October 18th, 1947

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P.O. Box 4868
Cleveland Park Station
Washington 8, D.C.

Mr. K. G. Jansky
P.O. Box 107
Red Bank, New Jersey

Dear Mr. Jansky:

A great deal has transpired since I last saw you in May. The Central Radio Propagation Laboratory of the National Bureau of Standards has embarked on a substantial investigation of cosmic and solar radio waves and I have been fortunate enough to be chosen to supervise this program.

The Public Relations Office of NBS has requested me to write a semi-technical article on cosmic static for the popular scientific press. Two copies of the text are enclosed with this letter. It will probably be placed in "Tel-Tech" or "Electronics". Any comments or alterations will be appreciated. To help illustrate this article, I would like to secure a picture of your antenna as shown on page 119 of the December 1934 issue of the Bell Laboratory Record. To be suitable for reproducing purposes, it should be a sharp high-contrast print with a glossy finish. The size should be about 8 x 11 inches.

From time to time, I am called upon to make short talks on the general subject of cosmic static and it is my custom to review the field from your discovery, down to the latest developments. In general, I try to adjust the subject to the level of experience of the audience. In any case, one picture is worth a thousand words, so I would appreciate a slide showing your antenna. Also a slide of the MUSA shown on page 342 of the July 1937 issue of Bell Technical Journal would be desirable.

If any charges are associated with the making of the above print and slides, I will be pleased to see that they are defrayed, upon receipt of a bill.

Next time you are in Washington, please contact me at the below address and I will be glad to show and explain our undertaking on celestial radio waves.

Very truly yours,

Grote Reber, Radio Physicist
Experimental Ionospheric Research Section
Central Radio Propagation Laboratory

# COSMIC RADIO INVESTIGATIONS

by Grote Reber
Radio Physicist, National Bureau of Standards

With the use of higher frequencies in communication and radar equipment, both solar and cosmic radio noise have come to be recognized as increasingly important. Recent advances in design of ultra-high frequency receivers, which greatly reduce internal set noise, indicate that the limiting factors in the use of the equipment will be those arising from natural phenomena.

Atmospheric static ceases to be a major problem above about 15 megacycles, but it is at this level that cosmic noise becomes noticeable. Unlike static of terrestrial origin, cosmic noise exists audibly as a low steady hiss. In the case of FM equipment, the FM signal itself tends to supress this noise within a certain range of the transmitting station. However, as distance from the station increases, the ratio between the strengths of the competing signals changes in the favor of cosmic noise until it completely drowns out the FM signal. On television screens, cosmic noise may cause low contrast, picture jumpiness, and snow to appear. The main center for the generation of cosmic noise is the constellation Sagittarius in the Milky Way. Because of this, there is a slow change in noise intensity as the position of the earth changes relative to the constellation.

About fifty years ago it was recognized that radio, heat, visible, ultraviolet, and x-ray radiations are all different manifestations of the same electromagnetic phenomenon. An immediate result of this knowledge was the suggestion that radio waves should be arriving from the sky along with visible light waves. However, since the science of radio communication was then in its infancy, quite some time was to elapse before suitable equipment for the detection of celestial radio waves was developed.

## Discovery

In 1932 at the Bell Telephone Laboratories, Holmdel, N. J., K. G. Jansky was studying the azimuthal direction of arrival of thunderstorm atmospherics on an automatic intensity recording system by means of a rotating directional antenna tuned to a frequency of 20.5 megacycles. When no other disturbances were present it was observed that small residuals appeared on the automatic recorder. These were traced down and ultimately found to be arriving from a variety of directions which approximated the plane of the Milky Way. The celestial origin of these radio waves was demonstrated by the fact that the source always remained in the same place with reference to the stars irrespective of the motion of the earth around the sun. The rotating antenna with which the cosmic noise was received is shown in Figure 1. It is highly directive in the horizontal plane and rotates on a vertical axis in synchronization with the recorder. Thus the recordings give the direction of signal reception as well as their intensity. However, little information is obtained regarding the vertical angle at which signals arrive.

This discovery of Jansky clearly demonstrated that radiowaves were coming from space. There remained the immediate problem of determining accurately where this radiation is coming from so that a celestial radiomap of the sky may be plotted just as a visible star map is drawn. In other words, high resolution of celestial detail is desirable.

## Investigation at Wheaton

From considerations of physical optics and theoretical physics, the author decided that, to obtain greater resolution, further experiments should be performed at the highest possible frequencies. This decision was based upon two lines of reasoning. First, the resolving power of any mirror is proportional to its diameter in wavelengths of the reflected radiation, and for any given mirror size the number of wavelengths in the diameter is directly proportional to the frequency of the radiation. Consequently for any given size of reflecting mirror that might be used to capture incoming radiation, the resolving power will be greater for higher frequencies. Second, if it is assumed that the intensity-frequency relation of cosmic static follows Planck's black body radiation law, the intensity of the radiation at radio frequencies should be proportional to the square of the frequency. Thus it appeared that by working at very high frequencies a large amount of energy would be collected to operate the receiver and that any progressive decrease of receiver sensitivity with frequency should be more than counterbalanced by a corresponding increase in intensity.

On the basis of these preliminary considerations, the apparatus shown in Figure 2 was constructed on the writer's property at Wheaton, Illinois. It is a radio-type meridian transit, in which the high-frequency energy from space is collected by a mirror and absorbed by a drum which takes the place of a photographic plate in the optical telescope. Within the drum is an antenna with a transmission line to the receiver or high-frequency amplifier mounted at the end of the drum. The mirror has a diameter of 31.5 feet and a focal length of 20 feet. It is constructed of galvanized iron supported on a wooden framework fastened at all joints with steel gusset plates and machine bolts. The circular track has a steel rim and runs upon double-flanged crane wheels mounted on four concrete piers. A locking mechanism at each wheel prevents the mirror from turning in the wind. A turning mechanism between the two piers at left allows the mirror to be turned by means of a crank to any declination from +90° to -32°. Motion in the north-zenith-south plane is thus obtained, while east-west motion is provided by the rotation of the earth in relation to the celestial sphere.

Initial tests with this equipment at 3300 megacycles produced no results, and later tests at 910 mc proved equally disappointing, but finally at 160 megacycles positive results were obtained about nine years ago. Automatic recording equipment was then secured, and a survey of the sky was begun.

The experimental procedure for such an investigation is relatively simple. The mirror is set for some desired declination and the sky is allowed to drift by as the earth rotates. Thus, a band around the sky is scanned, and any cosmic radio noise intercepted is recorded on the machine of Figure 3. Sample traces obtained in this way are shown in Figure 4. After several hundred traces are secured, sufficient data is available to plot the constant-intensity contours shown in Figure 5. (Here the indicated coordinates are in declination and right ascension for the two hemispheres of the sky.) Intensity is in terms of watts per square centimeter, circular degree, megacycle band.

<u>Interpretation</u>

The results shown in Figure 5 may be more easily interpreted if the data in the plane of the Milky Way is replotted as a curve of intensity versus galactic longitude at zero galactic latitude (Figure 6). The major maximum is in Sagittarius near the "Teapot." Minor maxima are in Cygnus near the "Northern Cross" and in Cassiopeia near the "W". The broad maximum in the winter Milky Way extends from Canis Major up toward Orion. The minimum is in Perseus.

If a simple assumption is made that the intensity of the disturbance is related to the amount of material between the sun(earth) and the edge of the galaxy; then Figure 6 is a crude outline of the part of the Milky Way near us. Figure 7 is a picture of Messier 101 for comparison. Now if we place ourselves to the left and about three quarters of the way out from the center of the spiral it will be observed that a large amount of material is to the right as in the direction of Sagittarius in Figure 6. This large mass obscures whatever detail is present to the right of center. Looking up we may see down two spiral arms which are equivalent to the maxima in Cygnus and Cassiopeia of Figure 6. The minimum of Perseus is off to the left where very little material exists in Figure 7; and the blunt maximum from Canis Major to Orion is equivalent to looking at an arm broadside as would be the case looking down from our left hand position in Figure 7.

Admittedly, the above discussion is quite speculative and crude. To learn more, still greater detail and higher resolving power is necessary. A survey recently made with this apparatus at 480 mc gave three times the resolving power of Figure 6. Although these data have not yet been analyzed, examination of traces shows the same general picture with some differences of detail.

## Later Work

Hey, Phillips, and Parsons in England have recently made a survey at 64 megacycles, in which the general features of Figure 5 were verified, even though the resolving power was inadequate to bring out new detail. The phenomenon has been detected at 30 megacycles by Franz in Germany and down to 9.5 megacycles by Friis and Feldman in this country. Cosmic static has been encountered by a number of radar investigators both here and in England. The disturbance manifests itself as a limiting range condition to early warning radars in the frequency band 40 to 110 megacycles.

## The Future

In the field of cosmic noise, the two chief problems to be solved are the determination of the intensity-versus-frequency function of the radiation and a more accurate survey of intensity versus position at a variety of frequencies. Both of these problems are being attacked at the radio propagation laboratory of the National Bureau of Standards at Sterling, Virginia. To investigate the first, a series of measurements are being made over the frequency range from 25 to 110 megacycles by means of a battery of highly sensitive, specially designed receivers, each tuned to a particular frequency. A simple dipole, without reflector, one quarter wave length above ground, is used because it has a very broad acceptance pattern and will integrate the cosmic radio waves from a large region of the sky. Similar smoothed curves are thus obtained at several frequencies and the results are easily comparable on an intensity basis. Details of these findings will appear in a Bureau publication sometime in the next several months. The second problem requires the highest possible resolving power, which may be obtained with apparatus similar to that used at Wheaton either by going to higher frequencies or by using larger collectors. It is expected that both lines of attack will be employd at the Bureau, where equipment to operate at 1400 megacycles is now under construction. The results of these investigations will aid the Bureau in its program of predicting best frequencies for radio communication between any two points and should also increase our present store of scientific knowledge concerning the Milky Way.

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