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NRL REPORT NO. R-3109

EQUIPMENT FOR MEASUREMENT OF RADAR AREA OF V-2 ROCKET

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EQUIPMENT FOR MEASUREMENT OF RADAR AREA OF V-2 ROCKET

by

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ABSTRACT

A system for quantitative measurement of the peak signal amplitude of the individual pulses of reflected energy from a radar target is described in detail. In this system each echo pulse returned from the target is lengthened and made rectangular in shape. The amplitude of these lengthened pulses determines the position of a spot on an oscilloscope, which is photographed on a continuously-moving film. This equipment has been operated successfully in a determination of the radar area of V-2 missiles at White Sands Proving Ground, New Mexico.

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EQUIPMENT FOR MEASUREMENT OF RADAR AREA OF V-2 ROCKET

INTRODUCTION

The Wave Propagation Research Section of Radio Division I and the Search Radar Section of Radio Division II have been actively engaged in the development of equipment for the measurement of radar area. Recently this equipment was applied to radar observations of the V-2 missiles being fired at the White Sands Proving Ground, New Mexico. This report describes the equipments which have been developed and the measurement techniques which have evolved; later reports will present analyses of the data which have been obtained.

REQUIREMENTS OF SYSTEM

From a target such as the V-2 Rocket, it is probable that, due to spinning, tumbling, or vibration of the rocket, variations in missile aspect will occur and cause rapid variations in the signal strength of the returned echo. It was decided that the overall time constant of the equipment measuring the echo should be short enough to permit an examination of the "modulation envelope" formed by successive echoes returned from the missile. This requires equipment which will record photographically, from an oscilloscope presentation, the amplitude of each pulse. This special radar apparatus will be referred to in this report as "pulse-to-pulse" equipment. Ordinary motion picture methods were considered undesirable because of the large amount of film required. Instead, each pulse of the radar echo is converted to a spot on an oscilloscope, the horizontal position of the spot being determined by the amplitude of the echo. The oscilloscope is photographed on a film which moves continuously in a vertical direction, thus separating the spots and giving a pulse-by-pulse record of the radar echo amplitude. In order to obtain sufficient exposure of the film it was found desirable to lengthen the returned echo pulse and to make it rectangular in shape.

Further, in order that the valleys and peaks of the modulated echo might be studied without successive adjustments of the receiver gain control, it was necessary to employ an i-f system in the equipment with a dynamic range greater than the 20 to 25 db range found in the normal radar receiver-indicator. The pulse-to-pulse equipment, as designed, employs an i-f amplifier with a dynamic range of approximately 50 db.

In addition to the continuously-moving-film pictures. conventional 35-mm motion pictures of the type "A" monitor oscilloscope are taken. These pictures enable discernment of pulse amplitude change during the length of a single pulse. This information could not be obtained from the pulse-to-pulse record as this system records only the peak amplitude of each pulse.

FUNCTIONAL DESCRIPTION OF EQUIPMENT

A block diagram of the pulse-to-pulse system appears in Figure 1.

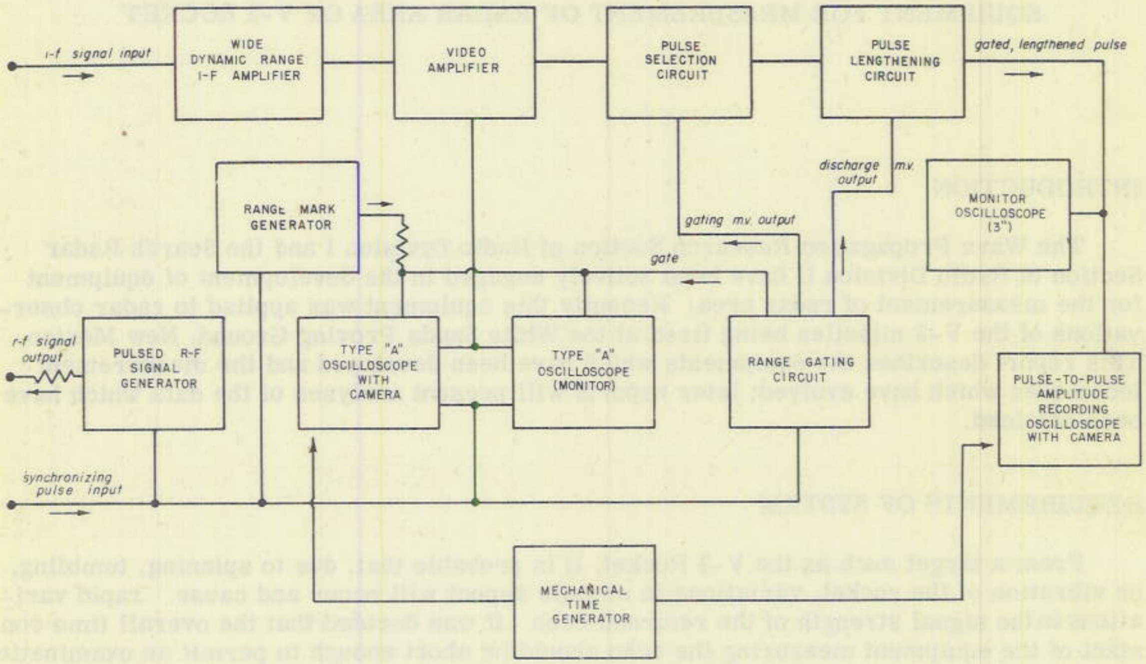

Figure 1. Block diagram of pulse-to-pulse system.

This equipment requires a synchronizing pulse from the radar keying circuit, and an i-f signal output from a stage beyond the receiver converter. The point at which this i-f signal is obtained must be one at which saturation does not occur for signals as great as 50 db above minimum detectable signal.

The i-f signal is amplified in a radar i-f amplifier which has been modified to have a dynamic range of 50 db, and which has a detector circuit that is linear for low signal-input levels. The output of this detector is amplified in a two-stage video amplifier.

The amplified video signal divides into three paths. One path is to a normal type "A" oscilloscope used for tracking by the operator. The second path is to another type "A" oscilloscope which is photographed by a 35-mm motion picture camera operated at 12 frames per second. The third path is to the "pulse-selection" or "gating" circuit. Since the pulse-lengthening circuit will operate on any signal at its input, it is necessary to select by a range-gating circuit the particular echo-pulse which is to enter this lengthening circuit. Only this gated echo-pulse is present at the output of the range-gating circuit. The range-gating circuits which control the pulse-selection circuit also place a gate or notch on the type "A" monitor oscilloscope to enable the operator to tell which echo is being selected.

This gated video pulse is transformed in the pulse-lengthening circuit into a rectangular pulse several-hundred microseconds wide, with an amplitude corresponding to the peak of the video pulse at the input of the circuit.

The output of the pulse-lengthening circuit splits into two paths: one is to a conventional 3-in. oscilloscope employing a slow-sweep speed, used to monitor the output of the system; the other path is to the horizontal plates of the pulse-to-pulse amplitude recording oscilloscope. This oscilloscope does not employ a sweep; the presentation is a spot which moves horizontally each time a pulse is received, for a distance proportional to the amplitude of that pulse.

Recording of the position of this spot is made by the use of a continuously-moving-film camera whose lens is permanently open. As the film moves vertically and the spot horizontally, the picture on the film consists of a vertical "base line", formed by the spot during the intervals between echo pulses, and a series of dots at a distance, to the left of the base line, determined by the amplitudes of the received echo pulses. The base line appears to be unbroken, instead of dashed as would be expected; the gap which should occur in this line each time the spot is deflected is apparently masked on the film by the "fogging" effect of the bright spot. An example of this type of presentation on film may be seen in the photograph of Figure 2.

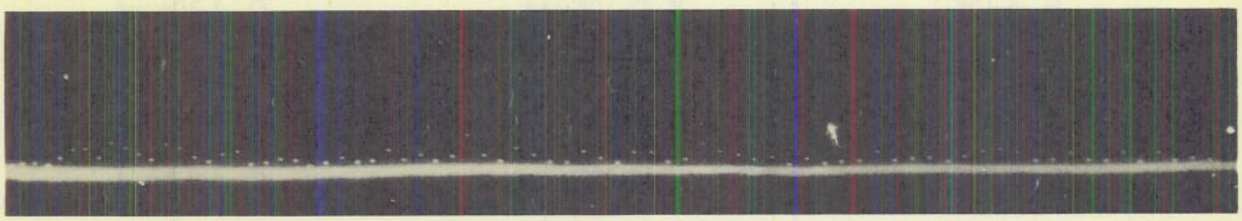

Figure 2. Pulse-to-pulse recording.

Range markers every 100 microseconds, produced by a pulsed generator, are placed on both type "A" oscilloscopes to provide a range calibration. Accurate information on the position as a function of time for the missiles fired at White Sands has been provided by the Aberdeen Proving Ground group. They obtain this information by recording range, azimuth, and elevation from a Signal Corps Engineering Laboratory SCR-584 radar used in conjunction with a beacon in the rocket.

In order to correlate the signal-amplitude data obtained by the pulse-to-pulse equipment with the accurate position data, one-second time markers, started the instant the rocket is fired, are placed on both the A-scope camera film and on the pulse-to-pulse camera film. Small neon bulbs, flashed every second by a mechanical timing device, are placed in front of both cameras in the plane of the cathode-ray tube. Each bulb is placed inside a block of black bakelite through which a small hole is drilled. This affords a concentrated source of light, with no reflections, which is recorded on the film as a small spot.

The output of a pulsed r-f signal generator, such as the Navy LAF or LAE, synchronized by the radar, is fed into the r-f input of the radar receiver (as shown in Figure 1) through a suitable decoupling network. This signal generator is used for calibration of the equipment.

CIRCUIT DESCRIPTION

A complete circuit diagram appears in Figure 3, with a parts list given in Table I. The method used in the White Sands tests for obtaining the i-f signal from the radar receiver is also shown.

In order to obtain a dynamic range of 50 db in the pulse-to-pulse equipment, modifications were made on a normal radar i-f amplifier employing type 6AC7 tubes. The 160-ohm cathode resistors were replaced with 1000-ohm resistors, R_1, R_2, R_3, R_4, and the cathode bypass condensers were removed. Sufficient degeneration was thus produced to

PARTS LIST

Table 1

R 1 1K	R 23 .056K	R 46 4.7K
R 2 1K	R 24 100K	R 47 4.7K
R 3 1K	R 25 .056K	R 48 50K pot
R 4 1K	R 26 100K	
R 5 10K	R 27 10K pot	C 1 30mmf
R 6 27K	R 28 82K	C 2 30mmf
R 7 25K	R 29 100K	C 3 0.5mfd
R 8 27K	R 30 27K	C 4 0.5mfd
R 9 2.4K	R 31 500K	C 5 0.25mfd
R 10 27K	R 32 30K pot	C 6 500mfd
R 11 not used.	R 33 56K	C 7 0.25mfd
R 12 27K	R 34 2.2K	C 8 0.25mfd
R 13 4.7K	R 35 200K pot	C 9 0.01mfd
R 14 .56K	R 36 2.7K	C 10 0.005mfd
R 15 10K	R 37 3.3K	C 11 350 mmfd
R 16 3.3K	R 38 56K	C 12 0.01mfd
R 17 56K	R 39 2.2K	C 13 0.002mfd
R 18 10K	R 40 25K	C 14 0.25mfd
R 19 56K	R 41 2.2K	C 15 0.25mfd
R 20 10K	R 42 330K	C 16 500mfd
R 21 2.2K	R 43 100K	C 17 0.01mfd
R 22 100K	R 45 30K	C 18 0.25mfd

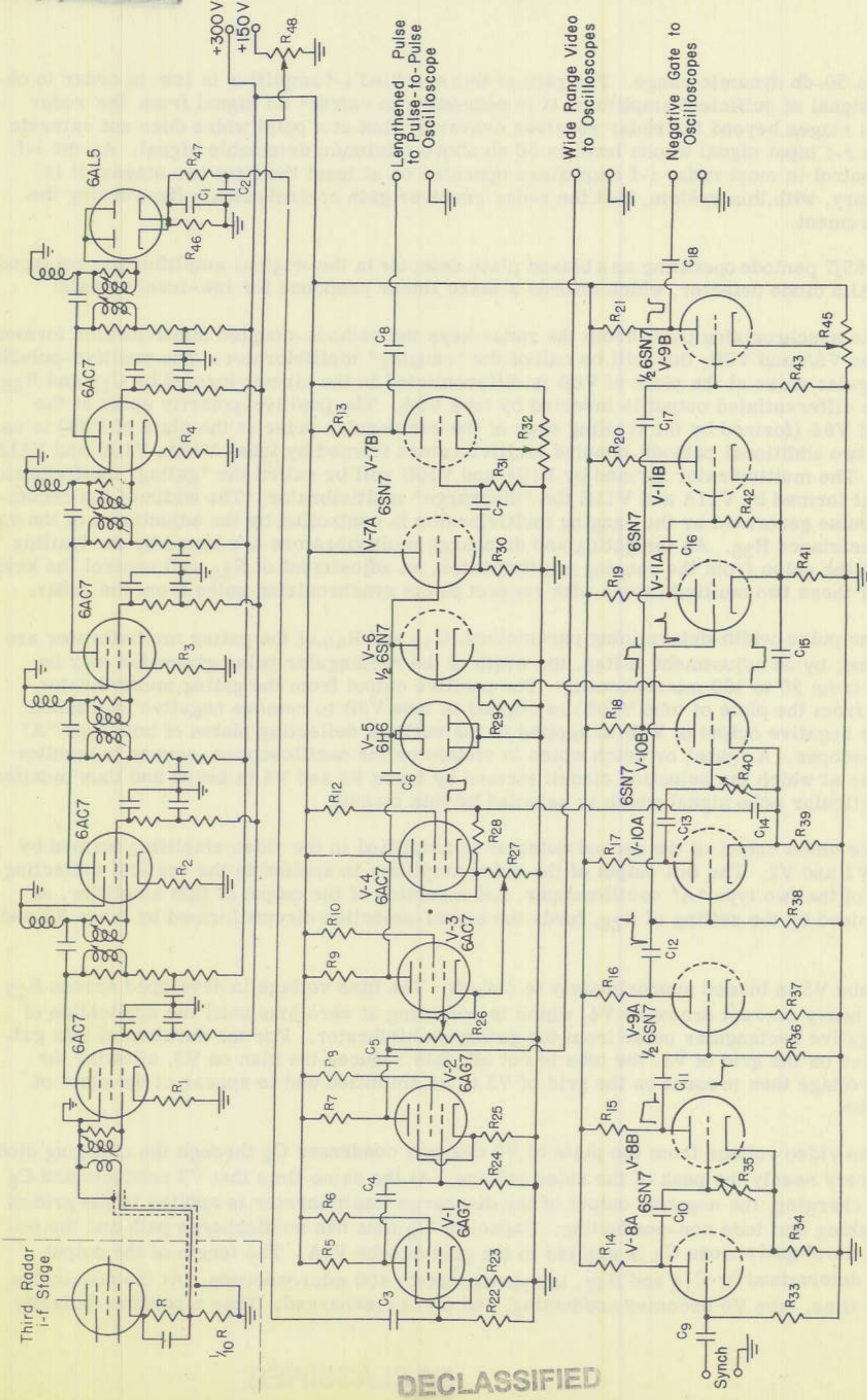

Figure 3. Complete circuit diagram

yield a 50-db dynamic range. The gain of this modified i-f amplifier is low; in order to obtain a signal of sufficient amplitude, it is necessary to extract i-f signal from the radar several stages beyond the radar receiver converter, but at a point which does not saturate with an r-f input signal whose level is 50 db above minimum detectable signal. As the i-f gain control in most radar i-f amplifiers operates on at least the first two stages, it is necessary, with this system, that the radar receiver gain control remain fixed during the measurement.

A 6SJ7 pentode operating as a biased plate detector in the original amplifier was replaced by a 6AL5 diode detector, which affords a more linear response for low-level signals.

The synchronizing pulse from the radar keys the cathode-coupled multivibrator formed by tubes V8A and V8B; this will be called the "ranging" multivibrator. The positive-polarity rectangular pulse at the plate of V8B is differentiated in the circuit formed by C_{11} and R_{36}, and the differentiated output is inverted by tube V9A. The positive-polarity spike at the plate of V9A (formed by the trailing edge of the rectangular pulse at the plate of V8B) is used to key two additional cathode-coupled multivibrators formed by tubes V10A, V10B and V11A, V11B. The multivibrator formed by V10A and V10B will be called the "gating" multivibrator, and that formed by V11A and V11B the "discharge" multivibrator. The width of the rectangular pulse generated by the ranging multivibrator is controlled by the adjustment of the variable resistance R_{35}. As the gating and discharge multivibrators are keyed by the trailing edge of the pulse from the ranging multivibrator, an adjustment of R_{35} will control the keying time of these two multivibrators with respect to the synchronizing pulse from the radar.

The pulse-width-determining parameters, C_{13} and R_{40}, of the gating multivibrator are such that, by an adjustment of R_{40}, the width of the rectangular pulse generated may be varied from 20 to 100 microseconds. The positive output from the gating multivibrator (taken from the plate of tube V10B) is clipped in tube V9B to remove negative overshoot, and the negative output of V9B is applied to the vertical deflecting plates of both type "A" oscilloscopes. A "gate" or notch which is visible on the oscilloscopes serves to monitor the time at which the selection circuit formed by tubes V3 and V4 is keyed and thus monitors the particular echo signal which is selected by this circuit.

The video output of the second detector is amplified in the video amplifier formed by tubes V1 and V2. The full output of the video amplifier is applied to the vertical deflecting plates of the two type "A" oscilloscopes, and a portion of the output of this amplifier, as determined by the setting of R_{26}, feeds the signal-selection circuit formed by tubes V3 and V4.

Tube V3 is biased approximately to cut-off. The bias voltage is developed across R_{27} by the heavy current drawn by V4, which is operating at zero bias until the application of the negative rectangular pulse from the gating multivibrator. For the duration of this gating pulse on the grid of V4, the tube is cut off; this reduces the bias on V3, allowing the video voltage then present on the grid of V3 to be amplified and to appear at the plate of that tube.

The video voltage from the plate of V3 charges condenser C_6 through the charging diode V5 to very nearly the peak of the video voltage. At the same time that V3 conducts and C_6 starts charging, the negative output of the discharge multivibrator is applied to the grid of V6, making that tube non-conducting. Capacitor C_6 thus has no discharge path and the potential developed across C_6 is applied to the grid of tube V7A. The length of the output pulse, determined by C_{16} and R_{42}, is approximately 400 microseconds. At the conclusion of this time, tube V6 becomes conducting, and C_6 is discharged. Thus a positive-polarity rectangular pulse of 400 microseconds width, and of a magnitude proportional to the magnitude of the video pulse charging C_6, is applied to the grid of V7A.

The output of the cathode follower feeds the clipper stage V7B, which removes the negative overshoots on the output pulse. The output of the clipper stage feeds the "Y" amplifiers of the pulse-to-pulse amplitude-recording oscilloscope, which is a standard Dumont 208-B oscilloscope with the tube rotated 90° to permit the use of the "vertical" amplifiers for horizontal deflection.

OPERATING PROCEDURE

As has been mentioned previously, to obtain a high-level input signal the i-f input to the pulse-to-pulse system is taken from a point as many stages past the radar-receiver converter as the requirement of a 50-db dynamic range will permit. This equipment has been installed on two radar systems, the SCR-270-DA and the AN/TPS-1B, and in both cases the output was obtained across an unbypassed resistor inserted in series with the original cathode-bias resistor of the third i-f stage in the radar receiver. This added resistance should be very small in comparison with the cathode-bias resistor, in order that the normal operation of the radar be unimpaired. If, due to the requirements of the radar operator using the main oscilloscope of the radar, the i-f amplifier must be operated at a high gain, this point may have to be changed in order to assure a 50-db dynamic range at the pulse-to-pulse system input. When the gain of the radar i-f amplifier has been set and the point of input chosen, the pulse-to-pulse-system i-f gain may be adjusted to obtain a desired dynamic range.

Potentiometer R_{26}, which controls the level of video signal at the selection circuit, is adjusted so that the dynamic range is not limited by tube V3; i.e., the signal should not approach saturation in V3 before it approaches saturation in the i-f amplifier.

Tube V3 is operating approximately at cut-off bias due to the voltage developed across R_{27}. This potentiometer is adjusted so that the voltage developed across it during the gating pulse is just above cut-off bias for tube V3, so that a small current flows through the tube, and, due to cathode coupling with the gating stage V4, an amplified gate appears at the plate of tube V3. This gating is lengthened in the pulse-lengthening circuit and appears in the output. Adjustment of R_{27} so that the lengthened gate pulse just raises over the base line adjusts the system for zero signal input, and indicates that the bias on tube V3 is correct.

Potentiometer R_{32} which controls the clipping level of tube V7B, is adjusted to clip all negative overshoots of the output pulse.

Potentiometer R_{45}, which controls the clipping level of tube V9B on the gating monitor pulse, is adjusted to clip all negative overshoots of the gate pulse, and may be used to control the height of the monitor gate on the type "A" oscilloscopes.

The film speed in the pulse-to-pulse recording camera is set so that each dot produced in the pulse-lengthening circuit is resolved. This speed is thus dependent upon the radar pulse-repetition frequency. The intensity of the spot on the oscilloscope must be adjusted for different rates of film travel and film speeds. For example, using Eastman Super XX film, a pulse rate of 320, a Dumont 208-B oscilloscope with a P5(blue) screen, and a lens speed of f/1.5, a film speed of four inches per second gives satisfactory resolution, and a proper exposure is obtained with the oscilloscope intensity control set for approximately half brilliance.

The system herein described has been operated in conjunction with the SCR-270-DA and AN/TPS-1B radars at White Sands Proving Ground, N. M. The completed pulse-to-pulse equipment was installed in the maintenance van of SCR-270-DA Number 2 operated by the Army Air Forces at Hueco Site, New Mexico.

Measurements taken indicate that the equipment functions satisfactorily for the measurement of radar area. Film records obtained during firings of the V-2 missile are being analyzed, and later reports will contain the results of these measurements.

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