Algonquin Radio Observatory

National Research Council of Canada. Radio and Electrical Engineering Division

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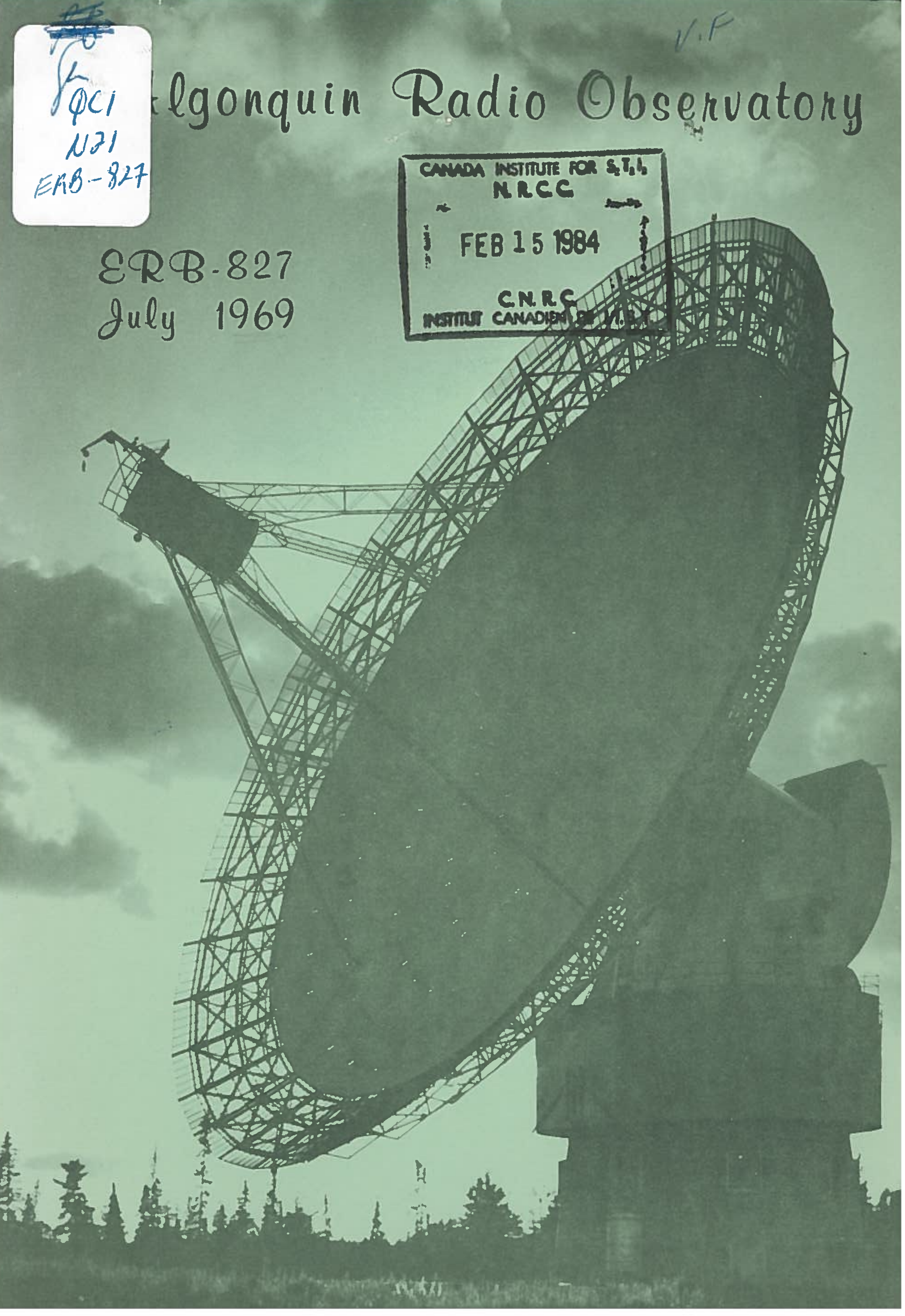


Algonquin Radio Observatory

Canada's national radio observatory is situated about 160 miles west of Ottawa, deep in the forest of Algonquin Park, Ontario, a provincial park of close to 2,000,000 acres set aside as a wild life sanctuary on the height of land between the Ottawa River and Lake Huron. The observatory was established in 1963 on a 135-acre site, made available by the province of Ontario and chosen for its freedom from man-made radio noise.

Radio and Electrical Engineering Division

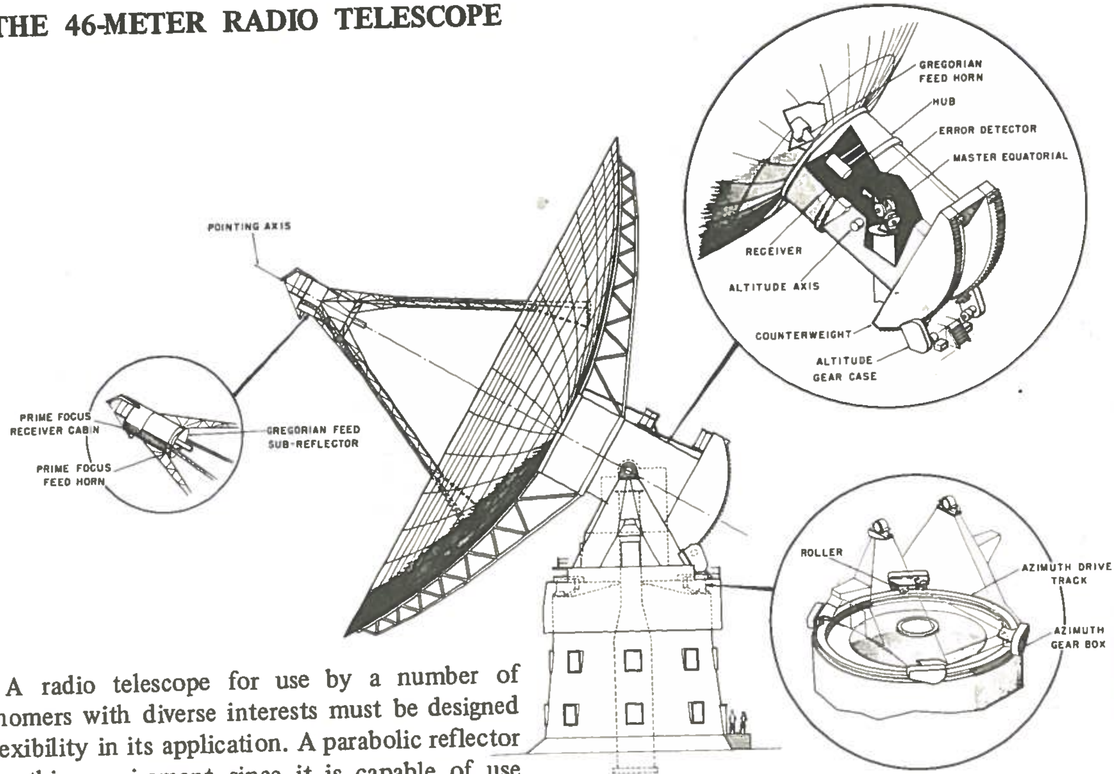
NATIONAL RESEARCH COUNCIL *of* CANADA

Man's understanding of the universe has been significantly enlarged by astronomical observations at radio wavelengths. Although the early measurements were made with relatively simple equipment, modern radio astronomy requires complex instruments of large size and high cost. The Algonquin Radio Observatory was established to meet many of the needs of Canadian radio astronomers and provides a variety of instruments for the use of scientists in both universities and government institutions. The facility is operated by the Radio and Electrical Engineering Division of the National Research Council. The relative remoteness of the site within a provincial park ensures that it will be comparatively free from radio noise of terrestrial origin for many years to come.

The existing instruments at the Observatory include telescopes suitable for observation of solar, planetary, galactic, and extragalactic emissions. The major instrument is a 46-meter alt-azimuth mounted paraboloid which was completed in 1966. Intended for operation primarily in the centimeter wavelength region, it has been used at wavelengths as short as 8 mm. This telescope is a general-purpose instrument, as is the smaller 10-meter equatorially mounted paraboloid. A precisely calibrated horn-reflector is used for measurements of the absolute intensities of strong radio sources. Several instruments are available for solar observation at a wavelength of 10-cm and in the UHF region. A recently completed 10-cm array provides high resolution in one dimension for studies of the structure of solar bursts.

A section of the site has been set aside for development by the University of Toronto. Present instrumentation includes a horn antenna which has been used for galactic background studies and an 18-meter paraboloid which is nearing completion.

THE 46-METER RADIO TELESCOPE

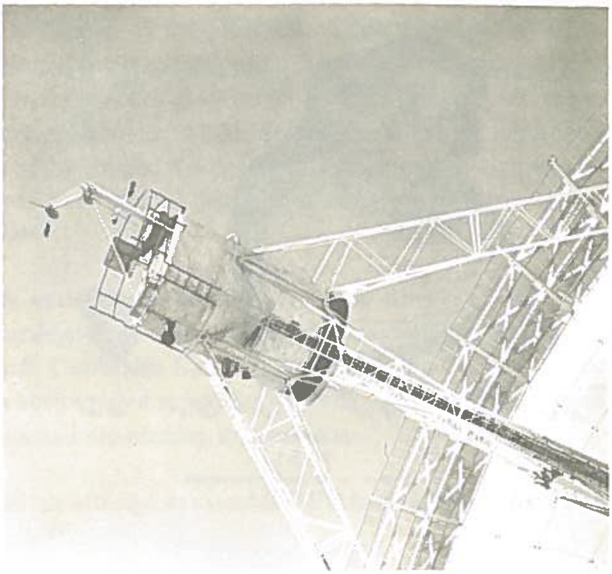


A radio telescope for use by a number of astronomers with diverse interests must be designed for flexibility in its application. A parabolic reflector fulfills this requirement since it is capable of use over a wide range of wavelengths and can accommodate many different types of research activity. The 46-meter fully steerable paraboloid was designed for general use, but with primary emphasis on centimetric wavelengths where many interesting aspects of astronomy are yet to be explored. The design was carried out and construction was supervised by Freeman, Fox and Partners, construction engineers of London, England in response to a performance specification put forward by the National Research Council. The prime contractor was Dominion Bridge Company of Montreal. It was completed in the summer of 1966 and full time astronomical research activities began in July of that year.

The telescope is mounted on a tapered concrete tower 13 meters high and 15 meters in diameter at the base. The entire steel structure, some 900 tons, is carried on four gear boxes fitted with integral rollers that run on a circular track 11 meters in diameter. A direct friction drive is used for this azimuthal rotation. This turret assembly carries two large A-frames which support the elevation trunnions. Elevation motion of the reflector is imparted by two gear boxes whose drive pinions engage circular rack segments fitted to the ends of the counterweight legs. The weight of the reflector is only partially counterbalanced; hence, one face of the rack teeth makes contact with the pinion at all times, eliminating backlash in the elevation servo loop.

The reflector proper is built around a central hub 7.5 meters in diameter and 6 meters high. Fitted to the hub are 36 radial cantilevered trusses or ribs, which are interconnected by ring girders. The reflecting surface over the inner 36 meters consists of stiffened steel plate, 6 mm thick, which acts integrally with the ribs in stiffening the reflector structure. Each individual panel in the surface plate has been shaped to the desired paraboloidal surface with a manufacturing tolerance of 0.25 mm rms. The outer 4.5-meter annulus consists of stressed mesh panels of 1-mm steel wire on 6-mm centers. Ninety-eight percent of the incident energy at 10-cm wavelength is reflected by this mesh. An adjusting screw and target is located at the corner of each panel. Adjustment to a paraboloidal shape has been made by optically siting each target and raising or lowering the corner of the panel as required. Radio measurements confirm that the surface has been adjusted to a best fit paraboloid with an rms error of about 0.9 mm.

Four lattice-type feed legs support a cylindrical cabin just beyond the focal point of the reflector. Receiving equipment is housed in this cabin on a platform whose axial position can be changed from the control room. This allows adjustment of the focus to be made to suit different receivers and to allow for a slight change in the focal length of the best-fit paraboloid with changes in temperature and elevation. The receiving apparatus can be withdrawn from the focal region in order to allow a Gregorian system of operation, in which the incoming energy is reflected from an ellipsoidal sub-reflector into a conical horn protruding from the central hub. The two methods of operation, Gregorian and prime focus, allow a change of receiving equipment and wavelength to be made in a couple of minutes.

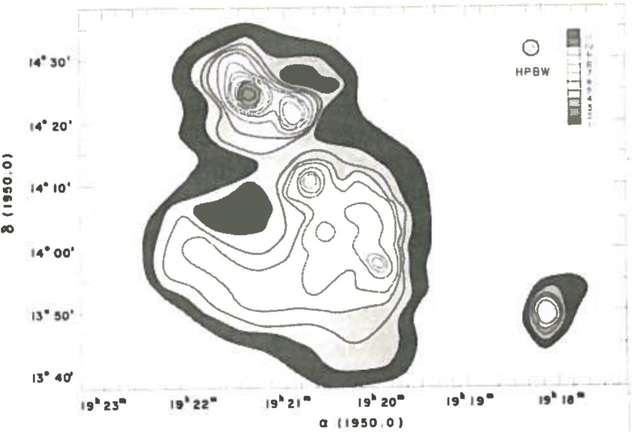


Conversion from celestial co-ordinates to the alt-azimuth co-ordinates of the telescope is accomplished by a small equatorially controlled mirror independently mounted at the intersection of the azimuth and elevation axes, and by a light beam and error detector system mounted on the hub structure. The light beam is reflected from the mirror and error signals are applied to the azimuth and elevation motors, causing the telescope to follow the motions of the mirror. To avoid dynamic coupling with the telescope, the mounting of this master equatorial unit is isolated from the tower and turret structure. Alignment errors between the telescope and the master equatorial unit are not more than 3–5 seconds of arc.

It will be evident that with this type of guidance system, many of the errors in telescope pointing are contained within the servo loop. Refraction, the main source of pointing error not contained in the servo loop, varies with zenith angle in a predictable fashion, and is compensated for by a programmed bending of the error detector light beam.

Performance & Specifications

Focal length	18 meters
Diameter	36.5 meters solid, 45.7 meters to edge of mesh
Surface accuracy	rms departure from paraboloid of best fit 0.9 mm
Beamwidth	1.5 min arc at 1.35 cm 2.7 min arc at 2.85 cm
Aperture efficiency	0.42 at 2.85 cm
Range of motion	Azimuth ±205° Zenith angle −5° to 83°
Rates of motion	Azimuth – variable to 24°/min Zenith angle variable to 15°/min Equatorial (1) sidereal or solar rate (2) variable scan rates 0–2.5°/min (3) slewing rate – variable to 25°/min (4) incremental – variable 0 to ±40 arc sec/sec



W 51

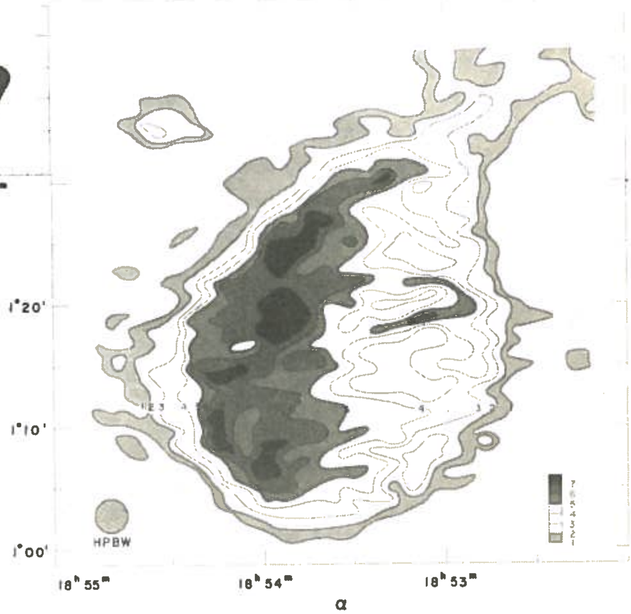
CONTOURS OF ANTENNA TEMPERATURE IN UNITS OF 0.1° K

Radiation from an ionized hydrogen region 20,000 light years away 2.8 cm wavelength. This region may represent the integrated emission from a spiral arm of the galaxy seen end on.

←

Emission at 2.8 cm from remnants of a supernova. The gaseous material flung out by the exploding star is expanding into the surrounding interstellar gas.

→



W 44 (1950.0 co-ordinates)

CONTOURS OF BRIGHTNESS TEMPERATURE IN UNITS OF .075°K

A data acquisition system forms an integral part of the 46-m telescope facility. A 24 bit general purpose computer with magnetic tape, paper tape and teletype input-output devices makes up the hardware side of this system. The software side consists of a flexible data acquisition program plus a library of sub-programs designed for immediate data processing. From these, the astronomer can put together a set of programs which will best meet his observing needs.

The telescope is a general purpose instrument and has been used in a great variety of programs and over wavelengths from 13.5 meters to 8 mm. Since 1966, 40% of the time has been used for astronomical research by NRC astronomers, 20% by Canadian University Astronomers and 5% by other Canadian and non-Canadian agencies. The remaining time has been used up in maintenance, performance testing, and equipment changes. In the last year NRC usage has decreased with a corresponding increase in use by university scientists.

One of the co-operative research programs that has involved the use of this telescope has been long-baseline interferometry. The principle of using completely separate telescopes for the detection of signals from small diameter sources was pioneered by a group of astronomers, scientists and engineers from universities and government agencies across Canada. Canadian astronomers from two universities and two government agencies have been active in measuring the diameters of quasi-stellar sources at a wavelength of 75 cm. Baseline distances between telescopes of up to 5000 km have given useful information about the diameter and structure of these interesting objects. At this distance the resolving power of the interferometer is of the order of 0.01 second of arc.

This wavelength does not, however, take advantage of the precision of this telescope. At centimetric wavelengths it ranks among the most powerful radio telescopes in the world. The variability of quasars and other compact extragalactic sources is a subject of great interest and of great importance in the study of the energy processes in these remarkable sources. About 50 sources are being monitored routinely with observations taken at wavelengths of 2.8 cm and 4.6 cm about once a month. One source, VRO 42.22.01, exhibits extremely rapid variations and a special program of twice weekly observations at two wavelengths has been undertaken for it alone.

Other programs have been concerned with extragalactic sources. The flux densities of approximately 150 sources from the Third Cambridge Catalogue have been measured at a wavelength of 2.8 cm. The microwave spectra of sources from the Fourth Cambridge Catalogue and from the Ohio Catalogue have been determined. Considerable interest has been excited in sources believed to have optically thick regions at short centimetric wavelengths. Their spectra have maxima in this region.

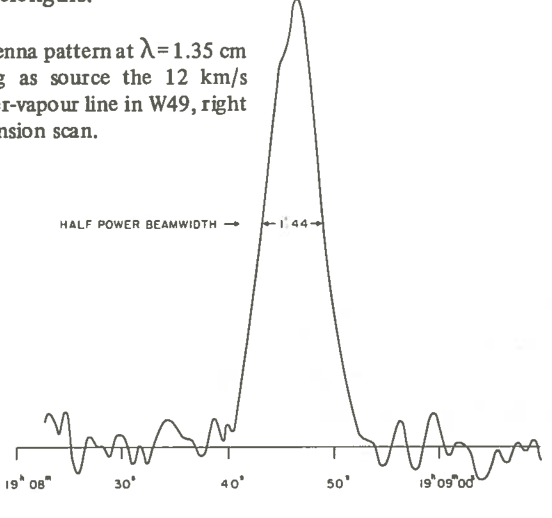
Measurements of the linear polarization and an attempt to measure circular polarization have also been made on extragalactic sources.

At wavelengths shorter than 5 cm the angular resolution available with this telescope is significantly better than that used in most galactic work. A considerable part of the telescope time has been spent in observations of various types of radio sources within our galaxy. A detailed program of observation of planetary nebulae is under way with measurements being made at wavelengths of 9.4 cm, 4.6 cm, and 2.8 cm. Some 200 planetary nebulae are included in this program which, when completed, will rank among the most exhaustive radio studies of planetary nebulae yet undertaken.

A survey of a section of the galactic plane has been completed at a wavelength of 9.4 cm and a number of galactic objects have been mapped at 4.6 cm and 2.8 cm. The compact HII regions have been the object of continuing examination and are of considerable interest in the consideration of the early stage of star formation. Mapping of HII regions with a resolution of 3 min of arc will continue to be an important part of the observing schedule of the 46-m telescope.

Among other programs of galactic observations, the first radio observation of an X-ray source was accomplished at a wavelength of 4.6 cm, and observations of planets have been made at centimetric wavelengths.

Antenna pattern at $\lambda = 1.35$ cm using as source the 12 km/s water-vapour line in W49, right ascension scan.



Observations of spectral lines have not played a large part in the astronomical programs on the 46-m telescope up to the present time. However, the first observation of the 6-cm line from an excited state of OH was made on the telescope and recently the 1.35-cm water vapour line was observed. It is anticipated that an increasingly large proportion of telescope time will be devoted to spectral line observations. The recently increased interest in line emission and absorption due to interstellar molecules will lead naturally to increased use of the telescope at wavelengths as short as 8 mm.

THE 10-METER RADIO TELESCOPE

This instrument consists of a 10-meter diameter paraboloid carried on an equatorial mounting. The *f/D* of the reflector is 0.4, and the surface accuracy is approximately 0.063 cm rms, making it suitable for efficient use down to 1.3 cm wavelength. Prime focus feeds and receivers are mounted on a quadrapod structure which is attached to the reflector near its rim.

The equatorial mount, which was designed within the division, affords full-sky coverage. Provision is made for slewing about both the declination and polar axes. The polar axis can be rotated synchronously at the sidereal rate for tracking celestial objects, and higher speeds can be superimposed on this motion to permit more rapid scans. The scanning motion is imparted through a mechanical differential, and is derived from two separate motors, one covering the range 0.0005°/min to 0.050°/min and the other the range 0.050°/min to 1°/min. The motor for the slower speed is a stepping motor, driven from a pulse generator. The higher speed is obtained from a dc motor whose speed is controlled through the armature voltage in response to an error signal. This is derived by counting pulses generated by a wheel fitted to the motor shaft, and comparing these pulses with those from a reference generator.

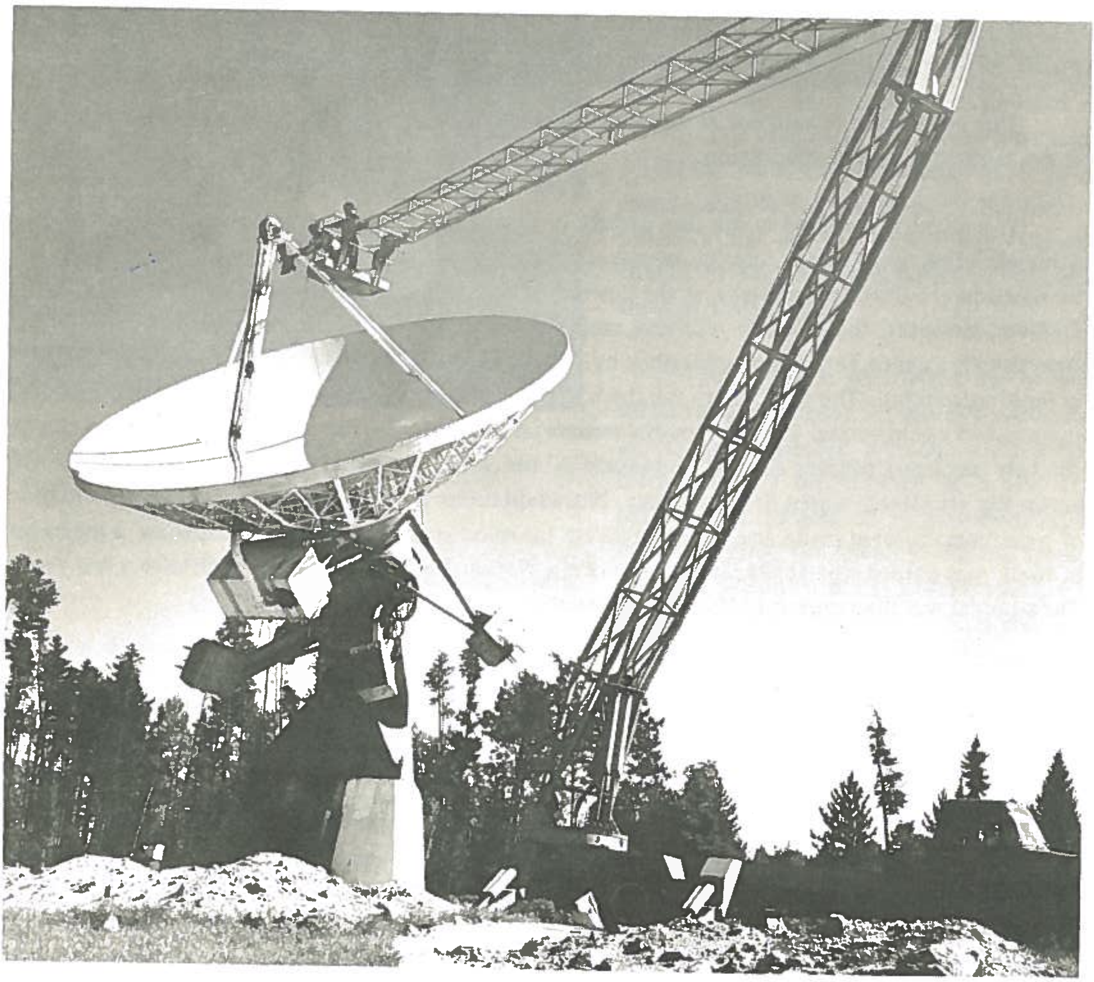
Telescope position is displayed in both analog and digital fashion. The analog display is by means of printed film strip, servo driven from synchros fitted to the hour angle and declination axes. The digital system consists of reversible counters which register pulses derived from incremental encoders fitted to the shafts. The analog system, which is non-ambiguous, serves to provide a periodic check on the count of the digital system.

Most of the observing time on the telescope has been spent on surveys of the galactic plane at a wavelength of 10 cm. Completed work includes surveys of the Cassiopeia and Cepheus regions of the galactic plane and of the Cygnus-X region. A considerable number of discrete sources imbedded in a general continuum of radiation were observed. Most of these sources are regions of ionized hydrogen surrounding very hot stars. A minority are believed to be remnants of supernovae explosions. The Cygnus-X region has also been surveyed at a wavelength of 4.5 cm. Observations at two frequencies permit separation of these two types of sources. The ionized hydrogen regions provide a view of stars at a very early stage in their evolution and, of course, the supernovae represent a very late stage in stellar evolution. Radio astronomical observations thus complement the optically derived picture of stellar evolution.

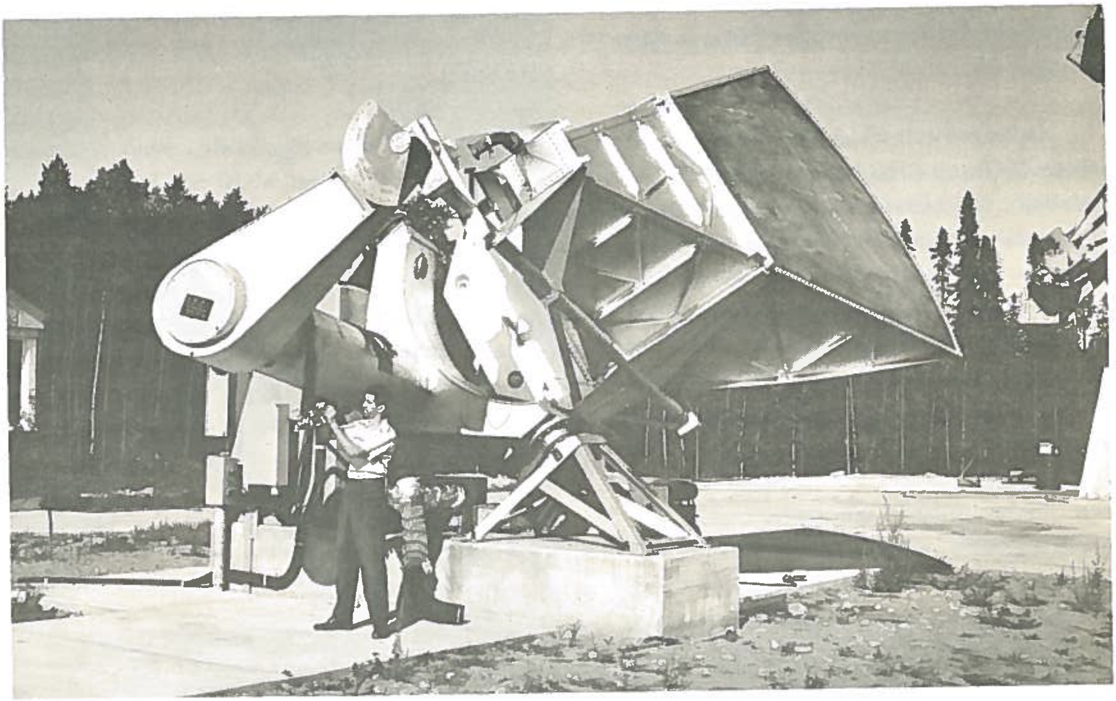
The University of Toronto has conducted polarization studies of the galactic radiation at 700 MHz. Observations of this type provide a significant step towards understanding the structure of the magnetic field of the Galaxy, which, in turn, is important in understanding the structure and evolution of the Galaxy.

Other projects which have been completed using the 10-meter telescope include a study of the solar eclipse of June, 1963, and a determination of the atmospheric attenuation at 10 cm. In addition, the University of Toronto has successfully used the telescope at its shortest wavelength to date, 8.6 mm. At this wavelength the sun, the moon, and several discrete sources were observed.

The recent detection of spectral line emission near 1.3 cm from water vapour and ammonia molecules in the Milky Way has opened up a new area of usefulness for the 10-meter telescope. The combination of the 10-meter and 46-meter telescopes operating as an interferometer at 1.3 cm will provide important new information on the angular sizes of the water vapour and ammonia concentrations.



HORN-REFLECTOR GAIN STANDARD



This instrument is used for absolute measurements of the intensity of emission from radio sources in the centimeter wavelength region.

The quantity required is the flux density or power per unit area of reception. The power received, although often quite weak, can be measured in a fairly straightforward manner by using a resistive termination at a fixed temperature, as the power meter or standard of comparison according to Nyquist's theorem. However, the effective receiving area of the antenna, which is always less than the geometrical area, usually cannot be ascertained, either by experiment or calculation, for the types of antennas used in radio astronomy. The difficulties are much alleviated if the antenna is quite small. This horn reflector represents a compromise. To detect radio sources, it is physically too small, but it will detect a few of the very strongest sources such as Cassiopeia A and the Crab Nebula in Taurus. In order to measure accurately its effective area, it is too large, but adaptations to the standard techniques used in this type of measurement were made and a very accurate measurement was obtained. This work, a major project in itself, was carried out at the laboratories of the National Research Council at Ottawa a few years ago. The antenna was then moved to its present mount.

There are several incidental advantages to this particular antenna design, compared to the more usual parabolic reflector, when used for absolute measurements. Aside from its sturdy construction, the sidelobe level and background reception are exceptionally low. Provision is made to check for any possible deterioration or aging effects of the antenna (presumably, if present, due to the plastic cover). The building which resembles an elevated garage, contains equipment for this purpose. Up to the present time no such deterioration has been detected.

The antenna, along with suitable radiometers and power measuring devices, has been used to measure the absolute flux density of Cassiopeia A, Taurus A, Cygnus A, and Orion A at wavelengths of 9.5 cm and 4.5 cm. Measurements at 2.2 cm are under way at the present time.

UNIVERSITY OF TORONTO SITE

Photo courtesy
Canadian Electronics Engineering

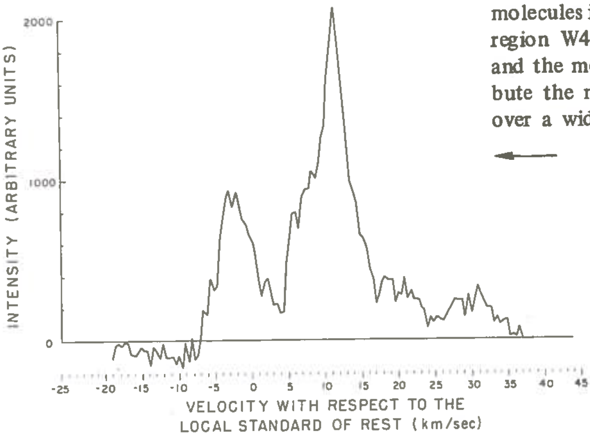
The facilities of the University of Toronto site are directed toward radio astronomical investigations in the centimeter through meter wavelength range. Both the instruments presently available and those under development are intended to operate in this wavelength range. The existing instruments are a 2.5-meter horn reflector antenna and a fully steerable 18-meter paraboloid.

The horn antenna is particularly suited to absolute flux density measurements because its gain and pattern can be computed from its geometry. Furthermore, the very low side and back lobes minimize the noise contributed by thermal radiation from the antenna's environment. A limited absolute survey of the sky has been carried out at 43 cm. The results of this survey have been combined with a similar survey at 1 meter made earlier in Toronto to study the spectral index of the galactic background. Further studies at shorter wavelengths are planned for this instrument.

The 18-meter paraboloid has a mesh surface and is designed for use at wavelengths of 10 cm or greater, although limited performance may be achieved at 5 cm. The paraboloid is located on an altitude-azimuth type mounting. The telescope control system which is presently under development, will employ a digital computer, which may also be used for data acquisition. The telescope is intended to constitute one element of an interferometer consisting of two or more elements with one movable antenna. It will also be used with the 46-meter telescope as a fixed interferometer. In either case this instrument will be an important asset in the study of the structure of galactic and extragalactic radio sources at high resolution.

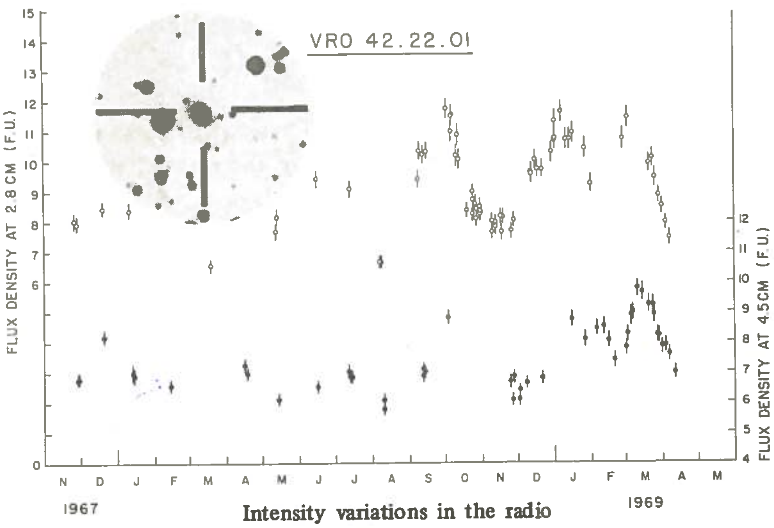
The 18 meter paraboloid alone will be used for a survey of galactic radiation at 18 cm in polarization and total intensity. Other surveys of a similar nature are possible.

The facilities available at the University of Toronto site enable radio astronomers and graduate students to undertake a wide variety of important investigations in radio astronomy.



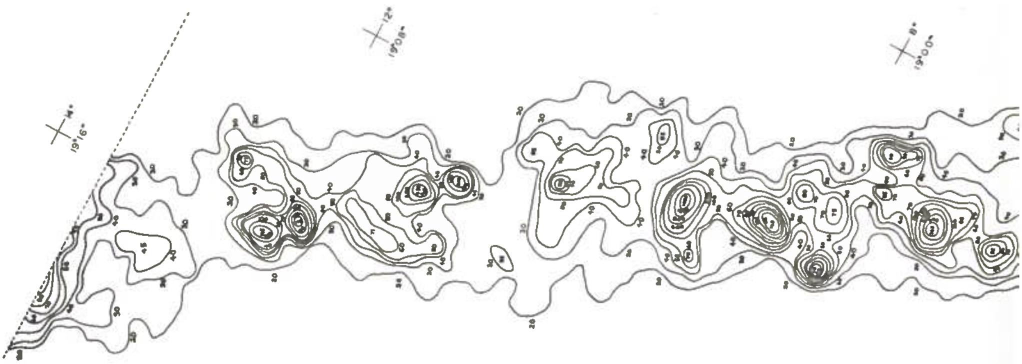
Line emission from water vapour molecules in the ionized hydrogen region W49. The Doppler effect and the motions of the gas distribute the narrower band emission over a wide range of frequencies.

The spectrum of a source gives a great deal of information about its physical characteristics. The spectra of many sources are studied at centimeter wavelengths. The diagram shows some of the more unusual ones.

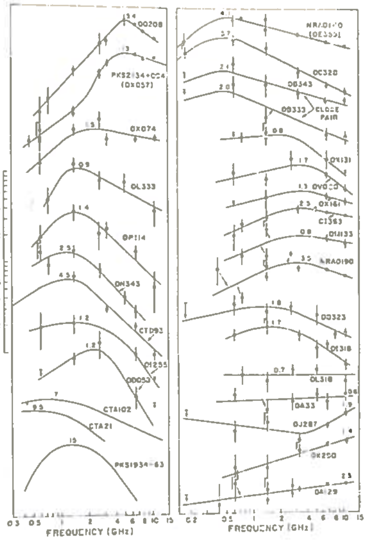


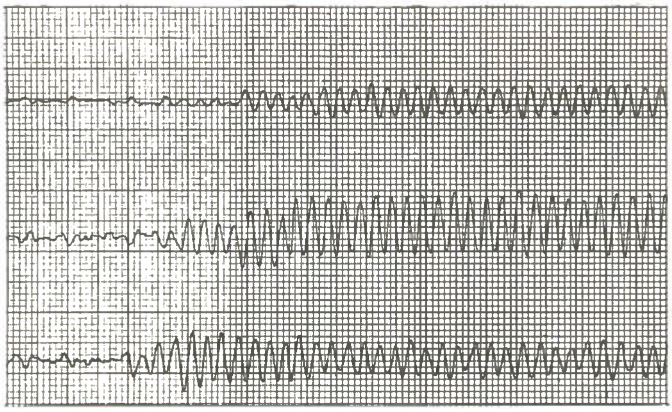
Intensity variations in the radio emission from an unusual object. Inset shows the optical object identified with the radio source.

2.8 cm radiation from a region in the direction of the star γ Cygni. The structure of the emission is similar to that of Cas A and suggests that it is associated with the remnants of a supernova.

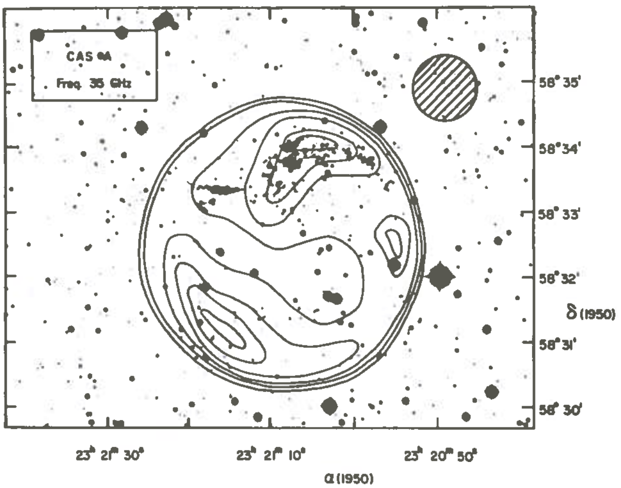


Detailed map of a section of the galactic plane made at 9.4 cm wavelength by astronomers from Queen's University, Kingston.

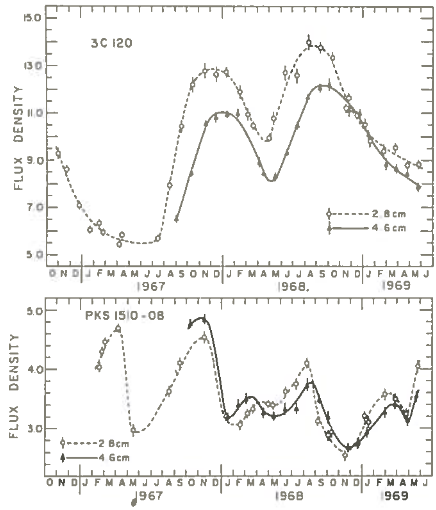




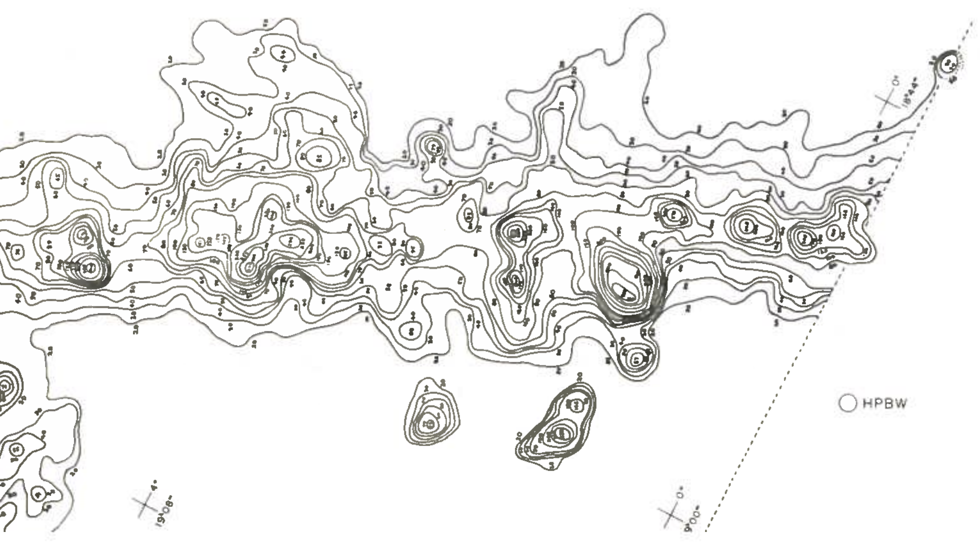
Interference fringes observed at 73 cm from the source 3C 286. These fringes resulted from the long baseline interferometer experiment between ARO and Jodrell Bank, England. The baseline of 2851 km is equivalent to $3.88 \times 10^6\ \lambda$.



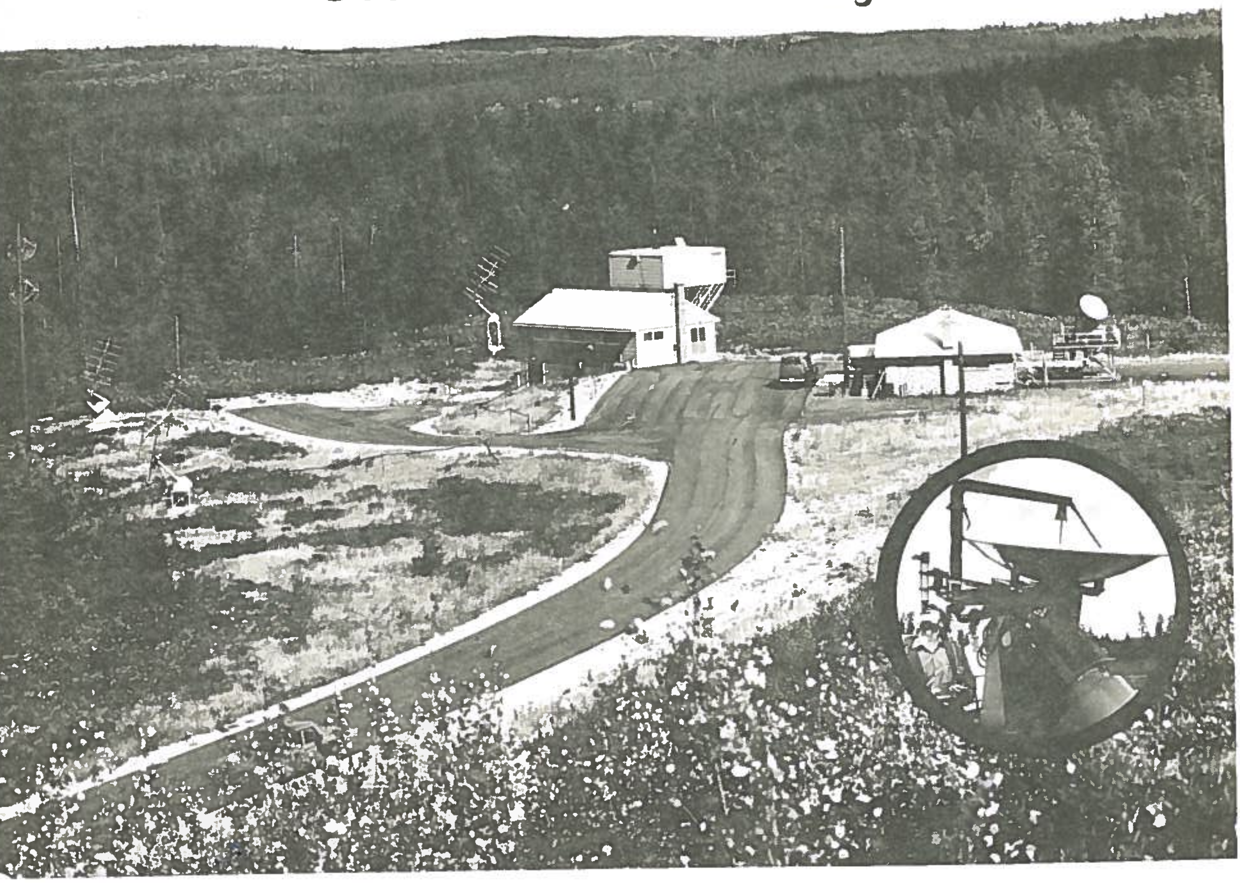
Map at 8 mm wavelength of the supernova remnant Cas A, made by astronomers from the University of Toronto



Contrasting behaviour in two variable sources. 3C 120 behaves as expected on the basis of a widely accepted theory; there is a relatively rapid increase and slow decrease in flux density.



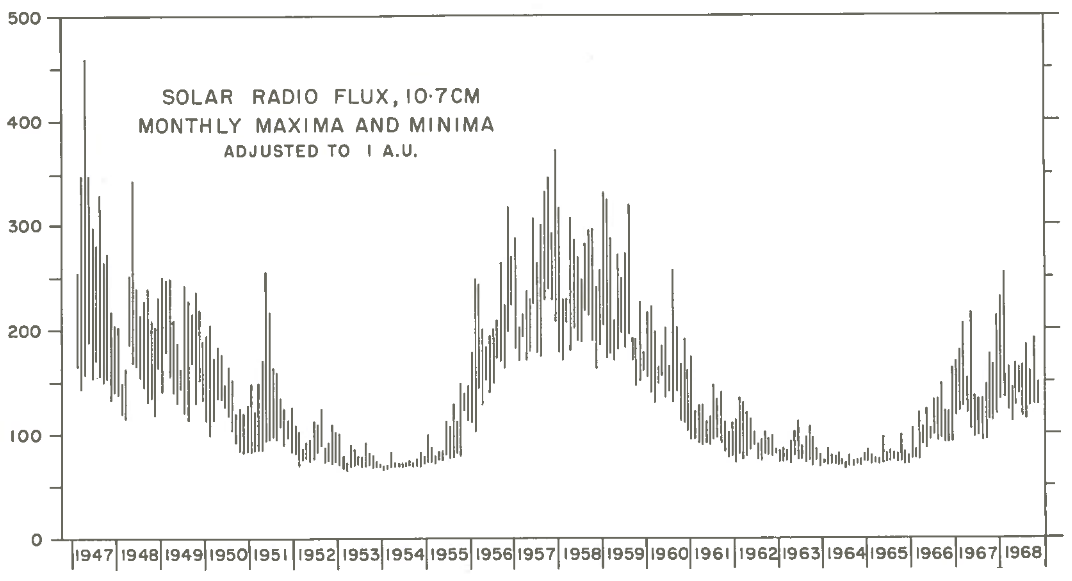
Solar Radio Astronomy



Solar noise studies were initiated in Ottawa by the National Research Council as a result of the 2800-MHz radio observations made at the time of the partial eclipse of the sun on November 23, 1946. It was shown that in addition to an emission from the undisturbed solar disc, there was a strong emission from the vicinity of a large sunspot group, and that the high temperature of 1.5 million degrees could be assigned to the emitting surface. Similar high values of temperature are observed optically in the solar corona and suggest that the mechanism of radio emission is probably located in the corona. Such high temperatures account for the strong ultraviolet and X-ray portion of the solar spectrum which produces the major portion of the ionization in the earth's upper atmosphere. In view of the significance of these ionizing emissions, it was anticipated that daily observations of the microwave flux would provide a new measure of the solar ultraviolet and X-ray flux which would not be affected either by transmission through the earth's atmosphere or by low-level water vapour clouds. Consequently, in February 1947, daily observations of the sun were commenced and have been continued on this basis ever since.

The present solar microwave observations at ARO are made with a 6-foot parabolic reflector, polar-mounted so that the sun can be followed from sunrise to sunset. The beam is considerably wider than the solar radio disc of some 36 minutes of arc, ensuring that the radio emission from any point on the disc is uniformly received within the flat portion of the main lobe. Solar signals are collected at the focus by a small pyramidal horn and conveyed in standard waveguide to the radiometer building.

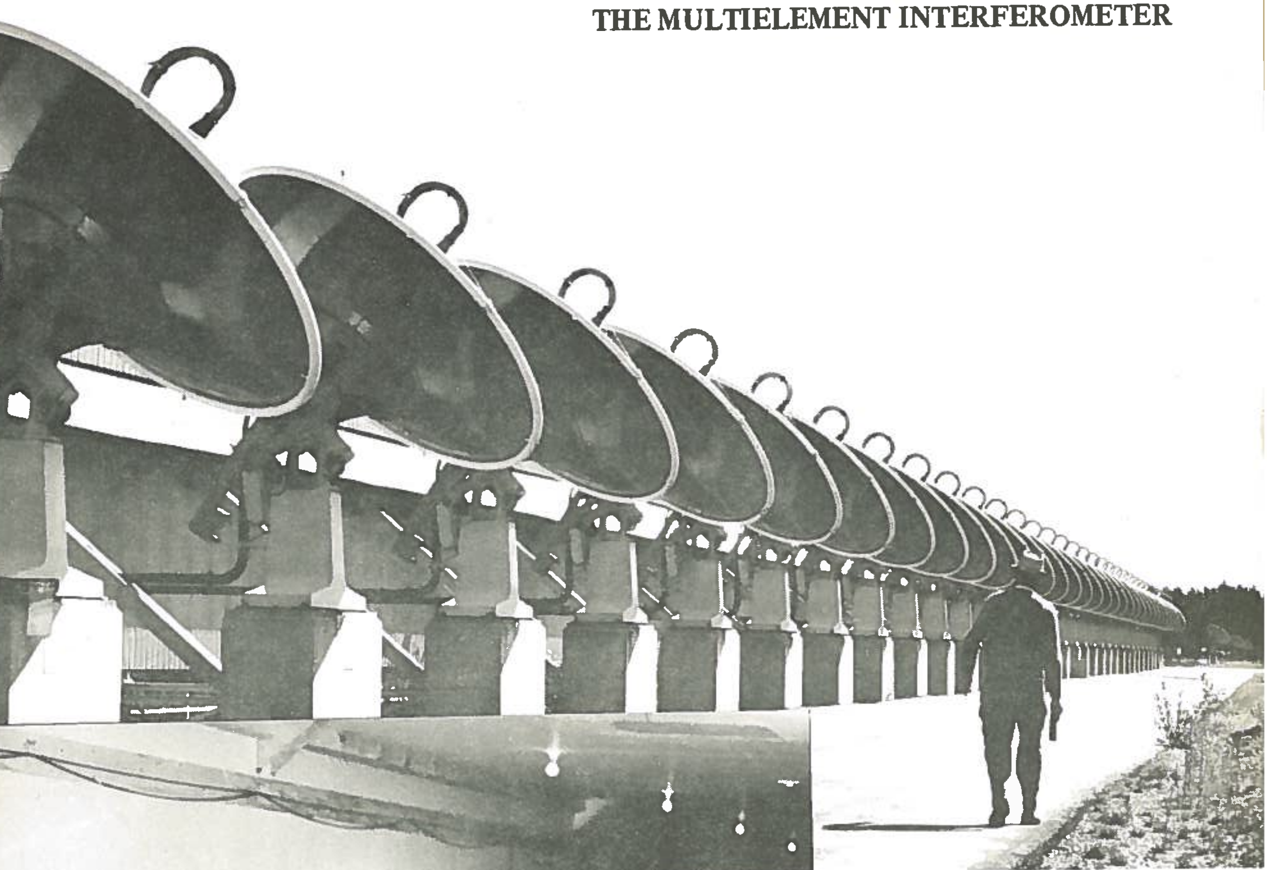
The strip chart records of solar radio noise from sunrise to sunset are analyzed into a daily level of emission and into sudden enhancements of noise. Variations in the daily level occur over a period of several days. Comparison with optical observations made at other observatories shows that two components are present: (1) an emission from the undisturbed solar atmosphere, and (2) the slowly varying emission which originates from condensations of electrons above sunspots. The daily level of flux has been widely used as an index of solar activity in studies of the solar control of the critical frequencies of the ionosphere and in studies of the variations of the atmospheric drag of satellites in the earth's upper atmosphere. In the graph below, monthly high and low values have been plotted and the two values are joined by a line to show the limits of the variations of the daily flux for nearly two complete sunspot cycles. It will be noted that in 1954 and in 1964, the emission from sunspots was a minimum and that the steady emission from the quiet sun was predominant. In 1947, 1958, and more recently in 1968–69, the emission from sunspots reached a series of peaks. The magnitude of the present peak is much smaller than the two preceding peaks and is taken as an indication of the long term cycle of about 80 years. Studies for the absolute calibration of the solar flux which are essential for such observations are in progress in Ottawa.

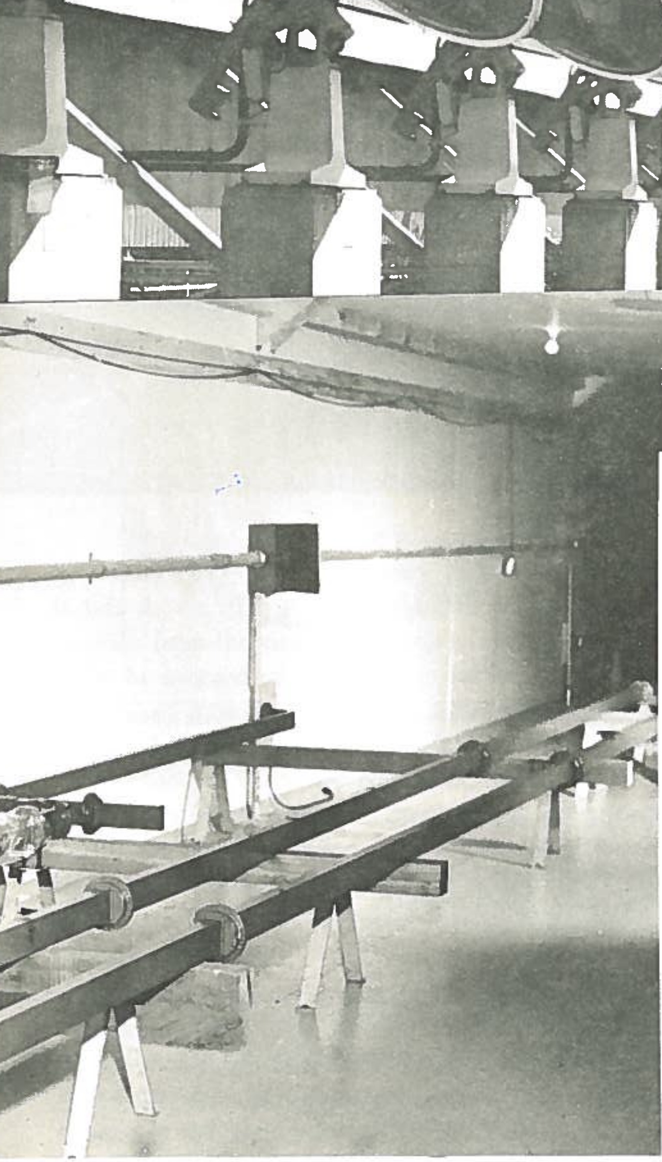


Plot of monthly high and low values of daily 10.7 cm solar flux outlines the slowly varying component of radio emission associated with sunspots, superimposed upon a steady emission from the undisturbed solar disc.

The sudden enhancement of solar noise, or noise burst, is an indication of the occurrence of a solar flare. In the more intense flares, various kinds of energy are suddenly released and disappear into interplanetary solar space. These include solar cosmic rays, X-rays, ultraviolet and visible light, radio waves and solar particles. With the advent of space missions, solar radio observations on earth will be of assistance in evaluation of the role of solar ejections as they affect the environment of the space craft. The observatory contributes to the rapid interchange of solar data on a world basis by originating a URANO gram each day.

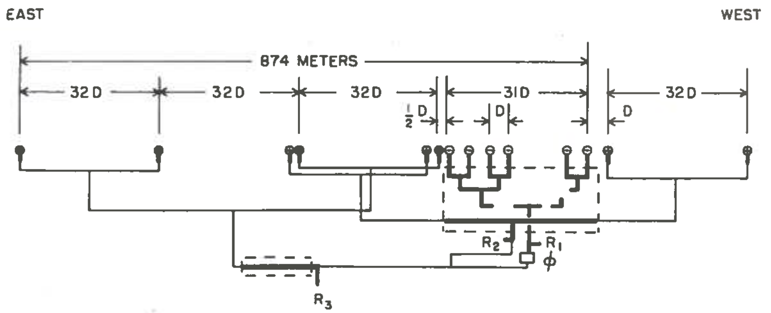
THE MULTIELEMENT INTERFEROMETER





Interior of Waveguide Shed

The multielement interferometer, which is designed primarily for solar observations, consists of forty 3-meter parabolic reflectors spaced along an east-west line of slightly over one kilometer. The instrument produces three independent records from three groups of antennas at a wavelength of 10 cm. The group of antennas that provides most of the collecting area is a uniformly spaced array of thirty-two antennas. Interference fringes from the array are fan-shaped with a width of $1\overset{\prime}{.}5$ and a separation of approximately $50'$ in the east-west direction. Solar drift curves from more than 60 fringes can be obtained in a day's observation with the array, which covers a period of four hours centered on the meridian. Each antenna is polar mounted and driven in both hour angle and declination by small stepping motors. Some details of the individual antenna mounts can be seen in the photograph.



⊖ 32 ELEMENT ARRAY AS COMMON INTERFEROMETER ELEMENT, OUTPUT R_1

⊕ 4 ELEMENT GRATING TO FORM POLARIZATION INTERFEROMETER, OUTPUT R_2

● 4 ELEMENT GRATING TO FORM COMPOUND INTERFEROMETER, OUTPUT R_3

D = 6.8 METERS ($22\frac{1}{2}$ FT)

▬ WAVEGUIDE LINE

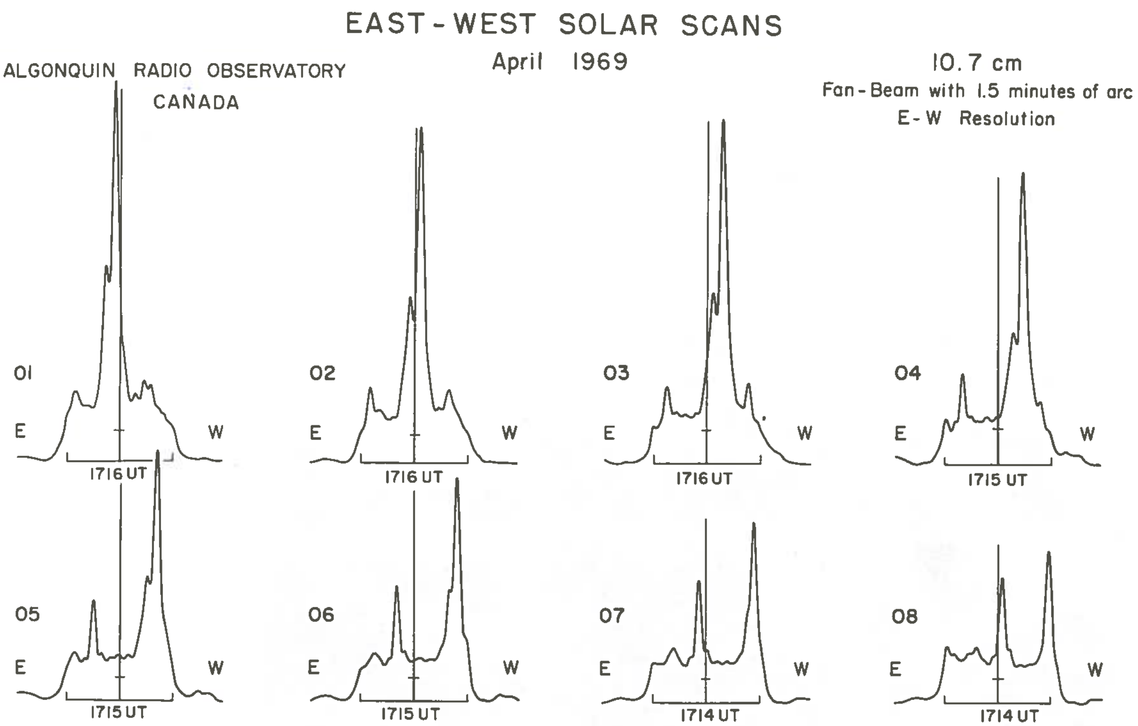
— BURIED COAXIAL CABLE

□ φ PHASE MODULATOR

- - - WAVEGUIDE SHEDS

Geometrical arrangement of the interferometer

The array antennas are inter-connected with a branched system of waveguide lines which are enclosed for temperature stability within an insulated shed. The waveguide gives good phase coherence over a band of 400 MHz centered at 2800 MHz (10.7 cm), and this full bandwidth is used on the meridian with a tunnel diode receiver. Narrower bandwidths are used off the meridian, however, to avoid broadening of the array beam.

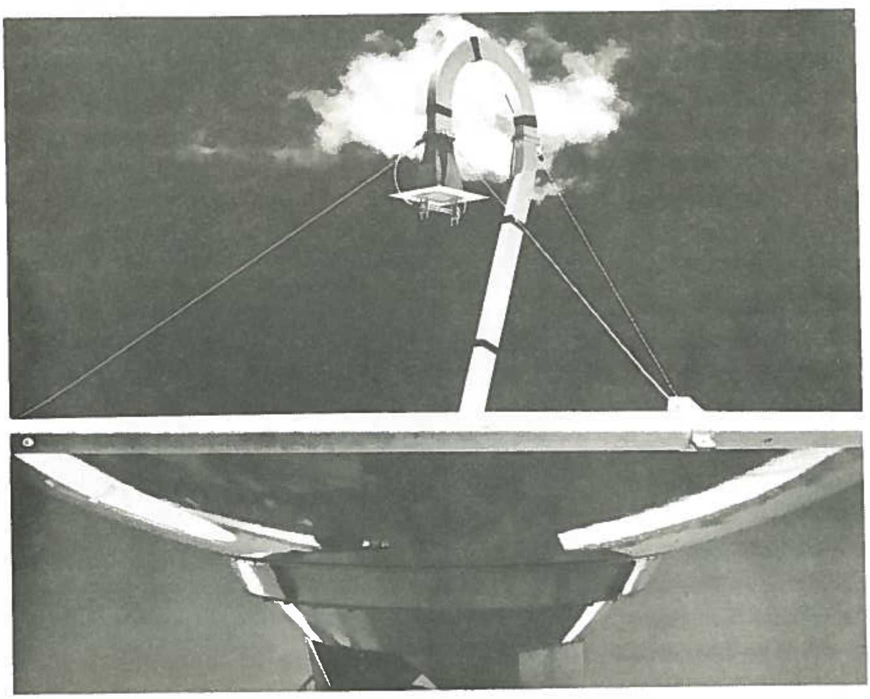


Daily drift curves for part of the month of April

By itself, the 32-element array is able to resolve at least the gross features of many active regions on the sun, but generally more resolution is required to reveal fully the structural detail. The two groups of widely spaced four-element gratings provide the necessary increase in resolution when they are combined with the array. One of the gratings is arranged symmetrically about the array and is fitted with Faraday rotators in the reflector feeds which sample two orthogonal polarizations. Signals from the grating are combined with those from the array using a phase-switching technique which effectively multiplies the amplitude patterns of the two groups of antennas. The result, for the symmetrical interferometer, is a single-lobed fan beam with an east-west width of 30″. The symmetry of the arrangement allows greater ease and accuracy in measuring the phase difference between orthogonal components of the signal. The second grating of four antennas is placed entirely to the east of the array and, when combined with the array, forms a compound interferometer with a single-lobed beam of 15″ east-west width.

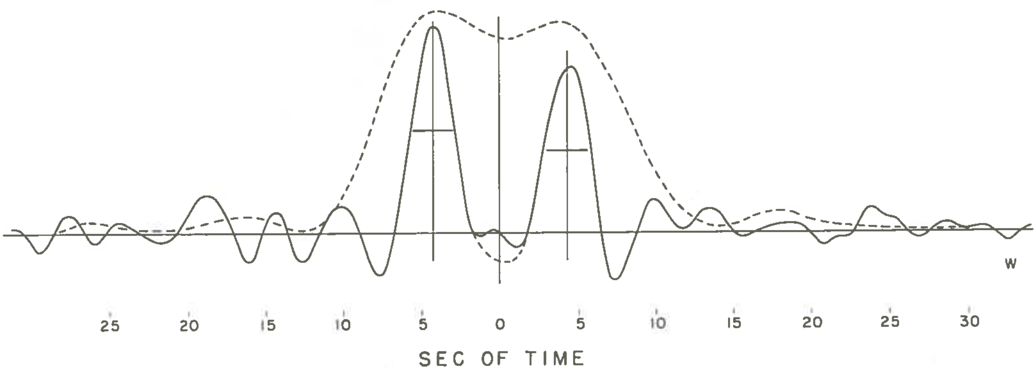
Most of the transmission line for the grating antennas is buried to a depth of 3 feet where diurnal temperature changes are reduced to about 1% of their surface value. Continuous lengths of large diameter coaxial cable are used because of its suitability for burial, and wide-band amplifiers are installed at the base of each grating antenna to overcome losses in the cable. A small section of the grating lines is composed of waveguide in order to balance the transmission characteristics to antennas in either the array or gratings.

At present, because of residual misalignments in position of the outlying antennas of the gratings, most observations involving the gratings require phase adjustments which depend upon the coordinates of the radio source. For this reason routine observations have not been as easily made with the compound or symmetrical interferometers as with the array alone. Observations have recently been completed, however, which have defined the alignment errors and should allow adjustments to be made to remove them.

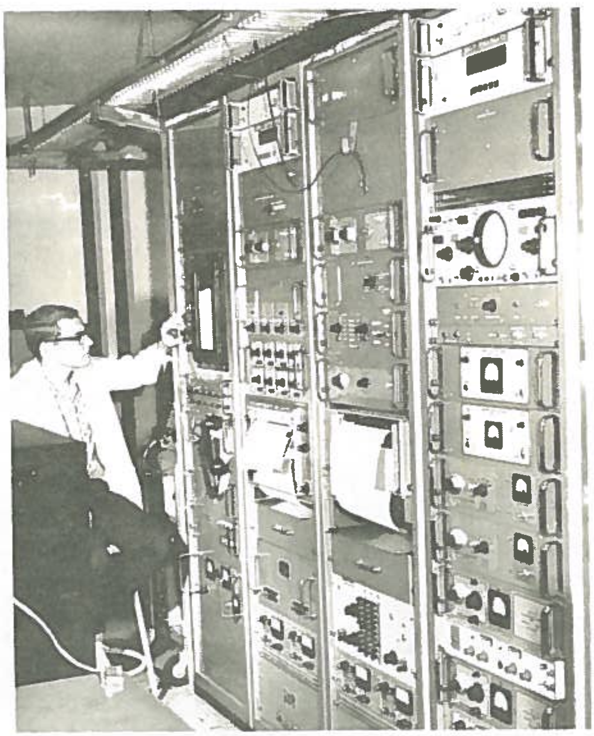


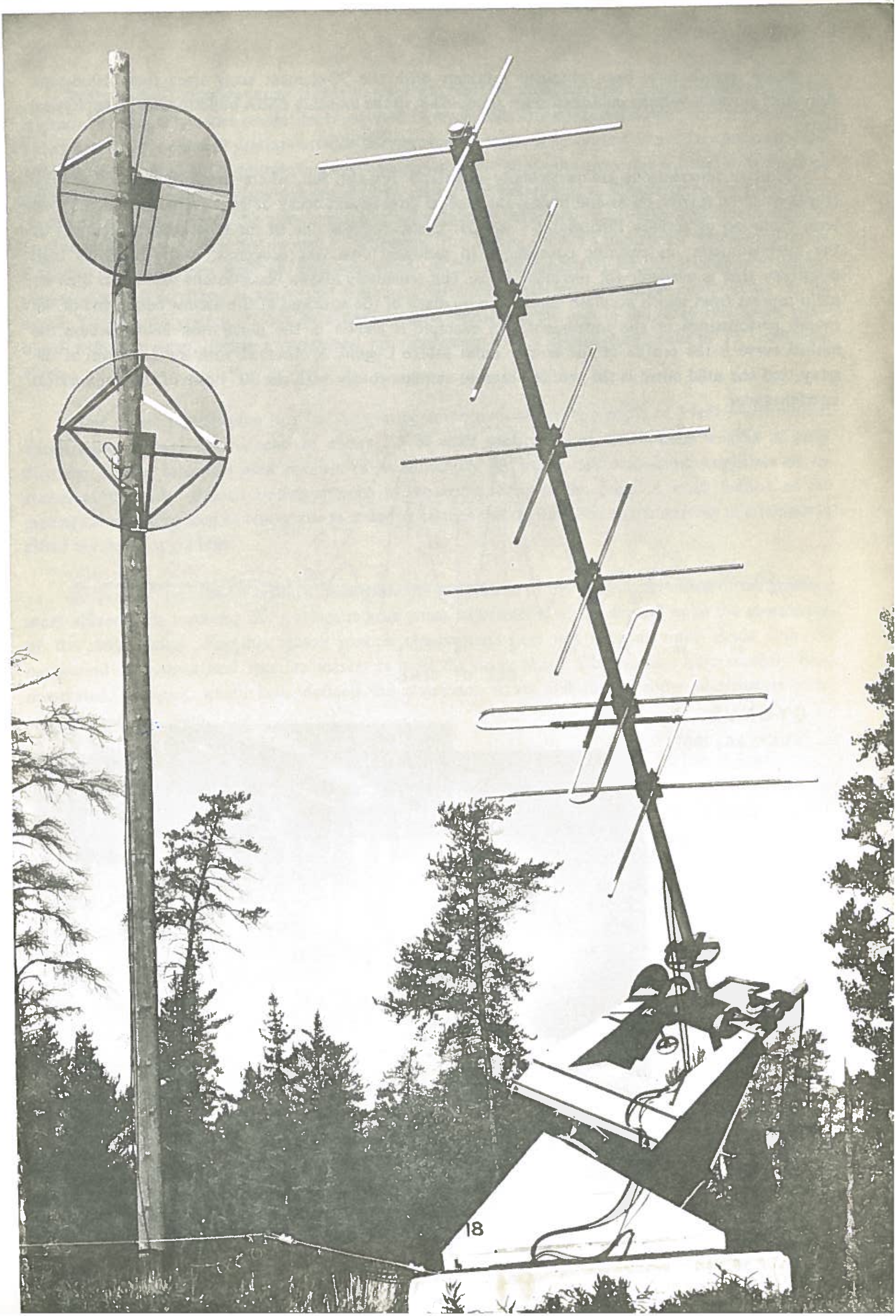
Solar records have been obtained routinely with the 32-element array since June, 1966, and daily drift curves have been published since June, 1968, in the monthly ESSA bulletin 'Solar Geophysical Data'.

Routine observations are particularly important for the sun, where the time scale of activity ranges over the sudden flares and bursts, the gradual growth and decay of active regions, and the long term evolution of activity throughout a sunspot cycle. Possibly one of the most valuable features of the interferometer, in ensuring consistency in sustained observing programs, is the relatively high sensitivity that is available for meridian scans. The sensitivity allows observations of intense discrete radio sources from which accurate checks can be made of the positions of the narrow beams and of the overall performance of the instrument. An example is shown in the illustration below, where the dashed curve is the profile of the double radio source Cygnus A observed with the $1'.5$ beam of the array, and the solid curve is the profile observed simultaneously with the $30''$ beam of the symmetrical interferometer.



CYGNUS A
JULY 26, 1967





SOLAR OBSERVATIONS AT METER WAVELENGTHS

Early radio observations of the sun at meter wavelengths were made in 1948 at the National Research Council in Ottawa. In 1958, some preliminary observations of solar radiation were carried out at 48 MHz, and in 1961 an expanded program was implemented at the observatory. At the present time two sets of equipment are in operation; a 74-MHz polarimeter and a 74-MHz short-baseline interferometer. A supplementary program is the monitoring of a VLF (60 kHz) transmitter for the detection of solar flare effects on the ionospheric D layer.

If the electromagnetic radiation incident upon an antenna can be resolved into two coherent orthogonal components, the radiation is polarized. All antenna systems do not provide complete information regarding the polarization of radiation incident upon them. At the Algonquin Radio Observatory a cross-polarized antenna with orthogonal linear elements is used. The orthogonally related intensity outputs of the antenna are then combined, with appropriate phase delays, to yield complete polarization information. Vertical, horizontal, right, and left circular components and the total intensities of the orthogonal components are sampled sequentially 200 times per second by the polarimeter and recorded on both magnetic tape and a multichannel chart recorder. The availability of the data on magnetic tape for repeated processing by computer plus a choice of polarization parameters to be computed provide flexibility in data analysis.

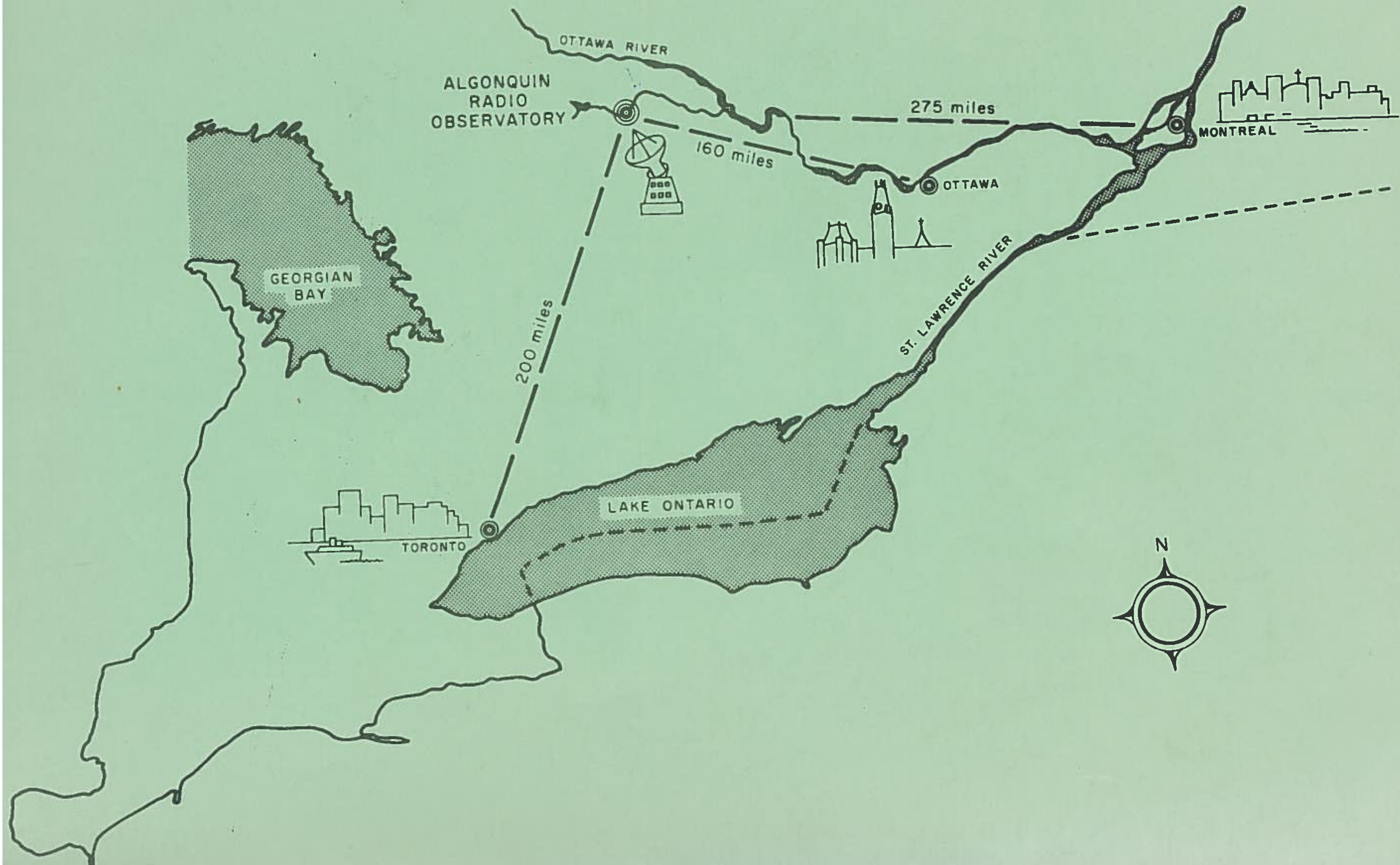
The frequency of 74 MHz is protected for radio astronomy use in the North American region; however, at this frequency, the solar signals observed using the broad beam of the Yagi antenna are confined to those sufficiently intense to exceed the flux level of the galactic background. Comparative observations using the narrower beam of the 46-m telescope at 74 MHz have shown that the observations of solar signals arising out of the unpolarized solar background exhibit the same characteristics as those of higher intensity that arise out of the galactic background.

Since the radiation from the quiet sun at 74 MHz is below that of the galactic background, a simple phase-switched interferometer is used to monitor the quiet sun. The antennas are 6-element stacked Yagis placed 25 wavelengths apart, giving a fringe pattern of 2.5°. The solar intensity is obtained by forming the ratio of the solar emission and the emission from a known radio source, such as Cassiopeia A.

A commercial VLF receiver is used to monitor the 60 kHz transmission from National Bureau of Standards station WWVB at Boulder, Colorado. Solar flares emit X-ray radiations which enhance the ionosphere D layer propagation, and thus the signal level of WWVB is a sensitive indicator of solar flare activity.

Solar radio activity at meter wavelengths originates in the solar corona at heights of one-half to two or more solar radii above the visible photosphere. In order to understand the mechanisms involved, detailed information is necessary on the fine structure, the spectrum, the polarization, and the relationships that exist between the initiating disturbances which usually are associated with solar flares. The observing program described above complements programs carried on in the United States and other parts of the world; particular emphasis is placed on high time-resolution and polarization of solar radio events which can have durations as short as one-hundredth of a second.

Solar activity is also manifest in the phenomena of the aurora. In recent years the city lights of Ottawa have made the optical observing program of this Division more and more difficult. The establishment of an optical program is presently under way at the Algonquin Radio Observatory to measure auroral properties and the airglow of the night sky in a location which is remote from city lights and automobile headlights. In addition to spectrographic and photometric observations in the infrared and visible regions, an all-sky camera using colour film has been installed to photograph the entire night sky in this remote location. The camera is programmed to take 30 pictures per hour during the hours of darkness.


OTTAWA RIVER
ALGONQUIN
RADIO
OBSERVATORY
275 miles
160 miles
OTTAWA
MONTREAL
GEORGIAN
BAY
200 miles
ST. LAWRENCE RIVER
LAKE ONTARIO
TORONTO
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