

★ A Product of the **SHURE** Laboratories

A new concept of

"SUPER-CARDIOID" OFFERS FURTHER

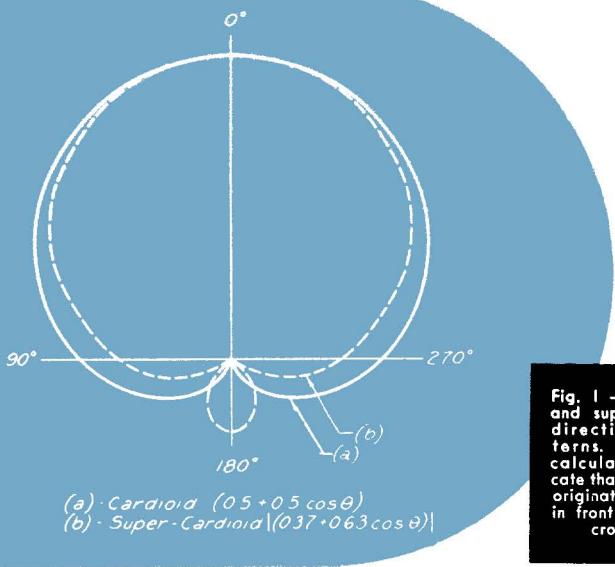


Fig. 1 — Cardioid and super-cardioid directional patterns. Probability calculations indicate that few sounds originate directly in front of the microphone.

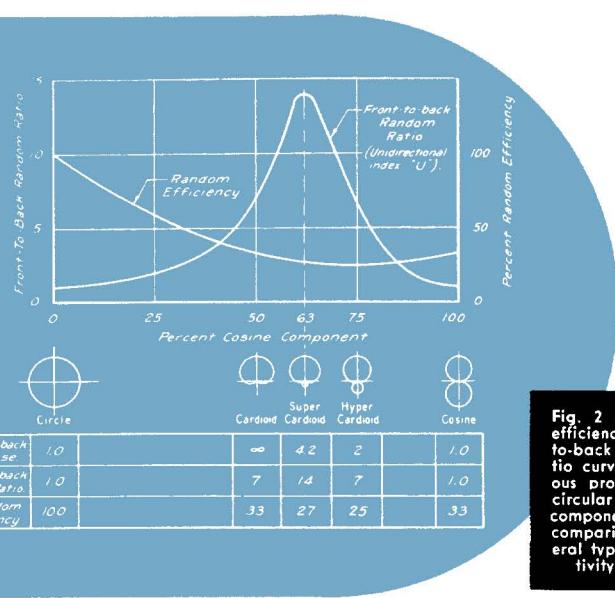


Fig. 2 — Random efficiency and front-to-back random ratio curves for various proportions of circular and cosine components and a comparison of several types of directivity patterns

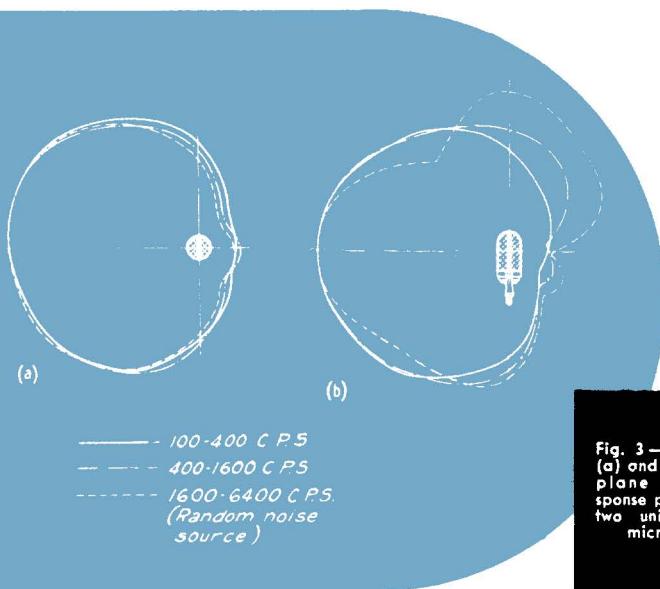


Fig. 3 — Horizontal (a) and vertical (b) plane polar response pattern of a two-unit cardioid microphone

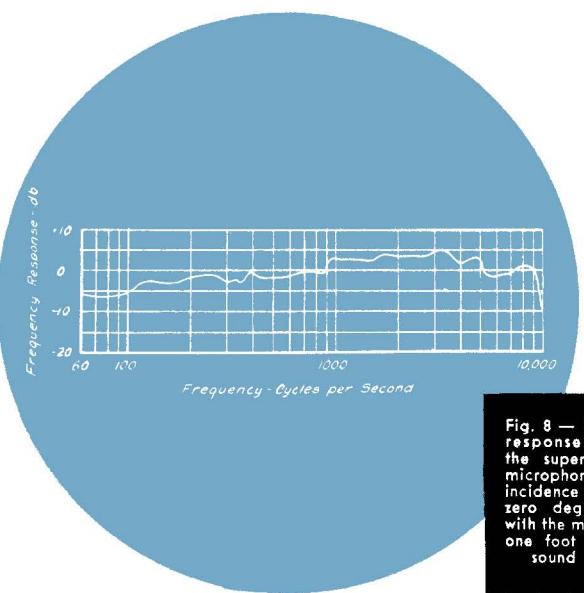


Fig. 4 — Frequency response curve of the super-cardioid microphone with incidence angle of zero degrees and with the microphone one foot from the sound source

Directional Performance

AMPLIFICATION OF SOUND PICK-UP PROBLEMS

The following excerpt from the January 1942 issue of ELECTRONICS MAGAZINE explains the development of the SUPER-CARDIOID MICROPHONE by Shure Engineers. It gives an interesting insight into the theory and construction of this newest contribution to the microphone field.

Unidirectional microphones have been accorded an ever-increasing acceptance in recent years in the broadcasting, recording and public address fields. The advantages which a cardioid (or heart-shape) pattern presents over a non-directional pattern, found in pressure microphones, are a two-thirds decrease in reverberation energy pickup, separation of the desired from the undesired sounds, and simplification of microphone placement problems. The cardioid is obtained through the addition in equal proportions of a bi-directional (cosine law) characteristic and a non-directional circular characteristic, resulting in the expression $\rho = (0.5 + 0.5 \cos \theta)$ shown in Fig. 1A¹. Later studies indicated that for maximum unidirectional action it is necessary to mix the circular and cosine law characteristics in a different proportion.

The Super-Cardioid

The cardioid fulfilled the formerly accepted definition of a unidirectional microphone as "one which has a high front-to-back response ratio" i.e. is sensitive at the front and relatively insensitive at the rear, along the line passing through the 0 to 180 deg. axis. It is apparent, however, that sounds originating precisely at the front or at the rear of a microphone occur relatively infrequently. The function of a unidirectional microphone appears to be more properly defined as that of accepting the sounds arriving from an imaginary hemisphere at the front of the microphone, and rejecting those arriving from a hemisphere at the rear of the microphone. Calculations based upon the probability of arrival of sounds from random directions indicate that the optimum pattern in accordance with this definition occurs when the proportions of circular and cosine components are in a ratio of 37 percent to 63 percent

(see Appendix). This pattern has been termed the super-cardioid, and is shown in Fig. 1B.

Another commonly accepted index of directivity, although not necessarily of unidirectional properties, is the random efficiency of a microphone², i.e., its ability to receive sounds arriving from all directions, as compared with that of a non-directional microphone having equal normal incidence efficiency. Decrease in reverberation energy pickup is given, in percent, by $E = 100 (1-\eta)$ where η is the random efficiency expressed as a fraction. Again, probability calculations indicate that minimum random efficiency occurs when the proportions of circular and cosine components are in a ratio of 25 percent to 75 percent. This pattern has been termed a hypercardioid.³

Twice as Unidirectional

The polar patterns obtained with various proportions of circular and cosine components, is shown in Fig. 2 which also lists (a) front-to-back response ratio; (b) front-to-back hemispherical random ratio; and (c) random efficiency. The super-cardioid is roughly twice as unidirectional as the cardioid or the hyper-cardioid from the standpoint of front-to-back random ratio. On the basis of random efficiency, it permits a 73 percent decrease in reverberation energy pickup, as compared with 66 percent for the cardioid and 75 percent for the hyper-cardioid. The hyper-cardioid has a front-to-back discrimination of only 2 to 1 and is, therefore, somewhat unsatisfactory as a unilateral microphone. These considerations definitely point toward the super-cardioid as providing a more satisfactory unidirectional pattern. These conclusions have been checked by extensive field tests in which microphones employing different patterns were used.

The Single Unit Unilateral Microphone

Early cardioid microphones were constructed using a velocity-type ribbon microphone, connected in series with a pressure ribbon microphone.¹ In later years various cardioid microphones have been developed following the same principle, but employing other types of pressure units in combination with a velocity element.⁴ Considerable manufacturing experience with such microphones indicates that the two-unit cardioid process entails many technical difficulties and high basic costs, because (a) the frequency response of the two component microphones must be held to close limits to produce a good directional pattern at all frequencies; and (b) electrical networks have to be provided between the two units to compensate for the effect of phase shift, due to the difference in operating principle of the velocity and pressure units, and due to the physical separation between the units which becomes significant at higher frequencies. There is considerable evidence that other investigators found similar problems in connection with two-unit uni-directional microphones.

Realization of these difficulties led to the development of single-unit uniphase cardioid microphones operating on the principle of acoustical phase shift. A uniphase piezoelectric cardioid microphone was first made available in 1937,⁵ and a uniphase moving-coil cardioid microphone appeared shortly afterward. Recent studies of the general acoustical problem involved resulted in the development of a new single-unit microphone with a super-cardioid pattern and with a greatly improved performance.

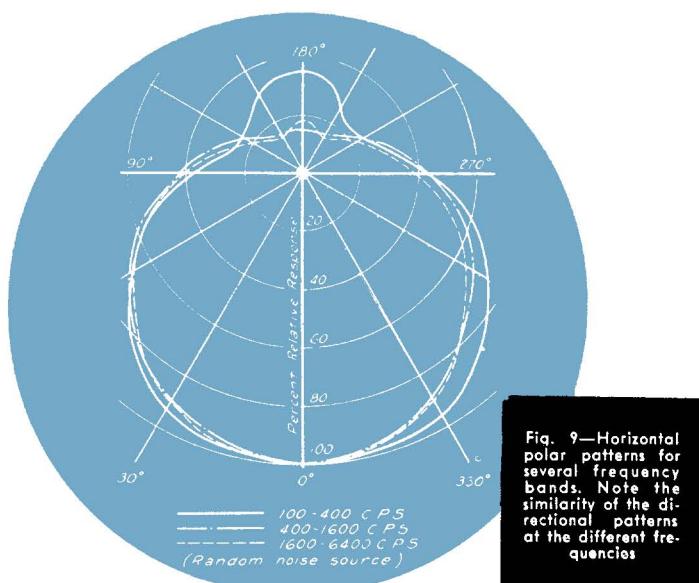


Fig. 9—Horizontal polar patterns for several frequency bands. Note the similarity of the directional patterns at the different frequencies.

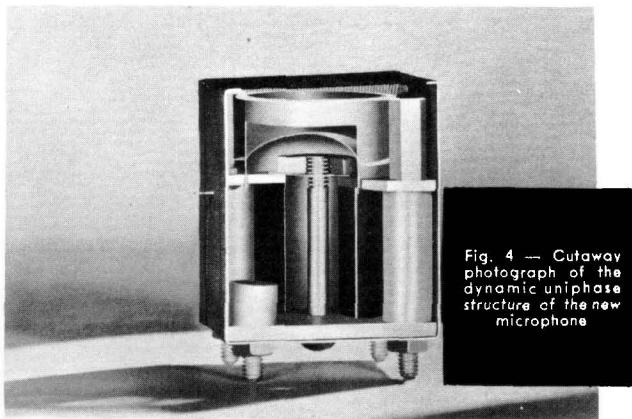


Fig. 4 — Cutaway photograph of the dynamic uniphase structure of the new microphone

Features of the Super-Cardioid

The new microphone has the following features: (a) a super-cardioid pattern for optimum unidirectional properties, and low random noise pickup; (b) an excellent frequency response, sensitivity, and high signal-to-noise ratio; (c) ruggedness and low wind-noise pickup common to moving-coil microphones; (d) simplicity and economy which result from the use of only one translating unit, and (e) axial symmetry at all frequencies. The point (e) has not been generally recognized in connection with two-unit unidirectional microphones. However, it is obvious that since such units are not symmetrical about the normal axis, they are not capable of having polar patterns symmetrical in all directions. The distortion of the polar pattern increases with frequency and with separation of the two units. This is indicated in Fig. 3, which shows polar patterns in the horizontal and the vertical plane of a commercial two-unit cardioid microphone, in which the separation between the pressure and the velocity units is two inches. These polar patterns were obtained by using three bands of random frequency noise, of 100 to 400, 400 to 1600, and 1600 to 6400 cps. Horizontal plane patterns closely approximate a cardioid; however, the patterns in the vertical plane are distorted at high frequencies, where the separation is comparable to the wavelength of sound. There is no evidence of such a considerable pattern distortion with the single unit microphone. It is evident, therefore, that the single unit microphone may be more effective, in eliminating sounds reflected from above or below, than a conventional two unit microphone.

Structure and Theory of Operation

A cut-away photograph of the dynamic uniphase structure is shown in Fig. 4, and a cross-sectional view is shown in Fig. 5. The moving coil is wound on a tubular bobbin and suspended from two elastic spiders. It has been found advisable to use the clearance between the moving coil and the inner pole piece as one of the phase shifting network elements. The action of this network is described in detail below. The volumes enclosed between the diaphragm and the inner pole piece, and inside of the magnet, are also used as part of the phase shifting network. These volumes are subdivided by an acoustical screen A. The magnetic circuit return consists of the outer pole piece and four iron bars, which are designed to provide an adequate magnetic path, and at the same time permit a free access of sound waves to the slit S between the inner pole piece and the coil. The complete unit is covered with a wind screen and suspended in a cradle, the object of which is the elimination of stray vibration pickup.

Referring to Fig. 5, a plane sound wave, approaching the unit from the front, first acts upon the front of the diaphragm with a pressure P_a , then flows around the outer pole piece, past the slit S, acting upon it with a pressure

P_b . The time required in traveling from the diaphragm to the slit is d/C_v second, where d is the effective air distance from the diaphragm front to the slit, and C_v is the velocity of sound (34,400 cm per sec). This time interval corresponds to a phase shift of $\omega d/C_v$ radians. If the wave is approaching parallel to the diaphragm (90 degree incidence), the time of arrival at the diaphragm, and the median time of arrival at the slit are identical, and P_a and P_b are in phase. Likewise, it is apparent that for waves arriving from any other angle, θ , the effective distance d is decreased by the factor $\cos \theta$, and hence the phase shift between the pressures at the diaphragm and the slit is $\phi_1 = (\omega d/C_v) \cos \theta$ radians. Therefore, ϕ_1 may be compared in function with the velocity (cosine) component of a two-unit unidirectional microphone.⁶

The pressure P_b at the slit acts upon the acoustical network and produces a pressure P_c within the volume under the diaphragm. The magnitude of P_c is the same as that of P_b but it is shifted in phase by an angle ϕ_2 which, in the super-cardioid case, is $37/63$ of ϕ_1 , at any given frequency. The phase angle, ϕ_2 , depends solely upon the network constants, and is, therefore, entirely independent of the direction of sound incidence. Hence ϕ_2 may be compared in function with the pressure (circular) component of a two-unit unidirectional microphone. It is apparent, therefore, that by surrounding a moving-coil element with an appropriate phase shifting network, an effect is produced which is equivalent to that obtained by combining a velocity microphone with a pressure microphone. A properly designed phase shifting network is the heart of the uniphase unidirectional microphone.

Principles of Acoustical Network Design

A discussion of this nature would not be complete without a brief mention of the principles of acoustical network design. Acoustical network analysis is carried out by the use of equivalent electrical circuits. The equivalent circuit theory assumes that sound pressure is equivalent to voltage, and that velocity of the air volume is equivalent to electrical current. The corresponding circuit equivalents are as follows: Acoustical mass (inertance) is equivalent to inductance, acoustical capacitance (compliance) is treated as electrical capacitance, and acoustical resistance is represented by electrical resistance.⁷ Referring again to Fig. 5, the slit S is represented by a series resistance R_s and inductance L_s in Fig. 6. The volumes under the diaphragm, V_1 , and within the magnet, V_2 , are represented as condensers C_1 and C_2 . The acoustical screen A is also represented as a series resistance R_s and inductance

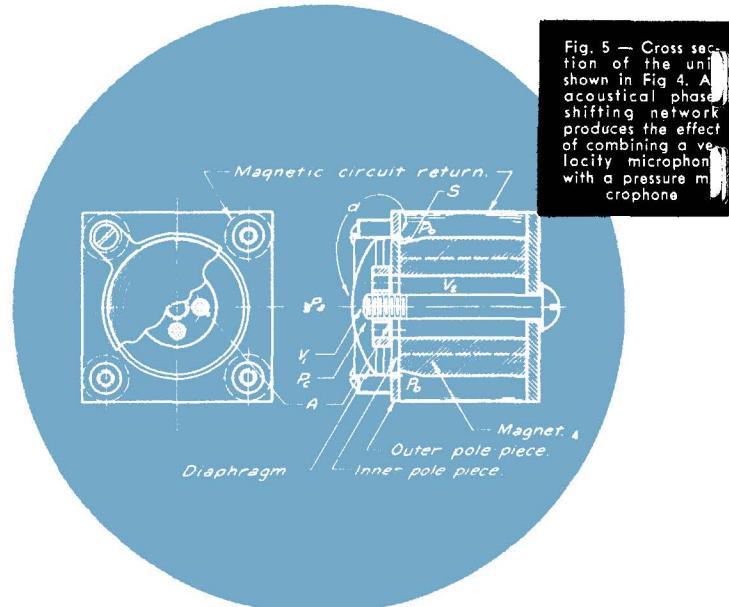


Fig. 5 — Cross section of the unit shown in Fig. 4. An acoustical phase shifting network produces the effect of combining a velocity microphone with a pressure microphone

L . The equivalent electrical circuit of the acoustical network is shown in Fig. 6. Voltage E_b represents the pressure P_b , and voltage E_c represents the pressure P_c . The two voltages should be equal in magnitude and displaced in phase through an angle proportional to frequency. This design objective is achieved by determining the values of the electrical circuit components for the desired performance, and then translating these values into the acoustical elements in the microphone structure. The phase shift and relative magnitudes of pressures within the super-cardioid microphone unit illustrated in Fig. 5 are shown in Fig. 7.

The phase shift angle increases directly with the frequency. Therefore, the net pressure difference between the diaphragm sides also increases with the frequency. However, the coil is suspended in such a manner that its mechanical impedance rises directly with the frequency within practically all of the audio frequency spectrum. The velocity of the coil is, therefore, independent of frequency and a flat frequency response results.

Frequency Response and Directivity

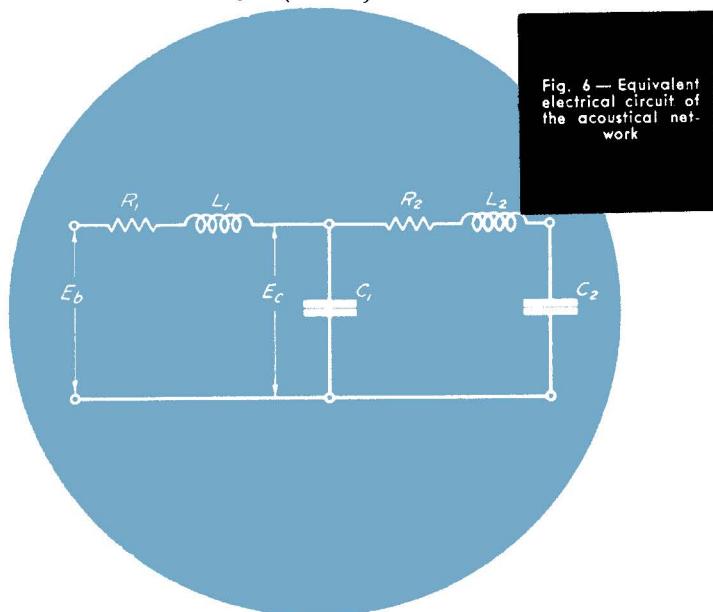
Frequency response of the new super-cardioid microphone is shown in Fig. 8 for 0 deg. incidence at one foot from sound source. Polar patterns are shown in Fig. 9, for random noise frequency bands of 100 to 400, 400 to 1600, and 1600 to 6400 cps, indicating that the directional properties are alike at all frequencies.

The new unit is doubly wind screened, and in common with other moving coil microphones, is notably free from wind noises. This enhances its value in broadcasting from outdoor locations where windage pickup may constitute a problem. The super-cardioid pattern provides an easy means of eliminating undesired noises by proper microphone orientation. Because of the inherent sturdiness of the moving-coil structure, the new microphone is well adapted for remote broadcasting as well as studio work.

Appendix

Random efficiency (sometimes called directional efficiency) of a directional microphone may be defined as the ratio of power delivered into the amplifier (due to a random sound field incident from all directions with equal intensity and random phase distribution) to the power that would have been delivered under the same conditions by a microphone with equal sensitivity in all directions. The random efficiency of a microphone with a response symmetrical about the normal axis is given by:²

$$\eta = \frac{1}{2} \int_0^\pi \left\{ f(\theta) \right\}^2 \sin \theta \, d\theta \quad (1)$$



where $f(\theta)$ expresses the directional sensitivity of the microphone for sounds arriving from angle θ in terms of percentage of 0 deg. incidence response.

What might be called the front random efficiency of a microphone η_f , that is, the random efficiency based on sounds arriving from the front hemisphere, is obtained by integration from 0 to $\pi/2$; likewise the rear random efficiency of a microphone η_r , based on sounds arriving from the rear hemisphere, is obtained by integration from $\pi/2$ to π . In a microphone having a directional pattern in the form of a Limaçon,

$$f(\theta) = (1 - k) + k \cos \theta \quad (2)$$

where k is a fraction representing the contribution of the cosine unit to the total output. The values for η_f , η_t , and η_r are given by substitution of Eq. (2) into Eq. (1), and integrating from 0 to π , 0 to $\pi/2$, and $\pi/2$ to π respectively. Performing these integrations, the following relations are obtained:

$$\eta_f = 1 - 2k + 4/3 k^2 \quad (3)$$

$$\eta_t = \frac{1}{2} - k/2 + 1/6 k^2 \quad (4)$$

$$\eta_r = \frac{1}{2} - 3/2 k + 7/6 k^2 \quad (5)$$

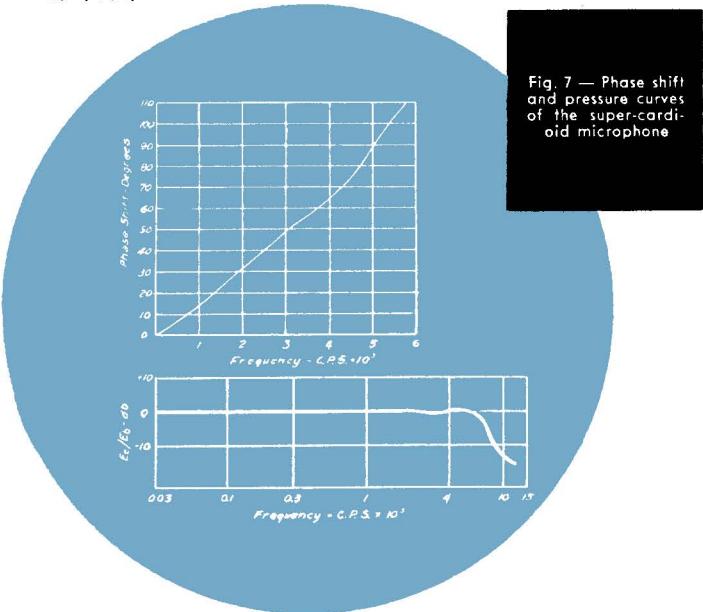
The unidirectional index of a microphone has been taken as a ratio of η_t to η_r :

$$U = \frac{\frac{1}{2} - k/2 + 1/6 k^2}{\frac{1}{2} - 3/2 k + 7/6 k^2}$$

A plot of the function U (Fig. 2) shows that the maximum unidirectional ratio of 14 to 1 is obtained when $k = 0.63$. The pattern corresponding to this maximum, $f(\theta) = 0.37 + 0.63 (\cos \theta)$ has been called a super-cardioid. Substituting $k = 0.63$ into Eq. (3), the super-cardioid pattern is found to have a random efficiency of 27 percent.

References

- (1) J. Weinberger, H. F. Olson and F. Massa, Uni-Directional Ribbon Microphone. *Jour. Acous. Soc. Am.*, Vol. 5, No. 2, p. 139 (1933).
- (2) Benjamin Baumzweiger, Graphical Determination of Random Efficiency of Microphones, *Jour. Acous. Soc. of Am.*, Vol. 11, No. 4, p. 477 (1940).
- (3) Ralph P. Glover, A Review of Cardioid type Uni-Directional Microphones, *Jour. Acous. Soc. Am.*, Vol. 11, No. 3, p. 296 (1940).
- (4) R. N. Marshall and W. R. Harry, New Microphone Providing Uniform Directivity over an Extended Frequency Range, *Jour. Acous. Soc. Am.*, Vol. 12, No. 4, p. 481 (1941).
- (5) Benjamin Baumzweiger, A New Unidirectional Microphone, New Products Section, ELECTRONICS, p. 62, February, 1939.
- (6) For a rigorous mathematical analysis of the Uniphase, see B. B. Bauer, Uniphase, Unidirectional Microphones, *Jour. Acous. Soc. of Am.*, Vol. 13, No. 1, p. 41 (1941).
- (7) Standards on Electroacoustics. *Institute of Radio Engineers*, p. 13 (1938).



Applications of the "556"

The *Super-Cardioid* provides a high degree of directivity, vertically and horizontally, over a wide frequency range from 40 to 10,000 cycles and therefore is effective for bass and treble tones as well as for intermediate tones. This, together with wide-angle pick-up, excellent sensitivity and smooth, wide-range response, makes the "556" highly useful for symphony or for a single artist or announcer. It gives prominence and definition to the direct sound—brings out the true quality of the sound to be reproduced.

STUDIO BROADCASTING

The "556" stops troublesome reflections in small studios—cuts down reverberation effects and random noise in larger studios. You can place the microphone with its back, or "dead" zone, close to the wall and obtain more usable studio space—without worrying about echoes from the wall. All this facilitates microphone placement, simplifies microphone technique.

REMOTE BROADCASTING

Compact size and rugged, shock-proof construction make the "556" *Super-Cardioid* especially useful for indoor and outdoor remotes. It is convenient to take along, easy to handle—and highly immune to mechanical vibration, wind noises and temperature conditions. In theatres, auditoriums, churches, sportscasts, night clubs and similar applications, it stops interference from audience and random noise—picks up the direct sound more distinctly and reproduces it more faithfully.

RECORDING

The advantages of the *Super-Cardioid* are equally effective in Recording. This Microphone stops the recording of unwanted sounds—permits you to

SHURE



Super-Cardioid Broadcast Dynamic Microphone

record in a small studio without worrying about room reflection or random noise effects.

PUBLIC ADDRESS

The performance of the *Super-Cardioid* solves many troublesome problems in public address installations. It kills feedback—stops objectionable reflection and background noise—permits more volume and better audience coverage. Where necessary, microphone and loud speakers can be placed close together. Sensitivity and pick-up range enable performers to stand away from the microphone and move about more freely. This simplifies sound set-ups and microphone placement—and assures better pick-up and reproduction.

MODERN DESIGN

The "556" is *modern as tomorrow*. Its functional design and handsome appearance make it worthy of any studio or remote location. The case is die cast and finished in rich satin chrome. Construction is rugged throughout. Employs a specially-suspended double-wind screened moving coil system. The moving-coil assembly is supported in the case by a damped spring system.

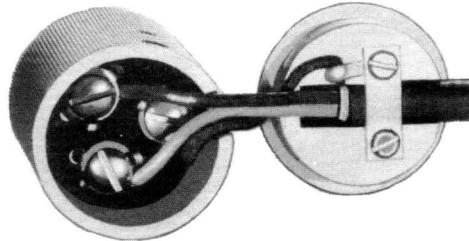
MOUNTING

A built-in flexible rubber-cushioning unit between the case and the mounting fixture provides effective transverse vibration isolation. Screw terminals for output (balanced-to-ground) are readily accessible by removing threaded bottom. (See illustration below.) The Microphone tilts forward or backward through an angle of 150 degrees. Standard $\frac{5}{8}$ "-27 thread. Adapters to W. E. and R. C. A. threads will be furnished on request with Microphone, at no extra charge.

HIGH QUALITY, WITH ECONOMY

The moderate price of the "556" is made possible only by the Shure *Uniphase* single-unit construction which eliminates the delicate matching of two dissimilar elements in one microphone. This means *uniformity, extra ruggedness, and economy* in production. One unit in the microphone does the work of two with equal efficiency—you pay only for the one instead of for two.

Try the "556" SUPER-CARDIOID Dynamic for effective solution of your microphone problems—now.

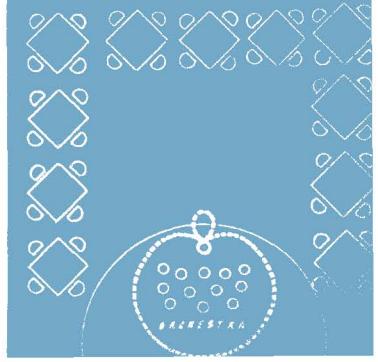
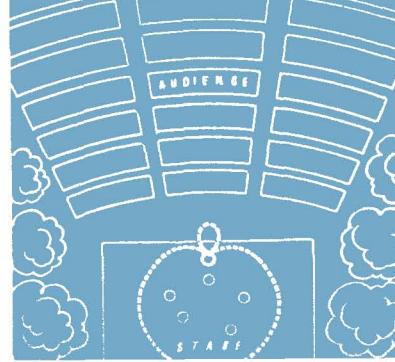
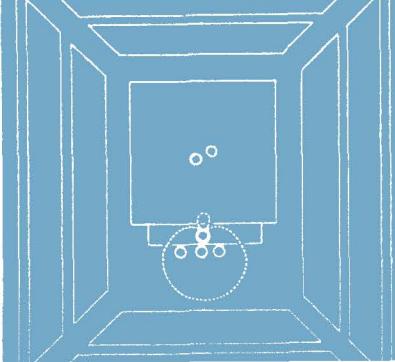
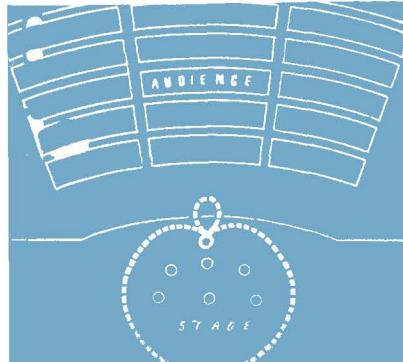


Studio

Sports

Pavilion

Night Club



SHURE 556 "SUPER-CARDIOID" BROADCAST DYNAMIC MICROPHONE

Available in low and high impedance models. Smooth wide-range response from 40 to 10,000 cycles at the front—dead at the rear. Rugged, shockproof. Practically unaffected by atmospheric conditions. Permissible cable length practically unlimited on low impedance models. Equipped with 18" stub of rubber-covered two-conductor shielded cable, trimmed on free end for attachment of connector plug. Stub may easily be replaced by longer length of cable if desired. Case dimensions: 4½" high, 3¼" wide, 3½" deep. Height overall, including built-in isolation mounting fixture, 8". Net weight 2¾ lbs. Shipping weight 4½ lbs. (Does not include accessories listed below.)

Model 556A. Super-Cardioid Microphone. For 35-50 ohm circuits. Output level into 50 ohms: 62.8 db below 6 milliwatts for 10 bar signal. Code: **Rudom.** List Price

\$75

Model 556B. Super-Cardioid Microphone. For 200-250 ohm circuits. Includes internal transformer. Output level into 250 ohms: 63.8 db below 6 milliwatts for 10 bar signal. Code: **Rudop.** List Price

\$75

Model 556C. Super-Cardioid Microphone. High impedance. Includes internal transformer. Output level: 55 db below 1 volt per bar. Code: **Rudor.** List Price

\$75

SHURE STANDS AND ACCESSORIES FOR THE "556" BROADCAST MICROPHONE

Model S36A. Streamlined Desk Mount. Functionally designed—beautifully styled. Provides stable support at correct height for desk or rostrum. Adapters available for other type microphones. Attractively finished in Iridescent Gray. Base: 2½" high, 5" wide, 7" long. Net weight 1 lb. Shipping weight 1½ lbs. Code: **Rusef.** List Price

\$4

Model S510A. Broadcast Heavyweight Floor Stand. Contributes to better microphone performance. Low "stabilized" extra heavy 3-leg base hugs the floor and provides firm footing on uneven surfaces. Pure gum rubber base isolation. Legs are shaped to give maximum floor space for artists and permit easy use in crowded quarters. Extra-heavy, non-vibrating, large-diameter tubings. Quick, positive, fool-proof friction-lock permits instant, smooth, stable height adjustment from 45° to 79°. Free-wheeling mounting screw with 5/8"-27 male thread for easy attachment or removal of microphone. Inner tubing has ½" pipe thread outside and 5/8"-24 machine thread inside, adapts stand for mounting R.C.A. and W.E. microphones. Leg spread 16½"; finished in baked enamel. Diameter of tubings: outer 1¼", inner 13/16"; finished in satin chrome. Net weight of tubing assembly 6½ lbs. Net weight of base 22½ lbs. Shipping weight 32 lbs. Code: **Rusop.** List Price

\$35

Model A86A. Cable-Type Transformer. Matches 35-50 ohm and 200-250 ohm microphones to high impedance amplifier input—makes it convenient to run long microphone lines from low impedance microphone to high impedance amplifier. Magnetically shielded case. Terminals easily accessible. Compression fittings seal-in microphone and amplifier cables. Removable rubber rings. Case Diam. 1½", length 2½" (not including compression fittings). Finished in chrome and gray. Complete with 7 ft. single-conductor shielded cable for connection to amplifier. Spring cable protectors. Shpg. wt. 1½ lb. Code: **Rudeb.** List Price

\$12

Model A72A. Call Letter Plate. Attractive call-letter plate for Shure "556" Super-Cardioid Microphones. Fits on the case of the microphone easily and snugly. Makes call letters visible from all four sides, with practically no effect on directional characteristic of microphone. (Lettering can easily be applied by user.) Satin and black finish. Dimensions: 7-5/32" high, 6-9/32" wide, 1½" deep. Net weight 6½ oz. Shipping weight 12 oz. Code: **Rudic.** List Price

\$10

Model A35A. Suspension Adapter. For overhead suspension. Provides two loops for non-twisting support. 5/8"-27 thread. Dimensions: 5" long, 1¾" high, ¾" wide. Net weight 4 oz. Shipping weight 6 oz. Chrome plated finish. Code: **Rudem.** List Price

\$1.50



Model S36A. Desk Mount.



Model A86A. Cable Transformer.



Model A72A. Call Letter Plate.

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