional sounds and delivers a quadraphonic SQ-encoded pair of electrical signals suitable for recording or broadcasting [1], [2], [3], [4]. The Ghent microphone may be placed in the midst of a group of dramatic performers moving freely around the microphone; or it may be suspended in a concert hall so that its front reception area covers an orchestral or operatic stage, with the remainder of the reception perimeter transducing the ambience and the audience sounds in proper space perspective; or, it

*Named for the city in Belgium where it was conceived by the principal author of this paper. The Ghent System was first described in brief outline in a paper by B. B. Bauer, "Quadraphony, Spatial High Fidelity and Compatibility" [1] (first distributed privately during the 1976 Zurich meeting of the AES), as revised in July 1976.

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may be suspended over the conductor's podium to record the orchestra in a surround-sound mode. In each case, the result is a stereo- and mono-compatible quadraphonic matrix output which can be reproduced on a conventional radio or phonograph player or SQ-decoded for display over four loudspeakers. Thus, the Ghent Microphone System promises to become an important tool for the audio engineer.

An example of the sound pickup problem solved with the Ghent microphone is shown in Figure 1a where four performer's positions are designated by circles (A), (B), (C) and (D). The performances are picked up with proximate microphones connected to the respective terminals LB (Left Back), LF (Left Front), RF (Right Front) and RB (Right Back) of an SQ matrix encoder (2) producing encoded output signals LT and RT*. Let us assume that each microphone receives predominantly the acoustical contribution of the performer at its designated position; this results in properly encoded output signals. Next, assume that in a dramatic performance motion is desired. For example, (A) might make his entrance from the left-back position, begin his lines, and move in the direction of the arrow passing the left-front location and eventually taking on a position at (C). Between the designated positions, the conditions for proper encoding

*LT = Left Total, RT = Right Total

are violated because the total acoustical power picked up by the microphones varies as the square of the distance, and, except when the performer is near a microphone, his voice is picked up by all the microphones at lowered level and with uncontrolled phase differentials. Instead of seeming to move smoothly through the prescribed path during reproduction the performer's voice will jump from one loudspeaker position to another as he nears the respective microphones, with undefined location in between.

When a performance is recorded in a studio, the performers can remain stationary near their respective microphones, the recording engineer simulating the desired motion by means of a sin/cos pan-pot. (This, of course, involves added cost and artistic judgment.) But when broadcasting a live play or operatic performance before the public, the actors must naturally move around, making it ordinarily impossible to maintain a well-defined encoded signal*.

One solution which can be envisioned for this dilemma is suggested in Figure 1b. Here, four coincident transducers are used in a quadrant arrangement. each of the four transducers--(LF), (RF), (LB) and (RB)--defining

*This problem exists also with ordinary stereophonic sound pickup.

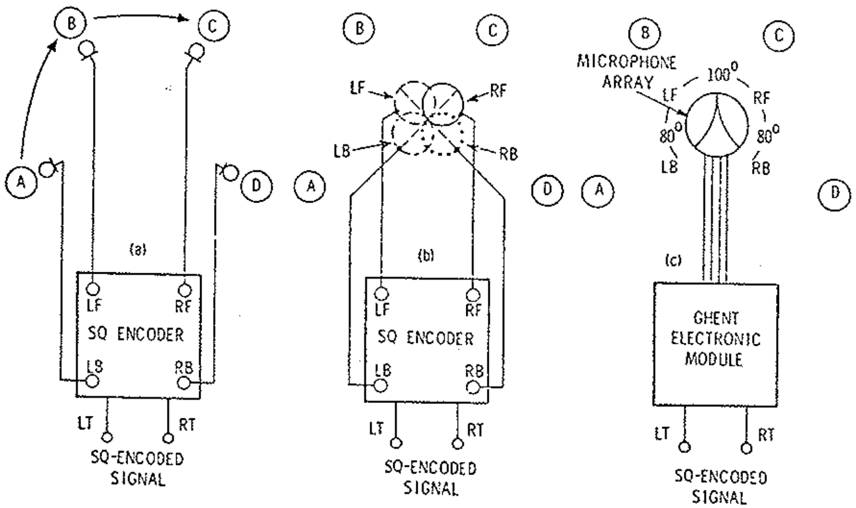

Figure I. Explanation of the Need for the SQ Ghent Microphone

a sensitivity pattern which is one-half of that of a gradient microphone, i.e., which is circular to one side only, as might be represented by the equation cos θ over the range of angles of -90° (270°) through 0°, to 90° and with no response whatsoever over the azimuthal angles between 90° through 180° to 270°, where θ is measured in the azimuth plane from the axis of the maximum transducer sensitivity. Such an array constitutes an "acoustical pan-pot," each adjoining pair receiving every sound source in its proper sin/cos relationship, the total system power remaining constant with θ. Since the transducers are coaxial, there is no phase differential between them, and the encoded signals, LT and RT, when accurately decoded, produce a corresponding quadraphonic display of the moving sources.

The difficulty with the solution offered in Figure 1b is that the type of transducer described therein does not exist in practice. One can approximate it with a second-order limaçon unit responding to the equation $[m + (1-m)\cos\theta]\,[n + (1-n)\cos\theta]$ with suitable choice of m and n [5], and while such microphones have been built experimentally [6], they are not likely to become commercially available in the near future. The nearest available commercial microphone embodies four cardioid-pattern transducers; but used by itself this microphone cannot be employed successfully for the described purpose because the cardioid pattern is much broader than the desired unidirectional circular pattern, with a minimum of three transducers at all times receiving signals from one source, and with a maximum adjacent channel separation for signals in any one quadrant of 6 dB.

The Ghent solution described in this paper is outlined in Figure 1c. The microphone array embodies four limaçon transducers coaxially positioned, formed (mechanically or electrically) in a manner to be described. The four elements are connected to a Ghent electronic module also to be described which serves as a special matrix encoder. The resulting output LT and RT delivers nearly ideally-encoded SQ signals with a constant power vs azimuth response within a fraction of 1 dB. The 100° at the front of the microphone module is defined as a "front" reception area. Over this area, near-ideal stereo response is obtained with more than 40 dB separation between the positions LF and RF. At LB and RB, accurately SQ-encoded signals are obtained. As the source moves from LB to LF, CF (Center Front), RF, and RB the SQ-decoded output also follows this same path. The "back" 100° provides a code similar to

that of a "forward-oriented" SQ encoder, described below. The stylized design on the microphone array in Figure 1c is proposed as a symbol to identify the Ghent Microphone System.

The problem which the Ghent Microphone System solves, of course, is not limited to dramatic performances. The requirement to pick up distant sounds with directional precision and with integrity of intensity and phasing is often encountered in orchestral and surround-sound recording and broadcasting environments, and the Ghent System can be of significant value in these instances.

Forward-Oriented Encoder

It is both fortuitous and fortunate that the Ghent Microphone System as finally developed furnishes an SQ code similar to that produced by an SQ forward-oriented encoder, which is the one most popularly used for SQ matrix broadcasting [7]. This encoder has been described in previous papers but for ready reference it is shown schematically in Figure 2a. The four sources of sound, E, F, G, H, produce signals which are applied to the corresponding terminals, LB, LF, RF, and RB. These signals are combined within the encoder by means of "psi" (phase-shift) networks as shown within the broken-line enclosure. The two encoded outputs, LT and RT, are represented by the phasor groups adjoining each output terminal.

Let us study the outputs produced individually by the aforementioned four sources, as well as those produced by intermediate sources CF (Center Front), CR (Center Right), CB (Center Back), and CL (Center Left) which may be applied with a pan-pot to the respective pairs of terminals. Referring to Figure 2a, it is seen, for example, that with the source F, the LF signal appears only at the LT terminal, precisely as with stereo. This is symbolized by the phasors LT and RT in the upper left-hand corner of Figure 2b, RT being zero. Similarly, with the source G, RF appears only at RT, the LT output being zero as shown in the upper right-hand corner of Figure 2b. The source E, at LB, produces signals 0.71 LB at both output terminals, with the LB and LT leading LB in RT by 90°. Similarly, with the source H, at RB, 0.71 RB signals appear in both LT and RT, but the latter leads the former by 90°. At first glance this appears as zero stereo separation for LB and RB, but an actual audio separation for the back channels is perceived because

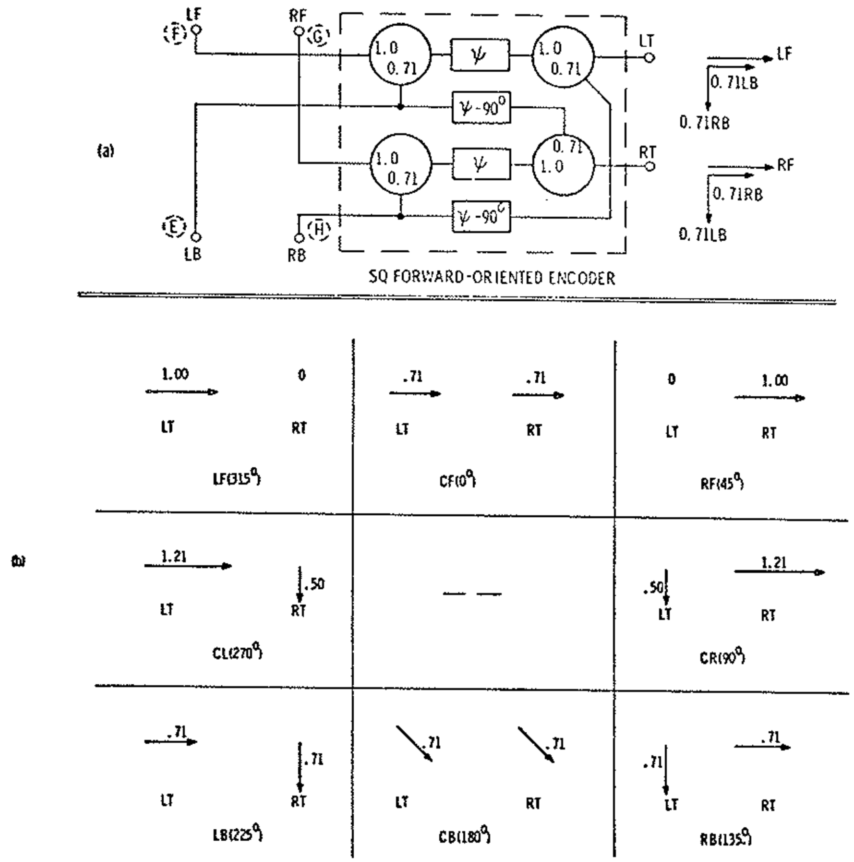

Figure 2. The SQ "Forward-Oriented" Encoder and the Corresponding Output Phasors

of the reaction of human hearing to quadrature signals [8].

The intermediate signals CF, CB, CL and CR are assumed to be "panned" into the corresponding adjoining channels resulting in the application of in-phase signals to each with a 0.71 factor. The phasors LT and RT corresponding to these four cases are also shown in their respective positions in Figure 2b.

It is noted that the important CF signal produces LT and RT which are equal and in phase, precisely as with stereo. It is also seen that CB is encoded as if it were CF and thus is transmitted without attenuation in the monophonic mode. This is a preferred choice when broadcasting discrete four-channel material which may (inadvertently) contain important center-back information --information which otherwise would be lost or attenuated greatly for the monophonic listener if it were encoded with the SQ-basic or position encoders or with some other types of matrix system (none of which maintain the integrity of

the front channels).*

<u>The Ghent Microphone System</u>

The principle of the Ghent Microphone System is shown in Figure 3. The microphone array consists of four limaçon-pattern transducers with polar response defined by the equation, $0.3 + 0.7 \cos \theta$, where θ is the angle respecting the axis of maximum sensitivity of each transducer. The four transducers are oriented in space as shown in the left-hand side of the figure, with the two front elements, L1 and R1, being positioned at $\pm 65^\circ$, and the two back elements, L2 and R2, being positioned at

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* Codes other than SQ are known to encode the center-back signal decodably with monophonic transmission of +3 to -13.1 dB, but at the expense of diluting the front-channel separation in stereo to a mere 8.7 to 7.7 dB and producing center-front phase errors of up to 70° (see Ref.1,Table 1). This, in our view, is too much of a sacrifice in stereo fidelity to provide for the monophonic transmission of the relatively inconsequential center-back signal which, in any event, can be "decodably" SQ-coded with the aid of the recently developed center-back "London Box" [9] producing a loss in the monophonic transmission mode of but 3.9 dB.

$\pm 165^\circ$, with respect to the 0° direction. The four elements actually are vertically coaxial, i.e., the origins of the patterns fall on top of each other. In Figure 3, they are shown separated from the center only for clarity.

To complete the Ghent System, a special encoder is needed, shown at the right-hand side enclosed by the broken-line rectangle. The encoder consists of psi-networks which are identical to those normally used in a conventional SQ encoder. Specifically, the networks labeled ψ connected to the front transducers have a phase shift which is linear with the log of frequency; those labeled ψ-90° also have a similar phase shift function which, however, is displaced from the first one by -90° (lagging) at all frequencies. The latter networks are connected to the back transducers, and their outputs are multiplied by 0.7 and summed to the outputs of the opposite front transducer's psi-networks to form the combined signals LT and RT.

We will now demonstrate that these two latter signals correspond to the encoded signals of a forward-oriented encoder for directions labeled CF, RF, RB, CB, LB, and LF.

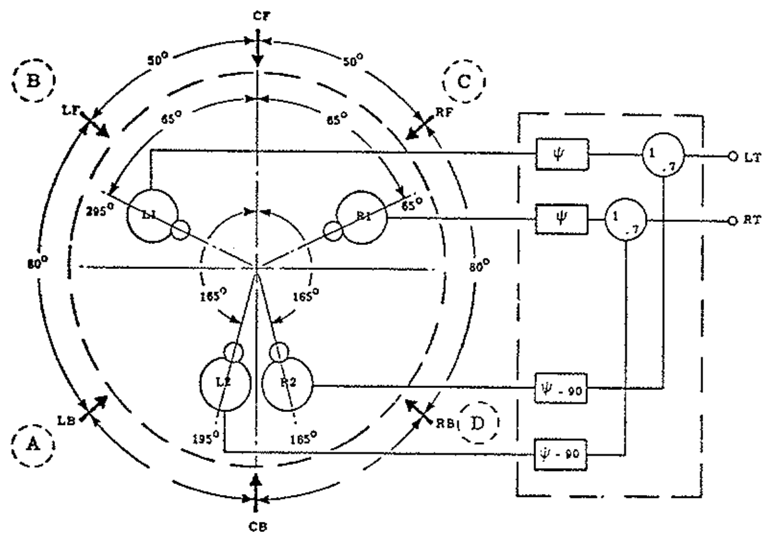

Figure 3. Schematic Principle of the Ghent Microphone System

At first, one is likely to wonder why the seemingly unlikely configuration of the limaçon transducers in Figure 3 followed by the simple encoding apparatus should produce an SQ-coded output. That this is so is demonstrated in Figure 4. In the upper part of this figure, the polar patterns of the four limaçon transducers have been redrawn in rectangular coordinates. Let us consider the -50° position, where both R1 and L2 cross the 0 line. Since these two terms constitute the RT output, only LT output exists. This LT signal consists of two components, $L1 = 0.3 + 0.7 \cos (65^{\circ} - 50^{\circ}) = 0.98$, and a quadrature component $R2 = 0.7 [0.3 + 0.7 \cos (50^{\circ} + 165^{\circ})] = -0.19$. This latter component is added at 90° lagging phase as shown in Figure 4b in the upper left corner, the two components forming a unity signal. Therefore, the -50° incidence of sound corresponds to the left signal of .tereo or the left-front signal of SQ.

An opposite situation obtains at the $+50^{\circ}$ incidence where the L1 and the R2 components cross the 0 line, while the R1 and L2 components yield a total sum of unity as shown in the upper right-hand corner of Figure 4b, thus

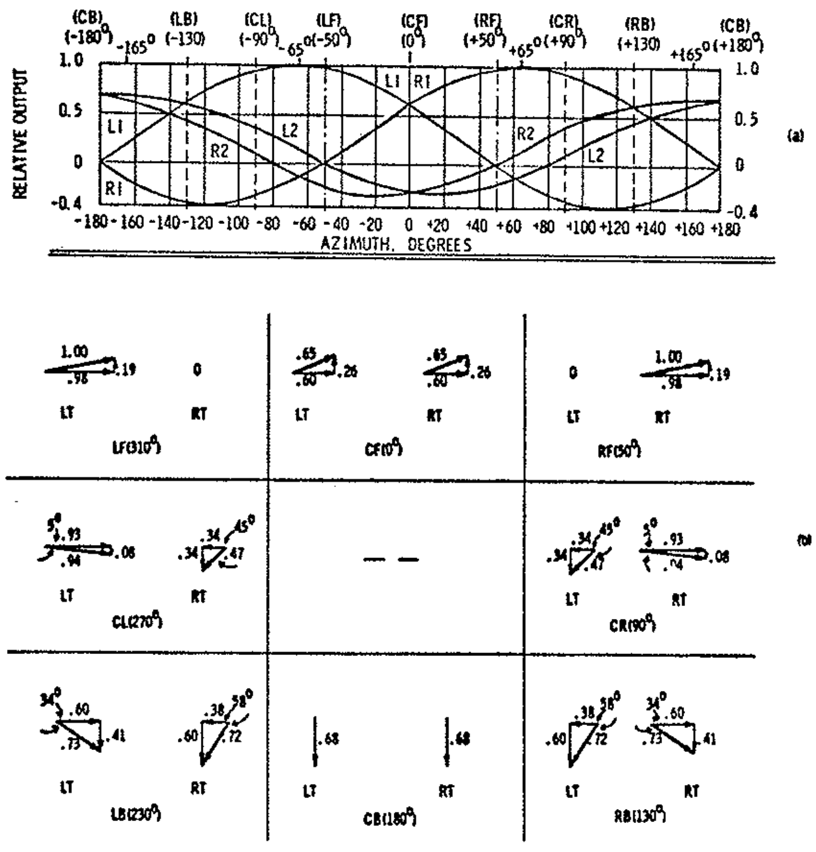

Figure 4. Analysis of Ghent System SQ-Encoding Performance

corresponding to the right channel of stereo or the right-front channel of SQ.

Proceeding next to -130° azimuth, we note that this is the intersection angle for L1 and L2, both of which, for this angle, provide a relative output of 0.60. Also, we note that at -130°, R1 and R2 are very nearly equal in magnitude but of opposite sign. With these observations in mind, we construct the outputs LT and RT for -130° sound incidence shown in the lower left part of Figure 4b, and we note that the resultant output voltages, LT and RT, are very nearly equal and in quadrature with each other, with RT lagging behind LT. This is the requirement for producing the left-back signal of SQ. In the same manner it is shown that for $+130^{\circ}$, the LT and RT outputs for the Ghent System are almost precisely equivalent to those required to produce a right-back code of the SQ system.

Considering now the derived directions, CF, CB, CL, and CR, we note that for CF at 0°, the relative outputs of L1 and R1 are 0.60 and of L2 and R2 are 0.26, the latter both being negative. Adding the corresponding outputs in their proper quadrature phase relationships produces LT and RT having equal relative outputs of 0.65, and in a precise

in-phase relationship with each other. This corresponds to the center-front signal of SQ at the level 0.7 dB below that ideally desired. The output for CB, or 180° azimuth, is determined as follows: the outputs of the two front transducers, L1 and R1, both are 0; while the outputs of the element L2 and R2 both are 0.68. Thus, the resulting LT and RT are very nearly the same as those obtained with the forward-looking encoder, except that the level of the output signal is reduced by 0.4 dB from the desired 0.71.

Respecting the CR and CL signals, we notice that at 90°, R1 has a relative output of 0.93 while L2 has a relative output of 0.08. Together they form a phasor which has a relative amplitude of 0.94 at an angle of -5°. We also note that L1 is a negative 0.34 while R2 is a positive 0.34, and, since the latter quantity is shifted by 90° by the corresponding psi-network, the resultant is 0.47 at an angle of -135°. The total stereo power represented by the two phasors is $0.94^2 + 0.47^2 = 1.10$, which is 0.4 dB relative to unity power; and while the phase differential is in excess of that provided by the forward-oriented encoder, the divergence actually is smaller than that correspondingly produced by the SQ basic encoder and, therefore, this signal is satisfactorily decoded by an SQ decoder.

In summary, if one compares the phasors produced by the Ghent Microphone System with those for the forward-oriented encoder shown in Figure 2, it is noted that the code for the four corner signals is almost exactly and precisely replicated as well as (with inconsequential deviations) the code for the derived signals. Thus the SQ performance of the Ghent System is well within the limits of acceptability in normal recording and broadcasting practice.

A computer readout which provides tabulation at 5° intervals around a circle for the Ghent System is shown in the Appendix. It is noted that the power sensitivity does not deviate more than ± 0.6 dB all around which is very comparable with the magnitude of precision often encountered with high-quality broadcasting and recording microphones. This allows the recording director to control the relative levels of various performers regardless of azimuth simply by varying their distance to the microphone array. With the studio reverberation time suitably selected, it is possible to provide an audible sense of distance as a result of both level and direct/reverberation signal changes. The recording director can readily draw equal-level circles around the microphone position and radial directional lines to facilitate the positioning and movement of the performers.

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Directional Efficiency

The theory of directional efficiency of quadraphonic (or, as as we know, stereophonic) microphones, has not been formulated to this date. We can, however, obtain an estimate for the directional efficacy of the Ghent System by calculating the random energy response of the individual channels. Keeping in mind that each "encoded" channel of the Ghent microphone consists of two limaçon transducers with the polar patterns defined by the equation $\rho = m + (1-m) \cos \theta$, we can readily calculate its random efficiency from the equation [10].

$$R.E. = \tfrac{1}{2} \int_{0}^{\pi} \rho^{2}(\theta) \sin\theta \, d\theta$$

and for $m = 0.3$ this turns out to be 0.253 , which corresponds to the front transducer in each channel. To it we have to add the random efficiency of the back transducer which is combined in quadrature with a voltage coefficient of 0.7 corresponding to a power coefficient of 0.49. Thus, the back transducer in a random field contributes 0.49 X 0.253 = 0.124 units of random power of the front unit for a total random response of 0.377. This is equivalent to the random response of a single limaçon microphone with m = 0.56, not much different from a cardioid whose m = 0.5. Thus, one can anticipate that the Ghent microphone will have approximately the same direct/reverberant pickup performance as a pair of crossed cardioids used in an "intensity" or M-S microphone system, but of course, with the added channel separation capability corresponding to its quadraphonic performance.

Elevation Angle

While the Ghent microphone can be positioned on a microphone stand or suspended from the ceiling in the middle of a performing group for the desired directional reception, there is also the option of placing it above performers distributed over an area at a sufficient height to equalize the distance vs. the angular sensitivity to the various players, still retaining in a large measure its SQ-encoding capability.

Let the Ghent array o in Figure 5 be suspended above the plane of the performers in such a manner that they are arranged within a circular area a-c-b which subtends a cone a-o-b with a dip angle Ω below the horizontal plane d-o-e. Along the perimeter of the circle passing through a-b the coefficient 0.7 in the limaçon equation 0.3 + 0.7 cos θ is now diminished by cos Ω. Let Ω, for example be 20°. Then, cos Ω = 0.94. The coefficient 0.3 must now be attenuated by a factor 0.94, becoming 0.28, to retain the desired SQ-encoding properties for the performers on the perimeter of a-b. As the performers come near the center of the circle, c, they will appear to be increasingly drawn to the center front of the quadraphonic field or the center

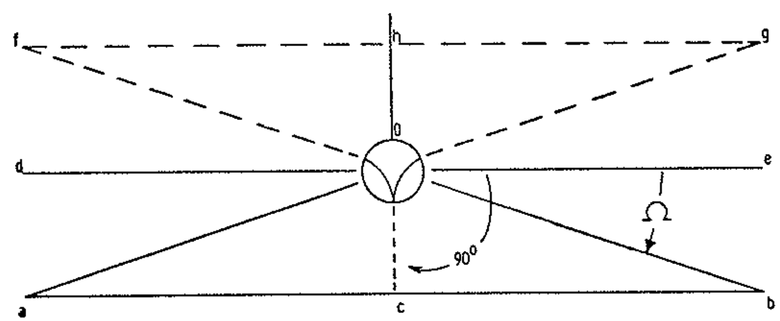


Figure 5. Performance of the Ghent Microphone Array O Suspended Over a Circular Area a-c-b

of the stereophonic display, and the performer immediately below the microphone at c (90° dip) will appear precisely at center front. Because the sensitivity of the limaçon microphone at 90° now is 0.28, while oc/ob = sin 20° = 0.34, the differences in distance of the performers over the area are approximately compensated by the differences of reception sensitivity at various dip angles, resulting in a relatively uniform pickup sensitivity over the whole circular area a-b.

There will, of course, be a corresponding "upward-looking" conical surface f-o-g with the sensitivity over the surface f-h-g being roughly uniform.

Construction of a Practical Ghent Microphone Array

Microphones embodying four limaçon units oriented in the manner shown in Figure 3 are not a standard commercial item, and the design and manufacture of such a microphone would be a rather major undertaking. Fortunately, with the cooperation of the Neumann Company, we were able to obtain one of their modified QM-69 microphones in which four limaçon patterns were provided in two oppositely oriented pairs, each of which could be rotated with respect to the other. The intention was to obtain the desired configuration of patterns by means of electrical matrixing of

adjacent transducer patterns. For a while this appeared to be a hopeless task until we recognized that the desired configuration could be obtained from a standard QM-69 microphone using a novel matrix technique.

The approach we used is shown in Figure 6. In a standard QM-69 Neumann microphone, the four cardioid patterns are adjusted into a quadrature orientation, as shown on the left hand side of the figure. (The four cardioid patterns are displaced off center for the sake of clarity. In reality they are arranged on a single vertical axis, the vertical displacement between the two opposite pairs being approximately 2.5 cm.) The polar equations corresponding to each of the cardioid transducers in the described orientation is shown near each of the patterns in Figure 6. It is noted that by subtracting the outputs of the units p and q, the term 0.5 drops out and the response becomes simply cos θ. This response is represented by the voltage E_c at the output terminal of the first subtractor junction. Likewise, by subtracting the outputs of units r and s, the polar pattern represented by sin θ is obtained, identified by the voltage E_s at the output of the second subtractor junction. As a third step, the outputs of the four cardioid transducers are added with coefficients 0.5 at the junction at the lower left hand corner of the figure, resulting in a voltage E_o which defines an omni-directional polar pattern. The resulting three polar patterns corresponding to the outputs E_o, E_c, and E_s are shown in the upper center of Figure 6 normalized to unity radius.

It should be noted that the polar patterns required for the Ghent Microphone System can be formed from four cosine-type patterns with their positive axes of maximum sensitivity oriented into the desired directions, which from Figure 3 can be identified as 65^o, 165^o, 195^o, and 295^o azimuth (to which an omnidirectional component is subsequently added). These can be obtained from E_c, E_s, and E_o by proper algebraic combinations of the sine and cosine patterns. From the equation and table in the upper right corner in Figure 6 it is seen that the coefficients required for each particular angle of inclination can readily be calculated. These coefficients are provided by means of isolating amplifiers associated with E_c and E_s, followed by four summing junctions to which they are added with the proper algebraic signs, and with the further coefficient 0.7 required by the limacon pattern, 0.3 + 0.7 cos θ, provided. The omnidirectional voltage, E_o, also is applied to the same summing junctions with the prescribed coefficient 0.3. In this manner, the four output signals L1, L2, R1, and R2 are formed which, followed by the simple encoder in Figure 3, result in the desired Ghent System performance.

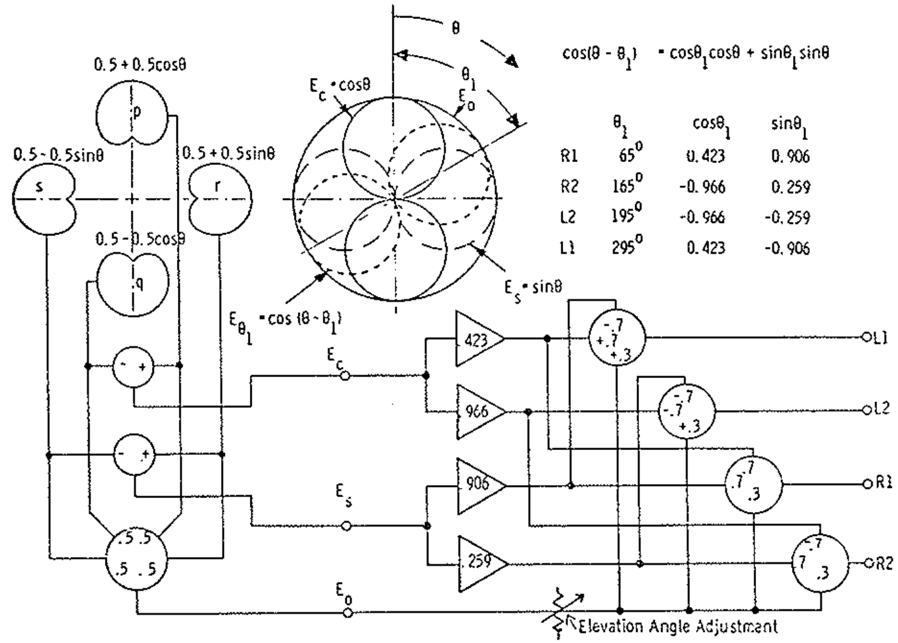


Figure 6. Construction of a Practical Ghent Microphone Array

A calibrated potentiometer to control the "dip" angle described above is shown following the E_o terminal in Figure 6.

The QM-69 Neumann microphone used as part of the Ghent System, together with the system's special encoder, is shown in Figure 7. The Ghent encoder module plugs directly into the SQ position encoder Model 4211, described elsewhere [3], [4], and it does not interfere with the application of auxiliary signals from proximate or distant microphones which one might desire to encode along with the output of the Ghent unit. Also, the aforementioned "London Box" can be combined with a remote signal source and the output of the Model 4211 encoder for adding a decodable mono-compatible CB signal, as described previously.

Experimental Verification

The first test on the Ghent Microphone System was conducted in the anechoic chamber at the CBS Technology Center. After measurements confirmed that the desired response was obtained, the encoded output was listened to in a studio provided with an SQ decoder and four loudspeakers. Persons walking around the microphones were clearly heard to traverse the corresponding path by listeners in the studio.

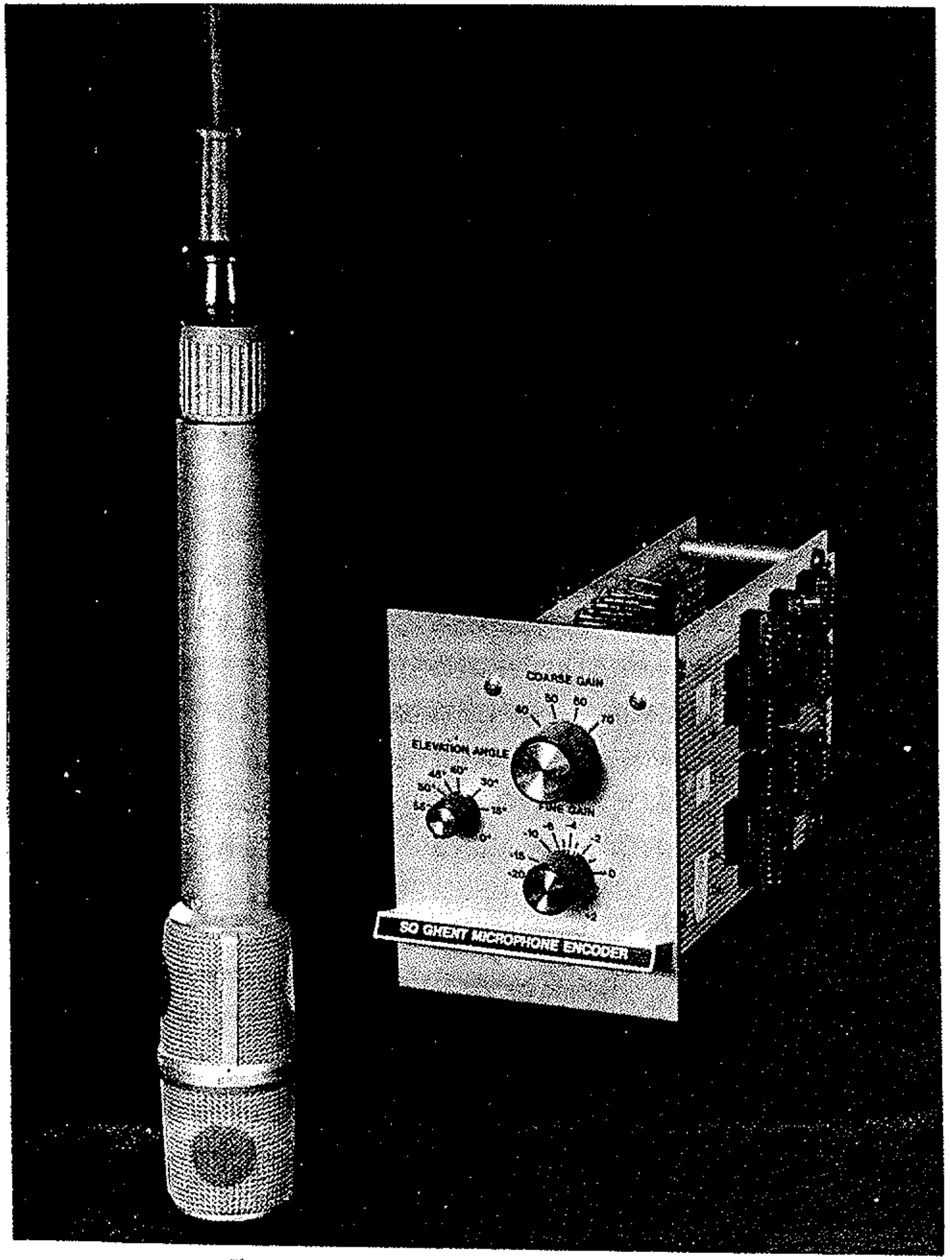


Figure 7. The Neumann QM-69 Microphone and the Special Microphone Encoder Used in the Ghent System

The first orchestral test of the Ghent Microphone System was conducted through the courtesy of Mr. Richard Kaye of Station WCRB in Boston on July 24, 1976 at the Tanglewood Music Shed (Boston Symphony Orchestra, with Leonard Bernstein conducting Liszt's Faust). The microphone was arranged on the stage approximately three feet in front of the conductor and ten feet above the stage floor. Audited in the control room via an SQ decoder and four loudspeakers, excellent channel separation was obtained with the listeners commenting favorably on the discreteness with which the various instruments, instrumental groups, the choir, and the soloists could be heard.

A second test was performed through the courtesy of Mr. F. J. Merrett of BBC Transcription Services on September 9, 1976 at the Royal Albert Hall, in London, (The BBC Symphony Orchestra and Stephen Bishop-Kovacevich playing the Brahms Piano Concerto Number 2 in B Flat Major). The Ghent microphone was arranged approximately three feet behind the conductor (into the audience) and approximately 15 feet above the podium, and so inclined as to provide a relatively even coverage of the stage on which the back instruments are placed on elevating platforms. The recorded tapes exhibit the proper spatial separation with total absence of the "comb-filter effect" sometimes heard when signals are picked up by distant spaced-apart microphones. The positions of the soloist

and the various instruments are clearly perceived in either the stereo or the quadraphonic modes and the instrumental balance is exemplary; and when decoded, the ambience and the applause are distributed around the quadraphonic field with complete naturalness providing an uncanny sensation of a concert-hall performance.

The Ghent microphone also was used to record excerpts of a rehearsal of Shakespeare's "The Merchant of Venice" at the BBC Kensington House, in London, demonstrating the ease with which performers are able to move around the microphone with a resultant fully stereo- and mono-compatible SQ-encoded signal.

Conclusion

The Ghent Microphone System has been shown to accept directional sounds over a 360° compass and convert them into a coded pair of signals in a manner similar to that of an SQ forward-oriented encoder. The front reception area, which sustains a 100° angle, provides conventional stereo as is required by the SQ code with full front channel separation between RF and LF at ±50°, respectively. The side 80° areas are SQ-coded for transition between front and back channels, and the ±130° directional sounds are coded as Right Back and Left Back signals of SQ, respectively.

The center-front signals are equal and in phase. The microphone has been evaluated under various conditions of orchestral and dramatic pickup to verify its theoretically predicted performance.

This ability to place a microphone at one point in space and to obtain a stereo- and mono-compatible SQ-quadraphonic-encoded pair of signals would seem to be of great value in a variety of sound-pickup applications. It is now up to the recording and broadcasting engineering community to evaluate the practical usefulness of the Ghent System.

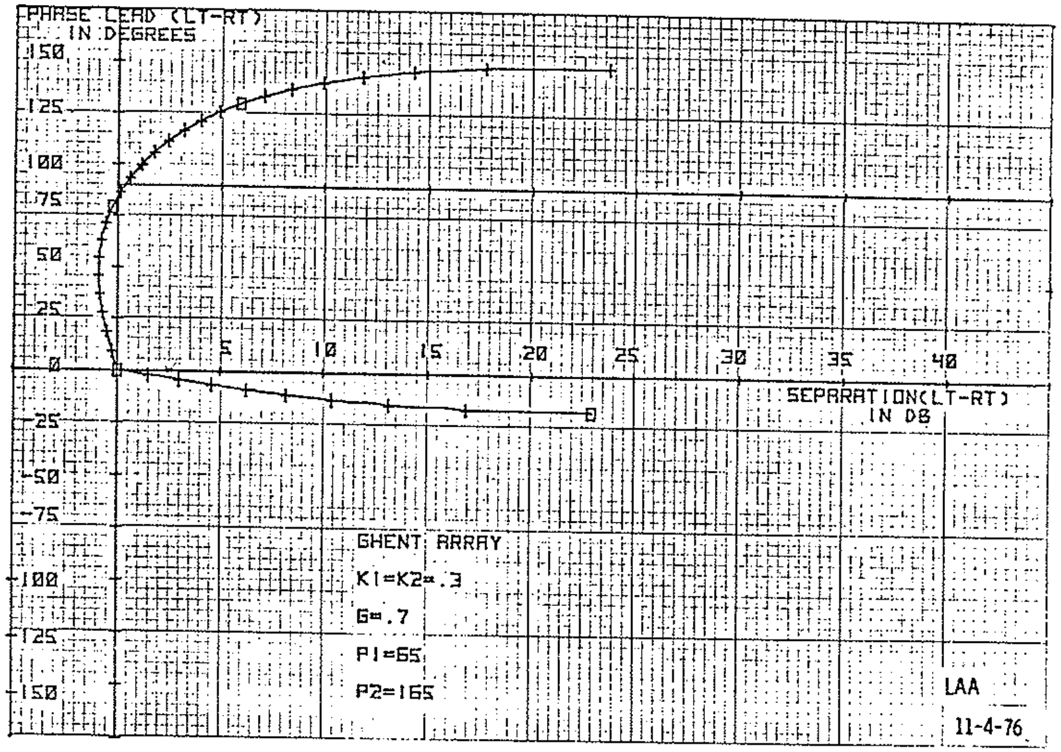
Acknowledgment

The authors acknowledge with gratitude the cooperation of Mr. Stephen F. Temmer of the Gotham Audio Corporation, in New York, and Messrs. Boré and Peus of Georg Neumann GmbH, in West Berlin, for their collective suggestions in connection with the use of the Neumann QM-69 Microphone, and for the loan of an experimental microphone.

References

1. B. B. Bauer, "Quadraphony, Spatial High Fidelity and Compatibility," presented at the Audio Engineering Society Meeting, Zurich, Switzerland, (March 1976).
2. B. B. Bauer, D. W. Gravereaux, A. J. Gust, "A Compatible Stereo-Quadraphonic (SQ) Record System," J. Audio Eng. Soc., vol. 19, pp. 638-646, (Sept. 1971).
3. B. B. Bauer, G. A. Budelman, D. W. Gravereaux, "Recording Techniques for SQ Matrix Quadraphonic Discs," J. Audio Eng. Soc., vol. 21, pp. 19-26, (Jan/Feb 1973).
4. B. B. Bauer, R. G. Allen, G. A. Budelman, D. W. Gravereaux, "Quadraphonic Matrix Perspective--Advances in SQ Encoding and Decoding Technology," J. Audio Eng. Soc., vol. 21, pp. 342-350, (June 1973).
5. See, for example, B. B. Bauer, "Random Efficiency of Second-Order Gradient Microphones," J. Acoust. Soc. Am., vol. 41, pp. 1545-46, (June 1967).
6. B. B. Bauer, U. S. Patent 2,305,599, Issued Dec.22, 1942, Filed April 8, 1941.
7. B. B. Bauer, "A New Encoder for SQ Matrix Broadcasts," BME, vol. 11, pp. 76-79, (March 1975).
8. T. K. Matsudaira, T. Fukami, "Phase Difference and Sound Image Localization," J. Audio Eng. Soc., vol. 21, pp. 797-798, (Dec. 1973).
9. B. B. Bauer, "Advances in Quadraphonic Matrix Broadcasting." Parts of this paper were presented at the IEEE Broadcast Symposium, Washington, D.C., September 24, 1976, and other parts at the Third Annual Society of Broadcast Engineers New York Convention, Hempstead, L.I., November 8, 1976.
10. R. P. Glover, "A Review of Cardioid-Type Unidirectional Microphones," J. Acoust. Soc. Am., vol. 11, pp. 296-302, (Jan. 1940).

APPENDIX



Ghent Array Encoding vs Azimuth

K1= 0.30 K2= 0.30 G= 0.70

P1= 65.00 P2= 165.00

SOURCE ANGLE	LT (MAG/PH)	RT (MAG/PH)	PHASE DIFF	SEPARATION (DB)	POWER (REF UNITY)
0	0.65/ 24	0.65/ 24	0	0.0	-0.71
5	0.70/ 23	0.59/ 25	-2	1.5	-0.70
10	0.75/ 22	0.54/ 26	-4	3.0	-0.68
15	0.80/ 20	0.47/ 27	-6	4.6	-0.63
20	0.84/ 19	0.41/ 28	-9	6.3	-0.57
25	0.88/ 18	0.34/ 29	-11	8.2	-0.50
30	0.91/ 17	0.28/ 30	-13	10.4	-0.42
35	0.94/ 15	0.21/ 30	-15	13.1	-0.33
40	0.96/ 14	0.14/ 31	-17	16.8	-0.24
45	0.98/ 13	0.07/ 30	-17	22.9	-0.14
50	0.99/ 11	0.01/ -35	46	45.8	-0.05
55	1.00/ 9	0.07/-140	149	23.7	0.05
60	1.01/ 8	0.13/-141	148	17.7	0.13
65	1.01/ 6	0.20/-140	146	14.2	0.21
70	1.00/ 4	0.26/-139	143	11.8	0.28
75	0.99/ 2	0.32/-138	140	9.9	0.33
80	0.98/ -0	0.37/-137	137	8.4	0.38
85	0.96/ -3	0.43/-136	134	7.1	0.41
90	0.94/ -5	0.47/-135	130	5.9	0.43
95	0.91/ -8	0.52/-133	126	4.9	0.44
100	0.89/ -11	0.56/-132	121	4.0	0.44
105	0.86/ -14	0.60/-131	116	3.2	0.42
110	0.83/ -18	0.63/-129	111	2.4	0.39
115	0.81/ -21	0.66/-127	106	1.7	0.35
120	0.78/ -26	0.68/-126	100	1.1	0.31
125	0.75/ -30	0.70/-124	93	0.6	0.25
130	0.73/ -35	0.72/-122	87	0.1	0.19
135	0.71/ -40	0.73/-119	79	-0.3	0.12
140	0.69/ -46	0.73/-117	71	-0.6	0.05
145	0.67/ -51	0.74/-115	63	-0.8	-0.01
150	0.56/ -57	0.74/-112	55	-0.9	-0.08
155	0.66/ -63	0.73/-109	46	-0.9	-0.14
160	0.66/ -69	0.72/-106	37	-0.9	-0.19
165	0.66/ -74	0.72/-102	28	-0.7	-0.24
170	0.66/ -80	0.71/ -98	19	-0.5	-0.27
175	0.67/ -85	0.69/ -94	9	-0.3	-0.29
180	0.68/ -90	0.68/ -90	0	0.0	-0.30