plane of polarization to which the equipment was sensitive could be varied by rotating the linearly polarized feed horn at the focus of the 50-foot reflector by means of a coaxial rotating joint. The beam-width of the reflector was 10.8 ± 0.5 minutes of arc between half-power points from drift scans of Virgo A.

The observations consisted of drift scans of the region taken at declination increments of 3 minutes of arc at a fixed position of the feed horn and of linear-polarization measurements made by continuously rotating the feed horn while tracking the position of highest intensity (*7a*).

The contour diagram of the region constructed from the drift scans is given in Fig. 1. Absolute position measurements were not made. The map was located by taking the position of the west source as $18^h50^m48^s$ right ascension, + 1°10′ declination epoch (1950.0), obtained from the observations of Scheuer (*6*), Gol'nev, Lipovka, and Pariiskii (*8*), and Pauliny-Toth, Wade, and Heeschen (*9*). Relative positions are good to ± 2 minutes of arc in both coordinates. Since the 50-foot reflector is altazimuth-mounted, the position angle of the plane of polarization to which the equipment was sensitive changed with local-hour angle. The total range in position angle over which observations were made was 39°, and the weighted average of the map is at position angle 11°. Considering the polarization integrated over the 10.8 minute-of-arc beam to be as high as 11 percent, the maximum possible error in the antenna temperature contours due to the above change in position angle during the observations is 7 percent and is reflected in the accuracy of the map of ± 0.04 degree Kelvin.

From the present observations W-44 is seen to be an extended crescent shape with a sharp eastern boundary closely resembling its appearance at 3000 Mc/s as observed with a 7-minute-of-arc resolution (*6*). The degree of linear polarization of the radiation, for the most part integrated by the 10.8-minute-of-arc beam, was measured to be 11 ± 2 percent at a position angle of 45° ± 5°. This is the first detection of linear polarization of the radiation from W-44 and strongly supports the interpretation of it as a supernova remnant. Since the polarization was integrated over a 10.8-minute-of-arc region of the source, smaller regions may be more highly polarized than 11 percent. For example, linear polarization in a 2-minute-of-arc portion of the Crab Nebula has been determined to be as high as 17.5 percent at 9400 Mc/s (*10*), probably over 20 percent at 5000 Mc/s (*11*) and 8 to 10 percent at 2830 Mc/s (*12*) whereas present observations at 8350 Mc/s of the integrated radiation from the whole source give 7 percent polarization. The total flux density of W-44, obtained by integration of the antenna temperature contours and corrected for the measured polarization, was $(95 \pm 25) \times 10^{-26}$ watt m^{-2} $(c/s)^{-1}$ based upon an assumed flux density of $(45 \pm 5) \times 10^{-26}$ watt m^{-2} $(c/s)^{-1}$ for Virgo A. This value is consistent with measurements at lower frequencies extrapolated with the use of a spectral index of −0.44 as determined by other observers (*5, 13*).

The source 3^m west of W-44 in Fig. 1 was first observed by Scheuer (*6*) and closely approximates a point source with the present resolution. The linear polarization and integrated flux density were measured to be 0.3 ± 1.5 percent at 72° ± 90° position angle and $(23 \pm 6) \times 10^{-26}$ watt m^{-2} $(c/s)^{-1}$, respectively. This flux density, and the absence of linear polarization, at 8350 Mc/s along with the flux density measurements of other observers (*8, 9*) indicate that this is a thermal source.

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11 July 1966

A Differential Anemometer for Measuring the Turning Tendency of Insects in Stationary Flight

Abstract. *A pair of thermistors forming part of a direct current bridge circuit was mounted in the wake of a moth in stationary flight. Differential changes in the thermistors' resistance provided a sensitive index of changes in the direction of the airstream as the insect made attempts to turn away from a source of ultrasonic pulses.*

Field observations (*1*) show that some moths of certain families, when in free flight, turn and take a course directly away from a source of faint ultrasonic pulses. Reception of pulses at higher intensity causes nondirectional diving and looping. These reactions increase the insects' chances of evading detection and capture by insectivorous bats (*2*) and have been the basis of a number of neurophysiological and behavioral studies (*3*). The differential anemometer was developed in an attempt to bring these behavioral responses into the laboratory for closer scrutiny. It proves to be extremely sensitive to changes in the location of a small stream of air, and it may have other applications.

The lift and forward thrust of a flying insect vary with the velocity and direction of the airstream ejected downwards and backwards by its moving wings. Detection of changes in the position of this wake relative to the body axis of an insect in stationary flight should provide an indication of attempts to change the direction of its flight path.

Moths were collected at light. Forty specimens belonging mostly to the genera *Feltia*, *Leucania*, and *Amanthes* have so far been studied. About one half of these showed stationary flight of reasonable duration, although in many cases its direction was too erratic for present purposes. Eight specimens showed consistent and repeated attempts to turn away from a small capacitative loudspeaker emitting ultrasonic pulses.

Each moth was mounted under carbon dioxide anesthesia with a small drop of Tackiwax applied to an insect pin whose tip just penetrated the notum. The pin was inserted in a crystal phonopickup in order to record changes in the frequency and amplitude of thoracic movement and hence wingbeat.

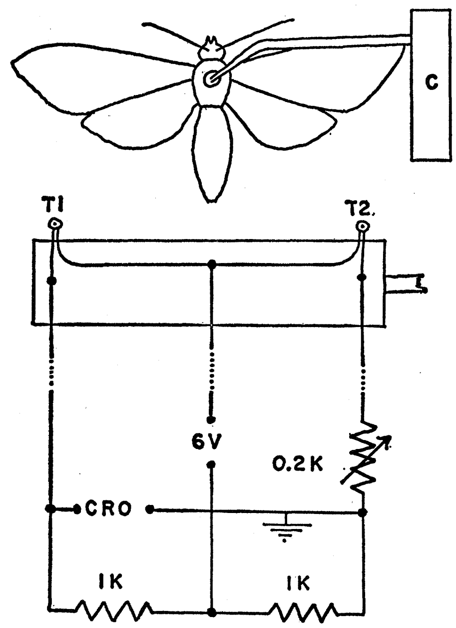

Fig. 1. Diagram of differential anemometer. *C*, phono-pickup bearing stylus to which moth is attached; *T1* and *T2*, bead thermistors attached to plastic strip and placed in wake of flying insect; and *CRO*, cathode ray oscilloscope. Components of bridge circuit as indicated; *1K* equals 1000 ohms.

Experiments were carried out in still air and darkness during the evening hours. This treatment did not seriously injure the insects. Four specimens released outdoors after flight sessions were recaptured on subsequent nights in the black light trap. Unfortunately, *Caenurgina erechtea* (*3*) could not be persuaded to fly steadily under these conditions.

The differential anemometer was placed horizontally about 1 cm behind and below the flying moth. It consisted of a pair of small thermistors mounted 2 to 3 cm apart on the edge of a sheet of thin plastic (3.5 by 2.0 cm, Fig. 1). Spacing was chosen to correspond roughly with the insects' wingspan. Bead thermistors (32A130, Graybar Electric) about 0.025 cm in diameter and with a resistance of 2000 ohms at 25°C were used. The thermistors projected about 1 mm beyond the leading edge of the plastic strip and were supported by cementing their leads to the plastic. Insulated wires connected the thermistor leads to the rest of the bridge circuit. This consisted of a potentiometer of a few hundred ohms in series with the thermistor of lower resistance for zero adjustment and a pair of wire-wound resistors (1000 ohms). The d-c channel of an oscilloscope served as indicator of bridge imbalance, and the voltage was supplied by a 6-volt battery.

This arrangement heats the thermistors to an undetermined temperature and causes a corresponding drop in their resistance. The bridge was balanced in still air and the thermistor pair was presented horizontally to the wake of a flying moth. I attempted to restore bridge balance by shifting the thermistor pair laterally in the airstream when the moth appeared to be flying steadily and not making turning movements. The latter can be identified by observing lateral bending movements of the head, antennae, and abdomen.

Figure 2 shows attempts of a flying moth to turn away from a loudspeaker when ultrasonic pulses originate first at 90 deg on its right side and then from a corresponding position on its left. An attempted left turn is accompanied by a relative increase in the airstream on the right side. This causes greater cooling of the right-hand thermistor, a corresponding disbalance of the bridge, and a downward deflection of the oscilloscope spot. With the moths tested in this study, a maximum attempt to turn was sufficient to cause full-scale deflection at a gain of 0.05 volt/cm.

The response time of the anemometer is adequate for present purposes. A change in airstream direction is signaled 60 to 70 msec after the onset of the stimulus (Fig. 2). During particularly vigorous flight, a ripple at wingbeat frequency may appear on the thermistor signal. The application of a higher bridge voltage and the use of smaller thermistors would shorten the response time. Sensitivity appears to be limited by the random turbulence present in "still" air.

Turning-away responses were shown most consistently by moths captured at light during the evening hours and studied at once. In four individuals turning-away was observed repeatedly and in both directions during continuous flights lasting 1 to 2 hours. At present there is insufficient evidence to define the conditions of this behavior, and these preliminary results are reported because they confirm the field observations (*1*) that some noctuid moths are able to

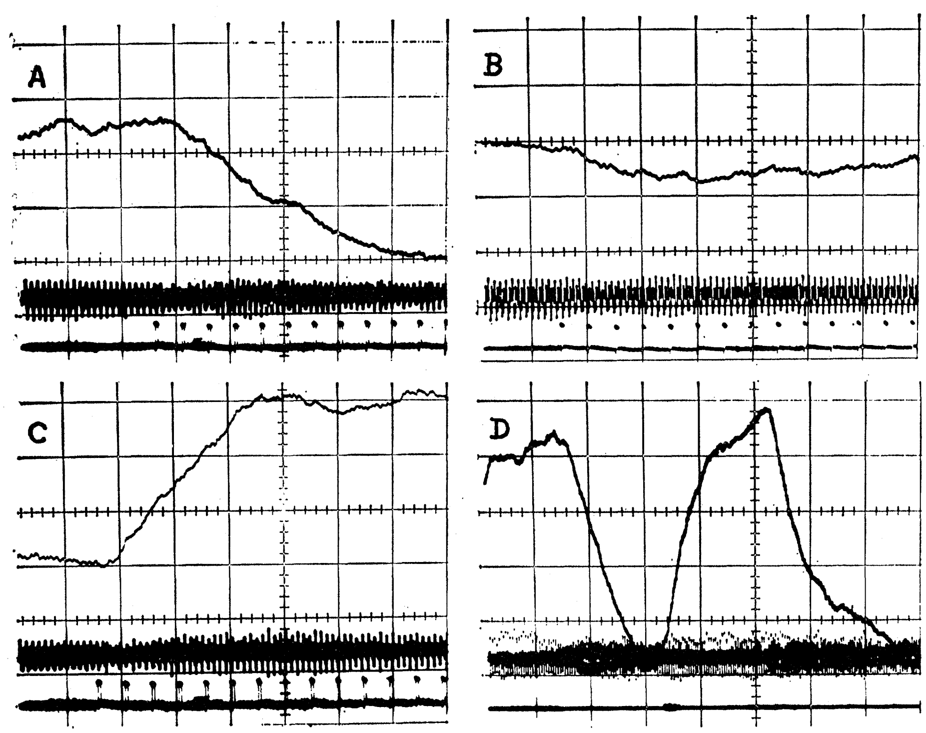

Fig. 2. Turning attempts of *Leucania multilinea* in response to signals from a 1.5-cm capacitative loudspeaker placed asymmetrically at a distance of 15 cm in the horizontal plane. Stimulus is a 40 kh pulse, 10 msec in duration, recurring at about ten times per second. Upper trace, signal of differential anemometer indicating attempted right turn by upward deflection. Middle trace, phono-pickup indicating frequency and amplitude of wing beats. Lower trace, signal indicating onset, duration, and repetition rate of ultrasonic pulses. A, loudspeaker at 90° on right side, sound intensity at moth –14 db re 1 dyne/cm^2. B, the same, sound intensity –24 db. C, loudspeaker at 90° on left side of moth, intensity –14 db. D, spontaneous swerving, no ultrasonic stimulus. Each major division of A, B, and C represents 0.2 second; that of D, 0.5 second.

orient with respect to a source of ultrasonic pulses.

The method has many possibilities. A second thermistor pair could be placed in the vertical plane to register tendencies to climb and dive. The signal generated by the anemometer suggests arrangements employing feedback, thus permitting study of the actual orientation of insects in stationary flight to sources of optic, acoustic, and other stimuli.

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4. This work was supported by an NIH Research Career Award and by grant AI-00947. Dr. S. Vogel of Duke University kindly read and criticized the manuscript.

25 July 1966

Pacemaker Synchronization

Abstract. *A method using the standard radio-frequency receiver was developed to telemeter biopotentials across the intact body wall; it can be employed to program a stimulus to the heart at any phase of the cardiac cycle. The small variations of potential across the electrodes of the implanted cardiac pacemaker change the natural resonant frequency of the receiver in direct relation to the electrical activity of the heart.*

By a new method one can telemeter cardiac electrical activity with the implantable radio-frequency cardiac pacemaker receiver heretofore employed only to forward electrical impulses to the heart for pacemaking (Fig. 1; *1*); an advantage is that one can now synchronize electrical events in the heart with electrical pacemaking, with no modification of the implanted apparatus—only of the external transmitter to change its type of impulse.

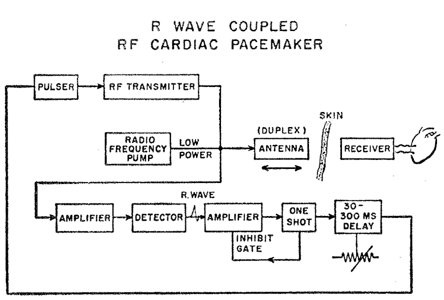

Fig. 1. Schematic diagram of the equipment.

Experiments were performed on dogs under nembutal anesthesia and endotracheal respiration. The cardiac electrodes attached to the radio-frequency receiver were of unipolar or bipolar configuration. Several sites on the ventricular surface were tested, and in some instances the polarity was reversed. The radio-frequency receiver was either located external to the body or implanted in the subcutaneous tissue; in one experiment several recordings were obtained with a direct transcutaneous wire.

Tests were also conducted with a cardiac-voltage simulator generating up to 10 mv which was applied to the electrode leads (Fig. 2). To detect frequency changes in the implanted circuit from signals arising in the heart, we employed Pound's marginal oscillating detector (*2*) to force a current of 5 to 10 μa at approximately 2 Mc/sec through the receiver's diode; when the cardiac signal influenced the diode's elecrical capacity there was an increase in the marginal oscillator's frequency; typically a shift of 21 cy/mv was obtained. Simultaneous recordings, made of the simulator's output, from a frequency-modulation receiver, tuned to 2 Mc/sec, demonstrated excellent correlation with the cardiac-voltage simulator's direct output. When the diode was intentionally short-circuited, no shift in frequency was observed.

When the cardiac-voltage simulator was replaced by a variable resistor, only a small change obtained. Thus our "RF-electrogram" is mainly the result of potentials generated by the heart—not the result of changes in its resistance. A small audio amplifier that demonstrated the electrogram was useful in determining the sites on the cardiac surface from which best to record.

Good electrographic recordings of the P-QRS-T complex were obtained when one electrode was implanted in the ventricle wall within 0.5 cm of the atrium, or when one was implanted in the outer atrial wall. Figure 3A shows direct epicardiac potentials telemetered from an implanted standard radio-frequency receiver whose electrodes were attached to each ventricle (*RF-EG*). The activity recorded, as expected, clearly precedes both the strain-gauge deflection (representing ventricular contraction) and the electromagnetic-flowmeter deflection, representing aortic arch flow.

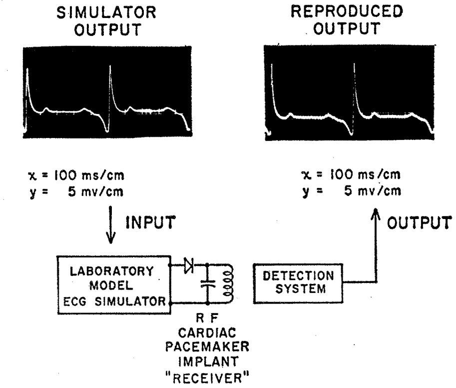

Fig. 2. Results with the output (up to 10 mv) of a cardiac-voltage simulator applied to the electrode leads.

Figure 3B shows delayed pacemaker synchronization with the R wave, resulting in coupled pacing; one may see that when the "delay" was adjusted to 180 msec immediate coupling followed, the rate decreased from 160 to 80 per minute, and there was a concomitant 10 percent increase in left ventricular pressure.

Two distinct problems remain: first, external signal interference preventing establishment of an isoelectric base line; second, the difficulty in determining the best sites for the electrodes, to insure

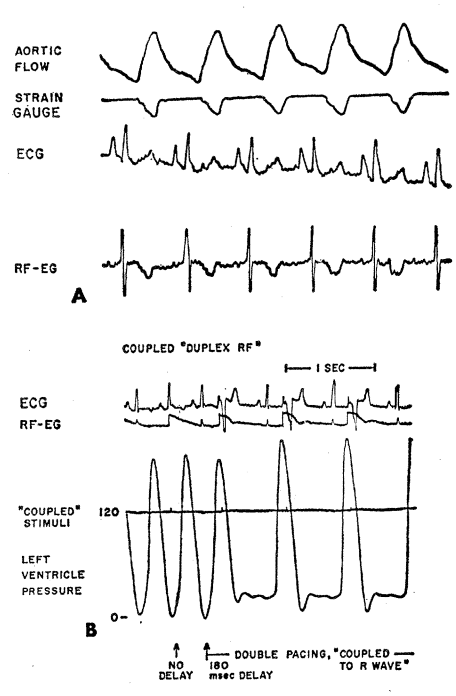

Fig. 3. A, Direct epicardiac potentials telemetered from an implanted radio-frequency receiver whose electrodes were attached to each ventricle (*RF–EG*). B, Delayed pacemaker synchronization with the R wave, resulting in coupled pacing.