DIRECTION FINDER OF ATMOSPHERICS

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Summary — In order to study the correlation of atmospherics with weather phenomena as well as to investigate the construction of the active weather phenomena such as thunderstorms, typhoons, etc., the authors devised recently a portable direction finder of atmospherics satisfying the present requirement of higher accuracy. Detailed explanation will be found in this paper.

1. Introduction

In recent years the investigations on the atmospherics have been extended by many workers, and the correlations of atmospherics with meteorological phenomena were studied more and more.

At present, it is required that the situations of each atmospherics are precisely decided.

Consequently, it is necessary to increase the accuracy of measurement and to add the exact accessory equipments.

In order to realize these new requirements, the direction finder of high sensitivity and excellent accuracy was produced by new systems.

The fundamental principle of this apparatus is an instantaneous type. The block diagram of this apparatus is shown in Fig. 1, and it consists of two antennas, two main amplifiers, a test oscillator, a buffer resistor box, two cathode-ray-tubes, a brilliance modulator, a timing circuit, a standard frequency signal receiving set, a second signal generator, and power supply circuits. The conventional two loop antennas oriented at right angles to each other are used, two straight system receiving amplifiers with seven stages, are used and have maximum gain of 126 db, and these have completely identical electric characteristics to each other. This apparatus has the receiving frequency range of 8-13 kc/s, but usually is operated at 10 kc/s.

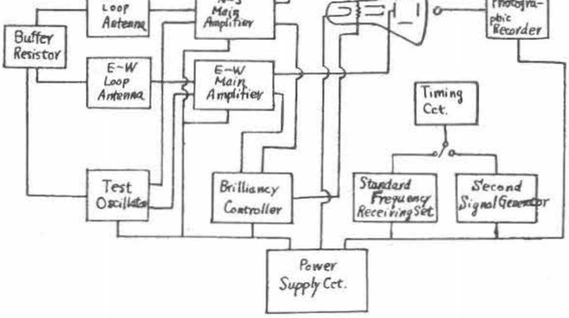

FIG. 1

As a synchronization between two stations, we used the standard frequency time signal (JJY), and for convenience of observation, we added a brilliancy modulator of the cathode-ray-tubes.

Every atmospherics which intervals is longer than 10 ms, could be perfectly recorded on the photographic film with the timing marks.

Employing this apparatus, we obtained the images on the screen, which were perfectly linear, but slightly elliptical at night, and especially more eccentric at sun rise and sun set.

This is a portable direction finder, and is carried to the observatory selected for the purpose of observation. One of the stations for observation is fixed in our laboratory.

2. Mechanical Design

We designed this set in consideration of movement.

Therefore, it must be conditioned not only the easyness of handling, installation, and movement, but also the limitation of dimensions.

It is necessary that the combination part between the antenna and receiving part is lengthened as long as possible to reduce the error of measurement.

All the materials used is duralumin. Each antenna is about 1 meter squre and the receiving part measures about 1.1 meter in height and 70 centimeters in width and 60 centimeters in depth.

In consideration of the weights of the power supply circuits, and the magnetic disturbance of the cathode-ray-tubes from the power supply circuits, we decided the arrangements in the receiving part as follows.

There are the power supply circuits on the lowest floor, and the standard frequency receiving set, timing circuit on the second floor, and the main amplifiers, test oscillator on the third floor, and the indicators, brilliancy controller, control pannel on the top floor.

Antenna

The antennas are the crossed frame antennas, and they are the dimensions of 1,010 millimeters square, the cross section area of 154 millimeters spuare, and were shielded by the cover of 2 millimeters duralumin in thickness, which is cut for 30 millimeters in width at two points by 6 millimeters bakelite in thickness in order to eliminate any electrostatic effects.

Each antenna was wound with 400 turns of 0.6 millimeter enameld, cotten-covered copper wire in four layers, each layer was wound in two sections to balance for the ground.

The winding method used is a close density winding with the insulator of empire cloth between the wire and the wooden spacers.

The wooden spacers of *cercidiphyllum japonicum* were employed in consideration of weight and moisture. And the brass screws were used to hold the spacers. As a result of measurement, the insulation between the wire and the shield cover and the electric characteristics of both loops are very excellent.

The buffer resistor box was hanged in the hollow cylinder which is used to combine the antenna with the receiving part. The buffer resistors of bifira winding were precisely made from manganin wire.

3. Main Amplifier

(See Fig. 2)

The output voltage of the loop antenna is coupled to the input terminal of main amplifier by the twinax cable, and we used the means of variable condenser to resonance at the measured frequency.

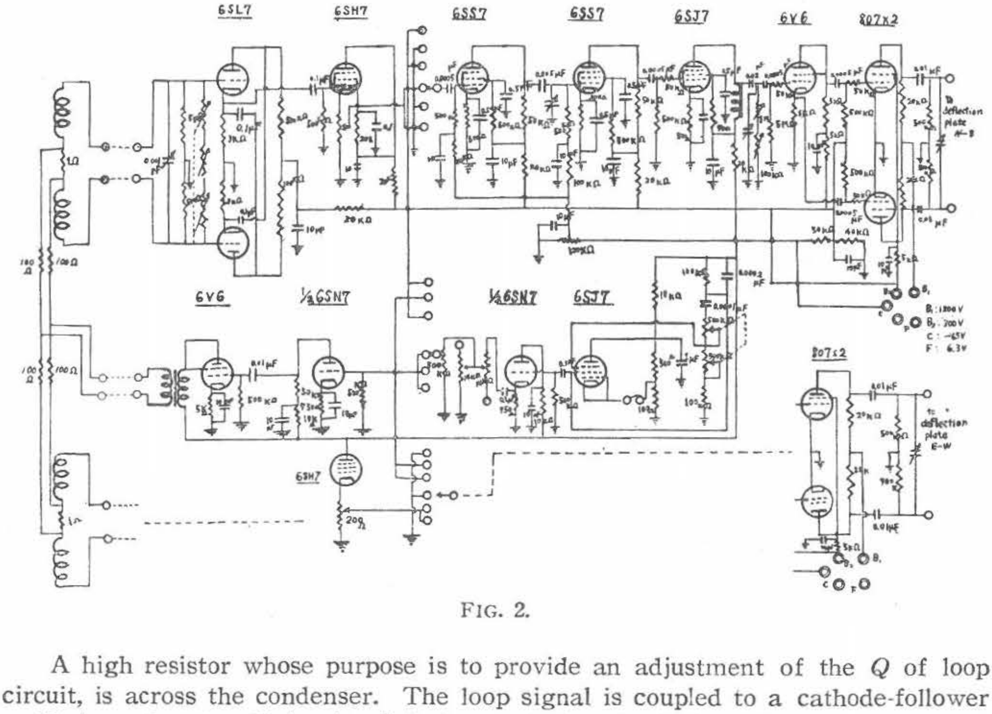

FIG. 2.

A high resistor whose purpose is to provide an adjustment of the Q of loop circuit, is across the condenser. The loop signal is coupled to a cathode-follower and balanced push-pull circuit. It is the particular circuit by which the same phase input is greatly attenuated, but the out of phase input is almost passed, and the input impedance of this circuit is very high.

Employing this circuit, the same phase input which cause the error such as the antenna effect, or the pick up of feeder is attenuated about 40 db, but on the other hand, the out of phase input which is the measuring signal, is attenuated only 3 db.

Therefore, we could improve the measuring accuracy. From the top stage, the signal is coupled to the cathode-follower circuit which is used to prevent the tube from the balanced circuit and to allow the gain to be varied by the conventional potentiometer method without introducting a phase shift.

From the cathode follower coupling stage, the signal goes to the line up switch which is used in the process of lining up of the amplifier. In normal operation, the switch applies the signal to the grid of the next stages which are two cascade connection stages of resistance-capacitance coupled amplification whose gain may be varied.

In these stages, these are used the variable μ tubes whose bias voltages are varied to control the gain of these stages without introducting a phase shift. In this case, we connected cascadely in two stages to obtain the required variable gain range, and employed a uni-control system for convenience of handling. (See Fig. 3.)

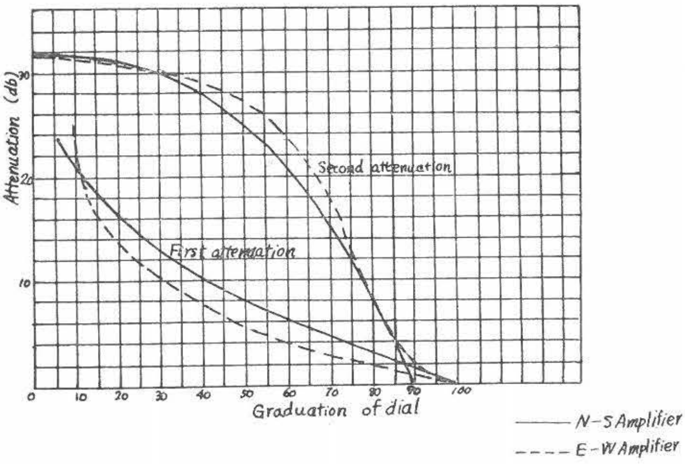

FIG. 3.

But because of possible difference in tube characteristics and in resistor or capacitor values, it is quite possible that the phase shift in both amplifiers may be slightly different.

To correct this difference the condenser connected in parallel to the grid leak of variable μ tube is adjusted. This is a small air variable condenser, but large to correct any phase difference which may appear in normal operation.

If the phase shift are made exactly the same at one frequency, they will be identical at all frequencies. From the resistance coupled stages, the signal is applied to a stage of tuned amplification, providing the inductor and condenser making up the tuned circiut to obtain the high gain.

As in the case of the tuned loop antenna circuit, this tuned circuit must be provided with means for adjusting the Q of the circuit, and again this is done by a high variable value of shunt resistor.

Then, the signal is applied to the phase inverter stage in which the signal is transformed into the balanced type. Instead of the transformer, the phase inverter tube was used to hold the good phase characteristics. In consideration of grid swing, this function was accomplished by the beam power tube which connected the screen grid with the plate to avoid the effect of screen current.

The push-pull signal is applied to the push-pull amplification stage by which the signal is amplified enough to deffect the beam in the cathode-ray-tube.

In this stage, a resistance capacitance coupled circuit of balanced type was used to equalize the phase shift over all frequencies, and a small air variable condenser was connected across the output terminal to equalize the stray capacity of wire.

The maximum total gain of this main amplifier is 126 db and the minimum is 76 db.

The maximum output voltage of no distortion is 1500 Volts in peak values. (See Fig. 4.) This is disturbed by the set noise at the maximum gain, but the

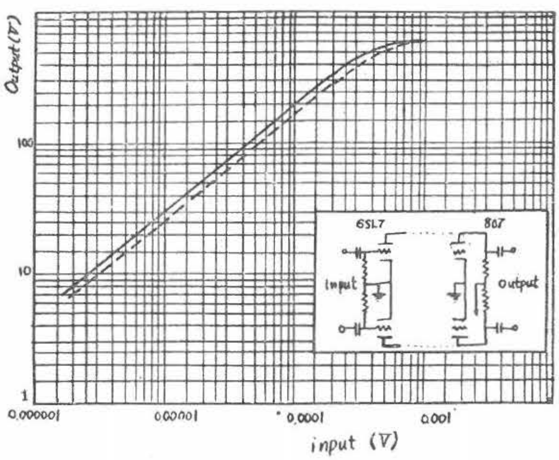

FIG. 4.

gain used in actual observation is about 80–100 db.

Therefore, the function for the main amplifier of the direction finder of a atmospherics is completely satisfied by this design.

4. Indicator, Brilliancy Controller, and Photographic Recorder

In order to record the clear image by a ordinary lens, a high speed acceleration and a fluorescent screen of good efficiency must be used. In this set, a high speed cathode-ray-tube had a fluorescent screen of zinc sulphite was used.

This set is provided with HSE-120-B which is made by the Nippon Electric Co. Ltd.

The deflecting voltages of 1,500 V are required to deflect the beam for 10 centimeters in lengh.

In the observing case, the recorder is fixed in front of the cathode ray tube by a tripod, and the space between the recorder and the cathode-ray-tube is covered by a hood.

Therefore, a monitor cathode-ray-tube must be used to avoid the inconvenience

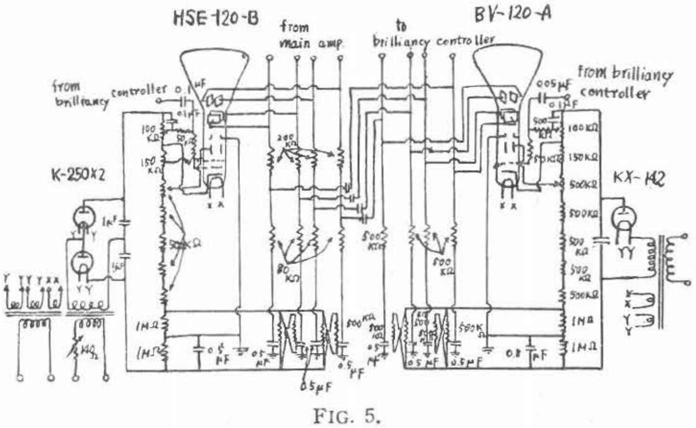

FIG. 5.

which the operating condition may be indistinct. The monitor cathode-ray-tube, BV-120-A, which is made by the Tokyo-Shibaura Electric Co. Ltd., is operated by about one fourth of the output voltage of main amplifiers. The diagram of this indicator is shown in Fig. 5.

In usual, in order to prevent the damage of the fluorescent screen and to reduce the fog of the photographic film, the negative out off voltage must be applied on the grid of these cathode-ray-tubes, and the electron beams will not appear on the fluorescent screens.

A brilliancy controller is used to expose the cathode ray beam, when an atmospherics is received. (See Fig. 6.)

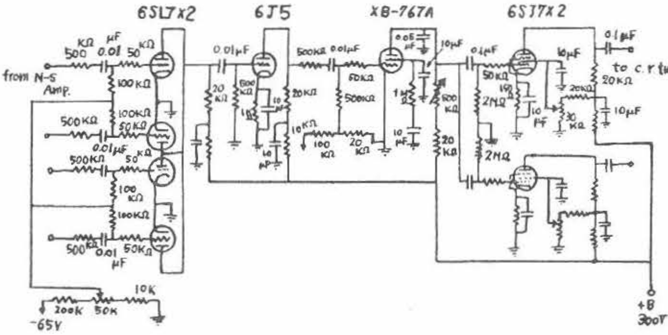

FIG. 6.

About one-sixth of the deflecting voltage of monitor is applied to the grid of 6SL7 which is the first stage of the brilliancy controller.

Two pairs of the input grids of push-pull connected 6SL7 which are connected a common load in the platesides, are connected to the outputs of N-S or E-W amplifier separately. When an atmospherics more than a threshold voltage is received in either N-S or E-W amplifier, a negative pulse is obtained across the plate load resistor. In this case, the number of the recorded atmospherics is limited by the adjustment of the bias voltage. This negative pulse is transformed to a positive pulse which is applied to the grid of a thyratron.

When a positive pulse is applied to the grid, this stopped thyratron which have a condenser and a variable resistor in its plate circuit, discharges the charges of the condenser instantaneously.

As this discharged condenser is charged through the high resistance at once, we obtain a single saw tooth wave which is transformed to a rectangular wave by means of dipping. This rectangular wave is applied to the grids of the cathode-ray-tubes. While this rectangular wave continue, the electron beams are exposed on the fluorescent screens. In this case, the duration of the rectangular wave is variable by the adjustment of the time constant in the plate circuit.

In order to record the image on the fluorescent screen, we used a photographic films of 16 millimeteres. The aperture ratio and the focal distance of its lens are $f=1.5$, $D=1$ inch respectively.

The film speeds are 20 millimeters/sec., 10 millimeters/sec., 5 millimeters/sec., and 2.5 millimeters/sec., in uniform speed, driven by a induction motor.

One value among the above is selected in consideration of the purpose of observation.

5. Accessory Equipments

1. Test-oscillator

A test-oscillator is employed for the lining up of the main amplifier. All pass band of the main amplifier must be covered by its frequeucy range, and its wave form distortion is out of the question.

For this purpose, we used a R-C oscillator. This output is connected to a attenuator through a cathode follower circuit of 1/2 6SN7. And the output signal which is obtained through a rough attenuator of 50 db, is used for the lining up of the main amplifier only.

When the antenna system and the set overall is lined up, the output signal of the attenuator is amplified by 1/2 6SN7 and again power-amplified by 6V6, and the output signal of 6V6 is applied to the antenna through the buffer resistors.

Even if the main amplifier operates at any gain, the output level of this test oscillator can respond to the gain variations of the main amplifier. The frequency range is from 4 to 14.5 kc/s and the deviation of the output voltage is ± 1 db for all pass band.

The connection diagram of this oscillator is shown in Fig. 2.

2. Standard frequency signal receiving set, timing circuit, and second signal generator.

In order to synchronize each stations, it is the best method that all observing sets receive the same signal and record it on the photographic film, separately. For this purpose, we used the standard frequency signal JJY. (4 MC/s and 8 MC/s) This receiver consists of a radio frequency amplifier, a frequency converter, a crystal filter, two intermediate frequency amplifiers, a detector, a low frequency amplifier and a power amplifier; and a sufficient automatic volume control is provided for the fading.

By the parallel connection of neon lamps in the plate load of this last power amplifier, the second signal concerned with the incoming signal, is obtained. And the images of these neon lamps arranged beside the cathode-ray-tube are photographed with the figures of atmospherics.

When the standard frequency signal cannot be received owing to the disturbances, a synchronized electric clock provided in this set must be used in stead of the standard frequency signal.

The block-diagram of these accessory circuits is shown in Fig. 7.

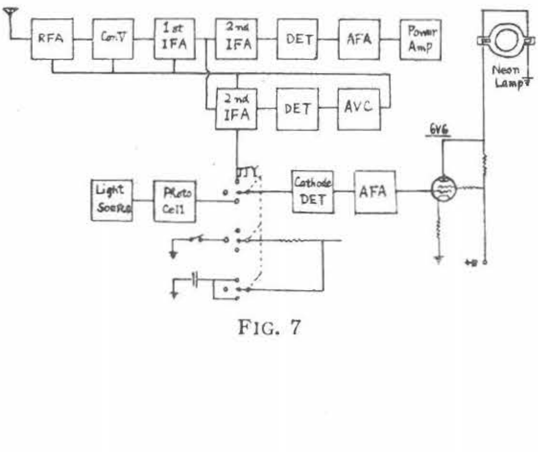

FIG. 7

6. Power Supply Circuits, Control Pannel

Power supply circuits were set on the lowest stage, and the power is supplied to every parts by many cables.

To reduce the coupling through the power source, and to control easily, the power supply circuits of every parts are independent, but the heater and bias sources are common. To obtain the most stable operation, a power source stabilized by the electron tubes and neon lamps was applied to the main amplifiers, test oscillator and brilliancy controller.

Many stabilovolts were used for the other power sources to hold the constant voltage. A ferro-resonance automatic voltage regulator was inserted in the primary circuits of the high tension sources of cathode-ray-tube and of the bias voltage source in order to obtain the good voltage regulation.

The A.C. line voltage is adjustable to hold in 100 Volts by means of slidac. A control circuit was provided in the indicator pannel to control these power supply circuits.

This consists of the main switch I, the main switch II and the pilot lamps.

The main switch I is concerned with the adjustment. And the main switch II is concerned with the photographic record. The block-diagram of the power supply is shown in Fig. 8.

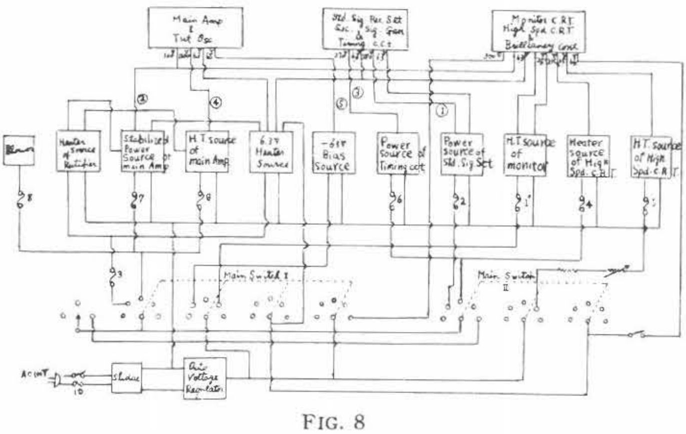

FIG. 8

7. Conclusion

The authors reported the characteristics of one of the direction finders as mentioned above. However, because three observation results at three stations are necessitated considering the accurate direction finding, three direction finders were prepared.

The front view of one of these equipments is shown in Fig. 9, an crossed frame antenna is shown in Fig. 10, a preliminal observation with other equipment is shown in Fig. 11, and an example of the records on a film is shown in Fig. 12.

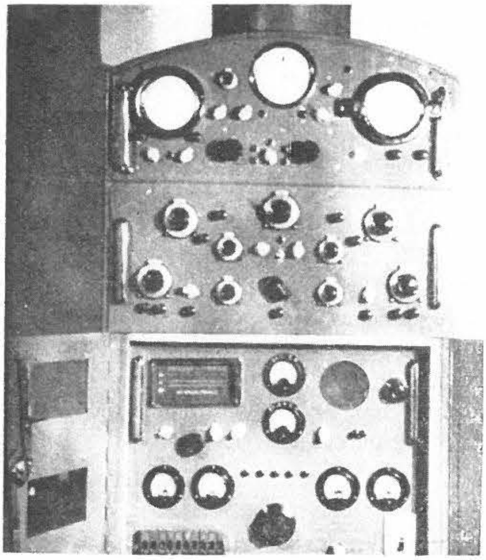

FIG. 9

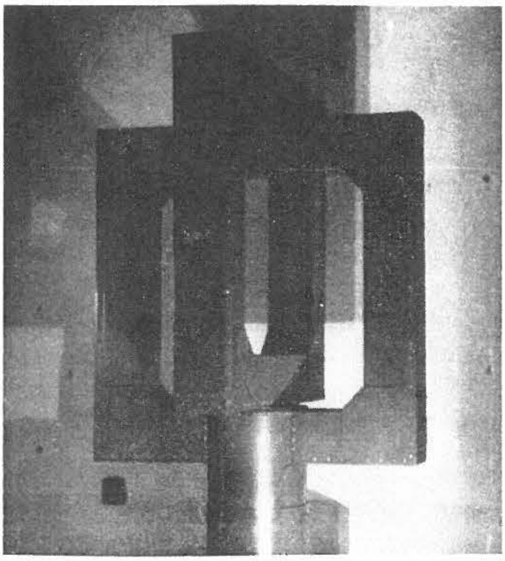

FIG. 10

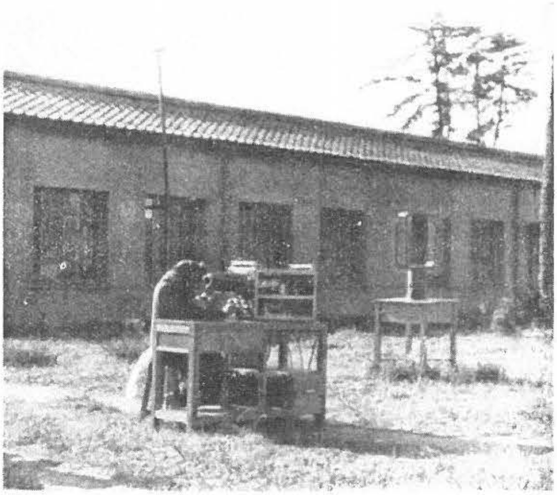

FIG. 11

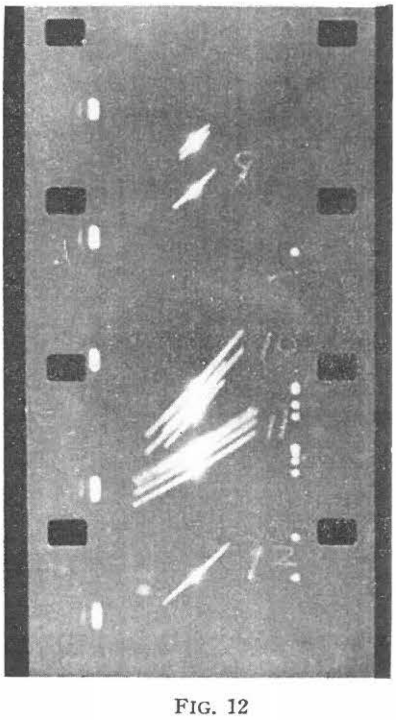

FIG. 12