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A MINIATURE 30-MHz COLLAR TRANSMITTER FOR SMALL ANIMALS[1]

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Abstract: The construction of a miniaturized pulsing transmitter, modified from an earlier design, is described. The transmitter with its antenna collar has a volume of 0.7 cc, weighs 1.5 grams, and costs about $25.50, including labor. An instrument package for rats containing transmitter, collar, 350-milliampere-hour (mah) battery, and waterproof covering weighs 6.5 grams, has a volume of 1.4 cc, and normally transmits signals for 800 to 1,700 feet over rolling grasslands for 18 to 30 days. The package appears to cause no gross behavioral changes in instrumented rodents as small as 60 grams body weight.

Bibliographies compiled by Barwick and Fullagar (1967) and by Schladweiler and Ball (1965) cover many of the diverse uses of telemetry equipment by biologists. None of the papers cited, however, describe inexpensive, expendable transmitters that are small and light enough to use on small rodents. To collect information on the life

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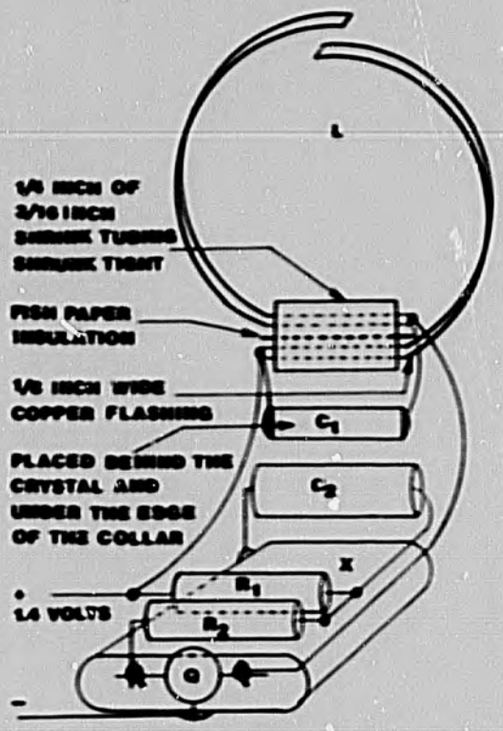

Fig. 1. Miniature collar transmitter. 1.4-volt battery. R_1 – ⅛-watt carbon resistor, 82,000 to 160,000 ohms. R_2 – ⅛-watt carbon resistor, 1,000 ohms. C_1 – NPO chip capacitor, 330 to 560 pf (case size 1505, Electro Materials Corp., Sorrento Valley Road, San Diego, California 92121). C_2 – Miniature tantalum capacitor, 10 to 22 µf (1420 series, Sprague Electronic Co., Carlisle, Pennsylvania 17013). X – Miniature crystal in HC-24 holder (Erie Technological Products, The Hunt Corp., Hill Electronics, Inc., 453 Lincoln Street, Carlisle, Pennsylvania 17013). L – Copper flashing, 0.022 × ⅛ inch. Q – Miniature transistor (MMT 2369, Motorola, Inc.).

history of small rodents and to evaluate control programs, biologists of the Denver Wildlife Research Center needed a pulsing transmitter that was crystal-controlled on our assigned 30-Megahertz (MHz) frequencies, not greatly affected by temperature, easy to attach to animals in the field, and suitable for inexpensive mass production from readily available components by persons familiar with miniature construction techniques. The widely used, reliable transmitter design decribed by Cochran and Hagen (1963), Tester et al. (1964), and Dodge and Church (1965), when built with the smallest commercially available components, still yielded a bulky transmitter package that had a volume of 2.3 cc and weighed over 8 grams (including 350-mah battery). In tests with this package by field station personnel of this Center, 2 of 140 instrumented Polynesian rats (*Rattus exulans*) became stuck in their burrows (G. A. Hood, personal communication), and the digging ability of instrumented pocket gophers (*Thomomys talpoides*) in a laboratory cage was reduced about 50 percent (W. E. Dodge, personal communication). We therefore miniaturized the design to produce a considerably more compact transmitter. It weighs 1.5 grams, has a volume of 0.7 cc (6.5 grams and 1.4 cc with 350-mah battery), and costs about $25.50, including labor, when built in quantity.

We thank V. G. Barnes, W. E. Dodge, G. A. Hood, P. E. Martin, and R. D. Nass of field stations of the Denver Wildlife Research Center for helping to determine transmitter requirements and patiently field-testing some of the prototypes. We also thank Ann H. Jones, editor, and A. L. Kolz, electronic engineer, both of this Center, for editorial assistance.

TRANSMITTER DESIGN

Construction of the transmitter is illustrated in Fig. 1. As in most previous designs, the collar is of soft copper flashing, which also serves as the antenna. To save space and weight, no circuit board is used; all components are soldered to each other, starting with the crystal.

Crystal

In early transmitters, by far the largest component was the 1-gram crystal in the HC-18/U holder. A miniature crystal was

available but reportedly was in a glass case and cost about $60.00. We therefore contacted several commercial firms and eventually accepted a crystal made to our specifications by Erie Technological Products (reference to trade names or manufacturers does not imply endorsement of commercial products by the federal government). This fundamental crystal is available on 20 to 30 MHz frequencies in the miniature HK-24 holder, weighs 0.32 gram, has about one-fifth the volume of its predecessor, and costs $11.00 in lots of 50 or more. In addition, transmitters built with this crystal have about a 30 percent lower voltage requirement, a 20 percent lower battery drain, and a 50 percent higher power output than transmitters with the larger crystal. The current drain is less variable between newly built miniature transmitters than transmitters constructed with our large crystals; this allows a more accurate prediction of transmitter life.

One disadvantage of the new crystal is that it is more easily pulled off frequency than a third-overtone crystal; therefore, extra care must be taken in adjusting the antenna collar to find the size where the signal is strongest and the current drain the least. We have found it helpful to briefly test each transmitter and mark the amount of collar overlap for the best electronic fit before sending the transmitter to the field. Transmitters of several collar sizes are stocked at the Hilo, Hawaii, field station so that they can be tried on, and then the collar ends overlapped and soldered together on the neck of the animals for the best electronic fit.

Other Components

Of several transistors tested, we found that the MMT 2369 (miniaturized version of the 2N2369) performed the best in our circuitry. We measure each order of MMT 2369's and discard all those with a current gain (beta) of less than 60.

Standard, ⅛-watt, miniature resistors (five percent tolerance) are used (smaller ones are available at one-sixth the size but about 1? times the price). The filter capacitor is varied, along with the charging resistor (R_1), according to the rate and width of pulse desired. To obtain three different pulse rates on the same frequency, we generally use capacitors of 10, 15, and 22 microfarads (mfd). Chip capacitors (10 percent tolerance), bought in lots of 100 and separated into groups by 20-picofarad (pf) increments, are used to tune the antenna circuit.

Battery

Several small 1.4-volt batteries are suitable; the final selection depends on the size of the animal and the desired life of the transmitter. As a rule of thumb, we try to keep the weight of the transmitter package less than five percent of the animal's weight. For small rodents, field station personnel normally use the 4.5-gram, 350-mah, No. 625T2 mercury battery, which will normally power the transmitter for 15 to 30 days. The *T2* suffix in the battery number indicates that the battery has soldering tabs. We believe that it is worth the effort to obtain small batteries with soldering tabs, because even experienced workers occasionally overheat a battery when soldering directly to the case. The No. 625T2 is usually available locally in the 250-mah size; a 350-mah size can be ordered from the factory. In our experience, locally obtained batteries are likely to have exceeded their shelf life, and factory-ordered batteries are most reliable, particularly if they are immediately refrigerated or placed in a freezer to increase their storage life. Limited tests also indicate that a much smaller battery, the No. 312 (0.7 gram, 1.4 volts, 40 mah), will power the transmitter for 5 to 7 days;

with this battery, the entire transmitter package weighs only 2.5 grams.

Potting

Of nine materials tested as waterproof and shockproof coverings for transmitter units, we have found Plas-T-Pair (local dealer, or Rawn Co., Spooner, Wisconsin) to be the most satisfactory. This fast-drying material is intended for dental work and repair of plastics and can be mixed rather carelessly and used at any desired consistency. We apply a thin coat for support during construction and as a first coat, then we add two or three thicker coats. Battery changes or other modifications can be made in finished units by cutting the material with a small soldering iron or dissolving it with acetone.

Construction Notes

Fig. 1 is an exploded view to describe the point-to-point soldering method of construction, and it includes a parts list and addresses for locating uncommon or newly developed components. The two pieces of the collar antenna, with 30 AWG end wires attached, are first insulated from each other with fish paper inside the shrink tubing, then attached at the top of the crystal with Plas-T-Pair (the antenna slightly overhangs the end of the crystal). Transistor terminals are soldered to the leads and to the case of the crystal, as illustrated. The other leads are then bent and soldered to each other and to the crystal case (negative or electrical ground). Finally, the chip capacitor (C_1), which fits under the overhanging antenna, is soldered to the antenna's wire leads.

Pulse Width and Rate

Although a narrow pulse lengthens transmitter life, we have found that a pulse shorter than about 25 milliseconds (ms) is not easily heard under the usual noisy receiving conditions. Allowing a 5-ms safety margin, we generally aim at a pulse width of 30 ms.

The pulse rate is also important in locating signals. For only one transmitter per channel, the best pulse rate for audibility and conservation of power seems to be about 80 to 100 pulses per minute. For short-range reception, a much slower rate could be used to extend battery life. For monitoring a large number of transmitters at once, multiple signals can be used. We have found that three signals per frequency, at about 60, 120, and 240 pulses per minute, can usually be distinguished reliably over a wide range of temperatures when collars are attached at the best electronic fit.

FIELD RESULTS

The reception range of this transmitter varied greatly, depending on receiving equipment, topography, vegetative conditions, diameter of the collar, pulse width of signal, obstructions, location of the animal, and similar factors. An expected range of 300 to 1,700 feet was generally realistic for animals above ground.

Limited tests with Polynesian rats in the laboratory and with wild thirteen-lined ground squirrels (*Citellus tridecemlineatus*) and Abert's squirrels (*Sciurus aberti*) indicated that the transmitter package should not seriously interfere with behavior, at least for the normal life of the transmitter. The hair of the instrumented animals became worn, and one rat developed a callus on the neck between 2 and 6 weeks, but no abrasions were evident. The two Abert's squirrels, both females, successfully reared litters while wearing their loose-fitting, 11-gram transmitter packages (each with a collar 1.4 inches in diameter, 7.5-gram, 500-mah battery, and heavy potting). In field studies with Polynesian rats in Hawaii,

rice-field rats (*Rattus rattus mindanensis*) in the Philippines, pocket gophers in Washington and Oregon, and red squirrels (*Tamiasciurus hudsonicus*) in Montana, field station personnel of this Center have reported no obvious behavioral changes in instrumented animals. Not counting experimental models, 278 of these minature collar transmitters have been requested and supplied to our field stations.

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