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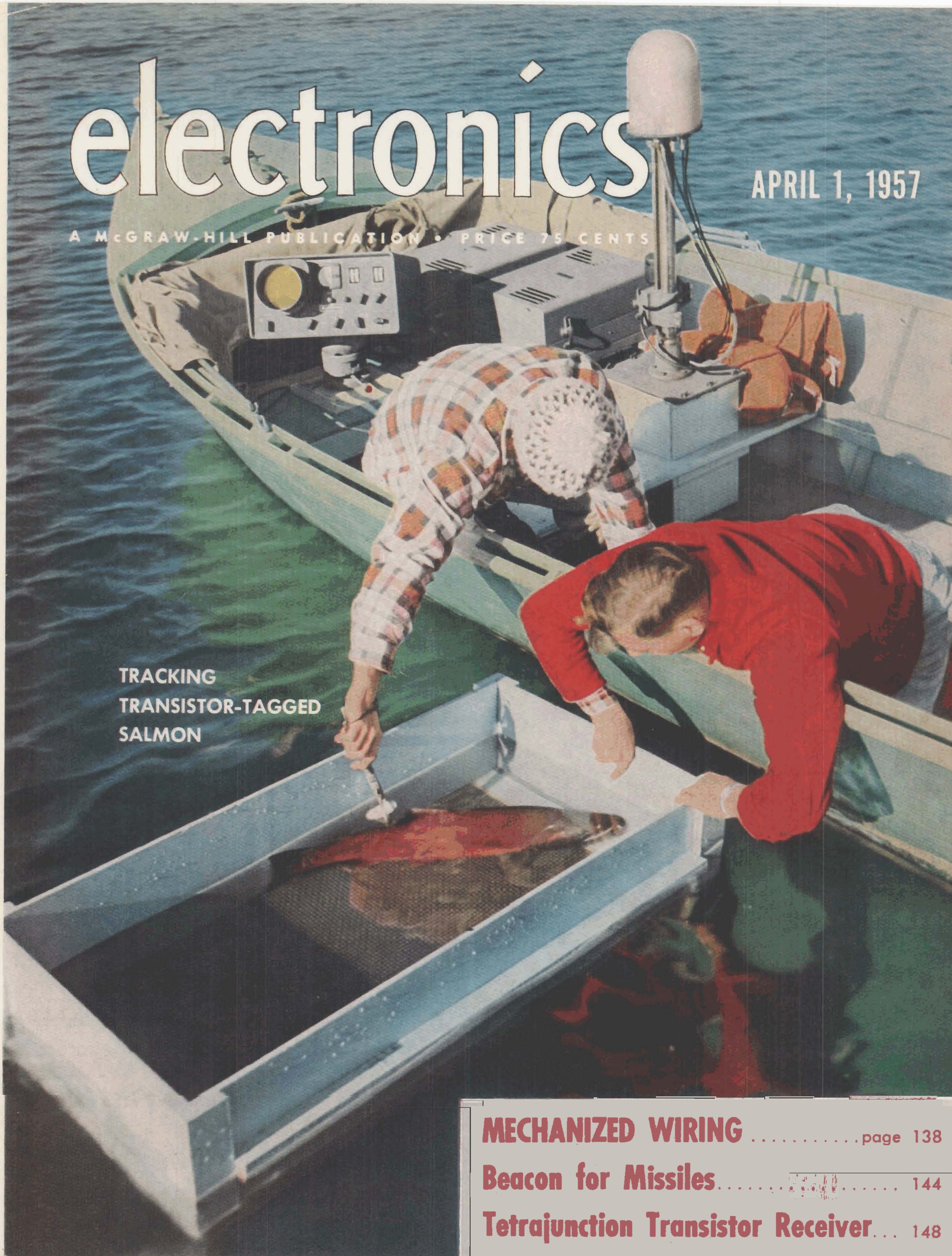

TRACKING TRANSISTOR-TAGGED SALMON

ULTRASONIC TRACER Follows Tagged Fish

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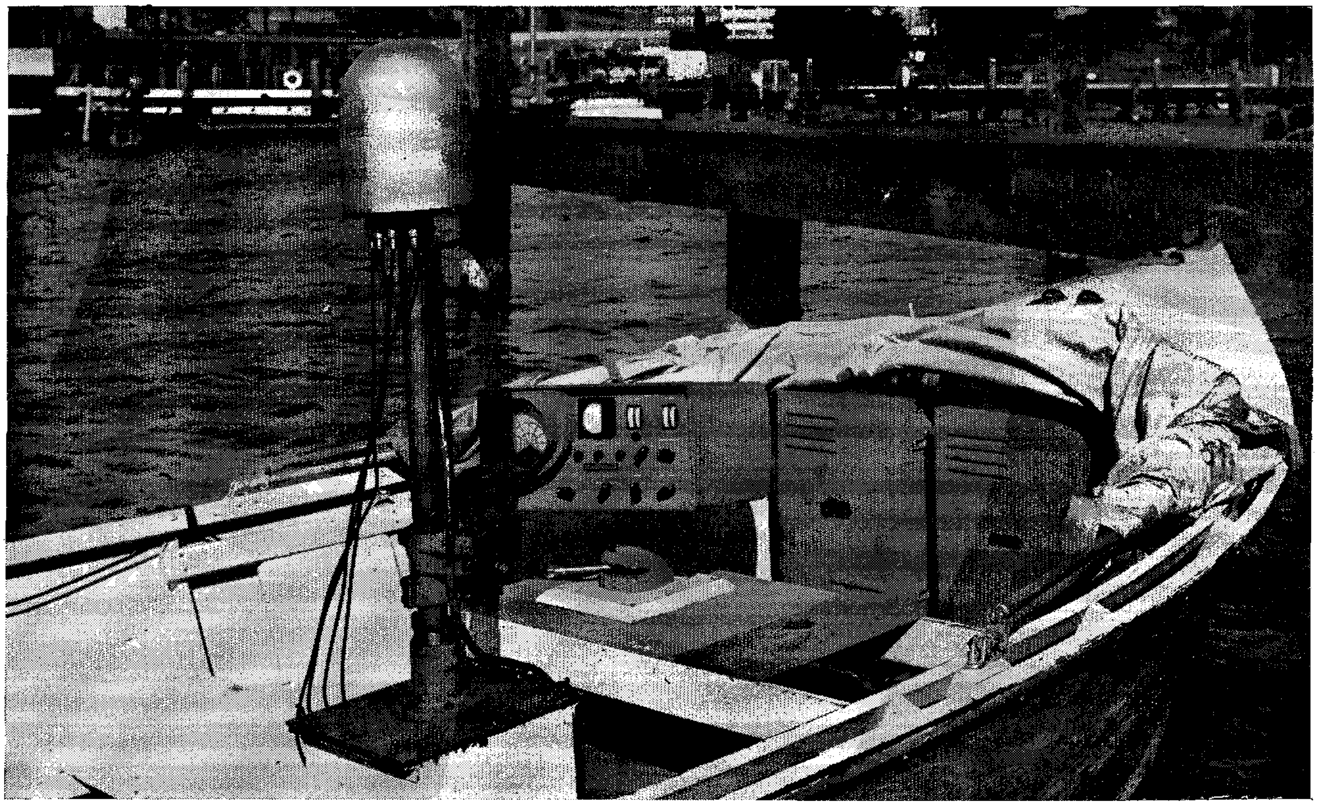


FRONT COVER: Field installation of automatic ultrasonic tracking and ranging system on U. S. Fish and Wildlife Service boat Wendy. Five-transducer array is on servo-driven rotating and tilting mount inside dome. Ultrasonic signals (132 kc for tracking and 270 kc for ranging) travel through air to water. Equipment can also be used for studying crabs and lobsters

ULTRASONIC TRACER

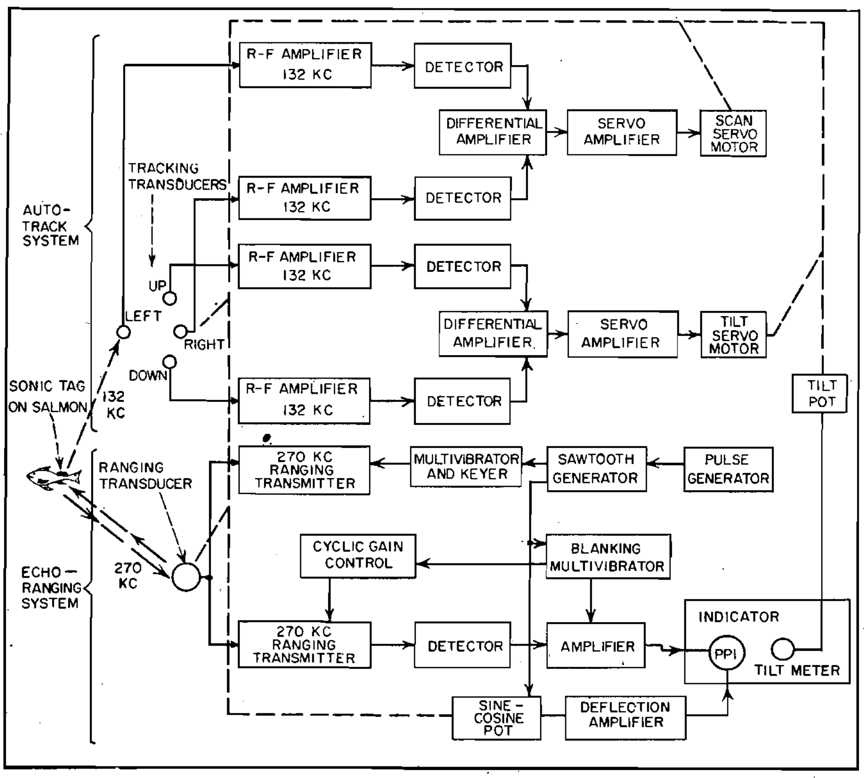
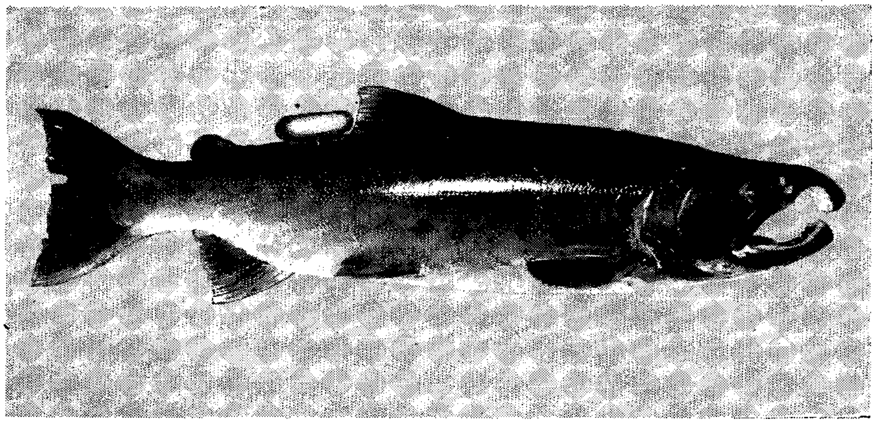


FIG. 1—Complete automatic tracking and ranging system for tagged fish

DEVELOPMENT of automatic ultrasonic tracking and ranging equipment for the Fish and Wildlife Service provides a method for obtaining information on adult salmon behavior in relation to dams in the Northwest. The design and production of this new research tool was prompted by the need for obtaining a more detailed knowledge of individual salmon behavior than has been possible by conventional methods.

The equipment consists of a miniature ultrasonic source (sonic fish tag), a self-positioning directional transducer array with a receiver-servo system (auto-track) and an echo-ranging system arranged as in Fig. 1.

In operation, the tracking system positions itself or homes on the sonic tag attached to a fish and aims the transducer in that direction. The range and bearing of the fish are displayed on a calibrated cathode-ray tube. The depth of the



Sonic tag on silver salmon has carefully adjusted buoyancy so as not to affect natural movements of fish. Pulse repetition rate of transistor oscillator in tag is adjustable; with appropriate receiver tuning facilities, up to ten different fish can be tracked simultaneously

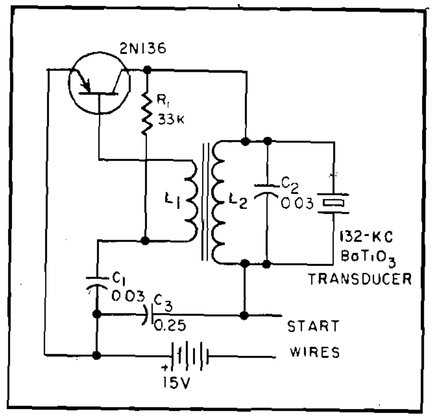


FIG. 2—Pulsed 132-kc ultrasonic oscillator used in sonic fish tag can be detected at distances up to 2,000 feet

SUMMARY —— Single-transistor pulsed ultrasonic oscillator with 7-hour battery life is clipped to adult salmon on spawning run. After fish is released, movement is tracked with sonar-type equipment on boat to obtain detailed fish behavior patterns in relation to dams. Servo-controlled four-transducer receiving array tracks tagged fish automatically to give elevation and azimuth. Sonar ranging transducer in center of array is thus aimed directly at fish

Follows Tagged Fish

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fish is calculated from the range and the angle at which the ultrasonic impulses from the equipment are projected into the water. By plotting the position of the fish and the position of the boat simultaneously, the operator is able to obtain detailed fish behavior patterns.

Ultrasonic Fish Tag

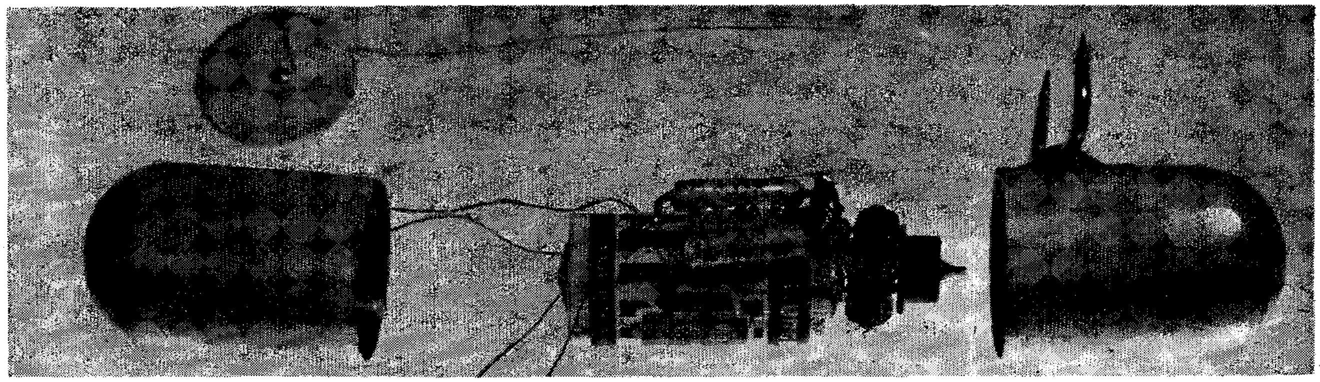
To permit attachment to relatively small fish with minimum modification of their behavior, the sonic tag must be of miniature size. Opposed to this requirement is the need for battery life of 8 to 12 hours. Accordingly, circuitry in the sonic tag was chosen to hold current requirements to a minimum.

The additional requirement of approximately neutral buoyancy modifies the package to some extent. The resultant capsule is $2\frac{3}{8}$ inches long, 0.9 inch in diameter, weighs 29 grams in air and displaces 27 grams of fresh water.

The capsule shell, spun from 7-mil aluminum, is provided with a soldered-on hog ring for attachment to the fish. The tag closes with a slip fit and is sealed with vacuum grease, a wrap of plastic tape and an over-all plastic dip to ensure water tightness to a depth of 30 feet.

Economy of battery life is improved by pulse operation of the sound source. The common-emitter transistor oscillator circuit used in the sonic tag is shown in Fig. 2. Here R_1 and C_1 establish an interruption rate of 2,000 pps and a pulse length of 200 microseconds. The values of L_2 and C_2 and the clamped capacitance of the transducer determine the 132-kc operating frequency.

The transducer used in the sonic tag is a barium titanate disk 0.040 inch thick and 0.86 inch in diameter. The disk is one-half wavelength in diameter, resonant in the radial mode at 132 kc. It has silver fired on both surfaces and small lead wires soldered to the nodal point or center of each side. The transducer mounts inside one end of the spun aluminum capsule, at the break point of the end radius. Epoxy resin cement secures it in place and gives acoustic coupling to the aluminum shell. This construction, which provides a marked benefit in matching the acoustic impedance of the disk to the water



Contents of ultrasonic fish tag. Crystal transducer (top) fits into left half of capsule, which is shaped and dipped in waterproofing plastic solution after assembly. Two leads at lower left come out of capsule through joint, for connecting together to complete circuit just before fish is released. Smaller tag is now being developed for use on small fish

load, gives the desirable nearly circular radiation pattern shown in Fig. 3.

With this circuit arrangement an r-f voltage of 25 volts peak-to-peak is developed across the transducer, providing a signal level of 5 microvolts at the receiver grid at 400 feet. The 15-gram 15-volt battery has a useful life of 7 hours at a current drain of 3 ma.

Automatic Tracking System

The servo-powered automatic tracking system uses four receiving transducers, each connected to one of the four receiving channels. Two of these transducers are used for azimuth tracking and two for elevation tracking. Each azimuth transducer has a beam pattern with a response 10-db down at 20 degrees from its axis. The transducers are mounted with an angle of 40 degrees between their axes. A sound source on the bisecting axis of a pair will produce in each a signal which is 10-db below its maximum response. If this source is moved from the bisecting or common axis toward either transducer axis, the output from that transducer will rapidly increase towards its maximum while the output from the other will decrease. If the two signals are used to balance each other in a difference amplifier, the resultant sharply defined null provides excellent sensitivity to small angular displacements from the common axis.

The receivers use a high-gain trf circuit with a bandpass of ± 4 kc to the 3-db-down point. Two of the tracking receiver channels and their common servo amplifier are shown in Fig. 4. Each channel has a biased triode (V_{5A} and V_{10A}) operating as a detector, feeding the 2,000-cps repetition rate frequency of the sonic tag to a zero-bias amplifier. The audio signals from the two channels are rectified by 1N38 diodes which are directly coupled to the grids of the cathode-follower difference amplifier. The output signal from the difference amplifier is a bidirectional d-c voltage which is then modulated by a 60-cps chopper. The chopped signal is amplified by a 60-db amplifier which drives an 8-watt 2-phase servo motor geared to the transducer clus-

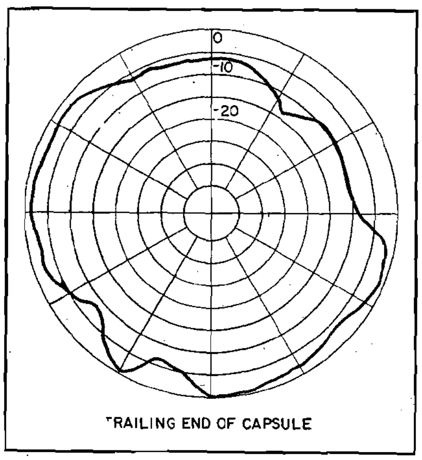


FIG. 3—Ultrasonic energy distribution pattern in horizontal plane for tag attached to fish

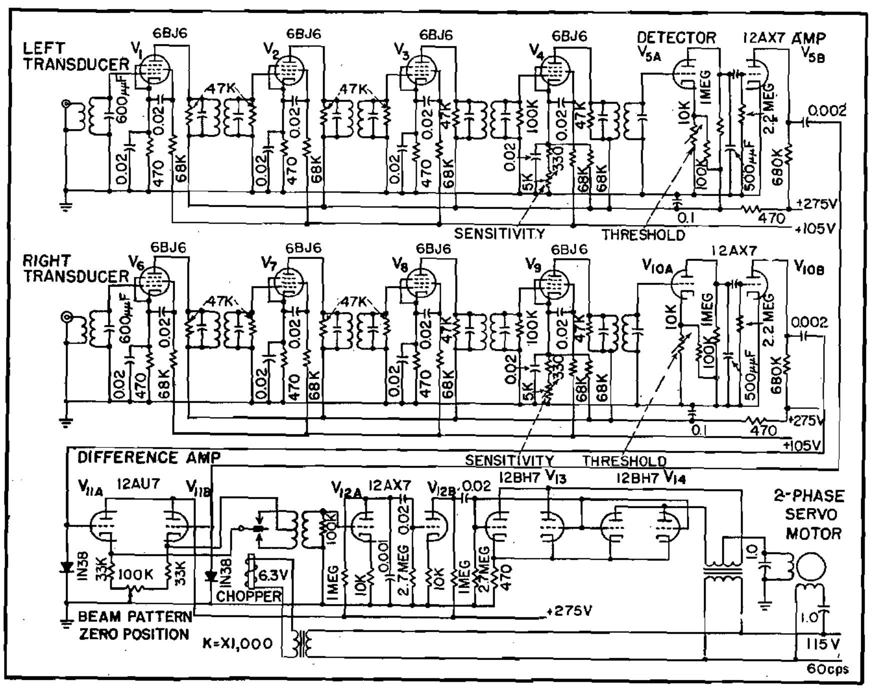


FIG. 4—Azimuth tracking receiver channels, servo amplifier and motor circuit for horizontal rotation of transducer array

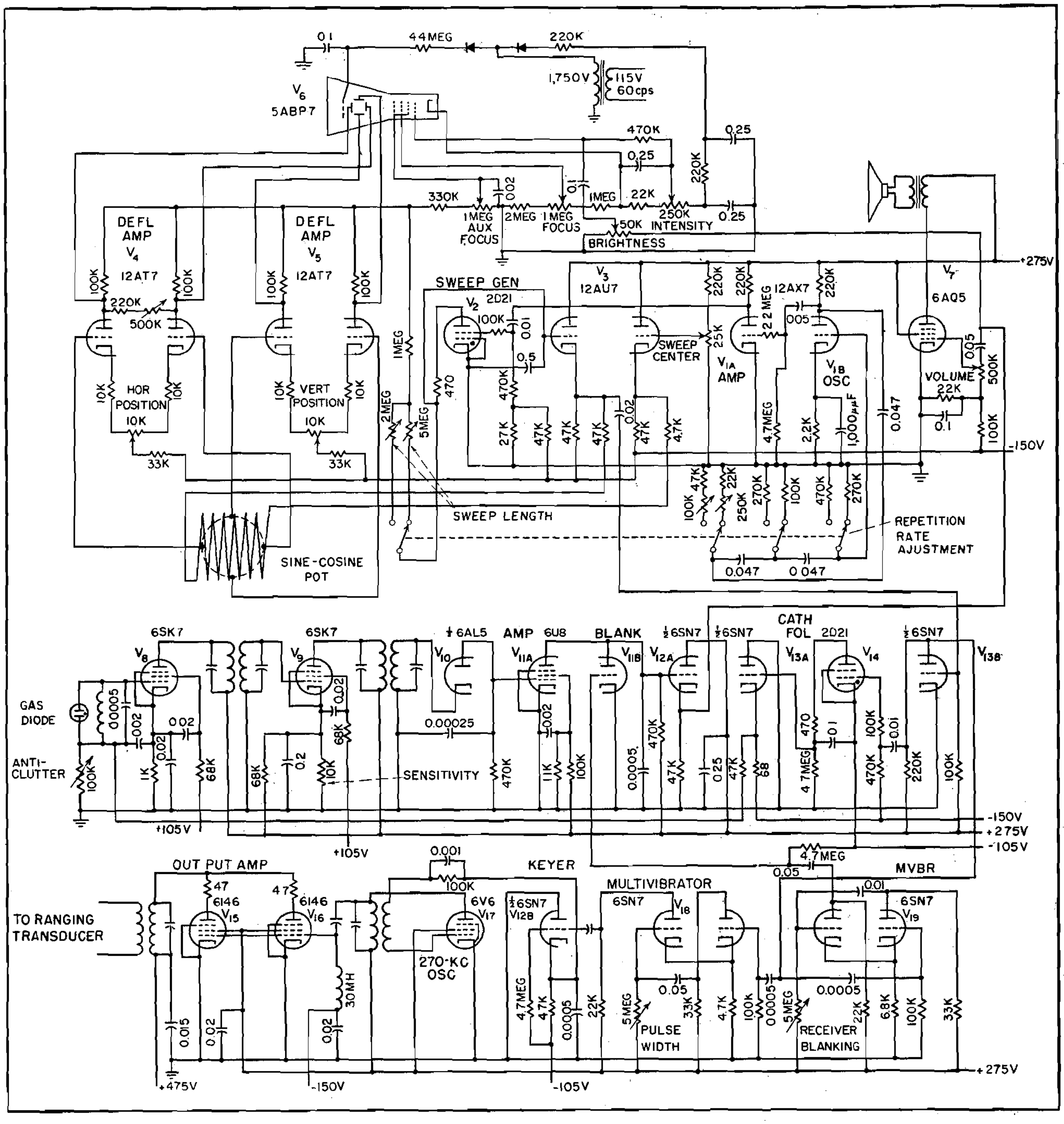


FIG. 5—Transmitter-receiver and indicator display circuits of echo ranging system

ter. Directional sensitivity is inherent in the phase sensitivity of the servo system.

Information on angular position of the sonic tag is presented to the operator as azimuth information and elevation angle (always negative). Azimuth angle is displayed on a ppi scope in conjunction with range information. This is accomplished by using the range sweep sawtooth signal as an input to a sine-cosine potentiometer which is rotated with the azimuth axis, as indicated in Fig. 5. The sine-cosine potentiometer output is amplified by four triode deflection amplifiers to provide a radial sweep for the cathode-ray tube, in synchronism with the transducer cluster azimuth angle. A conventional potentiometer is coupled to the elevation axis to transmit elevation data to a panel meter.

The ranging system may be described as an echo-ranging searchlight sonar system. A short pulse of ultrasonic energy is emitted by a direction transducer. The transmitted pulse encountering a target results in a small portion of the energy being reflected and returned to the receiving transducer as an echo. The transit time is then a measure of range.

In the ranging circuit of Fig. 5, a pulse repetition rate of 6 cps (400-foot range) or 3 cps (800-foot range) is generated by phase-