isoproterenol surmounted the blocking effect of propranolol on myocardial contractile force. Dose-response curves of isoproterenol after graded doses of propranolol indicate the existence of competitive antagonism between isoproterenol and propranolol. In addition, after administration of propranolol, the effect of isoproterenol on systemic arterial pressure was found to become biphasic, an initial increase being followed by a decrease. Hence, it is postulated that isoprotenerol possesses a vasoconstrictor (alpha-receptor stimulator) property which is usually hidden by a more marked vasodilator (beta-receptor stimulator) property of the drug.

The authors are indebted for generous supplies of propranolol (Inderal) and sodium heparin (Liquaemin and Panheparin), respectively, from Ayerst Laboratories, Organon Inc., and Abbott Laboratories, and also for the technical assistance of Mr. G. R. Mercer.

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A Transmitter for Telemetering Electrophysiological Data. (30178)

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In the study of normal animals and of animal toxicoses and disease processes it is often desirable to obtain information concerning the state of a body system over an extended period. Radio telemetry offers the advantage of being able to transmit electrophysiological data from an animal without the encumbrance of attached wires. Devices have been proposed, but are designed for a specific usage or are limited in frequency response and signal to noise ratio(2,3,4).

The objective of this study was to design a radio frequency transmitter that could be attached to an animal without interfering with the animal's behavior in its normal environment and also versatile enough to be used on an animal as small as a pigeon or as large as a cow. In the authors' opinion, a simplified practical device for use in physiological measurements was needed. The design objective was faithful transmission of electroencephalograms, electrocardiograms, and respiratory rates. Special emphasis was placed on size, weight, frequency response, input impedance, signal to noise ratio, stability and battery life. This paper reports the design of an instrument which meets most of the above objectives.

Description. The circuitry of the transmitter is shown (Fig. 1). It consists of a preamplifier and a high frequency oscillator. The preamplifier, consisting of transistors Q1 and Q2, offers a high input impedance of 500,000 ohms and a low output impedance with a voltage gain of approximately four. The oscillator section contains transistor Q3,

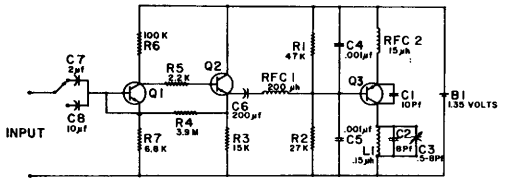

FIG. 1. Schematic diagram of transmitter.

Resistors

R1 47K 1/10 watt
R2 27K 1/10 watt
R3 15K 1/10 watt
R4 3.9 meg. 1/10 watt
R5 2.2K 1/10 watt
R6 100K 1/10 watt
R7 6.8K 1/10 watt

Radio frequency chokes

RFC1 200 μh ferrite
RFC2 15 μh miniature molded

Radio frequency coil

L1 .15 μh 7 turns No. 16 wire ¼ inch diameter ID ½ inch length

Capacitors

C1 10 pf silvered mica
C2 8 pf silvered mica
C3 .5-8 pf miniature piston trim type
C4 .001 μf miniature disc
C5 .001 μf miniature disc
C6 200 μf 6V subminiature electrolytic
C7 2 μf 6V subminiature electrolytic
C8 10 μf 6V subminiature electrolytic

Transistors

Q1 Texas Instrument No. 2N929
Q2 Texas Instrument No. 2N929
Q3 Motorola No. 2N741

Battery

B1 Burgess Hg-1R

coil L1, and capacitors C2 and C3, the values of which determine the resonant frequency. The complete transmitter is powered by a single 1.35 volt mercury battery.

The information signal from the biological system is applied to the input terminal which is coupled to the base of Q1 through either C7 or C8. This results in an amplification of the input signal voltage, and appears at the collector of Q1. The signal is then fed through resistor R5 to the base of Q2 which causes a current change in R3 and affords a low impedance output across this resistor. The voltage at this point is 180° out of phase with the input signal voltage and is fed back to the base of Q1 through R4 to establish the bias potential. The amount of feedback employed not only provides a high input impedance but also stability. The signal at the emitter of Q2 is fed through C6 and choke coil RFC2 to the base of Q3. This transistor varies its junction capacitance in relation to the signal voltage. This variation in capacitance causes the frequency of the oscillator to deviate in accordance with the applied voltage. RFC1 is used to keep the radio frequency from entering the amplifier but allows the information signal to pass to the base of Q3. R1 and R2 form a bias network to establish a quiescent point for operation of Q3. C4 and C5 by-pass high frequencies of the oscillator. RFC2 in the emitter circuit of Q3 forms a direct path for battery current while also exhibiting a high impedance at high radio frequencies. This accommodates the signal voltage from L1, C2 and C3, through C1, and sustains oscillation. Capacitor C7 is offered to allow low frequency cut off when respiration signals are not desired and capacitor C8 is offered to permit measurement of respiration rate when desired.

The chassis for mounting components consists of a bakelite board approximately 2 mm thick with 2 mm diameter holes spread 4 mm apart. The chassis measures 4.5 by 7 cm and is placed in a hinged plastic case measuring 5 by 7 by 2.2 cm. A 6 by 1.5 mm metal stud attached to the center of the chassis permits rigid mounting on the opposite side of the chassis to accommodate a battery spring connection. Subminiature solder terminals are used to attach the components firmly to the chassis board.

Animal preparation. Two silver electrocardiograph (ECG) electrodes (11/32 inch diameter disks) with binding posts soldered to the center, were placed subcutaneously in bantam roosters on each side of the rib cage opposite the heart. The transmitters were carried by the birds in a cloth harness attached by a loop around the base of each wing.

Silver wire electroencephalographic (EEG) electrodes were inserted at the dorsal midpoint of each cerebral hemisphere of sheep through 5 mm by 13 mm nylon screws that had been implanted in the calvarium, so that the beaded end of the electrodes contacted the dura mater(1). The two electrodes were connected to the transmitter which was strapped over the dorsal surface of the sheep's head midway between the ears. EEG electrodes were placed in pigeons and Leghorn roosters by drilling 2 holes 1 mm diameter, 5 mm apart through the calvarium over each cerebral hemisphere. A 24-gauge silver wire was passed through one hole in the calvarium and out the other hole and the 2 ends

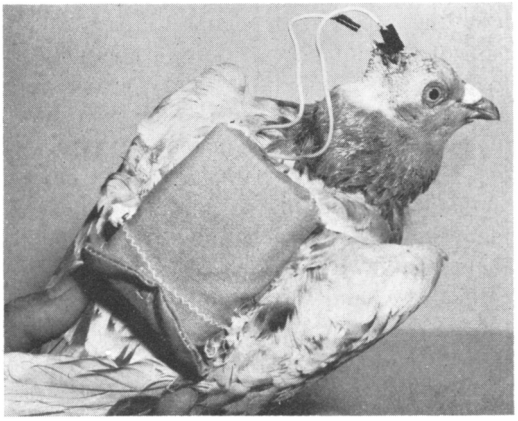

FIG. 2. Homing pigeon wearing a cloth harness containing radio transmitter which is connected to EEG electrodes.

were wrapped together. A small bead previously formed on the tip of the wire by heating it in a hot flame, prevented damage to the dura mater upon passage of the wire through the holes. This method provided approximately 5 mm of contact between the electrode and the dura mater. The holes were sealed, and the electrodes were insulated with dental acrylic resin* (Fig. 2).

To test the transmitter under actual experimental conditions, ECG recordings were made from bantam roosters and from a Holstein cow. Skin surface chest electrodes were used for recording from the cow. EEG recordings were made from sheep, Leghorn roosters and homing pigeons.

Results. The total weight of the completed transmitter including plastic case and battery was 65 g.

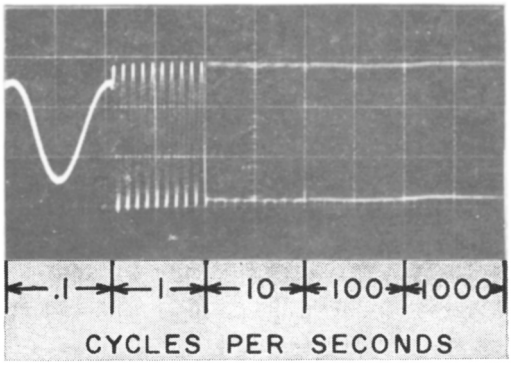

FIG. 3. Frequency response of transmitter showing flat response at 1 cps through 1,000 cps. Sweep speed of oscilloscope was 5 sec per cm.

The frequency response was within 0.5 decibel from 1 cycle per second (CPS) through 1000 with a useful frequency response of 0.1 CPS to 10,000 CPS (Fig. 3). These data were obtained by means of coupling the transmitter to a sine wave generator.† The information was portrayed on an oscilloscope‡ connected to the output of the receiver discriminator§ and was measured across a 10,000 ohm resistor. At 0.1 CPS there was only 25 to 30% reduction in amplitude. The instrument offered an input impedance of 500,000 ohms.

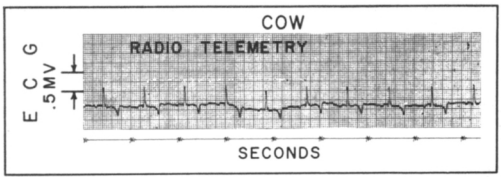

FIG. 4. Representative tracing of an ECG recording from a Holstein cow by radio telemetry.

Stable reception was obtained at a transmitting distance of 100 feet when a standard 300 ohm folded dipole receiving antenna was used. The current necessary to power the transmitter was approximately 3 milliamperes. This provided a battery life of approximately 330 hours when a Burgess Hg-1R battery was used. The transmitter frequency was adjusted for 94.0 megacycles. Recordings were made using a polychannel direct writing instrument.‖

A representative ECG recording from a cow is shown (Fig. 4). To examine the ability to transmit respiratory rate information simultaneously with the ECG, capacitor C8 was used at the input of the transmitter and the unit was attached to a bantam rooster. At a heart rate of 256 per minute and res-

* Acrylic 230 Polymer and Autopolymerizable Monomer, Borden Chemical Co., Philadelphia, Pa.

† Hewlett Packard Model 202A Function Generator, Hewlett Packard, Palo Alto, Calif.

‡ Fisher Model 100 F-M tuner, Allied Radio Corp., Chicago, Ill.

§ Tektronix Model 534, Tektronix Corp., Beaverton, Ore.

‖ Sanborn Model 350 Direct Writing Recorder; for EEG a 350-1500 low-level preamplifier and 350-3 EEG/ECG plug-in; for ECG a 350-3200 ECG preamplifier was used; Sanborn Co., Waltham, Mass.

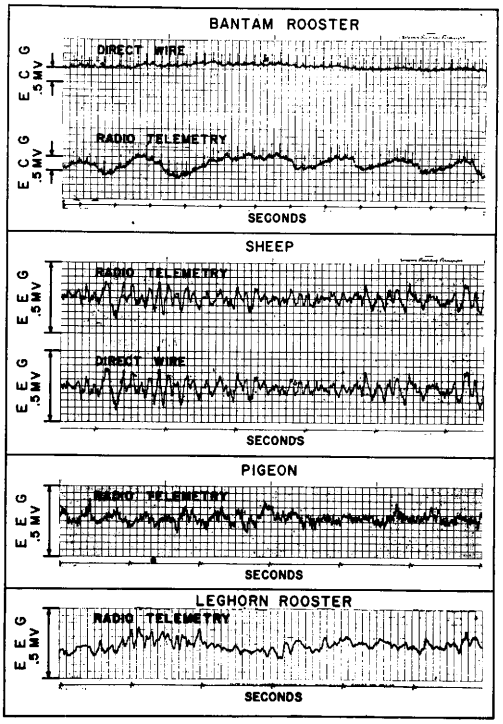

FIG. 5. Representative tracings of simultaneous recordings of ECG by direct wire and radio telemetry (bantam rooster); simultaneous recordings of EEG by radio telemetry (pigeon and Leghorn rooster). Note inclusion of respiratory rate with ECG recording by radio telemetry in bantam rooster.

piratory rate of 30 per minute, recordings obtained by radio telemetry faithfully reproduced the ECG recorded by direct wire and also accurately recorded the respiratory rate (Fig. 5, bantam rooster).

EEG recordings made simultaneously from a sheep by direct wire and radio telemetry were comparable (Fig. 5, sheep). EEG recordings from a homing pigeon and a Leghorn rooster are shown (Fig. 5). The birds tolerated the transmitter on their backs, after a training period of 2 weeks.

Discussion. Because the transmitter described herein encompasses a wide range of frequency response, from less than 1 CPS to 10,000 CPS, it may be used for measuring many types of physiological phenomena. The limiting factor for making high frequency response recordings would be the frequency response of the recorder rather than that of the transmitter.

The transmitter is small and suitable to be carried by birds such as pigeons and chickens, yet can easily be attached to large animals such as sheep or cattle. Its range of at least 100 feet makes possible recording from experimental animals or birds while in their natural environment.

There are many opportunities for use of radio telemetry for obtaining normal physiological data and in studying the effects of diseases and pharmacological agents on livestock and poultry. The elimination of cables and wires, which necessitates strict, unnatural confinement of the subject, gives many advantages over conventional direct wire recording systems.

The design of this transmitter has substantially met many of the objectives such as small size, light weight, excellent frequency response, high input impedance (500,000 ohms as compared to 10,000 to 200,000 ohms(2,3,4)), improved signal to noise ratio (by virtue of reduced voltage applied to the emitter collector junction—.6 volt as compared to 1.5 to 3.0 volts(2,3,4)), and long battery life (330 hours as compared to 5 to 48 hours(2,3,4)). There is need for further improvements in radio telemetry systems. Further reduction in physical size and prolonged battery life is important. Better carrier frequency stability is needed. More versatile and adaptable transducers are required and the systems should have the capability for simultaneous transmission of many physiological events from a subject.

Summary. A transmitter for radio telemetering a wide range of physiological phenomena has been described. It consists of a small (65 gram over-all weight) three-transistor device with a minimum number of components, having a usable frequency spectrum from 0.1 to 10,000 cycles per second. It offers an input impedance of 500,000 ohms. The system is versatile because a low frequency response can be added or eliminated depending upon the recording needs. It uses a single cell battery which has a life of approximately 330 hours.

The transmitter has been used to telemeter and to allow recording of electroencephalograms, electrocardiograms, and respiratory

rates from cattle, sheep, chickens and pigeons. Tracings made simultaneously by a direct wire system and radio telemetry were comparable in quality.

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Myocardial Contractile Protein: Dependence of Viscosimetric Properties on Organ Size.* (30179)

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Solutions of the contractile protein actomyosin characteristically undergo a marked reduction of viscosity upon the addition of ATP. It is generally believed that this response is the result of dissociation of the actomyosin into its components, actin and myosin(1). The magnitude of this change may be conveniently expressed as the "ATP sensitivity"(2) calculated in the following manner:

$$\text{ATP sensitivity} = \left(\frac{Z\eta - Z\eta_{ATP}}{Z\eta_{ATP}} \right) \times 100$$

where $Z\eta$ the viscosity number $= \dfrac{2.3 \log \eta \text{ rel}}{\text{C (protein conc) in g per l}}$

and η rel = the ratio of the outflow time of the protein solution to that of the solvent.

The subscript ATP refers to values obtained after addition of the nucleotide.

Determination of ATP sensitivity has been widely used in identification and characterization of contractile proteins. In the case of the heart it has been used to characterize myocardial contractile proteins extracted following a variety of experimental procedures concerned with the growth and function of that organ(3,4,5,6). In the course of such experiments conducted in this laboratory during the past several years, it became apparent that a significant relationship exists between ATP sensitivity and ventricular size(5) or age(6). This report is concerned with this relationship.

The experimental animals were male or female albino rats of the Sprague-Dawley strain. Actomyosin (Myosin B) was extracted by a modification of the method of Benson *et al*(7). Homogenized ventricular muscle was extracted in Weber's solution for 24 hours at 4°C in the presence of excess ATP. The soluble fraction containing the contractile proteins was separated by centrifugation at 12,000 *g* for 20 minutes. Actomyosin was precipitated by dilution to a molarity of 0.1 at pH 6.8 and separated by centrifugation at 10,000 *g* for 20 minutes. The pellet was then redissolved in 0.6 M KCl and the solution centrifuged again. All operations were carried out at 0-4°C. Nitrogen content of the supernatant was determined by micro-Kjeldahl technique and viscosimetric properties were studied using Ostwald viscosimeters at a temperature of 24°C and a pH of 7.0. The concentration of the protein solution was about 1.0 mg per ml. Care was taken to insure a constant concentration of ventricular myocardium in the extraction procedures and all determinations were based on aliquot samples. Pooling of hearts was carried out when necessary to achieve these requirements. Values for actomyosin content of rat ventricle obtained by this method are lower than those reported for the dog(3,4) or the rabbit(8). It is not clear whether

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