sound wave, its motions are impeded by a parallel combination of inductance and resistance. It is not logical for the piston to assume that the inductance disappears with the onset of the sound wave. Thus, the piston must conclude that the presence of the pressure p, everywhere in the vicinity of the mouth of the tube must prevent this "inductive" current from flowing into space, in effect by placing a pressure p at the "other end" of the inductance. This is shown in Fig. 2(c), which now gives us the complete equivalent circuit valid for the condition described above and which constitutes the proposed analog. It is to be noted that this circuit introduces no undue complexity and it can readily be formed of a low-impedance center-tapped resistor or transformer.

Let us now consider another microphone, one in which the piston at the end of the tube is blocked, thus effectively creating an "open circuit" condition at the entry of the transducer, as shown in Fig. 2(d). The pressure p_1 at the blocked piston then is given by an equation that can readily be derived from the equivalent circuit, as follows:

$$(p_1/p)=(1+j\mu)/[1+j(\mu/2)],$$

where $\mu=2\pi a/\lambda$; λ is the wavelength.

A curve of p_1/p vs μ is shown in Fig. 3, where it is compared against a similar function displayed by Morse[7] for the average sound pressure over an area of a 30° angular radius on a sphere of radius a confronting a plane wave. The good agreement shows that for those devices at least which approximate the spherical profile, the proposed analog conforms with reality.

The governing radius a (or area A) is the radius of the principal obstacle confronting the sound wave. The microphone impedance is assumed to be distributed uniformly over the face confronting the wave. However, if the face of the obstacle is solid and the entrance to the transducer is through a relatively small hole of area A_1, a more complicated situation arises. One might consider the small hole to add an element of radiation mass M_{a1} and an element of radiation resistance R_{a1} to the transducer and the appropriate equivalent circuit would appear to be as shown in Fig. 2(e), where the impedance of the small hole is seen as being driven from the network identified with the larger obstacle; p_1, then, is the sound pressure at the entrance of the small hole. The network associated with the larger area A, in this case has a negligible impedance compared with that identified with the area A_1.

The analog circuit herein proposed should be used with prudence to avoid straining the equivalence beyond the point of validity. For example, diffraction associated with a flat-faced cylinder or cube[8] is only imprecisely represented. However, to the degree that it brings us one step closer to correct equivalent circuit representations, the new analog appears to deserve a place in the "bag of tricks" of the acoustician.

Acknowledgment: The author is grateful to his recent graduate summer students in Acoustics at Pennsylvania State University, whose incisive queries about the analog circuit of the Helmholtz Resonator made him dust off the solution proposed above.

[1] B. B. Bauer, "Notes on Radiation Impedance," J. Acoust. Soc. Am. **15**, 223–224 (1944).
[2] The difference may be reduced substantially without loss of simplicity by an empirical adjustment described in the Note of Fig. 1.
[3] F. V. Hunt, *Electroacoustics* (Harvard Univ. Press, Cambridge, Mass., 1954).
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[6] B. B. Bauer, "A Century of Microphones," Proc. IRE **50**, 719–729 (1962).
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[8] G. G. Muller, R. Black, and T. E. Davis, "The Diffraction Produced by Cylindrical and Cubical Obstacles and by Circular and Square Plates," J. Acoust. Soc. Am. **10**, 6–13 (1938).

Received 7 July 1967 **15.3**

Addendum:

Robust Two-Input Correlators
[J. Acoust. Soc. Am. **41**, 1212–1219 (1967)]

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The contribution by J. L. Gastwirth to the above paper was supported by a grant from the NSF awarded to the Department of Statistics of the Johns Hopkins University.

Received 22 August 1967 **4.6, 4.7, 4.11**

Erratum:

Mechanistic Aspects of Hearing
[J. Acoust. Soc. Am. **41**, 1500–1516 (1967)]

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The correct word in the first line of the last paragraph on page 1514 is "without." This changes the meaning of the paragraph substantially: It should read, "A person suffering from sensorineural loss with*out* recruitment has to contend with an essentially irremediable loss."

Received 22 August 1967 **4.7, 4.11, 4.15**

Erratum and Note:

PEST: Efficient Estimates on Probability Functions
[J. Acoust. Soc. Am. **41**, 782–787 (1967)]

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In the Appendix to the above paper (p. 787), the formula for the ideal sweat factor is incorrectly given. The correct expression is

$$K_{\min}=p(1-p)/V^2.$$

The superscript was omitted from the published paper. We wish to thank B. Lopes Cardozo for bringing this error to our attention.

A program has been written for the PDP-8 family of computers to run PEST in real-time experimental control applications. Copies of the program are available from the authors.

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