HIGH ALTITUDE OBSERVATORY
OF THE
UNIVERSITY OF COLORADO

Observing Station:
CLIMAX, COLORADO

Research Center
UNIVERSITY OF COLORADO
BOULDER, COLORADO

Please reply to:
HIGH ALTITUDE OBSERVATORY
BOULDER, COLORADO

9 September 1960

Mr. Grote Reber
National Radio Astronomy Observatory
P. O. Box 2
Greenbank, West Virginia

Dear Mr. Reber:

Enclosed is a copy of our Solar Research Memorandum No. 57 which you requested in your letter of 29 August. Also, I am enclosing a reprint of an article from "Electronics" on the same subject.

We are now using more refined versions of the interference rejection circuitry than that which is described in these papers, although the basis is the same.

The equipments in which we are now using these techniques successfully are:

1. 18 mc. cosmic noise receiver (SCNA). These are total power receivers with a fixed antenna beamed vertically. Four of these units are in operation at various observatories.

2. 18 mc. phase switched interferometer with fixed antennas beamed vertically.

3. 36 mc. phase switched interferometer essentially the same as 18 mc.

4. 15 mc. to 33 mc. swept-frequency, phase-switched interferometer, with two steerable corner reflectors on a 900 foot baseline (a radio spectrograph).

5. 27 kc. atmospherics receiver, which we regard as a detection device for solar flares with little possibility of giving any quantitative data.

If you should have any need for any of the circuitry used in these receivers, I will be happy to pass along the details.

Our primary objective here is solar research in both optical and radio fields, but we have also done some ionospheric work using the radio stars as signal sources. Most recently, we have had considerable success in receiving radio emissions from Jupiter on the radio spectrograph, and we now have quite a number of observations of this planet in the range of 15 to 33 mc.

I am very much impressed by your accomplishments in radio astronomy, and hope that I may someday have an opportunity to meet you.

Sincerely,

Robert H Lee

Robert H. Lee

RHL:ajm
encls.

These people independently arrived at nearly same circuit and constants for minimum reading.

24 February 1956

HIGH ALTITUDE OBSERVATORY
of the
University of Colorado

Solar Research Memorandum No. 57

From: Robert H. Lee

Subject: Radio equipment for detecting solar flares.*

Contents

1. Introduction

The purpose of this report is to describe work done at HAO on a solar flare detection device utilizing specialized radio receivers as a means of measuring the disturbance created in the ionosphere.

Two distinct types of detection will be used. The first is called Sudden Enhancement of Atmospherics (SEA), and consists of a radio receiver operating near 27 kc/s., and recording the frequency and intensity of lightning bursts from various parts of the sunlit side of the earth. When a solar flare occurs, the reflecting ability of the D region of the ionosphere is improved suddenly and there is an increase in the strength of the signals received. The decay in signal strength is much slower indicating the recombination time of the ionization in the D region of the ionosphere.

The second method of detection is to record galactic or cosmic radio noise coming to us from space. This noise, in coming to us through the ionosphere, is partially absorbed. When a solar flare occurs, the absorption is suddenly increased. This is called a Sudden Cosmic Noise Absorption (SCNA). The region around 18 mc/s. appears to be a reasonable compromise frequency for this type of measurement. If a considerably higher frequency is used, the absorption becomes smaller and may be difficult to measure. If a lower frequency is used the interference from radio stations and atmospherics becomes more severe.

* The work described here was supported by a research and development grant from the U.S. Program for the IGY.

2. Present Status

The equipment is now in operation in a breadboard form at a site near Boulder. It has detected several flares and some subflares. It has also missed some subflares and class 1 flares for undetermined reasons.

3. Plans

After gaining more experience with the equipment, we plan to put it in a final form to be sent to other locations. We intend to assemble the equipment into a form which will permit unattended operation if necessary, at HAO, McMath-Hulbert Observatory and at Sacramento Peak.

4. Circuitry and Techniques

It was decided at the beginning of the project that noise-free locations for the equipment would be difficult to obtain and man, and that considerable effort should be spent in noise reduction schemes.

SEA The signal for the SEA receiver consists of individual bursts of atmospheric noise caused by thunderstorms. If the thunderstorm is sufficiently distant from the receiver that reception takes place by multiple reflections from the D-layer, the strength of the signals is increased at the time of a solar flare. Also there should be an extension of the area over which signals can be received. This phenomenon is adequately described by Ellison.[1]

At 27 kc/s. serious interference is created by power-leaks, brush-type electric motors, and a variety of electrical appliances. For this reason we have chosen a receiver which uses a shielded loop antenna, in order that the main powerline noise can be "nulled out." — This was later abandoned in favor of a 100' to 200' antenna working against ground, ~~with~~ away from power lines several hundred feet

Receiver We have chosen a war surplus unit, the Navy Model DZ-2, as the receiver. This receiver was designed to be used in Navy aircraft as a direction finder, and tunes from 15 kc. to 70 kc. and from 100 kc. to 1750 kc. It is somewhat more complex than is necessary for this application, but it is available complete with loop antenna at a reasonable price.

A cathode follower was added to the receiver and is used as an infinite impedance detector. Also the receiver front end was modified to permit the loop antenna to be used remotely.

Noise Rejection In spite of the use of the loop antenna, there is still an appreciable amount of noise received, so that if an ordinary averaging circuit were used the atmospherics received would be lost in the low level background.

Fortunately the atmospherics, though infrequent, are greater in amplitude than most of the peaks of the background "hash" after nulling the main source of powerline noise. This permits use of a base clipper to prevent the low level signals from reaching the signal integrating device. This clipper can be the same diode that permits the charge and discharge time constants of the integrating circuit to be different. This portion of the circuit is taken from the one designed by Mr. J. A. Ratcliffe (Cavendish Laboratory) for use by Ellison's group at Edinburgh.

The action of an atmospheric burst through the circuit, Fig. 3, is as follows: The burst coming from the infinite impedance detector in the receiver appears as a positive burst as shown in Fig. 2. When the amplitude becomes great enough, D1 will conduct, and the pulse will charge C1 through the capacitor C2 and the limiting resistor R1. As the amplitude of the burst drops, D1 will open, and C2 will be charged through R3 to a new level so that the diode bias is restored. Also the charge lost by C2 during the charging of C1 will be restored. The system is now ready for the next burst to be received at some undetermined later time.

To summarize, the integrator capacitor C1 is charged at a fast rate through R1 and discharged at a slow rate through R2. Cathode follower V1 maintains the proper bias across D1 for clipping low level noise out of the signal and provides a low impedance output to the recorder.

The voltage on capacitor C1 reaches equilibrium at a value given by average of pulses (above clip level) x R2/R1, assuming that C2 can reach equilibrium between pulses.

Noise Limiter In addition to clipping out some of the base level noise, it may be desirable to reject local thunderstorm bursts. This can be done on the basis of amplitude selection and is accomplished by the basic circuit shown in Fig. 5.

In this application V2 is biased beyond cutoff by the D.C. restoring circuit C3, D2, P1. If a positive burst of sufficient amplitude occurs, V2 will conduct, causing the burst to appear as a drop across R1. The voltage waveform presented to the integrator will then appear as in Fig. 6. The C1 charging current waveform will be the same as that portion of the voltage waveform above the D1 cathode level. R4 is a grid current limiting resistor for V2. Thus the system rejects bursts above the amplitude selected at P1, except for the leading and trailing edges which are below the rejection level. A typical waveform for a rejected burst is shown in Fig. 6.

The trailing edge of an atmospheric burst has somewhat less slope than the leading edge, so most of the charge accumulated from a rejected burst comes from the trailing edge. The trailing edge can be eliminated by the additional circuitry shown in Fig. 7. When a large burst comes from the receiver, C4 will be charged through D3 to about the peak value of the burst; then as the burst drops off, D3 will open, leaving C4 to discharge through R4 and the back-resistance of D3. By chosing capacitor C4 properly, the voltage waveform presented to the integrator will be as shown in Fig. 8. Only a small spike represented by the part of the curve above D1 cathode level will show up as capacitor charge.

It should be pointed out that there will be smaller bursts present in a local thunderstorm against which the system cannot discriminate. Therefor the best that can be hoped for is that there will be some discrimination against storms not in the immediate area but too close to be received by D layer reflection.

SCNA The signal for the SCNA is galactic or cosmic radio noise generated in the galaxy. In coming through the ionosphere the noise is attenuated, depending on the ionization present. When a solar flare occurs, the attenuation is increased. A paper by Shain and Mitra[2] describes some of the work done in this field.

At the frequencies chosen for this work (approximately 18 mc.), automobile ignition, power line noise, and radio stations are the chief sources of interference. In this case one cannot discriminate against "background" since this is what is to be measured.

The rejection technique for ignition and powerline noise is similar to that used in the SEA to reject local thunderstorm bursts. However, the rejected noise burst must be reduced only to the average level. If it is reduced too far, it will cause a decrease in the recorded signal level and would be worse than no rejection at all, since we are looking for decreases. This is accomplished by returning the cathode of the noise rejection triode to a point which varies as the average noise level, rather than to ground as in the SEA. Fig. 9 shows the voltage waveforms at the input to the averaging circuit (R3C3).

The rejection circuitry just described satisfactorily removes impulse-type interference from the receiver output. However, there still remains the problem of interfering radio stations. We have found that even though the receiver is tuned to an interference-free frequency that, after a time, an interfering station nearly always comes within the bandpass of the receiver and the galactic noise level is lost. In order to overcome this type of interference, the tuning dial of the receiver is mechanically driven so that it sweeps back and forth over a small range (50 kc. or so). When the output of the receiver is recorded, the trace appears as is shown in Fig. 10. Since the upward excursions from the noise level serve no useful purpose and cause the record to be cluttered, they can be eliminated by the circuit shown in Fig. 11. Capacitor C4 is charged slowly in a positive direction by R5. When it reaches the voltage level of the cathode of V2, D3 conducts, and prevents the capacitor from charging further. If an interfering signal causes the cathode of V2 to go positive, D3 opens, and C4 starts to charge slowly. As soon as the interference is gone, D3 conducts and rapidly discharges C4 down to a level determined by the background noise as averaged in R3C3.

If the charge rate of C4 is chosen to be much slower than the sweep rate on the tuning dial, the recording will be nearly a straight line representing the base noise level and ignoring the interfering radio stations.

Receiver The receiver now in use is an AGR-7 (aircraft version of Hallicrafters SX-28A) working into a DZ-2 receiver, making it a double conversion superhet with I.F.'s of 456 and 88 kc. The first R. F. stage of the AGR-7 was changed from a 6SK7 to a 6AC7 tube to improve the noise figure.

This combination gives a good shape factor (60 db width/6 db width) to the bandpass curve. In selecting bandpass one must compromise between having a band narrow enough to "fit" between interfering stations during a sweep but broad enough to make a satisfactory measurement in the short time the receiver is in a "hole" of the spectrum. This implies that a nearly rectangular bandpass shape would be most useful for this work.

The Hallicrafters SX-88 appears to be the most satisfactory commercial receiver for this purpose, as it has I.F.'s at 2075 kc. and 50 kc. and has a cathode follower output at the 50 kc. I.F. output. However manufacture has been discontinued on this reciever and it will be difficult to obtain.

The Hallicrafters SX-100 and the Collins R-390 will probably be satisfactory, and almost any reciever using the Collins mechanical filter should be satisfactory. Most commercial receivers should have the first R.F. amplifier replaced by a low noise pentode for this application, or a cathode coupled preamplifier may be used. A cascode preamplifier would also be quite satisfactory except that it is easily overloaded by strong signals on nearby frequencies. At times very strong signals are present on these frequencies, and receiver overloading may become a problem.

Receiver noise is not a terribly important problem, since the galactic noise level is high at this frequency, but reasonable efforts should be spent in improving the noise figure of the receiver.

Needless to say, gain stability in the receiver is important, so filament and B supply voltage should be regulated.

Antenna The receiving array we have chosen consists of two horizontal parallel halfwave folded dipoles, spaced one halfwave apart and driven in phase. The dipoles are placed one-tenth wavelength above a ground plane constructed of wires three-quarters wavelength long, spaced three feet apart, and running parallel to the dipoles.

This array was chosen because it can be easily constructed from "ladder line" television leadin wire, and there are no difficult phasing or impedance matching problems. It is also a relatively broadband array.

The vertical gain of the antenna is useful primarily as a means of discriminating against interfering signals arriving at low angles above the horizon.

5. Recording Scheme

The outputs of the SEA (27 kc.) and SCNA (18 mc.) recievers will be recorded on the same record, utilizing a time-sharing scheme. This will permit accurate comparison of the effects of flares at the two frequencies and will also effect considerable economy in first cost and in recording supplies.

The present method of recording utilizes a modified Leeds and Northrup "micromax" recorder. The SCNA (18 mc.) receiver output is placed so that its zero point is off the left hand side of the record. Increasing signal level moves the pen to the right. The SEA (27 kc.) record has its zero placed at about the center of the chart. Increasing signal level causes the pen to move to the right.

Thus we have a system where there are two approximately parallel traces on the record. At the time of a flare, the SCNA line deviates toward the left hand edge of the chart and the SEA toward the right hand edge.

Interference on the SEA record goes in the same direction as the SEA. For the SCNA record it goes in the opposite direction from the SCNA.

We plan to use a Sanborn recorder with a slow chart drive, as this will eliminate worry about ink supply and will provide more compact records.

6. Results

We have accumulated many yards of records, but until recently equipment failures, interference, and other problems have rendered most of the records useless as far as ability to detect small flares is concerned.

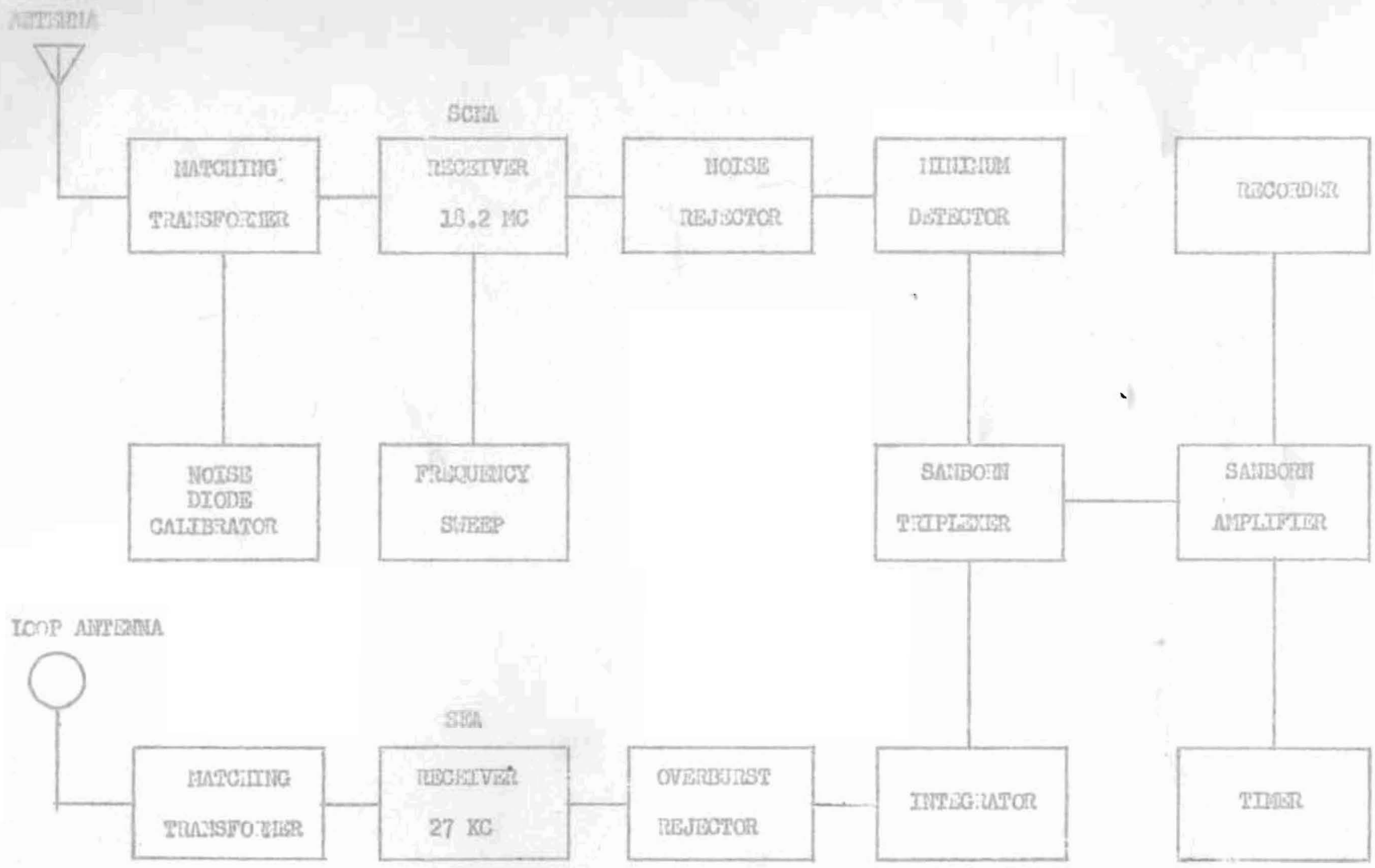
Recently, however, the equipment performance has been improved to the point where we are able to detect some subflares (class 1-). It also has the defect that it ignores some class 1 flares, for reasons we have not yet established. Larger flares are easily detected on the SCNA system, but the SEA system is not completely satisfactory. Attempts at improvement will be made.

We will leave the equipment in routine operation as much as possible in the future, although there are still modifications to be made. Results will be included, where possible, in the HAO weekly "Preliminary Report of Solar Activity."

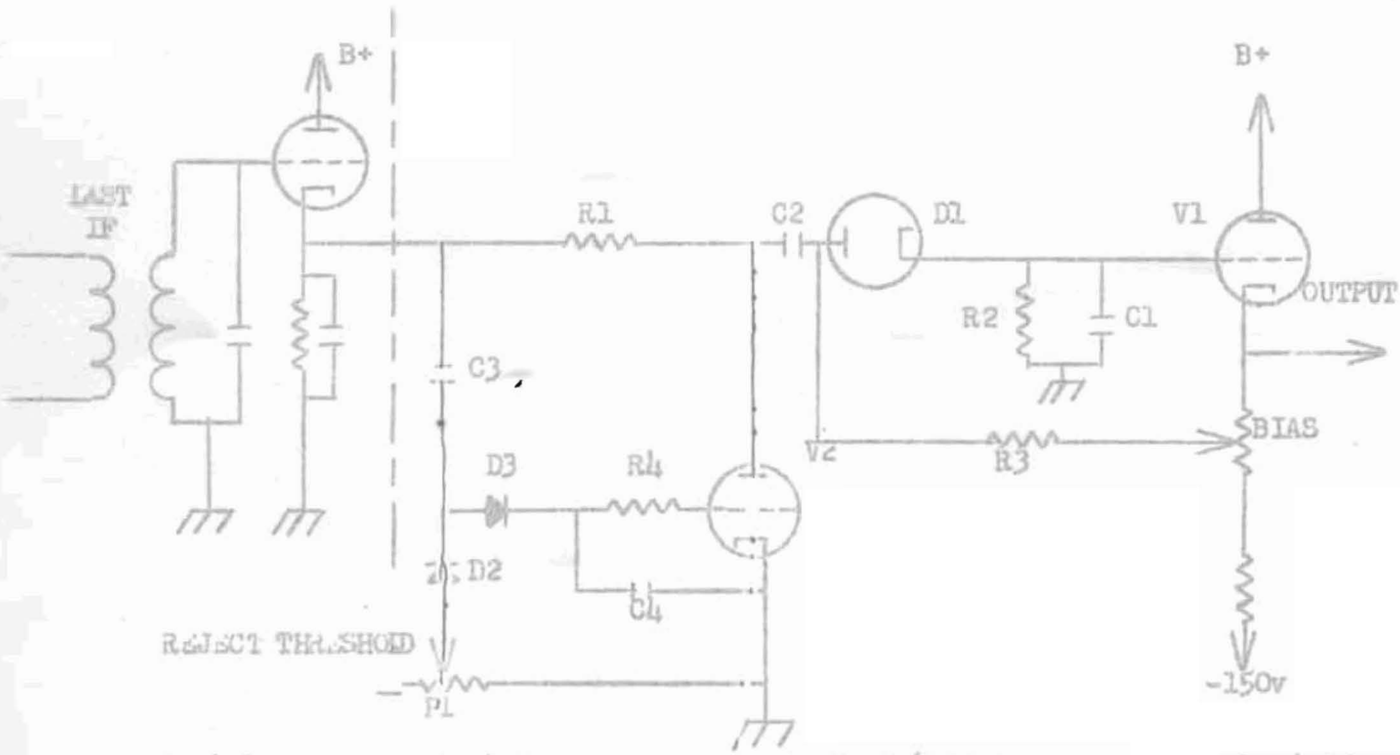
7. Bibliography

1. M. A. Ellison, "The H-alpha Radiation from Solar Flares in Relation to Sudden Enhancements of Atmospherics on Frequencies near 27 kc./s," Journal of Atmospheric and Terrestrial Physics, 4, 226 (1953).
2. C. A. Shain and A. P. Mitra, "Effects of Solar Flares on the Absorption of 18.3 Mc/s Cosmic Noise," Journal of Atmospheric and Terrestrial Physics, 5, 5/6 (1954).

rmb



BLOCK DIAGRAM



C1 4µfd	R1 47K Ω	V1 1/2 12AU7	D1 6AL5
C2 0.5µfd	R2 44M Ω	V2 1/2 12AU7	D2 IN38
C3 0.1µfd	R3 1M Ω		D3 IN38
C4 0.005µfd	R4 470M Ω		

FIG. 1 INTEGRATOR AND NOISE REJECTION CIRCUITS (SEA)

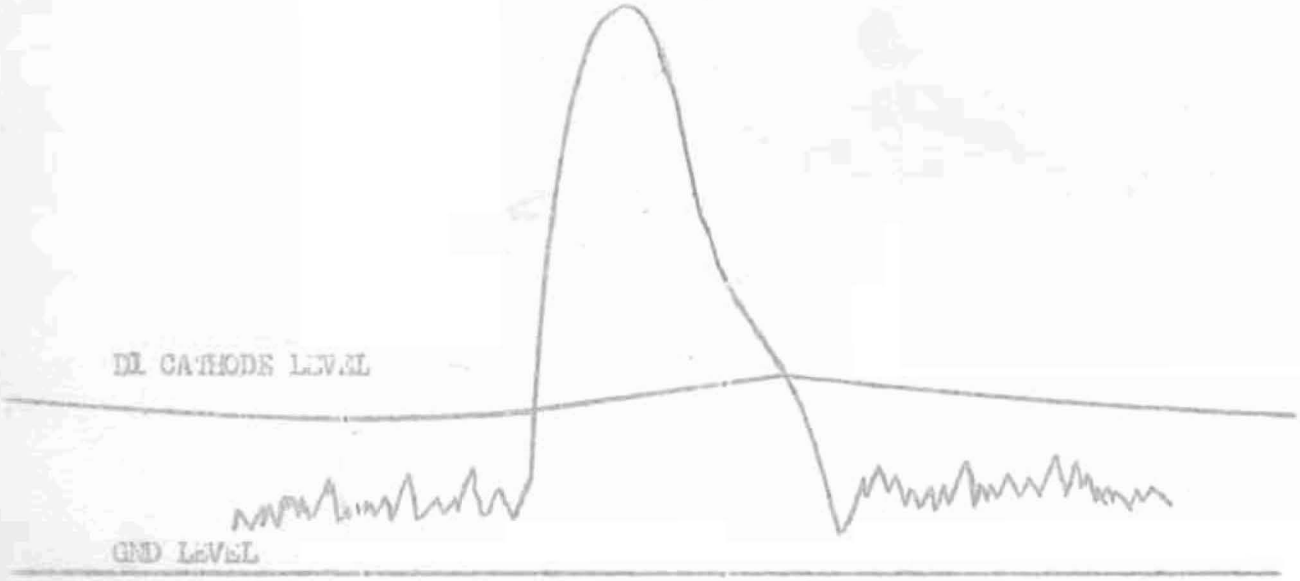


FIG. 2 OUTPUT SIGNAL FROM RECEIVER (SEA)

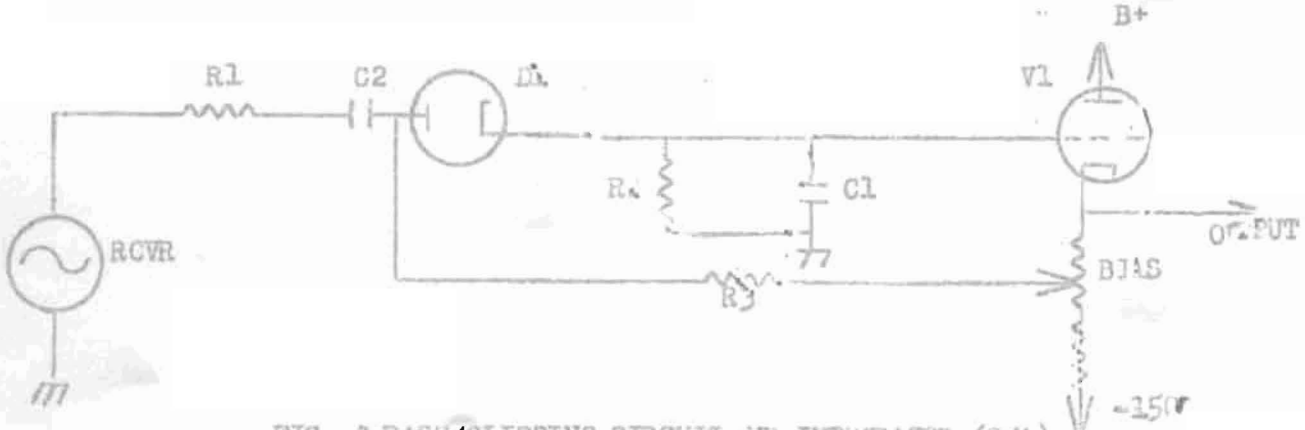
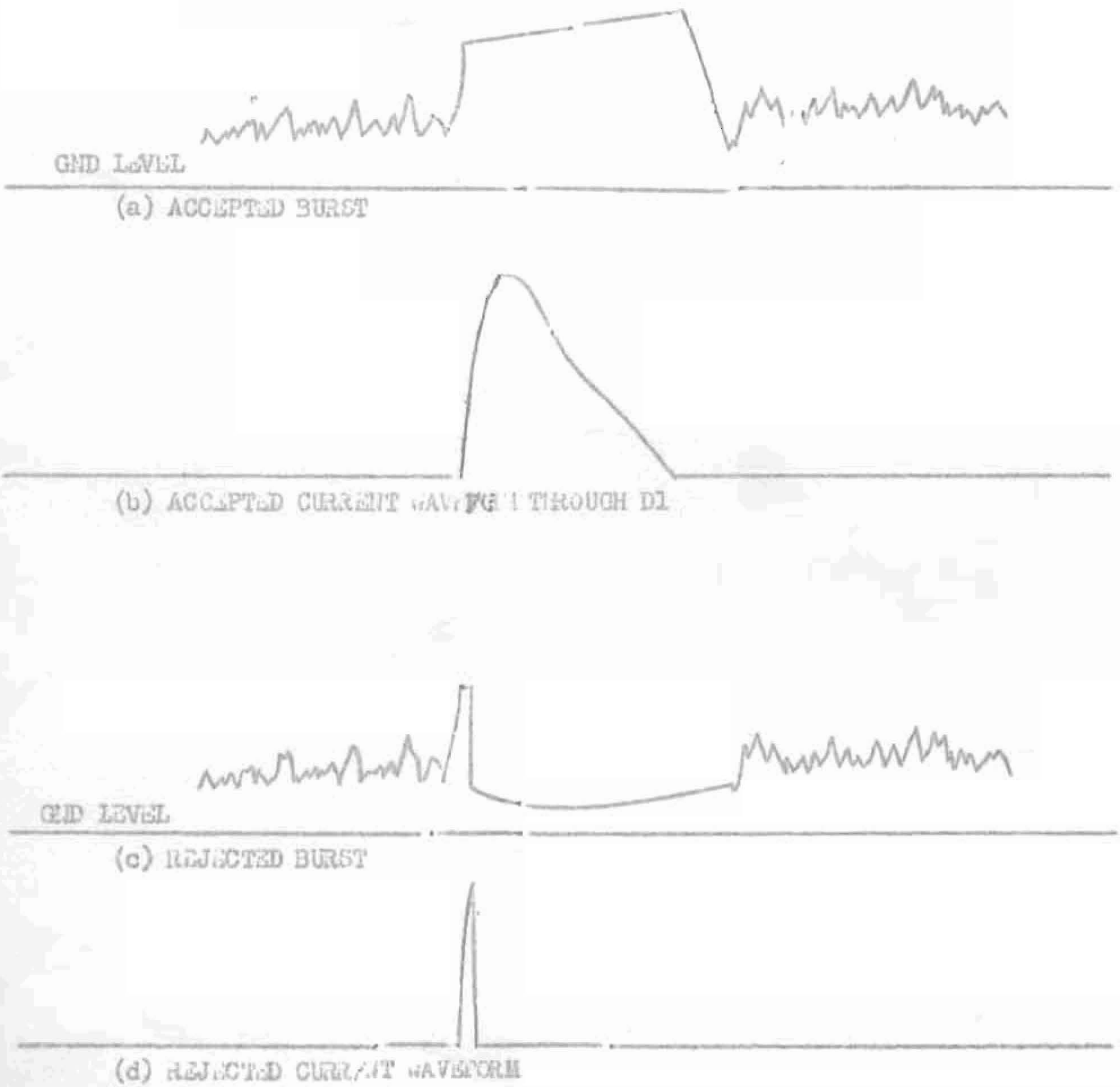


FIG. 3 BASE CLIPPING CIRCUIT AND INTEGRATOR (SEA)

FIG. 4 WAVEFORMS APPEARING AT THE ANODE OF D1 (FIG. 3)



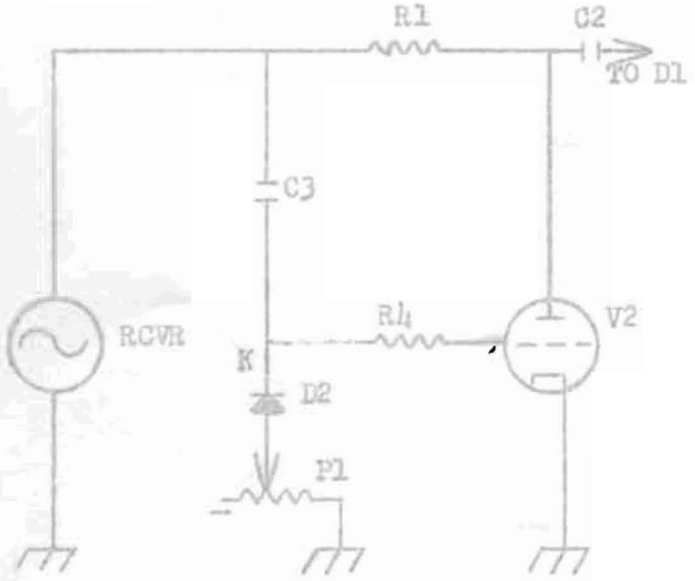


FIG. 5 BASIC AMPLITUDE SELECTION CIRCUIT

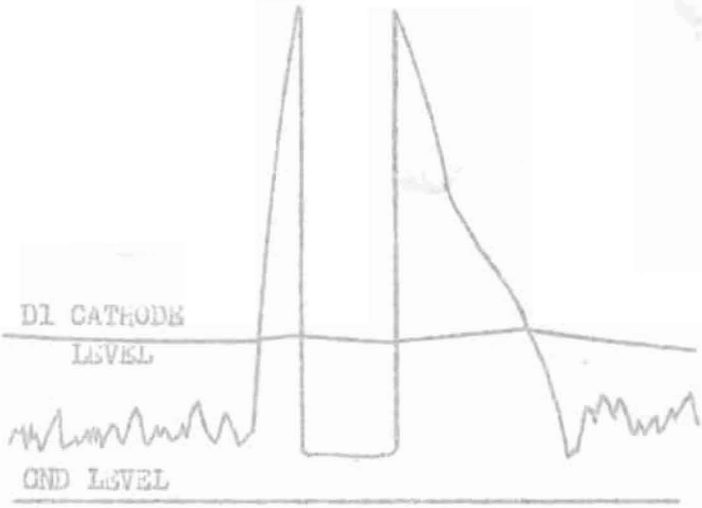


FIG. 6 OUTPUT OF BASIC AMPLITUDE SELECTION CIRCUIT FOR A REJECTED BURST

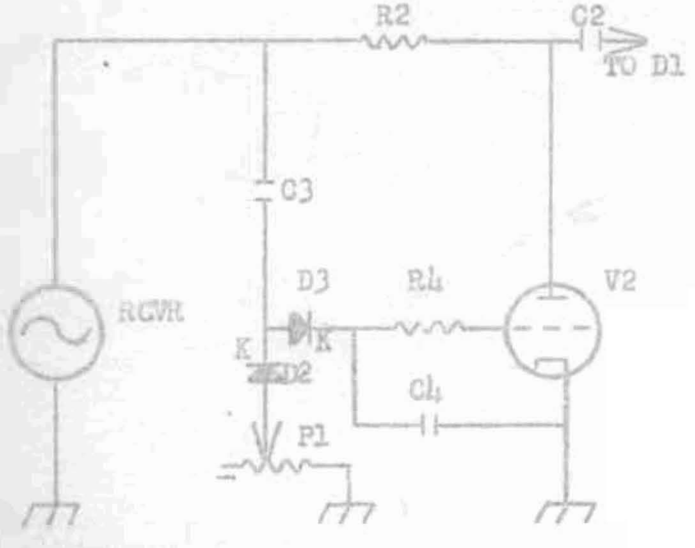


FIG. 7 AMPLITUDE SELECTION CIRCUIT INCLUDING THE AFTER PULSE ELIMINATOR

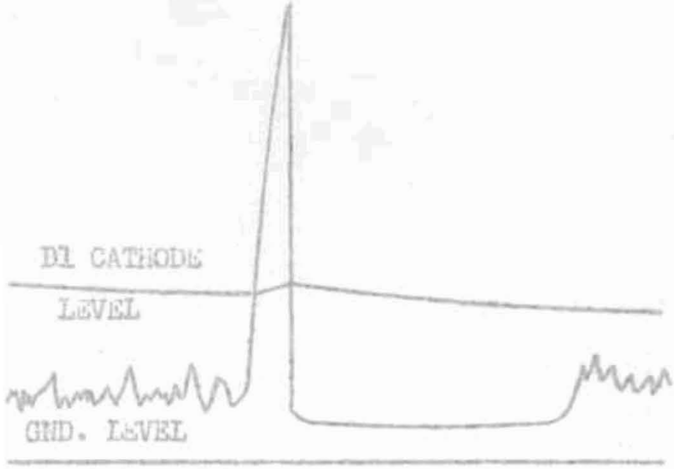
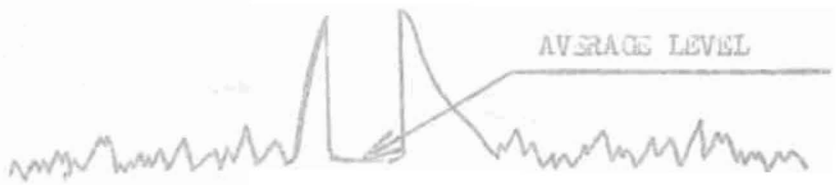
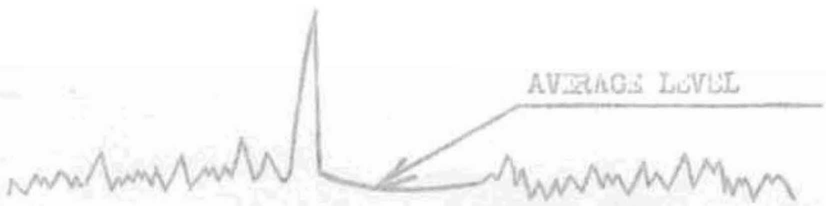


FIG. 8 OUTPUT OF AMPLITUDE SELECTION CIRCUIT AFTER THE INTRODUCTION OF THE AFTER PULSE ELIMINATOR

(a) RECEIVER OUTPUT WITH AN INTERFERING BURST



(b) WITH SIMPLE REJECTING CIRCUIT



(c) WITH REJECTION CIRCUIT AND TRAILING EDGE ELIMINATOR
FIG. 9 WAVEFORMS IN SCNA CIRCUITS

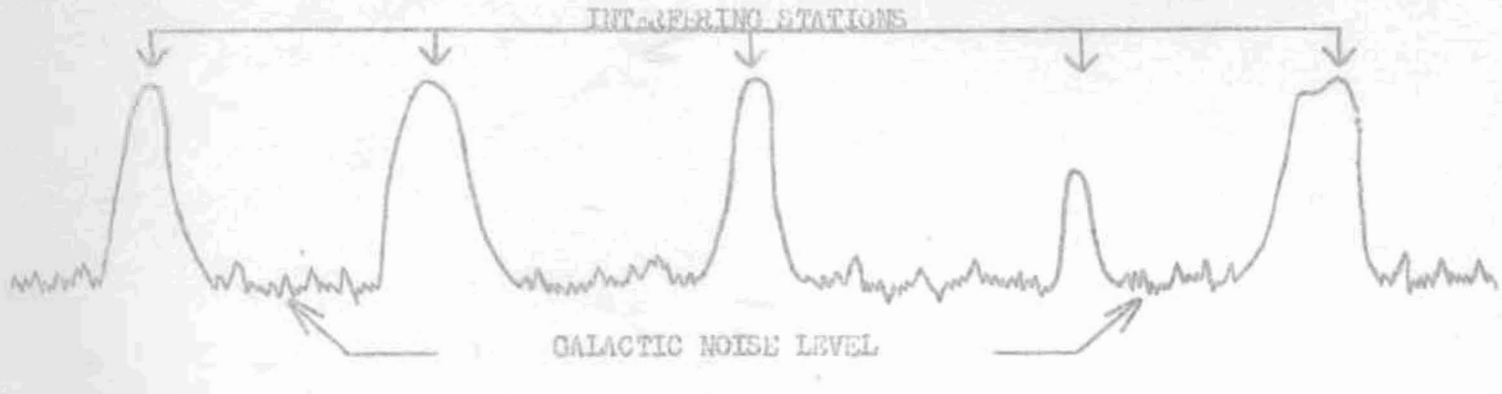
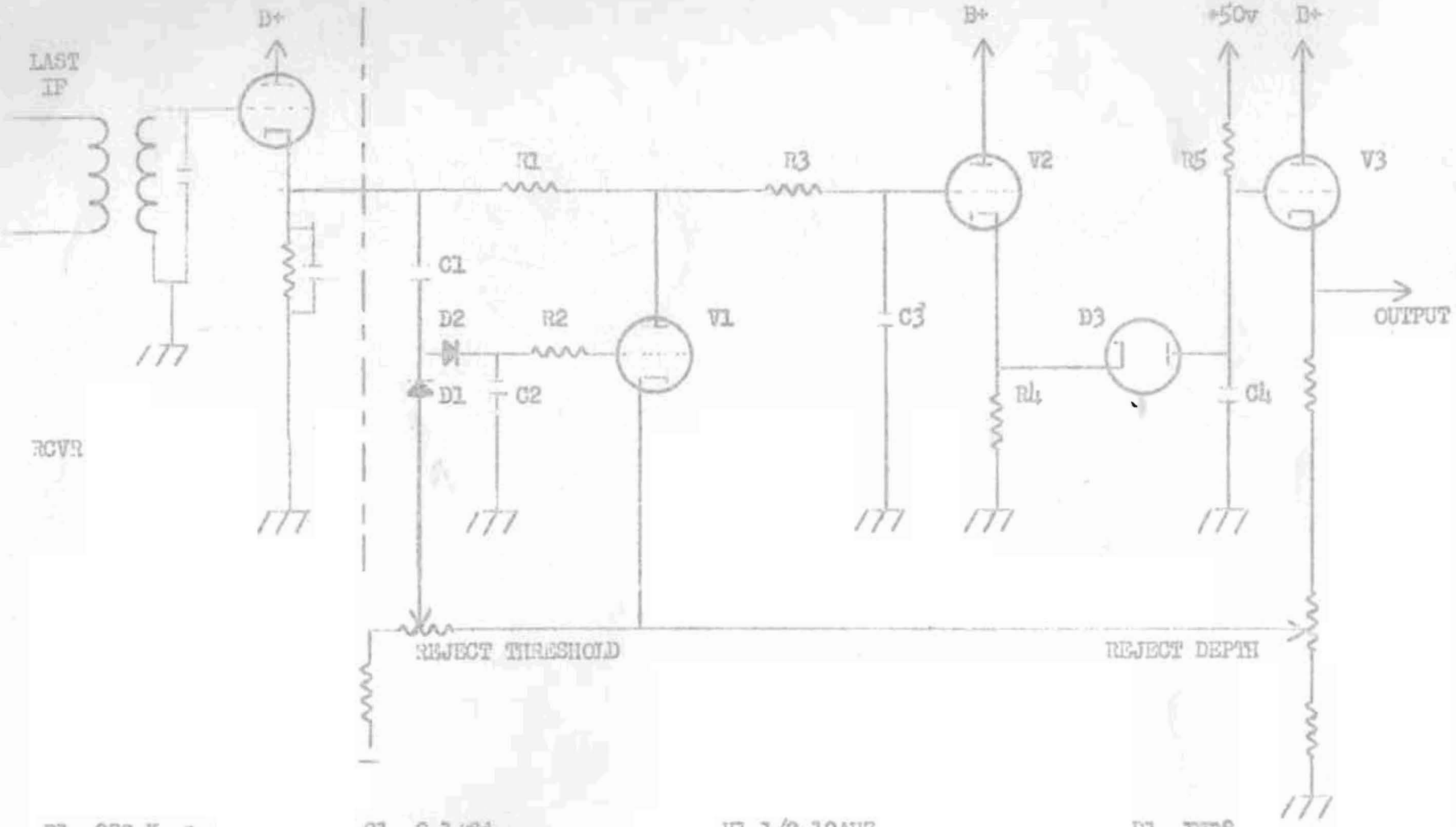
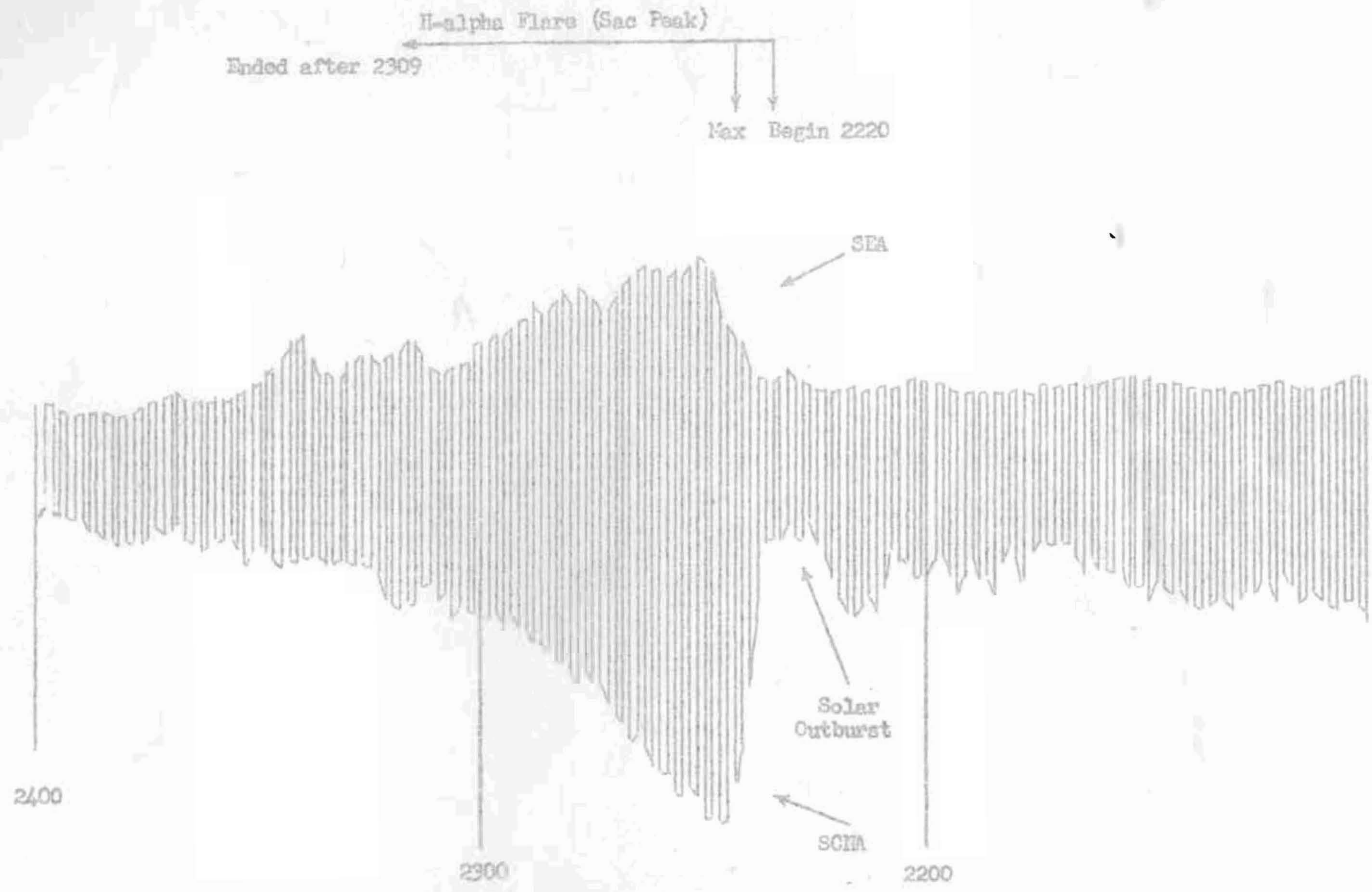


FIG. 10 A FAST RECORDING OF THE RECEIVER OUTPUT AS IT IS SWEPT OVER A NARROW RANGE OF FREQUENCIES (SCNA)



R1 270 K	C1 0.1 μfd	V1 1/2 12AU7	D1 IN38
R2 470 K	C2 0.002 μfd	V2 1/2 12AU7	D2 IN38
R3 1 M	C3 0.1 μfd	V3 1/2 12AU7	D3 6AL5
R4 6.8K	C4 10 μfd		
R5 100 M			

FIG. 11 SCNA INTERFERENCE REJECTING CIRCUITS



RECORD OF A CLASS 3 FLARE ON 29 FEBRUARY 1956
(All times in UT)

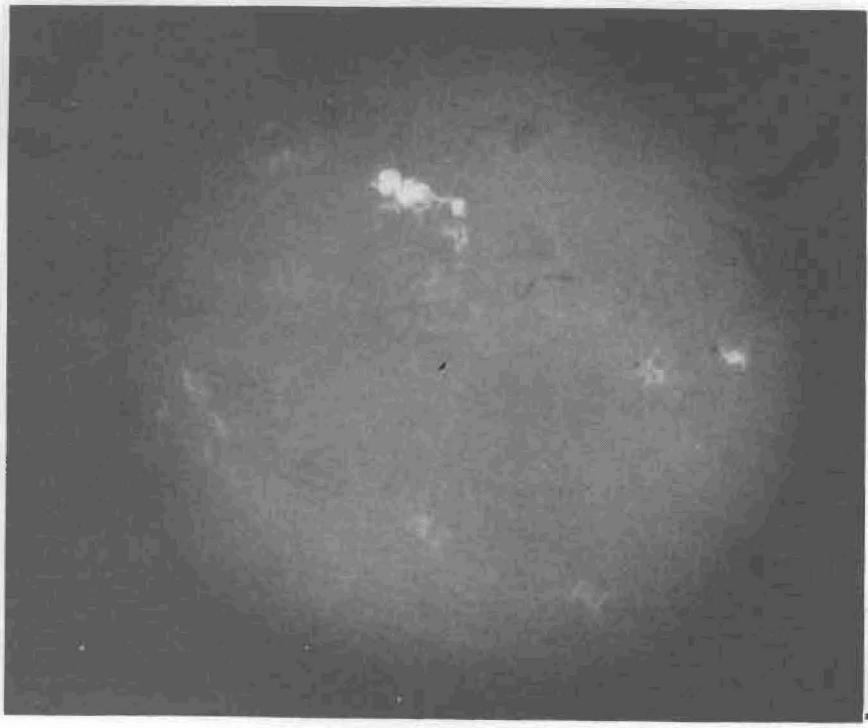
SOLAR-FLARE DETECTION FOR IGY

By ROBERT H. LEE
High Altitude Observatory
Boulder, Colorado

Misc Reprint No. 62
High Altitude Observatory
Boulder, Colo.

Reprinted from ELECTRONICS, March 1, 1957

330 W. 42nd St., New York 36, N. Y.



Photograph of solar flare taken at Sacramento Peak Observatory, Sunspot, New Mexico. The solar flare ionizes the atmosphere, resulting in changes that are detected by two radio receivers

By ROBERT H. LEE
High Altitude Observatory
Boulder, Colorado

SOLAR-FLARE

SUMMARY —— Two radio receivers, operating at 27 kc and 18 mc, intercept signal disturbances occuring in the D-layer of the ionosphere during a solar flare. The detection system indicates an increased signal caused by sudden lightning bursts and an attenuated signal caused by cosmic-noise absorption. Pulse analyzers discriminate against background noise, interfering radio stations and unwanted atmospheric disturbances. Signals are chart recorded on a time-sharing basis

WHEN a solar flare occurs, there is often a rapid increase in the radiation that ionizes our atmosphere, to form the ionosphere. This radiation is probably Lyman alpha (1,216 Angstroms), or some shorter wavelength. The effect is most commonly known as a sudden ionospheric disturbance or a sudden short-wave fadeout. A severe disturbance can cause a complete blackout of short-wave long-distance communication. This fading is caused by increased absorption of the radio waves as they pass through the D-region of the ionosphere at a height of about 80 kilometers.

Two distinct types of radio signals are used to detect and study these solar-flare effects. The system is shown in Fig. 1.

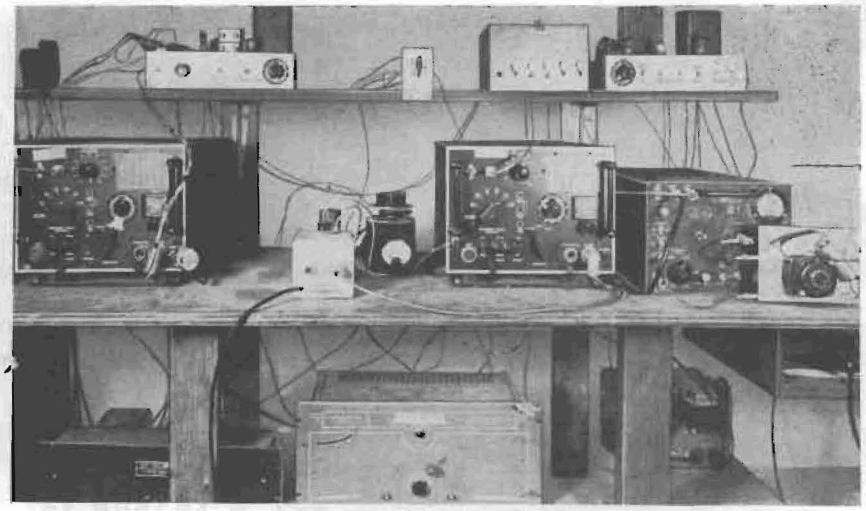
The first receiver, operating near 27 kc, detects any important sudden enhancement of atmospherics and records the frequency and intensity of lightning bursts from various parts of the world. When a solar flare occurs, the reflecting ability of the D-region of the ionosphere on the sunlit side of the earth is improved suddenly and there is an increase in the strength of the received signals. The decay in signal strength is much slower, indicating the recovery of normal ionization in the D-region.

The second method of detection records galactic or cosmic radio noise coming to us from space. This noise, in coming through the ionosphere, is partially absorbed. When a solar flare occurs, absorption is suddenly increased. This is called a sudden cosmic-noise absorption. The region around 18 mc is a reasonable compromise frequency for this measurement.

If a considerably higher frequency is used, the absorption becomes smaller and is difficult to measure. If a lower frequency is used, the interference from radio stations and atmospherics becomes more severe.

Noise-free locations are difficult to obtain and man, and considerable effort was spent in designing equipment that would discriminate against unwanted pulse signals.

Antenna array for solar-flare detection uses two parallel half-wave folded dipoles, spaced one half-wave apart and driven in phase



Solar flare detection equipment includes from left to right, a 27-kc receiver, noise calibrator, 18-mc receiver (second i-f), ARR-7 receiver (r-f and first i-f) and motor-driven radio frequency scanner. The two signal-interference rejectors are on top shelf, on both sides of timer. Chart recorder is not shown

DETECTION FOR IGY

The 27-kc receiver signal is caused by individual bursts of atmospheric noise due to thunderstorms. If the thunderstorm is sufficiently distant from the receiver that reception takes place by multiple reflections from the D-layer, the signal strength is increased at the time of a solar-flare. Also there is an extension of the area over which signals are received.[1]

At 27 kc, serious interference is created by power-leaks, brush-type electric motors and other electrical appliances. For this reason the receiver uses a shielded-loop antenna to null out main powerline noise. This receiver, the Navy model DZ-2, was designed as a direction finder and is available complete with loop antenna.

An infinite-impedance detector was added to the receiver with the front end modified to permit the loop antenna to be used remotely.

Background Noise

In spite of the use of the loop antenna, there is still an appreciable amount of noise received. If an ordinary averaging circuit were used, the atmospherics would be lost in the low-level background.

Fortunately the atmospherics, though infrequent, are greater in amplitude than most of the peaks of the background hash after nulling the main source of powerline noise. This permits use of a base clipper to prevent the low-level signals from reaching the signal-integrating device. This clipper can be the same diode that permits the charge and discharge time constants of the integrating circuit to be different.

Noise Discrimination

An atmospheric burst encounters the circuit shown in Fig. 2. The burst from the infinite-impedance detector in the receiver appears as

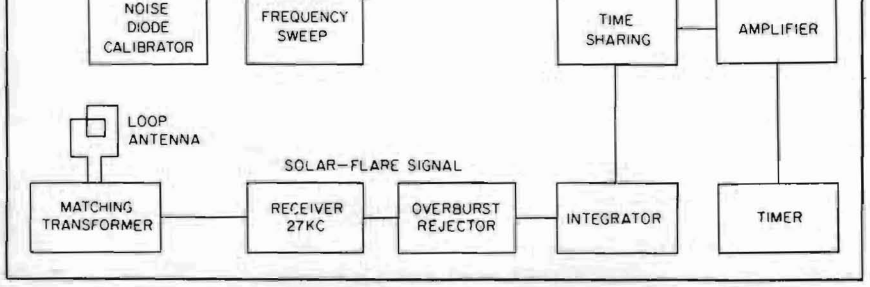


FIG. 1—Block diagram of solar flare and cosmic-noise detector

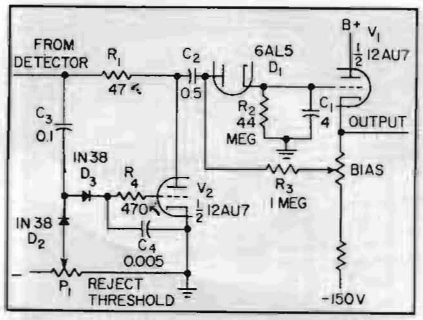


FIG. 2—Integrator and noice-rejection circuits in the 27-kc receiver

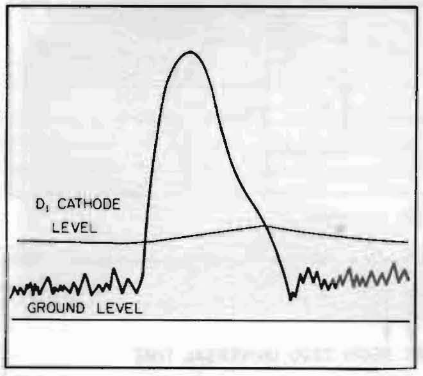


FIG 3.—Solar flare signal from the 27-kc receiver

a positive pulse as shown in Fig. 3. When the amplitude becomes great enough, D_1 conducts and the pulse charges C_1 through capacitor C_2 and limiting resistor R_1. As the amplitude of the burst drops, D_1 opens and C_2 is charged through R_3 to a new level so that the diode bias is restored. Also the charge lost by C_2 during the charging of C_1 is restored. The system is now ready for the next burst to be received at some undetermined later time.

The voltage on capacitor C_1 reaches equilibrium at a value given by average of pulses above clip level × R_2/R_1, assuming that C_2 can reach equilibrium between pulses.

Amplitude Selection

In addition to clipping out some of the base-level noise, it may be desirable to reject local thunderstorm bursts. This can be done by amplitude selection and is accomplished by V_2 in Fig. 2. In this application V_2 is biased beyond cutoff by the d-c restoring circuit C_4, D_2, P_1.

If a positive burst of sufficient amplitude occurs, V_2 conducts, causing the burst to appear as a drop across R_1. The voltage waveform presented to the integrator then appears as in Fig. 4A.

The C_1 charging current waveform will be the same as that portion of the voltage waveform above the D_1 cathode level. Thus the system rejects bursts above the amplitude selected at P_1, except for that part of the leading and trailing edges which are below the rejection level.

The trailing edge of an atmospheric burst has somewhat less slope than the leading edge, so most of the charge accumulated from a rejected burst comes from the trailing edge. The trailing edge can be eliminated by D_3 and C_4. When a large burst comes from the receiver, C_4 is charged through D_3 to nearly the peak value of the burst. Then, as the burst drops off, D_3 opens, leaving C_4 to discharge through R_4 and the back-resistance of D_3. By choosing capacitor C_4 properly, the voltage waveform presented to the integrator will be as shown in Fig. 4B. Only a small spike represented by the part of the curve above D_1 cathode level shows up as capacitor charge.

There will be smaller bursts present in a local thunderstorm against which the system cannot discriminate. Therefore, the best that can be hoped for is that there will be some discrimination against storms not in the immediate area, but too close to be received by D-layer reflection.

Cosmic-Noise Signal

The signal for the 18-mc receiver is galactic or cosmic radio noise generated in the galaxy. In coming through the ionosphere the noise is attenuated, depending on the ionization present. When a solar flare occurs, the attenuation is increased.[2]

At approximately 18 mc, automobile ignition, power line noise and radio stations are the chief sources of interference. One cannot discriminate against background since this is what is to be measured.

Cosmic Signal Level

The rejection technique for ignition and power line noise is similar to that used with the 27-kc receiver to reject local thunderstorm bursts. However, the rejected noise burst must be reduced only to the average level. If it is reduced too far, it will cause a decrease in the recorded signal level and would be worse than no rejection at all, since we are looking for decreases. Reduction is accomplished by returning the cathode of the noise-rejection triode to a point which varies as the average noise level, rather than to ground as in the 27-kc rejector.

Radio Interference

The rejection circuitry just described, satisfactorily removes impulse-type interference from the receiver output. However, there remains the problem of interfering radio stations.

To overcome this interference, the tuning dial of the receiver is mechanically driven so that it sweeps back-and-forth over a range of about 30 kc. Radio station interference can be eliminated by the circuit shown in Fig. 5.

Capacitor C_4 is charged slowly in a positive direction through R_5. When the potential reaches the volt-

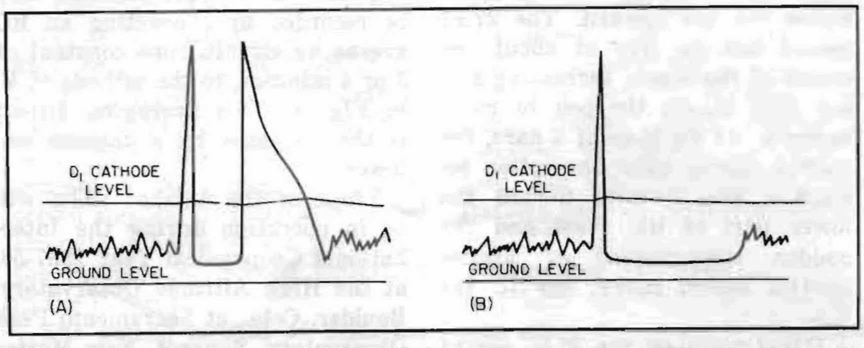


FIG. 4—Output of basic amplitude selector for rejected burst (A) and after pulse elimination (B)

age level of the cathode of V_2, D_3 conducts and prevents the capacitor from charging further. If an interfering signal causes the cathode of V_2 to go positive, D_3 opens and C_4 starts to charge slowly.

As soon as the interference is gone, D_3 conducts and rapidly discharges C_4 down to a level determined by the background noise as averaged in R_3, C_3. If the charge rate of C_4 is slower than the sweep rate on the tuning dial, the recording will be nearly a straight line representing the base noise level, ignoring the interfering radio stations.

The receiver used in the experimental system is an ARR-7 working into a DZ-2 receiver, making it a double conversion superhet with i-f of 456 and 88 kc. The first r-f stage of the ARR-7 was changed from a 6SK7 to a 6AC7 to improve the noise figure.

Antenna

The antenna array consists of two horizontal, parallel half-wave folded dipoles, spaced one half-wave apart and driven in phase. The dipoles are placed one-tenth wavelength above a ground screen.

The vertical gain of the antenna is useful primarily as a means of discriminating against interfering signals arriving at low angles above the horizon.

Chart Recorder

The present method of recording uses a pen recorder utilizing a time sharing system to record the output of both receivers on the same chart. A chart recording of a solar-flare is shown in Figure 6. The 18-mc receiver output has its zero point toward the bottom of the chart. Increasing signal level moves the pen upward. The 27-kc record has its zero at about the center of the chart. Increasing signal level causes the pen to move upward. At the time of a flare, the sudden cosmic noise absorption recording line deviates toward the lower part of the chart and the sudden enhancement of atmospherics record moves toward the top.

Interference on the 27-kc record goes in the same direction as the flare-signal record. For the 18-mc record the interference goes in the opposite direction from the cosmic-noise signal.

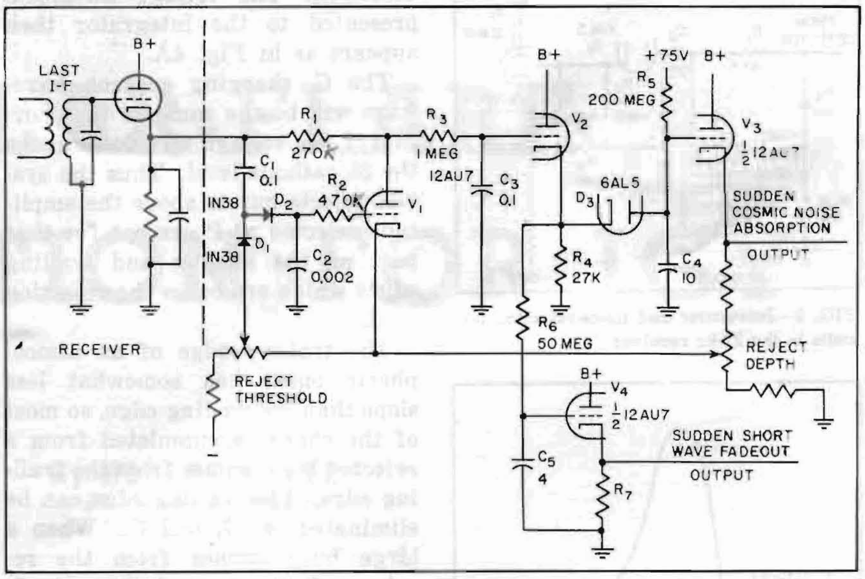


FIG. 5—Radio-interference rejector for the 18-mc receiver

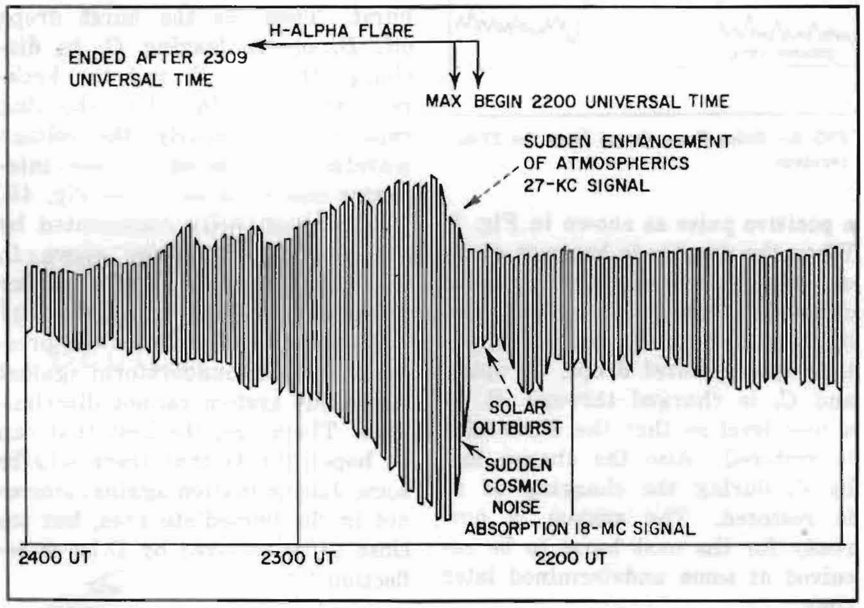


FIG. 6—Chart recording of solar flare shown in photograph. The two signed traces are recorded in universal time

Sudden short-wave fadeouts may be recorded by connecting an RC averaging circuit, time constant of 3 or 4 minutes, to the cathode of V_2 in Fig. 5. This averaging circuit is then isolated by a cathode follower.

Three of the finished units will be in operation during the International Geophysical Year 1957-58, at the High Altitude Observatory, Boulder, Colo., at Sacramento Peak Observatory, Sunspot, New Mexico and at McMath-Hulbert Observatory at Lake Angelus, Mich.

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REFERENCES

(1) M. A. Ellison, The H-alpha Radiation from Solar Flares in Relation to Sudden Enhancements of Atmospherics on Frequencies Near 27 kc. *J. of Atmospheric & Terrestrial Phys.*, 4, p 226, 1953.

(2) C. A. Shain and A. P. Mitra, Effects of Solar Flares on the Absorption of 18.3-mc Cosmic Noise. *J. of Atmospheric & Terrestrial Phys.*, 5, p 316, 1954.