A New Unidirectional Microphone

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ANNOYING effects of reverberation and background noise, which are almost invariably present in microphone setups may be greatly minimized, if not entirely eliminated, with a microphone sensitive only in the direction of the desired sounds and relatively insensitive in other directions. The importance attached to directional properties of microphones even in the early days of broadcasting and public address is evident in many attempts to use various kinds of reflectors and baffles to increase directional discrimination. Correctly designed microphone baffles are capable of producing some useful high-frequency directivity. However true unidirectional operation is unobtainable by such means inasmuch as diffraction effects become pronounced only at wavelengths considerably smaller than the important dimensions of the obstacles. The inability of such devices to cope effectively with the majority of microphone pickup problems becomes evident if it is remembered that the bulk of the acoustical energy is transmitted in the frequency range below 1000 cps.

True unidirectional operation can be obtained with a combination of a pressure-type microphone and a velocity-type microphone. This is analogous to the well-known unidirectional antenna array consisting of a vertical element and a loop. The voltage in a pressure-type microphone is independent of the direction of incidence of sound, while that of the velocity-type microphone reverses with the reversal of incidence. Outputs of the individual units therefore add for sounds arriving from the front and subtract for sounds arriving from the rear. Through careful design, substantial output cancellation is obtained for rear sounds throughout practically all of the acoustical frequency spectrum.

This procedure, although simple and straight-forward theoretically, has a number of practical drawbacks. The frequency response curves as well as the phase positions of the individual voltages must closely correspond in order to obtain an acceptable front-to-rear discrimination at all the important frequencies. The correspondence required, in view of difference in operating principle of the units, necessitates elaborate and expensive selective processes to achieve proper matching of the units, which naturally is reflected in the high prices which such microphones command.

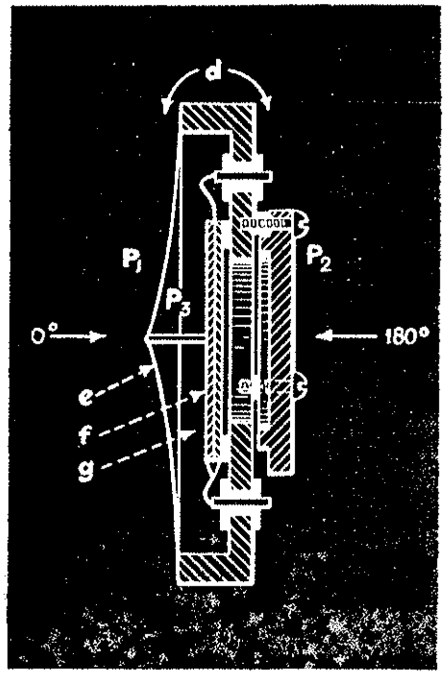

Fig. 1—Cross sectional view of the new Shure Brothers microphone, showing the essential component parts. This is a crystal-type unit

A new principle of unidirectional operation employing only one microphone unit was developed some time ago in the Shure laboratories, and has been embodied in the Model 730A "Uni-

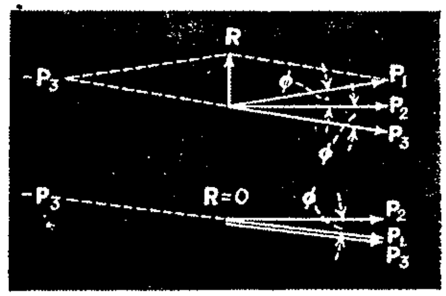

Fig. 2a (above) and Fig. 2b—Manner in which unidirectional microphone action is attained

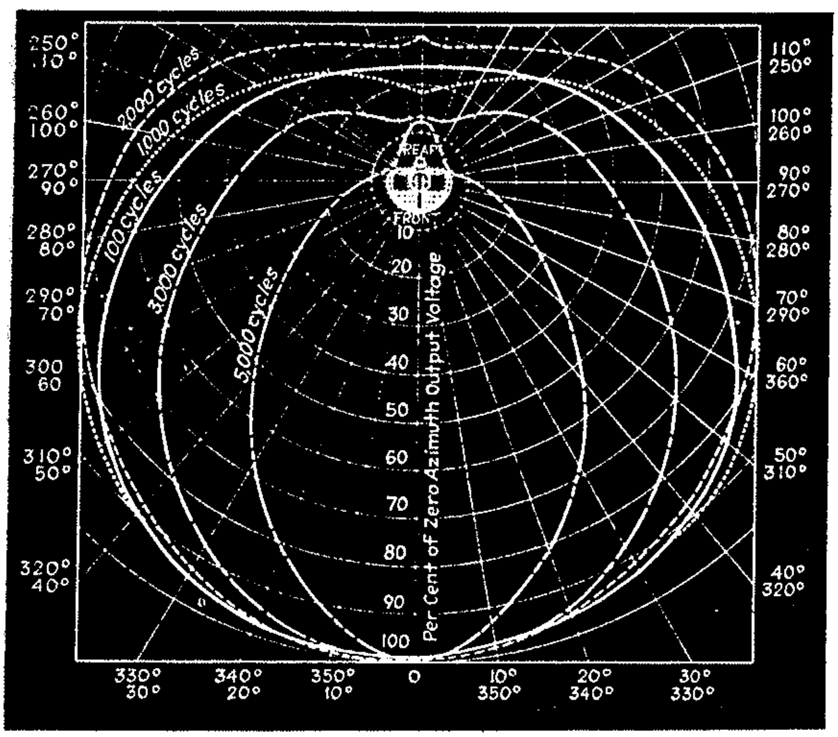

Fig. 3—Cardioid-shaped directivity pattern of the "uniphase" mike, given for several audio-frequency values

plex" Unidirectional Crystal Microphone. The new unit achieves unidirectional operation through the use of phase-shifting acoustical networks coupled to a diaphragm-type crystal element. The simplified structure obtained this way obviously has a number of technical advantages arising from the purely acoustical nature of the system. A cross-sectional view of the unidirectional mechanism is shown in Fig. 1 illustrating the essential component

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Unidirectional Microphone

parts. A light duraluminum diaphragm e is coupled to the bimorph Rochelle salt crystal f by means of a connecting rod. One side of the diaphragm is exposed directly to the sound waves, while the other is adjacent to the enclosure g forming part of the acoustical network structure which affords communication with the rear side of the unit.

A sound wave moving in the direction indicated by the 0° arrow arrives at the front of the microphone a trifle earlier than it does at the rear because of the additional distance d which it must travel. Therefore the sound pressure P_1 leads P_2 by a phase angle

$$\phi = \omega d/c \qquad (1)$$

where ϕ is the angle in radians and c is the velocity of sound.

For 180° incidence the relative phase position of P_1 and P_2 is inverted and the latter leads the former by the same angle ϕ.

The pressure P_2 acts through the acoustical network developing a pressure P_3 in the chamber g. The net effective pressure upon the diaphragm and hence upon the crystal, is the vector difference between P_1 and P_3. Through proper selection of constants of the acoustical network it is possible to attain a condition whereby at all important frequencies P_3 is of the same magnitude as P_2 but lags it by the angle ϕ given in Eq. (1).

The manner in which unidirectional action is attained may be shown conveniently by reference to vector diagrams of Fig. 2. Fig. 2a represents the front or 0° incidence of sound. P_1 leads P_2 by the angle ϕ, and P_3 lags P_2 by the same angle. Therefore P_1 and P_3 are displaced by an angle 2ϕ. Subtraction of P_3 from P_1 gives the resultant pressure R which acts upon the piezoelectric crystal.

Figure 2b represents the phase position of sound pressures for the rear or 180° incidence of sound. For this incidence P_1 lags P_2 by the angle ϕ, and since P_3 also lags P_2 by the same angle, P_1 and P_3 are in phase and the subtraction of the latter from the former gives a resultant net diaphragm pressure equal to zero. The microphone will not, therefore, produce electrical output for sound waves arriving from the rear.

It has been tacitly assumed that P_1 and P_3 have the same magnitude. This assumption is valid if the wavelength of sound is several times as great as the dimensions of the instrument, which in the above microphone is true up to approximately 2500 cycles per second. At higher frequencies the described pressure relationship does not hold, but diffraction effects tend to give a relatively low sensitivity for sounds arriving from the rear. Through careful design of the external case housing the microphone unit, unidirectional action is maintained at all the important frequencies of the sound spectrum, with an average front-to-back discrimination of approximately 15 db.

Equation (1) indicates that the phase angle ϕ is proportional to frequency, and an examination of the vector diagram of Fig. 2a will show that this causes the resultant pressure upon the crystal to increase with frequency. Electrical compensation is provided in the microphone to achieve a smooth wide-range front-side response.

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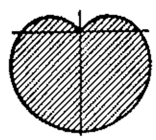

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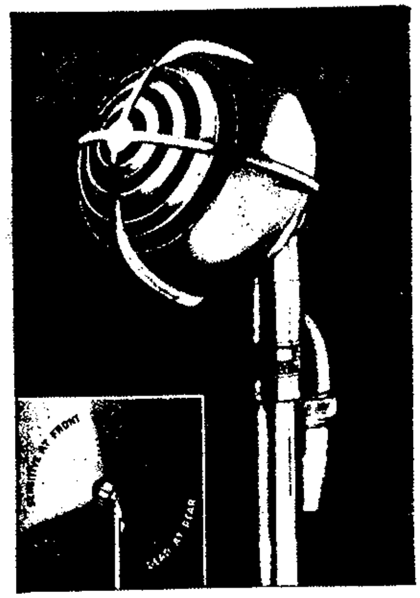

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