NRL REPORT 3791

A SYSTEM OF SIGNAL-FREQUENCY RECORDING FOR USE WITH RADAR SET AN/APR-9

NAVAL RESEARCH LABORATORY

WASHINGTON, D.C.

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ABSTRACT

A system of visual recording for signals received by Radar Set AN/APR-9 was devised in order to evaluate the operational use of the system, particularly for short signal bursts such as flash-type communication systems and narrow-beam rotating radars. The band coverage of the AN/APR-9 radio-frequency tuner is plotted across recording paper six inches wide. The writing stylus is servo controlled by the tuner mechanism and portrays received signals by making short marks on the recording paper. The system is intended primarily as an aid to the operator, enabling him to retune the receiver to any recorded signal. Use of the recorder does not alter the normal operation of the AN/APR-9 equipment.

PROBLEM STATUS

This is an interim report on the problem; work is continuing.

AUTHORIZATION

NRL Problem R06-10R
BuShips Problem S-1255.6
NR 506-100

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A SYSTEM OF SIGNAL-FREQUENCY RECORDING FOR USE WITH RADAR SET AN/APR-9

INTRODUCTION

It has been recognized that employment of Radar Set AN/APR-9 as a radio-countermeasures intercept receiver is a difficult and tiresome task for the operator. Particular signal perception difficulties arise in the case of short-duration signals, such as flash-type communication systems and narrow-beam rotating radars, and in the case where very short pulse widths are encountered.

Signal-Presentation Methods Employed by the AN/APR-9 Receiver[1]

The AN/APR-9 mixer-amplifier receives signals from the preamplifier in the r-f tuner over a 20-Mc bandwidth centered at 160 Mc, and provides an audio output for aural reception, video outputs for signal analysis equipment, and a panoramic output that is used in the AN/APR-9 indicator unit for a panoramic presentation of the 20-Mc band. Either of two video outputs can be selected by a bandwidth switch on the remote control unit. One of these (termed the wide video) has a 4-Mc bandpass and contains all signals present in the 20-Mc bandwidth of the receiver i-f; the other (termed the narrow video) has approximately a 0.7-Mc bandwidth and presents only those signals in a 0.7-Mc portion at the center of the 20-Mc band. Part of the amplified 160-Mc i-f voltage is fed to a second mixer and combined with the output of either of two oscillators to produce a second intermediate frequency of 42 Mc. The first oscillator (a sweep oscillator) is mechanically swept from 108 to 128 Mc about 25 times per second; the second oscillator (a fixed oscillator) has a frequency of 118 Mc. The output from the second mixer is amplified in a 42-Mc i-f amplifier which has a bandwidth of about 0.7 Mc to the 3-db points, and then detected. This detected output provides either a vertical deflection voltage for the panoramic presentation when the sweep oscillator is in use, or a narrow-band video output for analysis when the fixed oscillator is in use. Either oscillator is selected at the remote-control unit by means of the bandwidth switch, mentioned previously, which simultaneously selects the corresponding video voltage that is fed to the video-output terminals. A frequency discriminator, which is coupled to the sweep oscillator, produces a voltage proportional to the frequency of the oscillator, and this voltage is amplified and used to provide the horizontal deflection for the panoramic presentation.

When the receiver is being used to search for signals, the bandwidth switch is normally placed in the wide position so that the 20-Mc bandwidth of the first i-f is displayed on the panoramic oscilloscope and received signals are fed through the narrow-band i-f

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[1]Handbook of Maintenance Instructions for Radar Set AN/APR-9 (AN 16-30, APR-9-3), BuShips, 15 March 1949

and video to the vertical deflection plates. All signals present in the 20-Mc band are fed through the wide-band video amplifier and appear simultaneously at the video-output terminals of the receiver.

The AN/APR-9 equipment utilizes four separate r-f tuners so that continuous frequency coverage from 1000 to 10,750 Mc is provided in four bands. Each tuning mechanism is motor driven and has a frequency scan per second of approximately 50 Mc. The tuning motor can be energized manually or by an automatic sector-scan mechanism. When the receiver is being tuned, a given frequency will remain within the 20-Mc bandwidth of the panoramic display approximately 0.4 second.

Intercept-Probability Studies

A study of the intercept probability of the AN/APR-9 panoramic indicator for various types of signals is now in progress at this Laboratory. Data compiled thus far for pulse-type signals show a marked decrease in intercept probability for a given signal level when the pulse repetition frequency is decreased to values approaching the panoramic scan rate. The narrow bandwidth (0.7 Mc) of the panoramic signal channel and poor response of the vertical video amplifier results in the attenuation of short-duration pulses.[2] The narrow bandwidth is favorable for longer pulses due to the effective improvement of the signal-to-noise ratio.

Experience has shown that if an operator sees a signal on the panoramic indicator when the receiver is being tuned, the tuner mechanism can frequently not be stopped until after the signal has left the receiver passband. If the signal is of an intermittent nature considerable time may be required to relocate it. Continuous visual monitoring of the panoramic presentation rapidly causes operator fatigue. Blinking of the eyes or a brief glance at the receiver controls may permit signals to pass by unnoticed.

This Laboratory has considered several possible methods of increasing intercept probability. A means has been devised for automatically stopping the AN/APR-9 r-f tuner mechanism when a signal intercept is received and before the signal has left the receiver passband.[3] The frequency recorder recently built at this Laboratory is intended primarily to aid the operator by displaying signal intercepts which might otherwise be missed, by enabling accurate retuning of the receiver to any previously intercepted signal, and by producing a permanent record of all signal-intercept frequencies. The recorder, as well as the automatic stop device, utilizes the wide-band video output which contains all signals present in the 20-Mc bandwidth of the receiver i-f.

Although various signal recorders have been used previously with lower frequency-range receivers, several of the techniques employed in the use of the present recorder with the AN/APR-9 receiver (including the writing circuit, the step paper advance and the servo-controlled sector scan) are believed to be new. The recorder is a laboratory model intended for use in the evaluation of a signal-recording technique employed with the AN/APR-9 receiver.

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[2] Bullock, G. M., "Investigation of Certain Mechanical and Electronic Characteristics of Radar Set AN/APR-9," (Confidential), NRL Letter Report C-3940-164A/49, Figure 2, 6 December 1949

[3] Markell, J. H., "Airborne Automatic Search and Jam - Receiver Control C-719 (XB-2)/APR-9," (Confidential), NRL Letter Report C-3940-69A/50, 7 August 1950

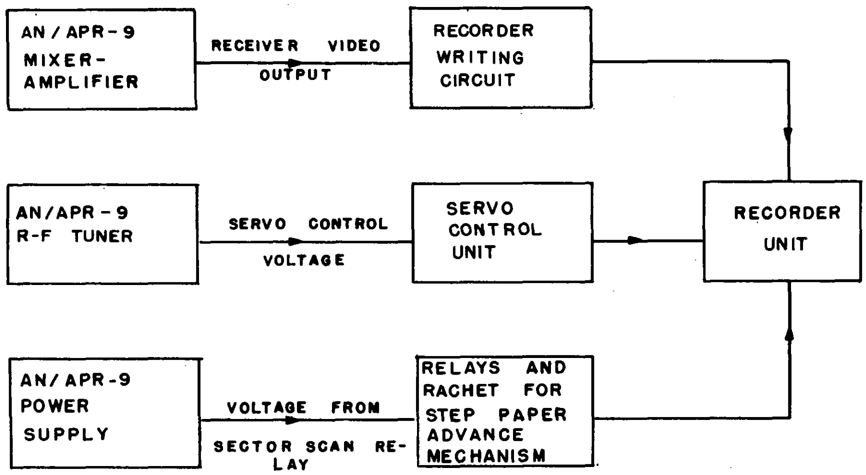

Figure 1 - Block diagram showing basic components of the signal-frequency recorder with associated components of the AN/APR-9 receiver

COMPONENTS OF THE AN/APR-9 SIGNAL-FREQUENCY RECORDER

Basic components of the AN/APR-9 signal-frequency recorder are a recorder unit, a recorder writing circuit, a servo-control unit, and a step paper-advance mechanism (Figure 1).

Recorder Unit

The recording medium is six-inch-wide Teledeltos paper, which is marked by an electrical discharge from the writing stylus through the paper to a conducting roller (Figure 2). The total band coverage is plotted across about five inches of the recording-paper width, with frequency increasing from left to right. In the recorded sample (Figure 2) radio-frequency tuner TN-129 with a band coverage from 2.30 to 4.45 kilomegacycles was used and the receiver was continuously sector scanning from 2.50 to 3.83 kilomegacycles. The receiver and recorder gain controls were turned up rather high so the effect of random noise is shown. The weak, narrow-beam 2.8-kMc radar was intercepted only occasionally and was missed by the panoramic indicator observer until the recorder indicated the presence of the signal and the receiver tuner was stopped at the recorded frequency.

Recorder Writing Circuit

The wide-band video output from the AN/APR-9 mixer-amplifier (Figure 3) is fed to a potentiometer which controls the writing sensitivity and is normally adjusted so the receiver noise output is faintly visible as light random dots on the recording. Since the video output is of rather low level it is amplified by two conventional video amplifiers (V-101 and V-102) utilizing 6AU6 tubes. Two stages of amplification are used in order to achieve a positive output polarity.

This positive signal is applied to the grid of the first triode section of a 12AT7 tube (V-103A). This triode is operated as a cathode follower with both resistance and capacity (1.5 megohms and 0.005 microfarad) in the cathode circuit (Figure 3). The cathode condenser was limited in capacity to a value which would permit it to reach about 60 percent of full charge when maximum cathode current existed for about one microsecond. The cathode resistor was chosen sufficiently high so that the condenser would maintain a reasonable portion of its charge when subjected to recharging rates as low as 50 cps. The

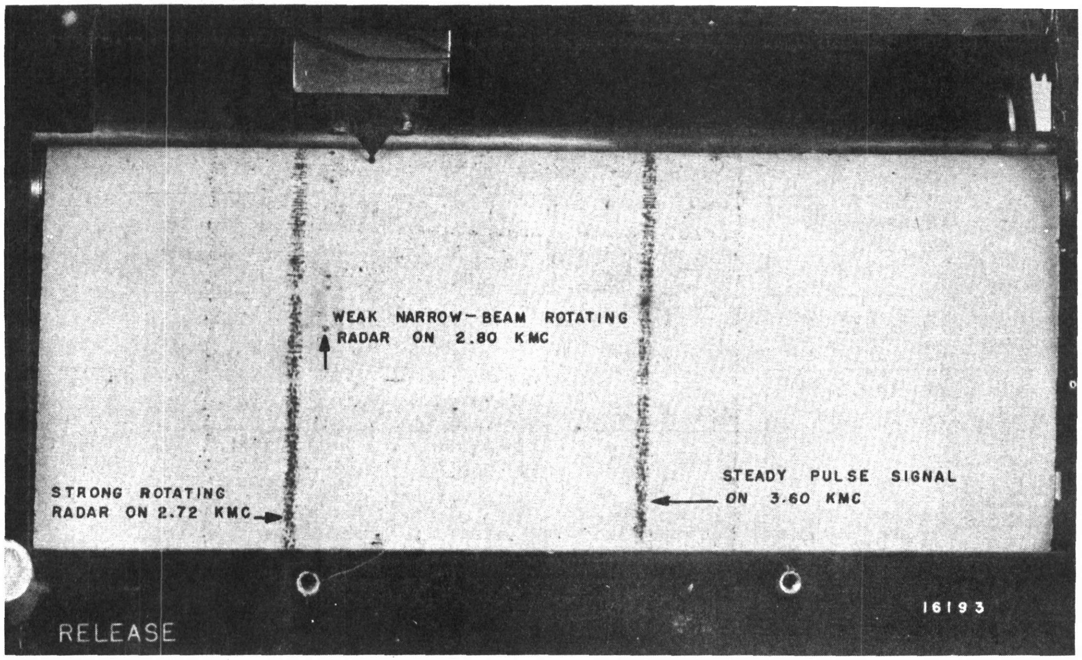

Figure 2 - Front panel of recorder unit showing writing stylus, recording paper, and typical signal-frequency recordings

charging and discharging time constants of the cathode circuit thus determine the shortest pulse and/or lowest pulse repetition frequency to which the circuit will respond. However, when the charge time is made extremely short and the discharge time is made extremely long, random high noise spikes are given excessive emphasis and are easily mistaken to be signals. The values used were determined empirically by observing recordings of various pulse widths and pulse repetition frequencies in the presence of noise.

The second triode of the 12AT7 (V-103B) is operated as a conventional cathode follower and serves as a driver for the 2D21 thyratrons (V-104 and V-105) which control the stylus writing current. The 800-cycle power line used to operate the AN/APR-9 receiver is also used, with a step-up transformer, to furnish the thyratron plate supply. Direct-current coupling is used between V-103A and V-103B and between V-103B and the thyratrons, because a given frequency remains within the 20-Mc receiver passband for a period of about 0.4 second, when the receiver is being tuned. An intercept of a steady signal produces a recorded mark about one-sixteenth inch in length. Strong signals produce a somewhat longer mark.

The minimum AN/APR-9 signal-input levels required to produce clear signal-frequency recordings of pulsed signals having unusually short pulse lengths and low repetition frequencies were determined (Figures 4 and 5). When the pulse repetition frequency was maintained at 60 cps and the pulse width was decreased from 1.0 to 0.5 microsecond, a 3-db signal strength increase was required. However, when the repetition frequency of the 0.5-microsecond pulse was increased (values of pulse repetition frequency well above 60 cps are normally associated with signals having 0.5-microsecond pulse widths) the 3-db sensitivity loss was regained. When pulse widths were made greater than one microsecond and/or repetition frequencies were made greater than 60 cps there was

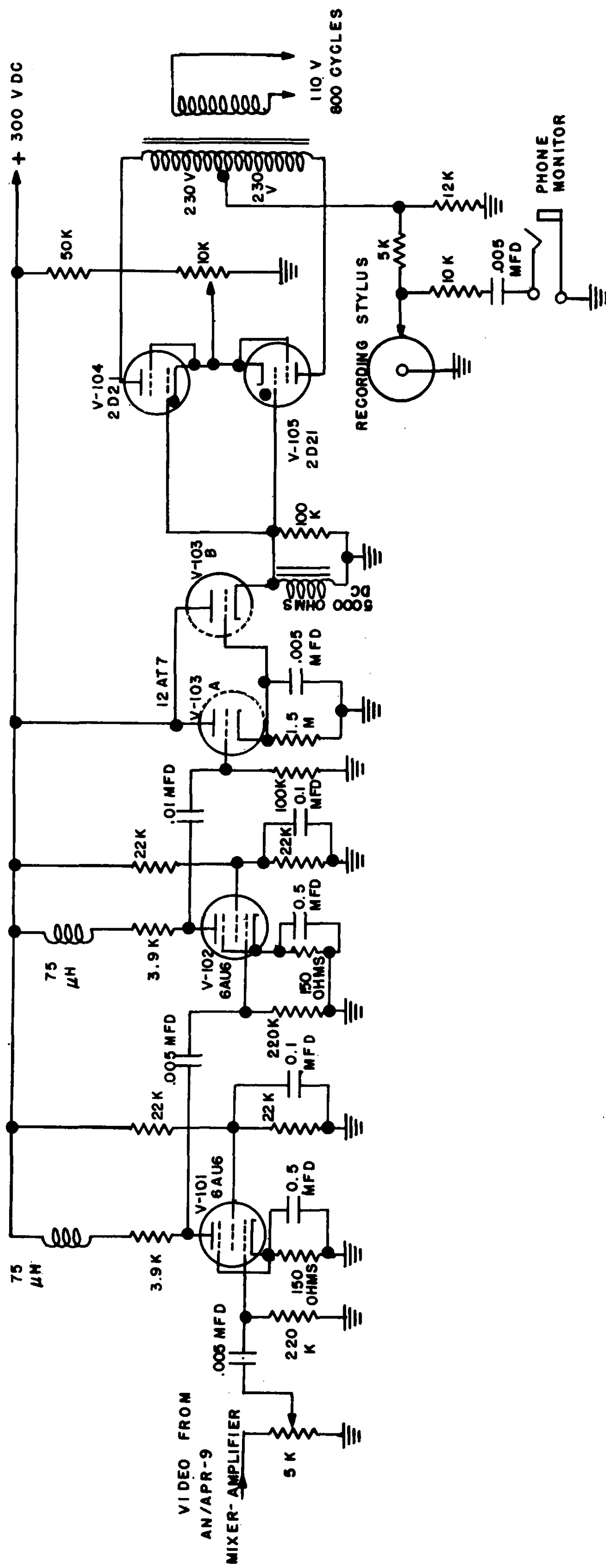

Figure 3 - Schematic diagram of writing circuit for AN/APR-9 signal-frequency recorder

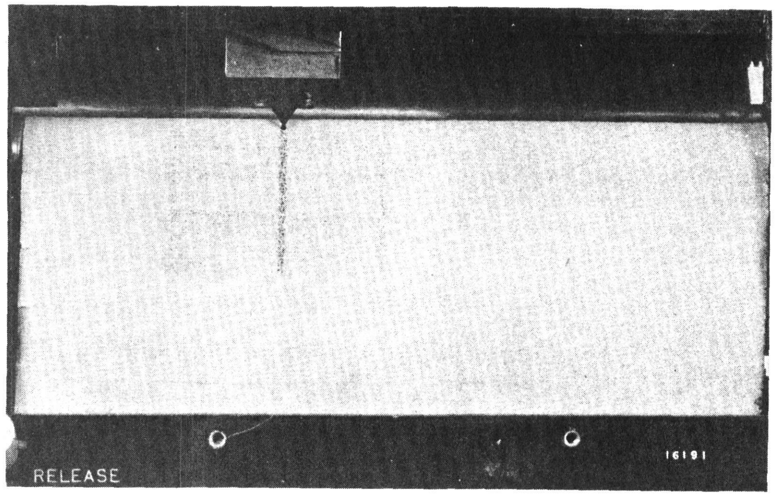

Figure 4 - Recording of a pulsed signal having a frequency of 3.0 kMc, a pulse width of 0.5 microsecond and a pulse repetition rate of 60 cps. The signal-input level to the AN/APR-9 receiver was 47 db below one milliwatt

no appreciable change in required signal input levels. A pre-production model of the AN/APR-9 receiver was used when the above measurements were performed and some variation of results is to be expected if other receivers are employed since considerable variation in signal-to-noise ratio has been noted in different AN/APR-9 receivers.

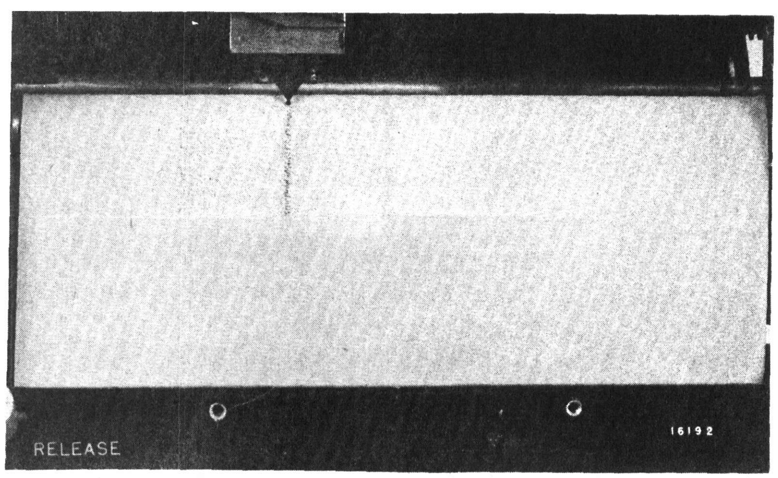

Figure 5 - Recording of a pulsed signal having a frequency of 3.0 kMc, a pulse width of 0.5 microsecond and a pulse repetition rate of 60 cps. The signal-input level to the AN/APR-9 receiver was 50 db below one milliwatt

Servo-Control Unit

The shaft of a ten-turn 30,000-ohm potentiometer (Figure 6) is connected to the tuner-mechanism shaft already present at the front panel of the radio-frequency tuner. No drilling of the tuner panel was necessary. The regulated, 105-volt, positive, direct-current source from the AN/APR-9 power supply is connected across both this potentiometer and a reference potentiometer mechanically connected to the stylus drive. A direct-current control voltage proportional to the radio-frequency tuner position is then obtained from the arm of the first potentiometer and a direct-current servo-feedback voltage is obtained from the arm of the second potentiometer. These two voltages are then fed to a modulator circuit which produces an alternating-current output having an amplitude proportional to the difference in magnitude of the direct-current control voltages and undergoing a 180-degree phase reversal when the polarity of the direct-current difference voltage is reversed. This alternating-current control signal goes through conventional voltage and power amplifiers and is used to energize one phase of the two-phase ac control motor. The other motor phase is energized by the power line. The gear ratios used between the control motor, the feedback potentiometer and the writing stylus are given on the diagram (Figure 6).

The tracking error of the servo system is less than 0.1 percent (about 2 Mc) of the frequency-band coverage of the radio-frequency tuner. This rather high tracking accuracy enables the operator to tune any previous intercept within the 20-Mc passband of

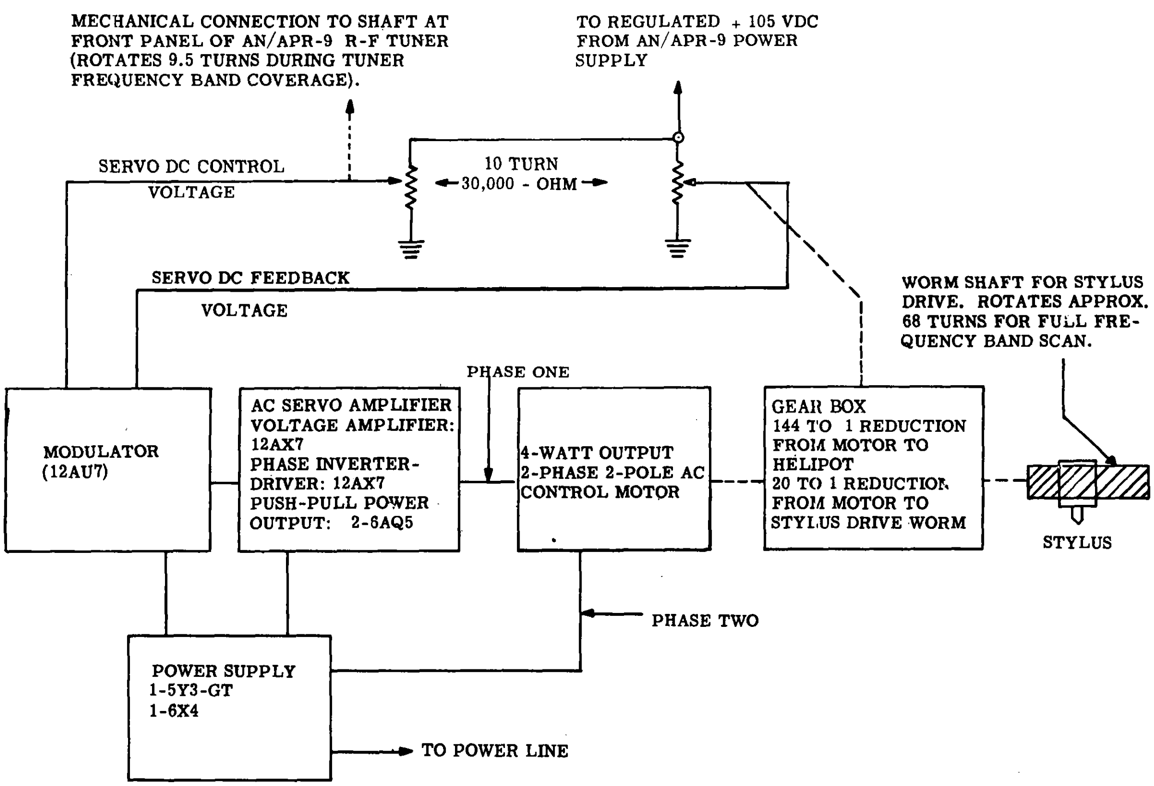

Figure 6 - Detailed block diagram of servo-control unit for writing stylus of AN/APR-9 signal-frequency recorder

the panoramic indicator by observing when the writing stylus is directly over the recorded mark.

Step Paper-Advance Mechanism

A constant recording-paper pulling speed was considered to be unsatisfactory since the time required to record one frequency scan or line can vary as much as one hundred to one depending upon the width of the frequency sector being observed. A constant-speed paper movement would also not provide proper spacing for consecutive lines in the regions where reversal of the scan direction occurs. The automatic step method used (Figure 7) advances the recording paper one line (about 0.015 inch) when the AN/APR-9 radio-frequency tuner automatic sector scan reverses direction. The paper advances one line when the manual-auto scan switch is operated but does not advance during manual operation of receiver scan, thus enabling the operator to set the stylus accurately to a noted intercept and observe the signal on the panoramic indicator or employ analysis equipment.

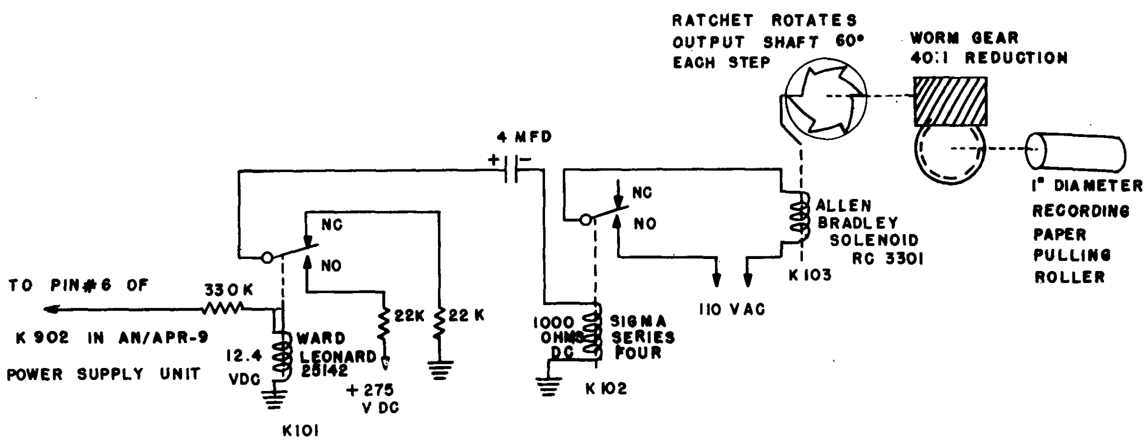

Figure 7 - Automatic step-advance mechanism for recording paper

Relay K-101 (Figure 7) alternately opens and closes with successive scan reversals, and relay K-102 closes momentarily during each scan reversal thus energizing solenoid K-103 which advances the ratchet one step.

CONCLUSIONS

The signal-frequency recorder system is considered quite satisfactory for its intended use in studies to investigate the value of a signal-frequency recording technique when employed with the AN/APR-9 receiver. Numerous trials have shown that an operator can consistently retune the receiver to a recorded intercept with sufficient accuracy so that the signal appears on the panoramic indicator.

Frequency calibrations have been omitted from the recording paper because a separate frequency scale is required for each of the four AN/APR-9 radio-frequency tuners.

A scale properly calibrated for the tuner in use can be employed to determine the frequency, with a maximum error of about one percent of the tuner band coverage.

This experimental recorder system was constructed as a laboratory model and basic mechanical components of an available commercial recorder were adapted for use in order to reduce machine-shop work. The requirements of a compact and rugged military version of the system were kept in mind, however, and served as a guide for the choice of tube types and circuitry. The development of a prototype model should include consideration of other types of recording media, as the Teledeltos paper has poor visual contrast and the voltage required for marking varies somewhat at different points on the paper. The ease of attaching the recorder to the AN/APR-9 receiver should also be given further consideration. The laboratory model requires a video signal from one of the mixer-amplifier front-panel outlets, the attachment of a potentiometer to the radio-frequency tuner front panel, and the paper-advance control voltage and the regulated 105-volt direct current from the receiver power supply. It is believed the development of a prototype model should include placement of the regulated direct-current supply in the recorder power supply, and consideration of methods of obtaining the paper-advance control from direction reversals of the servo mechanism or its associated circuit voltages.

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