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VOLUME 15 NUMBER 4 **OCTOBER 1967**

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Journal of the Audio Engineering Society. Volume 15, No. 4, October, 1967. Published quarterly by the Audio Engineering Society and supplied to all members in good standing. Publication office, 104 Liberty Street, Utica, N. Y. 13502. Executive office, Room 428, Lincoln Building, 60 East 42nd Street, New York, N. Y. 10017. Entered as second class mail at the post office at Utica, N. Y. Subscription to nonmembers, $11 per year. The Journal is indexed in the **Applied Science & Technology Index.**

Directional Microphones

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A comparison of gradient, end-fired line, and cross-fired surface wave microphones has been carried out. The subjects considered include the directivity as a function of the dimensions and of frequency, the problem of obtaining a uniform directional pattern with respect to frequency, and the ambient noise response and relative pickup distances of directional microphones.

INTRODUCTION A directional microphone is an acousto-electronic transducer for converting acoustic vibrations into the corresponding electrical undulations which exhibits a variation in response to sounds arriving from different directions with respect to some reference axis of the system. The main reason for the use of directional microphones is to pick up desired sounds and discriminate against unwanted sounds such as reverberation and noise. Directional microphones may be divided into two main categories, namely the gradient types which depend for directivity upon the difference in pressure, or powers of the difference in pressure, between two points in space, and wave types which depend for directivity upon some form of constructive and destructive wave interaction. The purpose of this paper is to describe the construction, operation, and performance of gradient and wave type directional microphones.

GRADIENT MICROPHONES

A pressure gradient microphone is a microphone in which the electrical output corresponds to a component of the gradient or space derivature of the sound pressure.

A first-order pressure gradient microphone is a microphone in which the response corresponds to the difference in pressure between two points in space. The first-order pressure gradient response resembles the particle velocity in a sound wave and as a consequence this type of microphone is termed a velocity microphone. A first-order pressure gradient microphone may be depicted as consisting of two pressure-sensitive elements separated by a distance that is small compared to the wavelength, connected in phase opposition as shown in Fig. 1. The directional characteristic of a first-order pressure gradient microphone is of the cosine type, given by the equation

$$e_1 = e_0 \cos\theta \qquad (1)$$

where e_1 = output of the microphone for the angle θ, θ = angle between the direction of the incident sound and the line joining the two elements, and e_0 = output of the microphone for $\theta = 0$. The directional characteristic of the first-order pressure gradient microphone is also shown in Fig. 1.

A unidirectional microphone is a microphone that responds predominantly to sound incident from a single solid angle of a hemisphere or less. The most common

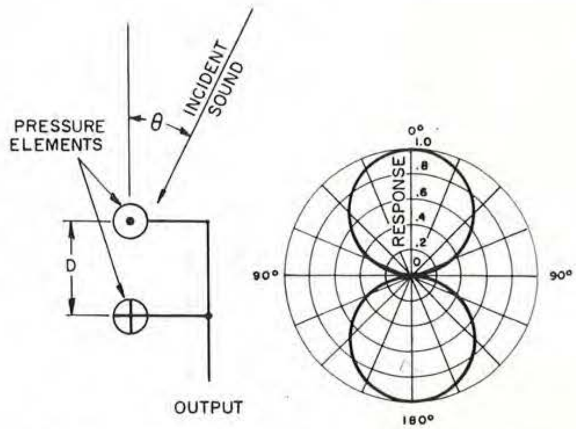

Fig. 1. Elements of a first-order bidirectional gradient microphone and corresponding directional characteristic.

unidirectional microphone is the one of gradient type in which the directional characteristic is a cardioid. A unidirectional microphone may be depicted as two pressure-sensitive elements separated by a distance that is small compared to the wavelength, connected in phase opposition through a delay network. The directional characteristic of the first-order gradient unidirectional microphone is given by the equation

$$e_1 = e_0(D_2 + D_1 \cos\theta) \qquad (2)$$

where e_1 = output of the microphone for the angle θ, θ = angle between the direction of the incident sound and the line joining the two elements, e_0 = output of the microphone for $\theta = 0$, D_1 = distance between the elements, and D_2 = path length of the delay. For $D_1 = D_2$ the directional characteristic is a cardioid, as shown in Fig. 2. The directional characteristic for $2D_2 = D_1$ and $D_2 = 2D_1$ are also shown in Fig. 2.

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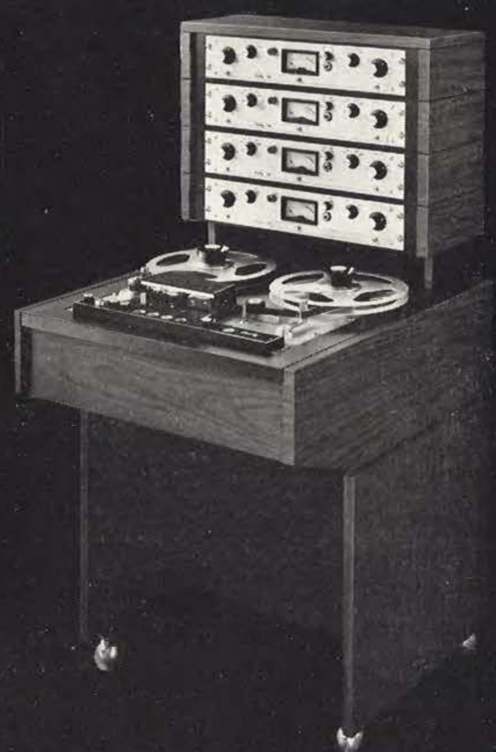

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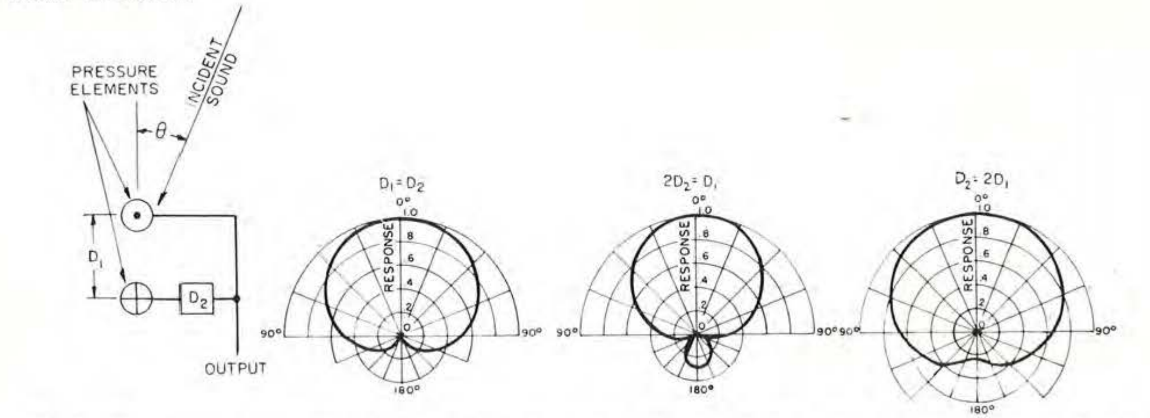

Fig. 2. Elements of a unidirectional gradient microphone and directional characteristics for various ratios of D_1 and D_2.

A second-order pressure gradient unidirectional microphone is depicted in Fig. 3. In this form, the second-order gradient unidirectional microphone consists of two gradient microphones of the first order connected in phase opposition combined with a delay line. The directivity pattern of the second-order gradient unidirectional microphone is given by

$$e_2 = e_0(D_2 + D_1 \cos\theta)\cos\theta \qquad (3)$$

where e_2 = output of the microphone for the angle θ. θ = angle between the direction of the incident sound and the line joining the two elements, e_0 = output of the microphone for $\theta = 0$, D_1 = distance between the two first order gradient elements, and D_2 = path length of the delay.

The directional characteristics for $D_1 = D_2$ and $2D_2 = D_1$ are shown in Fig. 3. A consideration of the directional characteristics of Fig. 3 shows that these are much sharper than one lobe of one of the cosines of Fig. 1.

WAVE MICROPHONES

Line Microphones

A line microphone is a wave-type directional microphone consisting of a single straight-line element or of an array of continuous or spaced electroacoustic transducing elements disposed on a straight line. In the end-fired line microphone the maximum response occurs for sound arriving along the axis of the microphone. Typical end-fired line microphones are depicted in Fig. 4. In Fig. 4a the line microphone consists of a number of small pipes with the open end as pickup points, equally spaced on a line, and with the other end connected to a transducing element. In Fig. 4b the line microphone consists of a tapered tube connected to the transducing element. In Fig. 4c the holes of Fig. 4b are replaced

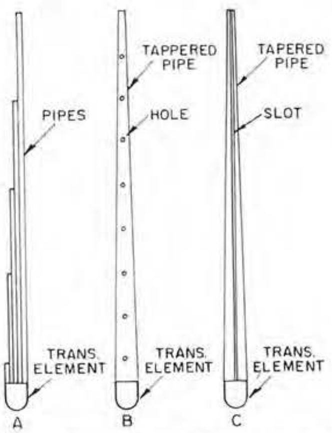

Fig. 4. Different types of end-fired line microphones. The pickup systems are: **a.** A bundle of different lengths of pipe with the open ends as pickup points; **b.** A tapered pipe with holes as pickup points; **c.** A tapered pipe with a slot as pickup point.

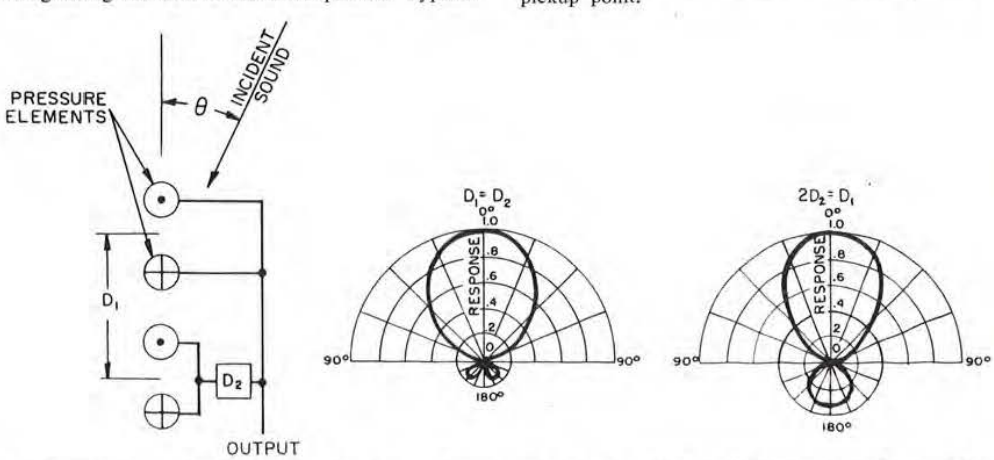

Fig. 3. Elements of a unidirectional second-order gradient microphone and directional characteristics for two different ratios of D_1 and D_2.

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