AS / GR BK

NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia

Quarterly Report

April 1, 1972 - June 30, 1972

RESEARCH PROGRAMS

140-foot Telescope

		Hours
Scheduled observing		1133.25
Scheduled maintenance and equipment changes		1050.75
Time lost due to:	equipment failure	19.50
	power	0.50
	weather	6.25
	interference	0.00

The following line observations were conducted.

Observer	Program
J. Ball (Harvard), K. Bechis (MIT), W. Wilson (Aerospace Corp.), and P. Schwartz (NRL)	Monitor of 18-cm OH emission from 36 infrared stars.
D. Dickinson (Smithsonian) and E. Chaisson (Harvard)	Attempt to detect far infrared sources in the 18-cm OH line.
G. Knapp (Maryland) and F. Kerr (Maryland)	Search for weak 18-cm OH emission in the direction of several globular clusters to determine OH to dust ratios.
E. Chaisson (Harvard) and L. Goad (Harvard)	Search at 18-cm wavelength for H, He, and C in a neutral region along the line of sight toward K3-50.
P. Baker	Search at 18-cm wavelength for H157α recombination line emission from a high velocity hydrogen gas cloud impact region.
B. Zuckerman (Maryland) and B. Turner	Search at 17.5-cm wavelength for interstellar sodium.
R. Rubin (Illinois)	Search for the following molecules: 1) NH_2CN (cyanamide) at 1580 MHz, 2) $CH_2N\ OH$ (formoxime) at 1779 MHz, 3) CH_2CHNC (vinyl isocyanide) at 1552 MHz, and 4) HN CO (isocyanic acid) at 1604 MHz.

Observer	Program
M. Goss (Max-Planck-Institut für Radioastronomie, Bonn, Germany) and E. Churchwell (Max-Planck-Institut für Radioastronomie, Bonn, W. Germany)	Detailed study at 3-cm wavelength of the region of the Norma-Scutum Arm (ℓ = 30°) in the H85α-recombination line.
H. Tovmassian (Byurakan Astrophysical Observatory, Armenia), L. Doherty (National Research Council, Canada) and B. Balick	Observations of 3-cm recombination lines of H, He and C in Orion A.
G. Verschuur	Observations of 21-cm high velocity hydrogen profiles at selected galactic longitudes and latitudes to test a model of high velocity clouds.
R. Benson (Illinois), H. Tigelaar (Illinois), W. Flygare (Illinois) and B. Turner	Search for the following molecules: 1) C_2H_5CN (ethyl cyanide) at 1437 MHz, 2) CH_2CHCN (vinyl cyanide) at 1371.84 MHz, and 3) $CH_2CH_2CCH_2$ (methylene cyclopropane) at 1431.99 MHz.
R. Giovanelli (Indiana), T. Cram, and G. Verschuur	Measurements at 21-cm wavelength of velocity dispersions of high-velocity clouds.
R. Davies (Jodrell Bank) and D. Buhl	Observations of high-velocity cloud A at the 21-cm line of neutral hydrogen.
G. Knapp (Maryland) and G. Verschuur	Mapping at 21-cm wavelength of cold hydrogen emission clouds.
F. Kerr (Maryland), W. Rose (Maryland), and G. Knapp (Maryland)	Search for 21-cm neutral hydrogen from globular clusters.

The following continuum observations were conducted.

N. Vandenberg (Maryland), W. Erickson (Maryland), T. Clark (NASA-Goddard), G. Downs (JPL), and P. Reichley (JPL)	Observations at 2.3 GHz using the NASA-Goldstone 210-foot telescope and the NRAO 140-foot telescope to monitor the motions and apparent positions of pulsars.
D. Shaffer (Caltech), M. Cohen (Caltech), J. Broderick (NAIC), D. Jauncey (Cornell), B. Clark and K. Kellermann	Three station VLB at 7850 MHz using the Haystack 120-foot telescope, the NASA-Goldstone 210-foot telescope, and the NRAO 140-foot telescope.
D. Shaffer (Caltech), A. Moffet (Caltech), M. Cohen (Caltech), A. Maxwell (Harvard), D. Harris (Harvard) and K. Kellermann	Three-station VLB at 2.8 cm to monitor source intensity and motion changes using the Harvard Fort Davis 85-foot telescope, the Caltech Owens Valley 130-foot telescope and the NRAO 140-foot telescope.

Observer	Program
B. Burke (MIT), G. Papadopolous (MIT), S. Knowles (NRL), K. Johnston (NRL), and J. Moran (Smithsonian)	Water-vapor line observations at 22 GHz using the Haystack 120-foot telescope, the NRL 85-foot telescope at Maryland Point and the NRAO 140-foot telescope.

During this quarter the 140-foot telescope was removed from operation to replace the mechanical pilot drive and readout system with an H316 computer, to replace the old control console with a more flexible and useful one, to overhaul various telescope hydraulic units, and to adjust the telescope surface panels. At the end of the quarter, the telescope is again in operation.

Interferometer		Hours
Scheduled observing		1978.25
Scheduled maintenance and equipment changes		205.50
Time lost due to:	equipment failure	8.75
	power	1.25
	weather	0.75
	interference	0.00

The following continuum observations were conducted at 2695 and 8085 MHz unless specifically noted.

Observer	Program
B. Balick	Observations in an attempt to detect Of-type stars.
B. Balick and R. Hjellming	Partial synthesis of several 10 minute arc regions near the galactic center to study spectra, polarization and identification of sources and to search for possible time variations.
D. De Young and D. Hogg	Observations to measure the time variations in the complex sources Vir A, Cyg A, and Cas A.
W. Zaumen (MIT), S. Rappaport (MIT), J. Spencer (MIT), and C. Canizarias (MIT)	Observations to measure to a high degree of accuracy the positions and intensity variations with time of X-ray sources.
B. Burke (MIT) and J. Spencer (MIT)	Measurements of the emission from H II regions in the galaxies M31 and M33 and detailed studies of other regions in M31.

Observer	Program
F. Briggs (Cornell) and F. Drake (Cornell)	Observations at 8085 MHz of the major satellites and thermal features of Jupiter and at 20 cm observations of Jupiter and Neptune.
J. Wardle (Brandeis)	Monitor of variable sources for polarization and intensity.
K. Johnson (Arizona) and K. Kellermann	Monitor of 30 sources for variations in flux density.
P. Kronberg (Toronto, Canada)	Observations at 8085 MHz to measure the polarization structure of extragalactic radio sources.
C. Wade and R. Hjellming	Monitor of the slow decline of Nova Delphini 1967 and Nova Serpentis 1970 and a search for radio emission from new novae.
R. Hjellming, C. Wade, and E. Webster	Monitor for variability Algol, Sco X-1, novae and other binary stars.
B. Burke (MIT), J. Spencer (MIT), and G. Murthy (MIT)	Monitor the emission from Sco X-1.
E. Olsen (JPL)	Structure and polarization studies of Jupiter.
R. Sramek	Studies of the radio cores in normal elliptical galaxies.
H. Tovmassian (Byurakan Astrophysical Observatory, Armenia) and R. Sramek	An attempt to detect nonthermal radio emission from Markarian galaxies of the M82 type.
J. Wardle and R. Sramek	Linear polarization observations of elliptical galaxies.
J. Basart (Iowa State), G. Wrixon (Bell Laboratories) and D. Buhl	Observations at 1410 MHz to measure the polar heating of Venus.

The following very long baseline observations were conducted.

P. Hemenway (Virginia), A. Moffet (Caltech), M. Cohen (Caltech), D. Muhlman (Caltech), W. Cannon (Caltech), B. Clark, R. Sramek, and K. Kellermann	Four-telescope experiment at 1410 MHz using two NRAO 85-foot telescopes and two Owens Valley Radio Observatory 90-foot telescopes to collect astrometric

Observer	Program
P. Hemenway *et als*., continued	and geodetic data and to do the preliminary work to measure the general relativity theory light bending effect.
M. Ewing (Caltech), A. Moffet (Caltech), W. Cannon (Caltech), G. Papadopolous (MIT), and P. Crane (MIT)	Observations at 1410 MHz to measure pulsar proper motion and parallax using the Caltech Owens Valley 130-foot and two 90-foot telescopes and the three NRAO 85-foot telescopes.

300-foot Telescope		Hours
Scheduled observing		2050.50
Scheduled maintenance and equipment changes		133.50
Time lost due to:	equipment failure	50.50
	power	0.25
	weather	5.25
	interference	3.25

The following line observations were conducted.

Observer	Program
G. Verschuur and W. Burton	Measurements of 21-cm neutral hydrogen for all 300-foot visible galactic longitudes at several galactic latitudes.
R. Giovanelli (Indiana), T. Cram, and G. Verschuur	Mapping of 20 high velocity clouds for detailed structure at the 21-cm line of neutral hydrogen.
P. Baker	Investigation of the relationship of the neutral hydrogen distribution at 21 cm to the galactic 40-cm nonthermal radio emission in areas of the galaxy as follows: 1) an intermediate latitude region with considerable structure, 2) an intermediate latitude region with high-velocity gas flows; and 3) a region passing through the galactic plane.
C. Gordon (Hampshire College), K. Gordon (Hampshire College), and J. Lockman (Massachusetts)	Survey at 385 MHz of strong H II regions to detect low-frequency recombination lines.

The following continuum observations were conducted.

Observer	Program
I. Pauliny-Toth (Max-Planck-Institut für Radioastronomie, Bonn, W. Germany), M. Davis, and K. Kellermann	Observations at 6-cm wavelength to extend the "fast" and "deep" 6-cm source surveys, whose specific objections are: 1) to determine the number flux density relations at 6 cm and compare them with those at longer wavelengths, 2) to determine the manner in which the spectral index distribution varies with wavelength and intensity, and 3) to obtain a 6-cm finding list comparable to the 3C and 4C catalogs.
R. Sramek	Survey of normal galaxies at 6-cm wavelength.
F. Owen (Texas)	Observations of Abell clusters of galaxies at 20-cm wavelength.
N. Sarma (Tata Institute, India)	Measurements at 20-cm and 40-cm wavelength of the flux densities of approximately 24 sources observed with the Ooty radio telescope in India at 92-cm wavelength.
H. Tovmassian (Byurakan Astrophysical Observatory, Armenia)	Observations at 20-cm wavelength of AE Capricorni (which has an optical similarity to BL Lac) to test whether its radio characteristics are similar to BL Lac.

The following pulsar observations were conducted.

R. Manchester (Massachusetts)	Continuation of pulsar polarization and timing measurements over the frequency range of 250-500 MHz.
D. Backer	Investigation of pulsar sub-pulse phenomena over the frequency range 250-500 MHz.

In addition to the above, D. Wilkinson (Princeton) and E. Groth (Princeton) searched for short time scale pulsations or bursts in extragalactic sources to find and measure dispersion due to intergalactic ionized hydrogen over the frequency range 250-500 MHz.

36-foot Telescope		Hours
Scheduled observing		1926.00
Scheduled maintenance and equipment changes		258.00
Scheduled tests and calibration		152.25
Time lost due to:	telescope and receiver failure	50.75
	digital system failure	30.25
	power	3.25
	weather	45.25
	interference	0.00

During this quarter a new spectral-line receiver covering 33-50 GHz was placed into routine operation. Aerospace Corporation successfully used a new 115-GHz receiver with the NRAO spectral-line system. Tests of the proposed Cassegrain system were made using up to an 800 pound front-end box; no degradation of the antenna efficiency was found at 3.5 mm, and installation will proceed this summer.

Observer	Program
D. Buhl and L. Snyder (Virginia)	Mapping and high-resolution spectra of HCN and X-ogen; search for new molecules at 70-100 GHz.
R. Gammon and C. Gottlieb (Harvard)	Search for isotopically substituted carbon dioxide, ethane, and acetylene at 68-88 GHz.
C. Gottlieb (Harvard)	Search for aminoacetonitrile at 88-90 GHz.
R. Rubin (Illinois) and T. Cram	Search for hydroxylamine and formamide at 65-100 GHz.
A. Penzias (Bell Labs), R. Wilson (Bell Labs), K. Jefferts (Bell Labs), P. Solomon (Minnesota), H. Liszt (Princeton), and N. Scoville (Minnesota)	Study of carbon monoxide, formaldehyde, and carbon monosulfide and their isotopes, in the galactic center and in dark clouds.
P. Solomon (Minnesota), K. Jefferts (Bell Labs), A. Penzias (Bell Labs), and R. Wilson (Bell Labs)	Study of methyl cyanide and carbonyl sulfide, and search for more polyatomic and ring molecules at 73-112 GHz.
W. Wilson (Aerospace), P. Schwartz (NRL), and E. Epstein (Aerospace)	Study of hydrogen cyanide emission in carbon stars at 88 GHz.
B. Zuckerman (Maryland), P. Palmer (Chicago), B. Turner, and M. Morris (Chicago)	Study of carbon monosulfide and search for deuterated water and hydrogen cyanide and other molecules at 79-115 GHz.

Observer	Program
B. Zuckerman (Maryland), P. Palmer (Chicago), B. Turner, and M. Morris (Chicago)	Search for CH_3SiH_3 and SiH_3CN at 87-99 GHz.
P. Palmer (Chicago), M. Morris (Chicago), B. Zuckerman (Maryland), and B. Turner	Study of hydrogen cyanide, X-ogen, and other molecules in IR stars at 85-95 GHz.
M. Morris (Chicago), P. Palmer (Chicago), B. Turner, and B. Zuckerman (Maryland)	Search for new sources of cyanoacetylene at 73 and 82 GHz.
W. Wilson (Aerospace), E. Epstein (Aerospace), P. Schwartz (NRL), and W. Fogarty (Arizona)	Search for carbon monoxide and cyanogen emission in late M-type stars at 110-116 GHz.
W. Wilson (Aerospace), E. Epstein (Aerospace), P. Schwartz (NRL), and W. Fogarty (Arizona)	Survey of carbon monoxide emission in various types of galactic sources.
F. Shimabukuro (Aerospace)	Search for solar recombination lines at 109-115 GHz.
H. Weaver (California), D. Williams (California), W. Wilson (Aerospace), E. Epstein (Aerospace), and P. Schwartz (NRL)	Study of galactic spiral arm structure in the carbon monoxide line.
H. Tovmassian (Byurakan Astrophysical Observatory, Armenia)	Search for millimeter-wave emission from Markarian galaxies at 31 GHz.
W. Dent (Massachusetts) and R. Hobbs (NASA-Goddard)	Monitoring of variable sources for accurate time variation curves at 31 and 85 GHz.
A. Barrett (MIT), P. Myers (MIT), and R. Martin (MIT)	Observations of methyl alcohol in H II regions and IR stars at 48 GHz.
M. Morris (Chicago), P. Palmer (Chicago), B. Zuckerman (Maryland), and B. Turner	Study of carbon monosulfide and cyanoacetylene; search for new molecules at 44-50 GHz.
R. Hobbs (NASA-Goddard), B. Zuckerman (Maryland), and S. Knowles (NRL)	Search for SiN and SiO at 43 GHz.
R. Benson (Illinois), H. Tigelaar (Illinois), W. Flygare (Illinois), and B. Turner	Search for hydroxylamine, isocyanic acid, dimethylamine and others at 44-50 GHz.

Observer	Program
R. Gammon and B. Turner	Search for magnesium oxide, methinophosphide, ethyl alcohol, and other molecules at 34-43 GHz.
M. Simon (SUNY-Stony Brook) and M. N. Simon (SUNY-Stony Brook)	Search for pyrimidine and pyridine at 45 GHz.

ELECTRONICS DIVISION--EQUIPMENT DEVELOPMENT

During the past quarter the manpower assignments within the Electronics Division have been divided among the following programs:

Cooled 2-cm Receiver	5%
Cooled Mixer Development	9%
0.5-1 GHz Receiver	6%
45-foot Telescope Equipment	10%
Interference Protection	2%
Very Long Baseline Interferometer	6%
Cooled 21-cm Receiver	9%
Millimeter-Wave Development	9%
140-foot Control System	10%
Antenna Development	3%
Advanced Correlator Development	3%
Visitor Support and Routine Maintenance	28%

During this quarter the 21-cm cooled paramp receiver has been tested on the 140-foot telescope. The initial measurements indicate that the system temperature is about 50° K. The 15-GHz cooled paramp has been delivered to NRAO at the end of this quarter. The 0.5-1 GHz receiver may be delayed due to the unsatisfactory performance of the paramps delivered this quarter.

The Laser antenna measuring instrument has been completed and has been shown to be capable of measuring distances up to 60 meters with an accuracy of $\pm$ 0.1 mm. Work is continuing on the electronics for the new 45-foot telescope addition to the interferometer.

Work has started on a multifrequency front-end covering 2, 6, 18 and 21 cm for the 140-foot telescope. This receiver may also be a pre-prototype for the VLA.

ENGINEERING DIVISION

In the second quarter of 1972, the Engineering Division has been concentrating its time on the following major items.

1. Preparation of design studies for expansion of the Charlottesville office.

2. Review of design and manufacturing progress of the 45-foot antenna. Inspection of manufacturer's work.

3. Procurement of transport trailer for the 45-foot antenna.

4. Preparation of design studies, schedules and construction plans, specifications and invitations to proposers for various segments of the VLA project.

5. Progress reviews of prototype panel fabrication for 65-meter antenna project.

6. Design review of transport system for the VLA project.

COMPUTER DIVISION

Hardware: The disk memories for the DDP 116 on-line computers at Green Bank were delivered during this quarter. The graphics CRT on the IBM 360/50 has sufficient usefulness that a more modern replacement has been ordered to give an eight-fold speedup of plotting, plus hitherto unavailable hard copy capability.

Software: At the 36-foot telescope further improvements and expansions were made in the "FORTH" programs on both DDP 116 (pointing) and H316 spectral-line processor) computers. At Green Bank the 140-foot real-time program, totally revised to work on two linked processors, the new H316 (pointing) and the old DDP 116 (data taking), is now operating in a preliminary form. At the interferometer several improvements have been made in the existing software. For the 300-foot telescope, special versions of the real-time program requested by outside users are under development. A special translator, which will run on the Green Bank IBM 1130 and produce code for the DDP 116's, is in final checkout. In Charlottesville, the IBM systems work has included improvements in the accounting and timing algorithms, the CRT-driving programs, and a reorganization of the method of daily cleanup of disk space in order to better utilize the recent IBM 2319 disk addition. Various personnel have also contributed to revisions of the IBM 360 assembler and simulator for DDP 116's and to methods of utilizing PERT or CPM programs for management of large projects, such as the VLA.

ANTENNA DESIGN STUDIES

VLA

The NSF budget for FY 1973, which contains the initial funding for the VLA, has not yet been acted upon by Congress. Site acquisition procedures have been started.

65-Meter Telescope

See Appendix C.

SUMMER STUDENT PROGRAM

Twenty-eight students are participating in our student program this summer. They were selected from the 165 applications received from 74 different colleges and universities. Five students are based in Green Bank, two in Tucson, and twenty-one in Charlottesville. These students will spend at least eleven weeks at the Observatory as research assistants to the scientific staff and in the Electronics and Computer Divisions of the Observatory.

A full lecture series, 26 in total, will be given by the staff on various topics in radio astronomy and instrumentation. Students are encouraged to attend the regular NRAO colloquia and seminars. With the exception of those based in Tucson, the students will assist in our public education program in Green Bank as tour guides for the tourists who visit there at a rate of more than 1200 per week.

The NRAO student program was started in 1959 with ten students participating. Since that time 341 students have participated in the program. Several students have returned as Ph.D. thesis students, while others have later joined our staff as full-time employees.

Following is a list of the 1972 summer students, their academic year just completed, their college and their hometown.

Graduate Students

Name	Year	School	Hometown
Bania, Thomas M.	1	U. of Virginia	Glen Rock, N. J.
Camana, Peter C.	1	Ohio State	Pennsburg, Pa.
Cherry, Michael L.	1	U. of Chicago	Philadelphia, Pa.
Gibson, David	2	U. of Virginia	Charlottesville, Va.
Hansen, Stanley	2	U. of Massachusetts	St. Joseph, Mo.
Lockman, Jay	2	U. of Massachusetts	Norwood, Pa.
Maas, Stephen	1	U. of Pennsylvania	Drexel Hill, Pa.
Peterson, Steven	1	Cornell	Cedar Rapids, Iowa
Stickney, Philip	1	U. of Arizona	Tucson, Ariz.
Wey, Changlin A.	1	U. of Michigan	Taipei, Taiwan

Undergraduate Students

Bechis, Dennis J.	3	Harvard	Dorchester, Ma.
Bonnell, Mary P.	3	Dartmouth	Summit, N. J.
Chandler, John F.	3	MIT	Willmington, Dela.
Chesley, Duncan M.	3	Dartmouth	Pownal, Ma.
Chin, Francis	4	U. of Toronto	Hong-Kong
Diadiuk, Vicky	4	MIT	Mexicco, D.F. Mex.
Edward, Susan	3	Wellesley	Alexandria, Va.
Fisher, Vernon	4	West Virginia U.	Meyersdale, Pa.

Name	Year	School	Hometown
Gandet, Thomas	3	Kansas	Lawrence, Kan.
Grayson, Daniel	4	U. of Chicago	St. Charles, Ill.
Jorgensen, Gary	4	Seton Hall Univ.	Colonia, N. J.
Kennett, Rosemary	3	Nottingham U., England	Sutton, Surrey
Lapedes, Alan	3	U. of Virginia	Princeton, N. J.
Lucagnani, Linda	4	Wellesley	Key West, Fla.
Pettersson, Lars	3	Chalmers	Goteborg, Sweden
True, Michael	4	Indiana	South Bend, Ind.
Yeung, Patrick	4	Princeton	Hong Kong
Zook, Alma	4	Pomona	Monterey Park, Calif.

PERSONNEL

Appointments

Gottlieb, Carl A.	Visiting Asst. Scientist	April 17, 1972
Napier, Peter J.	Research Associate	April 18, 1972
Marymor, Julius	Contracts Manager	May 15, 1972
Wardle, John F. C.	Visiting Asst. Scientist	June 1, 1972
*Fejes, Istvan	Jr. Research Associate	June 2, 1972
Gordon, Kurtiss J.	Visiting Asst. Scientist	June 7, 1972

*Part-time

Terminations

Davis, Michael M.	Assistant Scientist	June 16, 1972
Gottlieb, Carl A.	Visiting Asst. Scientist	June 16, 1972
Brosche, Peter	Visiting Asst. Scientist	June 30, 1972
Cutitta, Ignatius F.	Purchasing Manager	June 30, 1972

Appendix A

OBSERVATORY COLLOQUIA

The NRAO colloquium program for the past fiscal year is outlined below. Speakers are usually invited by our scientific staff and generally talk on topics of current interest in radio astronomy or closely allied fields. The Astronomy Department of the University of Virginia also invites speakers to participate in their own colloquium series. These series are announced jointly and are well attended by our staff, university physicists and astronomers and by students. The outside speakers listed below visited the NRAO in our colloquium series.

Name	Institution	Date
R. S. Booth	Jodrell Bank	July 8, 1971
W. N. Brouw	Leiden Observatory and Westerbork Observatory	August 5, 1972
C. E. Heiles	University of California, Berkeley	September 2, 1971
N. H. Dieter	University of California, Berkeley	September 9, 1971
J. Heidmann	Observatoire de Paris	October 7, 1971
Y. L. Chow	University of Waterloo	October 12, 1971
J. E. Felten	University of Arizona	December 9, 1971
N. J. Wolff	University of Minnesota	December 20, 1971
H. von Wurmb	University of South Florida	January 13, 1972
J. H. Taylor	University of Massachusetts	February 3, 1972
P. S. Conti	Joint Institute for Laboratory Astrophysics and Department of Physics and Geophysics, University of Colorado	February 17, 1972
V. Radhakrishnan	Raman Research Institute	February 23, 1972
G. R. Knapp	University of Maryland	February 24, 1972
S. E. Strom	State University of New York, Stony Brook	March 16, 1972
G. T. Wrixon	Bell Telephone Laboratories	March 23, 1972
S. Mitton	Mullard Radio Astronomy Observatory	April 6, 1972
W. J. Welch	University of California, Berkeley	May 15, 1972
H. van der Laan	Sterrewacht te Leiden	May 19, 1972
R. D. Davies	Nuffield Radio Astronomy Laboratory	May 23, 1972
F. J. Gardner	Max-Planck-Institut-für Radioastronomie	May 25, 1972
A. Yahil	Institute for Advanced Studies	June 1, 1972
R. B. Tully	University of Maryland	June 8, 1972
K. W. Riegel	University of California, Los Angeles	June 22, 1972
G. Wynn-Williams	California Institute of Technology	June 29, 1972

Appendix B

A list of Observatory reprints issued since June 30, 1971.

No.	Title	Author	Reference
	Series A		
201	Observations of a Rotating Neutral Hydrogen Cloud	G. L. Verschuur	Astron. J., 76, 105-109, 1971
202	OH Emission from Interstellar HI Clouds	G. L. Verschuur	Astrophys. Letters, 7, 217-220, 1971
203	Comments on the Excitation and Abundance of Interstellar SiO, Based on a Search at 87 GHz	D. F. Dickinson C. A. Gottlieb	Astrophys. Letters, 7, 205-207, 1971.
204	A Continuum Map of M17 at λ 1.94 cm and its Restored Brightness Distribution	M. A. Gordon T. B. Williams	Astron. & Astrophys., 12, 120-125, 1971
205	The Fine Structure of Cygnus A	G. K. Miley C. M. Wade	Astrophys. Letters, 8, 11-15, 1971
206	Observations of Intermediate-Velocity Clouds and a Model for Their Existence	G. L. Verschuur	Astron. J., 76, 317-321, 1971
207	From Radio Astronomy Towards Astrochemistry	D. Buhl L. E. Snyder	Technol. Rev., 73, 54-62, 1971
208	Anomalous OH Emission from New Types of Galactic Objects	B. E. Turner	Astrophys. Letters, 8, 73-77, 1971
209	An Initial Search for the Interstellar Formyl Radical, HCO, and for $HC^{13}O^+$	K. B. Jefferts A. A. Penzias R. W. Wilson M. Kutner P. Thaddeus	Astrophys. Letters, 8, 43-44, 1971
210	HI Clouds with Spin Temperatures Less than 25° K	G. L. Verschuur G. R. Knapp	Astron. J., 76, 403-408, 1971
211	The Millimeter-Wavelength Spectra of Extragalactic Radio Sources	K. I. Kellermann I.I.K. Pauliny-Toth	Astrophys. Letters, 8, 153-160, 1971
212	Radio Observations of Selected HII Regions	H. J. Wendker	Astron. & Astrophys., 13, 65-70, 1971

Appendix B, continued

No.	Title	Author	Reference
213	The Polarization of Strong Radio Sources at 9.5 mm Wavelength	J.F.C. Wardle	Astrophys. Letters, 8, 183-186, 1971
214	A Parametric Amplifier for 46 GHz	J. Edrich	Proc. IEEE, 59, 1125-1126, 1971
215	Short-Term Stability of the Crab Pulsar	J. Pfleiderer	Astron. & Astrophys., 13, 496-497, 1971
216	Condensation of Solid Hydrogen in Contracting Interstellar Clouds	T. Nakano	Prog. Theor. Phys., 45, 1737-1746, 1971
217	Properties of OH Emission Associated with Infrared Stars	W. J. Wilson A. H. Barrett	Proc. Conf. on Late-Type Stars, 77-94, 1971 (edited by G. W. Lockwood and H. M. Dyck) KPNO Contrib. 554)
218	Joint Soviet-American Radio Interferometry	K. I. Kellermann	Sky & Telescope, 42, 132-133, 1971
219	The Structure of Double Radio Sources	J.F.C. Wardle	Astrophys. Letters, 8, 221-225, 1971
220	The Radio Source CTB 1	A. G. Willis J. R. Dickel	Astrophys. Letters, 8, 203-207, 1971
221	The Structure of Compact Extra-galactic Radio Sources	D. S. De Young	Astrophys. Letters, 9, 43-46, 1971
222	Aperture-Synthesis Observations of M17 and W49A at 2.695 GHz	W. J. Webster, Jr. W. J. Altenhoff J. E. Wink	Astron. J., 76, 677-682, 1971
223	An H137β Line Survey of Twenty-one Galactic Radio Sources	F. F. Gardner D. K. Milne P. G. Mezger T. L. Wilson	Astrophys. Letters, 6, 87-91, 1970
224	Search for Interstellar SH at Radio Frequencies	C. E. Heiles B. E. Turner	Astrophys. Letters, 8, 89-91, 1971
225	The Structure and Polarization of 3C 459 at 610 MHz	J.F.C. Wardle	Astrophys. Letters, 8, 53-55, 1971

Appendix B, continued

No.	Title	Author	Reference
226	Radio Recombination Line in NGC 7027	R. H. Rubin P. Palmer	Astrophys. Letters, 8, 79-82, 1971
227	Radio Stars	R. M. Hjellming C. M. Wade	Science, 173, 1087-1092, 1971
228	A Green Bank Sky Survey in Search of Radio Sources at 1400 MHz. I. A Spectral Analysis of the 5C1 Sources	J. Maskowski	Astron. & Astrophys., 14, 215-222, 1971
229	A Green Bank Sky Survey in Search of Radio Sources at 1400 MHz. II. Spectral Properties of the 5C1 and 5C2 Sources	J. Maslowski	Astron. & Astrophys., 16, 197-203, 1972
230	Microwave Receivers for Molecular Line Radio Astronomy	D. Buhl L. E. Snyder	Nature-Phys. Sci., 232, 161-163, 1971
231	Observations of OJ 287 at Optical and Millimeter Wavelengths	T. D. Kinman E. K. Conklin	Astrophys. Letters, 9, 147-149, 1971
232	Polarization of the Drifting Sub-pulses of Pulsar 0809+74	J. H. Taylor G. R. Huguenin R. M. Hirsch R. N. Manchester	Astrophys. Letters, 9, 205-208, 1971
233	Rotation Measure and Intrinsic Angle of the Crab Pulsar Radio Emission	R. N. Manchester	Nature-Phys. Sci., 231, 189-191, 1971
234	Comments on a Paper by K. Rohlfs	W. B. Burton	Astron. & Astrophys., 16, 158-160, 1972
235	Low-Noise Parametric Amplifiers Tunable Over One Full Octave	J. Edrich	IEEE J. Solid-State Circuits, SC7, 32-37, 1972
236	A Simple Vacuum System Substrate Heater	R. J. Mattauch	Rev. Sci. Instrum., 43, 148-149, 1972
237	Chemical Constituents of Interstellar Clouds	D. Buhl	Nature, 234, 332-334, 1971
238	Radio Recombination Lines from Planetary Nebulae	Y. Terzian B. Balick	Astrophys. Letters, 10, 41-47, 1972

Appendix B, continued

No.	Title	Author	Reference
239	A Search for OH in Nine High-Latitude Selected Areas	F. J. Kerr G. R. Knapp	<u>Astron. J.</u>, <u>76</u>, 993-994, 1971
240	National Radio Astronomy Observatory [Annual Report]	D. S. Heeschen	<u>Bull. Amer. Astron. Soc.</u>, 4, 141-149, 1972
241	The Nature of 3C 391	A. H. Bridle M.J.L. Kesteven	<u>Astron. J.</u>, <u>76</u>, 958-964, 1971
242	The NRAO 5-GHz Radio Source Survey I. A Survey of Faint Sources	M. M. Davis	<u>Astron. J.</u>, <u>76</u>, 980-992, 1971

<u>Series B</u>

No.	Title	Author	Reference
233	OH Radio Emission Associated with Infrared Stars	W. J. Wilson A.H. Barrett J. M. Moran	<u>Astrophys. J.</u>, <u>160</u>, 545-571, 1971
234	Radio Observations of the Infrared Object IRC 10216	K.I. Kellermann I.I.K. Pauliny-Toth	<u>Astrophys. J.</u>, <u>166</u>, L17-L18, 1971
235	An Interferometer Map of the Water-Vapor Sources in W49	K. J. Johnston S. H. Knowles W. T. Sullivan III J. M. Moran B. F. Burke K. Y. Lo D. C. Papa G.D. Papadopoulos C. A. Knight P. R. Schwartz I. I. Shapiro W. J. Welch	<u>Astrophys. J.</u>, <u>166</u>, L21-L26, 1971
236	Infrared Stars: Search for 3.5 Millimeter Radiation and Tentative Detection of VY Canis Majoris	W. J. Wilson	<u>Astrophys. J.</u>, <u>166</u>, L13-L16, 1971
237	Radio Observations of Nova Scuti 1970	V. Herrero R. M. Hjellming C. M. Wade	<u>Astrophys. J.</u>, <u>166</u>, L19-L20, 1971

Appendix B, continued

No.	Title	Author	Reference
238	The Neutral-Hydrogen Distribution and Rotation Parameters of the Spiral Galaxy NGC 2403	W. R. Burns M. S. Roberts	Astrophys. J., 166, 265-274, 1971
239	On the Interpretation of Observations of Neutral Hydrogen in External Galaxies	M.C.H. Wright	Astrophys. J., 166, 455-464, 1971
240	Lunar Rocks and Thermal Anomalies	D. Buhl	J. Geophys. Res., 76, 3384-3390, 1971
241	Origin of the Solar System	T. Nakano	Prog. of Theor. Phys., 44, 77-98, 1970
242	Observations of Compact H II Regions with Optical Counterparts	R. H. Rubin B. E. Turner	Astrophys. J., 165, 471-478, 1971
243	Radiation Transfer of Radio Recombination Lines in the Diffuse Interstellar Medium	M. A. Gordon	Astrophys. J., 167, 21-25, 1971
244	The 1/4 keV X-Ray Background: A Reply	R. L. Brown	Nature-Phys. Sci., 229, 85, 1971
245	Precise Radio Source Positions: A Comparison of Two Independent Lists	C. M. Wade H. Gent R. L. Adgie J. H. Crowther	Nature, 228, 146-147, 1970
246	Observations of Rapid Fluctuations of Intensity and Phase in Pulsar Emissions	J. H. Taylor G. R. Huguenin	Astrophys. J., 167, 273-291, 1971
247	Physical Characteristics of W49A as Determined from Radio Recombination Lines	M. A. Gordon D. C. Wallace	Astrophys. J., 167, 235-243, 1971
248	The Dynamics of Extended Extragalactic Radio Sources	D. S. De Young	Astrophys. J., 167, 541-551, 1971
249	Non-LTE Analysis of Data on Radio Recombination Lines for Five HII Regions	M. H. Andrews R. M. Hjellming	Astrophys. J., 167, 245-248, 1971

Appendix B, continued

No.	Title	Author	Reference
250	A Measurement of the Gravitational Deflection of Microwave Radiation Near the Sun, 1970, October	R. A. Sramek	Astrophys. J., 167, L55-L60, 1971
251	Detection of Radio Recombination-Line Emission Associated with Distributed Ionized Hydrogen	P. D. Jackson F. J. Kerr	Astrophys. J., 168, 29-35, 1971
252	Discovery of Interstellar Silicon Monoxide	R. W. Wilson A. A. Penzias K. B. Jefferts M. Kutner P. Thaddeus	Astrophys. J., 167, L97-L100, 1971
253	Properties of PSR 0525+21	R. N. Manchester	Astrophys. J., 167, L101-L105, 1971
254	Radio Emission From X-Ray Sources	R. M. Hjellming C. M. Wade	Astrophys. J., 168, L21-L24, 1971
255	Black and White Holes	R. M. Hjellming	Nature-Phys. Sci., 231, 20, 1971
256	Filled-Aperture Antennas for Radio Astronomy	J. W. Findlay	Ann. Rev. Astron., Astrophys., 9, 271-292, 1971
257	Interstellar Carbon Monosulfide	A. A. Penzias P. M. Solomon R. W. Wilson K. B. Jefferts	Astrophys. J., 168, L53-L58, 1971
258	Electron Density and Temperature in the Diffuse Interstellar Medium Determined from Recombination Lines	M. A. Gordon S. T. Gottesman	Astrophys. J., 168, 361-371, 1971
259	Faraday Rotation of the Crab Pulsar Radiation	R. N. Manchester	IAU Symposium, 46, 118, 1971
260	Crab Pulsar Radiation Characteristics	R. N. Manchester	IAU Symposium, 46, 209-210, 1971
261	Detection of Millimeter Emission Lines From Interstellar Methyl Cyanide	P. M. Solomon K. B. Jefferts A. A. Penzias R. W. Wilson	Astrophys. J., 168, L107-L110, 1971

Appendix B, continued

No.	Title	Author	Reference
262	Detection of Interstellar Carbonyl Sulfide	K. B. Jefferts A. A. Penzias R. W. Wilson P. M. Solomon	Astrophys. J., 168, L111-L113, 1971
263	Radio Emission From Antares B	R. M. Hjellming C. M. Wade	Astrophys. J., 168, L115-L116, 1971
264	6-Centimeter Formaldehyde Absorption and Emission in the Orion Nebula	M. Kutner P. Thaddeus	Astrophys. J., 168, L67-L71, 1971
265	The Radio Structure of Quasars--A Statistical Investigation	G. K. Miley	Mon. Not. Roy. Astron. Soc., 152, 477-490, 1971
266	High-Resolution Observations of Compact Radio Sources at 6 and 18 Centimeters	K. I. Kellermann D. L. Jauncey M. H. Cohen B. B. Shaffer B. G. Clark J. Broderick B. Rönnäng O.E.H. Rydbeck L. Matveyenko I. Moiseyev V. V. Vitkevitch B. F. C. Cooper R. Batchelor	Astrophys. J., 169, 1-24, 1971
267	Observations of Pulsar Polarization at 410 and 1665 MHz	R. N. Manchester	Astrophys. J., Suppl. Ser., 23, 283-3, 1971
268	Radiofrequency Observations of Symmetric Nebulae Around Wolf-Rayet Stars and an 07f Star	H. M. Johnson	Astrophys. J., 167, 491-498, 1971
269	Individual Radio Pulses From NP 0531	J. M. Sutton	IAU Symposium, 46, 97-102, 1971
270	Compact Radio Sources in the Nuclei of Galaxies	K. I. Kellermann	Nuclei of Galaxies, 217-244, 1971, (D.J.K. O'Connell, ed., American Elsevier).

Appendix B, continued

No.	Title	Author	Reference
271	Discovery of Para-Formaldehyde and the 2-Millimeter Formaldehyde Distribution in the Orion Infrared Nebula	P. Thaddeus R. W. Wilson M. Kutner A. A. Penzias K. B. Jefferts	Astrophys. J., 168, L59-L65, 1971
272	Millimeter Observations of CO, CN, and CS Emission from IRC + 10216	R. W. Wilson P. M. Solomon A. A. Penzias K. B. Jefferts	Astrophys. J., 169, L35-L37, 1971
273	Microwave Detection of Interstellar Formamide	R. H. Rubin G. W. Swenson, Jr. R. C. Benson H. L. Tigelaar W. H. Flygare	Astrophys. J., 169, L39-L44, 1971
274	Properties of Pulsars	G. R. Huguenin R. N. Manchester J. H. Taylor	Astrophys. J., 169, 97-104, 1971
275	A 21-Centimeter Study of the Spiral Galaxy Messier 33	K. J. Gordon	Astrophys. J., 169, 235-270, 1971
276	Excitation Temperatures of the 18-Centimeter OH Transitions in an Absorbing Cloud	R. N. Manchester M. A. Gordon	Astrophys. J., 169, 507-514, 1971
277	OH as a Constituent of the Interstellar Medium	B. E. Turner	Highlights of Astronomy, 2, 378-390, 1971, (DeJager, C., ed., Reidel)
278	Radio Emission from Interstellar Hydrogen Cyanide and X-ogen	L. E. Snyder D. Buhl	Highlights of Astronomy, 2, 407-412, 1971, (DeJager, C.,ed. Reidel)
279	Rapid Optical Variability of the Source PKS 1514-24	F. Biraud	Nature, 232, 178-179, 1971
280	New Ammonia Lines and Sources in the Galaxy	B. Zuckerman M. Morris B. E. Turner P. Palmer	Astrophys. J., 169, L105-L108, 1971

Appendix B, continued

No.	Title	Author	Reference
281	The Small-Scale Structure of Radio Galaxies and Quasi-Stellar Sources at 3.8 Centimeters	M. H. Cohen W. Cannon G. H. Purcell D. B. Shaffer J. J. Broderick K. K. Kellermann D. L. Jauncey	_Astrophys. J._, _170_, 207-217, 1971
282	Radio Emission from the Nucleus of NGC 5128	C. M. Wade R. M. Hjellming K. I. Kellermann J. F. C. Wardle	_Astrophys. J._, _170_, L11-L13, 1971
283	Counts of Radio Sources at 6-Centimeter Wavelength	K. I. Kellermann M. M. Davis I.I.K. Pauliny-Toth	_Astrophys. J._, _170_, L1-L5, 1971
284	The Absence of Formaldehyde Radiation Toward Cold Regions of the Galactic Plane	M. A. Gordon M. S. Roberts	_Astrophys. J._, _170_, 277-279, 1971
285	New Galactic H_2O Sources Associated with H II Regions	B. E. Turner R. H. Rubin	_Astrophys. J._, _170_, L113-L118, 1971
286	HCN in IRC + 10216	M. Morris B. Zuckerman P. Palmer B. E. Turner	_Astrophys. J._, _170_, L109-L112, 1971
287	Further Radio Observations of Scorpius X-1	C. M. Wade R. M. Hjellming	_Astrophys. J._, _170_, 523-528, 1971
288	Nonthermal OH Emission in Interstellar Dust Clouds	B. E. Turner C. Heiles	_Astrophys. J._, _170_, 453-462, 1971
289	Pulsar Radio Emission from Expanding Charge Sheets	E. Tademaru	_Astrophys. Space Sci._, _12_, 193-203, 1971
290	Solar Radio Recombination Lines	P. S. Berger M. Simon	_Astrophys. J._, _171_, 191-200, 1972
291	On the Distribution of OH in the Galaxy I. Correlation With Continuum Sources and With Formaldehyde	B. E. Turner	_Astrophys. J._, _171_, 503-518, 1972

Appendix B, continued

No.	Title	Author	Reference
292	On Equipartition in Galactic Nuclei and Gravitating Systems	W. C. Saslaw D. S. De Young	Astrophys. J., 170, 423-429, 1971
293	The Gaseous Content of Galaxies	M. S. Roberts	IAU Symposium, 44, 12-36, 1972
294	Crab Pulsar Radiation Mechanism	R. N. Manchester E. Tademaru	Nature-Phys. Sci. 232, 164-165, 1971
295	Pulsar Rotation and Dispersion Measures and the Galactic Magnetic Field	R. N. Manchester	Astrophys. J., 172, 43-52, 1972
296	Interferometric Observations of Pulsars at 2.7 and 8.1 GHz	G. R. Huguenin J. H. Taylor R. M. Hjellming C. M. Wade	Nature-Phys. Sci., 234, 50-51, 1971
297	Search for Pulsed Radio Emission from Scorpius X-1 and Cygnus X-1	J. H. Taylor G. R. Huguenin R. M. Hirsch	Astrophys. J., 172, L17-L19, 1972
298	Solar Radio Emission at 1.2 mm Wavelength	M. R. Kundu	Solar Phys., 21, 130-136, 1971
299	High-Resolution Observations of Compact Radio Sources at 13 Centimeters. II.	J. J. Broderick K. I. Kellermann D. B. Shaffer D. L. Jauncey	Astrophys. J., 172, 299-305, 1972
300	Number Counts and Spectral Distribution of Radio Sources at Centimeter Wavelengths	I.I.K. Pauliny-Toth K. I. Kellermann M. M. Davis	IAU Symposium, 44, 444-452, 1972
301	The N(S) Relationship at 1400 MHz	A. H. Bridle M. M. Davis	IAU Symposium, 44, 437-443, 1972
302	Radio Emission from Compact Objects	K. I. Kellermann	IAU Symposium, 44, 190-213, 1972
303	The Radio Structure of Quasars	G. K. Miley G. H. Macdonald	IAU Symposium, 44, 216-221, 1972

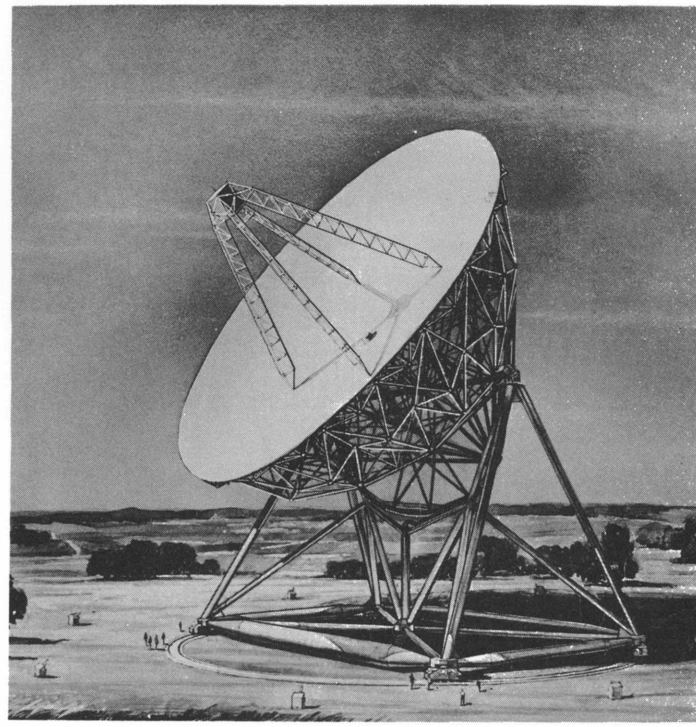
Appendix B, continued

No.	Title	Author	Reference
304	Radio Spectrum of Cygnus X-1	R. M. Hjellming C. M. Wade V. A. Hughes A. Woodsworth	Nature, 234, 138, 1971
305	Structure of Non-thermal Radio Source G55.7+3.4 in the Direction of CP 1919	M. R. Kundu T. Velusamy	Nature-Phys. Sci., 234, 54, 1971
306	Survey of Molecular Lines Near the Galactic Center. I. 6-Centimeter Formaldehyde Absorption in Sagittarius A, Sagittarius B2, and the Galactic Plane from $\ell^{II} = 359\overset{\circ}{.}4$ to $\ell^{II} = 2\overset{\circ}{.}2$	N. Z. Scoville P. M. Solomon P. Thaddeus	Astrophys. J., 172, 335, 353, 1972
307	Cyclo-Synchrotron Radiation at Small Angles	E. Tademaru	Astrophys. J., 172, 327-330, 1972
308	Decoupling of Magnetic Fields in Dense Clouds with Angular Momentum	T. Nakano E. Tademaru	Astrophys. J., 173, 87-101, 1972
309	Polarized Solar Radio Emission at mm Wavelengths Associated With Sunspot Magnetic Fields	S. Edelson E. B. Mayfield F. I. Shimabukuro	Nature-Phys. Sci., 232, 82-84, 1971
310	Interstellar Molecules and the Origin of Life	D. Buhl C. Ponnamperuma	Space Life Sci., 3, 157-164, 1971
311	Pulsar Parameters from Timing Observations	R. N. Manchester W. L. Peters	Astrophys. J., 173, 221-226, 1972
312	Possible Evidence for an Intergalactic Medium in Cluster of Galaxies	D. S. De Young	Astrophys. J., 173, L7-L11, 1972
313	Radio Stars Beta Persei and Beta Lyrae	C. M. Wade R. M. Hjellming	Nature, 235, 270-271, 1972
314	Position and Identification of the Cygnus X-1 Radio Source	C. M. Wade R. M. Hjellming	Nature, 235, 271, 1972

APPENDIX C

A 65-METER RADIO TELESCOPE FOR MILLIMETER WAVES

J. W. Findlay



We have recently finished the first stage of the design of a new, large, fully-steerable radio telescope. It is to be 65 m, 213 ft in diameter, and it is intended to work down to short millimeter wavelengths. By we I mean a design group from the Observatory; I will not list all the members, but the main work has been in the hands of Dr. von Hoerner, W. G. Horne, W. Y. Wong, C. Yang, and V. Herrero. Otto Heine from California has worked very closely with the group as a consultant. The last 2-1/2 years work has grown out of an earlier design study made for a 300-ft telescope. We realized that the success of the 36-ft telescope on Kitt Peak made it necessary for us to try to get a good instrument capable of working down to about 3.5 mm. We therefore set ourselves the task of designing the telescope to the following specifications:

Dish diameter	:	65 m (213 ft)
Mounting	:	Altitude - Azimuth
Sky Cover	:	Complete--but no tracking inside a small zone near zenith
*RMS surface accuracy	:	0.22 mm (0.009 inches)
*Short wavelength limit	:	3.5 mm (86 GHz)
*Tracking accuracy	:	3 arc seconds RMS
Slew rates (both axes)	:	20° per minute
Optics	:	Prime focus f/D = 0.43 Cassegrain--subreflector diameter 3.7 m (12 feet)
Instrument cabins	:	Behind prime focus; behind Cassegrain focus
Equipment room	:	Rotates in azimuth

*This performance is only possible under benign environmental conditions.

--continued, next page--

These specifications, of course, are remarkable in that we are suggesting that a large telescope can be built to work in the open air at a wavelength of 3.5 mm. For reference one might remember that the original design specification for the 140-ft telescope was that it should work at 3 cm, though, of course, it has in fact been successfully used at wavelengths as short as about 1 cm. To go to this short wavelength limit requires that we understand the structural deflections of the telescope and that these are so managed that they do not impair the performance of the instrument. The principle of homology which Dr. von Hoerner first stated allows us to do this. What we have done is to design the structure that supports the reflector in such a way that as the dish is tilted, although the structure bends, the surface remains parabolic in shape. The focal length of the parabola may change somewhat and so may the direction of its axis. These two effects need not impair the performance of the instrument.

But in addition to the use of homology for managing the gravitational deflections of the telescope, it is essential that we understand how the instrument will be affected by the wind and temperature on the site where it will eventually work. This is more a matter of analysis and understanding than of design, although we have tried in the design to reduce as much as we can the effects of wind in destroying both the pointing accuracy and the surface accuracy of the telescope, and also the effects of temperature, and particularly temperature differences, in distorting the telescope structure. We believe that the telescope we have designed will operate at its short wavelength limit on clear nights when the wind is below about 18 mph. When the sun shines on the telescope, we expect the resulting temperature differences to degrade its performance so that it may only work at wavelengths longer than 1 cm. Thus, the telescope will always be a large, valuable radio telescope, but it will only do its best and most precise work under nighttime conditions when the wind is not blowing too hard.

The Scientific Uses of the Telescope

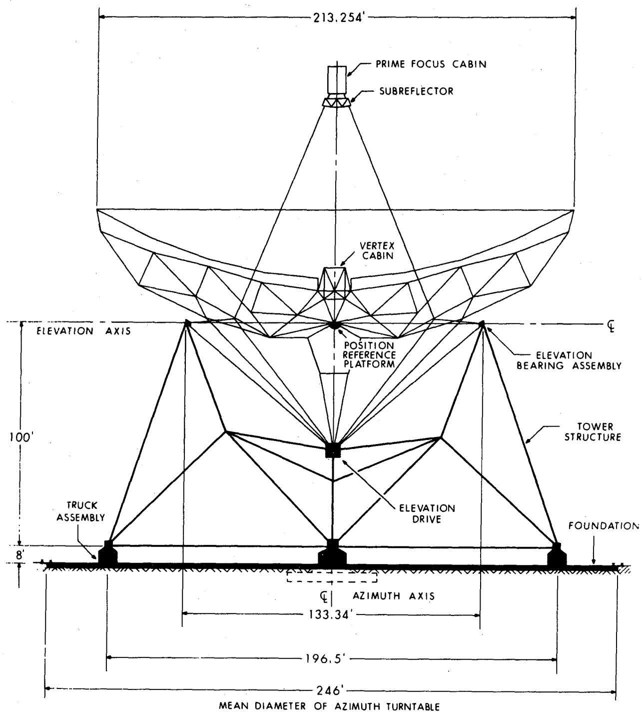
Despite the work done with the 36-ft, the wavelength region below 1 or 2 cm has been only studied in a very preliminary way. The main task of the new telescope would be to explore the properties of many radio sources in this region of the spectrum. Of course, one of the most obvious tasks that one can see at present is to extend the observations of spectral lines, particularly the spectral lines coming from more complicated molecules, to a large number of sources and almost certainly to a large number of new lines. Already about 40 spectral lines of many molecules have been observed between the frequency range of 20 GHz up to 115 GHz. Quite conservative estimates suggest that many more lines of those molecules already observed and many lines of new molecules will be found in this frequency range.

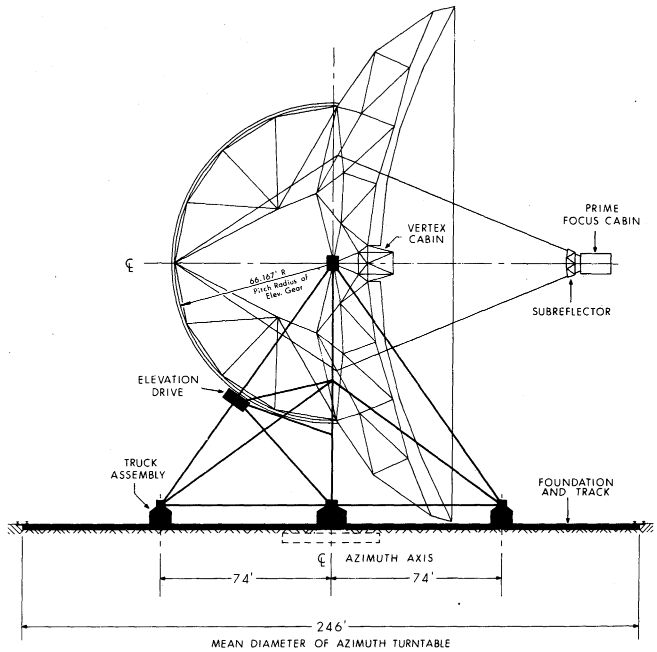
The astronomical interests in these lines are great. But so, also, is the hope of finding more complex organic molecules which are often popularly referred to as indicators of the way in which life has formed in our own galaxy. Of course, in addition to the line studies, all radio observations in the continuum need to be made in much greater depth and detail in this new spectral region. Quasars show their greatest variability at very short wavelengths. The new radio stars which have been detected with the Green Bank interferometer will be observed and others may be found in the millimeter-wave part of the spectrum. The study of the sun, the moon, and the planets is all a region where a large millimeter-wave telescope can be expected to make new discoveries. The telescope can also be thought of as one end of possible interferometer or VLB experiments. And, of course, by the time it is built, radio astronomy will have almost certainly turned up new problems, the details of which we cannot at present see.

The Design of the Telescope

We have already said that the telescope will incorporate the principles of homology in its structural design. Although this sounds as though it might lead to an unusual sort of structure, the two diagrams (Figures 1 and 2, page 5) show as outline drawings, that the 65-m telescope in concept does not appear to be very different to other large radio telescopes. It is a wheel and track

--continued, next page--





Figures 1 and 2 - Outline drawings of the telescope shown pointing to the zenith and to the horizon. (The trucks do run on the azimuth rails; it so happens that both these views look either end-on or side-on to the rectangular telescope base.)

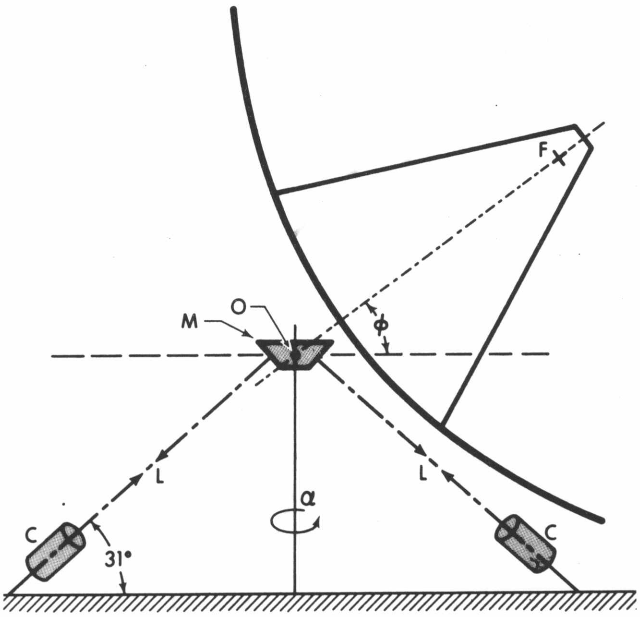
design where the dish is supported on a tower which in turn rotates in azimuth on wheels rolling on railway track. This basic design is one where it is fairly easy to obtain the necessary stiffness and strength for the supporting structure at not too great a cost. Although it is obvious to emphasize the importance of the perfection of the reflector surface of a large telescope, it is also necessary to be sure that not only the telescope surface is good, but that the whole instrument can be pointed accurately enough to meet the demands placed on it.

The half-power beam width of this telescope at 3.5 mm wavelength will be about 15 seconds of arc. It is therefore necessary to be able to point the instrument so that we know where the radio beam is in the sky to an accuracy of about 3 seconds of arc. Many factors enter into the solution of this pointing problem, and here we will refer only to one which leads to a rather novel aspect of the new telescope. Normally, the direction in which radio telescopes are pointed is found by mounting precise encoders on the axes of rotation of the instrument. It is more desirable to measure where a telescope is pointing by making angular position measurements at the point where the azimuth and elevation axes intersect. In the present instrument we plan to mount a stable reference platform at this axis intersection and to measure the elevation and azimuth feed directions with respect to this platform. These measurements will be made with very precise but essentially conventional encoders. The trick is, of course, to maintain such a reference platform stable in position in space. This we plan to do by essentially locking the platform position onto the direction of light beams transmitted from a number of stable autocollimators mounted on the ground around the telescope. (See Figure 3, page 6.)

The indications on these autocollimators, the light from each of which is reflected back from a seven-sided mirror on the refer-

--continued, next page--

ence platform, will be used to control, by servo loops, the orientation of the platform to remain fixed in space. Tests of this system were run at Green Bank about a year ago by using a single autocollimator and a simulated mirror system mounted on the deck of the 140-foot telescope, and these measurements showed that the system would work to a precision of about 1 arc second.



The principle of the stable reference platform. The platform is at O, where elevation and azimuth axes intersect. M is a 7-sided mirror and CC are 2 of 7 autocollimators. M is locked onto the light beams LL, and the elevation and azimuth angles ϕ and α are measured with respect to M.

Now let us turn to the problems of the reflector surface itself. Two main difficulties have to be overcome. First, a method has to be found by which surface plates can be manufactured to a smoothness of about 2.5 thousandths of an inch. The second difficult task is to devise a means by which such surface plates can be mounted and adjusted on the surface of the final telescope so that the total surface error still lies at about 9 thousandths of an inch. These two problems are so important that two solutions have been found for each of the problems. Dr. von Hoerner developed at Green Bank the first method by which the plates could be made to the required accuracy. The photographs (Figure 4a and 4b, next column)

--continued, next page--

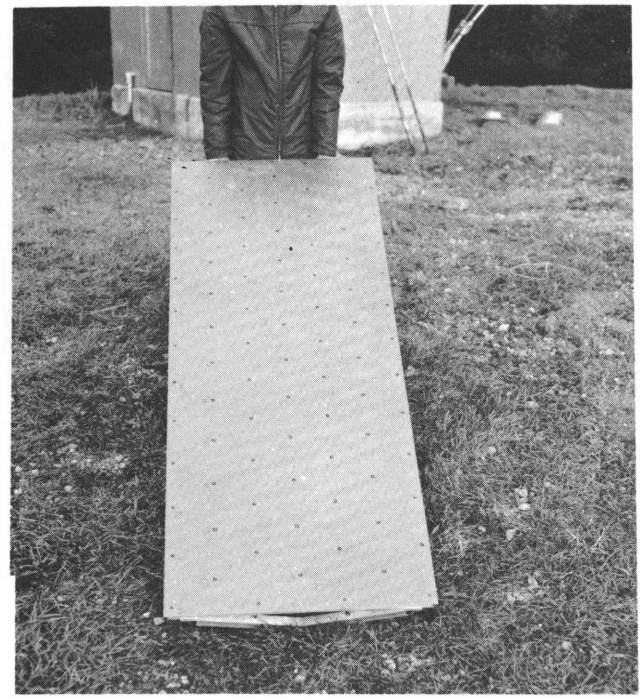


Figure 4a.

Figure 4b.

Two photographs of the von Hoerner surface plate, designed, built, and tested at Green Bank. (The arms in one picture belong to S. Smith.)

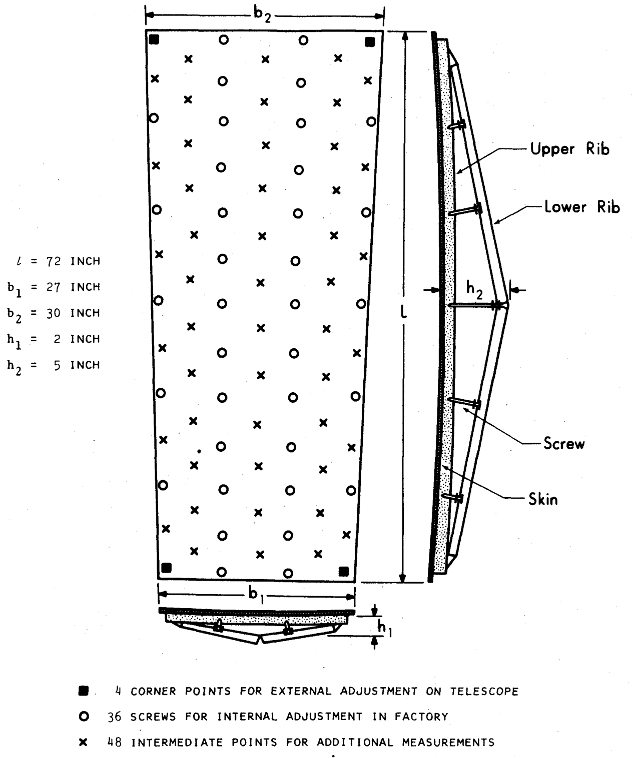


Figure 5 - The von Hoerner surface plate. The sheet aluminum skin, originally flat, is pulled against the rib structure by 36 adjustment screws which are finally cemented to lock them.

and diagram (Figure 5, above) show one of the surface plates made at Green Bank which, after many modifications, has been tested and proved not only to have the required surface accuracy but to maintain it even after a man has walked backwards and forwards over the reflector surface. The second method by which the plates might be made has been developed by the Philco-Ford Corporation and essentially makes each plate first by making an aluminum casting which produces in rough form both the surface plate and its supporting backup structure. Next, this casting is machined on a numerically controlled machine to the required surface accuracy. We believe both these methods will work, and the one finally to be used will be chosen when the final design of the telescope is complete.

To measure the surface plates on the telescope, the use is suggested first of a high-quality steel tape to measure the distance to a target point on the surface and then, second, to measure the angular position of this target using the known angle by which a quartz pentaprism reflects a ray of light. This method is different in detail from the one presently used for the 140-ft telescope but in principle it is essentially the same.

A second possible method for measuring the surface is to rely entirely on range measurements. To prove that such a method would work, a distance measuring equipment has been developed at Green Bank which can measure distances up to 60 meters to an accuracy of better than 0.1 millimeters. This instrument has been the work of John Payne and, in a prototype form, it has been quite extensively tested. Such an instrument could be used to set the surface of the 65-m telescope by making two range measurements, both starting from the dish vertex; one going directly to a target and the other going to the target position via a reflector placed near the telescope focal point. This technique is very attractive because it is capable of being completely automated. The reading time for a single target could be only a few seconds and very many targets could be measured and the measurements recorded in digital form in a relatively short time.

Estimates of Cost

There are, of course, two main reasons for carrying out a quite detailed design study of this kind. The first is to determine that the instrument that is being designed can be built and will in fact perform as well as the design suggests. The second, and very important result of such a study, is to say what it would cost to build the telescope. Therefore, in making cost estimates we have used a variety of sources of information and have done our best to check one against the other and all against our own estimates. We will not give the details of the cost estimate here, but only the final result. We believe that the cost of the telescope complete on a reasonable site, but not including the costs of radiometers and electronics used for observation, would be in 1972 dollars about $9.4 million.

We have also estimated that such a new telescope would need a staff associated with it of about 26 people, and that if it came into use in the Observatory it would require

--continued, next page--

about half a million dollars more in operating funds per year to keep it going. It might be worth noting that when we say "operating funds" we do not include the additional cost which would be required to provide it with the up-to-date electronics through the years and that this sum might be as high as a further quarter of a million dollars annually. We have also estimated that from the time at which we knew we were going to be funded for such a telescope to the time when it first started observations would be about three years.

Telescope Sites

The site on which such a telescope would be built has not been decided. However, it does seem clear, although perhaps unfortunate, that such a telescope should not be built on the Green Bank site. This fact arises almost entirely from the need for a clear atmosphere, as free from clouds as possible, for as large a part of the year as possible. Green Bank has on the average, measured over many years, about 80 cloud-free days per year. Good sites in the southwest of the United States can run as high as 260 cloud-free days per year. This shows that such a telescope, to be free from clouds, should be located somewhere in the southwest. A second important atmospheric factor is that for millimeter-wave observations the atmosphere should be as dry as possible. Again, although there are some very dry and very cold nights in Green Bank, on the average low water vapor in the atmosphere can be found for a much larger part of the year if one searches for high sites in the arid southwest.

Many sites have been surveyed and studies made of them for this telescope. And although no decisions have been arrived at, a very possible location would be to associate it with the Very Large Array on the site near Socorro in New Mexico.

Conclusion

The work of this design group has now been written into a report, and this report is going for its final printing. We hope that it will be possible fairly soon, to get the necessary funding for a telescope of this kind, but we can even now look ahead already far enough into the way in which funds can come from the Federal Government via the Science Foundation, and it seems clear that there must be a waiting period of at least two years before we could make the first move in building this telescope.

****