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AN IMPROVED RANGE ERROR DETECTION SYSTEM FOR MK 50 SIMULTANEOUS LOBING RADAR

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AN IMPROVED RANGE ERROR DETECTION SYSTEM FOR MK 50 SIMULTANEOUS LOBING RADAR

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UNCLASSIFIED

December 12, 1949

Approved by:

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ABSTRACT

A description is given of a range error detection system with a high degree of noise balance, wide frequency response, and output stability, to improve the automatic tracking stability of the MK 50 Simultaneous Lobing Radar. Parallel, cascade gates and a differential transformer are used to achieve a d-c noise balance of nearly 40 db. A relatively low impedance, drift-free output without the use of a cathode follower or d-c amplifier is obtained with a single wide-gate output. Bench tests of the system are shown and analyzed.

PROBLEM STATUS

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

AUTHORIZATION

NRL Problem R12-01D
NO 284-609

AN IMPROVED RANGE ERROR DETECTION SYSTEM FOR MK 50 SIMULTANEOUS LOBING RADAR

INTRODUCTION

In an automatic fire control radar such as the Mk 50, it is desirable that after target acquisition the radar track the target automatically in range as well as bearing and elevation.

The mechanism of automatic range tracking is as follows: The range unit generates a range gate which selects the desired target. The target selected is passed into a time discriminator which detects any time or range differential between the range gate and the target, developing a range error signal which is fed back to the range unit to maintain the range gate on the target.

There are many methods by which range error detection may be accomplished; the systems are familiar to those concerned with such problems and therefore will not be enumerated here. Experience with most conventional error detection systems has shown them to possess inherent limitations that render them unsuitable for the degree of stability and performance required by the Mk 50. These limitations are for the most part due to long-time instability of d-c amplifiers, nonlinearity of gates at low signal levels, and unequal noise distribution during the gating interval. The range error detection system to be described here was designed to minimize or eliminate these limitations. A block diagram of the complete system is shown in Figure 1.

DESCRIPTION

Figure 2 is a schematic diagram of the Mk 50 range error detector system. This system is composed of an early and late gate, whose output is passed into a differential transformer which develops from its inputs an error video. The amplitude of the error video is a function of the degree of range error, and the polarity is a function of the gate which holds the target video. The output of the differential transformer is amplified and drives a long gate. This final gate develops a ± d-c voltage which may be used to drive the range error modulator directly.

Video Amplifier

The radar video entering this system is of low level (+0.5 volts), and as such must be amplified before use in the error detector. The video amplifier, consisting of tubes V_{13}, V_{14}, and V_{15A}, was designed to have two stages of amplification giving a gain of 38.5 db and a bandwidth of 6.0 Mc. The design of this amplifier is conventional and no further

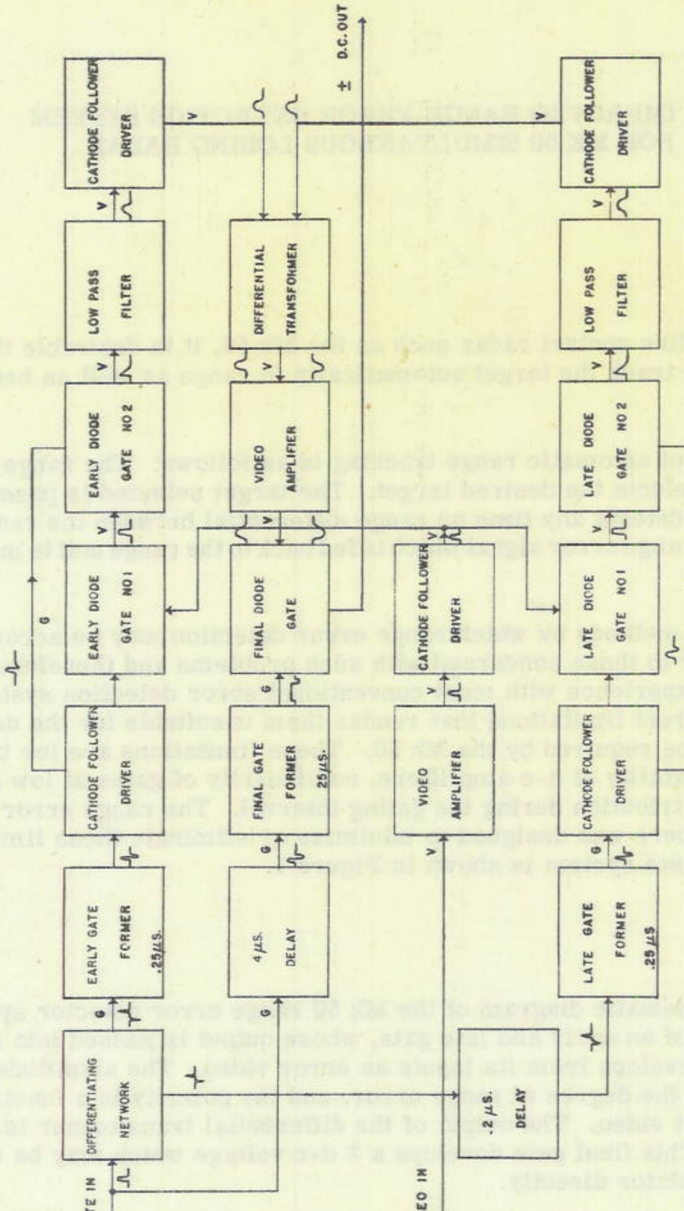


Figure 1 - Block diagram of Mk 50 range error detector

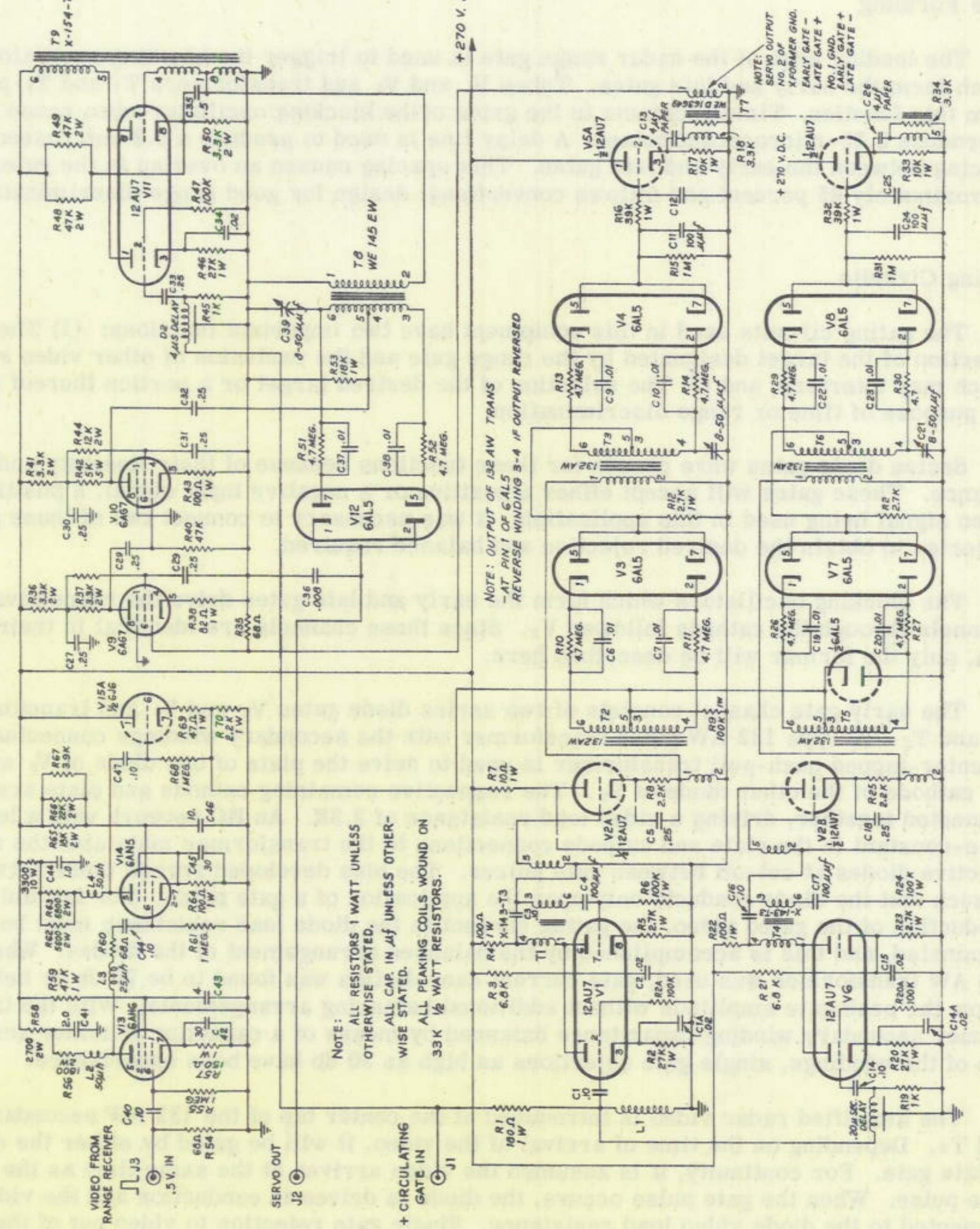


Figure 2 - Range error detector

explanation is believed necessary. The video amplifier is followed by a cathode follower driving the early and late gates.

Gate Forming

The leading edge of the radar range gate is used to trigger the blocking oscillators which form the early and late gates. Tubes V_1 and V_6 and transformers T_1 and T_4 perform this function. Time constants in the grids of the blocking oscillator tubes cause them to produce 0.25-microsecond pulses. A delay line is used to produce a 0.2-microsecond spacing between the early and late gates. This spacing causes an overlap in the gates of approximately 25 percent and follows conventional design for good range discrimination.

Gating Circuits

The gating circuits used in this equipment have two important functions: (1) The selection of the target designated by the range gate and the exclusion of other video signals which may interfere; and (2) The selection of the desired target or a portion thereof for the purpose of time or range discrimination.

Series diode gates were chosen for these functions because of their linearity and balance. These gates will accept either a positive or a negative input signal, a positive video signal being used in this application. It was necessary to connect two of these gates in series to obtain the desired rejection and balance required.

The blocking oscillators which form the early and late gates drive the respective gate channels through the cathode follower V_2. Since these channels are identical in their operation, only the former will be described here.

The early gate channel consists of two series diode gates V_3 and V_4 and transformers T_2 and T_3. A Type 132 AW pulse transformer with the secondary windings connected as a center-tapped push-pull transformer is used to drive the plate of one diode of V_3 and the cathode of the other diode of V_3. The respective remaining cathode and plate are connected together, driving a video load resistance of 2.2K. An RC network with a long time-constant in the plate and cathode connections to the transformer maintains the respective diodes at cut-off between gate pulses. The bias developed across these networks is such that the diode conducts only upon the application of a gate pulse. For faithful reproduction of the gated video, the gating current in the diode load resistance must be eliminated, and this is accomplished by the balanced arrangement of the diodes. When a 132 AW transformer was used, gate current cancellation was found to be 20 db or better below the peak gate amplitude without additional balancing arrangements. With the transformer secondary winding capacitance balanced by means of a capacitor trimmer across one of the windings, single gate rejections as high as 30 db have been experienced.

The amplified radar video is introduced at the center tap of the 132 AW secondary T_2 and T_5. Depending on the time of arrival of the video, it will be gated by either the early or late gate. For continuity, it is assumed the video arrives at the same time as the early gate pulse. When the gate pulse occurs, the diode is driven to conduction and the video is connected to the diode video load resistance. Single gate rejection to video out of the gate pulse interval is approximately 20 db below the peak video amplitude without balancing arrangements. With balancing arrangements such as for the gate pulse, video rejection as high as 25 db may be obtained.

The video appearing across the diode load resistance of this first gate is fed into another gate system V_4 and T_3 and is again gated by the early gate pulse. The action of this second gate is identical with that of the first gate except that the load for the second diode gate consists of an RC network with a 100-microsecond time constant that stretches the video pulse to approximately 100 microseconds. This system of gating provides gate pulse rejection as great as 50 db and ungated video rejection of 40 db or better. These diode gates have been found to be quite linear over a 40-db range of video input with the video levels used.

Differential Transformer

The stretched video output of both the early and late gate is of positive polarity separated only by a time difference. In order to derive a positive or negative error video (dependent upon which gate the video is in), it is necessary to invert one channel and take the algebraic difference of the two channels. This may be done with a differential amplifier with a single-ended output or a video transformer.

Several forms of differential amplifiers were tried but none was found to be satisfactory for the degree of balance and linearity required in this system.

A search of video transformers was made and the Western Electric type D-163649 video transformer (T_7) was found to be suitable. When properly loaded, this transformer passes the 100-microsecond error video without appreciable distortion and, what is most important, its separate windings are very well balanced so that no additional balancing arrangements are necessary. Unfortunately, the output impedance of this transformer is low (70 ohms) so that there is a step-down of the video voltage from the primary (3300 ohms) to the secondary. This loss of video signal is compensated by a two-stage class A video amplifier following the transformer. It should be pointed out that this transformer was used because of its availability during development of this system and does not represent the final solution to the transformer problem.

The two transformer primary windings are connected in phase opposition. One winding is driven by the early gate channel through a cathode follower V_{5A} and produces a positive video signal in the secondary of the transformer, while the late gate channel produces a negative output in the transformer secondary. Thus the algebraic difference of the two gate channels appears across the transformer secondary, the polarity of the voltage difference depends on which gate holds the video, and the amplitude of the error video depends on the time differential between radar video and the early and late gates.

Error Video Amplifier

The error video amplifier, consisting of tubes V_9 and V_{10} is designed to pass a 100-microsecond pulse and has an over-all gain of approximately 40 db. The output of the error video amplifier drives the final gate directly.

Error Video Gate Forming Blocking Oscillator

The final gate is keyed by a 25-microsecond blocking oscillator pulse. The blocking oscillator V_{11} and T_9 is keyed by the range gate which is delayed 4 microseconds by a delay line, thus permitting the final gate pulse to operate on the peak of the error video. The action of this blocking oscillator is conventional, and it has an 80-volt output which drives the error video gate directly.

Error Video Gate

A large charging condenser was used in the output in order to obtain a relatively low output impedance. In this way the range drive modulator could be driven directly from this unit and the necessity for a d-c amplifier was eliminated. This condenser was made as large as possible while maintaining the frequency response of the system. A 0.008 microfarad condenser was found to be an optimum value with regard to output impedance and frequency response, and the long charging time (25 microseconds) enabled the condenser to be charged to the peak value of the error video while maintaining the frequency response.

The action of the diode gate V_{12} and T_8, is identical with the early and late gates except that in place of a video load, a condenser is used, making it a boxcar circuit.

The transformer T_8 used in this gate is a 145 EW pulse transformer and requires a capacity trimmer across one of the secondary windings to balance the gate current as well as the video.

PERFORMANCE DATA

Performance specifications for the range error detector were set forth by experience gained from Mk 50 system tests. These specifications required a noise balance of 40 db or better as a S/N of 1, a bandpass of 100 cps, and an output voltage of ± 20 volts.

The following table lists the results obtained in laboratory bench tests performed on this range error detector at a pulse repetition rate of 1000 pps.

Noise balance (S/N = 1) = > 40 db

Frequency response = 0 - 100 cps

Output voltage (+0.5V input) = ± 30 volts d. c.

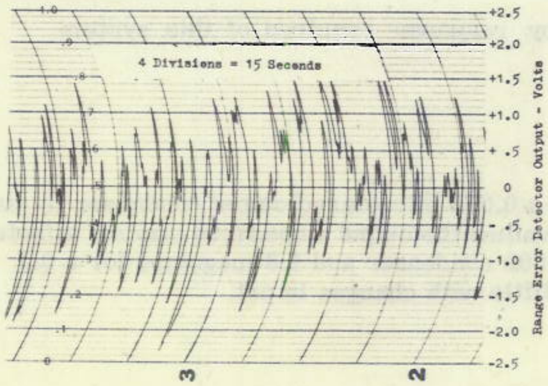
Output impedance = 2 megohms.

Noise Balance

A high degree of noise balance is necessary to prevent the radar from "running away" on noise. This noise balance should have short-time, as well as long-time stability, to prevent range drift. Figures 3 and 4 are recorder charts showing the short- and long-time stability of this unit for an S/N ratio of unity. An average value of noise unbalance was determined by subtracting the positive and negative areas above and below the balance point. From the resultant area the average d-c unbalance was computed for both short- and long-time periods. In both cases the noise balance was better than 40 db. Noise balance is unaffected by changes in prf. There is, however, a d-c unbalance with changes in prf but this may be corrected by readjustment of the balance condenser.

Frequency Response

Frequency response curves for different output charging condenser values are shown in Figure 5. As can be seen from these curves, a 0.008 microfarad charging



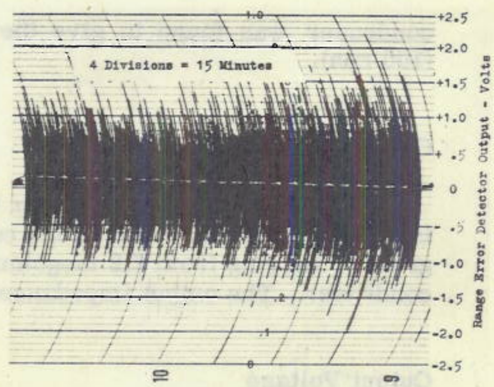


Figure 3 - Recorder charts showing short-time stability of the Mk 50 range error detector

Figure 4 - Recorder charts showing long-time stability of the Mk 50 range error detector

Note: Dotted line shows zero axis shift due to drift in recording instrument.

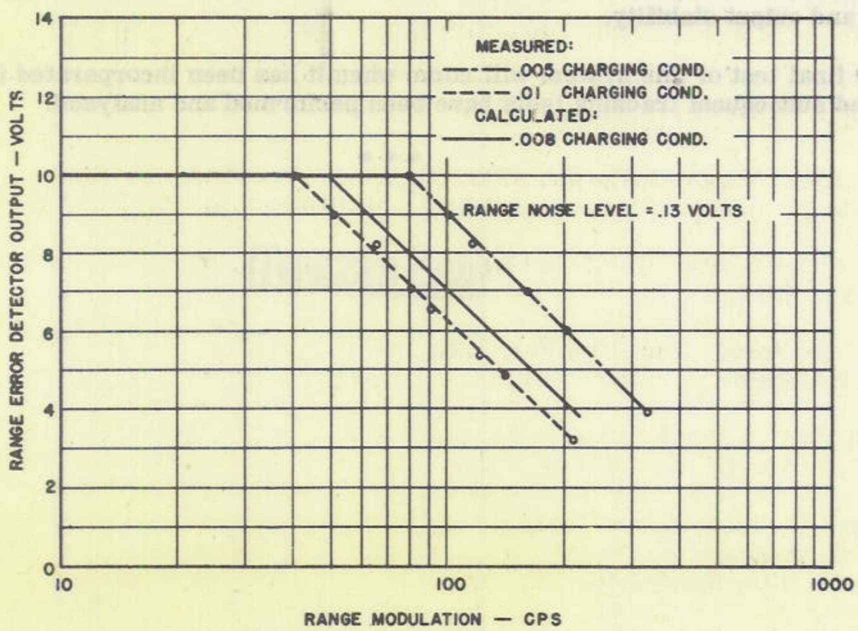


Figure 5 - Frequency response of Mk 50 range error detector

condenser was found to give the frequency response required of this system (100 cps).

Output Impedance

The output impedance of this unit when a 0.008 microfarad output condenser is used is about 2 megohms. For other condenser values the output impedance was not affected greatly, varying from 2.2 megohms for a 0.005 condenser and 1.8 megohms for a 0.1 condenser. The output impedance changes little with changes in prf.

Output Voltage

For a 0.5 volt video input signal, the output voltage was ± 30 volts d.c. at 1000 pps.

The output voltage changes about 10 percent with changes in prf of ± 500 pps.

CONCLUSIONS

The range error detector described here fulfills the specifications set forth by Mk 50 system tests under laboratory test conditions. It is superior in performance to the former Mk 50 range error detection method in that it has a higher degree of noise balance and output stability.

The final test of this system will come when it has been incorporated into the Mk 50 radar and subsequent tracking tests have been performed and analyzed.

* * *