The continuity of the membrane is tested by connecting one of the input terminals of the current amplifier to the cathode of the electrode and the other to a separate Ag/AgCl electrode, both electrodes being dipped into 0.1 *M* KCl.

The electrode current changes throughout its useful life-time as shown in Figure 3. Calibrated measurements without the need of frequent recalibration are possible in phase II. Therefore the electrodes are stabilized prior to use in air-saturated water until this phase is reached. Phase II is normally long enough for one day of experimentation. When the electrode has reached phase III, the tip cover can be removed with acetone and the electrode can be recycled, starting with grinding the tip.

[10] The author is indebted to Dr. C. M. BALLINTIJN for valuable advice during the development of the electrode, to Dr. C. J. DEN OTTER and Mr. W. J. BEUKEMA for comments on the manuscript, and to Mr. G. THOMAS for suggestions regarding the English text.

Wireless Microphone for Studies of Animal Vocalizations

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Summary. A microphone collar for obtaining good quality recordings of animal vocalizations is described. An inexpensive, commercially available wireless microphone was modified and mounted on a collar with a hearing-aidbattery pack. The complete assembly weighs 25 g, and is readily accepted by domestic cats.

In studying the vocalizations of animals, it is often difficult to record the sounds of low intensity. The conventional solution for this problem is to use highly directional microphones (e.g., parabolic reflectors). The disadvantages are that the axis of the microphone must be aimed rather carefully at the particular animal, and that the unwieldy dimensions of the reflector, which become inevitable at lower frequencies, result in certain practical limitations. Further, unsurmountable difficulties appear if faint vocalizations of two individuals in close proximity are to be distinguished, or if the animal which is to be recorded has a noise source situated behind it. Due to these technical difficulties, a serious bias in favor of loud signals is introduced into studies of animal vocalization and communication by means of sound.

One of us (W.M.S.) has experimented several years ago with radio transmitters to record the soft contact calls of turkeys during movement of the flock, but at that time it proved too expensive to come up with a system of sufficient range, frequency response, and reliability. Recently we found a commercially available wireless microphone[1] operating in the FM range (tuneable between 88 and 92 MHz) which can be modified easily to fit a cat's collar, and which allowed us to make high quality recordings of a variety of vocalizations.

Because the microphone in its original form was too bulky, we discarded the housing and arranged the components on a 25 mm wide strip of soft chamois leather fitted with a button fastener (Figure 1). The electret condenser microphone (a cylinder of 11 mm length, 9 mm diameter, and 1.8 g weight) was attached in the middle of the collar, and to either side was attached the circuit board (18 mm × 58 mm, with the components 15 mm thick) and the battery pack respectively. In an earlier version we used the standard nine-volt transistor battery (15 mm × 25 mm × 50 mm, 33.5 g), but now have substituted eight 1.35 V mercury hearing aid batteries (Mallory Duracell RM312) spot-welded in series. Weight

[1] 'Realistic' brand 'Apollo FM-91 Wireless Microphone', marketed by Radio Shack, A Tandy Corporation Company, catalog number 33-1048A selling currently (August 1975) for $ 19.95.

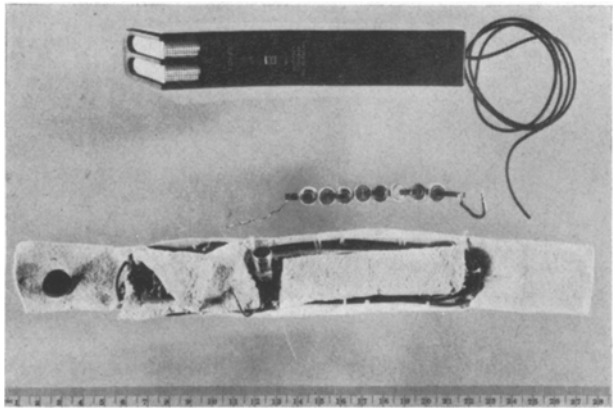

Fig. 1. Wireless microphone in its original, commercially available form (above), and stripped version mounted on collar (below); the collar is displayed with the battery pack pulled out and the circuit board exposed at one corner.

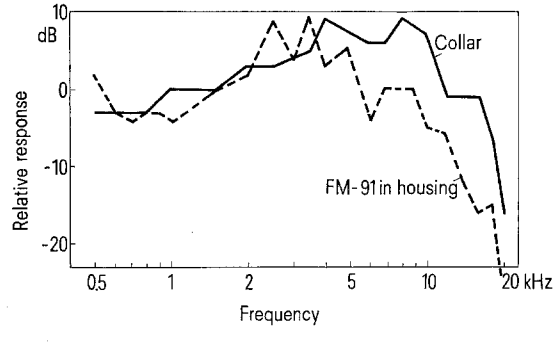

Fig. 2. Combined frequency response of the wireless microphone, receiver (Blaupunkt Frankfurt-Stereo US, Model #7630629), and tape recorder (Uher 4000 Report L). At 1.0 kHz, +64 dB re 2×10^{-3} N/m² gave full saturation on tape recorder (0 dB on meter).

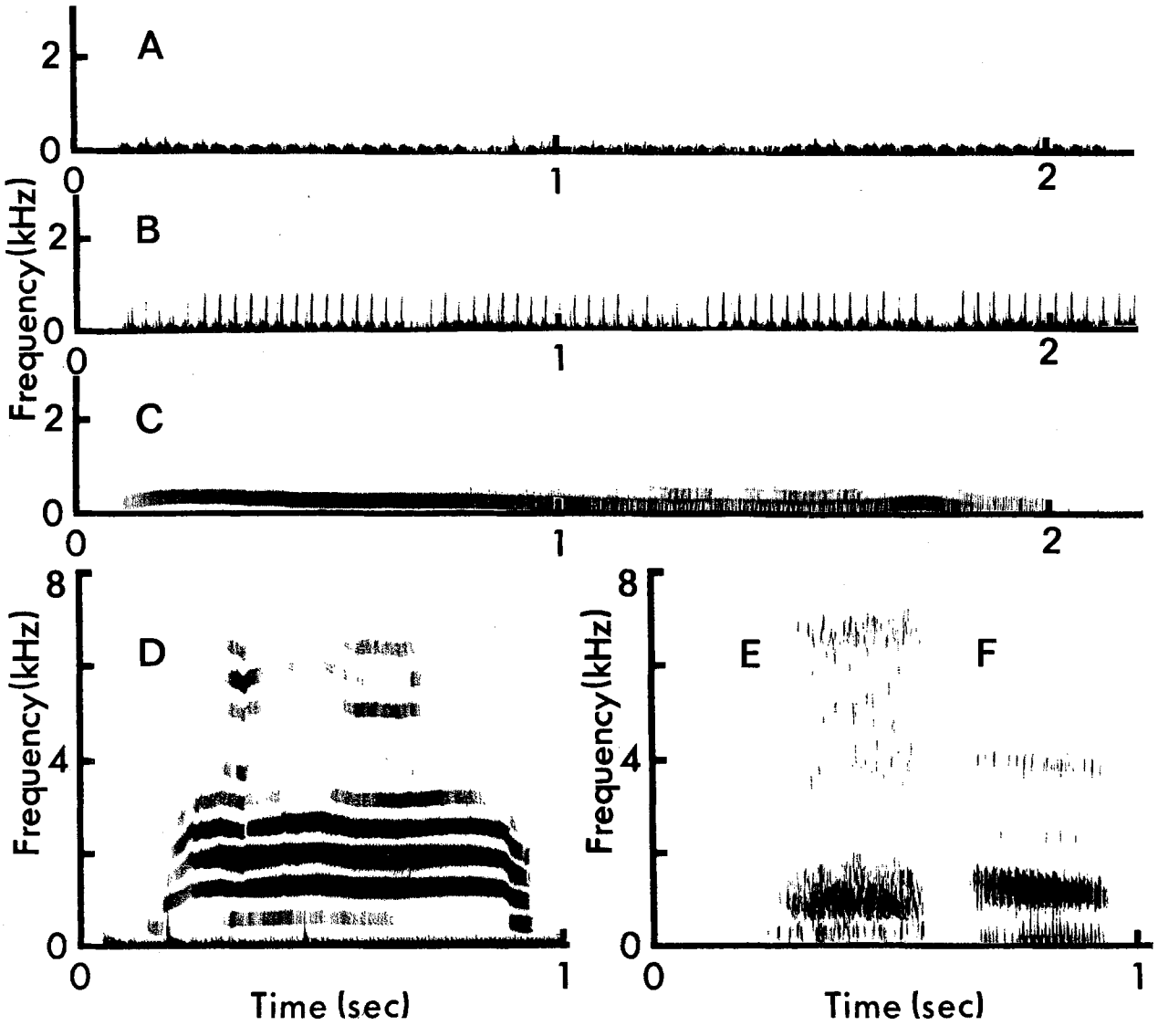

Fig. 3. Sound spectrograms of cat vocalizations, recorded with the microphone collar. A) Purring by adult male cat. B) Purring by four-month-old male kitten. C) Growl by adult female. D) Wail-type vocalization by adult female. E) and F) Hiss followed by snort by adult female.

of this battery assembly is 6.3 g[2]. The circuit board is enclosed in a chamois pouch to protect the components from dirt, moisture, and the animal's scratching. The antenna wire is looped and sewn around the periphery of the collar. The complete collar weighs 24.8 g and is accepted without difficulty by all 14 of our cats.

The range of transmission varies greatly with the type of receiving antenna and the sensitivity of the receiver. Indoors (wooden frame house and steel framed brick building) we had excellent reception up to 10 m, and outdoors in an unobstructed environment, up to 65 m. The frequency response of our system is shown in Figure 2.

Figure 3 shows some examples of sound spectrograms (Kay Elemetrics Corp. Sona-Graph Model 6061B) obtained with the microphone collar. These vocalizations were selected to demonstrate the frequency range and signal/noise ratio of the system. A and B illustrate the frequency differences in the purring[3] of an adult cat and a kitten. Both examples were elicited by stroking and were recorded indoors. C shows the modulation pattern of the growl[3] contrasts with a purr, although both have about the same low frequency range. The cat was about seven meters up a tree growling at another cat when this was recorded. D is an example of a wail-type vocalization[3] with many harmonics; it was given by the animal as she was walking through a wooded area. This particular vocalization was sonagraphed with the automatic gain control set at 0.3 to emphasize the higher harmonics picked up by the system. E and F also show harmonic complexity. The microphone collar clearly transmits the low fundamental of the snort and the upper harmonics of the hiss extending to about 7 kHz. These two vocalizations were given in rapid succession as the cat was being threatened by another cat.

[2] The authors are grateful to E. V. Patrick for designing the battery assembly.

[3] M. Moelk, Am. J. Psychol. *57*, 184 (1944).