

Probe-tube microphone assembly

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A method of making in-the-ear probe-microphone measurements is described, using readily available equipment. The procedure is designed to make such measurements easier and safer than they have been in the past.

Subject Classification: 85.62; 65.80.

INTRODUCTION

Probe-tube microphone measurements of sound pressures in the human ear can provide data of great value, but such measurements are not used routinely because of the difficulty of the procedure and because of fear of injury to the subject. Elaborate devices have been employed to keep the probe motionless relative to the subject.

A relatively simple and inexpensive method of making in-the-ear probe measurements is described below. While the danger of this measurement procedure is substantially less than that of previous procedures, the ear canal must always be considered as vulnerable to injury, and the probe-tube installation must be made with care and by skilled personnel.

I. PROBE-MICROPHONE ASSEMBLY

The probe-microphone assembly consists of a hearing-aid microphone—in this case the Knowles XL-9073, the flat-response version of the microphone described by Killion and Carlson¹—and a formed piece of plastic tubing, as shown in Fig. 1. The probe tube is made of flexible polyethylene for safety reasons, but the bend that takes it into the ear canal must be rigid if the position of the probe tip is to remain stable. Medical tubing (Clay-Adams Intramedic PE-200, 0.075-in. o. d., 0.055-in. i. d.), which can be formed by moderate heat, was used.² A length of solder or soft wire inserted into the tubing allows the probe to be bent to the desired angle for the heat treatment, after which the jig can be removed without changing the shape of the formed piece. Boiling water or a light bulb will serve for the heat. The tubing fits over the 0.055-in. microphone inlet nozzle, and is cemented in place. The cut edge of the tubing should be smoothed with fine sandpaper.

Probe tubes of different lengths and shapes are suitable for different subjects and/or for measuring SPLs at different points in the ear canal. The design shown in Fig. 1 is convenient for most adult ears when measurements are to be made toward the far end of the canal.³ The individual subject's canal length should be checked (by otoscope, for example) before insertion of the probe.

A very small piece of absorbent cotton, inserted about halfway down the longer section of the probe tube, pro-

vides acoustical damping. Damping towards the microphone end of the tube has a greater effect on the first resonance peak, while damping at the open end has a greater effect on the second peak.

II. INSTALLATION OF THE PROBE MICROPHONE

Probe-microphone measurement procedures are likely to involve a comparison between successive in-the-ear measurements under different conditions. In the earphone-transfer procedure described by Corliss and Burkhard,⁴ the probe remains in position while the subject puts on different earphones. In the free-field calibration procedure described by Villchur,⁵ ear-canal sound pressures created by an earphone are compared with sound pressures created at the same point in the canal by a calibrated free-field source.⁶ It is vital to such procedures that the position of the probe tip stay the same for the different measurements. When the microphone is taped securely just above the tragus as shown in Fig. 2 (far enough back from the joint of the jaw so as not to disturb the proper seating of a circumaural earphone cushion), the probe-tip position is stable. The probe-tip position is not so stable with other microphone positions. If the microphone is taped to the concha, for example, the mechanical pressure of an earphone cushion tends to move the tip from its free-field

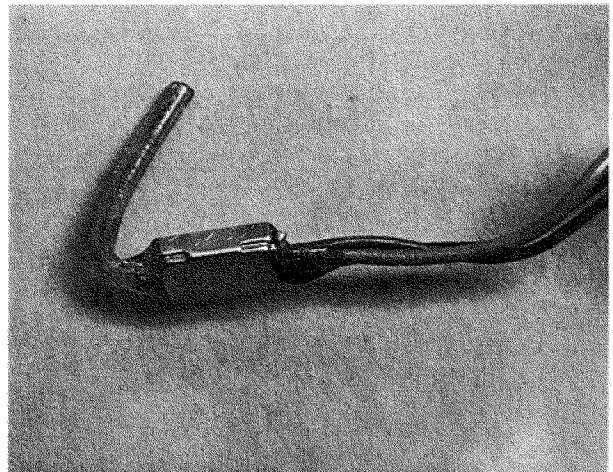


FIG. 1. Probe-microphone assembly. Overall length of the probe tube is *ca* 2 cm, with a 70° bend 0.4 cm from the microphone.

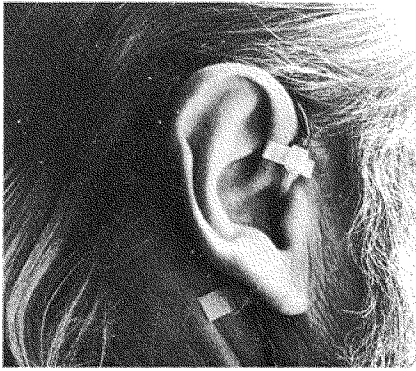


FIG. 2. Probe microphone in place, held by masking tape.

position, even when the cushion is the circumaural type. Probe-tube stability must be checked after the microphone is in place, which can be done by watching to see whether the tube moves when an open earphone cushion is pressed against the head.

Before installing the probe microphone, the subject's external ear should be cleaned with soap and water so that the tape will hold well, and the ear canal should be cleaned with a Q-tip and wax softener to prevent the probe from becoming clogged with wax. It goes without saying that even with flexible tubing, careful insertion into the ear canal is essential, particularly with short canals.

III. PROBE-MICROPHONE RESPONSE

Figure 3 shows the typical frequency response and sensitivity of the probe-tube microphone both with and without damping. This curve is compared with that of the Brüel & Kjaer $\frac{1}{4}$ -in. capacitor microphone, against which the probe microphone was calibrated. The exact frequency response and sensitivity of the probe microphone may be expected to vary by a few decibels from unit to unit, so that individual calibration is required.

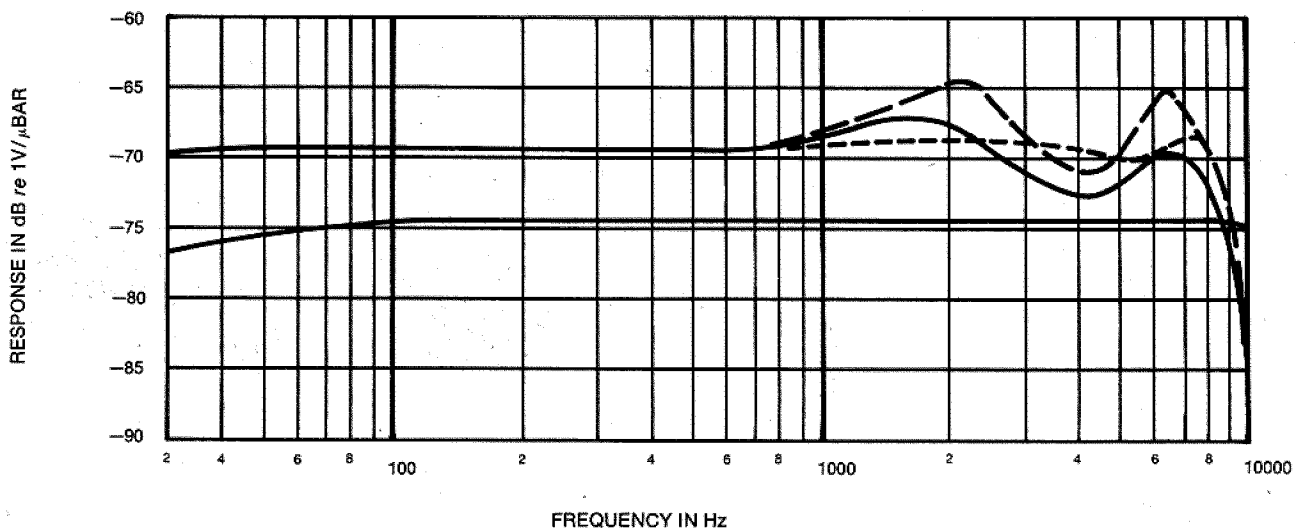


FIG. 3. Typical frequency response and sensitivity of Knowles XL-9073 microphone (output connected in source-follower mode): — with damped probe; - - - with undamped probe; - - - - without probe. Sensitivity of Brüel & Kjaer $\frac{1}{4}$ -in. microphone, used as the calibrating standard, is shown in the lower solid-line curve.

The *C*-weighted noise of the XL-9073 microphone is approximately $7 \mu\text{V}$. For the damped probe-microphone assembly this is equivalent to an SPL at 1 kHz of 40 dB *re* $0.0002 \mu\text{bar}$. The *A*-weighted noise is 10 dB lower. The signal-to-noise ratio does not drop as much at high frequencies as it would if the probe tube had to be long enough to allow the body of the microphone to clear an earphone cushion. A long, small-diameter tube introduces substantial high-frequency signal attenuation without affecting the electrical noise.

The upper end of the undistorted dynamic range of the microphone is at least 130 dB SPL with a $\pm 1.5\text{-V}$ powder supply, and at least 150 dB SPL with a $\pm 5\text{-V}$ supply.

IV. ELECTRICAL CIRCUIT

Electrical power is needed for the internal FET pre-amplifier in the XL-9073, and is supplied by two AA cells housed in a commercial battery holder, such as the Keystone 140. The leads from the microphone to the power supply are 0.5 m long, allowing the battery holder to be pinned to the subject's clothing. The subject himself should be at ground potential, a condition that prevents spurious oscillations. An alligator-clip lead is used to connect the ground side of the battery holder to a gold ring worn by the subject.

V. DISCUSSION

Earphone-coupler measurements have sometimes been substituted for real-ear measurements in evaluating earphones. The coupler is a valuable tool for checking the calibration of known earphone drivers, but if a coupler is used to evaluate unknown earphones it is likely to provide invalid and misleading measurements: The coupler does not adequately take into account the effect of the transfer of the signal from earphone to ear, and of the intersubject and cushion-fit variation in that transfer. In order to know the sound stimuli actually delivered to a subject by an earphone, it is necessary to obtain either subject responses or objective probe-mi-

crophone measurements. The probe assembly described here is designed to make such measurements easier and safer than they have been in the past.

ACKNOWLEDGMENTS

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¹M. C. Killion and E. V. Carlson, "A Wideband Miniature Microphone," *J. Aud. Eng. Soc.* 18, 631-635 (1970). The XL-9073 microphone is available from Knowles Electronics, 3100 Mannheim Rd., Franklin Park, Illinois 60131.

²Vinyl tubing (such as Markel Flexite E, which is formed in the same way as the polyethylene) may also be used. Size 16 has

essentially the same i.d. as PE-200 medical tubing but an o.d. greater by 0.010 in. Size 18 has the same o.d. as the medical tubing but a smaller i.d. (0.042 in.), the latter increasing the peak-to-trough ratio of the probe response. For the 2-cm damped-probe assembly the ratio is increased to about 8 dB. A smaller-diameter probe may be made from Inframedic PE-160 tubing (0.045-in. i.d., 0.062-in. o.d.), at the price of accepting the larger peak-to-trough ratio.

³A deep probe measurement is preferable when measuring the response of a supraaural earphone, since the normal transmission characteristics of the ear canal may be changed by the mechanical pressure of a supraaural cushion (see Ref. 5).

⁴E. L. R. Corliss and M. D. Burkhard, "A Probe Tube Method for the Transfer of Threshold Standards between Audiometer Earphones," *J. Acoust. Soc. Am.* 25, 990-993 (1953).

⁵E. Villchur, "Free-Field Calibration of Earphones," *J. Acoust. Soc. Am.* 46, 1527-1534 (1969).

⁶A simple probe-microphone measurement of pressures in the cushion-enclosed cavity yields data of uncertain meaning, except in the region below 1 kHz. At higher frequencies, the pressure at a given frequency may vary as much as 20 dB over different locations within the cavity (see Ref. 5).