W-60 TYPE ATMOSPHERICS WAVEFORM RECORDER

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Summary—This paper describes the W-60 type atmospheric waveform recorder. The amplifier is aperiodic, covering the frequency range 50 c/s to 80 kc/s, and requires at maximum gain, a signal of 14.5 mV r.m.s. at the input grid to give a half full-scale deflection on a 5″ cathode ray tube. (referred to hereafter as c.r. tube.)

The time base is triggered by the atmospherics and is variable over the 500 μ sec. to 10 milli-sec. Brilliance modulation of the c.r. spot by a pulse from the time base makes the trace visible only for the duration of the sweep. A camera is employed with the c.r. tube and the exposure are made on perforated 16 mm film. After each exposure, the film is automatically moved on to the next frame, 60 exposures per minute being possible. Provision is made for the synchronization with the c.r. direction finding equipment so that the position of origin of each record may be determined.

I. Introduction

As one part of research in the nature and origin of atmospherics, three direction finders have been operated at our Research Institute of Atmospheric for the determination of sources of atmospherics radiated from lightning flashes.

But to further the research, the following improved wave form recorder was designed, produced by us and operated with two direction finders in summer 1952.

II. Method of Measurement

One of the basic requirements of the equipment is to enable us to obtain the waveform as faithfully as possible by amplifying all important components of the energy received from a lightning flash. A Method of measurement is as follows.

The frequency spectrum of the energy of radiation from lightning flash determines the band width of the amplifier, the approximate limits of 50 c/s to 80 kc/s were chosen. To maintain the frequency response over this band, it is necessary to adapt following aerial system. An aerial is connected in series with a condenser to earth in parallel connection with a high resistance, which connects in parallel with the amplifier. The time constant determined by values of this resistance and the total capacity to earth of the aerial should be small compared with the period at the higher frequency limit. And then, the field change appears across the earthed condenser, and amplified by the aperiodic amplifier, the output of which connected to the deflection plate of the c.r. tube. Also the wave form photographed by a camera records directly the field changes at the aerial.

III. Principle of Operation

A block shematic diagram of the recorder appears in Fig. 1. The voltage changes induced in a vertical aerial by atmospheric disturbances are amplified by an aperiodic amplifier, the output of which is connected to the deflection plate of c.r. tube so as to produce a vertical deflection of the spot, and also, in the same way, its 1/3 output is connected to the monitering c.r. tube.

The signal may be passed through the filters (5th harmonic of the main supply and 17.442 kc/s). A trigger signal is obtained at the stage immediately succeeding the filters, and, after amplification, operates the trigger-pulse generator which produces the rectified pulses of negative polarity. The negative pulses trigger a time base and the time base, by its trigger action, generates a rectangular wave form voltage of negative polarity which is used (1) as a pulse for brilliance modulation of the c.r. tube, (2) as a gating pulse for generating the sweep voltage, (3) as a synchronous pulse which is transfered to the c.r. direction finding equipment.

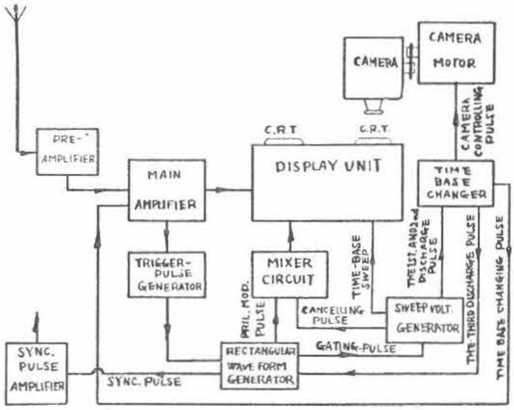


FIG. 1

The following sequence of operation is performed as follows.

1) The brilliance modulation pulse is transfered to the mixer circuit.

2) By the gating action of the gating pulse, two sweep voltages are generated, each of them is followed by a discharge pulse of a fast rise. Two sweep voltages are amplified, and the symmetrical output of the final stage is connected to the horizontal deflection plate of the c.r. tube, and its 1/3 output to the horizontal deflection plate of the monitering c.r. tube. The first discharge pulse is connected to the above mixer circuit for the purpose of cancelling the return visible trace of sweep line. The first and second discharge pulse is transfered to generate a rectangular waveform voltage for changing a time base. Both the first and second discharge pulse are connected to a time base changer. By the gating action caused by the first and second discharge pulse, at the same interval as the single sweep a rectangular waveform voltage of positive polarity is generated as the same time duration as the single sweep, which is also followed by a discharge pulse of a fast rise. The rectangular waveform voltage which act as a time base changing pulse is connected to some stage of the amplifier.

To terminate the durations of the brilliance modulation pulse, double sweep voltage and the time base changing pulse at the same time, the discharge pulse is fed back from the time base changer to the time base. The same pulse is connected to a camera control unit.

The following sequence of observation is performed by the camera unit, and the method of photographing is that the waveform is displayed in halves devided along two sweeps, and the results are photographed on the stationary film.

Upon receipt the discharge pulse for operating the camera control unit, the film photographed is automatically made to advance to the next frame.

Provission is made for the synchronization between the waveform recorded and the c.r. tube direction finding equipment. From the former the synchronous pulse is transfered to the latter, resulting in timing a neon lamp which is mounted beside the face of the c.r. tube, and it is photographed on the continuously moving film on the side of the recorded direction figures of atmospherics.

For the purpose of viewing the performance of the equipment, before and during the observation, a monitering c.r. tube, which is connected in the same way as the main c.r. tube, is equiped with the waveform recorder.

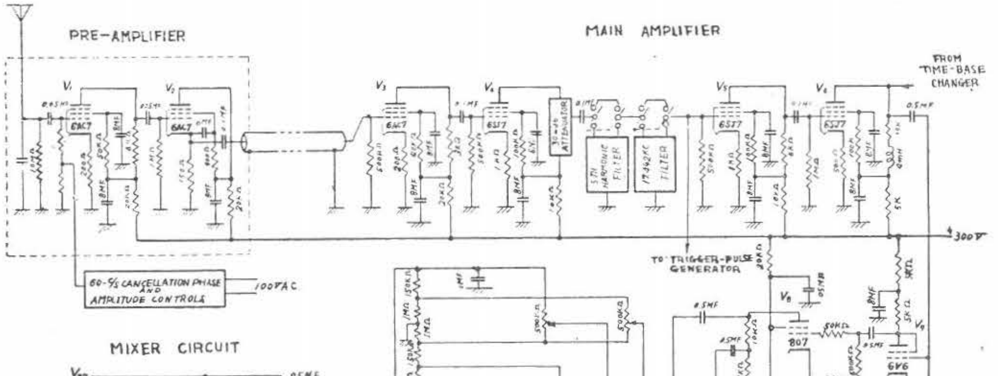
IV. Detailed

(See Fig. 2)

1. Aerial, Aerial System, and Pre-Amplifier.

The aerial is a vertical single wire 10 metres long (82 PF). It is connected at its lower end in series with a condenser (2,000 PF) earthed in parallel connection with a resistance (10 MΩ), the unearthed side of the condenser is connected by a condenser (0.02 μF) to the input grid circuit of the pre-amplifier in parallel connection with a earthed resistance (1 MΩ).

The pre-amplifier consists of two stages of the valves V_1 and V_2. To the input grid circuit of the first stage V_1 is applied by the output of an amplitude and phase compensator of the main supply frequency. The second stage V_2 is a cathode-follower, which is connected at the cathode to the input grid circuit of the first stage V_3 of the main amplifier by the concentric cable with the outer side earthed. As the 60 c/s inductive compensator is adjustable in phase and amplitude, the controllable range of phase covering 360°. It consists of an a.c. voltage dividing potentiometer and a transformer with a variable resistor and a fixed condenser in the secondary circuit. The output is applied across the earthed resistance connected in series connection with the earth side of the grid leak of the valve V_1, to cancell the unwanted hum picked up by the aerial.



MAIN C.R.TUBE (DISPLAY UNIT)

FIG. 2*a*

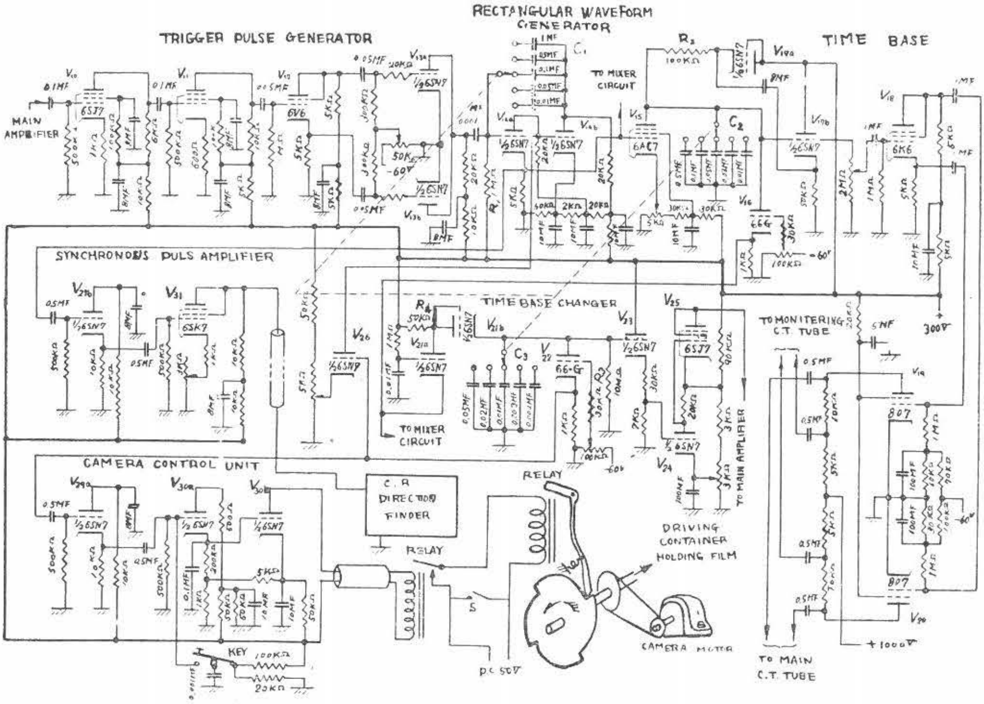


FIG. 2b

To minimize internally-generated hum, the heater supply of the amplifier is balanced with respect to earth.

2. *The Main Amplifier*

The over all gain of the main amplifier is controlled by a 1,000 ohm resistance potentiometer forming the plate load of V_4. The maximum attenuation is 30 db, and may be inserted in steps of 3 db. The interference of, at the lower side of the passband of the amplifier, the 5th harmonic of the mains supply is experienced. For the purpose of rejecting the unwanted interference, the 5th harmonic filter can be inserted by the switch S_1 into the circuit between V_4 and V_5, which consists of a parallelly connected two T type networks. The appreciable carrier interference of the frequency 17.442 kc/s is also experienced, when the Yosami Transmitting Station about 17 miles away is operating on 17.442 kc/s. For the same object described above, a bridged T filter tuned 17.442 kc/s can be also inserted, by the switch S_2 into the circuit between V_4 and V_5.

Another interference is, further more, experienced, the most part of which is a relative pure sine wave in the neighbourhood of the frequency 4.5 kc/s, and it is deduced to be generated at some factory about 1 mile away, when operating. It is impossible to deal with the interference in such a way as above described, because the filter required would seriously disturbe the atmospherics signal. But the above interference disappers at some times in the daytime and during the night.

A paraphase amplifier V_7 drives a push-pull output stage (V_8-V_9). An undistorted output of 560 V peak to peak may be delivered to the deflection plate of the c.r. tube, and its 1/3 output may be also added to the c.r. tube of the moniter-ing c.r. tube.

3. Trigger Pulse Generater.

The purpose of the trigger pulse generator is to produce suitable pulse as to be capable of triggering an rectangular waveform generating circuit instantaneously when an atmospherics signal is received.

For this reason, the whole wave clipping circuit is used to produce such pulse as above described, in any case whether the first cycle of an atmospherics signal is of positive or negative polarity.

It has two input grids arranged symmetrically with a cathode bias voltage and the resistor forming a common plate load of the two valves. Upon receipt a symmetrical input at the two input grids, pulses of negative polarities are developed across the common resistance which is used as a trigger pulse for the rectangular waveform generator.

To converse a single polarity of atmospherics signal to a symmetrical output and to amplify up to the limit of trigger level required for triggering a retangular waveform generator, two stages of per-amplifiers containing a paraphase amplifier are added to the whole wave clipping circuit.

The common bias voltage may be adjusted by controlling a resistance potentiometer, which makes it possible to control the trigger level.

4. Rectangular Waveform Generator

For the purpose of generating a single rectangular waveform voltage, so-called one shot multivibrator (V_{14a}-V_{14b}) is employed. The performance of the circuit is of common knowledge, so the circuit is outlined as follows. This circuit resides normally in a stable state when the valve V_{14a} is conductive, and the valve V_{14b} has zero conductance biased below the cut off. Upon receipt the negative trigger pulse from the trigger pulse generator, the circuit quickly transfers to a semi-stable state, only tempolarily stable, when the valve is cut off, and the valve V_{14b} is conductive.

After a certain interval of time determined approximatly by values of the capacitance C_1 and the grid leak R of the valve V_{14a} the circuit will transfer to its original stable state.

The transfering between two statê of the circuit results in generating a single rectangular waveform with a steep rise across the cathode resistance of the valve V_{14a}.

5. Time Base Sweeping Circuit

The object of the time base is to produce double sweep voltages which are amplified by the following amplifing stage to be capable of producing the full scale deflection of c.r. tube.

Upon receipt the gating pulse from the rectangular waveform generator, the valve switching circuit V_{15} is cut off, and it follows that the capacitor C_2 is being charged up.

The voltage across the capacitor C_2 increase up to the set threshold voltage of the thyratron tube V_{17}, by charging, and on instant over it, the capacitor discharges through the thyratron valve.

The same sequence of operation is repeated once more for the duration of the gating pulse, and double sweep voltages, first, and second discharge pulses are generated.

A paraphase amplifier V_{18} drives the final stage of symmetrical connection, the output of which is connected to the horizontal deflection plates of the main c.r. tube. In the same way its 1/3 output is connected to the monitering c.r. tube. A multi-position switch enables the appropriate changing on the capacitors C_1, C_2, and C_3 described later, to be selected at the same time by a unit controll.

6. Time Base Changer

The time base changer is a circuit required to produce a rectangular waveform for changing the time base, so as to the waveform may be displayed divided in halves in two steps, *i.e.* up stain and down stain, on the c.r. tube. And also the pulse for terminating the durations of the brilliance modulation pulse, of double sweep voltages, and of the pulse for changing the time base, are obtained in the circuit.

After amplified to the purpose, the pulse for changing the time base is superposed on an atmospherics signal at the plate of the fourth stage V_6 in the main amplifier. The 3rd positive discharge pulse is conversed to negative one.

Upon receipt the 1st positive discharge pulse of a fast rise potential from the time base, the valve switching circuit V_{21a} is cut off and the capacitor (C_3) is charged by the valve current through R_4 for its duration, but on instant its duration ends, the capacitor discharge through the resistance (R_3) until once more the 2nd discharge pulse cuts off the valve switching circuit. Upon receipt the 2nd discharge pulse similliar to the 1st one, the potential of the capacitor exceeds abruptly over the set threshold voltage of the thyratron V_{22} and discharges through it followed by the positive discharge pulse (the 3rd pulse) of a fast rise, the resulting positive rectangular waveform is produced across the condenser, and across the cathode resistance.

In this case the time constants of charging ($R_4 \times C_3$) and discharging ($R_3 \times C_3$) must be selected so as to the above sequence of performance may accomplished, and a good flat top of a rectangular waveform may be obtained.

7. Mixer Circuit

The brilliance modulation pulse from the rectangular waveform generator is connected to the valve V_{27}, and the first discharge pulse is also connected to the valve V_{28}. The former valve is connected in parallel connection with the latter valve.

The modified brilliance modulation pulse is connected to both the brilliance modulation grid of the main c.r. tube and the monitering c.r. tube.

8. Synchronous Pulse Amplifier Circuit

To synchronize the waveform recorder with the direction finding equipment, the synchronous pulse obtained from the rectangular waveform generator is amplified by two stages in succession, then the output is transfered by the cable to the neon lamp mounted beside the face of the c.r. tube.

Upon receipt the synchronous pulse, the neon lamp firing for some short time. Its illumination is photographed on the continuously moving film on the side of the direction figures of atmospherics.

9. Display and Camera-Control Unit and Source

The display and camera-control unit consists of the main c.r. tube, the camera, the camera motor and the associated amplifier. The main c.r. tube is the 120H-

B11 type and its accelerating voltage is 6,000 volt. The monitering c.r. tube is the 120E-B1 type and its accelerating voltage is 2,000 volt. The camera lens has the aperture of $f/1.4$ and the focal length of 50 mm. Each of the two cassettes, driven separately by the two induction motors, holds raw film and photographed film respectively. A belt-wheel on each motor driving shaft is belt-combined to its corresponding belt wheel on the shaft of the cassettes. During observation, normally, the camera motors are driven by the application of the mains supply and its driving shaft being revolved, while the shafts of the cassettes are mechanically stopped. Then, upon receipt the atmospherics, the 3rd discharge pulse from the time base changer is amplified and it operates the electro-magnetic relay forming the plate-load of the V_{30b}. Accordingly, the successive electro-magnetic relay is energized and it enables the shafts of the cassettes to go free from the mechanical stopper (Fig. 2*b*), just enough to make the photographed film advance to the next frame.

To remove the influence of the variations of the source, the source was stabilized. The influence of the inferior quality of brilliancy on the c.r. tube-screen caused by the hum of the direct high voltage, applied to the main c.r. tube, was cancelled in the side of the main c.r. tube.

V. Performance

The performance of the equipment is largely governed by the characteristics of the amplifier.

At maximum gain, the amplifier requiers 14.5 mV r.m.s. at the input grid to produce a half full scale trace on the c.r. tube. At maximum gain, the maximum undistorted output voltage corresponds to 20 mV r.m.s. at the input grid.

The amplitude-frequency characteristics are given in Fig. 3. The upper curve represents the amplifier only, while the lower curve shows the effect of adding to the filters.

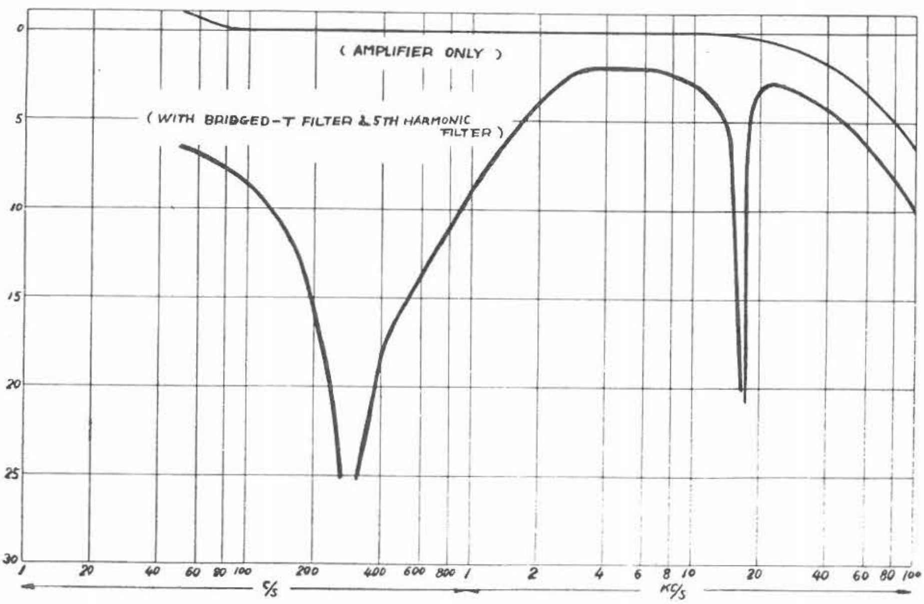


FIG. 3

The rise in characteristic of the amplifier only is appreciable with decreasing frequency.

Some modification would be found, if the main energy component contained in the atmospherics were in the neighbourhood of 17.442 kc/s or 300 c/s.

The time delay of a starting part of the waveform on the c.r. tube is governed in the most part by the trigger level of one shot multivibrator. The trigger level can be lower comparatively small by adjusting the grid bias of the normally cut off tube of one shot multivibrator. And when nois interference is negligible, the above time delay may be kept to a comparatively small value.

It is necessary to specify the records with this equipment. The observations of direction finding and waveform of atmospherics were made in Sep. 1952 at two stations. In Fig. 4*a* and *b*, two examples are shown, the one (Fig. 4*a*) is the typical ionospheric reflexion type, and the other (Fig. 4*b*) represents a leader stroke and many successive ionospheric reflexions.

In Fig. 5 the front view of the W-60 type waveform recorder is shown.

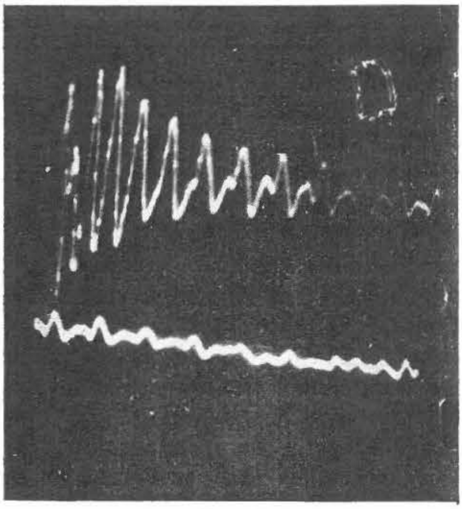


FIG. 4*a*

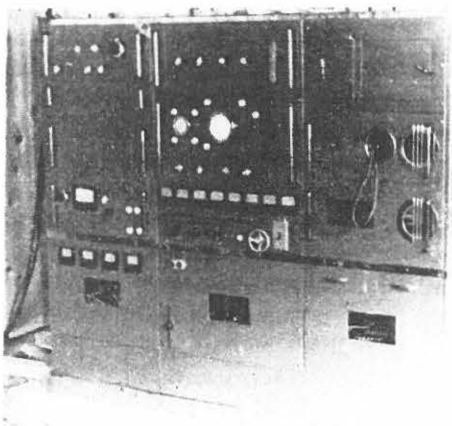


FIG. 5

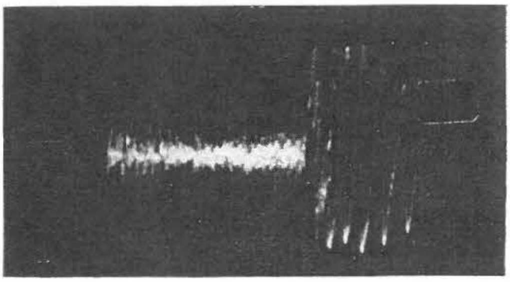


FIG. 4*b*