Proceedings of the Institute of Radio Engineers
Volume 21, Number 10 *October, 1933*

TECHNICAL PAPERS

ELECTRICAL DISTURBANCES APPARENTLY OF EXTRATERRESTRIAL ORIGIN*

By
KARL G. JANSKY
(Bell Telephone Laboratories, Inc., New York City)

Summary—*Electromagnetic waves of an unknown origin were detected during a series of experiments on atmospherics at high frequencies. Directional records have been taken of these waves for a period of over a year. The data obtained from these records show that the horizontal component of the direction of arrival changes approximately 360 degrees in about 24 hours in a manner that is accounted for by the daily rotation of the earth. Furthermore the time at which these waves are a maximum and the direction from which they come at that time changes gradually throughout the year in a way that is accounted for by the rotation of the earth about the sun. These facts lead to the conclusion that the direction of arrival of these waves is fixed in space; i.e., that the waves come from some source outside the solar system. Although the right ascension of this source can be determined from the data with considerable accuracy, the error not being greater than ±7.5 degrees, the limitations of the apparatus and the errors that might be caused by the ionized layers of the earth's atmosphere and by attenuation of the waves in passing over the surface of the earth are such that the declination of the source can be determined only approximately. Thus the value obtained might be in error by as much as ±30 degrees.*

The data give for the coördinates of the region from which the waves seem to come a right ascension of 18 hours and a declination of −10 degrees.

INTRODUCTION

DURING the progress of a series of studies that were being made at Holmdel, N. J., on the direction of arrival of atmospherics at high frequencies,[1] records were obtained that showed the presence of very weak but steady electromagnetic waves of an unknown origin. The first indications of these waves were obtained on records taken during the summer and fall of 1931. However, a comprehensive study of them was not begun until January, 1932. The first complete records obtained showed the surprising fact that the hori-

* Decimal classification: R114. Original manuscript received by the Institute, June 22, 1933. Presented under a different title at the meeting of the American Section of the U.R.S.I., Washington, D. C., April 27, 1933. Revised for publication and presented before Eighth Annual Convention, Chicago, Illinois, June 27, 1933.

[1] Karl G. Jansky, "Directional studies of atmospherics at high frequencies," PROC. I.R.E., vol. 20, p. 1920; December, (1932). The waves referred to are those of group three in the above paper

zontal component of the direction of arrival of these waves changed nearly 360 degrees in 24 hours, and at that time this horizontal component was approximately the same as the azimuth of the sun. These facts led to the assumption that the source of these waves was somehow associated with the sun.

Records of these waves have now been taken at frequent intervals for a period of more than a year. The data obtained from these records, contrary to the first indications, are not consistent with the suppositions made above relative to the source of the waves, but indicate that

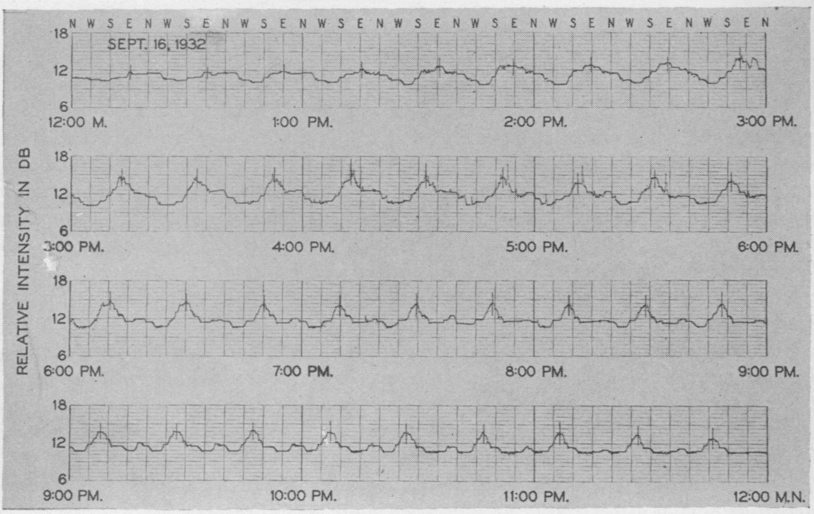

Fig. 1—Sample record of waves of extraterrestrial origin

the direction of the phenomenon remains fixed in space, that is to say, its right ascension and declination remain constant.

Apparatus

The apparatus used and the type of records obtained were described in detail in a former paper.[1] Briefly, however, the apparatus consists of a rotating antenna array, a short-wave measuring set, and an automatic intensity recorder. The array is highly directive in the horizontal plane and is rotated about a vertical axis so that data obtained with the system, like that obtained with a loop rotating on a vertical axis, give the horizontal component of the direction of arrival of signals, but tell nothing directly about the angle the direction of arrival makes with the horizontal plane. The operation of the recorder is synchronized with that of the rotating array so that the records show directly the horizontal component of the direction of arrival of signals as well as their intensity. The apparatus was tuned to a wavelength of 14.6 meters during all the experiments.

RESULTS

Fig. 1 shows a sample record of the waves of unknown origin obtained with this apparatus. The time at which the array was pointed in the direction from which the unknown waves come is clearly indicated on the record by the humps in the curve. The direction of the waves at those times can be determined from the scale along the top of the record.

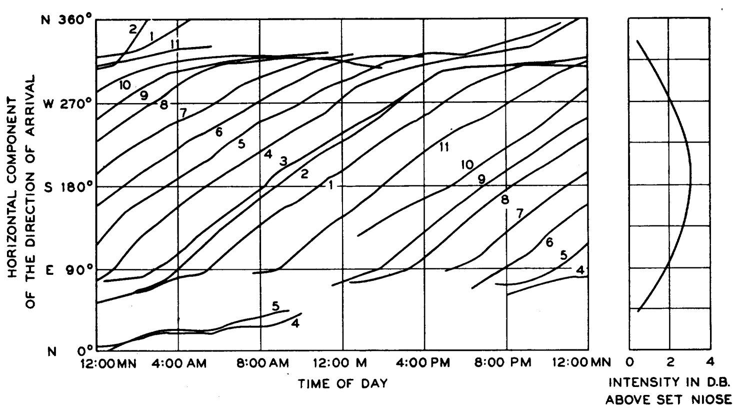

Fig. 2—Direction of arrival of waves of extraterrestrial origin.

1. Jan. 21, 1932
2. Feb. 24, 1932
3. March 4, 1932
4. April 9, 1932
5. May 8, 1932
6. June 11, 1932
7. July 15, 1932
8. Aug. 21, 1932
9. Sept. 17, 1932
10. Oct. 8, 1932
11. Dec. 4, 1932

If, now, the horizontal component of the direction of arrival is plotted against the time of day a curve similar to one of those of Fig. 2 is obtained. Thus, data from the record just mentioned constituted part of that from which curve 9 of this figure was obtained. The figure shows curves for eleven different days spaced approximately one month apart during the year 1932. There is no curve for the month of November. These curves were obtained by averaging the data taken over several consecutive days so as to eliminate the errors made in measuring the records. The day assigned to a given curve is the middle day of the group over which the data for that curve were obtained. The curve at the right in the figure shows the variation in intensity of the waves plotted against the direction of arrival.

This figure shows: first, that the horizontal component of the direction of arrival changes nearly 360 degrees in 24 hours, and, then that there is a uniformly progressive shift of the curves to the left from month to month which at the end of one sidereal year brings the curve back to its initial position. These facts show that the waves come, not from the sun, but from a direction which remains constant throughout the year.

Discussion

To show that this is the necessary conclusion it will be necessary to digress a little from the subject and discuss the celestial sphere and celestial coördinates.

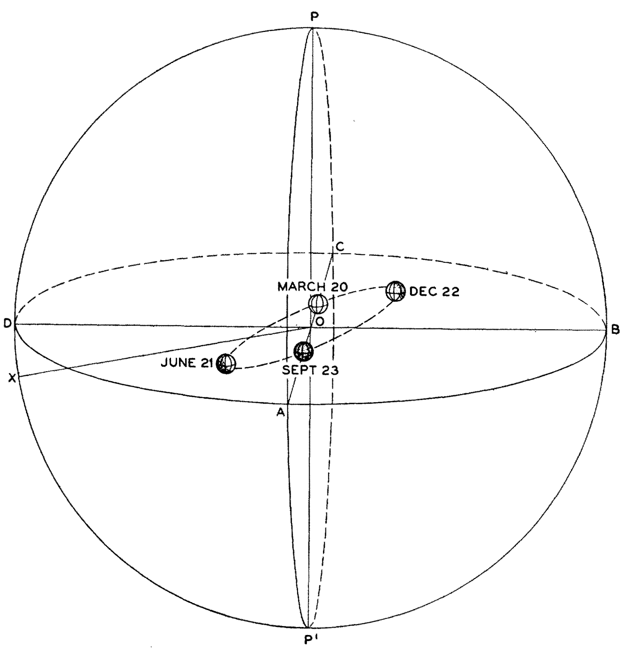

Fig. 3—Graphical representation of the celestial sphere.

The celestial sphere is that hypothetical sphere surrounding the earth upon which all the stars, whatever their distances, appear to be located. The direction of a star, then, is described by giving its apparent position on the celestial sphere, and its position on the sphere is given in terms of a pair of angles called the right ascension and declination of the star. Fig. 3 shows a graphical representation of the celestial sphere with the earth in its orbit around the sun at the center. The plane $ABCD$ represents the plane of the celestial equator and POP' the axis of the celestial sphere.[2] Right ascension is measured in hours

[2] For a more complete explanation of the system of coördinates used in this discussion see Russell-Dugan-Stewart, "Astronomy," vol. 1, chap. 1 or the opening chapters of any textbook on astronomy.

around the circle $ABCD$ eastward from the line OA as reference. The line OA is determined by the direction of the sun from the earth at the time it crosses the equator on the first day of spring. Thus the line OA lies at 0 hours, OB at 6 hours, OC at 12 hours, and OD at 18 hours; 24 hours of right ascension being equal to 360 degrees. Declination is measured in degrees above or below the equatorial plane, plus, if it is above the plane and minus, if below. The positions of the earth with

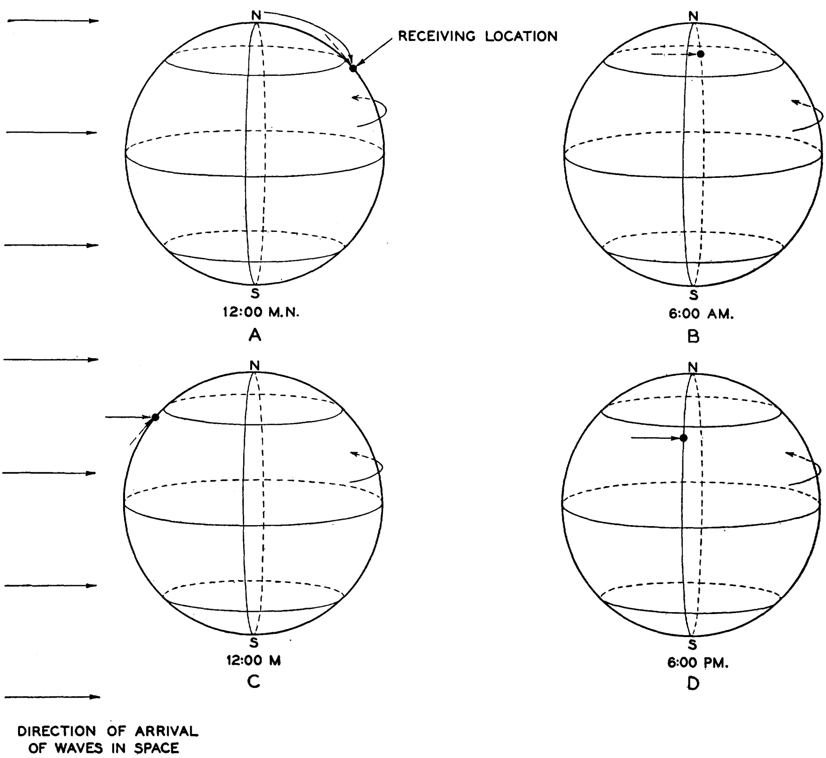

Fig. 4—The effect of the daily rotation of the earth on the direction of arrival as measured at the receiving location.

respect to the sun for the first day of each season are shown. Since the diameter of the earth's orbit is so small with respect to the distances to the stars, it is assumed that the earth is always at the center of the sphere at 0 and the rest of this discussion is based on that assumption. Accordingly, the plane of the celestial equator coincides with that of the earth's equator and the axis of the celestial sphere coincides with the earth's axis.

Now, if there were radio waves coming from a direction fixed in space and from a source so far removed from the sun that the directions of propagation throughout the whole solar system were substantially parallel, if there were no distortion in direction suffered by the waves during their passage through the ionized layers of the earth, if these waves had the ability to bend around the earth, and if there were no other unexplained phenomena taking place, then, for this idealized case, the horizontal component of the direction of arrival as measured at the receiving location would change 360 degrees during one complete rotation of the earth. Let us assume for the sake of argument that the right ascension of the direction of arrival of these idealized waves is 18 hours and its declination 0 degrees, that direction

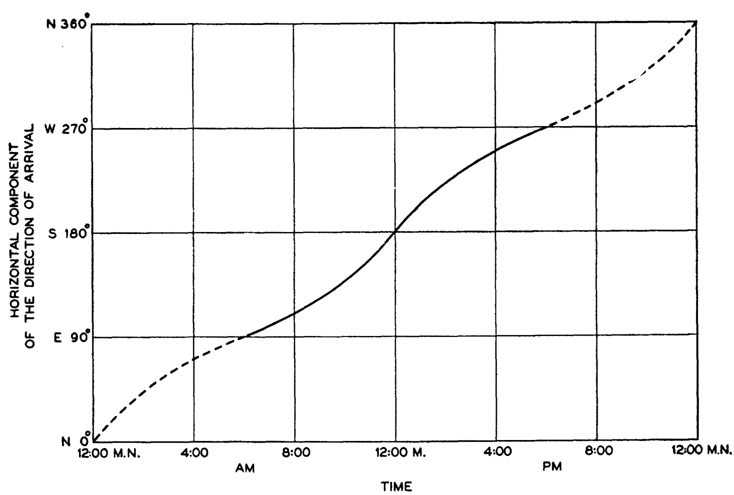

Fig. 5—Theoretical curve of the direction of arrival of idealized waves having a right ascension of 18 hours and a declination of 0 degrees.

represented by the line *DO* in Fig. 3. Then at midnight on the first day of winter, the relation between the direction of arrival and the location of the receiver will be as shown at *A* in Fig. 4. Since the receiver lies in north latitude 40 degrees 22 minutes and the declination of the direction or arrival of the waves is 0 degrees, then at the instant represented the horizontal component of the direction of arrival would be north as shown by the broken arrow. Six hours later the condition shown at *B* would exist and the horizontal component of the direction of arrival would coincide with the true direction and would be east. After another six hours, the direction of arrival would coincide with the meridian of the receiver, and its horizontal component would be south as shown by the broken arrow at *C*, after six hours more it would be west as at *D*, and finally after a complete rotation of the earth it would be back to north again. Or, if this horizontal component of the direction of arrival were plotted against time of day, a curve like that shown in Fig. 5 would be obtained. The curve is dotted for that portion of the time during which the earth would be between the source of the waves and the receiver. As will be seen from the figure, the horizontal component of the direction of arrival changes 360 degrees in about 24 hours, or in exactly 23 hours and 56.06 minutes since that is the time required for the earth to make one complete revolution with re-

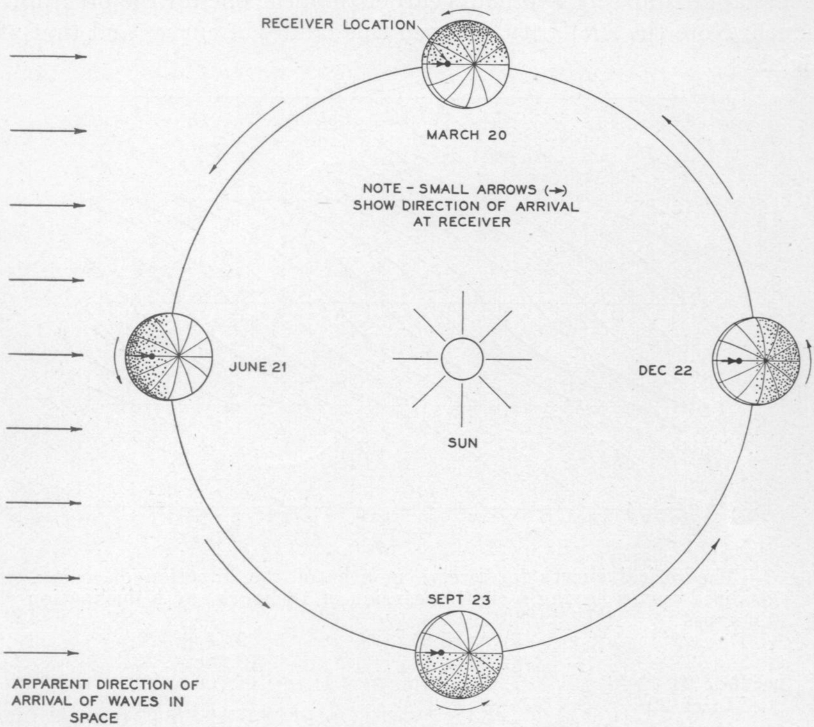

Fig. 6—The effect of the earth's orbital motion on the direction of arrival as measured at the receiving location.

spect to the stars. It is this difference between the length of the sidereal day and the mean solar day (3.54 minutes of solar time) that accounts for the uniformly progressive shift of the curves of Fig. 2 to the left.

Fig. 6 will illustrate just how this shift takes place. This figure shows the earth in its orbit around the sun as seen from above. If, as has been assumed, the direction of arrival of the waves has a right ascension of 18 hours, they can be represented by some such group of arrows as shown at the left in the figure. When the earth is in the position shown for June 21 then, regardless of the declination of the direction of arrival of the waves, the time at which this direction of arrival will coincide with the meridian of the receiver will be at midnight. On September 23 this time of coincidence will occur six hours earlier at 6:00 P.M. On December 22 it will occur another six hours earlier or at 12:00 noon and on March 20 it will occur at 6:00 A.M. Consequently if a curve like the one of Fig. 5 is plotted for every month of the year a family of curves like that of Fig. 7 will be obtained where each curve occurs approximately two hours earlier than the one for the preceding month. Note the similarity between this family of curves and that of Fig. 2.

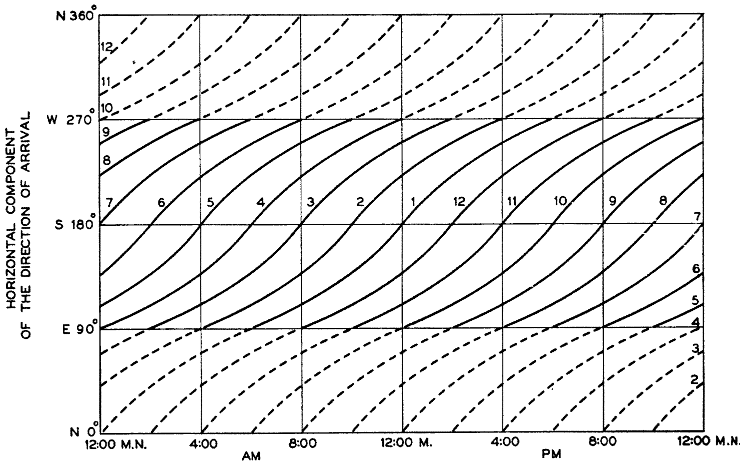

Fig. 7—Theoretical curves for twelve months of the direction of arrival of idealized waves having a right ascension of 18 hours and a declination of 0 degrees.

1. Dec. 22	5. April 21	9. Aug. 22
2. Jan. 21	6. May 21	10. Sept. 23
3. Feb. 21	7. June 21	11. Oct. 23
4. March 20	8. July 22	12. Nov. 22

It will be shown later that for idealized waves having a direction of arrival the declination of which is between -40 degrees, 22 minutes and $+40$ degrees, 22 minutes the horizontal component of the direction of arrival is south when, and only when, the direction of arrival coincides with the meridian of the receiver. Therefore, the times at which the curves of Fig. 7 cross the line whose ordinate is 180 degrees (south) are spaced approximately two hours apart, and if these times are plotted against the day of the year represented by each curve the points will all lie on a straight line[3] the slope of which will be 365.25/24 days per hour.

[3] Strictly speaking the line should not be exactly straight. Of the many reasons why this is so the most important is that the earth's motion in its orbit

It will be shown later that the declination of the direction of arrival of the waves detected by the measuring equipment is between the values of -40 degrees, 22 minutes and $+40$ degrees, 22 minutes. Consequently, if the right ascension remains constant then points obtained from Fig. 2 in a manner exactly similar to that just explained should fall on a straight line the slope of which should be 365.25/24 days per hour. It was in this manner that the points of Fig. 8 were obtained. The

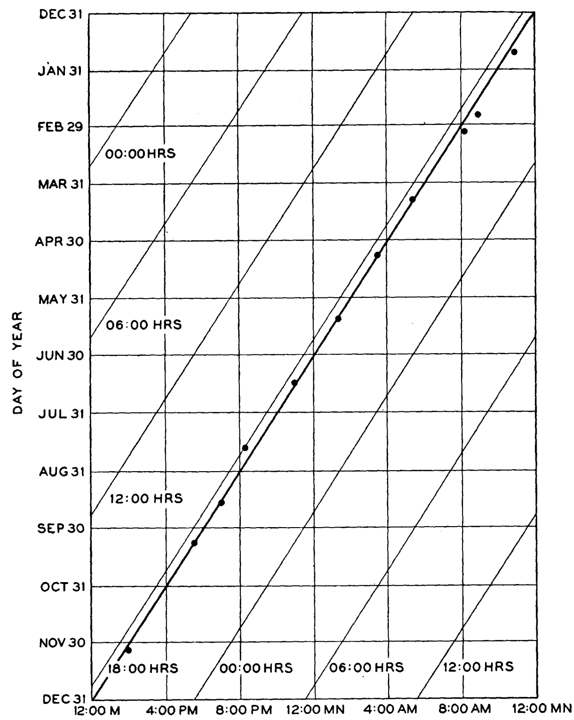

Fig. 8—Time of coincidence of the direction of arrival and the meridian of the receiver for the different days of the year.

correspondence of the points with the heavy line, the slope of which is 365.25/24 days per hour, cannot be accidental and proves that the right ascension of the direction of arrival of the waves is constant. The position of this heavy line on the graph is determined by the value of the right ascension. Thus the position of the curves corresponding to a right ascension of 0 hours, 6 hours, 12 hours, and 18 hours are shown by the light diagonal lines on the figure.

is not uniform. However, the effects are all so small that the greatest deviation would be scarcely perceptible on the curve so they will not be considered in this discussion.

From the relative positions of the heavy line and the light lines it will be seen that the measured direction of arrival occurs at a right ascension of approximately 18 hours, 30 minutes; however, because the mechanism of the recorder takes a finite time to record the field strength values, the directions measured on these records lag behind the true directions by a value varying from 4 degrees to 9 degrees. If the measured values are corrected for this error the right ascension of the direction of arrival becomes approximately 18 hours.[4]

Referring to Fig. 3, if the direction of arrival has a right ascension of 18 hours then it must lie in that half of the plane *PDP'B* to the left of *PP'*. One such direction is represented by the line *XO* in the figure.

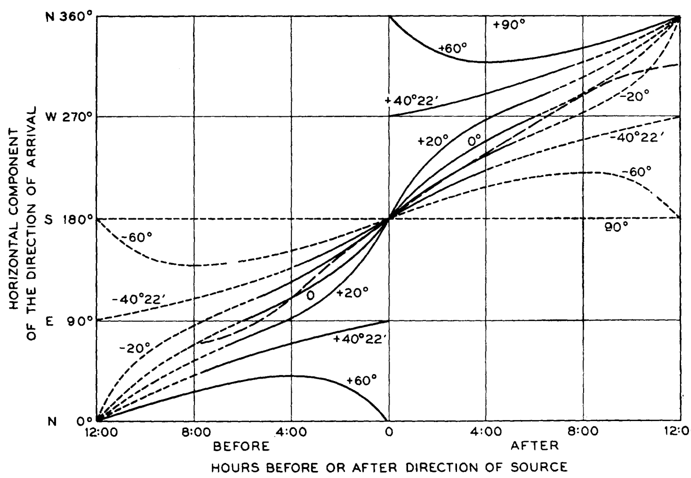

Fig. 9—Comparison between the actual curve of the horizontal component of the direction of arrival and the theoretical curves for different declinations.

The curve of Fig. 5 was drawn for the idealized waves having a declination of 0 degrees. Obviously, the shape of the curves would be considerably different for waves having different declinations. Fig. 9 shows the theoretical curves for several different declinations. In this figure the horizontal component of the direction of arrival is plotted against time, but here the time is given not in terms of the hours of the day but in terms of the time interval before and after the direction of arrival coincides with the meridian of the receiver. The values of declination used for the different curves are given in the figure. As before, the curves are dotted for that portion of the time during which

[4] The limit of error has not been exactly determined but is certainly not greater than ± 7.5 degrees, which is equivalent to ± 30 minutes of right ascension.

the earth would be between the source of the waves and the receiver.

For the purpose of making a comparison between these curves and those of Fig. 2, an average of the curves of Fig. 2 is shown in Fig. 9 by the broken line. It will be seen that for the greater part of the time during which the direction of arrival is above the horizon it lies between the curves for a declination of 0 degrees and -20 degrees, giving a value of roughly -10 degrees for the declination of the direction of arrival of the waves. In Fig. 3 the line XO is drawn with a declination of -10 degrees and right ascension of 18 hours so that it represents the apparent direction of arrival of the waves.

Beyond the point where the direction of arrival drops below the horizon, the average curve is not at all similar to the theoretical curves of Fig. 9. However, for that portion of the curves the intensity is very weak (see the curve at the right in Fig. 2) and the directions cannot be measured very accurately. Furthermore, as the time interval before or after the direction of arrival coincides with the meridian of the receiver is increased, the waves must travel through an increasing thickness of the earth's atmosphere so that any bending of the waves caused by the ionized layers would increase also. At the time the direction of arrival coincides with the meridian of the receiver this bending is confined to the plane determined by the right ascension of the direction of arrival, and will therefore cause no error in the measurement of the right ascension if the data used for its determination are taken at this time, as has been done. It may, however, affect the measurement of the declination. At all other times, whatever bending the waves suffer will cause errors in both measurements and this bending might be the cause of the difference between the theoretical and actual curves noted.

It may very well be that the waves that reach the receiver instead of coming from a single point fixed in space originate in the earth's atmosphere, but are secondary radiations caused by some primary rays of unknown character, coming from a source or sources fixed in space, and striking the earth's atmosphere. If this is so the disturbance measured by the receiver is probably the summation of very many waves of various intensities coming from secondary sources in the earth's atmosphere that are scattered over a considerable area. In this case the declination of the source of the primary rays may be considerably different from that obtained from the curves; however, the measurement of its right ascension would not be affected appreciably if made in the manner described above.

On the other hand it may be that the waves that reach the receiver are the primary waves themselves coming from a great many sources scattered throughout the heavens. In this case the direction measured would be the direction of the center of activity, and as before, the value of the right ascension would be accurate in spite of the bending of the rays in the ionized layers, and the declination would be in error by an amount equal to that for a single source at the center of activity.

From a consideration of the data and the method of interpretation it is believed that, in spite of the possible errors mentioned in the above cases, the declination of the source or center of activity, if there is more than one source, as measured would be accurate within an error not greater than ± 30 degrees.

The apparent direction of arrival of the waves has not as yet been definitely associated with any region fixed in space; however, there are two such regions that should be seriously considered. The point on the celestial sphere of right ascension 18 hours and declination -10 degrees, the direction from which the waves seem to come, is very near the point where the line drawn from the sun through the center of the huge galaxy of stars and nebulae of which the sun is a member would strike the celestial sphere. The coördinates of that point are approximately right ascension of 17 hours, 30 minutes, declination -30 degrees (in the Milky Way in the direction of Saggitarius[5]). It is also very near that point in space towards which the solar system is moving with respect to the other stars. The coördinates of this point are right ascension 18 hours and declination $+28$ degrees.[6] Whether or not the actual direction of arrival of the primary rays coincides with either of these directions cannot be determined definitely until some method of accurately measuring their declination is devised and the measurements made.

In conclusion, data have been presented which show the existence of electromagnetic waves in the earth's atmosphere which apparently come from a direction that is fixed in space. The data obtained give for the coördinates of this direction a right ascension of 18 hours and a declination of -10 degrees.

The experiments which are the subject of this paper were performed at Holmdel, N. J. (Latitude 40° 22′ N and Longitude 74° 10′ W) during the year 1932.

ACKNOWLEDGMENT

The writer wishes to acknowledge the help of Mr. A. M. Skellett, also of the Bell Telephone Laboratories, in making some af the astronomical interpretations of the data.

[5] H. Spencer Jones, "General Astronomy," pp. 358, 359; Forest Ray Moulton, "Astronomy," pp. 479, 504–509.
[6] Russel-Dugan-Stewart, "Astronomy," vol. 2, p. 661.