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Bibliography of Radio Astronomy

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SCHOOL OF ELECTRICAL ENGINEERING

CORNELL UNIVERSITY
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Radio Astronomy Report No. 2

December 15, 1948

BIBLIOGRAPHY OF RADIO ASTRONOMY

By Martha Elizabeth Stahr
Assistant Professor of Astronomy

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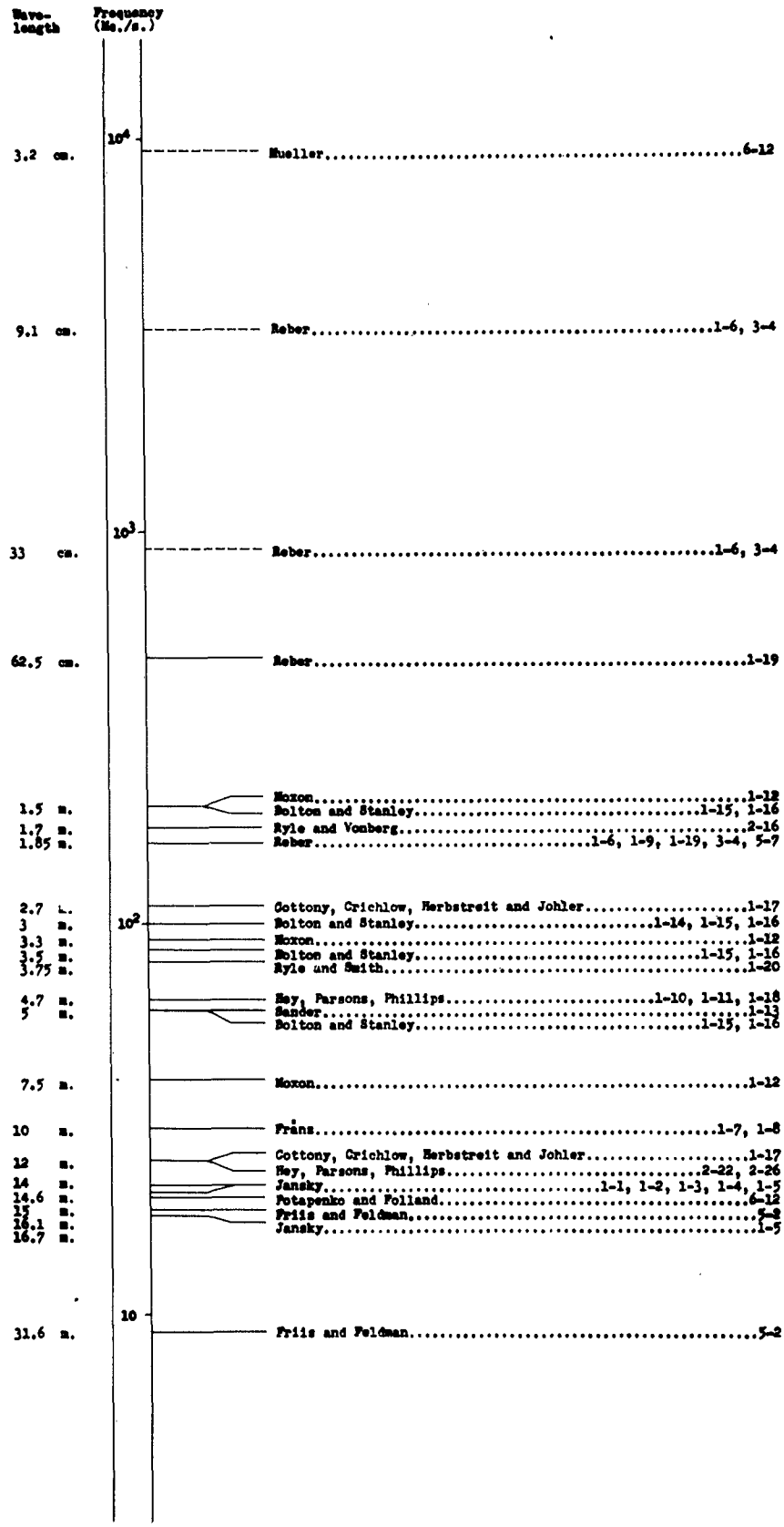
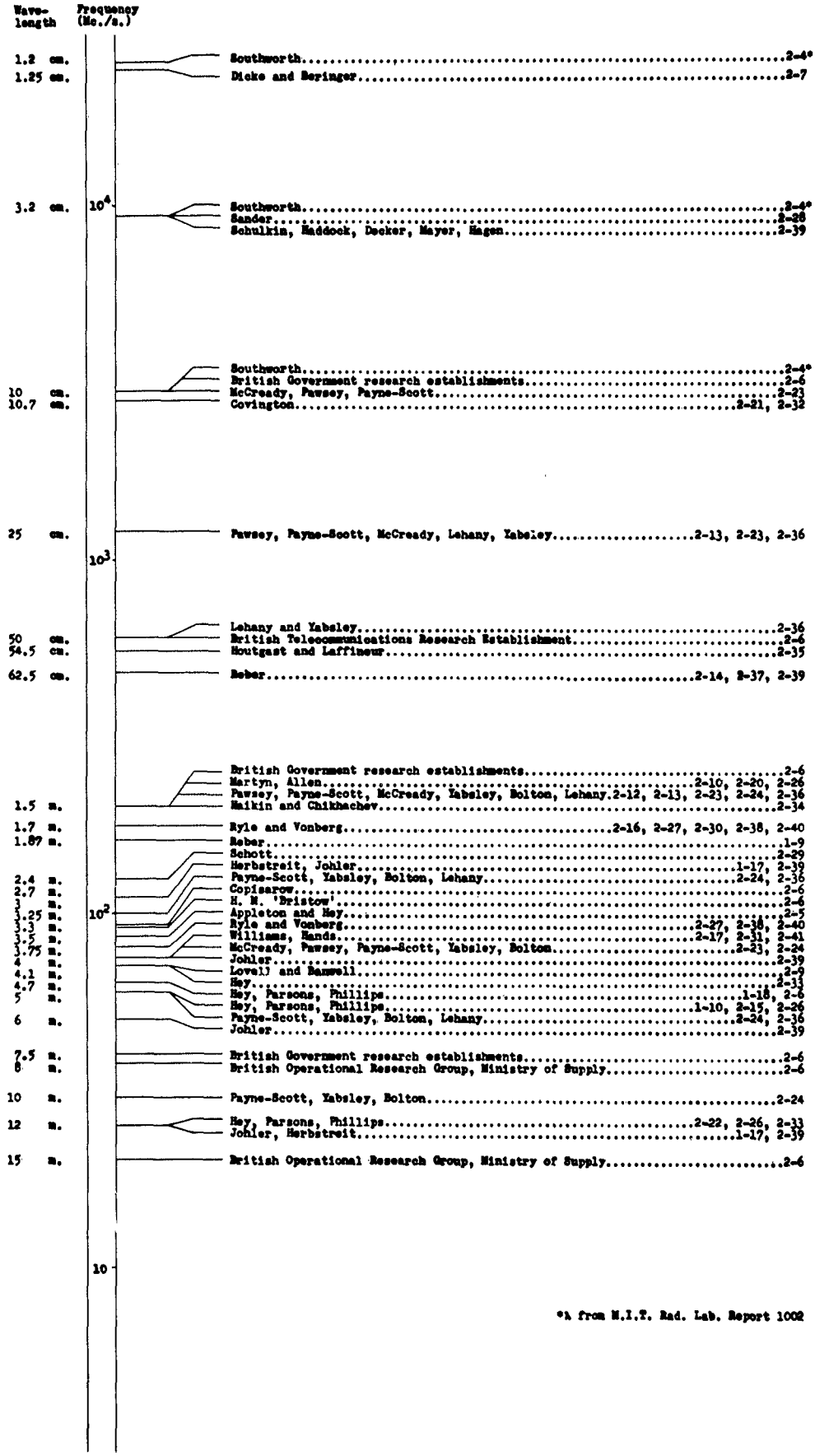
SUMMARY OF GALACTIC NOISE MEASUREMENTS



Galactic noise has been investigated at the wavelengths indicated above. The names of investigators and the numbers of appropriate references in the bibliography are given. Successful attempts to detect galactic noise are represented by solid lines, unsuccessful attempts by dotted lines.

SUMMARY OF SOLAR NOISE MEASUREMENTS



*A from M.I.T. Rad. Lab. Report 1002

The wavelengths at which systematic investigations of solar noise have been carried out are indicated. The names of investigators and the numbers of appropriate references in the bibliography are given.

INTRODUCTION

This report consists of an annotated list of references pertaining wholly or in part to that phase of radio astronomy which deals with radio-frequency radiations from extraterrestrial sources. The related fields of radio studies of meteors and auroras have been excluded, the geophysical aspects of their techniques and present aims suggesting the desirability of separate bibliographies.

For convenience the present bibliography has been subdivided into the following six sections:

1. Observations of galactic noise
2. Observations of solar noise
3. Theory of the emission of radio waves by the galaxy
4. Theory of the emission of radio waves by the sun
5. Theory and description of instruments
6. Reviews.

The articles in each section are arranged according to year of publication; within each year they are placed alphabetically by author, or by title if no author is given. The number assigned each reference designates the section to which it belongs as well as its location within that section. An author index of the entire bibliography is given on the final pages.

It is fully recognized that few articles in the field of radio astronomy fall exclusively in any single category listed above. Almost all reports of observational data, for example, contain information regarding the instruments with which those data were obtained. Reports of observations of galactic noise frequently suggest theoretical interpretations, and mention attempts, successful or unsuccessful, to detect solar noise at the same frequencies and with the same equipment. The more lengthy reports of new advances in any branch of radio astronomy generally review, at least in part, past work in this field. The classification of articles in six groups is consequently somewhat arbitrary and serves primarily as an indication of the major emphasis in subject matter. In order not to exclude articles of potential significance, rather wide latitude in the interpretation of subject matter has in a few instances been assumed, and the grouping must to some extent be considered provisional. For example, reports of noise received during fade-outs of short-wave radio communication have been listed in Section 2 although the direct solar origin of the noise has not necessarily been established.

At the end of each group, mention is made of articles containing information pertinent to that group but listed elsewhere in the bibliography.

The interpretation of the form followed in the statement of references will for the most part be evident without explanation. Abbreviations are used as follows for the titles of certain periodicals:

Ap.J.	Astrophysical Journal
J.I.E.E.	Journal of the Institute of Electrical Engineers
M.N.	Monthly Notices of the Royal Astronomical Society
Phil. Mag.	The London, Edinburgh and Dublin Philosphical Magazine and Journal of Science
Proc. I.R.E.	Proceedings of the Institute of Radio Engineers
Proc. Roy. Soc. A	Proceedings of the Royal Society, Series A
Terr. Mag.	Terrestrial Magnetism and Atmospheric Electricity.

All references have been checked for accuracy against the original papers, with the exception of a few which were known only through secondary sources. The latter are designated by asterisks and their sources are indicated in foot-notes. Deviations from the form of statement adopted elsewhere in the bibliography have been necessary in a few of these cases. In keeping with accepted bibliographical procedure, square brackets have been used to designate information supplied by the bibliographer.

Brief abstracts or annotations are given whenever possible except for references in Section 6. Abstracts prepared by the present writer, Martha E. Stahr, directly from the original articles are signed (MES). Section 5 is principally the work of Mr. Bob M. Fannin who has assumed the responsibility for the selection of articles included therein and, where necessary, for the preparation of the abstracts signed (BMF). Abstracts prepared by quotation, condensation, or adaptation from previously published abstracts are designated by a letter in parentheses, according to the following scheme:

(A) from author's abstract or summary
(E) from Electrical Engineering Abstracts (Section B of Science Abstracts)
(P) from Physics Abstracts (Section A of Science Abstracts)
(W) from Wireless Engineer.

For a few abstracts, dual sources are indicated.

Considerable effort has been expended to make the bibliography as complete as possible. It is recognized, however, that some pertinent articles may have been overlooked, especially since certain foreign periodicals published during World War II are not generally available in this country. As a convenience to the user of the bibliography, numerous blank spaces are provided in which additional references may be inserted. Since it is intended to keep the bibliography up-to-date and to issue revisions

from time to time, the writer would be most grateful for information concerning omissions or new papers dealing with any phase of radio astronomy, and would be much pleased to receive reprints if available.

Many thanks are extended to the various librarians, at Cornell University and elsewhere, who have assisted in tracking down some of the more elusive articles, and to certain colleagues and friends who have brought new articles to the writer's attention or have facilitated the work in other ways.

1. OBSERVATIONS OF GALACTIC NOISE

1932 1-1 Jansky, Karl G. "Directional Studies of Atmospherics at High Frequencies," Proc. I.R.E., 20, 1920-1932 (1932).

A system for recording the direction of arrival and intensity of static on short waves is described. In addition to static originating from thunderstorms, a steady hiss type static of unknown origin has been recorded. The direction of arrival of the latter varies throughout the day, going almost completely around the compass in 24 hours. (A)

1933 1-2 Jansky, Karl G. "Electrical Disturbances Apparently of Extra-terrestrial Origin," Proc. I.R.E., 21, 1387-1398 (1933).

For a period of over a year, directional records have been taken of the short-wave electromagnetic radiation of unknown origin reported by the author in 1932. The evidence indicates that the direction of arrival of this radiation is fixed in space. The coordinates of the source appear to be right ascension 18 hours and declination -10 degrees, the possible errors lying within $\pm$7.5 degrees and $\pm$30 degrees respectively. (MES)

1-3 Jansky, Karl G. "Electrical Phenomena that Apparently are of Interstellar Origin," Popular Astronomy, 41, 548-555 (1933).

The short-wave static of unknown origin which was detected by the author in 1931 arrives from a direction fixed in space at right ascension 18^h and declination -20°. These coordinates may be in error by as much as $\pm 30^m$ and $\pm 30^\circ$ respectively. (MES)

1935 1-4 Jansky, Karl G. "A Note on the Source of Interstellar Interference," Proc. I.R.E., 23, 1158-1163 (1935).

Further consideration of the data obtained during observations on interstellar interference has shown that these radiations are received any time the antenna system is directed towards some part of the Milky Way system, the greatest response being obtained when the antenna points

towards the center of the system. This fact leads to the conclusion that the source of these radiations is located in the stars themselves or in the interstellar matter distributed throughout the Milky Way. Because of the similarity in the sound produced in the receiver headset, it is suggested that these radiations might be due to the thermal agitation of charged particles. (A)

1937 1-5 Jansky, Karl. G. "Minimum Noise Levels Obtained on Short-Wave Radio Receiving Systems," Proc. I.R.E., 25, 1517-1530 (1937).

The theoretical minimum noise level of receivers is discussed and compared with the limit actually measured. It is pointed out that, on the shorter wavelengths and in the absence of man-made interference, the usable signal strength is generally limited by noise of interstellar origin. The powers obtained from this noise with various antennas and for different times of the day are given. Data are also given on the intensity and extent of man-made interference which is the limiting noise during most of the daylight hours. (A)

1940 1-6 Reber, Grote. "Cosmic Static," Ap.J., 91, 621-624 (1940).

Preliminary measurements of radiation from the Milky Way at 162 megacycles have been made. A variation of intensity with galactic longitude has been observed. Attempts to detect radiation at 3300 megacycles and 900 megacycles have been unsuccessful. (MES)

1942 1-7 Fränz, Kurt. "Messung der Empfängerempfindlichkeit bei Kurzen Elektrischen Wellen," Hochfrequenztechnik und Elektroakustik, 59, 143-144 (1942).

The temperature corresponding to the radiation resistance of an antenna and the limit of sensitivity are discussed. Directional observations of noise from the celestial sphere at $\lambda = 10$ m. are briefly described. (MES)

1. OBSERVATIONS OF GALACTIC NOISE (continued)

1943 1-8 *Fortschritte der Hochfrequenztechnik [Leipzig. Akademische Verlagsges], 2, 685 (1943).

Report of measurements by K. Fränz at $\lambda = 10$ m.

1944 1-9 Reber, Grote. "Cosmic Static," Ap.J., 100, 279-287 (1944).

A survey of cosmic static at a frequency of 160 megacycles per second shows the center of this disturbance to be in the constellation of Sagittarius. Minor maxima appear in Cygnus, Cassiopeia, Canis Major and Puppis. The lowest minimum is in Perseus. Radiation of measurable intensity is found coming from the sun. (A)

1946 1-10 Hey, J. S., Parsons, S. J., and Phillips, J. W. "Fluctuations in Cosmic Radiation at Radio-Frequencies," Nature, 158, 234 (1946).

Short-period irregular fluctuations of cosmic noise at 5 meters wavelength have been observed from a source located in Cygnus and subtending an angle not exceeding 2°. The character of the variations suggests that they originate from a small number of discrete sources.(MES)

1-11 Hey, J. S., Phillips, J. W., and Parsons, S. J. "Cosmic Radiations at 5 Metres Wave-Length," Nature, 157, 296-297 (1946).

Cosmic noise at 64 Mc./s. has been observed and contour lines showing its distribution on the celestial sphere between declinations -30° and $+60^\circ$ have been drawn. The main source lies in the Scorpio-Sagittarius region close to the galactic center, with an intensity of 13.2×10^{-21} watts/square meter/cycle/second/steradian. A secondary maximum lies in Cygnus. (MES)

* Reference and annotation from 6-9.

1. OBSERVATIONS OF GALACTIC NOISE (continued)

1-12 Moxon, L. A. "Variation of Cosmic Radiation with Frequency," Nature, 158, 758-759 (1946).

The results of measurements of cosmic radiation at 40, 90, and 200 Mc./s. are reported. In each case the increase of noise level between high galactic latitude and the galactic plane is plotted as a function of galactic longitude. The resulting curves for the three frequencies are generally consistent with each other and with a similar curve drawn to represent the observations of Hey, Phillips and Parsons at 64 Mc./s. Expressed in terms of an equivalent temperature the cosmic noise is found to be proportional, along the galactic equator, to the inverse 2.7 th. power of the frequency, and in the direction of minimum noise to the inverse 2.1 st. power. Possible sources of error and possible explanations for the difference in frequency law are discussed. (MES)

1-13 Sander, K. F. "Measurement of Galactic Noise at 60 Mc/s," J.I.E.E. IIIA, 93, 1487-1489 (1946).

Measurements have been made of the extraterrestrial noise picked up by an aerial on different bearings at different times of the day. This noise is expressed quantitatively by the equivalent temperature of the aerial radiation resistance. Temperatures between 1800 and 10000 ^{o}K have been observed. (A)

1948 1-14 Bolton, J. G. "Discrete Sources of Galactic Radio Frequency Noise," Nature, 162, 141-142 (1948).

Six new discrete sources of galactic noise on 100 Mc./s. have been found. Pertinent data concerning these and the previously recognized source of variable noise in Cygnus are tabulated. Present evidence suggests that the observed intensity and distribution of galactic noise result from three factors: (1) a 'base-level' due to free-free transitions as proposed by Henyey and Keenan; (2) an aggregate of emissions from individual stars in regions of high star-density; (3) a contribution from individual discrete sources. Suggestions as to the possible nature of the discrete sources are made. (MES)

1. OBSERVATIONS OF GALACTIC NOISE (continued)

1-15 Bolton, J. G., and Stanley, G. J. "Observations on the Variable Source of Cosmic Radio Frequency Radiation in the Constellation of Cygnus," Australian Journal of Scientific Research A, 1, 58-69 (1948).

An account is given of investigations on a strong variable source of radio-frequency energy in the constellation of Cygnus, including a determination of the size and celestial coordinates of the source and a study of the variations over a frequency range from 60 to 200 Mc./s. The frequency spectra are compared with those of galactic and solar radiation. The position of the source is found to be in a region of relatively low stellar density and not coinciding with an outstanding stellar object. A discussion of limits of distance and possible nature of the source is given. (A)

1-16 Bolton, J. G., and Stanley, G. J. "Variable Source of Radio Frequency Radiation in the Constellation of Cygnus," Nature, 161, 312-313 (1948).

Interference methods have been used for observing, mainly on 100 Mc./s. but also occasionally on 60, 85, and 200 Mc./s., the variable source of radio-frequency radiation in Cygnus. The location of the source is R.A. $19^h\ 58^m\ 47^s \pm 10^s$, Dec. $+41^\circ\ 41' \pm 7'$, and its angular width is less than 8'. The radiation consists of two components having different frequency dependence; one component is constant and the other shows considerable variation over short and long periods, the periodicity of the variations decreasing with diminishing frequency. The phenomenon may perhaps be explained by a mechanism similar to that proposed by Martyn to account for enhanced solar radiation on meter wavelengths. (MES)

1-17 Herbstreit, Jack W., and Johler, Joseph R. "Frequency Variation of the Intensity of Cosmic Radio Noise," Nature, 161, 515-516 (1948).

The intensity of cosmic radio noise has been measured at 25 Mc. and 110 Mc. by means of dipole antennas having similar directional characteristics. After the effects of ground and ionospheric absorption are minimized and allowance is made for the relative absorbing areas of the two antennas, the incident noise, both maximum and minimum, is found to be proportional to $f_{Mc.}^{-0.41}$. The records also indicate the occurrence of several short-time bursts of very strong noise radiation which occurred at times when sudden ionospheric disturbances were reported. (MES)

1. OBSERVATIONS OF GALACTIC NOISE (continued)

1-18 Hey, J. S., Parsons, S. J., and Phillips, J. W. "An Investigation of Galactic Radiation in the Radio Spectrum," Proc. Roy. Soc. A, 192, 425-445 (1948).

An investigation of the distribution of the sources of galactic radiation at 64 Mc./s. is described. Methods are discussed for measuring the characteristics of the receiving aerial and estimating the magnitude of the received galactic power by reference to the noise from a saturated diode. Possible sources of error are considered; an accuracy better than 1.2 db. (30%) is expected for the regions of highest radiation intensity. Comparison of the derived distributions of galactic radiation with other astronomical data does not clearly favor any one theory. Neither a simple theory in terms of a distributed source in interstellar gas nor one in terms of discrete centers of radiation analogous to sunspots appears adequate to account for the observed phenomena. It is suggested that sources of both types contribute to the observed radiation and that, in general, they must be very distant and associated with the main body of the galaxy. (W)

1-19 Reber, Grote. "Cosmic Static," Proc. I.R.E., 36, 1215-1218 (1948).

A brief description of the apparatus is given. The results of a survey of the galaxy made at a frequency of 480 Mc. are compared to a previous survey made at 160 Mc. The principal new findings are a projection from Sagittarius in the direction of the north galactic pole; a supplementary small rise in Aquila; and a splitting of the maxima in Cygnus and Orion each into two parts. (A)

1-20 Ryle, M., and Smith, F. G. "A New Intense Source of Radio-Frequency Radiation in the Constellation of Cassiopeia," Nature, 162, 462-463 (1948).

A series of interferometric measurements of the polarization of radiation from the variable source in Cygnus has been carried out on 80 Mc./s., and several new variable sources have been detected. A source in Cassiopeia is more intense than that in Cygnus but exhibits smaller fluctuations; a source in Ursa Major is less intense but more variable. Positions, maximum intensities, and limiting apparent diameters for both these sources are stated. The steady component of

1. OBSERVATIONS OF GALACTIC NOISE (continued)

radiation from the Cygnus and Cassiopeia sources was found to be randomly polarized. The polarization of the variable component, though difficult to determine, appears also to be random, an observation which contradicts the suggestion that the mechanism producing this component is similar to that producing the radiation from sunspots. (MES)

See also: 2-4, 2-16, 2-22, 2-26, 3-4, 5-2, 5-7, 6-9, 6-12.

2. OBSERVATIONS OF SOLAR NOISE

1936 2-1 Arakawa, Daitaro. "Abnormal Attenuation in Short Radio Wave Propagation," Report of Radio Research in Japan (National Research Council of Japan. Radio Research Committee), 6, 31-38 (1936).

The phenomenon of abnormal attenuation in short wave propagation as observed during the period from February to May, 1936 is described. A close relationship to solar activities is indicated by the fact that the disturbances were noticed mostly on daylight routes. High noise often accompanied the sudden fadings, especially in local circuits. (A,MES)

1939 2-2 Nakagami, M., and Miya, K. "Incident Angle of Short Waves and High-Frequency Noise During Dellinger Effect," Electrotechnical Journal (Institute of Electrical Engineers of Japan), 3, 216 (1939).

During occurrences of the 'Dellinger effect' a certain high-frequency noise resembling that of a grinder is received. Measurements of the incident angle of this noise are reported. (MES)

1945 2-3 Appleton, Edward V. "Departure of Long-Wave Solar Radiation from Black-Body Intensity," Nature, 156, 534-535 (1945).

Radio reception experience for the range of 10-40 Mc./s. has provided evidence that during periods of marked solar activity, the sun occasionally emits radio radiation greatly exceeding that of a black body at 6000° K. A brief quantitative discussion of the evidence is given. (MES)

2-4 Southworth, G. C. "Microwave Radiation from the Sun," Journal of the Franklin Institute, 239, 285-297 (1945), and Erratum issued with 241, No. 3 (1946).

The nature of thermal radiation is discussed and early work on extending the solar spectrum on the long wavelength side is reviewed. New measurements of solar radiation, at three rather widely spaced wavelengths between 1 cm. and 10 cm., are described. The magnitudes of

2. OBSERVATIONS OF SOLAR NOISE (continued)

the received intensities are substantially in agreement with those predicted by the Rayleigh-Jeans formula if the sun's temperature is assumed to be 6000 °K. The results of directional measurements suggest that there are rapid variations in the angle of arrival of solar noise which may perhaps be due to effects produced by the earth's atmosphere. (MES)

1946 2-5 Appleton, E. V., and Hey, J. S. "Circular Polarization of Solar Radio Noise," Nature, 158, 339 (1946).

According to the magneto-ionic theory of radio-wave propagation, when applied to the sun, characteristic polarizations are imposed on radio emissions from sunspot areas during passage through the ionized solar envelope. During a period of sunspot activity in July, 1946, the polarization of solar noise on 85 Mc./s. was observed to be circular and of the left-handed sense. (MES)

2-6 Appleton, Sir Edward, and Hey, J. S. "Solar Radio Noise - I," Phil. Mag., 37, 73-84 (1946).

The results of experiments on solar radio noise, especially those carried out during the period of sunspot activity, Jan. 30 to Feb. 14, 1946, are interpreted. The spectrum of the noise was observed at sea-level. The spectral curve has a peak at a wavelength of about 5 m., but the shape on the long wavelength side is deformed by ionospheric influences. Large and sudden increases in the intensity of the noise occur simultaneously with solar flares and short-wave radio fade-outs. (P)

2-7 Dicke, Robert H., and Beringer, Robert. "Microwave Radiation from the Sun and Moon," Ap. J., 103, 375-376 (1946).

The intensities of solar and lunar radiation at 1.25 cm. have been measured with a microwave radiometer. The variation of the former during the partial eclipse of July 9, 1945 agreed with the corresponding variation of optical intensity, indicating that the size of the sun's disc is not greatly different for the two wavelength bands. At 1.25 cm. the effective black body temperatures of the sun and the moon were found to be about 10,000° K and 292° K respectively. (MES)

2. OBSERVATIONS OF SOLAR NOISE (continued)

2-8 Hey, J. S. "Solar Radiations in the 4-6 Metre Radio Wave-Length Band," Nature, 157, 47-48 (1946).

On February 27 and 28, 1942, British Army radar equipments observed solar radiation in the 5-meter wavelength region. The power received was of the order of 10^5 times the expected black body radiation calculated for a solar temperature of 6000° K. The phenomenon appears to have been associated with the occurrence of a big solar flare. (MES)

2-9 Lovell, A. C. B., and Banwell, C. J. "Abnormal Solar Radiation on 72 Megacycles," Nature, 158, 517-518 (1946).

On several occasions in July and August, 1946, the solar energy on 72.6 Mc./s. was observed to exceed the normal black body value for T = 6000° K by a factor of over 1.9×10^4, the minimum solar level noticeable with the equipment employed. In one case the solar radiation intensity reached 1.3×10^8 times the normal black body value, and appears to have been closely associated with an intense solar flare. (MES)

2-10 Martyn, D. F. "Polarization of Solar Radio-Frequency Emissions," Nature, 158, 308 (1946).

Observations of solar radiation on a frequency of 200 Mc./s. were made in July, 1946 while a large sunspot group was crossing the solar disc. Before meridian passage of the group, the right-handed circularly polarized power received was some seven times greater than the left-handed whereas after meridian passage the latter was 5 times greater than the former. These results are consistent with theoretical considerations of the effect of the magnetic field of sunspots on the radiations observed. (MES)

2-11 *Norton, and Allen. U. S. Federal Communications Report, p. 7 (1946).

Noise detected at 44.9 Mc. during radio fade-out.

*Reference and annotation from 6-12.

2. OBSERVATIONS OF SOLAR NOISE (continued)

2-12 Pawsey, J. L. "Observation of Million Degree Thermal Radiation from the Sun at a Wave-Length of 1.5 Metres," Nature, 158, 633-634 (1946).

The distribution of the intensity of solar radiation on a wavelength of 1.5 meters, measured daily over a six months' period, is consistent with the co-existence of two sources. The first is steady and of intensity corresponding to a temperature of about one million degrees centigrade; the second is symmetrically distributed and highly variable, and exceeds the steady value on this wavelength for about 60% of the observations. (MES)

2-13 Pawsey, J. L., Payne-Scott, Ruby, and McCready, L. L. "Radio-Frequency Energy from the Sun," Nature, 157, 158-159 (1946).

The intensity of solar radiation at 1.5 meters has been observed during the period October 3-23, 1945. Comparison of its variation with that of total sunspot area indicates a relationship between the two phenomena. At 1.5 meters the sun's 'equivalent temperature' is of the order of 10^6 °K whereas at 25 cm. it is near 6000°K. The characteristics of solar radiation at the longer wavelength suggest that 'cosmic static' may have its origin in gross electrical disturbances in stars. (MES)

2-14 Reber, Grote. "Solar Radiation at 480 Mc./sec.," Nature, 158, 945 (1946).

Daily measurements of solar radio waves at 480 Mc./s. over a period of several months yield an intensity corresponding to an apparent solar temperature of about a million degrees. Slow day-to-day variations of about 15%, which are quite closely correlated with the apparent area of sunspots, are superposed. The measurements indicate a solar diameter of approximately $\frac{1}{2}°$. A great radio storm, occurring on November 21, 1946 and producing 'swishes' which probably rose to several thousand times normal, is described. The phenomenon lasted in greatly diminished form throughout most of the following night and may perhaps have originated in the earth's atmosphere. (MES)

2. OBSERVATIONS OF SOLAR NOISE (continued)

2-15 Royal Astronomical Society, Meeting of 1946 October 11. Observatory, 66, 360 (1946).

Mr. J. S. Hey described his observations of the solar flare of July 25 on a wavelength of 5 meters, and compared them with measurements of Hα line-width. He commented on the dependence of radio emission on wavelength, and cited instances demonstrating a lack of proportionality between sunspot area and radio emission. (MES)

2-16 Ryle, M., and Vonberg, D. D. "Solar Radiation on 175 Mc./s." Nature, 158, 339-340 (1946).

Solar radiation on 175 Mc./s. has been detected and distinguished from galactic radiation by means of the interference pattern resulting from the use of two aerial systems with a horizontal separation of several wavelengths. During a period of greatly increased solar radiation accompanying the passage of a large sunspot, the diameter of the source was found to be at most 10', a value not greatly exceeding that of the visual spot. The polarization, in periods of intense radiation, was found to be completely circular. (MES)

2-17 [Williams, S. E., and Hands, P.] "Abnormal Solar Radiation on 75 Megacycles," Nature, 158, 511 (1946).

Measurements of solar radiation on a wavelength of 4 meters were made during the passages of three sunspot groups in July and August, 1946. They indicate that solar noise consists of two components, one 'steady' or relatively slowly variable, the other abruptly variable. The likelihood of correlation between solar noise generation and certain other solar phenomena is briefly discussed. (MES)

2-18 Watts, J. M. "Noise Observed During Radio Fade-Out, August 17, 1945," Terr. Mag., 51, 122-125 (1946).

Severe noise at several frequencies in the range of 10 to 16 Mc./s. has been recorded during a radio fade-out. The time interval between the commencement of the fade-out and that of the noise was about 10 minutes. (MES)

2-19 Webb, H. D. "Project Diana," Sky and Telescope, 5, No. 6, 3-6 (1946).

The Army Signal Corps experiments in which contact with the moon was made by radar are described. The work was done on 110 megacycles per second. Mention is made of interference by solar noise at this frequency. (MES)

2. OBSERVATIONS OF SOLAR NOISE (continued)

1947 2-20 Allen, C. W. "Solar Radio-Noise of 200 Mc./s. and Its Relation to Solar Observations," M.N., 107, 386-396 (1947).

The solar radio-noise observing programme on Mount Stromlo is described. Daily means of (a) steady flux, and (b) number of bursts per hour have been plotted against sunspot and geomagnetic data. Both flux level and burst frequency increase during a solar radio-noise storm, and both are closely related to the central meridian passage of sunspots. However, some large sunspot groups do not produce solar noise. No close relation has been found between the emission from the sun of (a) radio noise, and (b) those particles which produce geomagnetic storms. No close correlation has been found between short period radio-noise phenomena and solar observations, but there are occasional outbursts of solar noise accompanying the commencements of flares. It is suggested that the noise source is located rather high in the corona. The observation of a noise outburst caused by a flare 37° from the main spot group can be explained if the source is more than 120,000 km. above the sun's surface. Physical arguments lead to a similar height. (A)

2-21 Covington, A. E. "Micro-Wave Solar Noise Observations During the Partial Eclipse of November 23, 1946," Nature, 159, 405-406 (1947).

Measurements of the energy emitted by the sun in the 2800-megacycle band were made at Ottawa, Canada during the partial eclipse of Nov. 23, 1946. The character of the energy variation suggests that the source is in the space surrounding the sun, either in the corona or in a prominence. A sudden decrease of energy by 25% occurred when the moon obscured a large group of sunspots. The average surface temperature for the eclipsed portion of the sun disregarding the spot area was 5.6×10^4 °K. (MES)

2-22 Hey, J. S., Parsons, S. J., and Phillips, J. W. "Solar and Terrestrial Radio Disturbances," Nature, 160, 371-372 (1947).

Enhanced D-layer ionization is sometimes indicated by absorption of galactic radio waves on occasions when there are no simultaneous bursts of solar noise. Two such instances for a wavelength of 12 meters are described. When the absorption precedes a solar radio burst, the delayed occurrence of the latter may perhaps be due to the interval of time required by an outward-traveling solar disturbance to reach a region of the solar envelope from which radio waves can escape. (MES)

2. OBSERVATIONS OF SOLAR NOISE (continued)

2-23 McCready, L. L., Pawsey, J. L., and Payne-Scott, Ruby. "Solar Radiation at Radio Frequencies and Its Relation to Sunspots," Proc. Roy. Soc. A, 190, 357-375 (1947).

Experimental studies of solar radiation on a frequency of 200 Mc./s. are described. This radiation has characteristics similar to those of thermal radiation but is always hundreds of times greater than the thermal radiation anticipated from the photosphere and sometimes greater by a factor of 10^4. The day-to-day intensity variations over a period of 6 months confirm a correlation with sunspots. The received intensity of radiation is subject to rapid fluctuations; sudden increases, or 'bursts,' of duration from a fraction of a second to a minute are characteristic. These rapid fluctuations are similar at widely-spaced receiving points, and it is concluded that most of them are extra-terrestrial, and presumably solar, in origin. Directional observations, based on the interference phenomenon as the sun rises over the sea, indicate that the radiation originates not uniformly over the sun's disk but in restricted areas in the immediate vicinity of a sunspot group. Values of received intensity are at times too great to be accounted for in terms of thermal radiation, so that another mechanism producing radiation must exist. Radiation from gross electrical discharges is suggested. (A)

2-24 Payne-Scott, Ruby, Yabsley, D. E., and Bolton, J. G. "Relative Times of Arrival of Bursts of Solar Noise on Different Radio Frequencies," Nature, 160, 256-257 (1947).

Observations of the relative times of arrival of solar noise bursts on 200, 75, and 60 Mc./s. with a few observations on 30 Mc./s., yield three main conclusions: (1) there is a lack of correlation between most bursts; (2) many of the larger bursts are correlated and occur not simultaneously, but in the sequence 200, 75, 60 Mc./s., with variable time lags of the order of a few seconds' duration; (3) very intense outbursts occasionally exhibit, in the same sequence, longer time delays of several minutes' duration. Some suggestions regarding the interpretation of these conclusions are made. (MES)

2-25 *Rocard, Y. "Observation of Electromagnetic Radiation from the Sun," Revue scientifique, 85, 422 (1947).

Direct reception on a radar receiver was effected in April, 1947 on board a French naval vessel. The wavelength used cannot be disclosed. The received radiation was at first little above the background noise in the receiver, but

*Reference and abstract from Wireless Engineer, 25, A.128, Abstract 1627 (1948).

increased very considerably in less than an hour. It appeared to consist of a succession of discharges analogous to those of lightning. The p.p.i. was quite confused by the parasitic signal over a considerable angular sector corresponding to the relatively low directivity of the aerial. The results are the first of their kind obtained in France. (W)

2-26 Royal Astronomical Society, Meeting of 1947 October 10. Observatory, 67, 201-207 (1947).

The Minutes, here given, report the following contributions and discussion of them by members present: an account by Stratton of a paper by C. W. Allen on "Solar Radio-Noise of 200 Mc./s., and its Relation to Solar Observations," a report by H. W. Newton on recent solar activity, a report by J. S. Hey on a study of the relationship between bursts of solar radio emission and increases in D-layer ionization, and a description by M. A. Ellison of a detached flare at the solar limb. (MES)

2-27 Ryle, M., and Vonberg, D. D. "Relation Between the Intensity of Solar Radiation on 175 Mc./s. and 80 Mc./s.," Nature, 160, 157-159 (1947).

The intensity of solar radiation has been recorded simultaneously on 175 Mc./s. and 80 Mc./s. during a period of several months. Apparently short-lived 'bursts' are not correlated on the two frequencies whereas very large bursts usually are. The general level of increased radiation emitted during periods of solar activity is consistent with an equivalent temperature which varies as λ^2, but there are marked departures from this relation on many days. There is evidence suggesting that day-to-day variations of intensity may be due partly to directed emission with a 'polar diagram' which is a function of the frequency and partly to variation of the effective temperature or the area of the source, which appears to be largely independent of frequency. (MES)

2-28 Sander, K. F. "Radio Noise from the Sun at 3.2 cm.," Nature, 159, 506-507 (1947).

Measurements of solar radiation at 3.2 cm. were made during a partial eclipse. They indicate that the sources of the radiation are mainly located around the sun's circumference. The value of the total radiation from the sun was found to be 4×10^{-18} watts/Mc./s./sq.cm. (MES)

2. OBSERVATIONS OF SOLAR NOISE (continued)

2-29 *Schott, E. "175 Megacycle Radiation from the Sun" [in German], Physikalische Blätter, 3, 159-160 (1947).

The author observed an UHF radiation from the sun when using 125 Mc./s. apparatus in Skagen (Denmark) during the war. Interference with the radar receiver was at its maximum when the direction of the sun coincided with the receiving maximum of the directional aerial. The effect was at maximum before and immediately after sunrise and sunset. No effect was observed at midday, and the local weather conditions had no effect. During May-June, 1940, the sun's radiation fluctuated daily. On days with strong solar radiation the amplitude of landmark radar echoes was also increased up to 10 times, echoes up to 250 km. distant having been recorded. The effect is thought to be due to circularly polarized or unpolarized solar radiation over a considerable frequency range. (P)

2-30 Thackeray, A. D. "A Short-Lived Solar Phenomenon in High Latitude," Nature, 160, 439-440 (1947).

A short-lived absorption flocculus in Hα light was observed at heliographic latitude 61° S. Line-shifter readings of the spectrohelioscope, if attributed to sight-line velocities, indicated a high acceleration of recession. Simultaneously special activity was observed in radio noise on 175 Mc./s. A possible connection between the two phenomena is suggested. (MES)

2-31 Williams, S. E. "Solar Radio-Frequency Noise Fluctuations and Chromospheric Flares," Nature, 160, 708-709 (1947).

Records of synoptic observations of flares and noise on 75 Mc./s. are given, which show frequent instances of bursts of noise being received at periods up to 30 minutes after the observation of a flare. This supports the theory that plasma oscillations, high up in the corona, from which the noise originates, are excited by corpuscular emission associated with the flare, rather than ultraviolet radiation. (P)

*Reference and abstract from Physics Abstracts (Section A of Science Abstracts), 51, 266, Abstract 2664 (1948).

2. OBSERVATIONS OF SOLAR NOISE (continued)

1948 2-32 Covington, A. E. "Solar Noise Observations on 10.7 Centimeters," Proc. I.R.E., 36, 454-457 (1948).

Daily observations of the 10.7-cm. solar radiation show a 27-day recurrent peak which has a strong correlation with the appearance of sunspots. In the absence of large spots the equivalent temperature of the sun is 7.9×10^4 °K. Sudden bursts of solar noise show a sharp rise lasting one or two minutes and a gradual decline to pre-storm value or to a somewhat higher value. Average burst duration is ten minutes. (A)

2-33 Drewe, E. C., and Maurice, D. "Solar Noise," Nature, 161, 167 (1948).

Strong interference was observed on television reception on August 31, 1947, lasting for about 45 seconds. Independent noise measurements on 25 and 73 Mc./s. showed strong solar activity, > 10μV./m. on a receiver with 20 Kc./s. bandwidth. The television signal field strength was 1½-3 mV./m. at 5 Mc./s. bandwidth. (E)

2-34 Haikin, S. E., and Chikhachev, B. M. "Investigation of Radio Emission from the Sun during the Total Solar Eclipse of May 20, 1947," Bulletin (Izvestiya) of the Academy of Science, Phys. Ser. XII, No. 1, 38-43 (1948). Available in English as Naval Research Laboratory Translation 183.

Observations of solar radiation on a wavelength of 1.5 meters were made during the total eclipse of May 20, 1947, by means of an antenna mounted on shipboard and consisting of 96 dipoles above a flat reflector. The minimum intensity was received after the end of totality and amounted to about 40% of the mean intensity from the uneclipsed sun. A general correspondence between the variation of radio emission and that of the total area of uneclipsed sunspots was observed but could not be established quantitatively. However, the intensity of the radio radiation was found to be closely related to that of the uneclipsed hydrogen prominences and flocculi. (MRS)

2-35 Houtgast, Jakob, and Laffineur, Marius. "Observation de perturbations remarquables du rayonnement solaire sur ondes decimétriques," Comptes rendus des séances de l'Académie des Sciences, 227, 717-718 (1948).

Solar radiation on a wavelength of 54.5 centimeters has been received with a 7.50-meter parabolic mirror installed at the Meudon Observatory. Although the observed signal is usually constant, brief enhancements sometimes occur.

2. OBSERVATIONS OF SOLAR NOISE (continued)

Descriptions of such occurrences, as observed on two occasions, are given. In one case the increase of solar radio radiation began two minutes after the start of a chromospheric eruption and preceded by one minute the commencement of a sudden fade-out of short-wave communications. (MES)

2-36 Lehany, F. J., and Yabsley, D. E. "A Solar Noise Outburst at 600 Mc./s. and 1200 Mc./s.," Nature, 161, 645-646 (1948).

Simultaneous observations of solar radiation on 200, 600 and 1200 Mc./s. are reported and discussed. On 200 Mc./s. a considerable number of short bursts are observed and the general level increases as some sunspots cross the meridian. On 600 and 1200 Mc./s. there is almost a complete absence of bursts; the levels remain fairly constant for any one day and show close correlation with sunspot area. An isolated exception, in the form of an outburst of radiation on 600 and 1200 Mc./s., is described. On this occasion a steady level was recorded on 200 Mc./s., and mild solar activity on 100 and 60 Mc./s. (MES)

2-37 Reber, Grote. "Solar Intensity at 480 Mc.," Proc. I.R.E., 36, 88 (1948).

A plot is given of the steady, background level of solar intensity measured at noonday on 480 Mc. during June, 1946 and the period from September, 1946 through May, 1947. Occasional bursts occurred on dates which are indicated; 'swishes' were observed at times when a very large group of spots was near the center of the solar disk. For the steady level, which must originate in the corona, the solar diameter is about 0°.7, but it shrinks to less than 0°.1 on days of great spots. (MES)

2-38 Ryle, M., and Vonberg, D. D. "An Investigation of Radio-Frequency Radiation from the Sun," Proc. Roy. Soc. A, 193, 98-112 (1948).

Measurements of solar radiation at frequencies of 175 Mc./s. and 80 Mc./s. are described. Special aerials and receiving equipment enabled solar radiation to be recorded separately from the galactic radiation, and also eliminated errors due to variation of receiver gain or internal noise. The results obtained indicate an equivalent surface temperature of the order of 10^6 °K, but values as high as 10^8-10^9 °K have been observed during the passage of large sunspots. Measurements of the diameter of the source, by a method analogous to Michelson's stellar interferometer, show that during periods of very great intensity the radiation originates in an area comparable with that of a sunspot. During periods of increased activity the radiation is mainly circularly polarised. (See also 5-15 and 5-16.) (W)

2. OBSERVATIONS OF SOLAR NOISE (continued)

2-39 Schulkin, M., Haddock, F. T., Decker, K. M., Mayer, C. H., and Hagen, J. P. "Observation of a Solar Noise Burst at 9500 Mc/s and a Coincident Solar Flare," Physical Review, Series II, 74, 840 (1948).

Observational data regarding a solar noise burst which occurred on 9500 Mc./s. on July 29, 1948 are given. The burst was accompanied by a solar flare in Hα light, solar noise bursts at 25, 50, 75, 110 and 480 Mc./s. and the commencement of a sudden ionospheric disturbance. This seems to be the first report of such a phenomenon above 3000 Mc./s. (MES)

2-40 Thomsen, J. L.; Ryle, M. "Solar Radio Emissions and Sunspots," Nature, 161, 134-136 (1948).

Ryle and Vonberg's extended observations on the ratio of 80 to 175 Mc./s. activity show a remarkable correlation with sunspot groups; groups in the earliest stages of vigorous development give the greatest emission, and the received energy is greatest somewhere near the time of central meridian passage. Ryle confirms, on the basis of observations extending over 12 solar rotations, the existence of periodicities of 27.9, 27 and 26.3 days. (P)

2-41 Williams, S. E. "Shape of Pulses of Radio-Frequency Radiation from the Sun," Nature, 162, 108 (1948).

The shapes of the 'tails' of 78 solar pulses on 75 Mc./s., traced out by means of a galvanometer spot which became stationary after sudden deflections in less than 0.25 sec., have been analyzed. 58 were found to be very probably exponential in shape, 11 less probably so, 4 probably not so and 5 definitely not. For the 58 exponential pulses, the times taken for the radiated power to decrease to half are tabulated and, in the case of pulses closely connected in time, are compared. No evidence was found for an exponential rise of the pulse curve. (MES)

See also: 1-9, 1-10, 1-17, 1-18, 3-4, 6-6.

3. THEORY OF THE EMISSION OF RADIO WAVES BY THE GALAXY

1936 3-1 Langer, R. M. "[Abstract:] Radio Noises from the Galaxy," Physical Review, Series II, 49, 209-210 (1936).

The unexpectedly intense radiation from the Milky Way in a wavelength range about 16 meters can be interpreted as originating from recombinations of electrons with particles of interstellar cold matter which have been ionized by diluted stellar radiation. For 16 meter waves the required dimension for such particles is about 1μ, a size also indicated, for much of the interstellar cold matter, by astronomical considerations. (MES)

1937 3-2 Whipple, Fred L., and Greenstein, Jesse L. "On the Origin of Interstellar Radio Disturbances," Proceedings of the National Academy of Sciences, 23, 177-181 (1937).

The intensity at the earth's surface of black body radiation from interstellar particles in the direction of the galactic center is calculated for a wavelength of 14.6 meters. The result fails by a factor of 10^4 to account for the intensity observed by Jansky. (MES)

1940 3-3 Henyey, L. G., and Keenan, Philip C. "Interstellar Radiation from Free Electrons and Hydrogen Atoms," Ap.J., 91, 625-630 (1940).

The intensity of the radiation produced by electrons and hydrogen ions is considered. For an electron temperature of 10,000° and a density of one electron per square centimeter, the expected intensity of radiation from interstellar space at a wavelength of 1.65 meters is 5.8×10^{-18} ergs/cm.^{2}/sec./deg.^{2}/Kc./s., a value in excellent agreement with that observed by Reber. The computations extend over the range 10 meters to 4400 A. (A)

3. THEORY OF THE EMISSION OF RADIO WAVES BY THE GALAXY (continued)

3-4 Reber, Grote. "Cosmic Static," Proc. I.R.E., 28, 68-70 (1940).

Equipment for receiving static from space at 160 megacycles is briefly described. The observed radiation, plotted as a function of galactic longitude, is interpreted as due to free-free transitions by particles of interstellar matter. Attempts to detect radiation at this frequency from various bright stars, Mars and the sun have yielded no positive results. (MES)

1945 3-5 van de Hulst, H. C. "Herkomst der Radiogolven" (Part II of "Radiogolven uit het Wereldruim" by C. J. Bakker and H. C. van de Hulst), Nederlandsch Tijdschrift voor Natuurkunde, 11, 201 and 210-221 (1945).

The radio-frequency radiation observed from our galaxy must be due to the interstellar gas, the stars being outruled by their small angular dimensions and the solid smoke particles being outruled by their low temperature. The spectral emission of a homogeneous layer of ionized hydrogen is computed. The continuous spectrum arising from free-free transitions has the intensity of black body radiation at wavelengths larger than 6 m. and has a nearly constant intensity at wavelengths smaller than 2 m., corresponding to a large and to a small optical thickness respectively. These intensities, shown in a figure, agree with those computed by Henyey and Keenan and tally fairly well with the observations. No better accordance is to be expected, owing to the unknown electron density and extension of the interstellar gas and to unsatisfactory data about the directional sensitivity of the antenna. Discrete lines of hydrogen are proved to escape observation. The 21.2 cm. line, due to transitions between hyperfine-structure components of the hydrogen ground level, might be observable if the lifetime of the upper level does not exceed 4×10^8 years, which, however, is improbable. Reber's observation of the Andromeda Nebula suggests a rather high electron density. A cosmological remark concludes the article. The low background intensity due to remote nebulae contradicts the Hubble-Tolman static model. (A)

3. THEORY OF THE EMISSION OF RADIO WAVES BY THE GALAXY (continued)

1946 3-6 Greenstein, J. L., Henyey, L. G., and Keenan, P. C. "Interstellar Origin of Cosmic Radiation at Radio-Frequencies," Nature, 157, 805-806 (1946).

The intensity of cosmic radiation at 5 meters as observed by Hey, Phillips and Parsons is compared with the intensity predicted by the authors on the theory that interstellar radiation arises from free-free transitions by electrons in the field of protons. The agreement is remarkably good. The suggestion that cosmic noise is produced by bursts of radiation from the stars is considered improbable, and arguments in support of this conclusion are stated. (MES)

3-7 Schklovsky, I. S. "On the Radiation of Radio-Waves by the Galaxy and by the Upper Layers of the Solar Atmosphere" [In Russian], Astronomical Journal of the Soviet Union, 23, 333-347 (1946).

The radiation of radio waves by the galaxy is interpreted by consideration of the usual dispersional absorption of radio waves as well as the 'free-free' absorption, and the equation of transfer is solved. The results obtained by Reber are discussed on the basis of Strömgren's theory on the ionization of the interstellar hydrogen. Strömgren suggests that the ratio of the volumes of zones of ionized and unionized hydrogen is 1:9, but the radio-wave data indicate that apparently the ratio is much smaller. The results of Reber and Southworth on the solar radio waves are analyzed, the factors of absorption being the same as in the galaxy. It is shown that the 1 cm. radiation is emitted by the outer corona ($r > 3\ R_\odot$), assuming the electron temperature of the latter is of the order of 3500°. Proper oscillations of electrons of the plasma of the outer corona are suggested as the origin of the sporadic long-wave solar radiation reported by Appleton. Such oscillations can be excited by the streams of charged particles moving through the corona with a velocity larger than the velocity of sound. The required space concentration of the particles is within reasonable limits. A possible correlation between the sporadic radio emission of the sun and the magnetic storms at the earth is suggested and some predictions upon the spectral composition of this radiation are made. (A)

3. THEORY OF THE EMISSION OF RADIO WAVES BY THE GALAXY (continued)

3-8 Townes, Charles Hard. "[Abstract:] Interpretation of Cosmic Noise - Radio Waves from Extraterrestrial Sources," Physical Review, Series II, 69, 695 (1946).

Assuming cosmic noise is due to radiation from interstellar ions of density n and at temperature T, the effective temperature of the Milky Way is found to depend on frequency ν as

$$Ta = T\left[1-\exp(-8 \times 10^{-8} \frac{n^2 S}{\nu^2})\right],$$

where S is the distance from the observer to the Milky Way boundary in the direction of observation. This gives qualitative agreement with some of the observational data. (W)

1947 3-9 Shklovsky, Joseph S. "Emission of Radio-Waves by the Galaxy and the Sun," Nature, 159, 752-753 (1947).

The results of modifying Henyey and Keenan's theory to allow for absorption of radio waves by electron damping in the galaxy are given, and the optical depth of the galaxy in various directions worked out from Reber's measurements. The results conflict somewhat with Strömgren's values for the extent of the zones of ionized hydrogen. The optical depth of the solar atmosphere for different frequencies has also been calculated. Reber's measurements in the meter region indicate a temperature of the outer corona of only 3500°. It is suggested that the very strong solar emissions reported by Appleton in the range 7 m. $<\lambda<$ 30 m. are caused by oscillations of the plasma of the outer corona. (P,MES)

3-10 Townes, Charles Hard. "Interpretation of Radio Radiation from the Milky Way," Ap.J., 105, 235-240 (1947).

The theory of emission of radio radiation by ionized interstellar gas is briefly discussed, and formulae are given for the radiation intensity. Experimental measurements of radiation received from the Milky Way between 3×10^{10} and 9.5×10^{6} cycles per second are analyzed and compared with theory. It is shown that radiation from interstellar gas explains the observed radio radiation from the Milky Way if the density of the electron gas is near 1 electron per cubic centimeter and its temperature is 100,000 - 200,000 °K. It appears difficult to explain such radiation, assuming the generally accepted conditions of density of 1 per cubic centimeter and temperature near 10,000 °K. (A)

3. THEORY OF THE EMISSION OF RADIO WAVES BY THE GALAXY (continued)

3-11 Woolley, R. v.d.R. "Galactic Noise," M.N., 107, 308-315 (1947).

The electron velocity temperature of interstellar space is examined. It is found that while temperatures of the order of 12,000 degrees may be expected so close to early type stars that hydrogen is mainly ionized, in other regions, where metallic ions greatly outnumber hydrogen ions, the temperature is only of the order of 1000 degrees. Galactic noise of intensity equal to that reported can only come from the hot regions, and probably only from regions where the hydrogen population considerably exceeds 1 per cc. It is pointed out that if the observed noise is due to free-free transitions, the areas where it originates should exhibit bright hydrogen emission in observable quantities. (A)

See also: 4-5, 4-6, 4-14, 6-9, 6-12.

4. THEORY OF THE EMISSION OF RADIO WAVES BY THE SUN

1946 4-1 Denisse, Jean. "Étude des conditions d'émission par l'atmosphère solaire d'ondes radioélectriques métriques," Revue scientifique, No. 84, 259-262 (1946).

The emission of electromagnetic radiation by electrons moving in the magnetic field of a sunspot is discussed. The power emitted from the region where the magnetic field is strong is calculated. In the corona, radiation with a wavelength of 10 cm. is possible. For such radiation to escape, a very high field gradient is necessary. The intensity at the earth's surface is estimated. (P)

4-2 Ginsburg, V. L. "On Solar Radiation in the Radio-Spectrum," Comptes rendus (Doklady) de l'Académie des Sciences de l'URSS, 52, 487-490 (1946).

The propagation of radio waves in the sun's corona is examined, and it is shown that the study of solar radiation in the radio spectrum gives a means for ascertaining the temperature of the corona. Recent experimental results and deductions from these are criticized. (P)

4-3 Kiepenheuer, K. O. "Origin of Solar Radiation in the 1-6 Metre Radio Wave-Length Band," Nature, 158, 340 (1946).

Abnormally intense solar radio-frequency radiation is taken to be due to electrons revolving in the magnetic field of sunspots. The intensity relative to radiation from the photosphere (assumed to be a 6000 °K black body) is calculated, and gives a result of the same order as experimental observations (about 10^4). The radiation from the corona would be about 10^8 times that from the photosphere in the general field of the sun of 50 gauss; this field is therefore apparently shielded. (P)

4-4 Martyn, D. F. "Temperature Radiation from the Quiet Sun in the Radio Spectrum," Nature, 158, 632-633 (1946).

On short radio wavelengths we should expect the sun to emit thermal radiation corresponding to temperatures ranging downwards from 10^6 degrees to approximately 10^4 degrees. Considerations of optical depth indicate that the maximum effective temperature should occur for $\lambda \gtrsim 1$ m.; at this wavelength the radiation emanates from the corona whose temperature normally approaches 10^6 degrees. At longer wavelengths a falling off in effective temperature results from a decreasing absorption coefficient whereas at shorter wavelengths the radiation begins to emanate from the cooler chromosphere. A 'limb-darkening' is predicted for wavelengths in the meter region and a very marked 'limb-brightening' for

4. THEORY OF THE EMISSION OF RADIO WAVES BY THE SUN (continued)

$\lambda < 60$ cm. Appleton's magneto-ionic theory of the ionosphere is applied to the sun, and the distributions of the 'ordinary' and 'extraordinary' radiations throughout the spectrum are given. Their intensities differ markedly over a wide range of wavelengths. (MES)

4-5 Saha, M. N. "Conditions of Escape of Radio-Frequency Energy from the Sun and the Stars," Nature, 158, 549 (1946).

A solar application of Appleton's magneto-ionic theory indicates that electromagnetic waves in the meter range can escape from the sun only if their frequency exceeds certain limits. For the o-waves, the limiting frequency depends on the maximum electron concentration through which the waves must pass; solar o-radiations cannot originate in the reversing layer or the chromosphere but only in the corona. For the e-waves the limiting frequency depends both on electron concentration and on the characteristic gyro-frequency of the electrons under the total prevailing magnetic field; in large sunspots, where high magnetic fields exist, e-waves can originate from layers of considerable depth. The stars from which radiations in the meter range can escape are the cooler ones of types G, K and M. (MES)

4-6 Saha, M. N. "Origin of Radio-Waves from the Sun and the Stars," Nature, 158, 717-718 (1946).

The strong magnetic fields associated with the active sun can give rise to waves of meter wavelength by transitions between the nuclear spin levels of atoms and molecules. Such transitions have been observed in absorption, for alkali atoms, but solar phenomena will probably depend on hydrogen and hydrides, for which approximate calculations are here given. (P)

1947 4-7 Bruce, Chas. E. R. "Origin of Solar 'Static,'" Nature, 159, 580 (1947).

Exception is taken to Martyn's statement regarding the difficulties attendant to the production in the solar envelope of electrical discharges similar to those causing the familiar terrestrial radio noise. The author's explanation of this phenomenon and his general theory, on which the difficulty does not arise, are cited. (MES)

4. THEORY OF THE EMISSION OF RADIO WAVES BY THE SUN (continued)

4-8 *Denisse, J. F. "Solar Radiation in the Ultra-Short Radio Region" [in French], Annales d'astrophysique, 10, 1-13 (1947).

Electrons of the solar atmosphere in motion in the magnetic field of a rapidly developing sunspot can give rise to electromagnetic radiation in the radio region. If this radiation is to emerge, a large variation in field strength must occur within a critical depth which is about 10 km. for a field strength of 100 gauss in the lower corona. The lowest layers of the corona give the strongest emission and relatively little absorption. The radiation reaching the earth should be partially circularly polarized (the sense depending on the polarity of the associated spot) and should reach 10^{-17} W./cm.^{2}/Mc./s. at a wavelength of 1 m. Radiation should be observed between a few tens of centimeters and a few meters, in good agreement with observation. (P)

4-9 Denisse, Jean F. "Sur les émissions radioélectriques solaires," Comptes rendus des séances de l'Académie des Sciences, 225, 1358-1360 (1947).

A theoretical explanation is given of the solar conditions which favor radio emission and also cause a considerable increase of electron kinetic energy. Numerical calculations are consistent with observations. (W)

4-10 Garwick, Jan V. "Sur les émissions radioélectriques du Soleil," Contributions de l'Institut d'Astrophysique de Paris A, No. 3 [1947] (Extraits des Comptes rendus des séances de l'Académie des Sciences, 224, 377-379, séance du 10 février 1947; 551-553, séance du 24 février 1947).

The gyromagnetic hypothesis for explaining the radio-frequency emissions of the sun leads to certain consequences here developed. To a good approximation, the intensity of the radiation, which must originate in the outer chromosphere or inner corona, is proportional to $H^{2/3}$ or $\nu^{2/3}$, where H = magnetic field of spot and ν = frequency. This theoretical result is consistent with observations for $\lambda > 5$ m. but is inconsistent at $\lambda = 2$ m.; no comparison is made for 2 m. $< \lambda <$ 5 m. due to a lack of observed data. Possible causes of the disagreement at $\lambda = 2$ m. are discussed and an absorption is postulated. The Doppler effect is found to have no importance for the observed radiation. (MES)

*Reference and abstract from Physics Abstracts (Section A of Science Abstracts), 51, 266, Abstract 2662 (1948).

4. THEORY OF THE EMISSION OF RADIO WAVES BY THE SUN (continued)

4-11 *Ginzburg, V. L. "Solar and Galactic Radioemission," Advancement of Physical Sciences (Uspekhi Fizicheskikh Nauk), 32, No. 1 (1947).

4-12 Martyn, D. F. "Origin of Radio Emissions from the Disturbed Sun," Nature, 159, 26-27 (1947).

The very strong solar radio emissions which are correlated with sunspots cannot be thermal in origin because of the impossibly high source temperatures which they would require. The electron gas above the chromosphere possesses, in the presence of a magnetic field, two natural periods of oscillation, and collisional friction in such an oscillating medium could produce radio waves of the type under discussion. The observed radiation would most likely come from the borders of prominence material. One mechanism capable of setting the medium into oscillation is described. Arguments are given against Kiepenheuer's theory that the observed radiation is produced by the free spiralling of individual electrons in the magnetic field. (MES)

4-13 Saha, M. N., Banerjea, B. K., and Guha, U. C. "On the Conditions of Escape of Microwaves of Radio-Frequency Range from the Sun," Indian Journal of Physics, 21 (and Proceedings of the Indian Association for the Cultivation of Science, 30), 199-221 (1947).

The conditions of escape of radio-frequency waves from the solar atmosphere are discussed with the aid of magneto-ionic theories of propagation of radio waves through an ionized atmosphere traversed by a magnetic field. It has been shown from these theories that the magnetic field of the spots actually enables the e-component of the waves to escape from deeper layers of the solar atmosphere and thus provides an explanation of the observational fact that radio waves are actually emitted by the spot regions themselves. It is shown that the same theories give a general and satisfactory explanation of all the facts observed so far, e.g., the circular polarization, and sudden intensification of emission with the onset of radio flares. Programs for further work are indicated. (A)

*Reference and manuscript translation from [U. S.] Research and Development Board, Technical Intelligence Branch.

4. THEORY OF THE EMISSION OF RADIO WAVES BY THE SUN (continued)

1948 4-14 Bailey, V. A. "Spontaneous Waves in Discharge Tubes and in the Solar Atmosphere," Nature, 161, 599-600 (1948).

It is found theoretically that a strongly ionized gas with constant electric and magnetic fields is octuply refracting, with 8 possible types of wave. One or more of these types may show negative absorption, i.e. amplitude grows with time, and the gas should be capable of generating oscillations. The consequences of this possibility are briefly discussed, and conditions for applying it as the explanation of abnormal solar noise and cosmic noise are stated. (P,MES)

4-15 Giovanelli, R. G. "Emission of Enhanced Microwave Solar Radiation," Nature, 161, 133-134 (1948).

A theory is outlined to explain the 'million degree' radiation from the neighborhood of sunspots. It is shown how electrons may obtain energies of 10^6 - 10^7 eV. near a rapidly growing sunspot field; the energy radiated by such electrons spiralling around the lines of force is estimated. (P)

4-16 *Kiepenheuer, K. O. "Metre and Centimetre Waves from the Sun," Funk und Ton Monatsschrift fuer Hochfrequenztechnik, April 1948, No. 4, pp. 165-170.

A general discussion is given of the correlation between short-wave radiation from the sun and the occurrence of sunspots, flares, etc., and of the magnitude of the solar temperatures and magnetic fields which would account for the observed effects. (W)

4-17 Martyn, D. F. "Solar Radiation in the Radio Spectrum. I. Radiation from the Quiet Sun," Proc. Roy. Soc. A, 193, 44-59 (1948).

The theory of the emission of thermal radiation from the solar envelope at radio frequencies is worked out in detail. The Lorentz theory of absorption is used in conjunction with Kirchhoff's law to derive the effective temperature of the various regions of the solar disk over the radio spectrum. A maximum effective temperature approaching 10^6 °C is found in the vicinity of 1 m. wavelength. Limb-brightening occurs at centimeter wavelengths. It is shown that Gaunt's quantum mechanical expression for free-free emission yields results

*Reference and abstract from Wireless Engineer, 25, A.150, Abstract 1920 (1948).

almost identical with the classical treatment, provided Chapman and Cowling's expression for the collision frequency in a fully ionized gas is used in the latter treatment. It is suggested that it may be preferable to treat problems of solar and galactic radio noise by classical methods, particularly when the refractive index of the medium departs appreciably from unity. (A)

4-18 Waldmeier, M. "Die Radiofrequente Strahlung der Sonnenkorona," Experientia, 4, 64-66 (1948).

From the theory of the free-free transitions of the electrons in the solar corona the absorption coefficient and optical thickness of the corona are calculated. From these the intensity of the coronal radiation at radio frequencies is deduced for different distances from the center of the sun's disc. The spectral intensity-distribution is given for radiation coming from the sun's center, from the sun's limb and from a point one solar radius outside the sun's limb. (A)

See also: 2-5, 2-10, 2-31, 3-7, 3-8, 3-9, 6-12.

5. THEORY AND DESCRIPTION OF INSTRUMENTS

1935 5-1 Johnson, J. B., and Llewellyn, F. B. "Limits to Amplification," Electrical Engineering, 53, 1449-1454 (1934), reprinted in Bell System Technical Journal, 14, 85-96 (1935).

The amplification obtainable in a vacuum tube amplifier is limited by the noise in the circuit. Of the various sources of noise the most fundamental and inevitable is thermal agitation of electricity. Other sources are the influence of ions and of shot effect and flicker effect on the current in vacuum tubes, poor contacts, mechanical vibration, and hum from a.c. cathode heating. These noises and their effects in limiting amplification are discussed in this paper. (A)

1937 5-2 Friis, H. T., and Feldman, C. B. "A Multiple Unit Steerable Antenna for Short-Wave Reception," Proc. I.R.E., 25, 841-917 (1937), reprinted in Bell System Technical Journal, 16, 337-419 (1937).

The antenna systems here discussed consist of end-on arrays of antennas, of fixed directivity, whose outputs are combined at the desired phase to get the required directional pattern. The vertical direction of the main lobe was variable by varying these phase differences. The experimental system, using six rhombic antennas, at the Bell Telephone Laboratory station near Holmdel, N. J., is described. The benefits ascribable to this system are (1) a signal-to-noise improvement of 7 to 8 db., referred to one of the six antennas alone, and (2) a substantial quality improvement due jointly to the diversity action and the reduction of selective fading. The effect on signal-to-noise ratio of diversity action, automatic gain control, and different detectors is discussed, and the theoretical values compared with the experimentally obtained ones. For this system it was found that automatic gain control causes about 3 db. loss in signal-to-noise ratio and that square law detectors were the best possible detectors as far as signal-to-noise ratio is concerned. (A,BMF)

1938 5-3 Reber, Grote. "Electric Resonance Chambers," Communications, 18, No. 12, 5-8 + (1938).

The characteristics of resonant chambers having an opening at one end and containing an antenna wire are discussed.

5. THEORY AND DESCRIPTION OF INSTRUMENTS (continued)

Numerous plots are given of chamber selectivity, chamber efficiency, chamber response, etc. versus the physical parameters of the chamber. (BMF)

1939 5-4 Jansky, Karl G. "An Experimental Investigation of the Characteristics of Certain Types of Noise," Proc. I.R.E., 27, 763-768 (1939).

The results of an investigation of the effect of the bandwidth on the effective, average, and peak voltages of several different types of noise are given for bandwidths up to 122 Kc. For atmospheric noise and that due to the thermal agitation of electric charge in conductors, both of which consist of a large number of overlapping pulses, the peak, average, and effective voltages were all proportional to the square root of the bandwidth. For very sharp, widely separated, clean, noise pulses, the average voltage was independent of the bandwidth and the peak voltage was directly proportional to the bandwidth. The experiments showed that when a linear rectifier, calibrated by a continuous-wave signal having a known effective voltage, is used to measure the effective voltage of noise of the type due to thermal agitation of electric charge in conductors, the measurements should be increased by $\frac{1}{2}$ decibel to obtain the correct result. (A)

1941 5-5 Burgess, R. E. "Noise in Receiving Aerial Systems," Proceedings of the Physical Society of London, 53, 293-304 (1941).

The estimation of the noise occurring in practical aerial systems is discussed, consideration being given to the various external noise fields, viz. thermal radiation, Jansky noise, atmospherics. The actual noise received may be expressed conveniently by the equivalent temperature T_r of the radiation resistance. The general problem of evaluating the signal-to-noise ratio for any values of received circuit- and tube- noise is analyzed and a criterion (K) of efficiency of an aerial system is deduced. The paper concludes with a numerical calculation of the performance of (1) a vertical aerial inductively coupled to a tuned grid circuit and (2) a tuned-loop aerial. (A)

5. THEORY AND DESCRIPTION OF INSTRUMENTS (continued)

1942 5-6 Herold, E. W. "An Analysis of the Signal-to-Noise Ratio of Ultra-High-Frequency Receivers," RCA Review, 6, 302-331 (1942).

This paper presents an analysis of the effect of the various sources of fluctuation noise on the signal-to-noise ratio of radio receivers. It is especially applicable at ultra-high frequencies. It is found that the signal-to-noise ratio depends upon the antenna noise; in addition, when bandwidth is not a consideration, it depends on the ratio of equivalent noise resistance to input resistance of the first tube, and, when bandwidth is a major consideration, on the product of input capacitance and equivalent noise resistance. An optimum coupling from antenna to first tube is found which results in an improvement in signal-to-noise ratio, this coupling often being considerably different from the adjustment for optimum gain. It is shown that the thermal noise from a wide-band interstage may be made negligible by concentrating all the damping on the secondary side. Calculations of typical receiver arrangements using triode type 955 and pentode type .95A mixers are given for 300, 500, and 1000 megacycles. (A)

5-7 Reber, Grote. "Cosmic Static," Proc. I.R.E., 30, 367-378 (1942).

A highly directive system for detecting and recording cosmic static on 160 Mc./s. is described and analyzed. Data are given on the variations in intensity of cosmic static in relation to various regions of the galaxy. The effects of interference are discussed. It is suggested that all cosmic static is equivalent to thermal agitation in which all space is the conductor and the input terminals of the detecting equipment are projected by means of an antenna system to some far-distant part of space. (A)

1943 5-8 Kleen, Werner. "Schwankungserscheinungen als Grenzen der Verstärkung und des Empfangs," Elektrotechnische Zeitschrift, 64, 473-478 (1943).

A review is given of the noise in receivers due to the antenna, the input circuits, and the tubes, each being discussed separately. The final result for the sensitivity

5. THEORY AND DESCRIPTION OF INSTRUMENTS (continued)

limit of a receiver with optimum antenna coupling is:

$$E = k T_o \left[\frac{T_a}{T_o} + 2\frac{R_a}{R} + 2\sqrt{\left(\frac{R_a}{R}\right)^2 + \frac{R_a}{R}} \right]$$

where E = the signal energy required for the output signal to equal the noise
k = Boltzmann's constant
T_a = antenna noise temperature
T_o = room temperature
R = input circuit resistance
R_a = equivalent grid noise resistance.

The first term denotes the effect of the antenna noise and the second term denotes the effect of noise due to the input circuit and tube. (BMF)

1944 5-9 Reber, Grote. "Filter Networks for UHF Amplifiers," Electronic Industries, 3, No. 4, 86-89+ (1944).

Diagrams are given of UHF filter networks using capacitances, inductances, and open coaxial lines as elements, and the associated theory is discussed. (BMF)

5-10 Reber, Grote. "Reflector Efficiency," Electronic Industries, 3, No. 7, 101+ (1944).

A discussion is given of the theoretical equations and the resulting theoretical curves for the efficiency of a parabolic reflector system with a cavity at the focus containing the antennas. The efficiency depends upon the size of the cavity opening and width of the acceptance pattern of the parabola. (BMF)

1946 5-11 Dicke, R. H. "The Measurement of Thermal Radiation at Microwave Frequencies," Review of Scientific Instruments, 17, 268-275 (1946), reprinted with minor changes from Massachusetts Institute of Technology. Radiation Laboratory. Report 787 (1945).

The connection between Johnson noise and black body radiation is discussed, using a simple thermodynamic model.

5. THEORY AND DESCRIPTION OF INSTRUMENTS (continued)

A microwave radiometer is described, together with its theory of operation. The experimentally measured root mean square fluctuation of the output meter of a K-band radiometer (0.4°C) compares favorably with a theoretical value of 0.46°C. With an r.f. bandwidth of 16 Mc./s., the .4°C corresponds to a minimum detectable power of 10^{-16} watts. The method of calibrating using a variable temperature resistive load is described. (A)

5-12 *Lehmann, G. "Etude de l'équilibre thermodynamique des antennes," Annales des télécommunications, May, 1946.

1947 5-13 Hopper, Andrew L., and Miller, Stewart E. "Considerations in the Design of a Radar Intermediate-Frequency Amplifier," Proc. I.R.E., 35, 1208-1219 (1947).

The theoretical problems involved in the design of an intermediate-frequency amplifier to provide an over-all bandwidth of 10 Mc./s. centered at 60 Mc./s. are qualitatively discussed. Data of practical importance to the engineer attempting to build a similar amplifier are given. Measured characteristics illustrate the end results achieved. (BMF)

5-14 Reber, Grote. "Antenna Focal Devices for Parabolic Mirrors," Proc. I.R.E., 35, 731-734 (1947).

The purpose and general nature of the receiving pattern are discussed. The results of calculations for the resistance and reactance of wide-angle cone antennas in free space are given. Several cone antennas in hemispherical enclosures have been measured and the impedance and phase-angle curves are shown. These results indicate that cylinders are more desirable than cones; therefore, two cylindrical antennas are tested. The results of the investigation show that by making the antenna more slender and providing fine tips: (a) the radiation resistance is increased, (b) the rate of change of phase-angle at resonance is increased, and (c) the resonant frequency is lowered. (A)

*Reference from 6-13.

5. THEORY AND DESCRIPTION OF INSTRUMENTS (continued)

1948 5-15 Ryle, M., and Vonberg, D. D. "An Investigation of Radio-Frequency Radiation from the Sun" Appendix 1, Proc. Roy. Soc. A, 193, 112-117 (1948).

A highly accurate system for measuring the temperature of the sun and the amplitude of its variations is discussed. The system, similar to Dicke's, consists of an arrangement for keeping the output of a noise generator the same as the received signal. This is done by rapid, automatic switching from one to the other, the amplitude of the resulting square wave, in case of inequality, being applied to the noise generator to correct its output. The output of the noise generator is then accurately determined by measuring the heater current of the noise diode, this being the means of changing its output. The accuracy of the system is also discussed. The following characteristics are obtained for a system using an amplifier of noise factor 11 db., input bandwidth 4 Mc./s., and output bandwidth 4 cps:

1. fluctuation of the output meter = $6^{\circ}5 \pm 2^{\circ}K$
2. maximum following error for small signals = $18^{\circ} \pm 2^{\circ}$ K.
3. maximum following error for large signals = $.4\% \pm .05\%$.

The calculated values of these quantities are 4°K, 13°K and .33% respectively. (BMF)

5-16 Ryle, M., and Vonberg, D. D. "An Investigation of Radio-Frequency Radiation from the Sun" Appendix 2, Proc. Roy. Soc. A, 193, 117-119 (1948).

Aerial systems used for measuring solar radiation are discussed. After the effective temperature of the antenna system is known, the receptivity of the system over a complete sphere relative to the receptivity from the direction of the source must be determined. Because of errors in this determination, and other uncertainties, it is difficult to establish the effective temperature of a $\frac{1}{2}^{\circ}$ source to better than $\pm 10\%$. To determine the diameter of the source and to take into account galactic background, the authors used an interferometer set-up. A discussion of the effect of mismatches is given. It is shown that any differences between the polar diagrams or impedances of the aerials would make the source diameter seem larger than it actually is. (BMF)

See also: 1-1, 1-5, 1-7, 1-9, 1-13, 1-18, 2-23, 2-34, 6-2.

6. REVIEWS

1943 6-1 Hardung, V. "Radiostörungen als Astronomisches Forchungswerkzeug," Bulletin Schweizerischer Elektrotechnischer Verein, 34, 348-350 and 371-374 (1943).

1945 6-2 Bakker, C. J. "Ontvangst der Radiogolven" (Part I of "Radiogolven uit het Wereldruim" by C. J. Bakker and H. C. van de Hulst), Nederlandsch Tijdschrift voor Natuurkunde, 11, 201-209 (1945).

6-3 "Radio Waves from the Sun," Nature, 156, 270-274 (1945).

1946 6-4 Appleton, Sir Edward. "Extra-Tropospheric Influences on Ultra-Short-Wave Radar Operation," J.I.E.E. IIIA, 93, 110-113 (1946).

6-5 *[British] Department of Scientific and Industrial Research. "Radio Noise from the Sun," Electronic Engineering, 18, 98 (1946).

6-6 Ferrell, Oliver Perry. "Noise During Radio Fade-Outs," Terr. Mag., 51, 449 (1946).

6-7 "Short-Wave Radio Emission from the Sun," Engineering, 161, 164 (1946).

6-8 Steinberg, Jean-Louis, and Denisse, Jean. "Parasites d'origine extraterrestre dans le domaine des ondes courtes," Revue scientifique, 84, 293-294 (1946).

6-9 Unsöld, A. "Die Kosmische Kurzwellenstrahlung," Naturwissenschaften, 33, 37-40 (1946).

1947 6-10 **Denisse, J. "Recent Research on Extra-Terrestrial Emission of Metre Waves," Revue scientifique, 85, 483-488 (1947).

*Reference from Wireless Engineer, 23, A.115, Abstract 1521 (1946).
**Reference from Wireless Engineer, 25, A.128, Abstract 1626 (1948).

6. REVIEWS (continued)

6-11 Jouaust, R. "Les émissions radioélectriques du Soleil et de la Voie Lactée," Astronomie, 61, 65-74 (1947).

6-12 Reber, Grote, and Greenstein, Jesse L. "Radio-Frequency Investigations of Astronomical Interest," Observatory, 67, 15-26 (1947).

1948 6-13 Lehmann, M. G. "Les bruits radioélectriques d'origine extra-terrestre, leur influence sur la technique des télécommunications," Onde électrique, 28, 164-172 and 200-205 (1948).

6-14 Williamson, Ralph E. "The Present Status of Microwave Astronomy," Journal of the Royal Astronomical Society of Canada, 42, 9-32 (1948), reprinted as Cornell University. School of Electrical Engineering. Radio Astronomy Project. Technical Report No. 1.

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