NRL REPORT 3925

A NEW RECEIVER-COMPUTER FOR STACKED-BEAM HEIGHT-FINDING RADARS

T. H. Chambers

Search Radar Branch
Radio Division II

January 24, 1952

NAVAL RESEARCH LABORATORY

WASHINGTON, D.C.

CONTENTS

ABSTRACT

Although the target-elevation-angle receiver-computer for the AN/SPS-2 stacked-beam height-finding radar is satisfactory from an electrical standpoint, it is too large and complicated for installation on smaller ships and aircraft. A new receiver-computer system greatly reduced in complexity, size, and weight is being developed for the AN/SPS-13 and the airborne surveillance radars.

The center-of-gravity principle of computing and its implementation in the new receiver-computer are discussed in this report. The computing method is also compared with the one used in the SPS-2 system to show that the strong signal performance of the two systems will be essentially the same.

Weak-signal performance of the new computer is also discussed, and it is shown that, although the basic computer is deficient in this respect, either of two modifications will bring its performance up approximately to that of the SPS-2.

Three test-model computers are described along with modifications necessary in the log receivers for two of these computers. Preliminary test results obtained on these test-model computers bear out the conclusion that their performance, both on weak signals and on strong signals, will approximate the performance of the SPS-2.

PROBLEM STATUS

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

AUTHORIZATION

NRL Problems R02-42 and R02-56
RDB Projects NA 050-511 and NL 412-010

Manuscript submitted December 12, 1951

A NEW RECEIVER-COMPUTER FOR STACKED-BEAM HEIGHT-FINDING RADARS

INTRODUCTION

A new type of receiver-computer is being developed for the measurement of target elevation angle in a stacked-beam height-finding radar.[1] Although the receiver-computer system developed for the AN/SPS-2 radar[2] possesses all the electrical characteristics desirable in the system, it is a rather large and complicated equipment and utilizes some 200 tubes in two different cabinets. If the stacked-beam height-finding radar is to be used on smaller ships and CIC aircraft, its size and weight must be reduced well below that of the SPS-2.

Although the ratio receiver,[3] the first simplified system investigated, showed promise of satisfactory performance and offered considerable simplification over the SPS-2 receiver-computer, it did not possess the inherent stability of the log receiver in the SPS-2 system[4]—an extremely important attribute for electronic equipment in military service.

The second simplified system investigated and finally adopted for use in the AN/SPS-13 and in the airborne surveillance radar is a combination of the logarithmic receiver and a new type of video computer. This new system operates on the center-of-gravity principle first proposed by the Air Force Cambridge Research Laboratory for the Volscan and Volir radars. It is, however, an improvement over these systems in two respects.* Computing is done only on the two or three strongest beams so that side-lobe errors are eliminated and noise errors are minimized; through the use of entirely different circuitry, system complexity is greatly reduced (from 60 or more tubes per beam to about 10 tubes per beam).

The new receiver-computer will use about 65 tubes for a seven-beam system while the SPS-2 uses approximately 200. Furthermore, instead of employing the 42 "screwdriver adjustments" and setup procedure of the SPS-2, the new computer will have only seven "screwdriver adjustments" which are made with the aid only of the continuous monitor system, without shutting down the equipment or applying a special setup procedure. The new system will, of course, retain the 14 log-receiver controls of the SPS-2 system.

---

[1] Varela, A. A., "Interim Report on AN/SPS-2 (XDQ) Radar System," NRL Report R-3313 (Confidential), July 14, 1948

[2] Herman, E. E., "The Elevation Angle Computer for the AN/SPS-2 Radar," NRL Report 3896 (Confidential), November 19, 1951

[3] Report of NRL Progress, p. 49, February 1951

[4] Chambers, T. H., "The High-Accuracy Logarithmic Receiver for AN/SPS-2," NRL Report 3848 (Confidential), August 17, 1951

*Refer to CREDITS, page 22.

ELEVATION-ANGLE COMPUTATION—STRONG SIGNALS

The basic problem of computing target elevation angle in the stacked-beam height-finder is one of instantaneously reducing a number of incoming signals (seven in the SPS-2 or SPS-13 systems or five in the airborne surveillance radar) to a single range-elevation-angle video. In the SPS-2 system, this reduction is accomplished by first selecting the two beams in which the target is strongest and then interpolating between them in accordance with the relative received signal strengths. Thus, the computation consists of the instantaneous solution of the equation

$$E_\theta = E_{\theta mn} + Ek_{\Delta\theta} \log \frac{e_n}{e_m} \qquad (1)$$

where

E_θ = the instantaneous voltage of the range-elevation-angle video,
$E_{\theta mn}$ = a pedestal voltage proportional to the crossover angle (or sine thereof) of the two beams receiving the strongest signals,
$Ek_{\Delta\theta}$ = a constant, expressed in volts, dependent on beam spacing, and
e_m and e_n = the received signal strengths of the two strongest beams.

Although the new computer is of the center-of-gravity type, the basic principles are exactly the same as in the SPS-2 system. To show this, let us consider the operation of the new computer. It measures target elevation angle by implementing the equation

$$E_\theta = Ir_{cg}, \qquad (2)$$

where

E_θ = the elevation-angle video voltage,
I = a constant current, and
r_{cg} = a resistance proportional to the elevation angle of the target (or the sine thereof).

The problem of elevation-angle measurement reduces to one of evaluating r_{cg}. This is done on the center-of-gravity basis as follows:

(a) Logarithmic receivers develop a video voltage proportional to the log of incoming signal strength; thus $E_j = E \log e_j$.
(b) A system of peak selectors selects the two or three strongest beams.
(c) A voltage E_a, representative of average signal strength in the selected beams, is subtracted from the selected log outputs; this voltage is so adjusted that $\sum_{\text{Selected } j\text{'s}} (E_j - E_a) = \text{constant}$.
(d) Each output is weighted in accordance with beam-center angle (or sine thereof).
(e) The weighted outputs are summed.

In the actual computer, steps (d) and (e) are not carried out by a series (addition) of separate weighted outputs, but rather, since superposition clearly applies, by passing appropriate portions of a constant current

$$\left[I = \frac{1}{R} \sum_{\text{Selected } j\text{'s}} (E_j - E_a) \right],$$

through appropriate taps on a single-tapped resistor which forms the weighting and summing network. In accordance with the above listed steps, we see that r_{cg} is given by the equation

$$r_{cg} = \sum_j \left(\frac{E \log e_j - E_a}{RI} \right) r_{\theta j} \qquad j \ni (E \log e_j - E_a) > 0$$

where

step (b) sets the limits of summation, and
step (c) sets the value of the constant E_a such that

$$\sum_j (E \log e_j - E_a) = RI \qquad j \ni (E \log e_j - E_a) > 0$$

and where

e_j = the signal strength from the j'th beam,

R = a fixed-value resistance which serves simply to make the term in the brackets dimensionless, and

$r_{\theta j}$ = the weight factor, in ohms, for the j'th beam.

Equation (2) may now be expanded to

$$E_\theta = I \sum_j \frac{(E \log e_j - E_a)}{RI} r_{\theta j} \qquad j \ni (E \log e_j - E_a) > 0 \qquad (2.1)$$

The similarity between this method of computing and the method used in the SPS-2 system may now be shown. If the summation is over two beams only, Equation (2.1) may be reduced to Equation (1) within a multiplying constant. In the two-beam case,

$$E_\theta = I \left[\frac{(E \log e_n - E_a)}{RI} r_{\theta n} + \frac{(E \log e_m - E_a)}{RI} r_{\theta m} \right]. \qquad (3)$$

But $r_{\theta n}$ and $r_{\theta m}$ are related to $E_{\theta mn}$ and $Ek_{\Delta\theta}$ because of the geometry of the antenna pattern; thus

$$r_{\theta n} = \frac{1}{I_1} \left(E_{\theta mn} + \frac{Ek_{\Delta\theta}}{2} \right), \text{ and}$$

$$r_{\theta m} = \frac{1}{I_1} \left(E_{\theta mn} - \frac{Ek_{\Delta\theta}}{2} \right),$$

where I_1 = a constant with the dimensions of a current.

Substituting these in Equation (3) and rearranging terms,

$$E_\theta = \frac{(E \log e_n - E_a + E \log e_m - E_a)}{R} \frac{E_{\theta mn}}{I_1} + \frac{(E \log e_n - E_a - E \log e_m + E_a)}{R} \frac{Ek_{\Delta\theta}}{2I_1}.$$

But, by step c, the terms in the first bracket are constrained to total I. Thus, this equation reduces to

$$E_\theta = \frac{I}{I_1} E_{\theta mn} + \frac{E^2}{2\,RI_1} k_{\Delta\theta} \ln \frac{e_n}{e_m}. \tag{3.1}$$

If constants are adjusted so that

$$I_1 = I, \text{ and}$$

$$R = \frac{E}{2I}.$$

Equation (3.1) becomes exactly the same as Equation (1).

The basic principle used in the new computer is thus exactly the same as the one used in the SPS-2 in a region where only two beams are used in the calculation. It can be shown that even when three beams are selected by the new unit, the method of computation is still similar to that of the SPS-2. In this case, the middle beam of the three selected acts as the pedestal while the outer two act as the source of interpolation voltage.

Because of this similarity, many of the strong-signal computation characteristics of the new unit may be deduced directly from the characteristics of the SPS-2 computer. In regions where the new computer selects only two beams, the computation method of the two units is effectively the same; thus, the errors may be expected to be the same. On the other hand, in the vicinity of a beam center, the SPS-2 computer has a region of uncertainty with regard to selection of a beam pair, but the new computer simply makes a smooth transition from one beam pair, through computation on all three beams, to the other beam pair. Thus, accuracy of the new computer may be expected to be slightly better in the vicinity of a beam center.

One further point should be brought out in connection with any discussion of system errors. It is strictly a practical point, but one of considerable importance in equipment for the military services. In the new unit, computation is actually made on the basis of a single, effective, elevation-angle voltage[5] instead of the pedestal-plus-the-interpolation voltage. The problem of gain equalization, with its attendant complexity of monitor system and setup procedure, is therefore eliminated.

The system has one other interesting feature. Since the peak selector used to choose the strongest beams is not constrained to select adjacent beams as in the SPS-2 computer, computation will continue even if a beam is lost owing to failure of some component ahead of the beam-peak selectors. Elevation-angle accuracy and detection range will, of course, be reduced over the range of elevation angles normally covered by that beam, but useful information will still be obtained. Repair or replacement of the defective unit may thus be made without complete loss of system performance.

---

[5] Since Equation (3.1) was obtained by mathematical manipulation, it does not correspond directly to the computation method shown by Equation (2) and therefore does not vitiate this statement.

ELEVATION-ANGLE COMPUTATION—WEAK SIGNALS

Whereas the previous section covered performance on strong signals, consideration will now be given to weak-signal conditions in which noise plays an important part.

In the absence of signal, the system will, like the SPS-2, compute fictitious elevation angles on the noise, but the distribution of these computed angles will be different from that for the SPS-2. The latter system is constrained to select and compute on a pair of adjacent beams. And since the probability of supplying the predominant instantaneous noise voltage is the same for each of the six pairs, computation will take place on each pair one-sixth of the time and the fictitious results will be approximately evenly distributed over the range of possible angles. As signal is introduced into one beam, the probability of selecting that beam will increase, and the number of computations on it and one or the other of its adjacent partners will increase; thus energy will be concentrated at a level corresponding to that beam.

In contrast, performance of the new computer in its simplest form is inferior in two respects. To operate properly on strong signals, the new computer will be set to "peak select out" only those channels which are some 12 to 16 db below the strongest channel. But the probability distribution curve for noise shows that the fluctuating noise voltage remains within a region only 10 db wide about 75 percent of the time. Thus, the probability is vanishingly small that any one channel will be 15 db above all other channels as required for operation of the peak selectors, and therefore the seven noise outputs of the seven receiving channels will be linearly mixed. This leads immediately to an approximate 8.5-db loss in sensitivity in the new computer as compared to the approximate 3-db loss[6,7] in the SPS-2.

Along with its loss in sensitivity, the new computer suffers a loss in accuracy even after the signal is strong enough to become visible. Because of the linear addition of noise from all seven sources, the fictitious elevation angles will have a Gaussian distribution centered at the system center of gravity (beam 4 in the 7-beam SPS-13 or beam 3 in the 5-beam airborne surveillance system). As signal is introduced into one channel, the system center of gravity will be shifted toward that channel, and the width of the distribution will be narrowed. It is possible, however, to get angle errors of more than a beamwidth on a minimum detectable signal for targets in beams 1 or 7. In contrast, the equivalent error in the SPS-2 computer averages about 1/4 beamwidth.

Together, these deficiencies mean that in its simplest form the computer will not perform well on signals less than about 12 db above noise. Such a deficiency is serious, but fortunately in this case it can be overcome. A study of the above shows that both losses result from the same cause, specifically, the failure of the peak selectors to operate on noise. This defect can be overcome either by using sharp peak selection on alternate beams or by noise accentuation.

The Alternate-Beam Sharp-Select Connection

In the alternate-beam sharp-select connection, the peak selectors are so interconnected and adjusted that a sharp selection among the even-numbered beams and among the odd-numbered beams is realized, while the selection ratio between the

---

[6] Lance, H. W., Peeler, G. D. M., and Randall, C. R., "Video Mixing and Minimum Detectable Signal in the SPS-2 Radar," NRL Report R-3123 (Confidential), September 1947

[7] This 3-db loss is composed of 1.6-db loss from the linear mixing of the noise from two channels and 1.4-db loss from the nonlinear mixing of six related pairs.

 [redacted]

selected-even and the selected-odd is maintained correct for strong-signal computation. A peak-select ratio of 4 or 5 db may be realized among the evens and among the odds with a simple, stable connection. Since this 4- or 5-db select ratio is sufficient to cause only a single channel of each group to be selected a large percentage of the time, mixing losses are reduced almost to the 3-db loss taken in the SPS-2 computer.[8]

In reference to the center-of-gravity error, as signal is introduced into the j'th channel, the probability is increased that this channel will be selected from its group so that the signal energy is concentrated at the video level equivalent to this channel. Although this reduces over-all system error, the resultant performance is not as good as in the SPS-2. Instead of being constrained to compute on the j'th channel and one or the other of its neighbors, as in the SPS-2, the new computer will compute on the j'th channel and any channel from the other set. This action is perhaps best visualized as computation on the j'th beam of one set and the center of gravity of the other set. Since this center of gravity will be approximately in the center of the coverage, it is clear that computing on weak signals in the higher and lower beams will be somewhat less accurate than in the SPS-2.[9]

In considering the effects of this modification of peak-select ratios on strong-signal computation, it is clear that there will be no effect for two-beam computing. Since two adjacent beams are utilized, they must obviously be one from each set, thus one even and one odd, and the computer is effectively unchanged. For a signal at beam center, computing is done under somewhat different conditions. Here computation is made on three beams, and interpolation voltage is obtained from the outer two. Since these two outer beams are of the same set, either both evens or both odds, the peak-select ratio between them is low and interpolation gain high. This, obviously, can introduce an error into the system. Fortunately, by adjusting the peak-select ratio between the two sets of beams to a level which allows three-beam computation over only a narrow range of angles (say one-tenth beamwidth), this error may be made extremely small.

It should be noted that a system using this type of connection cannot compute accurately with one beam out of operation. This is obviously true since the removal of one beam renders the grouping of evens and odds, established with all beams present, invalid.

The Accentuated-Noise Computer

A second method of securing improved performance on weak signals is through the use of accentuated noise; in this method, nonlinear video amplification is introduced between each log receiver and the computer. This amplification has a characteristic such that the gain to noise fluctuations is 3 or 4 times greater than the incremental gain to strong signals.

In operation, then, the 10-db fluctuation range of the noise will be presented to the computer at such a level that it appears as the equivalent of a 40-db fluctuation range. Since this is several times the peak-select ratio of the computer, a good nonlinear mix

---

[8] Since the 4- or 5-db select ratio is too broad to cause selection of only a single channel from each group 100 percent of the time, the loss will not be reduced to the 3-db level. For normal adjustment of the system, loss will lie between 3 and 4 db.

[9] Preliminary checks indicate a maximum error of perhaps one beamwidth on minimum detectable signal.

[redacted]

is obtained, and the mixing loss is reduced to between 2.5 and 3.0 db. Minimum detectable signal performance will then be equal to or better than that of the SPS-2 computer.

In regard to the weak-signal error, it is clear that as signal is introduced into one channel, the probability of selecting that channel will be increased, and computation will take place on that channel only.[10] The indicated elevation angle will be that of the nearest beam center so that the average weak-signal angle error will be one-quarter beamwidth, the same error expected from the SPS-2 computer.

The strong-signal performance of this computer type will be exactly as described earlier. Incremental gain to strong signals is normal, and the increased level caused by high, weak-signal gain is simply corrected by an automatic increase in E_a.

One strictly practical consideration should be mentioned in connection with this computer. The nonlinear video gain is not obtained through the use of a nonlinear video amplifier; instead it is obtained from a minor modification to the logarithmic receivers and is not expected to introduce stability problems.

THE TEST-MODEL RECEIVER-COMPUTER

The Logarithmic Receiver

The log receiver[11] (Figures 1 and 2) is a multistage receiver that uses nonamplified, back-biased i-f amplifiers to give the desired individual-stage limiting characteristics and to give detected outputs for summation in the normal manner for a successive-detection system. These receivers, designed for use in the SPS-2 system, not only

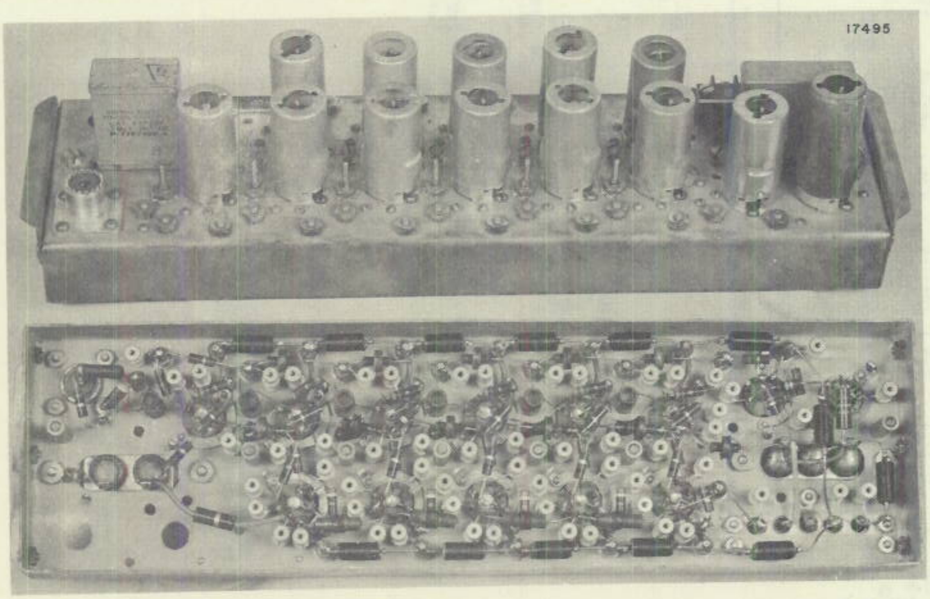

Figure 1 - The high-accuracy logarithmic receiver

[10] Attention is called particularly to the fact that computation is made here on one channel only and not on the adjacent channels of the SPS-2 or on the one channel and center of gravity of the alternate-channel sharp-select computer.

[11] These receivers are covered in detail by the author in NRL Report 3848, op. cit.

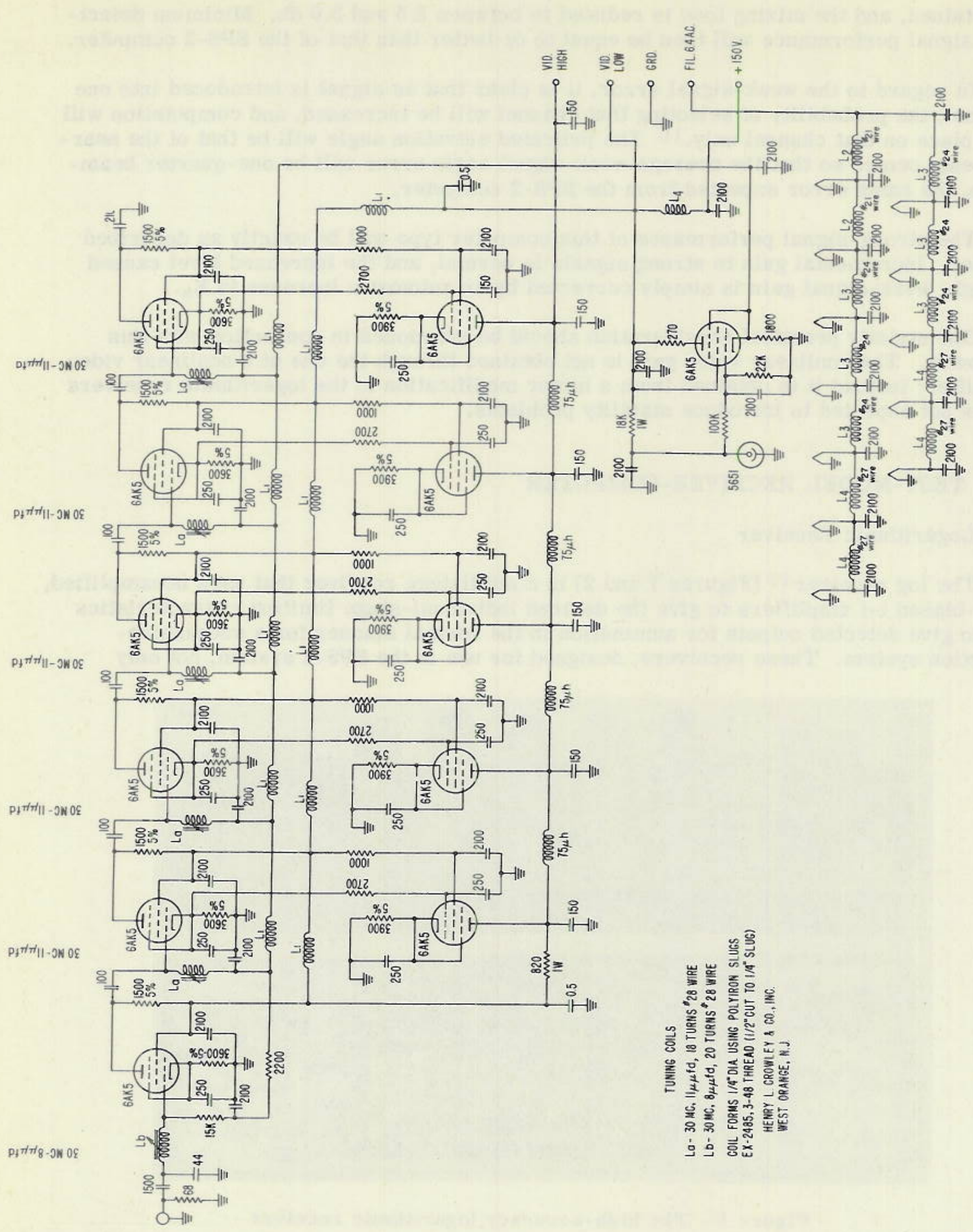

Figure 2 - Circuit diagram of the high-accuracy logarithmic receiver

develop the desired log characteristic with unusually good accuracy, but also have proved to be exceptionally stable and trouble-free. They were used, without modification, with the test model of the alternate-beam sharp-select computer.

The accentuated-noise computer depends for its action on an increase in the video gain for noise signals without any change in incremental gain to strong signals. Such a characteristic (Figure 3) is easily realized in the successive-detection log receiver.

If the gain to the low-level components of the last detected output of this receiver is increased by a factor of about 10 to 1, the characteristics will be those shown in Figure 4. It will be noted that this is exactly the characteristic desired for the accentuated-noise computer.

For the test-model computer, the increased gain was realized rather simply by raising the gain of the last pickoff tube to low-level signals. This was accomplished by connecting the cathode of this tube to the cathode of a crystal diode whose anode is returned to a low-impedance supply about two volts more positive than zero-signal cathode potential (Figure 5). Thus, for signal levels of two volts or less, the diode conducts, and the pickoff tube is degenerated in about 150 ohms (50 ohms crystal impedance plus 100 ohms source impedance) whereas for strong signals it is degenerated in 3600 ohms. This gives the desired gain ratio of about 10 to 1.

At first, some concern was felt for the effects of this change on the reliability and stability of the log strips, especially in view of the slightly different no-signal cathode potentials found in different strips. Figure 6 shows the characteristics of the seven

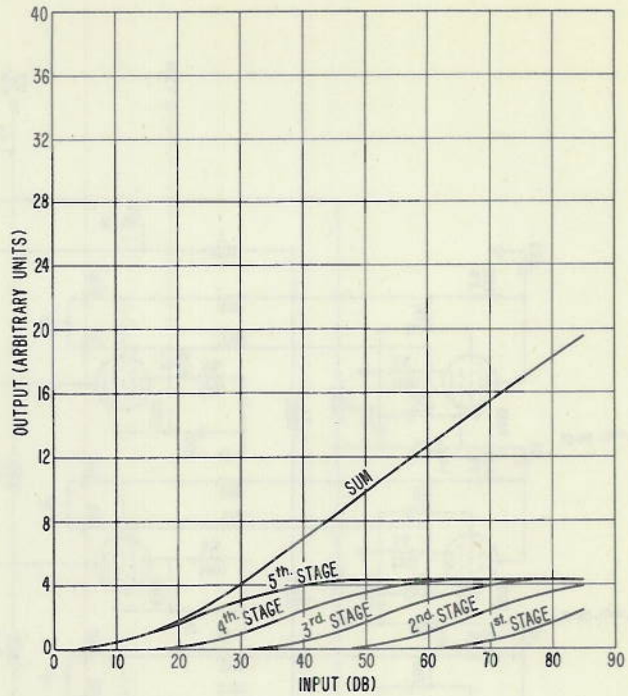

Figure 3 - Contributions of individual stages in a logarithmic receiver

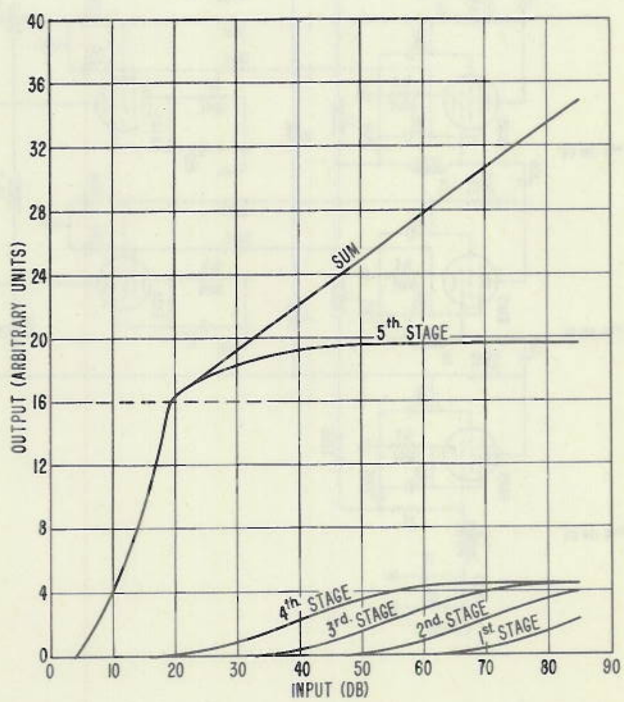

Figure 4 - Contributions of individual stages in the accentuated-noise logarithmic receiver

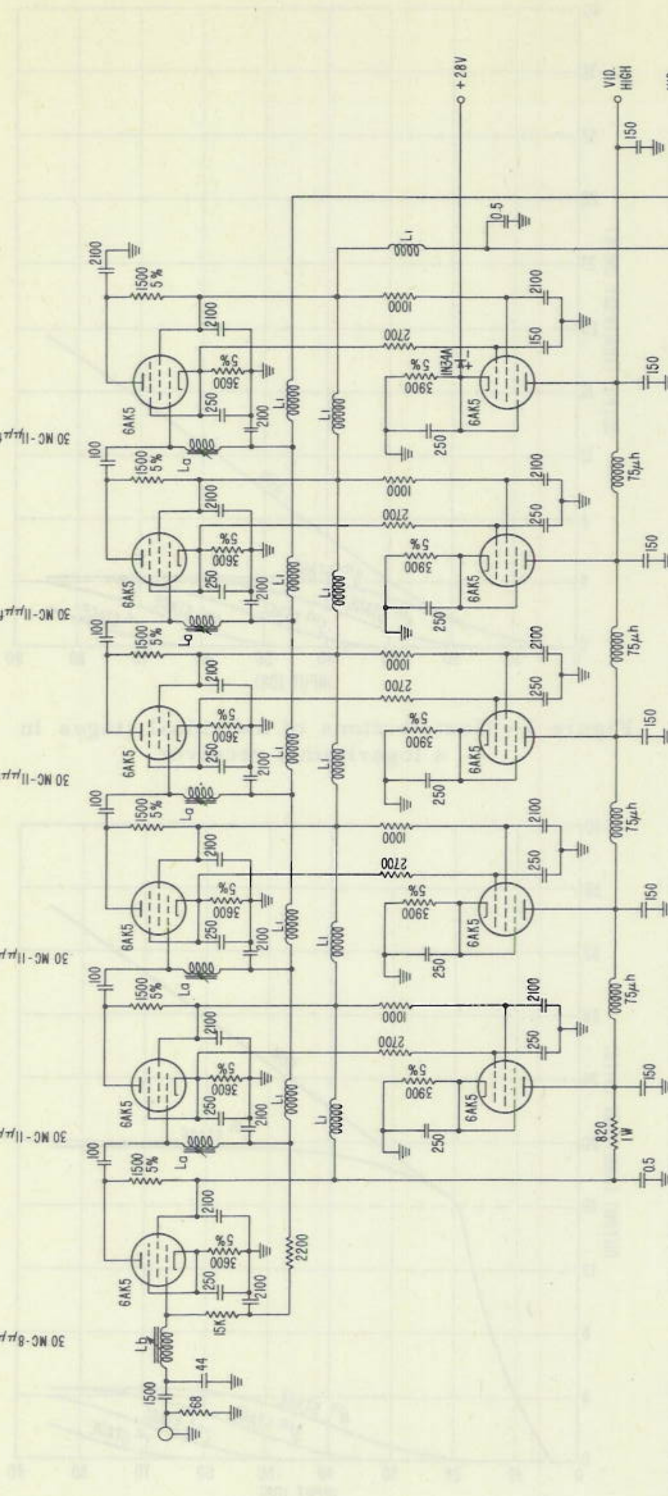

Figure 5 - Circuit diagram of the accentuated-noise logarithmic receiver

different strips converted for use in testing the accentuated-noise computer. It will be noted that variations are slight and of a character that can be corrected by the i-f and video-gain controls.

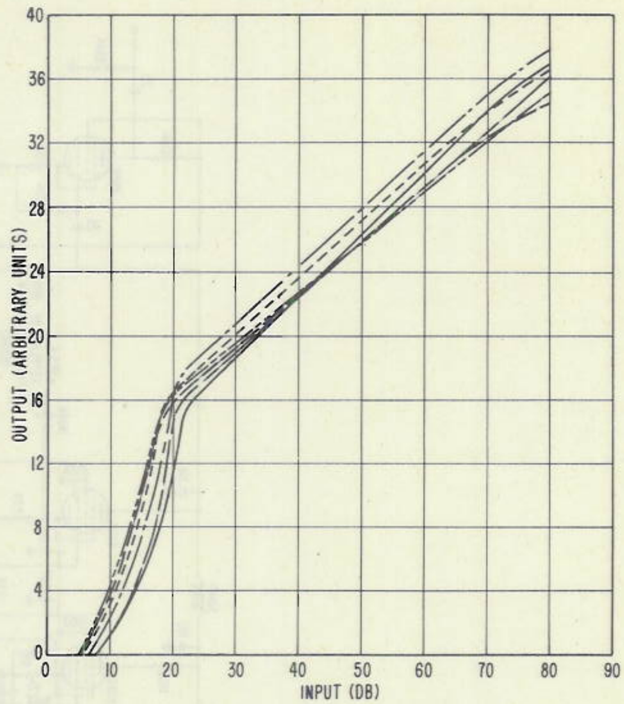

Figure 6 - Characteristics of seven accentuated-noise logarithmic receivers

As a prototype receiver for the SPS-13 system, a single test strip (Figures 7 and 8) was built in which all but the last pickoff tube were omitted. In this case, the summing delay line is placed directly in the plate circuits of the i-f amplifiers. The last pickoff tube was retained here so that the increased video gain at low-signal levels could be realized without upsetting i-f stage-to-stage symmetry. The cathode of this single pickoff tube was connected in exactly the same manner as before. This strip includes a single-stage video amplifier which raises the strip output level to about 15 volts positive and is intended to replace the video amplifiers included in the test-model computers. Thus, no preliminary video amplifier will be included in the final model computer. The characteristic output-input curve of this strip is shown in Figure 9.

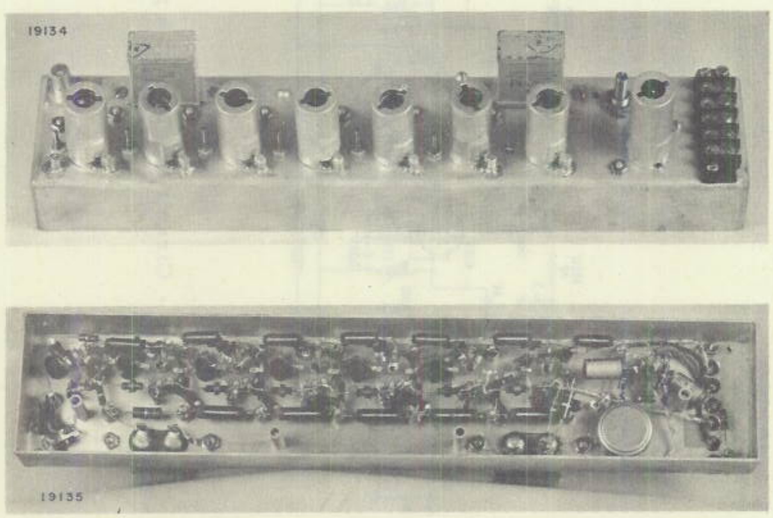

Figure 7 - Prototype accentuated-noise logarithmic receiver for SPS-13

 [redacted]

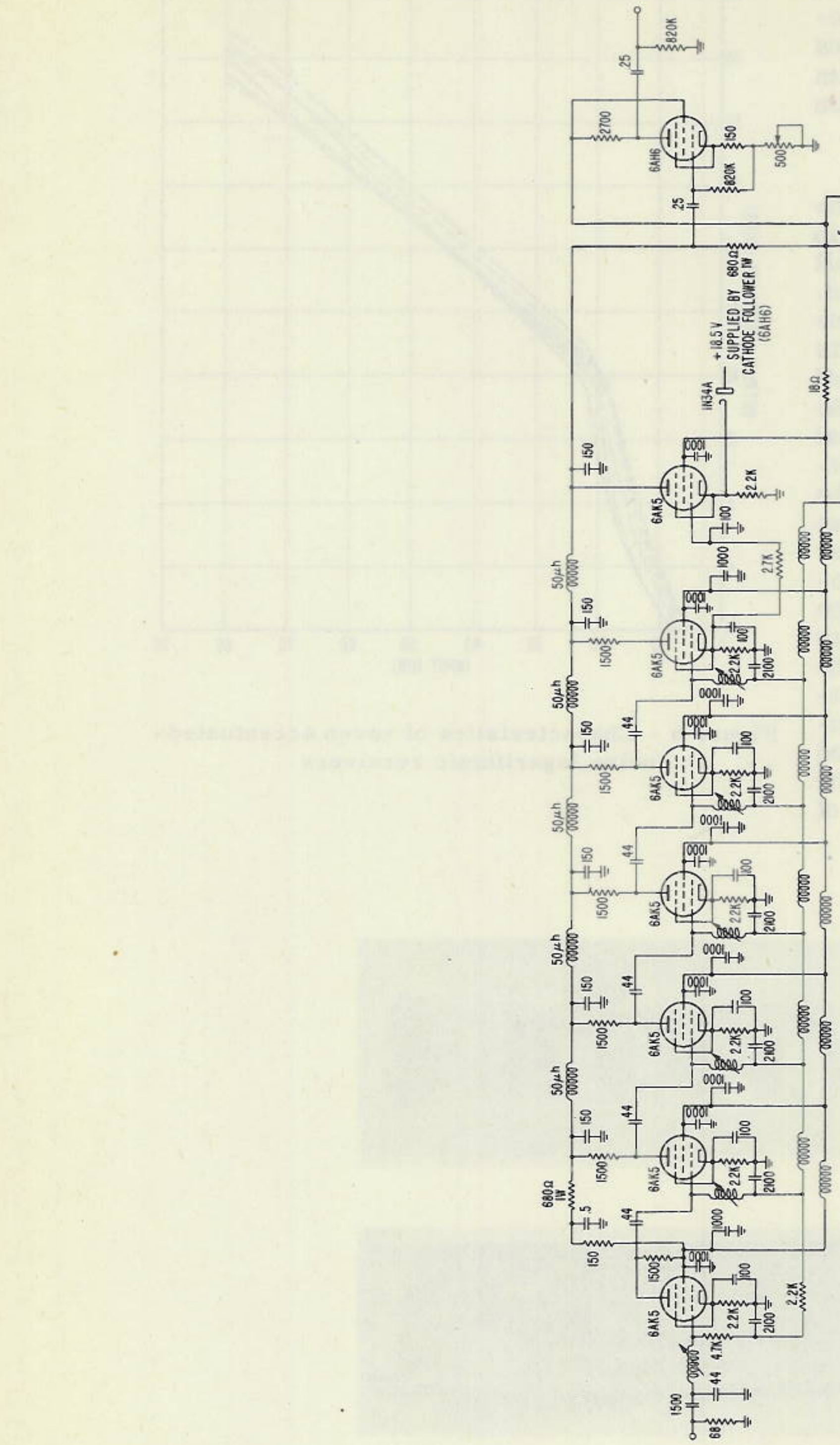

Figure 8 - Circuit diagram of a prototype accentuated-noise logarithmic receiver for AN/SPS-13

[redacted]

[redacted]

The Alternate-Beam Sharp-Select Computer

The test-model alternate-beam sharp-select computer (Figures 10 and 11) uses seven tubes, V1 through V7, as degenerative video amplifiers which serve to raise the video level from the maximum of 3.5 volts delivered by the log receivers to a maximum level of 30 volts and to invert its polarity to positive.

The next seven tubes, V8 through V14, are the peak selectors which take the high-level videos, after dc restoration by the 1N34A crystal diodes, and clip them as follows. The cathodes of all the even-numbered channels are tied together and thence through a resistor to the plate of the constant-current source, V15 and V16, where they join the return from the cathodes of the odds. If a signal is applied to an even, its cathode will rise in potential and will pull the cathodes of the other evens up with it. When the grid has risen about 2 volts, the cathode will have risen about 1 volt, and the other evens will be cut off and complete peak selection of this channel among the evens will be realized. Since 30 volts of input represents a 60-db signal into the receiver, this 2-volt rise will represent a peak-select ratio of about 4 db among the evens.

For the odds, the action is the same, resulting again in an approximate 4-db peak-select ratio. For peak selection between an even and an odd, somewhat different conditions exist. Because of the degenerating resistors between the evens and odds, it will be necessary for the grid of one to rise about 7.5 volts before cutting off the other. Thus a 15-db peak-select ratio between the selected-even and the selected-odd will be realized.

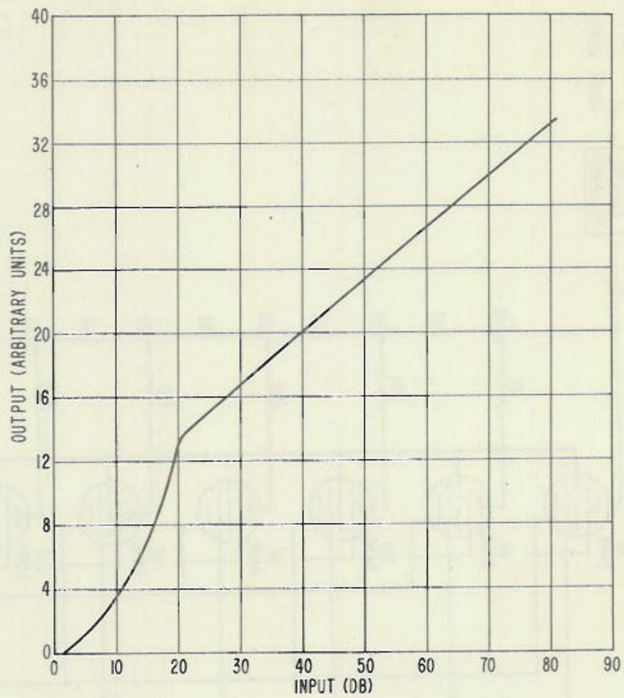

Figure 9 - Characteristic of prototype accentuated-noise logarithmic receiver for AN/SPS-13

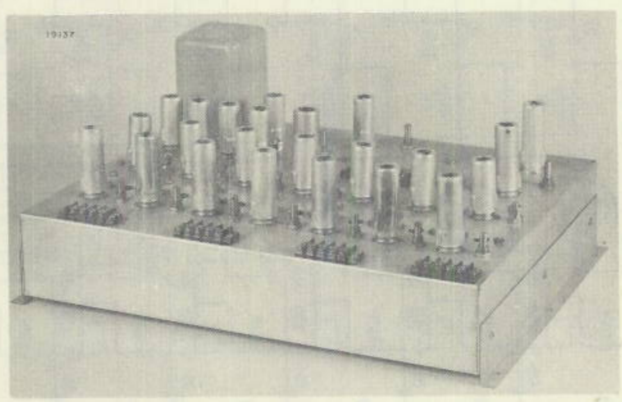

Figure 10 - Test-model computer using pentode peak selector

[redacted]

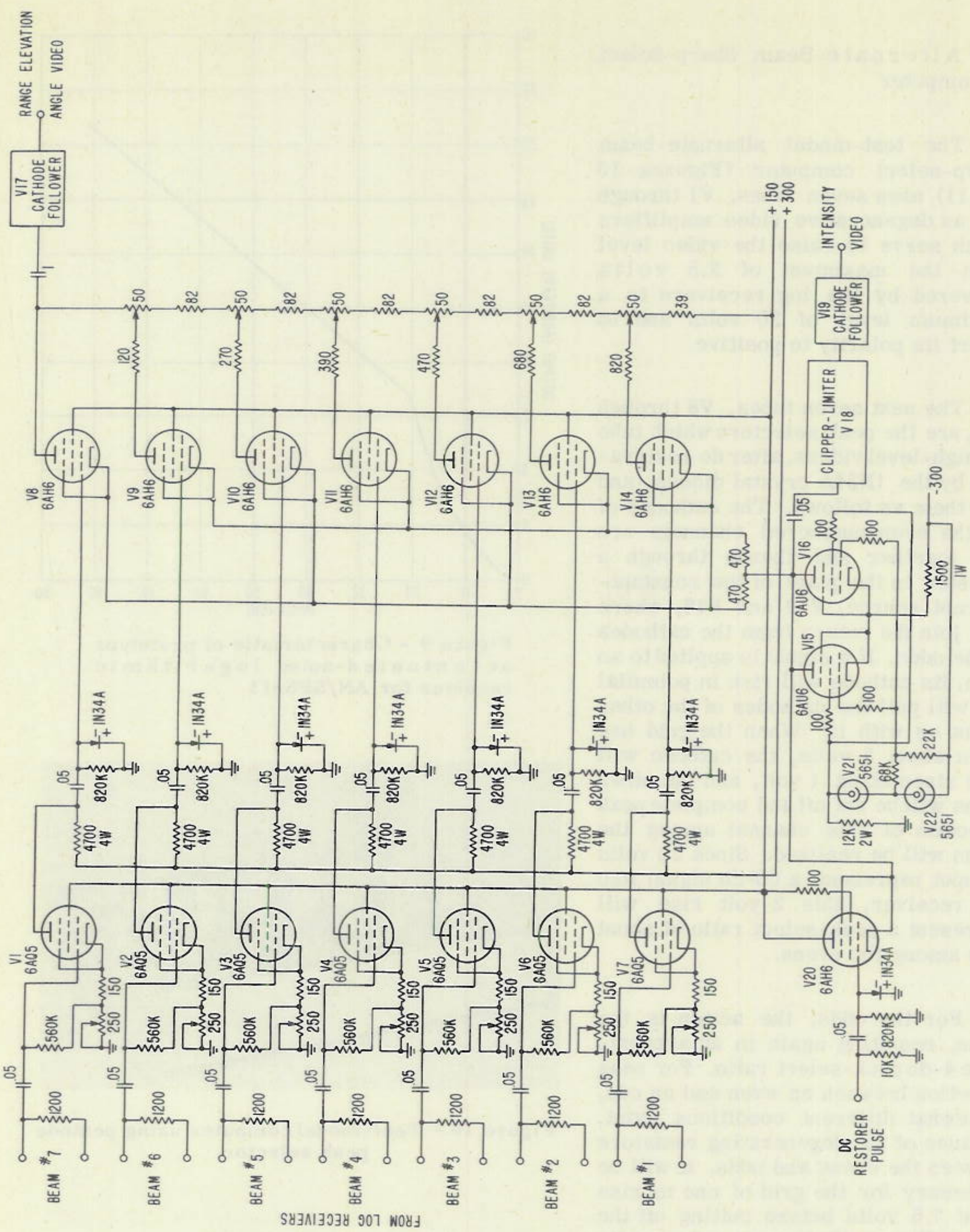

Figure 11 - Circuit diagram of the alternate-beam, sharp-select computer

In actual practice, the signal levels applied to the seven channels will be set by the antenna patterns[12] so that two channels will be relatively stronger (perhaps 10 db stronger) than all others, except in the vicinity of a beam center where only one will be strong and the two adjacent ones will be about 12 db below it. The computer will select these two strong signals and from them will compute an elevation angle in accordance with Equation (3).

It should be observed that peak selection and computation are accomplished on a current rather than a voltage basis. It will be clear, therefore, that the sum of the residuals after peak selection is a constant since the peak-selector tubes are supplied from a constant-current source. Furthermore, since the resistor in each cathode is several times larger than 1/Gm of the tube, the current in each conducting tube will be

$$i_j = \frac{E \log e_j - E_a}{R},$$

where

E_a = the voltage subtracted from the incoming pulse by peak-selector action, and

R = total effective, cathode-circuit resistance of the tube.

Assuming that the division of this current between screen and plate is constant, a fraction of each of these currents is multiplied by the appropriate weight factor (the resistance between the appropriate tap on the plate network and B+) and the resultants are added by superposition to give the elevation-angle video voltage. Tube V17 is simply a cathode follower used to reduce impedance and feed the video out over a low-impedance line.

Tubes V18 and V19 are included to recover an intensity video signal. Since the voltage E_a represents the average level of the selected log videos, it may be taken off the plate circuit of the constant-current source, clipped, and used as an intensity video signal for the range-height indicator (RHI) scopes.

Tube V20, a dc restorer pulse injector, is driven into conduction during indicator flyback time and simulates a target at zero elevation angle so that the dc restorers in the RHI have a base line against which to work. The two final tubes, V21 and V22, are gaseous regulators which serve to stabilize the constant-current source.

The Accentuated-Noise Computer

Two models of the accentuated-noise computer have been built and tested; the first of these was simply a modification of the computer in Figure 10. The seven peak-selector cathodes were rewired in accordance with the circuit of Figure 12, so that cathode resistors were included in all seven tubes and a uniform, peak-select ratio of 15 db was obtained.

---

[12] Adams, R. J., and Shoemaker, J. R., "Design of the AN/SPS-2 Antenna," NRL Report 3855 (Confidential), October 4, 1951

 [redacted]

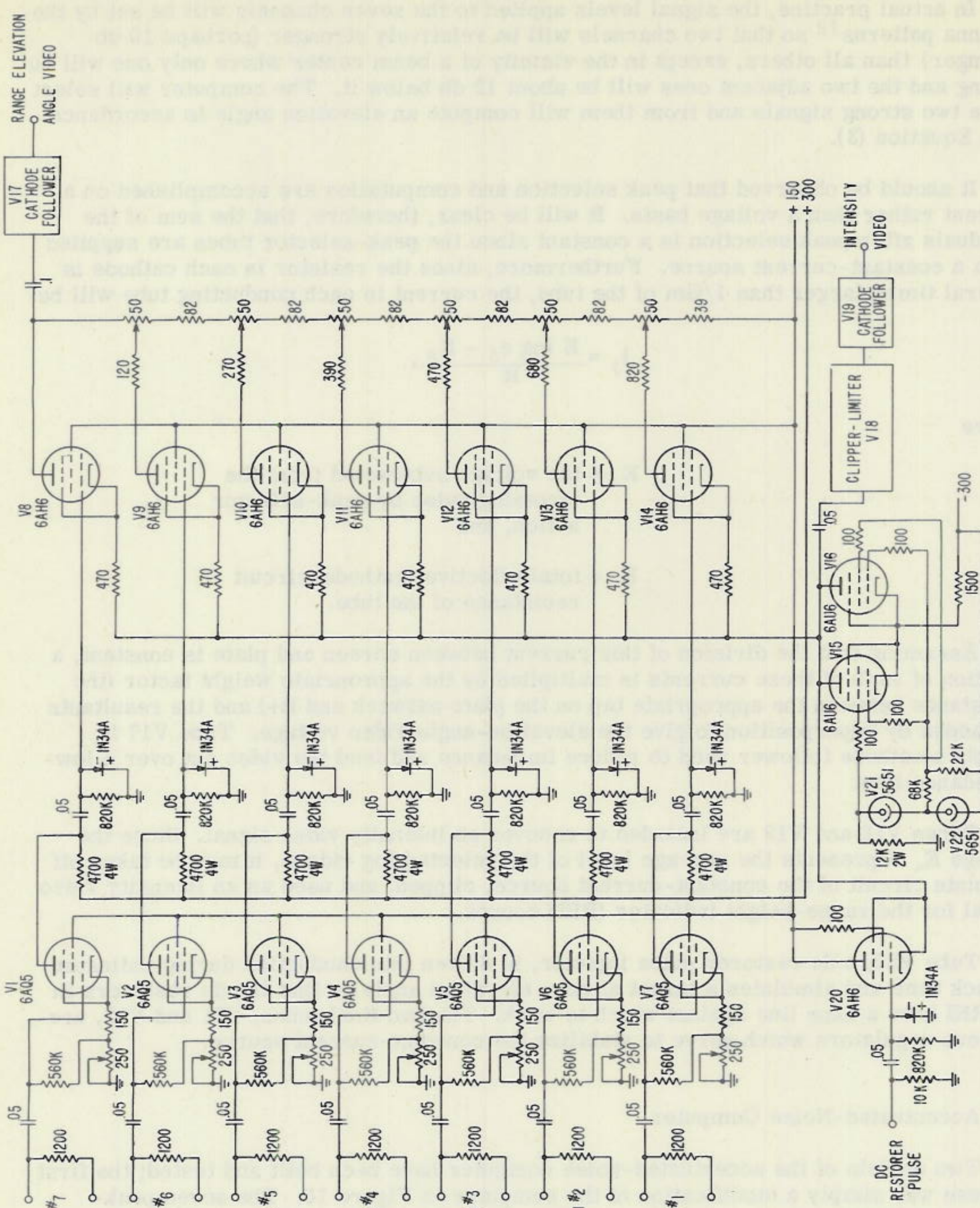

Figure 12 - Circuit diagram of the accentuated-noise computer

[redacted]

The second computer (Figures 13 and 14) was similar to the first except that double triodes were used to allow a reduction in size, weight, and the total number of tubes. Both computers were used with the log strips modified for noise accentuation.

COMPUTER PERFORMANCE

The test model of the alternate-beam sharp-select computer was set up and tested using seven test-model preamplifiers and log receivers built for work on the SPS-2. Input signals were supplied by a three-channel signal simulator also developed for SPS-2 work.

The loss in minimum visible signal as compared to the output of the single log strip containing the signal was found to be about 3.5 db. Estimated accuracy of elevation-angle measurement on this minimum visible signal is:

Target on	Error
Beams 1 and 7	1 Beamwidth
Beams 2 and 6	3/4 Beamwidth
Beams 3, 4, and 5	1/2 Beamwidth

For a single log strip, a signal 12 db above the minimum visible signal gave average errors of less than 1/10 beamwidth on all beams.

The pentode test-model accentuated-noise computer was set up and tested in similar fashion except that the log receivers were modified to provide the required noise accentuation. Using this computer, the loss in minimum visible signal was about 2.5 db. The error of elevation-angle measurement averaged about 1/4 beamwidth on a minimum visible signal and less than 1/10 beamwidth on a signal 12 db above minimum visible.

By way of comparison, the SPS-2 computer has a loss of about 3 db in minimum visible signal. Its computing error on a minimum visible signal will average about 1/4 beamwidth, and for a signal 12 db above noise, it will be less than 1/10 beamwidth.

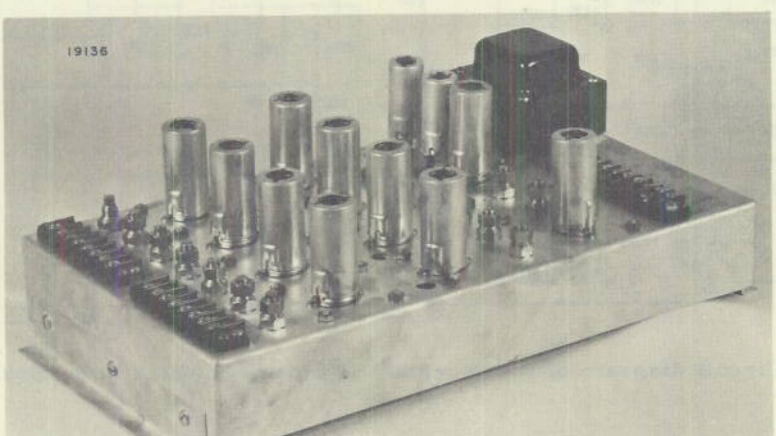

Figure 13 - Test-model accentuated-noise computer using double triodes

 [redacted]

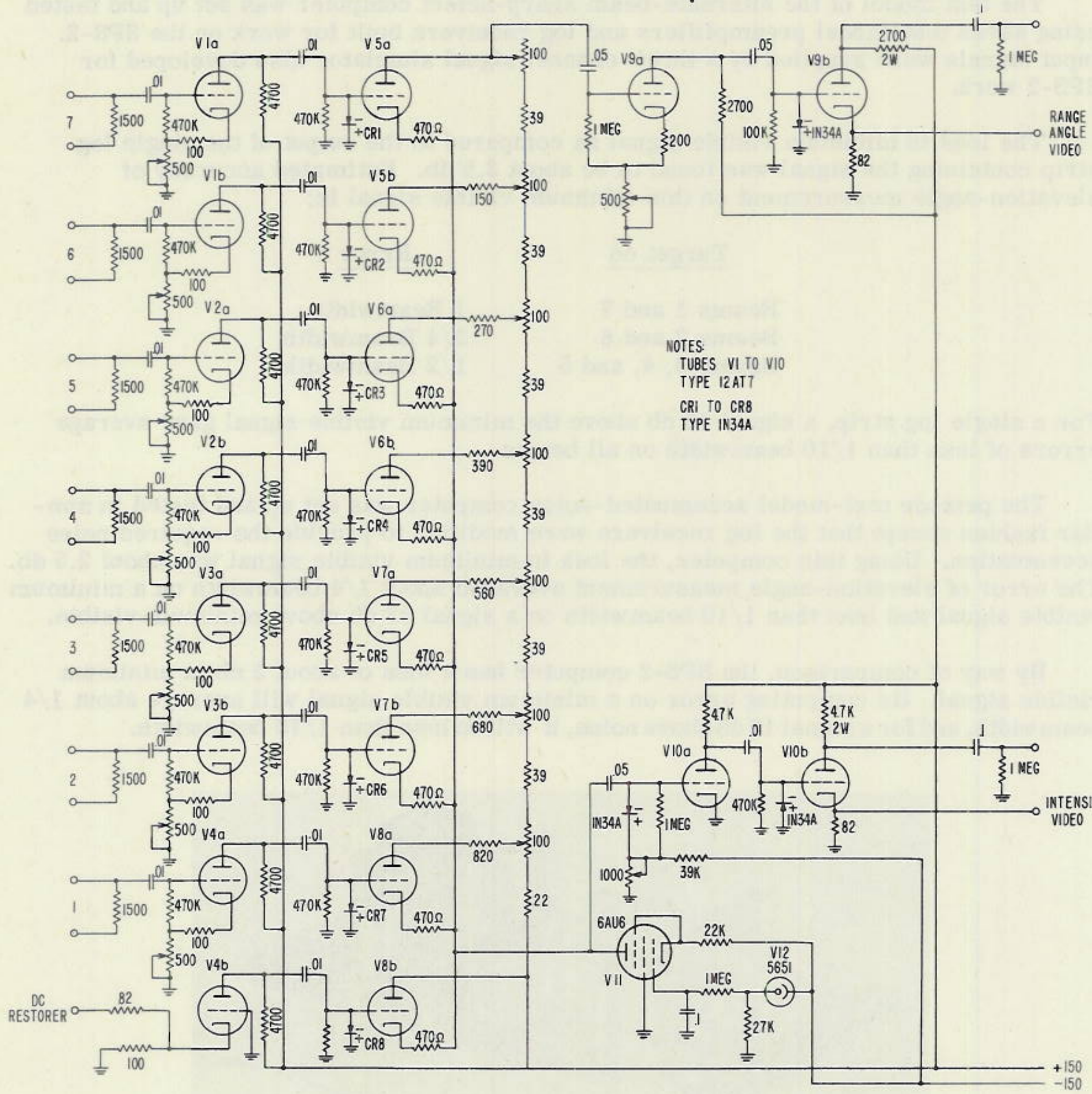

Figure 14 - Circuit diagram of the accentuated-noise computer using double triodes

[redacted]

THE MONITOR SYSTEM

The monitor system (Figure 15) to be used with the new receiver-computer, although simplified over the SPS-2 system, will provide monitoring for all below-decks functions of the elevation-angle measuring system.[13] During operation of the system, the monitor signal generator produces, during the radar flyback time, a sequence of five 30-Mc pulses which decrease in amplitude by about 10 db per pulse. These pulses are converted to the radar r-f frequency and fed to a mechanical commutator that switches them into the seven incoming waveguides in a sequence which simulates a target at a particular elevation angle during each monitor period. This switching sequence and the simulated target angles are shown in Table 1. It will be noted that this sequence is carried out on a time-sharing basis and requires a total of 16 repetition periods for the entire sequence including commutator recycling. The 400-pps repetition rate of the SPS-13 allows complete monitoring at 25 cps with a commutator speed of 1500 rpm.

Monitor presentation will be a 5-in. scope displaying elevation-angle video (Figure 16). Although a 5-in. scope is used, sensitivity equivalent to a 10- or 12-in scope is obtained by increasing video gain to about 2.5 times normal and then compressing the picture onto the scope face by a linear saw-tooth.

The primary function of this monitor system is, of course, to allow adjustment of the 21 controls (Figure 15) in the receiver-computer. The seven level controls, the only ones available as front-panel knobs, are the preamplifier gain controls; the seven slope controls usually locked after adjustment, are the log-receiver video gain controls. These two groups of controls will probably be set simultaneously at a daily system check period or after a receiver or preamplifier has been replaced. This adjustment

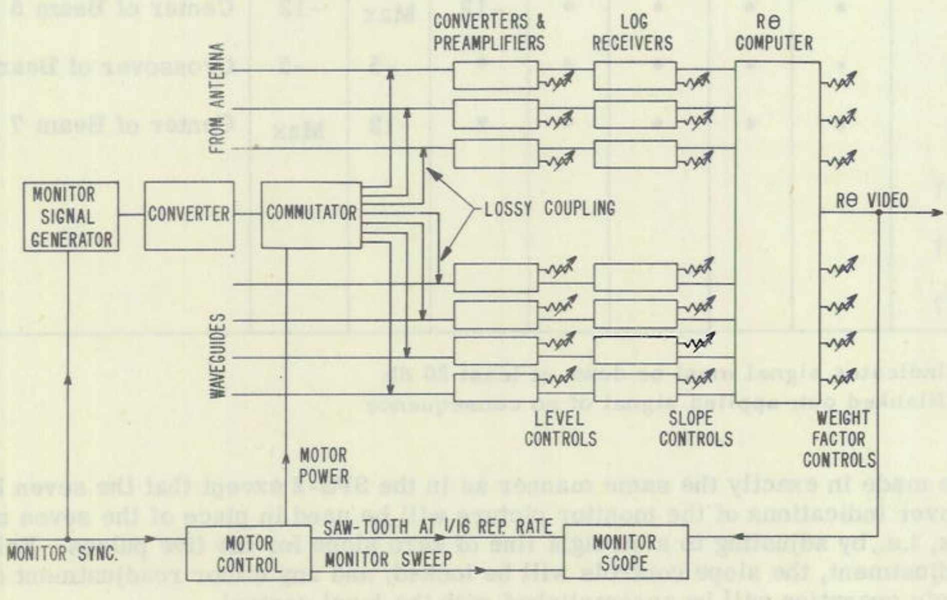

Figure 15 - Block diagram of the monitor system for the AN/SPS-13

[13] Note that the multiplier which converts from elevation angle to height is not monitored.

TABLE 1
Commutating Sequence

Monitor Period	Signal (db) Applied to Channel 1	2	3	4	5	6	7	Simulated Target Elevation Angle
1	Max	-12	*	*	*	*	*	Center of Beam 1
2	-5	-5	*	*	*	*	*	Crossover of Beams 1 & 2
3	-12	Max	12	*	*	*	*	Center of Beam 2
4	*	-5	-5	*	*	*	*	Crossover of Beams 2 & 3
5	*	-12	Max	-12	*	*	*	Center of Beam 3
6	*	*	-5	-5	*	*	*	Crossover of Beams 3 & 4
7	*	*	-12	Max	-12	*	*	Center of Beam 4
8	*	*	*	-5	-5	*	*	Crossover of Beams 4 & 5
9	*	*	*	-12	Max	-12	*	Center of Beam 5
10	*	*	*	*	-5	-5	*	Crossover of Beams 5 & 6
11	*	*	*	*	-12	Max	-12	Center of Beam 6
12	*	*	*	*	*	-5	-5	Crossover of Beams 6 & 7
13	*	*	*	*	*	-12	Max	Center of Beam 7
14†								
15†								
16†								

*Indicates signal must be down at least 20 db
†Blanked out; applied signal of no consequence

will be made in exactly the same manner as in the SPS-2 except that the seven beam-crossover indications of the monitor picture will be used in place of the seven monitor scopes, i.e., by adjusting to a straight line of zero slope for the five pulses. Following this adjustment, the slope controls will be locked, and any minor readjustment during the day's operation will be accomplished with the level control.

The weight-factor controls, which simply serve to match the computer to the individual antenna pattern, will be adjusted and then locked when the system is installed. Thereafter, they will be readjusted only when a peak selector tube in the computer is replaced.

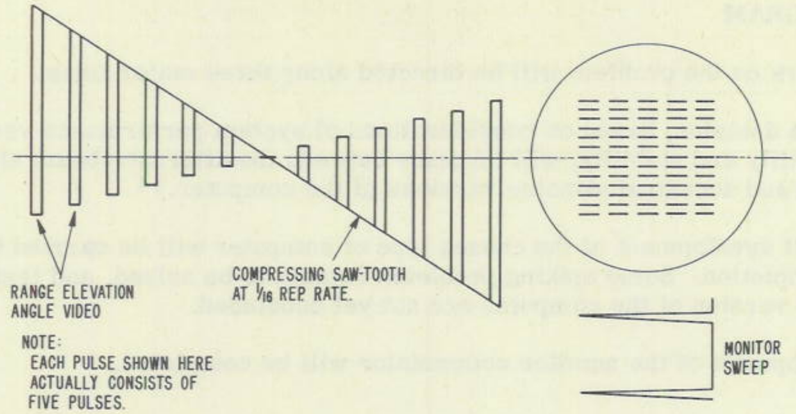

Figure 16 - The monitor scope presentation

The commutator which will be used with this system perhaps warrants some mention since the requirements placed on it are somewhat unusual in the field of coaxial switching. In the first place, an insertion loss between 10 and 20 db is reasonable for this unit. In addition it must supply five different signals (three simultaneously) at three different levels—the reference signal determined by the insertion loss, two signals 5 db below reference, and two signals 12 db below reference. Also the crosstalk into the unexcited outputs need be only about 20 db down from the reference signal.

Figure 17 shows a test-model commutator built for application in this problem at S-band. Preliminary tests indicate that with the addition of internal shielding, this unit may be satisfactory.

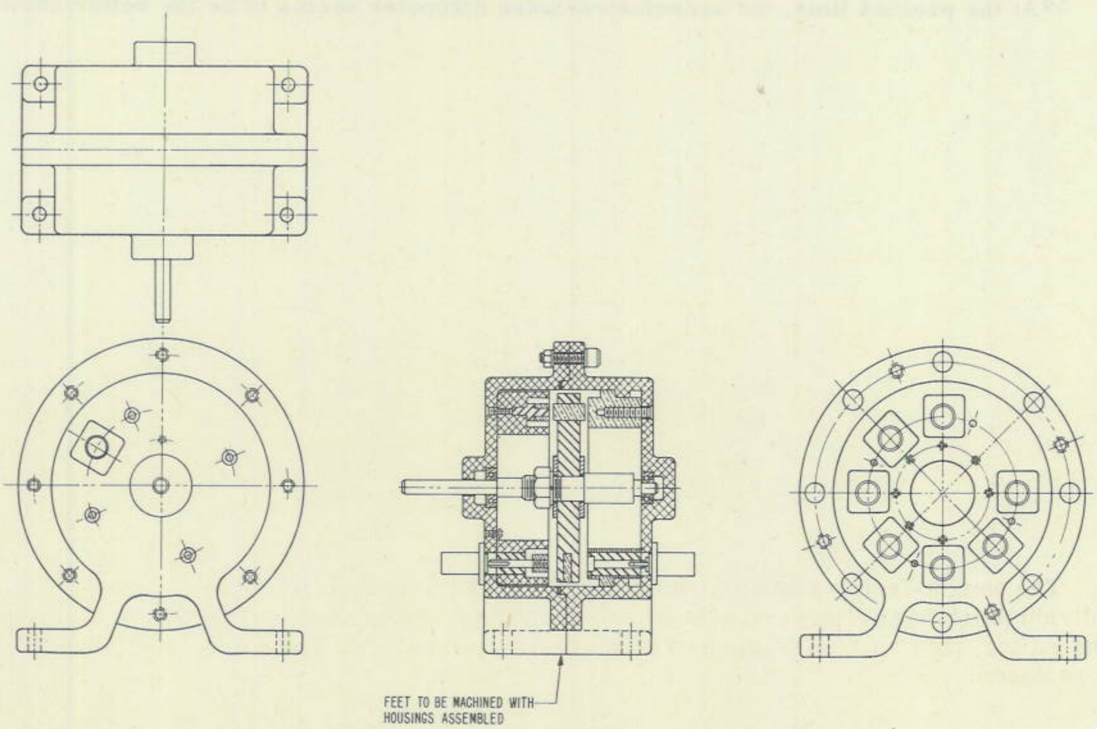

Figure 17 - Test-model commutator for the AN/SPS-13 monitor system

 [redacted]

FUTURE PROGRAM

Future work on the problem will be directed along three major lines:

(a) A firm decision, based on considerations of system performance versus reliability and stability, will be made between the alternate-beam sharp-select and accentuated-noise versions of the computer.[14]

(b) Circuit development of the chosen type of computer will be carried through to completion. Some spiking problems remain to be solved, and tests on the triode version of the computer are not yet concluded.

(c) Development of the monitor commutator will be completed.

CREDITS

The comparison of the present computer with the Volscan and Volir systems is in no way intended to reflect on the latter equipments. On the contrary, this Laboratory gives full credit to the Air Force's Cambridge Research Laboratory for the original proposal and development of the center of gravity method of computing target elevation angle in the stacked-beam radar.

The comparison of page 1 was made against the first proposed models of the Volscan-Volir computers. Later models of these computers employ instantaneous electronic switching to confine computing to the two or three beams containing strong signals.

* * *

[14]At the present time, the accentuated-noise computer seems to be the better choice.

[redacted]

NAVY-DPPO PRNC. WASH., D.C.