Automatic frequency control for R.D.I. ground beacon oscillator

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LABORATORIES
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THE NATIONAL RESEARCH COUNCIL OF CANADA
ELECTRICAL ENGINEERING AND RADIO BRANCH

AUTOMATIC FREQUENCY CONTROL
FOR
R.D.I. GROUND BEACON OSCILLATOR

OTTAWA
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Report no. ERB - 161

Laboratories
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AUTOMATIC FREQUENCY CONTROL
FOR
R.D.I. GROUND BEACON OSCILLATOR

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Photo 1. Parallel Line Discriminator

Fig. 1. Coaxial Line Discriminator

Fig. 2. Schematic of a.f.c. Circuit

Fig. 3. Parallel Line Discriminator Characteristic

Fig. 4. Temperature-Frequency Characteristic of Parallel Line Discriminator

ABSTRACT

A Radio Distance Indicator system, which indicates to the pilot of an aircraft his slant distance from one or more fixed ground beacons, has been developed at the National Research Council of Canada. The system comprises both airborne and ground equipments and has been described elsewhere.

This report describes an automatic frequency control device which may be applied to the ground beacon transmitter of the RDI system in order to improve its stability. The beacon transmitter stability without A.F.C. is nominally $\pm$ 0.1 per cent, but severe conditions may reduce this to $\pm$ 0.5 per cent. With this A.F.C. discriminator attached, the stability under the worst conditions is $\pm$ 0.03 per cent.

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Unclassified

1. General

The Radio Distance Indicator is an equipment employing secondary radar principles, the purpose of the system being to give the pilot of an aircraft his distance from a fixed ground installation or beacon. Such a system must be reliable in every respect so that the pilot will have confidence in the information provided to him, and in this regard the stability of the ground beacon signal frequency is an important factor. In addition to reliability, increased sensitivity, signal-to-noise ratio, and range are provided by a stable ground beacon frequency.

The ground beacon transmitter uses a self-excited, medium power oscillator operating at 228 mc/s. An attempt to use a crystal multiplier, with either pulsed or c.w. output, in order to stabilize the frequency of the transmitting oscillator, was unsuccessful. Reports on developments of similar equipment in other laboratories indicated that a c.w. crystal oscillator with pulsed amplifier would involve elaborate circuits requiring much more space than our system could accommodate. It was decided, therefore, to develop an automatic frequency control which could be attached to existing installations.

The frequency-determining elements of the oscillator are the tube interelectrode and stray capacities and a section of parallel line somewhat less than a quarter wave in length, this length being variable by means of a shorting bar driven by a lead screw. A system was devised whereby a small reversible motor drives this lead screw, the motor being controlled by a discriminator system. A discriminator was built having two quarter-wave sections of line as resonant elements, each section feeding a diode. The diodes control the motor by means of intermediate amplifiers and relays.

2. Requirements of the System

The discriminator was designed to have a centre or cross-over frequency of 228 mc/s and to permit a maximum deviation of transmitter frequency of ± 100 kc/s. In addition, the range over which control would be effective was to be ± 5 mc/s. Static balance was to be achieved in order to prolong the life of the relays. The space occupied was to be as small as possible so that re-design of the present equipment would be a minimum.

3. Discriminator Design

The circuit adopted for the discriminator uses two tuned circuits, one tuned above and the other below the cross-over point, with the diodes connected back-to-back.

In order to allow for loading of the circuits, and to permit loose coupling throughout, the first discriminator was designed to have as high a Q as was consistent with available materials and machining facilities. Accordingly, quarter-wave concentric line sections were used, (fig. 1). The frequency correction realized with this discriminator was ± 40 kc/s, with an operating range of 216 to 241 mc/s. However, due to the method of tuning the circuits, the temperature-frequency coefficient was excessive, and while this could have been overcome, a simpler design involving less machine work then seemed feasible in the light of results of experiments on the concentric-line set-up.

Therefore, the concentric lines were replaced by quarter-wave parallel lines, the construction being as shown in photo 1. The diodes are loosely coupled to the lines by direct connections to points on the lines near the grounded shorting bar. Tuning is done by means of moveable brass slugs near the shorted end, which effectively alter the inductive reactance of the circuits.

It can be shown, that for a uniform line, the temperature-frequency coefficient may be neglected over a practical temperature range, provided that the method of tuning is not affected by the linear expansion of the lines due to temperature; that is, any expansion of the lines must not alter their position with respect to the tuning elements. Hence, the method of inductive tuning by means of slugs parallel to the lines was adopted. A heat run on the discriminator showed no measurable temperature coefficient from 60° F. to 130° F., and that from 39° F. to 60° F. the cross-over point shifted only 40 kc/s (see fig. 4). This discrepancy is within the tolerances of the measuring instruments, so no trouble need be expected from temperature effects.

A frequency response curve of the discriminator was obtained using a ground beacon oscillator as signal source and a calibrated re-entrant cavity wavemeter as frequency standard. Results showed that, with a deviation of ± 100 kc/s from the cross-over point, the amplitude of the output pulses was 30 millivolts, for a peak r.f. input of .50 volts. For this same input, the output was 300 millivolts at 500 kc/s from centre.

4. Amplifier and Motor Circuits

For satisfactory operation, amplification is necessary following the discriminator. Fig. 2 is the schematic of the circuit. The cascaded 6AK5's are conventional resistance-coupled stages, except for the one addition of 0.002 mfd. across the input to the second tube. This capacitance widens the pulses and stabilizes the system. A 6J6 phase inverter splits the amplified pulses and feeds the grids of the 2D21 thyratrons 180° out of phase.

With no signal, the thyratrons are cut off with five volts negative, d.c., on the grids, d.c. bias being more satisfactory than the more readily available a.c. This voltage is obtained by rectifying one-half of the secondary voltage of a small power transformer.

Plate supply for the 2D21's is 225 volts, r.m.s., 60 c.p.s. a.c., supplied by the other half of the secondary of the same transformer.

Small d.p.d.t., d.c. relays in the plate circuits switch the line volts to the small split phase 110-volt induction motor, which controls the position of the shorting bar in the ground oscillator. Use is made of the additional contacts on the relays to provide interlocking action so that only one relay at a time can operate. This feature is intended to protect the motor in case of tube failure.

5. Alignment

Alignment of the discriminator circuits may be carried out as follows. Apply a pulsed r.f. signal of 50 peak volts at 226 mc/s and tune the lower frequency circuit for maximum response, as indicated on an oscilloscope connected to one of the thyratron grids. Similarly, tune the higher frequency circuit to 230 mc/s; check for cross-over at 228 mc/s. Compensation for discrepancies can be made by adjusting the diode couplings. That is, if the cross-over point is higher, say, than 228 mc/s, increase the coupling to the 226 mc/s line, readjusting the tuning slug, if necessary, to maintain the original settings.

6. Thyratrons

(a) Bias:

Set bias potentiometer to give five volts d.c., negative, between the arm of the potentiometer and ground.

(b) Protection during warm up:

The thyratron heaters must be permitted to warm up for at least ten seconds before plate voltage is applied. In present R.D.I. installations the main time delay may be utilized.

7. By-Passing the Motor Control

To tune the transmitter independently of the motor control, a manual-automatic switch SW1 is supplied. In the manual position, the relays are replaced by push-button switches, SW2 and SW3.

8. Performance

Tests of the system yielded satisfactory results as follows. With 300 volts positive plate supply for the amplifier and phase inverter, -5 volts bias on the grids and 225 volts r.m.s. on the plates of the thyratrons, the system maintained a ground beacon frequency of 228 mc/s ± 40 kc/s. The pull-in range is 220 to 233 mc/s. It will be noted that the frequency response is unsymmetrical, the system being useful 5 mc/s above and 8 mc/s below the centre (fig. 3). This was found to be caused by an unsymmetrical characteristic inherent in the 6AL5 duplex diode. The use of two separate diodes is not advisable from the standpoint of reliability, nor are they necessary, since a bandwidth of ±5 mc/s is achieved.

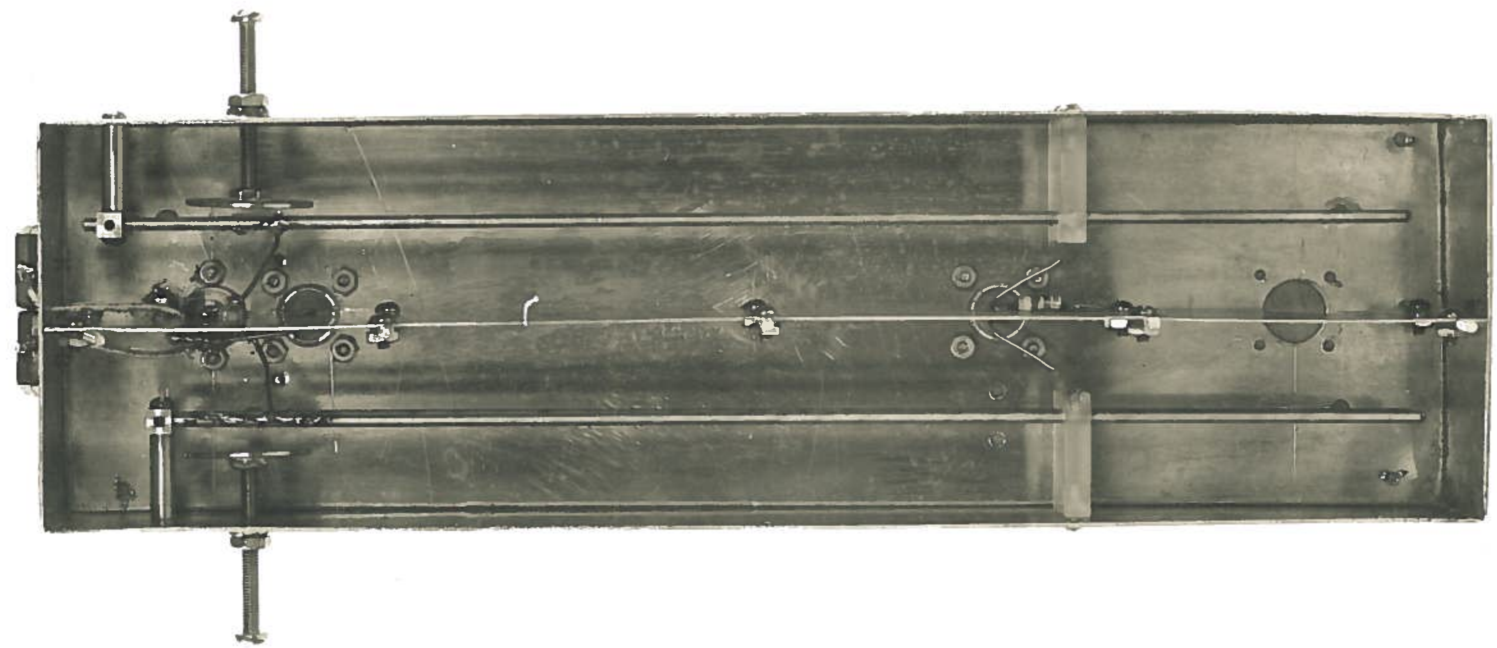
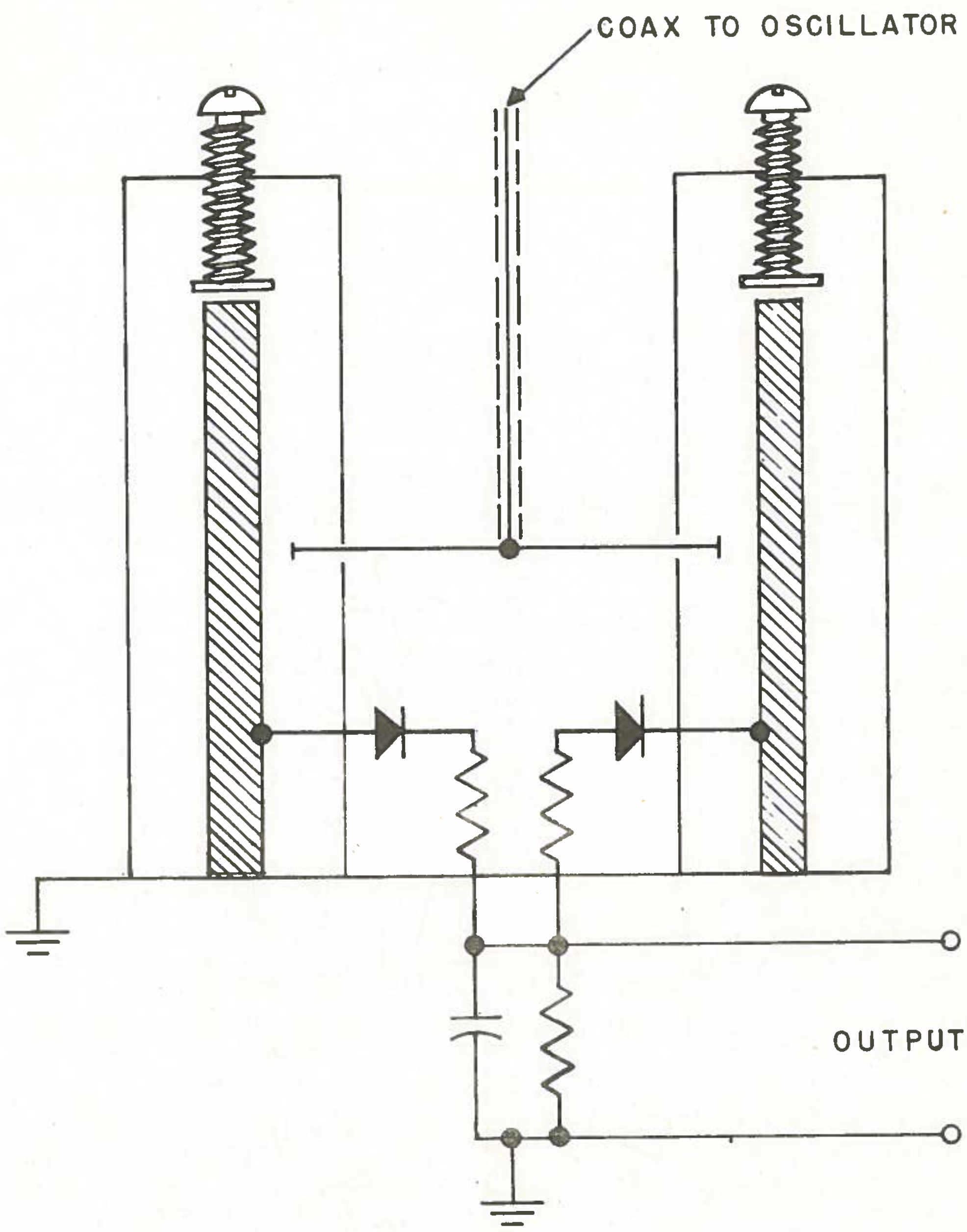


PHOTO I

PARALLEL LINE DISCRIMINATOR



COAXIAL LINE DISCRIMINATOR

FIG. 1

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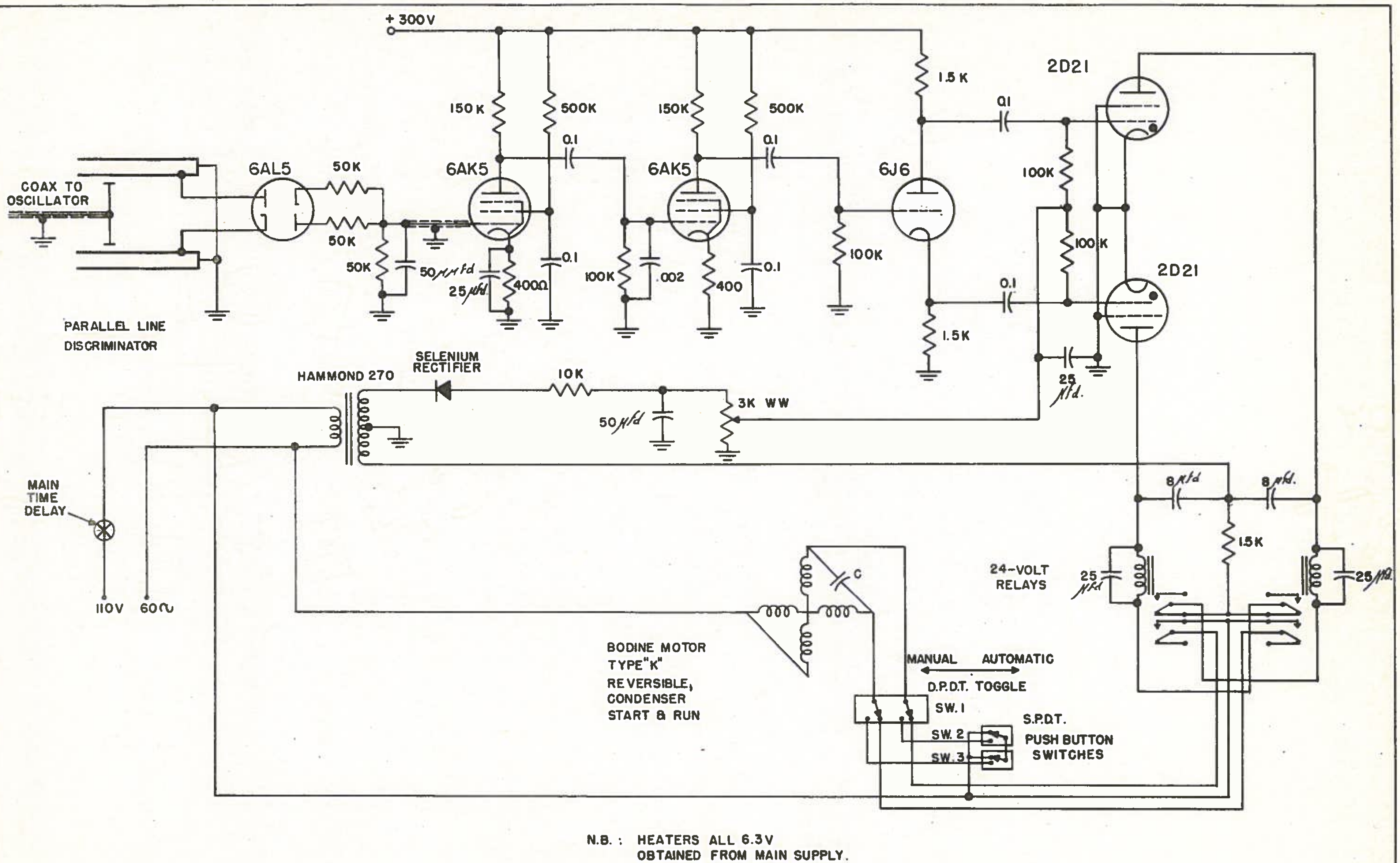
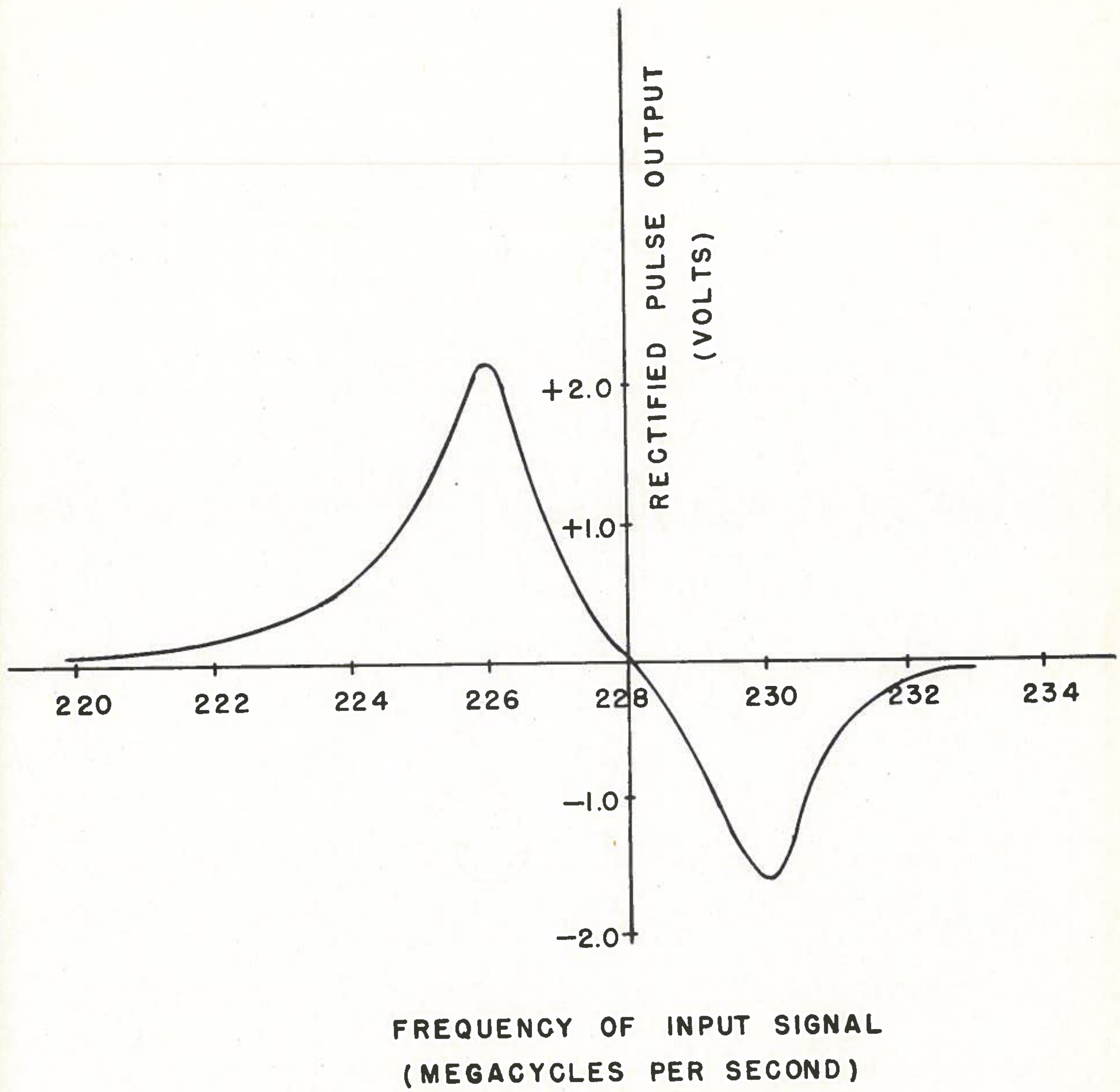


FIG. 2

SCHEMATIC OF A.F.C. CIRCUIT



PARALLEL LINE DISCRIMINATOR
CHARACTERISTIC
FIGURE 3

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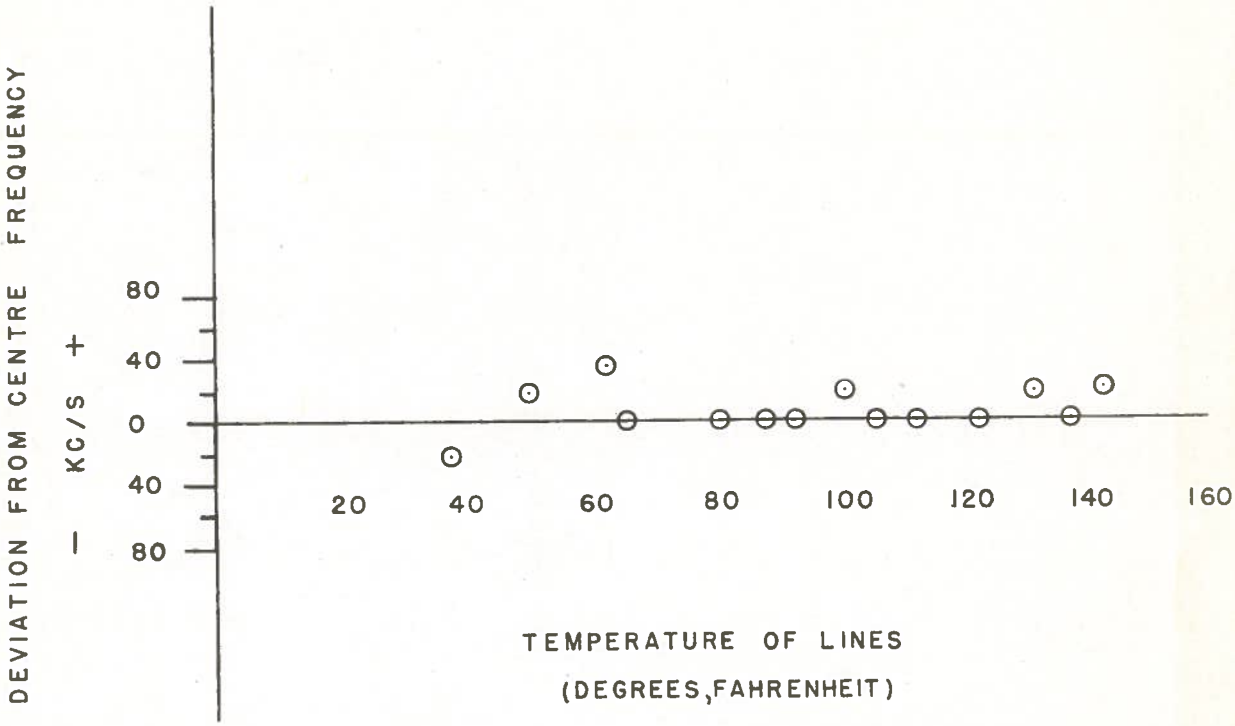

TEMPERATURE — FREQUENCY CHARACTERISTIC OF THE PARALLEL LINE DISCRIMINATOR.

FIGURE 4