Proceedings of the Institute of Radio Engineers
Volume 20, Number 12 *December, 1932*

DIRECTIONAL STUDIES OF ATMOSPHERICS AT HIGH FREQUENCIES*

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Summary—*A system for recording the direction of arrival and intensity of static on short waves is described. The system consists of a rotating directional antenna array, a double detection receiver and an energy operated automatic recorder. The operation of the system is such that the output of the receiver is kept constant regardless of the intensity of the static.*

Data obtained with this system show the presence of three separate groups of static: Group 1, static from local thunderstorms; Group 2, static from distant thunderstorms, and Group 3, a steady hiss type static of unknown origin.

Curves are given showing the direction of arrival and intensity of static of the first group plotted against time of day and for several different thunderstorms.

Static of the second group was found to correspond to that on long waves in the direction of arrival and is heard only when the long wave static is very strong. The static of this group comes most of the time from directions lying between southeast and southwest as does the long wave static.

Curves are given showing the direction of arrival of static of group three plotted against time of day. The direction varies gradually throughout the day going almost completely around the compass in 24 hours. The evidence indicates that the source of this static is somehow associated with the sun.

INTRODUCTION

FOR some time various investigators have made records of one type or another of the direction of arrival of static on the long wavelengths. Watson Watt has made a comprehensive study of the direction of arrival of static in England. Others working under him have used apparatus similar to his in Australia and Africa. Captain Bureau has done considerable work on the study of static in France. In this country, L. W. Austin with E. B. Judson working with him has worked on the long-wave static problem. Harper and Dean, also of this country, have made a study of the direction of arrival of long-wave static in Maine. Very little work, however, has been done on the direction of arrival of short and very short-wave static with the exception of the series of observations made by Mr. Potter as described in his paper on short-wave noise.[1]

* Decimal classification: R114. Original manuscript received by the Institute, May 26, 1932. Presented at the meeting of the American Section of the U.R.S.I. at Washington, D. C., April 29, 1932.

[1] R. K. Potter, "High-frequency atmospheric noise," PROC. I.R.E., vol. 19, p. 1731; October, (1931).

Description of Apparatus

Since the middle of August, 1931, records have been taken at Holmdel, N. J., of the direction of arrival and the intensity of static on 14.6 meters. Fig. 1 shows a schematic diagram of the recording system. It consists of a rotating antenna array, a short-wave measuring set, and a Leeds and Northrup temperature recorder revamped to record field strengths.[2]

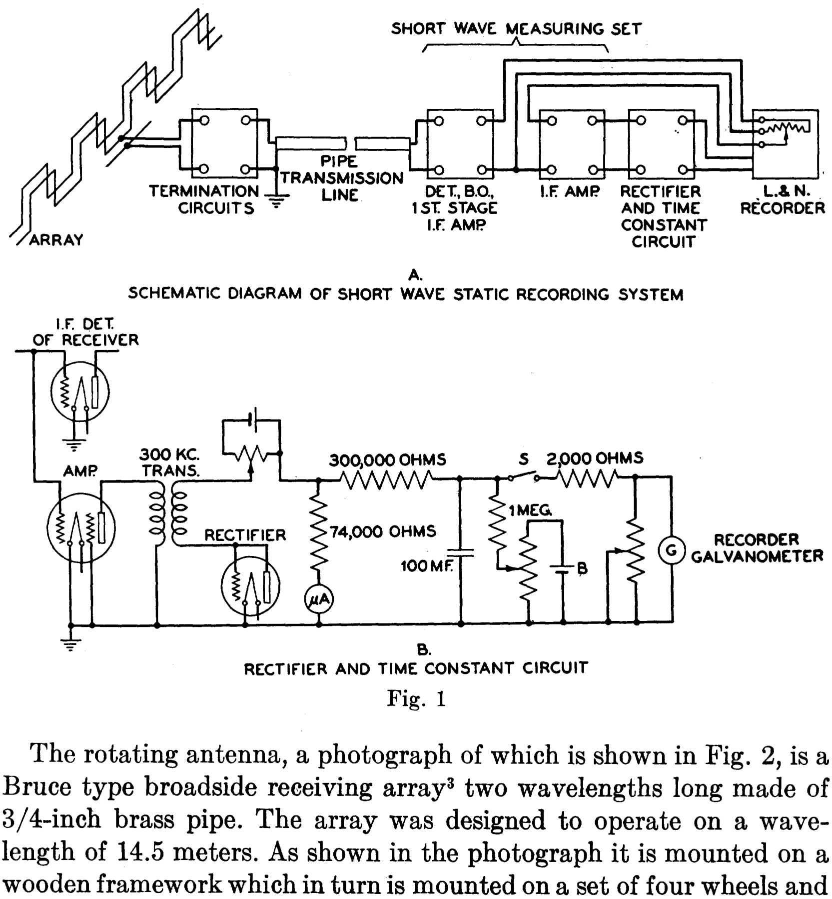

Fig. 1

The rotating antenna, a photograph of which is shown in Fig. 2, is a Bruce type broadside receiving array[3] two wavelengths long made of 3/4-inch brass pipe. The array was designed to operate on a wavelength of 14.5 meters. As shown in the photograph it is mounted on a wooden framework which in turn is mounted on a set of four wheels and a central pivot. The structure is connected by a chain drive to a small synchronous motor geared down so that the array makes a complete rotation once every twenty minutes.

[2] A detailed description of the measuring set and recorder is given in a paper by W. W. Mutch, Proceedings, this issue, pp. 1914–1919.

[3] A. A. Oswald, "Transoceanic telephone service, short wave equipment," *Jour. A.I.E.E.*, vol. 49, p. 267; April, (1930).

Since static on short waves is extremely weak most of the time, the recording system had to be made very sensitive; so sensitive in fact that the first circuit noise of the receiver is recorded.[4] On account of interference which was found on 14.5 meters, it was necessary to operate the system on a wavelength of 14.6 meters. This, however, made

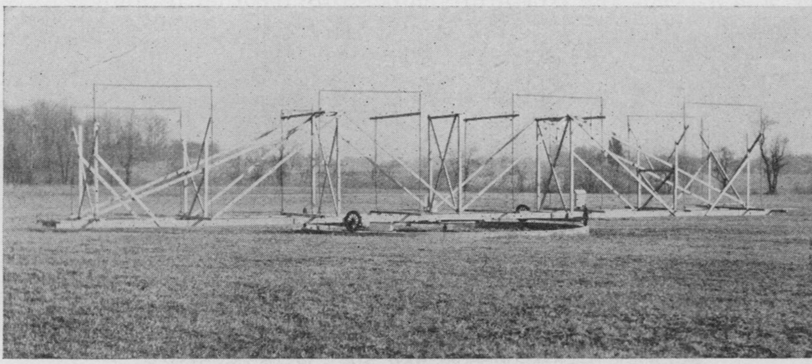

Fig. 2—Short-wave rotating antenna array.

little difference in the directivity of the array, the directional characteristic of which at this wavelength is shown in Fig. 3.

The array termination equipment is housed in a box mounted on the array and is connected to the measuring set in a small house about 275 feet away by means of a 3/8-inch copper concentric pipe transmis-

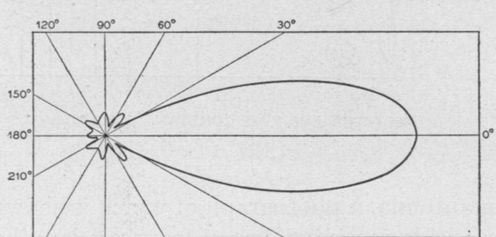

Fig. 3—Directional characteristic of array at 14.6 meters.

sion line buried about 6 inches in the ground. Fig. 4 is a schematic diagram of the array, the termination equipment and the copper pipe transmission line.

Fig. 5 is a photograph of the inside of the house, showing two receivers with their associated recorders. The apparatus on the right

[4] F. B. Llewellyn, "A study of noise in vacuum tubes and attached circuits," Proc. I.R.E., vol. 18, p. 243; February, (1930).

is the short-wave recording system. That on the left is a long-wave recording system, the records of which were used to compare with those

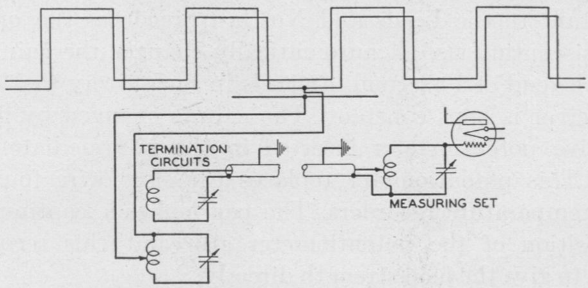

Fig. 4—Schematic diagram of array, termination, and pipe transmission line.

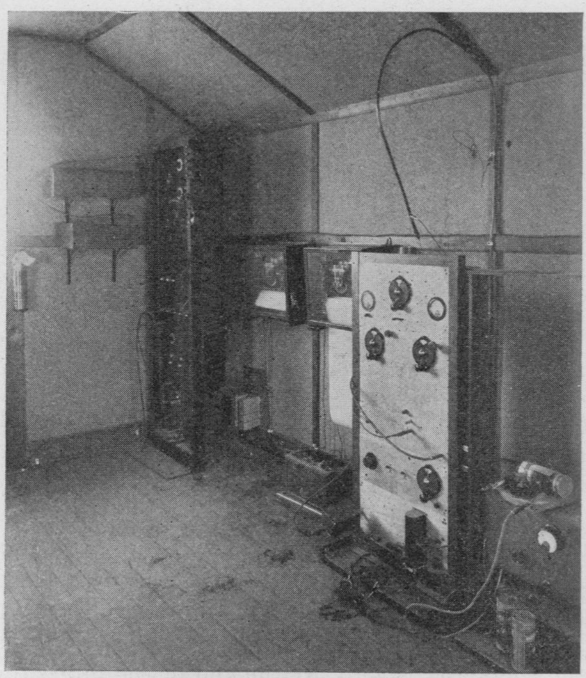

Fig. 5—Long- and short-wave static recording systems.

of the short-wave system. The long-wave antenna system consists of a rotating loop and an L type stationary antenna giving the familiar cardioid-shaped directional characteristic.

The receiver used is a short-wave field strength measuring set of the double detection type which was described some time ago.[5]

The output of this receiver is connected through a circuit with a long time constant to the Leeds and Northrup recorder the operation of which is discontinuous.[2] It automatically changes the gain of the receiver at the end of 10-second intervals in such a way that the output of the receiver is kept constant. The gain is changed by means of a noninductive potentiometer inserted in the intermediate frequency amplifier. This potentiometer replaces the slide wire found on the standard temperature recorders. The pen makes a continuous record of the position of the potentiometer arm and this record can be calibrated to give the field strength directly.

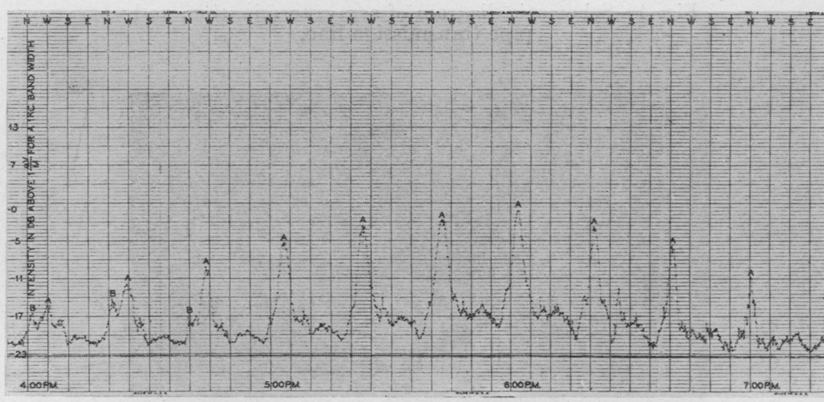

Fig. 6—Sample record of local thunderstorm static on short waves. August 27, 1931.

The operation of the recorder is as follows: For a period of 9 seconds the rectified output from the set charges the 100-microfarad condenser through the 300,000-ohm resistance, see Fig. 1B, the charge being proportional to the energy received from the static during the 9 seconds providing the rectifier is a square law device. During the same time the battery *B* charges the condenser in the opposite sense to the static. The battery *B* and associated resistance are adjusted so that if there is no change in the average static over the 9-second period the resulting charge on the condenser is zero. At the end of the interval the switch *S* is closed by a cam on the recorder shaft and the condenser is discharged through the recorder galvanometer. If the static level has not changed during the interval there will be no charge on the condenser

[5] H. T. Friis and E. Bruce, "A radio field strength measuring system for frequencies up to forty megacycles," Proc. I.R.E., vol. 14, p. 507; August, (1926).

and, hence the galvanometer will not be deflected and the gain of the receiver will remain unchanged. If the static level has increased or decreased the galvanometer will show a corresponding deflection and the recorder mechanism will decrease or increase the gain of the set accordingly.

In the system used the rectifier is not exactly a "square law" device being a two element rectifier in series with a resistance; however, as it was operated with a very small current (5×10^{-6} amperes) it approximated the square law sufficiently accurate for the present purpose.

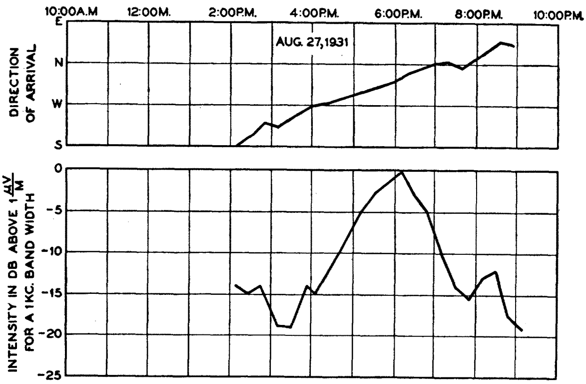

Fig. 7—Direction of arrival and intensity of local storm type static on 14.6 meters.

Results

From the data obtained it is found that three distinct groups of static are recorded. The first group is composed of the static received from local thunderstorms and storm centers. Static in this group is nearly always of the crash type. It is very intermittent, but the crashes often have very high peak voltages. The second group is composed of very steady weak static coming probably by Heaviside layer refractions from thunderstorms some distance away. The third group is composed of a very steady hiss type static the origin of which is not yet known.

During the time that records have been taken, static of the first group arising from several local thunderstorms has been recorded and studied. The data from a few typical records of these storms have been replotted and are shown in Figs. 7, 9, 10, 11, and 12. In these figures the upper curve shows the direction of arrival of the main stream or streams of static plotted against time and the lower curve shows the intensity of these streams at the corresponding times.[6] In addition to the main streams shown there were usually other minor streams, but these are difficult to follow in detail due to interference from random static from local squalls which are generally present during these periods. Fig. 6 is a section of a typical record of this type of static. It is the record for August 27 of which Fig. 7 is the replot. The peaks marked *A* indicate the position of the main storm. Those marked *B* show the position of one of the minor storms.

Fig. 7 shows the data obtained from this record. It represents a severe electrical storm that passed Holmdel early in the evening. During the early afternoon hours the storm was preceded by several thunder squalls. The static from these squalls was recorded, but there were so many of them and the direction of each changed so fast (as could be observed visually) that it was not possible to follow them on the records. During the late afternoon and early evening hours the static from the south grew stronger than that from the local squalls indicating that a definite storm center was forming there or approaching within range of the receiver from that direction. From then on this storm center did not follow a straight path but, as shown by the records, circled around the receiver and disappeared in the northeast. The manner in which the intensity increased and decreased as the storm passed is clearly shown on the lower curve of the figure.

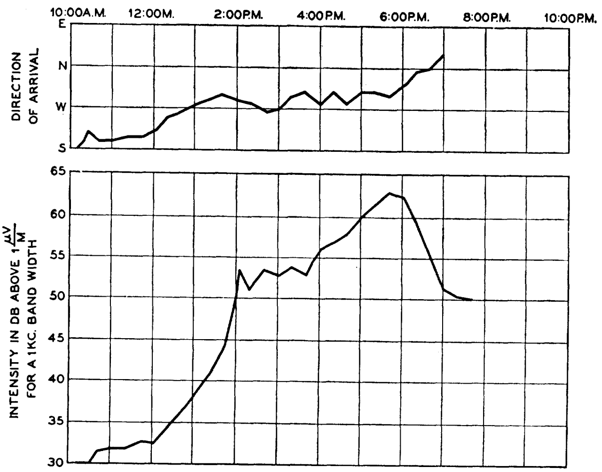

Fig. 8—Direction of arrival and intensity of local storm type static on 6936 meters. August 27, 1931.

[6] The band width of the receiver used was 26 kc but before plotting, the data were reduced to the case of a receiver having a band width of 1 kc, i.e., the intensity values were reduced by a factor of $\sqrt{26}$.

For the purpose of comparison, Fig. 8 shows the replot of the long-wave record for the same day.[7] Note that the ratio of the intensity of the long-wave static in microvolts per meter for a 1-kilocycle band width to that of the short-wave static was 63 db when the storm was

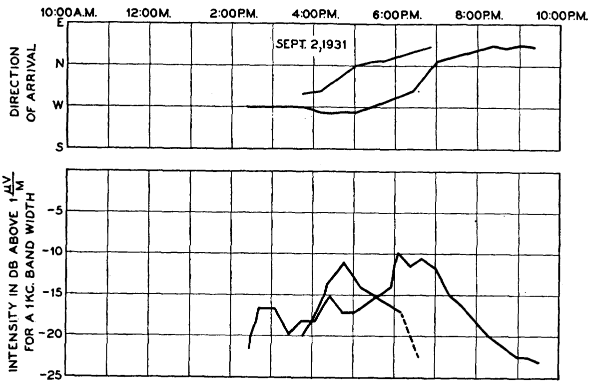

Fig. 9—Direction of arrival and intensity of local storm type static on 14.6 meters.

the severest. This ratio is probably a little too high because the rectifier device was not truly "square law." If we assume the inverse frequency law for the intensity of static this ratio should have been 53.5 db.

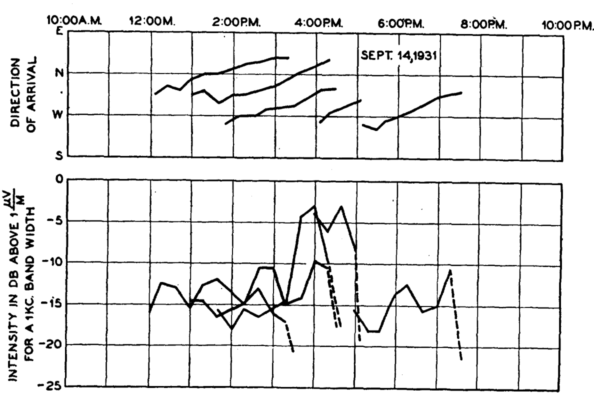

Fig. 10—Direction of arrival and intensity of local storm type static on 14.6 meters.

Fig. 9 shows the data obtained from the record of a well defined storm center that traveled in a straight or nearly straight line towards

[7] The long-wave data mentioned in this paper are all taken on a wavelength of 6936 meters.

the receiver. The static came from the west early in the afternoon, continued to come from that direction as the storm approached, and then as the storm passed Holmdel the direction shifted rapidly from the west through northwest and north to the northeast where it remained as the storm receded until the static no longer was strong enough to record. A minor storm preceded this main one by about an hour as is shown by the short curve preceding the main one. The main storm could clearly be seen passing Holmdel along the northern horizon, but at no time did it approach closer than 15 miles.

Fig. 10 shows the data obtained from the record of several small, but well defined storm centers that followed each other in rapid succession. On this day several small thunder squalls could be seen passing along the northern horizon.

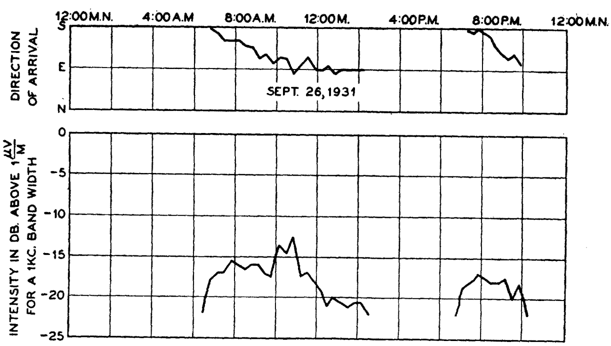

Fig. 11—Direction of arrival and intensity of local storm type static on 14.6 meters.

So far all of the records discussed have been of storms that approached from the southwest or west and passed northwest of the receiver. Fig. 11, on the other hand, shows the data from the record of two storms occurring the same day that approached from the south and passed the receiver on the southeast.

Finally Fig. 12 shows the data from a record of a storm that approached the receiver from the west and split, part of it passing to the north and part to the south of the receiver.

From these figures it is evident that on the average the thunderstorms were audible for four hours before and four hours after they reached Holmdel. Taking 35 miles an hour as the average velocity of a thunderstorm[8] this gives a distance of 140 miles that the storm centers were distant from Holmdel when the static could still be heard.

[8] *See* W. J. Humphreys, "Physics of the Air," p. 365. Also Ward, "The Climates of the United States," p. 322.

It is also worthy of note that by far the majority of storms came from the southwest and west and passed north of the receiver with only an occasional one passing south and southeast. The directions lying between southeast and northeast appear to be substantially free of this type of static at Holmdel and directional antennas built there to receive from those directions on short waves should be troubled with static only infrequently. Of course, this would not necessarily hold for other receiving locations. Locations in some sections, for example, would probably receive an equal amount of this type of static from all directions.

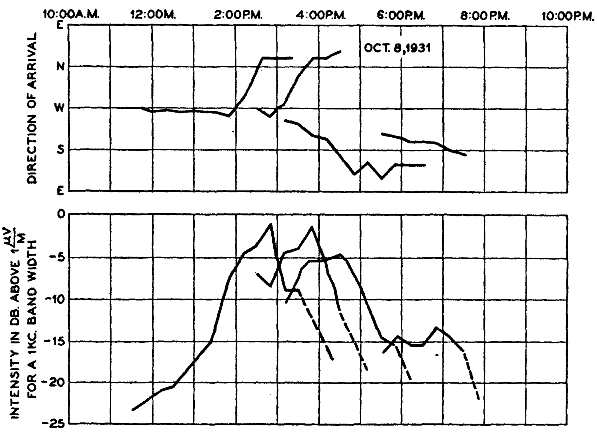

Fig. 12—Direction of arrival and intensity of local storm type static on 14.6 meters.

The static from the second group, which probably originates at long distances, is usually very weak on 14.6 meters. In fact, only occasionally is it strong enough to actuate the recorder. Because of this very few satisfactory records have been obtained of it. From the records that have been obtained, however, and from aural observations it has been determined that this static is of the crash and rumble type; its direction of arrival follows very closely that of the long wave static; and finally it is heard only when the long wave static coming from distant thunderstorms is very strong. It, therefore, probably comes from thunderstorms located some distance from the receiver. The most common directions of arrival of this static, as for the long wave static, are those directions lying between southeast and southwest.

On March 1, 1932, this kind of static was recorded by the short wave recorder from 2:30 P.M. to 3:50 P.M. The data obtained are shown and compared with those obtained on long waves in Table I. The direction of arrival for both the long and short wave static on this day was southeast. As shown in the table the difference between the intensity of the long and short wave static varied between 56 and 62 db. These values should also probably be somewhat lower because the rectifier is not a "square-law" device.

TABLE 1

Time	Intensity of static in db above 1(microvolt per meter) For a 1—kc band width		Difference
	Long-Wave	Short-Wave	
2:30 P.M.	34.0	−22.0	56.0
2:50	37.5	−24.0	61.5
3:10	37.0	−22.5	59.5
3:30	35.5	−24.0	59.5
3:50	37.0	−25.0	62.0

Since this static is so weak that it cannot be recorded much of the time, the crash method[1] of measuring static as used by Potter could probably be used to great advantage to measure it.

The static of the third group is also very weak. It is, however, very steady, causing a hiss in the phones that can hardly be distinguished from the hiss caused by set noise. It is readily distinguished from ordinary static and probably does not originate in thunderstorm areas. The direction of arrival of this static changes gradually throughout the day going almost completely around the compass in twenty-four hours. It does not quite complete the cricuit, but in the middle of the night when it reaches the northwest, it begins to die out and at the same time static from the northeast begins to appear on the record. This new static then gradually shifts in direction throughout the day and dies out in the northwest also and the process is repeated day after day. Fig. 13 shows the direction of arrival of this static for three different days plotted against time of day. Curve 1 is for January 2, 1932, curve 2 is for January 26, 1932, and curve 3 is for February 24, 1932. Fig. 14 is a photograph of a section of one of the records.

This type of static was first definitely recognized only this last January. Previous to this time it had been considered merely as interference from some unmodulated carrier. Now, however, that it has been detected it is possible to go back to the old records and trace its position on them.

During the latter part of December and the first part of January the direction of arrival of this static coincided, for most of the daylight hours, with the direction of the sun from the receiver. (See curve 1, Fig. 13.) However, during January and February the direction has gradually shifted so that now (March 1) it precedes in time the direction of the sun by as much as an hour. It will be noticed that the curves

2 and 3 of Fig. 13 have shifted to the left.[9] Since December 21, the sun's rays have been getting more and more perpendicular at the receiving location causing sunrise to occur at the receiver earlier and earlier each day. It would appear that the change in the latitude of

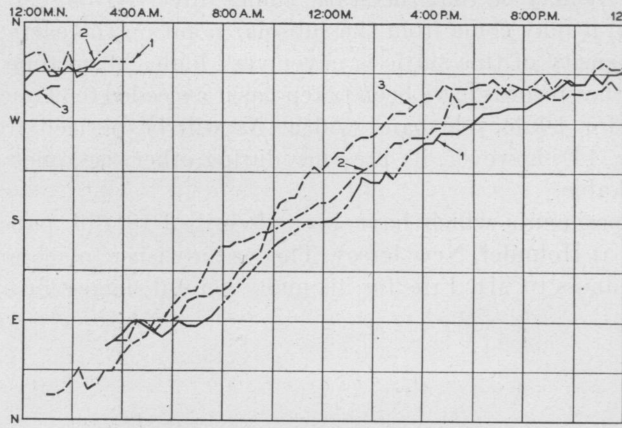

Fig. 13.—Direction of arrival of hiss type static on 14.6 meters.

Fig. 14—Sample record of short-wave hiss type static. February 24, 1932.

the sun is connected with the changing position of the curves. However, the data as yet only cover observations taken over a few months and more observations are necessary before any hard and fast deductions can be drawn.

The fact that the direction of arrival changes almost 360 degrees

[9] Since this paper was written the curve has shifted much further to the left. Now (May 25) it crosses south at 4:30 A.M.

during twenty-four hours and that the shift in the position of the curve observed during the three months over which data has been taken corresponds to the change in latitude of the sun affords definite indication that the source of this static is somehow associated with the position of the sun. It may be that the static comes directly from the sun or, more likely, it may come from the subsolar point on the earth.

The intensity of this static is never very high. At no time during the period that records have been taken has it exceeded 0.39 microvolts per meter for 1-kilocycle band width. As will be noticed from the record (Fig. 14), however, its presence during otherwise quiet periods is unmistakable.

The experiments which have been described in this paper were carried out at Holmdel, New Jersey. The writer wishes to acknowledge his indebtedness to Mr. Friis for his many helpful suggestions.