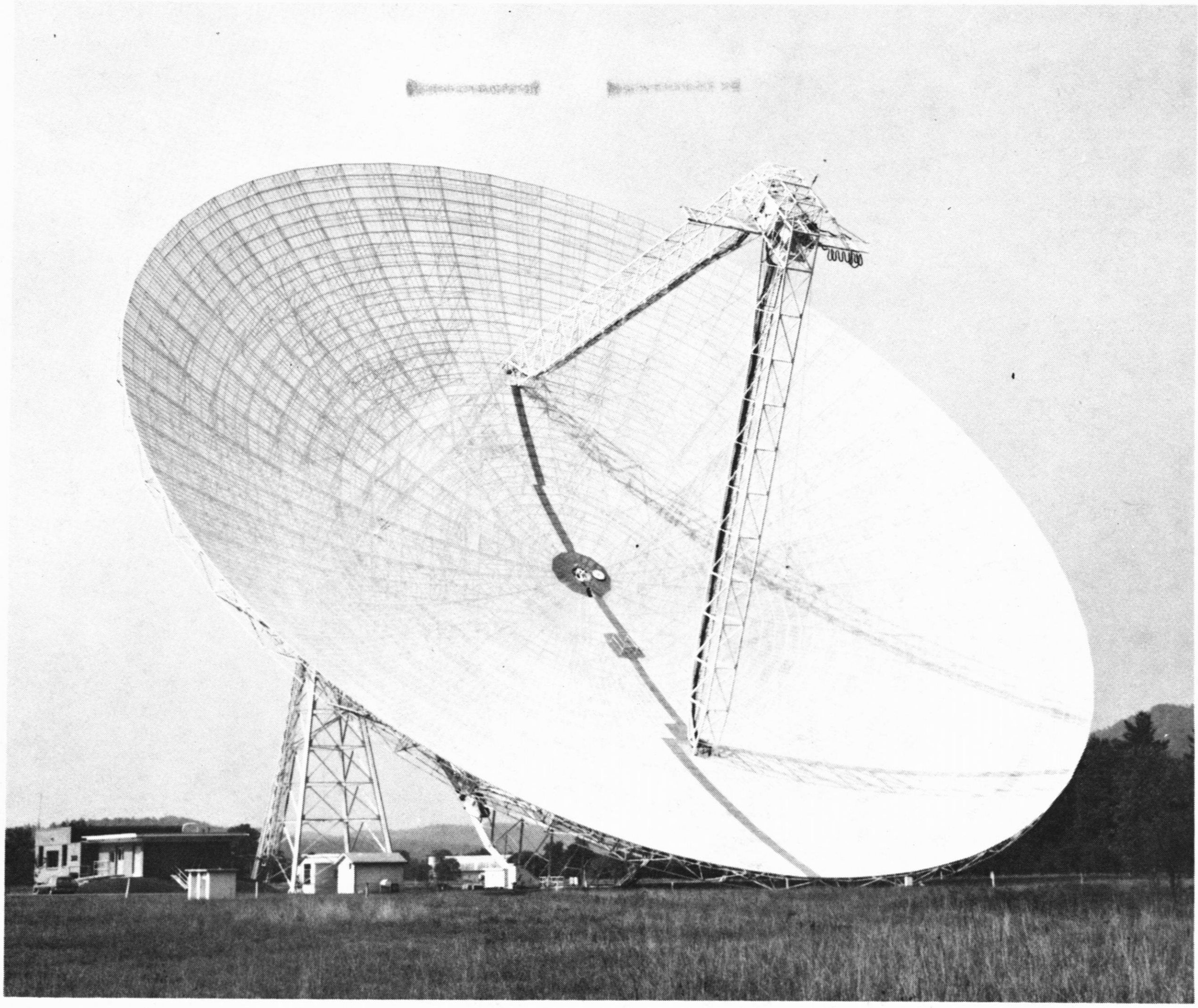
300 FOOT TELESCOPE

OBSERVER'S MANUAL

by

NRAO STAFF

REVISED MAY 1983



300 FOOT TELESCOPE

West longitude:	79° 50' 56".36
Latitude:	38° 25' 46".3
Height above sea level:	894 m
Diameter:	91.4 m (300 feet)
Focal length:	38.7 m (127 feet)
f/D:	0.424
Declination limits:	-18° 30' to 89° 50'
Pointing accuracy:	typically 30" rms, 10" rms at 6 cm
Highest observing frequency:	5 GHz, 6 cm

PREFACE

The preface to the previous edition of this manual contained an explicit disclaimer that the successful operation of an observing program is ultimately the observer's responsibility, although the NRAO will provide all possible assistance. This philosophy has not changed, but the disclaimer has been moved to an equally prominent setting: Chapter 1, page 1. The observer should feel free to direct inquiries at any time to the electronics staff, computer programmers, and especially the "friend of the telescope". The format of this manual has changed, and so this preface will serve as a guide to using this manual.

An effort has been made to separate out the reference material from the "cookbook" material. Chapter 1 contains an introductory overview of the observing system and the contents of later chapters. The material in Chapters 2 through 7 is primarily reference material, while Chapters 8 through 10 contain the actual guides to preparing an observing program, along with very brief reviews of topics explained more fully in the earlier chapters. Chapter 8 consists of a discussion of the task of getting the telescope on source, obviously relevant to all observations. Chapters 9 and 10 consist of descriptions of spectral line and continuum observing, respectively. Some repetition was unavoidable while striving to make these two chapters independent of each other.

Observers generally familiar with the 300 foot, needing reminders of the input card formats will find that material in the later chapters. New observers may also wish to begin with these later chapters (after reading Chapter 1), referring back to the material in the earlier chapters as required or desired. Those observers who read straight through this manual will find material organized (more or less) in the order of the signal path, from front end to back end.

The text for this manual has been prepared on an IBM Displaywriter. This greatly simplified the major format changes, and should help to keep things up to date in the future. On the other hand, it is not very easy to interleave text with figures and tables, and so these can be found at the <u>end</u> of each chapter.

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1. INTRODUCTION

This document describes the use of the 300 foot telescope for making astronomical observations. It consists of a compilation of the properties of the observing system requiring decisions, or at least an awareness, by the observer, along with a guide to preparing an observing program. This manual is intended as a guide to setting up an observing program which runs under computer control. The topic of data reduction is treated in separate documents, one each for line and continuum observations.

The reason for the existence of this manual is quite basic: the responsibility for the successful operation of an observing program rests with the observer. While the NRAO assumes many of the details of receiver set-up and telescope control, and equipment maintenance, the observer is expected to make enough on-line checks to insure that everything is working properly. It seems reasonable to expect that the observer should understand the equipment well enough to mentally trace a signal from the sky to the recording device. Many things are not obvious from looking at front panels, so some very fundamental questions to the staff may be in order. Everyone at the NRAO appreciates the fact that an observer cares enough about the experiment to understand the equipment about to be used.

The observer's basic responsibilities are to make equipment requirements known to the electronics staff in plenty of time, to provide the telescope operator with telescope control cards and receiver operation instructions, and to monitor and reduce the output data. Normally the observer on an assistant is expected to be in Green Bank during the entire run, and it is strongly suggested that the observer be in Green Bank from 1 to 7 days (depending on previous experience) before the start of the run to become familiar with current procedures. One or more of the scientific staff acts as "Friend of the telescope" and may be called upon at any time to answer questions or refer the observer to someone who can.

For the purposes of discussion, the chapters that follow describe the observing system broken down into components: (2) the telescope structure and its physical limitations, (3) some of the basic properties of receivers and feeds, (4) the problem of pointing, (5) the intermediate frequency system and continuum detectors including the digital continuum receiver, (6) the Model III autocorrelation spectrometer, and (7) the problem of interference. There are three computers in the system as well. The computers process and record the digitized detected signal at the end of the signal path, but they also control vital parts of the system so that observing can be more or less automatic. The chapters describing the system hardware take note of the points where computer input is available or required, but the step-by-step discussion of preparing the computer input for automated observing is deferred to later chapters which describe: (8) pointing the telescope, (9) spectral line observing, and (10) continuum observing. Computer input is in the form of punched card decks. One computer (the H316) is dedicated to positioning the telescope, and it needs to know about the pointing corrections. A second computer (the DDP116) runs the observing program and handles the data, and it needs to know how to configure the receiving system and what sequence of operations the observer wants to perform. The third computer (the MODCOMP) passively receives data from the DDP116 and is for interactive data processing, primarily using the POPS/CONDAR reduction programs.

This chapter is intended to provide an overview of the operation of the 300 foot telescope and its supporting electronics. The first section deals with hardware, and describes in general terms the set-ups for line and continuum observing. The second section deals primarily with software -- the POPS/CONDAR data reduction programs, and the properties of data transfer to the MODCOMP analysis computer. These sections show how the components of the observing system fit together as a guide to the detailed discussions in later chapters, and are not meant to standardize observing procedures. The observing system is very flexible, although somewhat cumbersome, and the observer is encouraged to plan an observing program around the best technique for the purpose and not around standard set-ups and reduction programs.

Under most circumstances, observing programs are run under computer control. However, the value of the telescope operator to a successful observing program should not be overlooked. Intervention by the operator, under instructions from the observer, to retune or change gains expands the flexibility of the whole system. At the observer's request, the operator can provide additional documentation on the log sheets, if necessary. Through experience, the operators have seen most of the things that can go wrong with the equipment, and are helpful in recovering from errors. Also in the category of parts of the system that talk back is the "Friend of the telescope," a resident advisor on the system with an astronomical perspective. The Friend may be the most useful advisor on adapting the system to the goals of a particular observing program. Finally, the computer programmers are the best source of information about the observing and data reduction programs.

The final two sections deal with day-to-day operations: scheduling, and daily routine. Unlike previously discussed parts of the system, these aspects have evolved slowly to their current state for the protection of the observer's data and priority.

1.1. OBSERVING HARDWARE

The two most commonly used receiver configurations, for line and continuum observing, are shown in Figures 1-1 and 1-2, respectively. A third, labeled "Pulsar system", might have been included, but it would essentially be a slight variation on Figure 1-2, with a specialized post-detection processor. The feed combination and number of data channels vary from one front end to another, so the diagrams are meant only to be representative. For more detailed information on a particular system, consult the receiver installation sheet normally given to the observer at the time of observing, or the appropriate electronics division internal reports, available on request, or talk to the engineer responsible for that receiver. Those properties of the telescope itself which are independent of the receiver/feed combination, such as rates and limits, are discussed in Chapter 2. A more detailed, but still largely receiver independent discussion of the properties of receivers and feeds is found in Chapter 3.

The intermediate frequency (IF) stages follow the front end box. In the spectral line system (Figure 1-1), the primary frequency determining element is the Universal Local Oscillator (ULO), which operates in the range of 250-500 MHz. The ULO is a computer controlled variable frequency synthesizer. A frequency counter continuously monitors the output frequency to ensure that it is equal to the commanded frequency. The ULO output frequency is multiplied up once or twice, depending on the receiver, by factors of 2 to 8 to equal the sky frequency plus or minus the IF. A set of variable local oscillators (VLO's) is provided for the second conversion, so that the sky frequency of two or more channels can be offset by using different IF's with a single ULO. The amount of offset is restricted only by the bandwidths of the front end and first IF amplifiers. Frequency switching is easily implemented under computer control.

The ULO may also be part of the continuum IF section, although most of its features are usually not needed. Frequency settings can be made manually.

The detector in the spectral line set-up is the Model III autocorrelation spectrometer. After appropriate filtering and conversion to baseband, the autocorrelator digitally samples the signal and forms the autocorrelation function, which is sent to the DDP116 computer. A Fourier transform is performed by the DDP116, which produces a spectrum to be written on magnetic tape, displayed on a monitor oscilloscope, and transmitted to the MODCOMP analysis system. Since absolute amplitude information is lost in one-bit sampling by the autocorrelator, the output of a total power monitor, with and without a calibration noise signal, is also recorded on tape for scaling the spectrum in the final reduction.

The autocorrelator sends signals which control frequency switching and the calibration noise source, so it is more than a digital filter. Observing bandwidths and correlator configuration are set manually on the front panel of the correlator, but the settings are compared to those specified on instructions to the DDP116 computer. The autocorrelator receives instructions to start and stop taking data from the DDP116 computer.

Multiplexed square law detectors and A/D converters sampled by the DDP116 make up the "analog" continuum detectors. The A/D's are typically sampled every second or so, with a minimum sample time of $0^{s}.5$. The computer can automatically calibrate the data by periodically turning on the calibration noise signal ("pulsed cal"). Without pulsed cals, sample times of $0^{s}.1$ to $0^{s}.4$ in steps of $0^{s}.1$ can be reached. A fast sampling program is available for pulsar work with sampling times as short as 1 millisecond, but it is not normally used for continuum work.

A digital radiometer system is also available for continuum observing. This is a new modular system providing modern features and improvements over the analog system. The analog system described above is computationally limited to elementary functions such as simple gain modulation balancing and analog subtraction for the Dicke switch mode, while occasionally providing for short integration features. The new digital system does all of this and more. Many complex computations are performed in real time as well as novel digital techniques for gain modulation Dicke switching, thus providing very stable and reliable operating characteristics. Combined with the very stable cooled GaAsFET front ends now available, reliable observations in the total power mode are possible. References for the digital receiver are Hallman 1978 [51] and Fisher 1978 [52].

1.2. DATA HANDLING

Digitized data from the autocorrelator, digital receiver, or multiplexed A/D's are received by the DDP116 computer. Spectral line data are Fourier transformed and scaled to form a calibrated spectrum. Frequency switched data are properly differenced. Continuum data from the A/D's are scaled if the pulsed cal method of calibration was used. The digital receiver passes already calibrated data to the DDP116. In each case the data are recorded onto a nine-track, 1600 BPI tape. These data tapes are normally sent to the NRAO Computer Division in Charlottesville for storage. In the event of a failure of the MODCOMP analysis computer, raw data are not lost, and may be retrieved from the telescope tape.

One of the most basic operations in sequencing a series of observations is sending timing signals to start and stop data taking. (The other basic operation is positioning the telescope on source, and obviously these two operations must be synchronized.) Start and stop times are specified by the observer, and passed on by the DDP116 computer. The uninterrupted block of data accumulated between start and stop times is a <u>scan</u>, which is identified by a <u>scan number</u> as well as other information concerning the system configuration. The identifying information is stored in a <u>header</u> which accompanies the data themselves on tape and in the analysis computer. A spectral line scan consists of a spectrum for which the total integration time is the difference of stop and start times. A continuum scan is a time series of samples of the radiometer output. A scan may consist of a number of subscans, called <u>records</u> since each corresponds to a physical record on tape. A record is the smallest amount of data which may be edited out if there is some problem with it.

Records are passed to the MODCOMP analysis computer where they are accumulated to form a single scan. It is not possible to edit bad records on the analysis computer. The accumulated scans are stored on a disk where they can be read but not changed. This disk can accommodate a total of 2560 spectral line scans plus 1600 to 2560 continuum scans, depending on their length. When the end of the available disk storage space is reached, the storage "wraps around"; i.e., the most recent scan overwrites the oldest one. Since the observer has no way of preventing this from happening, it is useful to estimate ahead of time how fast the disk will fill (based on the time per scan and number of scans per day), and to schedule data reduction in such a way that scans are not lost before they can be processed. If the telescope schedule is being shared with another observer, the number of scans produced under the other program(s) must be taken into account since there is only one data file of each type.

The on line analysis computer is available to the observer only during the observations. There is, however a duplicate analysis system in the Jansky Lab which can be used by reading in the telescope tapes or KEEP tapes. KEEP tapes are a way to save and transport reduced data, as described in the POPS/CONDAR manuals, and generally are a better archival medium than telescope tapes. Although KEEP tapes and telescope tapes are normally written at 1600 BPI, the MODCOMP can write 800 BPI tapes.

Off site data reduction can be done on the IBM 4341 computer in Charlottesville. Standard data reduction programs are available, or the observer may do as much of the programming as is desired. An observer desiring to make use of the Charlottesville computer should call extension 250 in Charlottesville to make the necessary arrangements.

Regardless of whether the observer will do any off-line data reduction, it is important to have a personal observer number, obtained from the computer department in Charlottesville. In contrast to project numbers assigned to proposals, an observer number or user number is permanently assigned, and follows an observer through life. This number is used to identify data on tape in the library in Charlottesville, and to keep some order in the tape library for the benefit of the observers. A single user number may suffice for a group of observers, but in NRAO files a single name is associated with each user number.

1.3. THE TELESCOPE OPERATOR

As mentioned in the introduction, the telescope operator's role in a successful observing program should not be overlooked. The operators have some general familiarity with the equipment, and are quite helpful when something goes wrong with the equipment. The operators know who to call when something goes wrong.

In the course of normal observing the operator can make routine adjustments in the system configuration, such as bandwidths, IF frequencies, gains, and autocorrelator configuration, on instructions from the observer. Observers have used such schemes as color coded source cards and notes written on source cards, as well as a sheet of written instructions, to insure that these changes follow the desired sequence. No scheme is foolproof since the operator may sometimes be away from the observing console. The header information accompanying the data may be insufficient to document whether a desired change actually took place, so in general it is desirable to keep the number of manual system reconfigurations to a reasonable minimum.

By virtue of their experience, the telescope operators are aware of conditions which may reduce the quality of the data, and if requested they can make brief comments on the observing logs. One of these conditions is interference, especially at low frequencies. Another is weather. The operator has the responsibility of shutting down to protect the telescope in conditions of winds exceeding 25 mph or heavy snow or ice loads. At the operator's discretion, any procedure or activity which is felt to be unsafe for the telescope, equipment or personnel, or which threatens data collection, may be halted.

On the other hand, the telescope operators are not astronomers, and they are not mind readers. An observer should discuss any special concerns or requirements with the operator rather than assume that they will be attended to. The operator on duty will "pass the word" to the operator on the next shift. The operators are not computer programmers and are not expected to reduce data, although they do have some familiarity with pointing checks.

1.4. SCHEDULING

Telescope observing schedules are normally sent to observers one to three months in advance. Assigned times are determined on the basis of the observing requests of many scientists and a reasonably efficient use of telescope time.

Beyond normal weekly maintenance and holidays the only reasons for 300 foot telescope shutdown are equipment failure, power failure, winds exceeding 25 mph, and heavy snow or ice loads. At least one engineer is available at all times to correct equipment malfunctions. Pointing accuracy and efficiency tend to degrade as the wind and snow load limits are approached, and it is the operator's duty to maintain telescope safety and to shut down at his or her discretion.

1.5. OPERATING ROUTINE

A scan by scan observing log is kept by the telescope operator giving time and position information of the telescope for later reference by the observer. The observer gets a copy of all observing logs taken for the program, and if a limited amount of additional information is wanted on these logs, the operator should be told at the beginning of the session.

Unless otherwise instructed, the operator will send the magnetic data tape to Charlottesville each weekday morning around 0800. Logs are sent to the Green Bank Telescope Services Division Office (room 214 in the Jansky Lab), and analog monitor charts and other plots are set aside for the observer each day at the telescope. Tapes sent to Charlottesville are put into an archive library. The tape librarian will send periodic reminders of an observer's holdings, along with requests to release tapes of no further use.

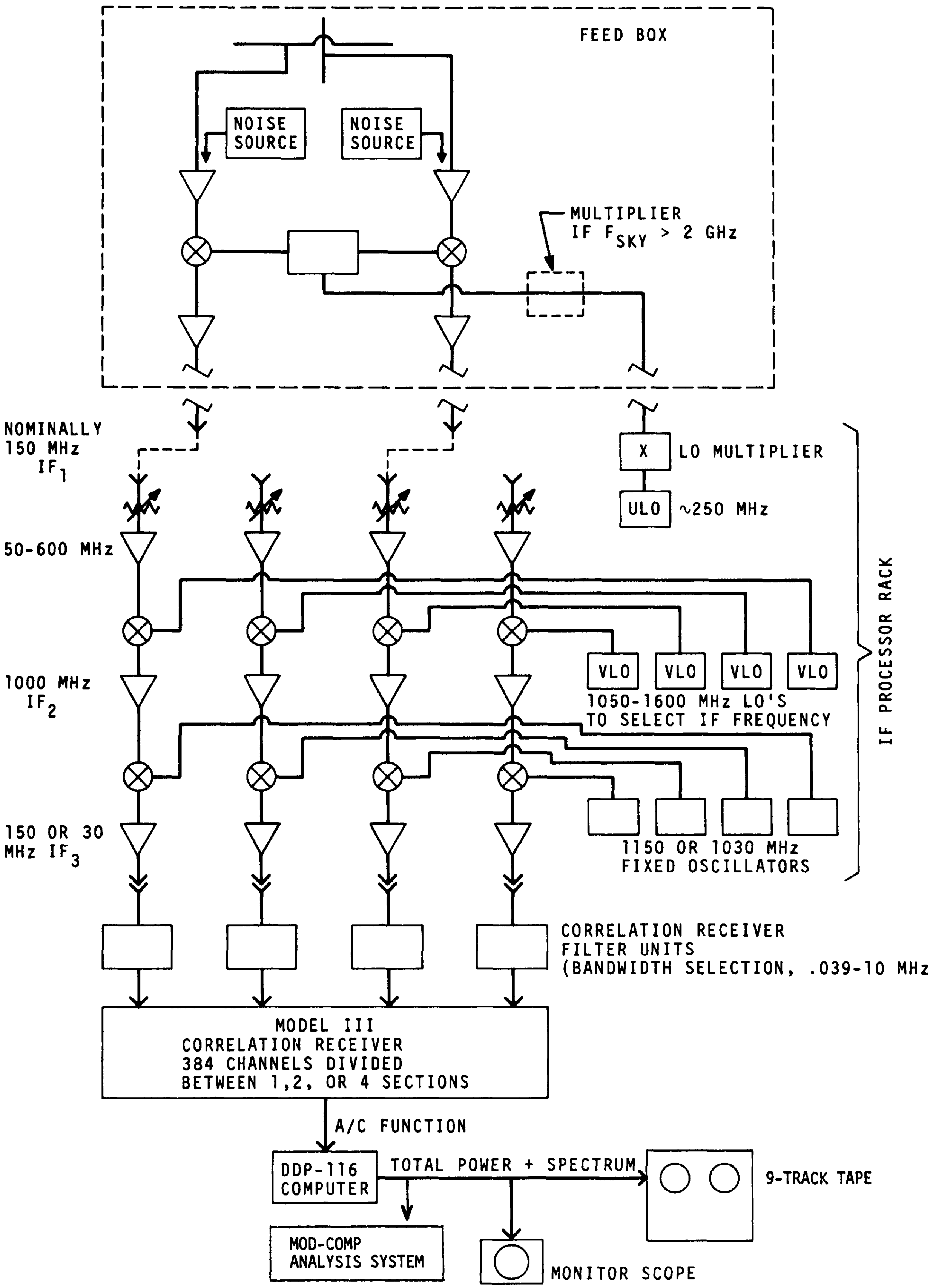

Figure 1-1. Basic spectral line system at the 300 foot telescope.

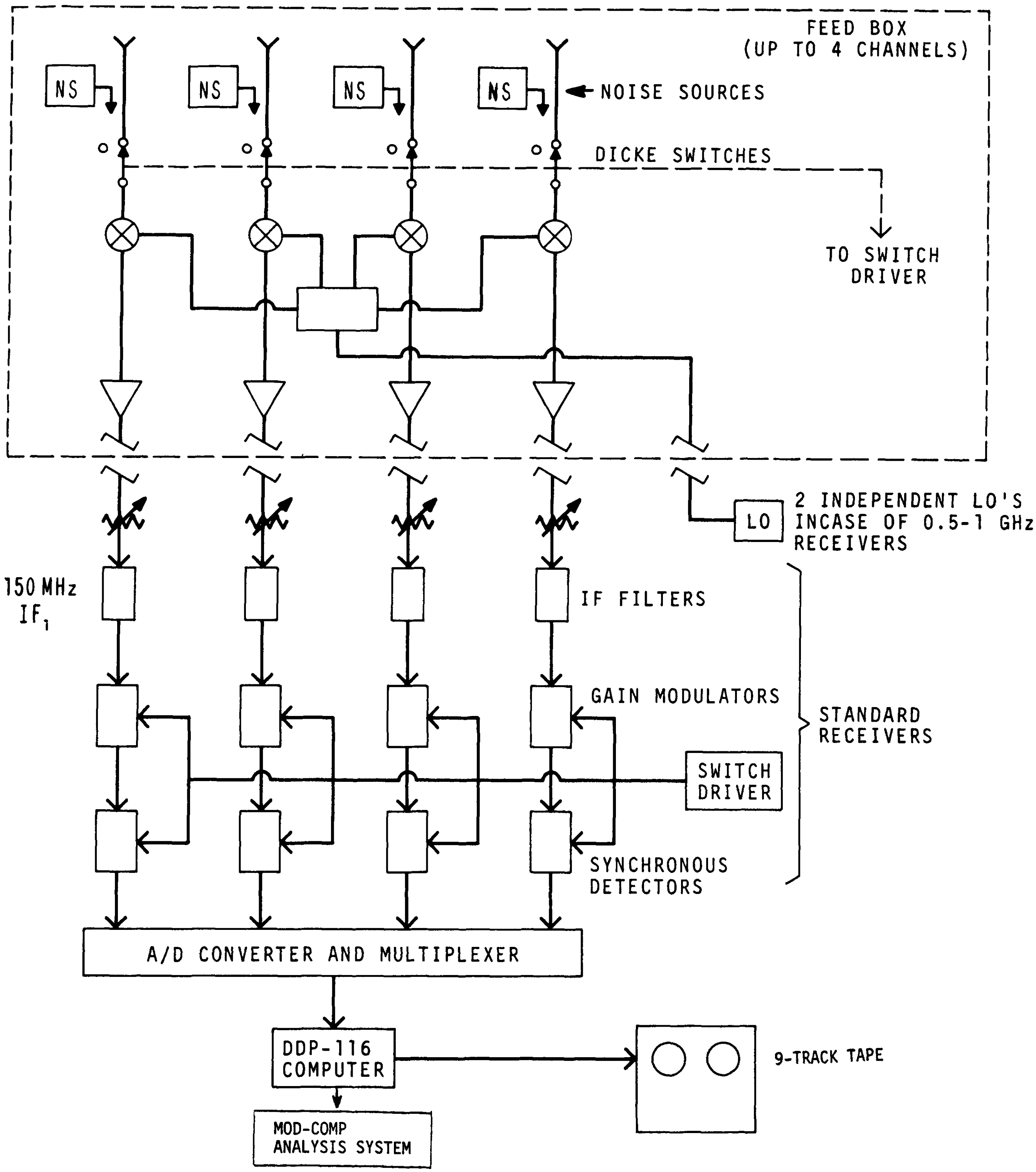

Figure 1-2. Basic continuum system with standard receivers at the 300 foot telescope.

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2. TELESCOPE STRUCTURE

This chapter describes the limitations on observations imposed by the physical structure of the telescope itself, aside from the obvious limitations of a transit instrument.

2.1. PHYSICAL LIMITS

The primary indicated declination limits are nominally +89°50' and -18°30' but may vary by a few arcminutes depending on temperature. Indicated coordinates are those indicated by the position encoders on the telescope structure, but they are quite close to the actual position on the sky. Beyond these limits the telescope can be driven manually to back-up limits of +91°04' and -19°30' with the variable speed motor. When operating in card control mode, it should be remembered that these limits are indicated and a 1950 or true position may be beyond the limits after precession and/or pointing corrections are applied. If a primary limit will be encountered, the telescope will not move under computer control from the current position.

Tracking in right ascension is accomplished by moving the feed in the focal plane. There are two feed carriage systems. One is a 14 m, fixed focus east-west set of rails, called the travelling feed, used for frontends below 1 GHz. The other, called the Sterling mount, is a more accurate mount for radiometers above 1 GHz and is capable of focusing, rotation and east-west translation up to 45 cm on either side of the telescope axis.

Hour angle limits are ±15 inches or about $\pm 2^{m} \sec \delta$ around the telescope's meridian on the Sterling mount (used above 1 GHz) and are ±275 inches or about $\pm 28^{m} \sec \delta$ on the travelling feed carriage. Hour angle limits using the 300-1000 MHz carriage on the travelling feed are ±132 inches (reference: Appendix D), allowing a total tracking time of about $33^{m} \sec \delta$, but the feeds are offset from the center of the box making the tracking limits asymmetrical (see section 4.2.3). The limits in terms of time are very slightly dependent on frequency and aperture illumination as explained in the section on beam deflection factor. Here again it should be remembered that precession and pointing corrections will make these limits unsymmetric about the true or 1950 meridian.

2.2. DRIVE SYSTEM LIMITS

Two motors are used for declination drive. One provides continuously variable speeds from 0 to 2°.25/minute (0 to 135'/minute), and the slew motor has a fixed nominal speed of 10°/minute.

A three second time delay is built into the declination drive system to allow for telescope deceleration before reversal of direction of travel or speed change. If the telescope position is dependent on a rate and start time with very close sequencing (e.g. in wobbles), this delay must be taken into account. A rule of thumb for slewing to a new position is to add five seconds for deceleration and position trim to the time required to slew at 10°/min . Additional time may also be required for receiver adjustments.

Maximum hour angle drive rates on the movable feed systems are 0.5 inches/sec (about 1°/min) on the Sterling mount and 1.5 inches/sec (about 3°/min) on the travelling feed carriage. Note that hour angle and right ascension rates are not the same due to the apparent motion of the sky.

The travelling feed system is fixed focus and fixed rotation angle. The Sterling mount allows rotation of the receiver box up to ±200° from indicated zero at a maximum rate of 13.°3/sec, and a total focus travel of 1270 mm at a maximum rate of 6.76 mm/sec. Indicated zero on the focus travel is an arbitrary point and the actual in-focus position will depend on receiver box dimensions. Refer to receiver data sheets to determine the beam configuration at zero rotation angle. Positive rotation is in the direction from north through east on the sky.

2.3. PERTINENT HISTORY

The 300 foot structure and surface has undergone many changes which affect its pointing and efficiency. As a consequence, many very careful measurements of antenna parameters made in the past may no longer be appropriate. To help the observer determine the validity of a previous set of calibrations, a brief history of the telescope from the installation of the present surface is given in Table 2-1. It is safe to say that any calibrations made before 1 December 1970 should be disregarded except as a guide for performing new measurements. Some of these changes probably had little effect on the performance of the telescope, but their effects should not be discounted without at least spot checks.

TABLE 2-1

A BRIEF HISTORY OF STRUCTURAL CHANGES

Date	Change
1 July - 7 Dec. 1970	Installation of new surface.
17 Sept. 1970	Installation of cryogenic lines on feed support legs.
16 April 1971	Installation of two 7/8" Heliax cables on south leg (0.5 lb/ft/cable).
20 April 1971	Welding of north and south feed leg joints to remove pointing hysteresis.
20-28 April 1971	Installation of Sterling mount.
24 June and 16 Sept. 1971	Line of panels from south leg to north lip reinforced for walking.
11-18 Nov. 1971	Addition of counterweights: 3000 pounds at south box and 6022 pounds at counterweight box.
26 Sept. 1972	Alignment of travelling feed rails to remove twist.
29 March 1973	Welding of gusset supports.
4 June - 29 July 1973	Painting of entire structure.
22 June 1973	Welding of two broken gussets on bottom cord, south of east bearing.
17 Jan. 1974	Removed east declination encoder for repair.
15 Feb. 1974	Installed interference monitor antenna above feed cabin.
18 July 1974	Reinstalled east declination encoder.
19 Sept. 1974	Removed west declination encoder for overhaul
24 Oct. 1974	Removed travelling feed assembly for repair and recabling.
18 Dec. 1974	Reinstalled travelling feed assembly.
27 Feb. 1974	Reinstalled west declination encoder.

TABLE 2-1 (Cont.)

27 Feb. 1975	Reinstalled west declination encoder.
12 May 1975	Began using west encoder for observations.
1 Apr. - 1 June 1975	North catwalk installed.
19 June 1975	South catwalk installed.
19-30 July 1976	Partial painting of structure.
6-15 July 1977	Slew drive motor overhauled.
21 Aug. - 1 Sept. 1978	Partial painting of structure.
22 Jan. 1979	East inductosyn installed.
5 Feb. 1979	Began using inductosyn for observations.
31 July - 20 Aug. 1979	Partial painting of structure.
10 Aug. 1979	Installed electronic level east tower.
10 Apr. 1980	Began using tower level to improve pointing.
14 July - 3 Aug. 1980	Partial painting of structure.
15 Sept. - 6 Nov. 1980	Installed new travelling feed assembly.

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3. RECEIVERS AND FEEDS

3.1. RECEIVER CONFIGURATIONS

There are quite a few receiver configurations available at the 300 foot, so it is essential that the observer specify the type of observing intended and any special needs. The observing proposal often does not contain enough detail to guide the engineer in charge, so the observer should get in touch with the engineer to make any special requirements known, preferably 2 to 3 weeks before the program is to begin. Some parameters, such as bandwidth, can be easily changed in the control room while others, such as polarization or feed and switch configurations, may require major feed or cable changes in the front end box which require several hours to accomplish.

The telescope installation data sheet, or receiver set-up sheet, is a basic source of information about an observer's own set-up. This sheet is prepared by the engineer who installed the receiver, and is available at installation time. It contains vital information about the feed polarization, i.e. which polarization goes to which data channel, and focus distance. It also describes receiver parameters such as bandwidth, system temperatures, and noise tube temperatures. The LO multipliers, needed by the computer to set the sky frequency, are also found on this sheet. Particularly useful for returning observers are comments on major changes in the system.

3.2. FEED PERFORMANCE: ON AXIS

This section is intended to outline the instrumental parameters, effects, and corrections with which an observer should be concerned when planning and executing an observing program -- except for the important subject of pointing, which is discussed in a separate chapter. Where parameters such as aperture efficiency and beamwidth have been measured with a specific radiometer system, they are given herein. These parameters are more extensively determined for some telescope-radiometer combinations than others, depending on their purpose and the extent of feedback from previous observers. In any case, it is ultimately the observer's responsibility to insure that the proper parameters are being used, although the values given herein are the best that are currently available. It is important to remember that parameters such as pointing corrections and focus, done at a particular wavelength, are not usable for a different radiometer, even at the same wavelength; a different feed on the same radiometer will also produce different aperture and beam efficiencies. Even the declination dependence of aperture efficiency will, in general, be different for different feeds at the same frequency.

At many places in this chapter, procedures are given for measuring the parameters under discussion. It would be most helpful if each observer contributed any calibrations performed during a program or call attention to incorrect information that may have been received from NRAO.

For convenience, the discussion of feed performance has been divided into two parts: "On axis behavior" and "Off axis behavior." These titles refer to the declination and hour angle dependence, respectively, of the various telescope parameters. Tracking in right ascension is accomplished by moving the feed in the focal plane. A different set of effects is associated with beam motion in each direction.

3.2.1. APERTURE EFFICIENCY

The operational definition of aperture efficiency is given in equation (3-1).

$$\varepsilon_A = \frac{2kT_A}{SA} \tag{3-1}$$

where T_A is the measured antenna temperature produced by a point source of flux density S, in the peak of the beam, and A is the geometrical area of the aperture (6567 m^2 for the 300 foot). If S is in Jansky's and T_A in Kelvins, then

$$\varepsilon_A = 0.420\ T_A/S \tag{3-2}$$

The aperture efficiency is a function of illumination, polarization, losses in the feed, and dish deformations. The first three of these can be a strong function of frequency because of changes in VSWR and feed radiation pattern. Dish deformations have their greatest effect at short wavelengths, of course, but the detailed dependence of aperture efficiency on them depends on the phase and amplitude structure of the wavefront striking the surface from the feed (using reciprocity and considering the feed as a transmitter). For this reason each radiometer-feed-surface combination behaves differently as a function of declination at the same wavelength.

In many cases only the relative variation of aperture efficiency with declination is important, the measurement of which requires only that the secondary calibration source (noise tube or diode) remain steady during the measurements. Absolute determination of the aperture efficiency is much more difficult because both T_A and S must be known. T_A is derived by comparison with an internal noise standard in the radiometer which can be measured in the lab to a few percent, at best, and at worst can be in error by over 25%. The method of calibration of the noise standard is important because it often varies with frequency. Therefore, a wideband noise standard value is not necessarily valid for narrow band spectral line work and vice versa.

The most reliable way to determine the aperture efficiency of the 300 foot is to do drift scans of as many sources as possible of known flux over as wide a declination range as needed for one's observations. Be careful not to choose variable sources or sources larger than a tenth of a beamwidth. Good references for radio source flux densities are Bridle et al., 1972 [47], Kellermann et al., 1969 [48], and Fomalont and Moffet 1971 [49]. A compilation of flux density calibrators is included in Appendix B to this manual. Remember that flux densities usually refer to a particular polarization angle at a particular frequency.

Properly calibrated drift scans may be obtained using the pulsed cal mode or the digital receiver. Otherwise, put a noise calibration on the record immediately before and after the source passes through the beam. A comparison of the peak source deflection to the noise calibration deflection will give the noise calibrator in flux units, which, if the noise calibrator is known in temperature units, can be used to find the aperture efficiency in equation (3-1). If the declination pointing corrections are not precisely known, drift scans at several declinations may be necessary or the peak deflection corrected assuming a beam shape once the pointing corrections are known. The on- off method of determining source deflections is difficult to use on the 300 foot because of the variation of aperture efficiency with hour angle when a source is tracked. Even if extensive calibrations have been made on a previous observing session, at least spot checks on the calibrations should be made every session.

To indicate the useful declination range of the 300 foot at several wavelengths, representative plots of aperture efficiency as a function of declination are given in Figure 3-1. Note the difference in curve shape for different feeds at 21 cm. All reports which are on file with the "Friend of the 300 foot" and which discuss any of the parameters in this chapter are referred to in the References. The various radiometers are too numerous to discuss individually and for some of them there is very little written information on their performance on the telescope. As more information becomes available for each radiometer, references will be added to the manual.

Recent investigations [53, 56] reveal lateral defocusing to be a primary cause of the shape of the curves in Figure 3-1. As the telescope deforms under the influence of gravity the new shape resembles a parabola with an axis slightly offset from the nominal axis. The focal point actually moves in the north-south direction away from the location of the feed, causing a loss of efficiency which is most severe at the higher frequencies.

3.2.2. BEAM EFFICIENCY

Beam efficiency is an often misunderstood term in observational radio astronomy. Consequently there are several definitions, each of which applies only in a very specific case.

In practice, beam efficiency, ε_B, is sometimes used to convert observed antenna temperature, T_A, into source brightness temperature, T_B, for an extended source. The strict relation between T_A and T_B is

$$T_A = \frac{\iint_{\substack{\text{entire}\\ \text{source}}} T_B(\theta,\phi)\, R(\theta,\phi)\, d\Omega}{\iint_{4\pi} R(\theta,\phi)\, d\Omega} \qquad (3\text{-}3)$$

where $R(\theta,\phi)$ is the power response of the antenna in the direction (θ,ϕ). Only if the source is of uniform brightness can an equation defining beam efficiency be written which contains only antenna parameters:

$$\varepsilon_B = \frac{\iint_{\substack{\text{source}\\ \text{solid angle}}} R(\theta,\phi)\, d\Omega}{\iint_{4\pi} R(\theta,\phi)\, d\Omega} \tag{3-4}$$

Even then the source extent appears in the integral limits. Thus, any definition of beam efficiency in terms of antenna parameters only is arbitrary and of little practical use except as a measure of antenna quality.

Two properties of the beam efficiency as defined by equation (3-4) are worth mentioning, however. First, the beam efficiency is usually greater than the aperture efficiency if the integral is over the main beam. Second, the beam efficiency varies more slowly with declination than does the aperture efficiency because power lost in the peak of the main beam generally goes into broadening the beam and into nearby sidelobes as the dish is deformed.

The exact procedure for treating extended source observations depends on the scientific objectives. If the total source flux density is the goal, one could either correct for beam response fall-off if the source is roughly a HPBW or less in extent (assuming one knows the source brightness distribution), or one can completely map the source. If the source area is mapped, the total flux is simply the integral under the source map divided by the normalized antenna beam integral. In this case the map intensities are expressed in "Jy per beam area" which in many cases is a much more useful physical unit than brightness temperature, and allows one to use the direct secondary noise source calibration in terms of point source flux density.

3.2.3. BEAM WIDTH AND BEAM SHAPE

Nominally the half-power beam width of the 300 foot in arcminutes is 0.5 times the wavelength in centimeters. It varies by as much as 15 or 20% from this (usually larger) depending on illumination taper and shadowing, declination, and to a certain extent on wavelength because of beam broadening at higher frequencies owing to surface irregularities. To a first approximation the one dimensional main beam shape is gaussian when the illumination taper is -15 db at the dish edge, as is the case with many NRAO feeds. However, the gaussian shape is a poor approximation above 1 GHz at extreme declination limits where the beam is decidedly asymmetrical, and at all frequencies when the feed is off axis, as will be discussed later. The north-south beam width is generally larger than the east-west beam width because of the feed support shadows [56].

Typical beam contour maps are given in Figure 3-2 at declinations of +47° and -15° for the cooled 21 cm receiver [4], and much deeper contours are shown in Figure 3-3 for the 21 cm four feed system [2].

Figure 3-4 is a plot of measured half-power beam widths for the four feed system. The declination effect on beam width is more pronounced at shorter wavelengths. Figures 3-2 to 3-4 are meant only to be representative, and each feed must be calibrated separately.

3.2.4. SIDELOBES AND SPILLOVER

The sidelobe structure will be a strong function of the feed illumination taper and surface irregularities. One feature which is always present is the east-west diffraction spike seen in Figure 3-3, which is caused by the feed supports. If the dish is heavily illuminated, Airy's rings will become apparent. These are normally suppressed by proper illumination taper. Sidelobes far from the main beam are typically 50 to 60 db down from the main beam and are the result of diffraction by sharp irregularities on the dish. Far sidelobe structure can be strongly frequency dependent; this could produce spectral baseline distortions when a strong source such as the sun is in those sidelobes.

Spillover, which is the power from the feed not intercepted by the dish, is roughly 60 db down from the main beam but subtends a large solid angle mainly in the direction of the 300 K ground. This can contribute 5 to 50 K to the total system temperature. The peak in the ground contribution to T_{sys} occurs when the antenna is near zenith position. Below 500 MHz, spillover can also pick up local power line and ignition interference.

3.2.5. FOCUS

Only the Sterling mount is capable of moving the feed parallel to the telescope axis. The travelling feed is a fixed distance from the dish and the placement of each feed with respect to the actual focal point is determined when the receiver front end is built. Only indirect checks, such as beam shape and sidelobe structure, can be made on the focus of receivers below 1 GHz. Even these checks are dependent on illumination and interactions with the feed support structure.

Two methods have been used to determine optimum focus for the 300 foot. The simplest, which has been successful at 21 cm, is to track a moderately strong source while quickly running the feed back and forth through the approximate focal plane. With appropriate position marks on the receiver output chart recording the peak efficiency point can be determined. For this method to work, one must know the pointing corrections accurately and stay within 2 or 3 beamwidths of transit, and the receiver baseline must not change due to dish reflections when the feed is moved in either focus or translation (tracking) when pointed at blank sky.

If the baseline variations are a problem in the above method, the alternative is to make drift scans of a number of sources, each at a different focal position. The relative source strengths usually are not known accurately enough to monitor the efficiency at the different focal positions, but the HPBW is a weak function of focus. With at least 5 or 6 drift scans, the point of minimum HPBW can be determined with sufficient accuracy to set very close to optimum focus.

3.2.6. POLARIZATION

Precise polarization measurements are difficult with any radio telescope because of the myriad of instrumental effects. However, a number of successful polarization observations have been made with the 300 foot (e.g. [10], in which most of the instrumental effects have been accounted for). This manual does not claim to define the best way to measure polarization in each case, so only a brief mention of some of the instrumental problems will be given.

Point source and extended source measurements differ in that beam shape and sidelobes are more important in the latter. Hence, unpolarized sources used for calibration must be roughly the same angular size as the unknown source. If a dual polarized feed is used, there may be a pointing offset between the two beams. Or, if a single polarization feed is rotated, its beam axis may not be coincident with the axis of rotation. Spillover will be different for opposite polarizations in a dual polarization feed or for different position angles of a single feed. This will cause a differential variation in system temperature of two feeds as the antenna is moved in declination, or a baseline variation as the feed is rotated.

The phase and amplitude distribution of the illumination will also be different for the two polarizations in a dual feed and at different position angles in a single feed, owing to the intrinsic properties of the feed and to interactions with the feed support legs. The latter is especially important at low frequencies. Also, surface panel resonances may cause significant depolarization, particularly at low frequencies. Differences in illumination will produce different aperture efficiencies at different position angles and may cause the declination correction curve of aperture efficiency to be different at different position angles.

In an effort to provide a secondary polarization calibrator, three wideband antennas were installed at the apex of the 300 foot to radiate a polarized signal to the feed. Two antennas (400-1000 MHz and 1-8 GHz) are fixed circularly polarized and the other (100-1000 MHz) is rotatable and linearly polarized. A great deal of caution must be exercised when using these antennas because of strong reflections from the feed support legs, particularly below 1 GHz. For example, in a couple of cases, between 250 and 500 MHz, the sense of circular polarization actually appeared to reverse when the feed was moved away from the feed supports. A comparison of the box rotation angle and calibration antenna angle, when the calibration signal is maximized, indicates that measurements of the position angle of linear polarization is probably good to 5 or 10° in most cases. However, one cannot trust any amplitude information obtained with the apex calibration antennas.

3.3. FEED PERFORMANCE: OFF AXIS

All of the on axis properties of the 300 foot apply when it is used in the tracking mode, but additional effects arising from off axis operation of a paraboloid must be taken into account. Comments on these additional effects are given below under section headings corresponding to those used in the on axis discussion. Most of the comments apply to multibeam systems where at least one of the beams is off axis. An NRAO internal report [11] treats many of the subjects in more detail.

3.3.1. APERTURE EFFICIENCY

Figure 3-5 shows the variation of aperture efficiency as a function of beam offset for two radiometers (250-500 MHz and the cooled 21 cm). Note that all of the low frequency measurements agree to within about 2% at all frequencies. The 21 cm points are systematically higher, and this may be due to a difference in illumination taper. Heavily tapered illumination will produce less relative fall off in aperture efficiency with feed offset than will more uniform illumination. Measurements have been made at 21 cm at widely different declinations, and little or no dependence of the shape of the curve in Figure 3-5 on declination is found.

The best method for measuring relative aperture efficiency as a function of hour angle is to track the right ascension of a reasonably strong source while scanning back and forth across the source in declination at a speed consistent with the antenna beamwidth. A source smaller than a tenth of a beamwidth should be used, and the antenna pointing corrections in right ascension and hour angle must be known accurately. If an absolute value of the aperture efficiency is to be obtained with the same series of scans, a noise calibration should be put on the record before and after the set of source scans. Measuring the aperture efficiency variation by continuously tracking a source is not advisable because of possible variations in the receiver baseline when the feed is moved in the focal plane.

Since the shape of the aperture efficiency versus beam offset curve depends on illumination, it should be measured for each separate feed when it is important. Note that if one is using the tracking feature of the 300 foot to increase sensitivity by integration, there is often little point in going beyond 5 HPBW, because even with proper weighting of the data very little increase in signal-to-noise ratio can be obtained with the addition of observations taken when the aperture efficiency is less than half its on axis value.

3.3.2. BEAM EFFICIENCY, BEAM WIDTH, AND BEAM SHAPE

The remarks under this heading in the previous section apply here with the additional complication that the beam efficiency changes while tracking a source. In equations (3-3) and (3-4), $R(\theta,\phi)$ would also be a function of time. Most of the power lost from the beam peak as the beam moves off axis goes into widening the beam (asymmetrically) and into the coma sidelobe. Thus, the limits on the integrals in equations (3-3) and (3-4) are especially critical. Figure 3-6 shows an example of beam distortion when the beam is off axis. The contour levels do not go quite low enough to show a separate coma sidelobe in this diagram. This figure is intended to be illustrative only because the details of the beam distortion will depend on individual feed properties.

3.3.3. SIDELOBES

One important additional sidelobe, the coma lobe, appears when the beam is moved off axis. It is located approximately 1.6 beamwidths from the main beam along a vector from the main beam to the telescope axis, and its strength is strongly dependent on beam deflection and somewhat dependent on illumination taper. The coma lobe can be as high as 10% for displacements of 4 HPBW.

The near and far sidelobes associated with on-axis operation are still present with the deflected beam, but their detailed structure will change with beam motion.

3.4. BASELINES

In continuum observations the term baseline refers to the output of a radiometer when the source is not in the main beam. If we neglect receiver instabilities and interference, the main sources of baseline variation with the feed on-axis are changes in ground radiation pick-up with changing declination, and time-variations in atmospheric radiation at frequencies above about 2.5 GHz. The first is not a problem with right ascension drift scans. The second is a strong function of the amount of water vapor in the direction of the beam. In the case of small source work, beam switching can help cancel atmospheric contributions to baseline instabilities, but at times the small-scale structure of the water vapor distribution can be so pronounced as to make 6 cm observations difficult even when beam switching.

During the day, the presence of the sun in the telescope sidelobes can be a source of serious baseline problems. The sun is moving with respect to the sidelobes regardless of whether the telescope is motionless for a drift scan or tracking at the sidereal rate.

Spectral baselines, or variation of receiver output with frequency, in the true total power sense are mainly a product of the receiver bandpass characteristics. The gross frequency dependence of the receiver system can be taken out by subtracting a reference spectrum, taken with the antenna pointed off the source or with the receiver switched to a resistive load or to a different frequency from the source spectrum. A number of secondary effects then become evident in the baseline, and in general these effects are difficult to eliminate entirely.

When the reference is taken by moving the antenna, instabilities in the receiver bandpass, and strong sources such as the sun or ground radiation in the antenna sidelobes, can cause undulations in the difference spectrum. Load or frequency switching can be done much more rapidly to eliminate effects of receiver bandpass drifts, but because the receiver front end characteristics will be considerably different at a different center frequency or when connected to a load, the baseline will still not be flat. Generally, if the total bandpass used is less than about 1 MHz, then load or frequency switching will produce acceptable baselines. Bandwidths above 1 MHz usually require operation in what is commonly called the total power mode, in which the reference spectrum is taken in a different part of the sky from the source. In this case one must be careful to take the reference spectrum with the feed in the same position(s) with respect to the dish (e.g., if a source is tracked, the reference point in the sky should be tracked over the same hour angles and roughly the same declinations) because of frequency dependent interactions of the feed and structure.

Some work on the 140 foot indicates that excess noise from either ground radiation or the sun can be scattered onto the dish surface and interfere with direct radiation into the feed. This interference is constructive or destructive depending on frequency and can be a source of spectral baseline ripples. Normally, ground radiation effects tend to cancel out in the total power mode at the 300 foot since the reference is usually taken at the same declination as the source observation. It is known, however, that the sun can cause baseline ripple with a characteristic length of 5 to 10 MHz and an amplitude at 21 cm of up to one Kelvin. No particular correlation of baseline ripple amplitude with solar hour angle has been established and many useful spectral line observations have been made during the day with a bandwidth of 10 MHz.

All of the above comments are intended only as guidelines because other observing considerations may be more important than baseline quality.

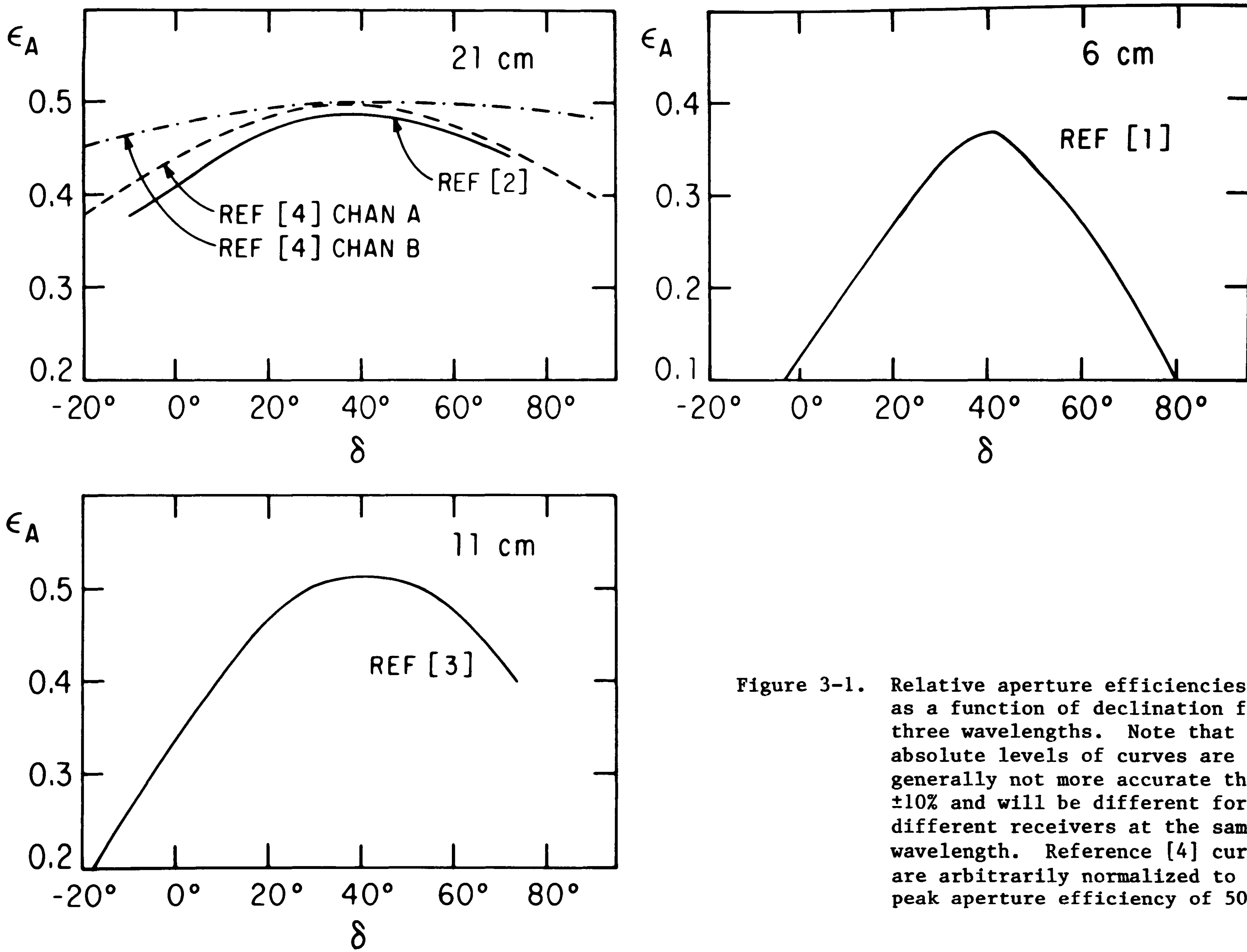


Figure 3-1. Relative aperture efficiencies as a function of declination for three wavelengths. Note that absolute levels of curves are generally not more accurate than ±10% and will be different for different receivers at the same wavelength. Reference [4] curves are arbitrarily normalized to a peak aperture efficiency of 50%.

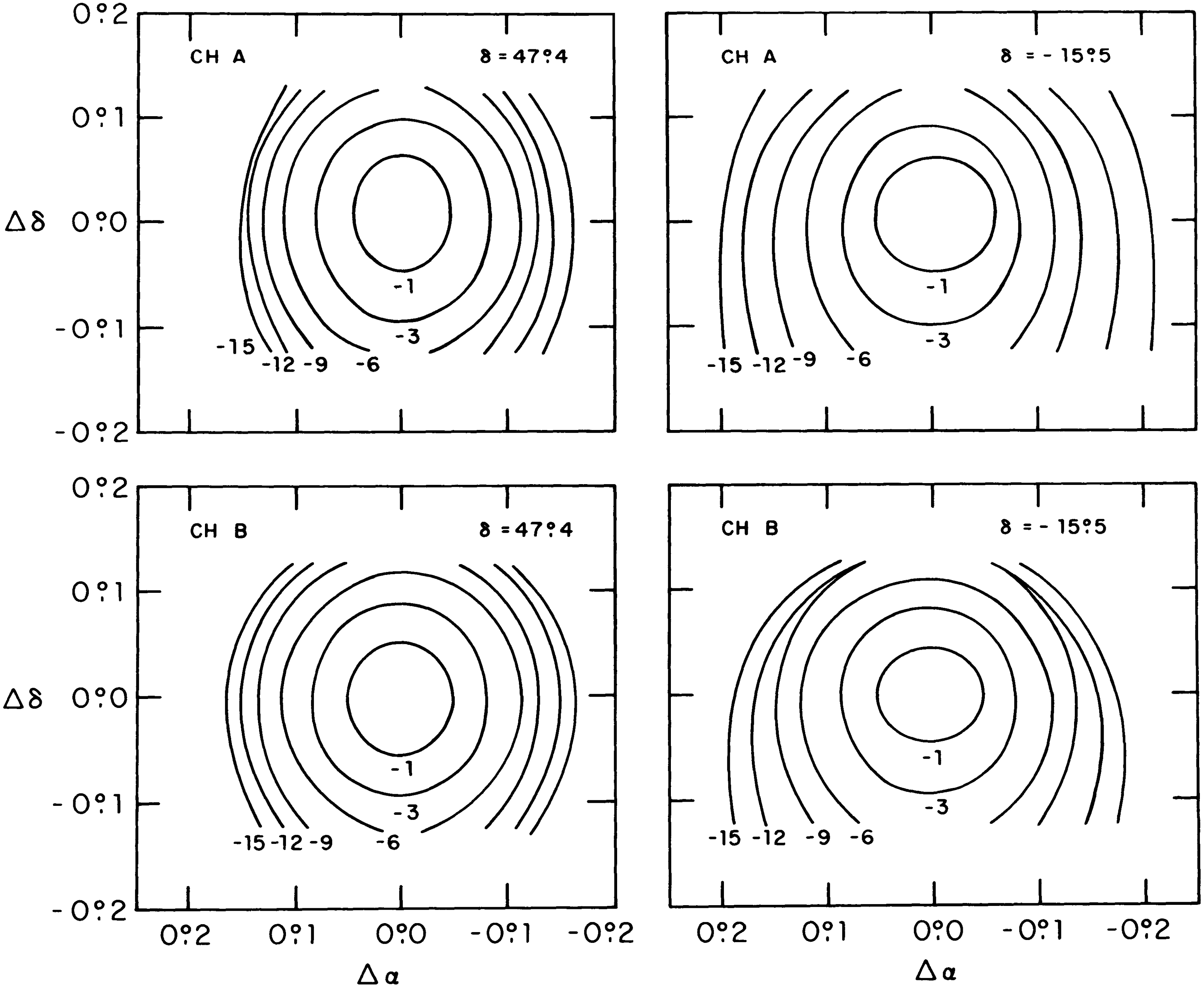
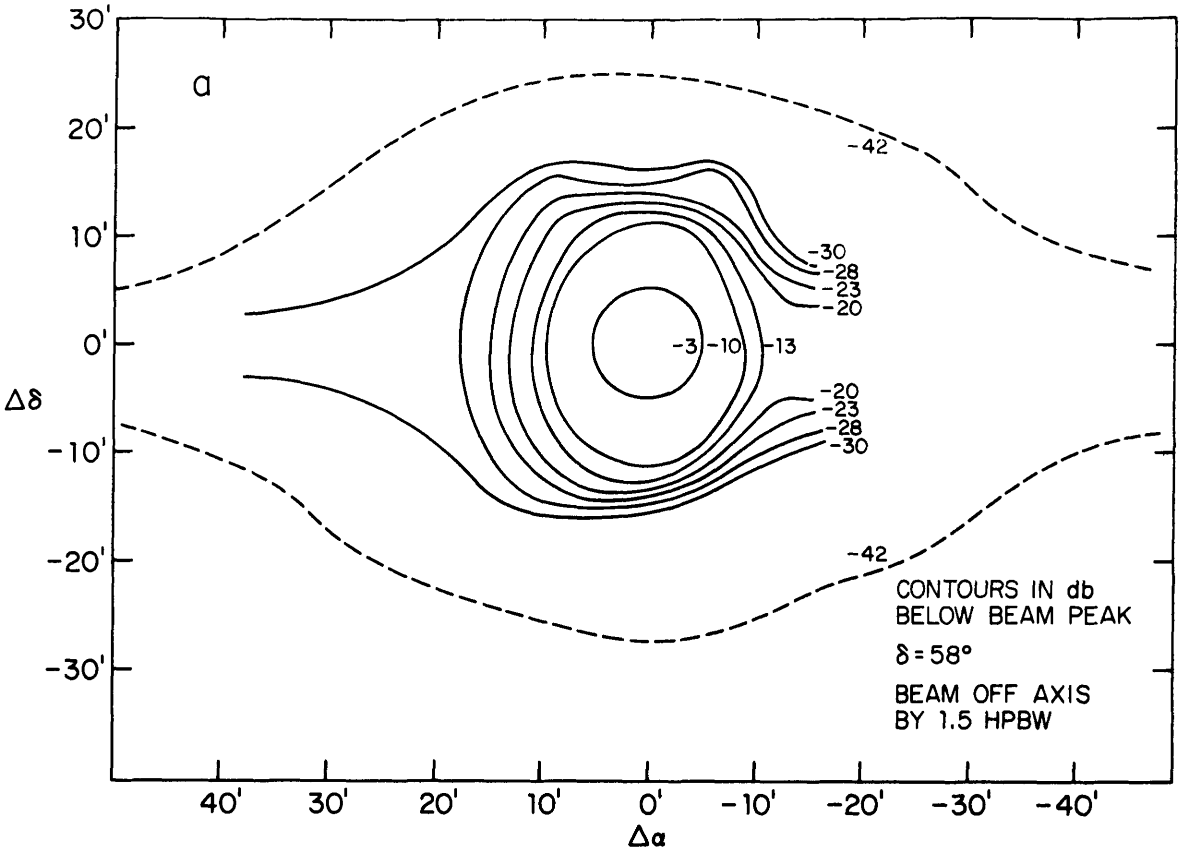


Figure 3-2. Beam shapes measured with the cooled 21 cm receiver feed on axis. Top figures are channel A with E vector north-south and lower figures are channel B with E vector east-west. Contours are at -1, -3, -6, -9, -12, and -15 db levels. Reference [4].



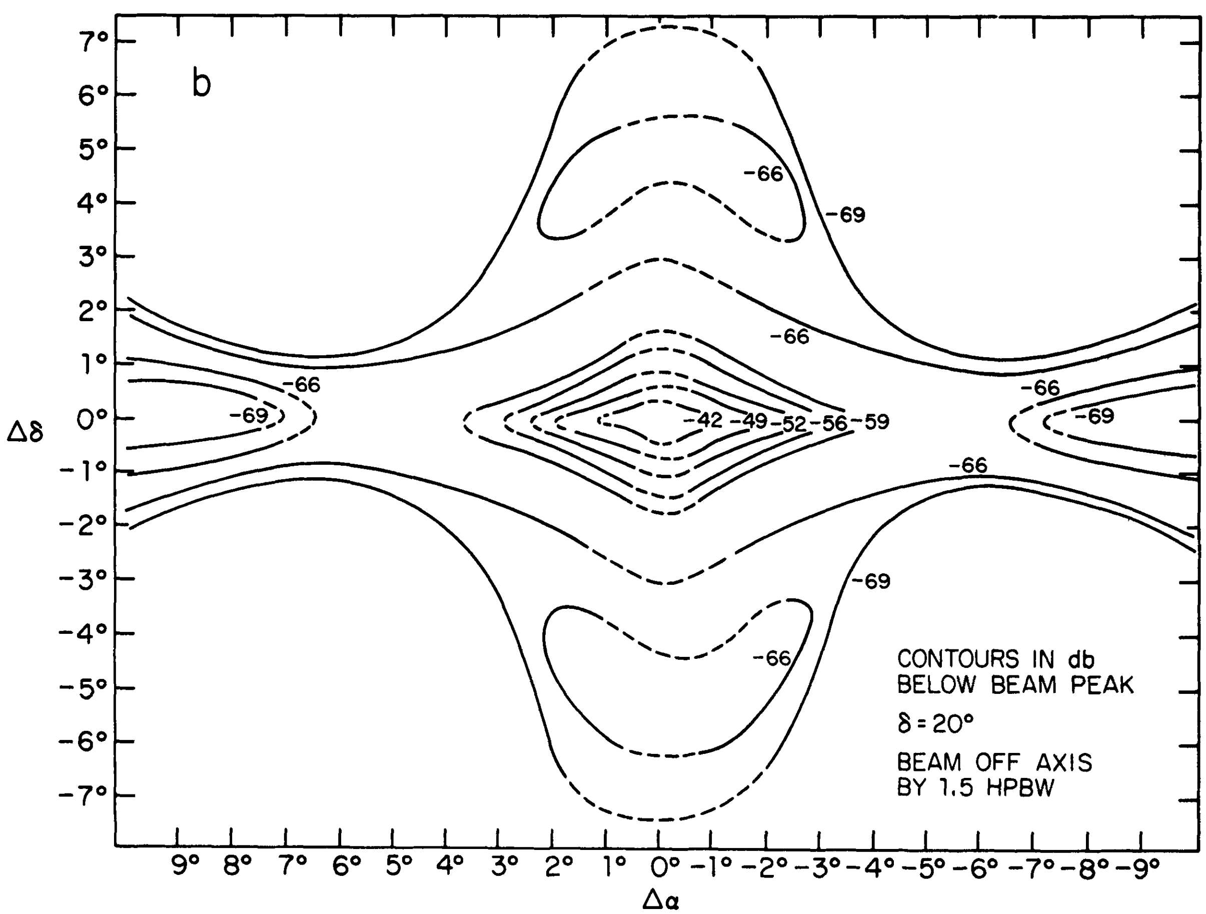


Figure 3-3. Example of low-level sidelobe pattern obtained by mapping Cas A (a) and the sun (b) with one of the 21 cm, 4 feed receivers. Reference [2].

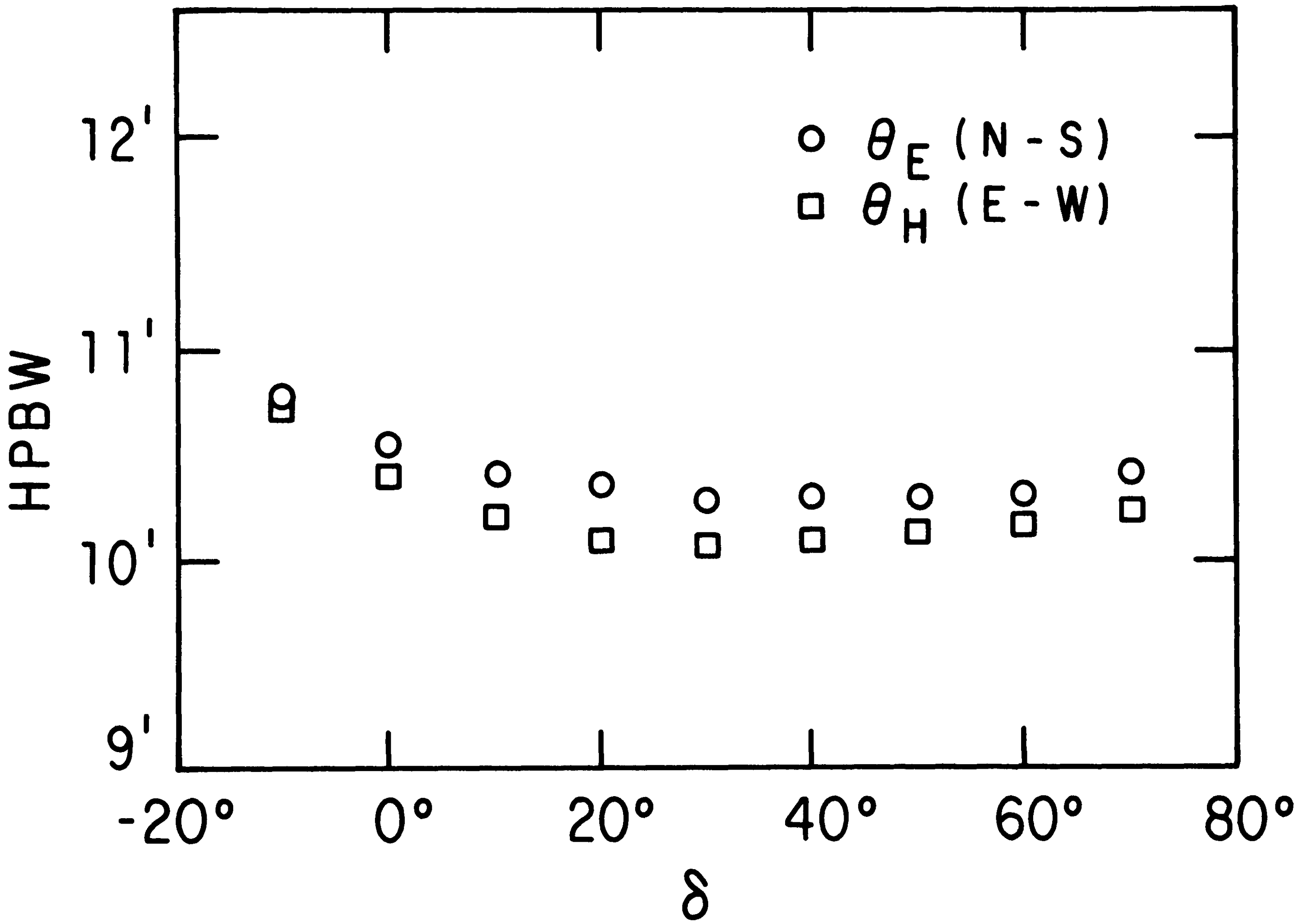


Figure 3-4. Typical behavior of half-power beamwidth as a function of declination. These data were obtained with one feed of the 21 cm, 4 feed system. Reference [2].

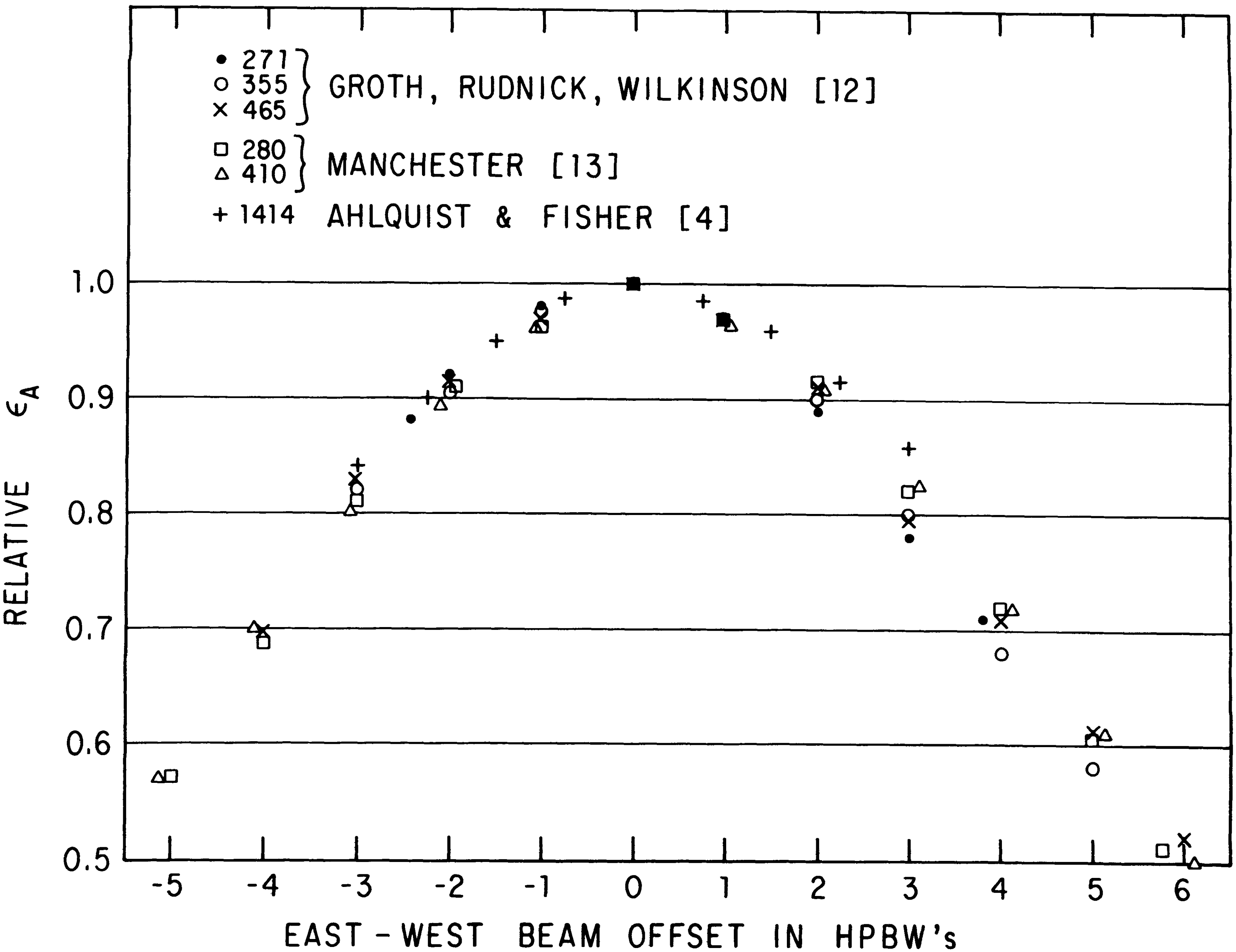


Figure 3-5. Relative aperture efficiency as a function of beam offset measured at several frequencies on the 300 foot.

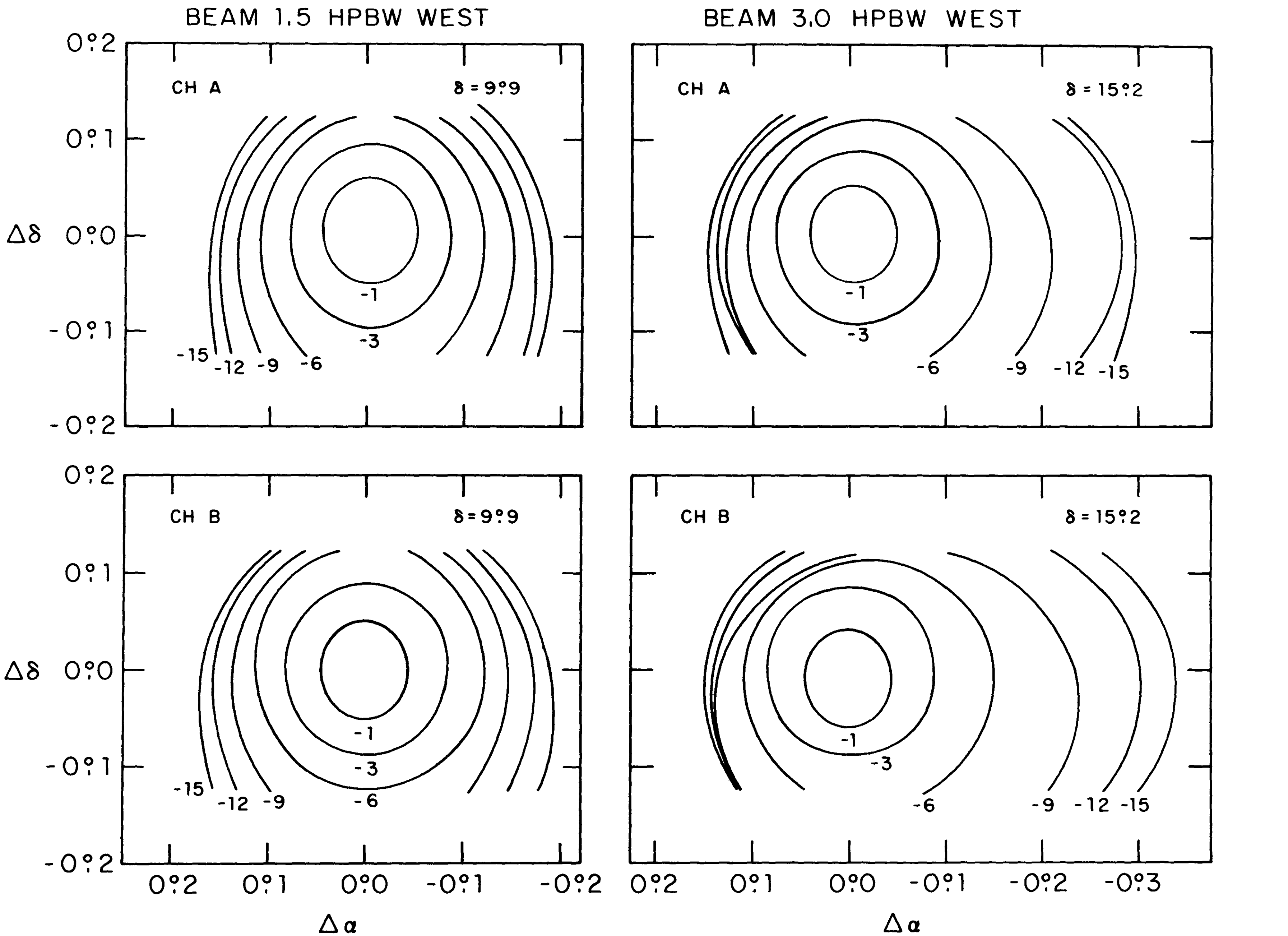


Figure 3-6. Examples of off-axis beam distortion measured with the cooled 21 cm receiver. Top figures are channel A with E vector north-south, and the lower figures are channel B with E vector east-west. Contours are -1, -3, -6, -9, -12, and -15 db. Ref. [4].

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4. POINTING

Pointing the telescope to the proper position on the sky is one of the most basic aspects of observing. The subject of pointing has received a considerable amount of attention, and continues to be a major aspect of telescope maintenance. Still, observations that depend critically on accurate pointing require attention by the observers themselves. As for others, there are very few programs so short that there is not enough time for at least spot checks of the pointing.

The purpose of this section is to acquaint observers with those aspects of telescope pointing that require their attention, or at least their awareness, the terminology involved, and procedures for improving the pointing.

The first subsection describes the four coordinate frames that are computed and carried along with the data. In particular, the difference between "apparent" and "indicated" coordinates is essential to the understanding of the nature of "pointing corrections." The second subsection describes the mechanics behind the application of pointing corrections, and summarizes what is known about the pointing for various receiver/feed combinations. The moral of this subsection is that there is no single pointing correction for all receivers, and that at the very least, the observer must be certain to choose the appropriate correction. The third subsection describes methods to refine to pointing.

4.1. COORDINATE FRAMES OF REFERENCE

The telescope position may be commanded in a number of coordinate frames of reference. The H316 computer performs the computations necessary to convert from one frame to another. The four frames that are used are epoch, apparent or true, indicated, and galactic.

The epoch coordinate frame consists of positions in equatorial coordinates at a given epoch. The only epoch now available is 1950.0.

The apparent coordinate frame consists of positions in equatorial coordinates at the epoch of the observations. The difference between epoch and apparent coordinates is precession, aberration, and nutation from 1950.0 to the epoch of the observations. Epoch and apparent coordinates are computed without any reference to the physical properties of the 300 foot telescope.

The indicated coordinate frame consists of positions as indicated by the position encoders on the telescope. Quite literally, the indicated coordinates are "what the dials read." The position encoders have been set so that indicated and apparent coordinates are nearly the same, but that is really a matter of convenience since indicated coordinates have no real astronomical meaning. But since the position encoders are part of the feedback loop for keeping the telescope at a commanded position, a position in any coordinate frame must finally be converted to a position in the indicated frame. Indicated coordinates are the "machine code" level instructions for telescope positioning.

The differences between apparent and indicated coordinates are due to slight misalignments in the telescope axes, encoder offset errors, and deformations of the telescope structure due to gravity and differential heating by the sun. Since these differences are small, the transformation from apparent to indicated coordinates is linear, as described in the next subsection. The pointing corrections are a functional fit to the differences between apparent and indicated coordinates, determined by measuring the indicated coordinates of sources with known positions.

The galactic coordinate frame consists of positions in new galactic coordinates. These coordinates are transformed to 1950.0 equatorial coordinates, and then treated as epoch coordinates. That is, they are precessed to the present epoch and pointing corrections are added.

4.2. POINTING CORRECTIONS.

4.2.1. POINTING CORRECTION EQUATIONS.

The pointing corrections are the difference between apparent and indicated positions. That is, they are the difference between the position that the astronomer wants to observe and the position indicated by the position encoders on the telescope. Since these differences are small, right ascension and declination corrections can be treated independently. The present method for implementing pointing corrections is to use standard equations in the H316 computer for which coefficients can be entered via cards.

The right ascension pointing correction equation is

$$\Delta\alpha = m + n \tan(\delta) + c \sec(\delta) \qquad (4\text{-}1)$$

where δ is the indicated declination, and where $\Delta\alpha$, m, n, and c are in seconds of time. This is the offset equation for a transit circle whose axis is displaced from true east-west and from the horizontal. The current values of m, n, and c are listed in Table 8-1, and are entered into the H316 computer on an "A" card (Section 8.1.1). This is the correction for observations on axis.

There is an additional correction for observations at non-zero hour angles, called the beam deflection factor (BDF). The BDF is the ratio of the angular displacement of the beam to the angular feed displacement [11]. The value of the BDF depends on the feed in use, but is usually between 0.84 and 0.875. However, beyond some critical hour angle the BDF increases in the sense that the feed need not be moved as far to obtain a given beam deflection. For the travelling feed, this critical angle was measured to be $3\overset{\circ}{.}15$ at 400 MHz by Greenhalgh [9], and a more recent measurement by Guiffrida and Haschick [32] indicates that this critical angle scales inversely with frequency (see [53]). Values of the BDF, critical angle, and additional BDF, for the travelling feed and for the Sterling mount, are entered into the H316 on a "T" card, as described in Chapter 8. It is necessary to calculate the additional BDF as a fraction of 2^{15} for entry into the computer. A specific example, taken from [9], is shown in Figure 4-1.

The declination pointing correction equation is more complex because the dish deformations are not easily modeled. The equation is

$$\Delta\delta = C_0 + C_1\,\delta + C_2\,\delta^2 + C_3\,\delta^3 - \Delta L \qquad (4\text{-}2)$$

where $\Delta\delta$ is in arc seconds, C_0, C_1, C_2, and C_3 are the pointing coefficients for a particular combination of receiver and feed, and ΔL is the level curve correction, described below. Particular sets of declination pointing coefficients are stored in the H316 computer and are identified by a two character identifier. The most recently determined coefficients are given in Table 8-1, and the identifiers are listed in Table 8-3. Ask the "Friend" about more recent updates to the pointing coefficients. The declination pointing coefficients are entered via a "D" card (Section 8.1.2).

4.2.2. ELECTRONIC LEVEL CURVE CORRECTION

In August 1979 an electronic level was installed on the east tower of the telescope to investigate the effect of differential heating by the sun. The level is a pendulum type electronic level, designed to be read remotely by computer. The level is mounted directly over the declination position encoder on the east tower. The level reads the tower tilt in the north-south direction only. In April 1980, the electronic level was incorporated into the feedback loop which keeps the telescope on position. It was found that the sun was causing a bending of the support structure which was directly reflected in the pointing. However, the telescope is not perfectly balanced, and so there is an unavoidable bending of the support structure as the telescope is moved. The level curve is this nominal relationship between the electronic level reading and the indicated declination, which is best measured on windless nights, preferably several hours after sunset to give the structure time to equilibrate thermally. This level curve is already incorporated into the nominal declination pointing curves described above, so the bending due to solar heating is the difference between the electronic level reading and the level curve. This difference is the level correction.

The level output is sampled every 0.2 seconds and averaged for 10 seconds. The nominal level curve is represented by a cubic polynomial in the indicated declination so that the level correction is:

$$\Delta L = \overline{L} - (\, L_0 + L_1\delta + L_2\delta^2 + L_3\delta^3 \,) \qquad (4\text{-}3)$$

where ΔL is in arcseconds, δ is the indicated declination, $\overline{L}$ is the ten second average level reading, and L_0, L_1, L_2, and L_3 are the nominal level curve coefficients. The current values of the level curve coefficients are listed in Table 8-1, and are entered into the H316 via an "L" card (Section 8.1.3). A positive level correction is in the sense of a northward tilt, and so the level correction is subtracted from the declination correction.

The console has a toggle switch which can be used to disable the level correction in case of malfunction or windy conditions. The telescope operator has control of this function. The H316 program checks the switch and prints a message on the CRT screen if the level correction is disabled.

4.2.3. TRAVELLING FEED RECEIVER OFFSETS

The travelling feed box (0.3-1 GHz) allows two feeds to be installed for observations at 300-500 MHz or 500-700 MHz, and 700-1000 MHz. The two feeds are physically offset from center by ±34 inches, so that the whole box must be moved to get either feed on axis. The 300-700 MHz receiver is located East on the box (-34 inches), and the 700-1000 MHz receiver is located West on the box (+34 inches). These offsets are entered on a "B" card in the observer's setup deck for the DDP116 computer, which passes the value to the H316.

The effect of the box offsets on the hour angle limits of this receiver is discussed in Appendix D. The point to remember is that for a tracking scan the source peaks up at the box offset. For example, the two low frequency feeds peak up at -34 inches of travel. This means that a source can be tracked for less time before transit and more time after transit. The 98 inches of travel before transit correspond to 12^m20^s sec δ of right ascension, and the 166 inches of travel after transit correspond to 20^m55^s sec δ. The calculations for the high frequency side of this receiver give the reverse answers. It is advisable to calculate these maximum offsets in beamwidths, heeding the advice of section 3.3.1 that there is little to be gained by tracking more than 5 HPBW's off axis, due to the loss of aperture efficiency.

4.3. REFINING THE POINTING

4.3.1. DETERMINING THE PVALS

If an observer is willing to devote a significant amount of time to pointing correction measurements, or if such measurements are derivable from one's observations, then new pointing coefficients can be derived. Programs which run on the IBM in Charlottesville are available for obtaining least-squares solutions for the pointing coefficients. However, if the observer is satisfied with the nominal coefficients that are available, then simple corrections can be applied quite easily to account for small feed offsets. Three correction terms, which are called PVALS at the 140 foot telescope, correct for a declination offset and for right ascension dial error and box offset. The corrections, P_1, P_2, and P_3, in minutes of arc enter the pointing correction equations as:

$$\begin{aligned} \Delta\alpha &= (m + P_2/4) + n \tan(\delta) + (c + P_1/4) \sec(\delta) \\ \Delta\delta &= (C_0 + 60\, P_3) + C_1\delta + C_2\delta^2 + C_3\delta^3 - \Delta L \end{aligned} \qquad (4\text{-}4)$$

In principle, P_1 and P_3 could be determined from the measurement of a single source if P_2 were assumed to be zero. However, the separation of right ascension box offset and dial error requires at least one pair of sources at widely separated declinations. If N pairs of sources are measured, the solutions for the pointing offsets are:

$$P_1 = \frac{1}{N} \sum_{m=1}^{N} \frac{(\Delta\alpha_1 - \Delta\alpha_2)_m}{(\sec \delta_1 - \sec \delta_2)_m} \tag{4-5}$$

$$P_2 = \frac{1}{N} \sum_{m=1}^{N} \frac{(\Delta\alpha_1 \sec \delta_2 - \Delta\alpha_2 \sec \delta_1)_m}{(\sec \delta_2 - \sec \delta_1)_m} \tag{4-6}$$

$$P_3 = \frac{1}{2N} \sum_{m=1}^{N} (\Delta\delta)_m \tag{4-7}$$

where subscripts 1 and 2 refer to the two measurements within a pair. There is a function in the POPS/CONDAR analysis programs for computing the PVALS. This function does not use equations (4-5) through (4-7), but instead performs a least-squares fit. The function is known as PVALS, and is literally a carry-over from the 140 foot analysis system. In particular, it asks for input as if it were possible to measure declination and right ascension offsets simultaneously, which is generally not the case on the 300 foot. Since P_3 is simply the average of all the declination offsets measured in a set of observations, it is perhaps more easily calculated by hand than by typing the numbers into the PVALS routine. In that case, the PVALS routine can be used to simplify the calculation of P_1 and P_2, inputting zero for the declination offsets.

4.3.2. MAKING POINTING MEASUREMENTS

The previous section described the calculation of corrections to the pointing derived from a set of pointing observations. This section describes in general terms the procedures for determining the pointing offsets.

If possible, a good place to start when refining the pointing is to measure the constant term in the nominal level curve. A long series of observations has shown that the shape of the level curve is stable, but that the zero point tends to change. It is not known whether the nature of this change is a slow drift or occasional jumps, but the change has been monotonic over a period of about two years. The simplest procedure for measuring the constant term is to command the telescope to declination zero and read the level. However, as described in the section on the electronic level, these measurements can only be made during the proper conditions, when the structure is in thermal equilibrium and there is no wind. If these conditions cannot be met, then the zero offset of the level reading must simply be corrected for by the declination correction P_3. An averaged level reading is passed to the MODCOMP analysis computer with all continuum scans, so it is not always necessary to read the meter.

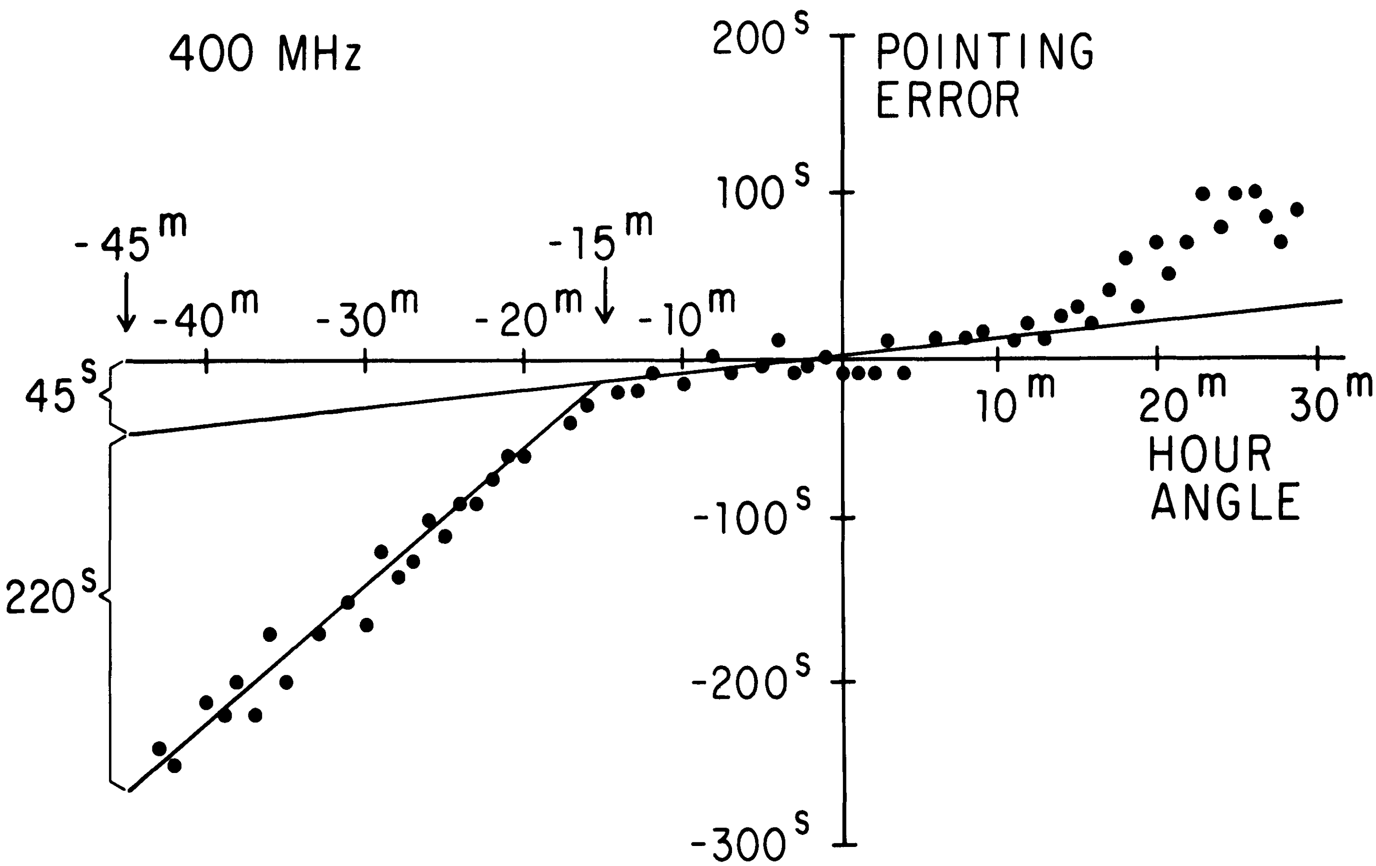
The right ascension and declination pointing offsets must be measured by drift scans and declination scans, respectively. The telescope operators know how to obtain and reduce these data to obtain the pointing offsets. The Friend has source card decks for making pointing observations, or observations can be run in a manual mode making use of the source lists in Appendix B. From experience, the most straightforward method of determing pointing corrections for a single feed are drift scans for $\Delta\alpha$ and at least two declination scans for $\Delta\delta$. The scans can be reduced in a straightforward manner on the MODCOMP. However, if the data are reduced from a chart recording, one must be very careful to allow for marker pen offsets and distortions due to receiver time constants. In either case, these effects can be canceled out in determining $\Delta\delta$ by taking an equal number of scans in either direction while tracking the sources in right ascension. Be careful not to allow the feed to get so far off axis that the curvature of the sky changes the apparent source declination as measured by the 300 foot.

If two or more offset feeds are available, such as on the 21 cm four feed or the 11 cm three feed systems, a fairly good measurement of $\Delta\delta$ can be made with a drift scan by measuring the relative responses of two or three of the beams to the source when they are spaced approximately half of a HPBW in declination. Such spacing can always be achieved by rotating the box to the appropriate position angle. This method assumes that the beam offsets and relative efficiencies are well known.

A third method which has proven successful at 21 cm is to track a pointing calibration source and move off to half power beam positions in the cardinal directions. If the response is not equal in opposite directions, the pointing offset can be computed. This method may be applicable to other frequencies as long as baselines do not vary with feed position and enough tracking time is available to complete the sequence. Because of the variation of aperture efficiency with hour angle, opposing offsets must be measured at equal distances from and not more than about three beamwidths from transit. When done from card control, this method offers the advantage of checking the entire sequence of telescope control as is used in actual observing.

Good references for accurate source positions are Bridle et al., 1972 [47], Fomalont and Moffet 1971 [49], and the VLA calibrator list. Appendix B consists of a calibrator source list and flux density list, furnished by P.C. Crane.

Observers who will be tracking their sources in right ascension may wish to measure the beam deflection factor (BDF), particularly if they wish to track sources at hour angles greater than 6 half-power beamwidths. The BDF can be measured fairly quickly by scanning the beam back and forth in right ascension across a reasonably strong source while recording the LST (and hence source hour angle, h), linear displacement of the feed, L, and receiver response on a chart recorder. From this record the angular feed displacement (L/focal length) and the beam deflection (h cos δ) for each source-crossing peak can then be determined, and the slope of the line defined by these points is the BDF. To the accuracy of measurement all determinations of the BDF have shown a linear relationship between L and h out to about 6 beamwidths, but at a critical distance of 3°.15 on the travelling feed at 400 MHz the slope changes abruptly from 0.854 to 0.868 [9]. A value of 0.856 has been recently determined for the cooled 21 cm receiver [4][54][55]. These values agree quite well with a value of 0.85 calculated for a -18 db illumination taper on the 300 foot [11]. The critical angle appears to scale with wavelength [32][55], so if beam displacements of more than 6 HPBW's are to be used, the critical angle and additional BDF will have to be determined at the frequency of interest.



SOURCE $\delta = 33°$

ASSUMED BDF = 0.84 AS FIRST APPROXIMATION

1. CENTRAL BDF $= 0.84 \left(1 + \dfrac{45^s}{45^m \times 60}\right) = \underline{0.854}$

2. CRITICAL DISTANCE $= 15^m \cos 33° = \underline{3.15°}$

3. ADDITIONAL BDF $= \dfrac{220^s}{30^m \times 60} = 0.12222$

ENTER AS FRACTION OF 2^{15}

$0.12222 \times 2^{15} = \underline{4004.9}$

Figure 4-1. Illustration of the change of the beam deflection factor as a function of hour angle. Reference [9].

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5. IF SECTION AND DETECTORS

This chapter describes some of the components of the observing system that determine the frequency band to which a receiver is tuned, and which bring the information in that band to the point where it is digitized. The Universal Local Oscillator (ULO) is a variable frequency synthesizer which can be computer controlled. The ULO is the basic frequency determining element in the system, since it generates the frequency signal which is mixed with the sky frequency signal to produce the intermediate frequency (IF) signal. The IF processor is a four channel device for mixing IF frequencies covering the wide range available from different receivers to the standard IF of 30 MHz used by the Model III autocorrelator plus a second output at 150 MHz.

The digitization of spectral line information is performed by the autocorrelator, which is the subject of Chapter 6. Continuum observations intended to calibrate line observations are also best performed using autocorrelator detectors. The process of digitizing the total power within the observed band for continuum observations is performed by square law detectors and analog to digital (A/D) converters. There are a number of parallel systems for accomplishing this. The "standard" continuum receiver consists of square law and synchronous detectors (among other things) whose output is fed into a network of A/D converters read directly by the DDP116 computer. The digital continuum receiver (DCR) is built around a powerful HP calculator which can digitize the output of internal or external square law detectors and then process those numbers to obtain a sophisticated variety of output data which is passed directly to the DDP116 computer. The variable bandwidth receiver contains a variety of bandpass filters in each of four channels, which allows the observed bandwidth to be changed easily. The square law detectors in this receiver have a very short rise time which allows fast sampling for pulsar observations. The 40 channel receiver is a filter bank of 1 MHz filters (measured at the 1 db points) separated in frequency by 1 MHz. This receiver has been used in a pulsar search.

The items discussed in this chapter are parts of the setup routinely handled by the engineer in charge of installation. Many observers have made successful observations without giving a moment's thought to the IF processor or square law detectors. This is not an advertisement to skip ahead to the next chapter -- quite the opposite, it is a warning that the documentation on a number of these items is rather thin, since most observers use them in standard modes. The documentation for the variable bandwidth receiver, in particular, seems to exist only as an oral tradition passed among pulsar observers. On the other hand, the digital continuum receiver is documented in a manual of its own, so that all of the items in this chapter consist of very brief descriptions.

5.1. UNIVERSAL LOCAL OSCILLATOR

The Universal Local Oscillator is a variable frequency synthesizer which generates the frequency used to mix from the sky frequency down to the intermediate frequency. Except for receivers for 300 MHz and below, the IF, rather than the sky frequency, is sent down from the front end to the control room. The ULO is therefore the primary frequency determining element in the system. The ULO can be commanded by computer to set three frequencies, F_o, F_1, and F_2. The ULO usually stays on F_o, for total power or continuum observations, or, for frequency switched observations, switches in the pattern F_o, F_1, F_o, F_2, commanded by a signal/reference pulse from the autocorrelator. The ULO can also be used in a manual mode, where all three frequencies and the choice of which is used can be set from the front panel.

The primary frequency generated in the ULO, F_o in hardware or L1 in software, is in the range 250-500 MHz. A frequency quadrupler is incorporated into the ULO so that the output frequency is in the range 1.0-1.99999 GHz. The frequency multiplier M that must be specified in the setup cards for the spectral line programs (Chapter 9) is therefore usually 4, except that there is a secondary output for which the multiplier is one.

An integral part of the ULO is a frequency counter, which monitors the primary frequency. These measured frequencies are passed back to the DDP116 computer for comparison with the commanded frequencies and the previous measurement. If the computer detects a discrepancy beyond a certain tolerance, an error message will be printed on the DDP116 teletype. The tolerance of these checks is ±100 Hz. An error does not halt the data taking. The ULO error messages and their meanings can be found in Table 9-5. If observations are made with the ULO in the manual mode, then the measured frequency passed back to the DDP116 is saved in the tape header with the data. The accuracy of this frequency measurement is also ±100 Hz.

5.2. IF PROCESSOR

The IF processor is a four channel mixer for converting an IF signal with a bandpass centered on frequencies in the range 50-500 MHz to a center frequency of 30 MHz, which is required by the autocorrelator. The IF center frequency is entered manually on the front panel. Each of the four IF channels, identified as A-D, can be set independently to a different frequency. If only two IF signals are present, processors A and C must be set. The maximum bandwidth of the output of the IF processor is 20 MHz, more than enough for the widest bandwidth available in the autocorrelator.

As with the ULO, the IF processor has a built-in frequency counter. The output of this counter should be the IF center frequency dialed in on the front panel. The counter switches between the four IF processors, returning four frequencies to the DDP116 computer. The computer makes a comparison between the measured IF frequency and that specified by the observer. A discrepancy results in a ULO error (Table 9-5). Actually, only IF channels A and C are checked by the computer. The accuracy of these checks is ±300 Hz.

For continuum observations, secondary outputs from the IF processor are available with wider bandwidths and a center frequency of 150 MHz. These secondary outputs have been used, for example, as input to the filter bank. In this connection it should be noted that four separate frequency synthesizers are used for the four channels, and so there is no phase coherence between the four output signals. Therefore it cannot be used with the IF polarimeter unless internal cabling is rearranged so that one frequency synthesizer drives both IF channels.

5.3. STANDARD CONTINUUM RECEIVER

The standard continuum receiver consists of amplifiers and square law detectors which operate at input frequencies of 5-300 MHz. The word "standard" should be taken simply to mean "analog", to distinguish it from the digital continuum receiver, just as those time pieces once thought of as standard must now be called "analog" watches. It is quite likely that the newer and more powerful digital continuum receiver will become the standard continuum receiver.

The analog outputs of the square law detectors, proportional to the total power , and/or analog outputs of synchronous detectors, proportional to the switched power in the observed bands, are fed into a multiplexed system of A/D converters which are sampled by the DDP116 computer. All the computer needs to know is the identifying number of the first A/D converter to sample, and the total number of data channels present. The computer assumes that the other data channels are on those A/D's which immediately follow that of the first channel. For example, if four receivers are in use with the first going to A/D number 8, then the other receivers are assumed to be on A/D's 9, 10, and 11. All other aspects of the setup of this receiver are quite well standardized, and are set by the installing engineer.

The gain of the receiver is set according to the <u>full scale temperature</u>, which is that antenna temperature which will saturate the receiver. Adjustment of the full scale temperature during the course of an observing program to allow observations of very strong continuum sources is a routine procedure for the telescope operators, <u>if a new full scale temperature is suggested by the observer</u>.

5.4. DIGITAL CONTINUUM RECEIVER

The digital continuum receiver (DCR) is a receiver built around a powerful Hewlett-Packard calculator. The DCR is described in a separate manual [57], and so only a general description will be given here. This system is a post-detection synchronous demodulator which can operate at switch rates of up to 500 Hz and can provide a variety of switching combinations, such as load or beam switching with or without calibration and noise adding radiometry. This receiver continuously computes the system temperature, receiver gain, and rms output noise. Any of these functions can be transmitted to the DDP116 computer along with, or instead of, the detected signal. The receiver contains amplifiers and square law detectors designed to operate at an input frequencies of 5-500 MHz, with provisions for total power inputs from external square law detectors. In either case, total power voltages are fed to voltage controlled oscillators (VCO's) followed by counters, to perform the analog to digital conversion. The calculator reads the counters, and applies an internally determined calibration factor, so that calibrated data in digital form are transmitted to the DDP116 computer.

There are many observing parameters which need to be set in the receiver's calculator. The calculator cannot read these parameters from the setup cards read into the DDP116 computer. One of these parameters is the full scale temperature to the computer, the antenna temperature at which data sent to the computer is saturated. As with the standard continuum receiver, adjustment of the full scale temperature to accommodate strong sources is an adjustment that can be made routinely by the telescope operator, if a new full scale temperature is suggested by the observer. It takes somewhat longer to adjust the full scale temperature on the DCR than it does on the standard receiver, about one minute.

5.5. VARIABLE BANDWIDTH RECEIVER

There are two primary distinctions between the variable bandwidth receiver and the standard analog receiver. These are (1) that it is easier to change bandwidths among those that are available, and (2) that the square law detectors have a very short rise time for fast sampling. This second feature makes this receiver the standard pulsar receiver. Bandwidths can be switched at the front panel to bandwidths of 10 kHz to 10 MHz in a 1, 3, 10 progression. Sample times down to 1 millisecond have been used in pulsar observations.

5.6. FABRI-TEK SIGNAL AVERAGER

The Fabri-Tek signal averager is a digital detector for periodic signals, primarily used for pulsar observations. The signal averager can be configured to sample 1, 2 or 4 input signals. The incoming signal is digitized at a rate which can be specified to a high precision, and successive samples are routed sequentially to the accumulator channels. After the last accumulator, the next sample goes back to the first accumulator for another sweep across the channels. The number of sweeps can be specified as a power of 2, up to 32 K, or 32768. The current integration can be viewed on a storage oscilloscope incorporated into the averager. At the end of an integration data taking stops so that the data can be read out to the computer. Data taking resumes after the data have been read out, without regard to the phase of the previous integration. This means that each integration begins at a different phase of a pulsar pulse, for example. The analog to digital conversion has a precision of 9 bits, and the accumulated data are read out as 16 bits.

5.7. IMPULSIVE NOISE BLANKER

A special purpose device available for continuum observations is an impulsive noise blanker. This is a device designed to remove automobile ignition, aircraft, and similar impulsive interfering signals from continuum observations, and has been found to be quite effective for this purpose [58].

5.8. 40 CHANNEL RECEIVER

The 40 channel receiver is a bank of 40 filters. Each filter has a 1 MHz bandwidth between 1 db points, and the filters are separated in frequency by 1 MHz. There is a separate square law detector for each filter. This receiver has been used for a pulsar search by combining various filter outputs to reduce the total number of outputs to eight. These outputs are then fed into the multiplexed A/D converters which are sampled by the DDP116 computer. Aside from the pulsar search group's own programs there is no software support for data obtained with this receiver. This filter bank was at one time used as a spectral line receiver, but support for that function was discontinued long ago.

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6. AUTOCORRELATOR

This discussion of the Model III correlation receiver is taken primarily from Electronics Division Internal Report No. 125, Correlation Receiver Model III: Operational Description, by A.M. Shalloway, R. Mauzy, and J. Greenhalgh, with an addendum by B. Vance [31].

6.1. SYSTEM DESCRIPTION

The receiving system described here is the equivalent of a multi-channel spectrum analyzer, and measures the power spectrum over a selected bandwidth and center frequency. It does this indirectly by first producing a one-bit autocorrelation function of the selected signal. The autocorrelation function is Fourier transformed by the on-line DDP116 computer to produce the power spectrum. The theory of digital autocorrelation receivers and a description of an early receiver are available in the literature [7].

The correlation receiver contains an IF-Filter System, an analog to digital (A/D) system, and a digital correlation system. The IF-filter system filters out a selected bandpass and heterodynes it to the video frequency range, i.e. so that one side of the bandpass is at zero frequency. This signal is clipped to provide a rectangular waveform of fixed amplitude. The only correspondence between the clipped and unclipped signal is their zero crossing points.

The clipped signal is then fed into the digital system where it is sampled at a frequency equal to twice the bandwidth. The output of the sampler is called a "one-bit" sample. It indicates only whether the signal is positive or negative. The digital system is a high speed special purpose computer which uses the sampled data to produce 384 point, 192 point, or 96 point one-bit autocorrelation and cross-correlation functions.

The correlation function is the result of an integration for a selected period of time (normally 10 seconds), as chosen by the observer. The integrated function is stored in a core memory until called for by the on-line DDP116 computer, and then the correlator starts another integration process for the next period of time.

In the process of clipping, amplitude information is lost. To recover the amplitude information, the unclipped bandpass signal is square-law detected, smoothed, and converted to a train of pulses by a voltage to frequency converter. Counters connected to the frequency converter outputs produce a count which is proportional to the total power in the received signal. These data are also sent to the on-line computer.

The on-line computer applies a clipping correction and performs an inverse Fourier transform to generate a power spectrum. The computer data are available as an on-line graph by means of a storage oscilloscope and as an output to magnetic tape and the on-line analysis computer (MODCOMP).

The operation of this system as a radio astronomy receiver can be similar to that of a continuum Dicke switched receiver. The receiver is continually switched between the signal to be observed and a reference signal. In the case of the correlation receiver, the two sets of data obtained are handled separately until it reaches the computer, at which point the reference may be added to or subtracted from the signal.

6.2. CONFIGURATIONS, BANDWIDTH, AND RESOLUTION

The autocorrelator has a total of 384 channels. These channels may be allocated to up to four receivers in four modes: (1) one receiver of 384 channels, (2) two receivers of 192 channels each, (3) two receivers of 96 channels each and one receiver with 192 channels, and (4) four receivers of 96 channels each. There are nine bandwidths available, ranging from 39.0625 kHz to 10 MHz in octave steps. The bandwidth of each receiver may be set independently.

The output spectrum produced by the on-line computer consists of computed points spaced df apart over a total bandwidth B. Each point represents the power within a filter having approximately a sin x/x shape with a half-power width W = 1.21 df, and a spacing between nulls of 2df. The relation between bandwidth, resolution, spacing and rms noise fluctuation, ΔT, is

$$df = B/N \qquad W = 1.21\ B/N \qquad (6\text{-}1)$$

$$\Delta T = \frac{3.06\ T}{\sqrt{\tau df}} \qquad (6\text{-}2)$$

where N is the number of channels (i.e., 384, 192, or 96), T is the system noise temperature, and τ is the integration time. Hanning smoothing the resulting spectrum results in a half-power width of 2df.

Equation 6-2 assumes that half of the observing time is spent on the signal spectrum and half is spent on the reference spectrum. This is the usual mode of observing since the 50/50 duty cycle gives the best sensitivity in the final spectrum. However, the correlator can run in a mode with a 90/10 duty cycle to improve the sensitivity in the signal spectrum -- the numerical constant in equation 6-2 is reduced to 1.63 -- but this advantage is lost unless at least nine reference spectra can be averaged together to obtain a comparable sensitivity. This is sometimes done in mapping programs. Current GaAsFET receivers are sufficiently stable for this scheme to work. The 90/10 duty cycle can only be used in switched power programs, but then the reference spectra cannot be obtained separately on the on-line analysis computer. Only the switched spectrum for each scan is available on-line, so the data must be reduced off-line. In the total power mode, signal and reference data (within the same scan) are simply added together to yield a single spectrum, so the 50/50 duty cycle <u>must</u> be used to give the proper weight to each portion of the data.

At the edges of a measured spectrum the rms fluctuation increases due to the attenuation at the edges of the band restriction filter in the correlator IF section. At the 6 db attenuation point the rms fluctuation doubles and data points beyond the 6 db level should be ignored. Approximately 7% of the spectrum should be dropped at each end, i.e. 25 channels out of 384, 12 channels out of 192, and 6 channels out of 96 at each end.

6.3. IF FILTER SYSTEM

The IF filter system may receive from one to four IF signals from the front-end box, provide filtering to establish the desired bandwidth, convert them to a lower frequency and clip the signals in preparation for digital processing. Other functions such as level control, gain modulation, total power detection, synchronous detection and voltage-to-frequency conversion are also included.

In each receiver, the input signal is filtered at 30 MHz and then converted to a lower frequency for the output of the next filter. The reason for the successive lowering of the frequency is to permit the final bandwidth determining filter to operate at the center frequency where its design will produce maximum cut-off slope. The filters are designed to have a sharp cutoff at the high end to minimize the aliasing of strong lines just beyond the band edge into the band. Each conversion causes the observed band of frequencies to be inverted, i.e., the internal mixers use the lower sideband. Low gain amplifiers are used between mixers and filters to correct for filter insertion losses, power loss due to bandwidth reduction and to provide an accurate source and load impedance for the filters. Diode switches are used for selecting filters and other signal paths because of their small size and low power drain.

The main signal output is a spectrum located between zero and a frequency equal to the bandwidth selected. This signal is fed to a clipper and then to the digital section for sampling and correlating. A parallel signal path through a square law detector and voltage-to-frequency converter provides an output frequency proportional to total power for counting and calibration in the digital system. The digital system furnishes switching signals to the filter system to operate the gain modulators, synchronous detectors, and test signals to the clippers.

6.4. DIGITAL UNIT

The clipper output, which is a rectangular waveform containing the frequency information of the original received signal, is sampled at a rate equal to twice the filter bandwidth (the Nyquist frequency). The sampled data are continuously stored at the end of a shift register of the appropriate length for each receiver. Each shift register feeds a one bit multiplier. The other input to the multiplier is the most recent data sample. A counter for each multiplier counts the number of correlations (both inputs positive or both inputs negative). Signal and reference counts are integrated separately. The core memory contains the following data: signal correlation function, reference correlation function, power counters, and control words. At the end of a "dump time", typically 10 seconds, an interrupt is sent to the computer and the computer can begin transferring the data.

At the beginning of a scan the correlator is synchronized to the computer by a pulse from the computer. Due to timing restrictions with interrupts from the on-line computer and data taking modes, some precautions are necessary when setting up an observing program. The two precautions that observers should be aware of are: allow at least one dump time between the end of one scan and the start of the next, and make the scan length be one second longer than a multiple of the integration period to insure that the data from the last integration are recorded on tape. A rule of thumb would be to allow at least 17 seconds between the end of one scan and the start of the next, and to keep successive start times from being on the same second modulo the integration time. This rule of thumb is repeated with emphasis in Section 8.2.3, where the procedure for preparing an observing card deck is given.

6.5. COMPUTER PROCESSING

There are two levels of computer processing to be discussed. The first is that of recovering properly scaled spectra from the normalized autocorrelation functions, and the second is that of the differencing schemes used to improve baselines.

The data received by the on-line DDP116 computer is processed in four major steps: (1) the one-bit autocorrelation function is normalized so that the value of the zero delay channel is one, and long delay channels tend to zero, (2) a correction for clipping (the van Vleck correction) is applied to each channel, (3) the corrected values are Fourier transformed, and (4) the spectrum is flipped end-for-end, if necessary, to correct for band reversals in the IF section. Data for each receiver are handled separately. The Fourier transform used has the property that the center of the band is in channel N/2 + 1, where N is the number of channels for that receiver.

The spectra are converted to temperature units by multiplying by the system temperature. The appropriate system temperature is the sum of receiver noise temperature, antenna signal temperature, and ½ the calibration noise source temperature, all averaged over the receiver bandwidth. This quantity can be computed by comparing the total power counters with the calibration noise source on and off, and knowing the calibration noise source in temperature units:

$$T_{sys} = \frac{P_{on} + P_{off}}{2(P_{on} - P_{off})} T_{NS} \qquad (6\text{-}3)$$

where T_{NS} is the calibration noise source excess temperature.

A differencing technique is usually used to improve spectral baselines. Each receiver generally has two sets of arbitrarily scaled numbers: a signal spectrum S_i, and a reference spectrum R_i. The basic difference between spectral line observing techniques is how R_i is obtained. In the total power mode, the reference spectrum is obtained in a different region of the sky as a separate scan. If possible, the telescope should track the same path in the hour angle-declination plane. In the frequency switched mode, the reference spectrum is taken in a different part of the receiver bandpass. The computer driven L.O. is used to switch back and forth between signal and reference bands at a rate of 1 Hz, typically, during a single scan. In either case, the calibrated difference spectrum is obtained from

$$T_i = \frac{S_i - R_i}{R_i} T_{sys} \tag{6-4}$$

Equation 6-4 provides a first order correction for the large scale instrumental profile. The assumptions which go into this calibration procedure are that the system temperature is uniform across the signal and reference passbands and that the signal to reference gain ratio in each channel is the same for all channels. Usually these assumptions are good to first order, but if a strong line is in the signal, or particularly the reference, or if widely separated parts of the frontend bandpass are used for frequency switching, or if the on source position contains a strong continuum source in total power, these assumptions may break down. A simple baseline subtraction will not necessarily compensate for differential gain across the passband.

In the total power mode, signal and reference spectra are obtained in separate scans, and the data passed to the on-line analysis computer are S_i and R_i in temperature units. The calculation in equation 6-4 must then be invoked by the observer in the on-line analysis computer. In the frequency switched mode of observing, however, the calculation of T_i is performed in the on-line DDP116 computer, and the signal and reference spectra are not available for separate processing.

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7. INTERFERENCE

Man-made and natural wideband interference such as ignition, power line and computer noise, oscillating TV boosters, relay arcing, and local thunder storms can be a severe problem when observing below 1 GHz. Although most of this noise has a very steep spectrum, it is sometimes strong enough to affect continuum observations at 21 cm. Since new man-made noise sources occur continually, an observer intending to make measurements below 1 GHz which would be affected by wideband noise should notify the Interference Office, Electronics Division, at least 2 weeks in advance so that steps can be taken to identify and alleviate the worst problems. Because the radiometers on the telescope are much higher above ground and more sensitive than those available in the mobile interference truck and at the lab, many of the problems will not show up until the receiver is installed on the telescope. If a problem is then encountered, the observer should seriously consider contributing some observing time, if necessary, to help find the source of interference. The Observatory personnel are on hand to help in any way possible, but they need as much information as the observer can provide.

Narrow-band interference is much more of a problem at lower frequencies, but errant radar signals or mixing products of lower frequency signals can occur at higher frequencies. Between 500 and 1000 MHz, band widths of 10 MHz or so can be used as long as one is careful to choose a clear frequency. Below 500 MHz band widths of 1 or occasionally 3 MHz are the maximum usable in most cases without encountering frequent bursts of aircraft transmissions. If one is confined to operating at a specific frequency, chances are high that a significant interfering signal will be within a few MHz of this frequency.

In general, interference originates in four categories of sources:

1. Internal to the radiometer in use, e.g., birdies, instabilities, etc.
2. Other radiometers and electronic equipment on the Green Bank site.
3. Government and nongovernment authorized transmitters within and outside the National Radio Quiet Zone (NRQZ).
4. Unintentional sources, natural and man-made.

7.1. INTERFERENCE INTERNAL TO THE RADIOMETER

Occasionally internal "birdies" or receiver instabilities appear to be external interference (or vice versa). Many types of interference are obviously external. Examples are: (1) Intermittent spectral spikes visible in the IF spectrum analyzer; (2) radar pulses or power line corona or ignition pulses or lightning crashes visible on the total power vs. time oscilloscope and/or audible on the audio monitor. If in doubt, ask the receiver engineer to check.

7.2. INTERFERENCE FROM ELECTRONIC EQUIPMENT ON GREEN BANK SITE

Most of our radiometers are potential sources of narrow-band interference. The most likely sources of interference are from high-level signals leaking from telescope coaxial cables. Examples are the Universal Local Oscillator (ULO) in the 1 to 2 GHz range and several upconverter pumps. The interferometer transmits to and from the 45 foot on several frequencies near 1300 MHz and at 14.5 GHz. Also, harmonics of the 70 MHz clock in the interferometer digital delay are observed up to nearly 2 GHz.

Table 7-1 lists, by frequency, potential interference of electronic equipment. This list is updated periodically. If in doubt, check with the Interference Office. Spectral line observers should check this list before observing. Note that only a few of these signals will exist at any one time and most have never been seen as interference.

7.3. AUTHORIZED TRANSMITTERS

Transmitters are authorized in the U.S. throughout the radio frequency spectrum except for the very few primary-exclusive and primary-passive radio astronomy bands. All U.S. Government transmitters are authorized by the FCC.

Only applications for new and modified fixed permanent transmitters within the NRQZ are reviewed by NRAO and kept at or below the criteria for allowable power density at Green Bank. A NRQZ Fact Sheet which lists the criteria is available from the Interference Office. The NRQZ procedures do not apply to temporary, mobile, airborne, balloon or satellite transmitters. Therefore, most interfering transmitters are beyond control by the NRQZ. Many interfering fixed transmitters on frequencies below 400 MHz are located outside the NRQZ. Some interfering transmitters inside the NRQZ are "grandfathered" in, such as those in the 73.0 - 74.6 MHz exclusive radio astronomy band. Spectral line observations will detect signals far below the NRAO/NRQZ criteria for frequencies outside the radio astronomy bands.

The primary benefit of the NRQZ is that it controls the signal levels from fixed transmitters inside the zone to prevent radiometer overload at frequencies below 470 MHz, to minimize potential interference at frequencies above 470 MHz, to further minimize interference in the radio astronomy bands, and thus reduce the interference level from what it would be without the NRQZ.

The Interference Office, room 107 in the Jansky Lab, keeps TNIA lists of all known U.S. Government and non-government fixed transmitters located inside the NRQZ. The lists are updated once a year. The old Green Bank "Quik Look" list is discontinued.

Since 1971, several interference surveys have been made. Those older than 2 or 3 years are obsolete. In 1981 surveys of rather low sensitivity were made in the 70-75 MHz and 1000-2000 MHz ranges. Contact the Interference Office for copies of those and more recent surveys. Table 7-2 summarizes the major interference-loaded bands in the 70 to 2000 MHz range.

Table 7-3 lists the WARC-79 Radio Astronomy Allocations for the U.S. up to 26 GHz. The WARC-79 allocations became effective in January 1982 but will not be implemented in the U.S. until later. Extra footnotes in Table 7-3 indicate the bands which have detectable signals. Table 7-3 is adapted from V. Pankonin, "Protecting Radio Windows for Astronomy", Sky and Telescope, April 1981.

7.4. UNINTENTIONAL SOURCES, NATURAL AND MAN-MADE

A troublesome type of interference is unintended radiation from various sources, especially at frequencies below 1 GHz. Obviously, NRAO has no control over natural sources such as lightning, sun, atmosphere and ionosphere. But we do have a degree of control over local man-made sources such as ignition, welding, power-line arcing, oscillating TV boosters, arcing switches and relays, computers, various on site electronic equipment, etc. For example, the interferometer links and digital delay system can be shut down by advance telescope scheduling.

The Green Bank staff person responsible for Local Interference Control tries to locate and eliminate potential interference from power lines and oscillating TV boosters, etc. An observer or telescope operator suspecting interference from local sources should immediately contact the Local Interference Control staff person via the Interference Office, Green Bank extension 107.

FREQ MHZ	STATUS	POTENTIAL SOURCE	LOCATION
43	•	VHF FM COMMUNICATIONS TX	REBER
50	P	CASS RX, 6/25 CM RX	140'
70	P	DIGITAL-DELAY CLOCK	INT
100	P	CASSEGRAIN RX	140'
100	P	HYDROGEN MASER	140'
100	•	VLB MRK II, VLB LO	140' OR 300'
100 - 160	P*	IF PROCESSOR LO	300'
100 - 500	P*	AUTOCORRELATOR MRK IV LO	140'
100 - 500	*	VLB MRK III	140' OR 300'
100 - 90000	•	ANTENNA PATTERN RANGE	LAB
103	P	IF PROCESSOR	300'
115	P	IF PROCESSOR	300'
120	P	AUTOCORRELATOR MRK III	300'
122.8	•	AIR-STRIP INTERCOM TX	JANSKY LAB
140	P	*2 HARMONIC DIG DELAY CLOCK	INT
200	P	CASSEGRAIN RX LO	140'
200 - 300	P	COMPUTERS (BROAD BAND)	140', 300', INT
210	P	*3 HARMONIC DIG DELAY CLOCK	INT
250 - 500	P*	ULO SYNTHESIZER	140', 300', LAB
280	P	*4 HARMONIC DIG DELAY CLOCK	INT
350	P	*5 HARMONIC DIG DELAY CLOCK	INT
420	P	*6 HARMONIC DIG DELAY CLOCK	INT
490	P	*7 HARMONIC DIG DELAY CLOCK	INT
550		.3 - 1 GHZ RX LO	140' OR 300'
560	P	*8 HARMONIC DIG DELAY CLOCK	INT
630	P	*9 HARMONIC DIG DELAY CLOCK	INT
700	P	*10 HARMONIC DIG DELAY CLOCK	INT
770	P	*11 HARMONIC DIG DELAY CLOCK	INT
840	P	*12 HARMONIC DIG DELAY CLOCK	INT
910	P	*13 HARMONIC DIG DELAY CLOCK	INT
980	P	*14 HARMONIC DIG DELAY CLOCK	INT
1000 - 1600	P*	IF PROCESSOR LO	300'
1000 - 1850	*	6/25 CM RX LO	140' OR 300'
1000 - 2150	*	1 - 2 GHZ RX LO	140' OR 300'
1000 - 2000	P*	ULO	140', 300', LAB
1030	P	IF PROCESSOR	300'
1050	P	*15 HARMONIC DIG DELAY CLOCK	INT
1050 - 1200	*	2 - 4 GHZ RX LO	140' OR 300'
1120	P	*16 HARMONIC DIG DELAY	INT
1150	P	IF PROCESSOR	300'
1190	P	*17 HARMONIC DIG DELAY CLOCK	INT
1200 - 2000	*	COOLED FET 18 CM OH RX LO	140' OR 300'
1250	•	CAS A CALIBRATION RX LO	CALIBRATION HORN
1250		.3 - 1 GHZ RX, UC PUMP	140' OR 300'
1260	P	*18 HARMONIC DIG DELAY CLOCK	INT
1278 - 1886	*	CASSEGRAIN RX LO	140'
1300	P	LINK TO 45'	INT TOWER
1300 - 1550	*	2 - 4 GHZ RX	140' OR 300'
1317.5	P	INTERFEROMETER LO	85' -1, -2, -3
1330	P	*19 HARMONIC DIG DELAY CLOCK	INT
1347.4	P	LINK FROM 45'	45'
1347.5	P	INTERFEROMETER LO	85'-1, -2, -3
1347.5		11 CM 3-FEED RX LO	300'
1347.6	P	LINK TO 45'	INT TOWER
1350		.3 - 1 GHZ RX, UC PUMP	140' OR 300'
1350 - 1650	*	COOLED FET 21 CM RX LO	140' OR 300'
1400	P	*20 HARMONIC DIG DELAY CLOCK	INT
1400		.3 - 1 GHZ RX, UC PUMP	140' OR 300'
1400	P	HYDROGEN MASER	140'
1427 - 1443	*	9 CM RX, LINE LO	140' OR 300'
1435		9 CM RX, CONTINUUM LO	140' OR 300'
1450 - 1650	*	21 CM 4-FEED RX VARIABLE LO	300'
1470	P	*21 HARMONIC DIG DELAY CLOCK	INT
1540	P	*22 HARMONIC DIG DELAY CLOCK	INT
1560 - 1720	*	2 - 4 GHZ RX LO	140' OR 300'
1610	P	*23 HARMONIC DIG DELAY CLOCK	INT
1633 - 1733	*	.3 - 1 GHZ RX LO	140' OR 300'
1650 - 1950	*	2 - 4 GHZ RX LO	140' OR 300'
1680	P	*24 HARMONIC DIG DELAY CLOCK	INT
1750	P	*25 HARMONIC DIG DELAY CLOCK	INT
1802 - 1818	*	9 CM RX, LINE LO	140' OR 300'
1810		9 CM RX, CONTINUUM LO	140' OR 300'
1820	P	*26 HARMONIC DIG DELAY CLOCK	INT
1890	P	*27 HARMONIC DIG DELAY CLOCK	INT
1980	P	*28 HARMONIC DIG DELAY CLOCK	INT
2100 - 2400	*	2 - 4 GHZ RX LO	140' OR 300'
2600 - 3100	*	2 - 4 GHZ RX LO	140' OR 300'
2695	P	INTERFEROMETER LO	85' - 1, -2, -3
2695		11 CM 3-FEED RX LO	300'
2854 - 2886	*	9 CM RX, LINE LO	140' OR 300'
2870		9 CM RX, CONTINUUM LO	140' OR 300'
3300 - 3800	*	6/25 CM RX LO	140' OR 300'
3300 - 3900	*	2 - 4 GHX RX LO	140' OR 300'
3604 - 3636	*	9 CM RX, LINE LO	140' OR 300'
3620		9 CM RX, CONTINUUM LO	140' OR 300'
5390	P	INTERFEROMETER PUMP	85' -1, -2, -3
5390		11 CM 3-FEED RX PUMP	300'
8085	P	INTERFEROMETER LO	85' -1, -2, -3
9000	P	CASSEGRAIN RX LO	140'
10000-10340		2 - 4 GHZ RX PUMP	140' OR 300'
11320-11390		2 - 4 GHZ RX PUMP	140' OR 300'
14000	P	CASSEGRAIN RX LO	140'
16000	P	CASSEGRAIN RX LO	140'
16170	P	INTERFEROMETER PUMP	85' -1, -2, -3
16900 - 17100	P	INT LINK TO/FROM 45'+14.2M	INT, PASSIVE REF
17400 - 17600	P	45' LINK	45', PASSIVE REF
20000-22000	•	TOURIST RX LO	TOUR CENTER
18000-26500	*	CASSEGRAIN RX LO	140'
33000-50000	*	CASSEGRAIN RX MASER PUMP	140'

P = ON SEMI-PERMANENTLY

* = MOVES AROUND DURING OBSERVING

• = INTERMITTENT USAGE

TABLE 7-1

INTERFERENCE POTENTIAL OF EQUIPMENT AT GREEN BANK

OCTOBER 1982

TABLE 7-2

Frequency Bands with Strong Interference

70 - 108	MHz	Communications, TV broadcast, FM broadcast.
108 - 118	MHz	Aircraft navigation beacons.
118 - 136	MHz	FAA aircraft communications.
136 - 138	MHz	Satellite down-link.
138 - 174	MHz	Communications (fixed, mobile, amateur, satellite).
174 - 216	MHz	TV broadcast.
216 - 225	MHz	Communications (fixed, mobile, amateur).
225 - 400	MHz	Communications (fixed, mobile, aircraft).
400 - 406	MHz	Satellite down-link, radiosonde balloon (403.0 MHz).
410 - 420	MHz	Communications (fixed, mobile).
420 - 450	MHz	Radar, amateur, satellite.
450 - 470	MHz	Satellite, mobile communications.
470 - 512	MHz	TV broadcast, mobile communications.
512 - 960	MHz	Weak signals: TV broadcast, mobile communications.
960 - 1150	MHz	VORTAC navigation.
1245 - 1300	MHz	FAA radar; link to 45-foot at 1300 MHz.
1255.76 & 1292.01 ± 3.5	MHz	FAA radar, Washington Center.
1347.4 - 1347.6	MHz	Interferometer 45-foot link.
1400.0	MHz	Interferometer Digital Delay harmonic.
1427 - 1470	MHz	Satellite, communications (fixed, mobile).
1559 - 1636	MHz	Radar
1636.5 - 1660	MHz	Satellite
1660 - 1700	MHz	Balloon radiosonde, satellite.
1677 - 1683	MHz	NOAA radiosondes, twice daily.
1700 - 1710	MHz	Satellite

TABLE 7-2 (Cont.)

Frequency Bands with Intermittent Interference	
406 - 410 MHz	Radio astronomy; weak signals from communications (fixed, mobile).
902 - 928 MHz	Motion detecting intrusion alarms.
2400 - 2500 MHz	Microwave ovens, intrusion alarms.
2800.0 MHz	NOAA Weather Radar at Charleston, WV.
2890.0 MHz	NOAA Weather Radar at Bolens, VA.
2980.0 MHz	NOAA Weather Radar at Pittsburgh, PA.
4800 - 5000 MHz	Second harmonic of microwave ovens.
5785 - 5815 MHz	Motion detecting intrusion alarms (46 mW ERP).
5925 - 6425 MHz	Point-to-point microwave (telephone) and satellite uplink.
7200 - 7500 MHz	Third harmonic of microwave ovens.
10500 - 10550 MHz	Intrusion alarms and police radar (1.2 W ERP).
24075 - 24175 MHz	Intrusion alarms and police radar (1.2 W ERP).

TABLE 7-3

INTERNATIONAL RADIO ASTRONOMY ALLOCATIONS IN THE UNITED STATES (WARC-79)

Frequency	Footnote	Use
13 360 - 13 410 kHz	Primary shared with active [2]	Cont.
25 550 - 25 670 kHz	Primary exclusive (special)	Cont.
37.5 - 38.25 MHz	Secondary [2]	Cont.
73 - 74.6 MHz	Primary exclusive *	Cont.
322 - 328.6 MHz	Primary shared with active [2]†	Cont. and D
406.1 - 410 MHz	Primary shared with active [2]	Cont.
608 - 614 MHz	Primary (active secondary)	Cont.
1330 - 1400 MHz	Notification of Use [2]	H
1400 - 1427 MHz	Primary -- passive band [1]	H
1610.6 - 1613.8 MHz	Secondary [2] +	OH
1660 - 1660.5 MHz	Primary shared with active [2]+	OH
1660.5 - 1668.4 MHz	Primary (active secondary) [2]+	OH
1668.4 - 1670 MHz	Primary shared with active [2]+	OH
1718.8 - 1722.2 MHz	Secondary [2]	OH
2655 - 2690 MHz	Secondary [2]	Cont.
2690 - 2700 MHz	Primary -- passive band [1]	Cont.
3260 - 3267 MHz 3332 - 3339 MHz 3345.8 - 3352.5 MHz	Notification of Use [2]	CH
4800 - 4990 MHz	Secondary [2]	Cont. and H_2CO
4990 - 5000 MHz	Primary shared with active [2]	Cont.
10.6 - 10.68 GHz	Primary shared with active [2]	Cont.
10.68 - 10.7 GHz	Primary -- passive band [1]	Cont.
14.47 - 14.5 GHz	Secondary [2]	H_2CO
15.35 - 15.4 GHz	Primary -- passive band [1]	Cont.
22.01 - 22.21 GHz	Notification of Use [2]	H_2O
22.21 - 22.5 GHz	Primary shared with active [2]	H_2O
22.81 - 22.86 GHz 23.07 - 23.12 GHz	Notification of Use [2]	NH_3
23.6 - 24 GHz	Primary -- passive band [1]	Cont. and NH_3

Footnote Types: [1] All emissions in the band between the frequencies listed are prohibited.
[2] In making assignments to stations, administrations are urged to take all practicable steps to protect radio astronomy from interference. Emissions from space of airborne stations can be particularly serious sources of interference.

These are the common names of atomic and molecular species in the table:
Cont. = continuum; D = deuterium, H = hydrogen, OH = hydroxyl, CH = methylidyne, H_2CO = formaldehyde, H_2O = water, NH_3 = ammonia, H^+ = ionized atmoic hydrogen, SiO = silicon monoxide, CS = carbon monosulfide, HN_3^+ = unnamed, CO = carbon monoxide, DCN = deuterium cyanide, NO = nitric oxide, C_2H = ethynyl radical, HCN = hydrogen cyanide, HCO^+ = "X-ogen."

All radio astronomy bands below 10 GHz have had occasional interference at Green Bank.

* "Grandfathered" signals at Green Bank.
\+ Radar, satellite, and/or balloon radiosonde signals at Green Bank.
† U.S. will <u>not</u> implement footnote [2].

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8. POINTING UNDER COMPUTER CONTROL

There are two computers involved in pointing the telescope, and both need certain input information if they are to work properly. This chapter is therefore divided into two major sections, each devoted to the input of a single computer.

At the more basic level is the H316 computer which performs the coordinate transformations. It needs to know the right ascension and declination pointing correction curves, the nominal level curve, the focal length of the telescope, and beam deflection factors for the Sterling mount and travelling feed (see Chapter 4). Cards containing nominal values for all of these items are already present at the telescope, except for those receiver/feed combinations that have never been pointed. Optional pointing corrections can be read into the H316 if the observer has made some pointing checks (see Chapter 4 for recommended procedures). The card formats for H316 instructions are described in section 8.1.

The DDP116 computer operates more at a supervisory level, and the particular concern of section 8.2 is that of scheduling an observing program to take data while the telescope is on source; that is, preparing a deck of source cards. Without this there is no observing program. There are two basic ways to point the telescope during an observation: (1) to track a source, or (2) to scan across the source. Tracking is more closely associated with line observing while scanning is more closely associated with continuum observing, but this association is not absolute. Both pointing modes are available in a number of different coordinate frames. The various pointing modes that are available, and their associated source card formats are discussed in section 8.2, along with comments on scheduling, and computer programs available to assist in scheduling.

8.1. ENTERING POINTING CORRECTIONS

Chapter 4 consisted of a discussion of the origin of pointing errors and the methods of correcting these errors. Basically, position encoders mounted on the telescope are part of a feedback loop for keeping the telescope on position. The position encoder readings give the indicated coordinates of the telescope position. These are close to the true or apparent coordinates on the sky, but differ due to encoder offsets, axis misalignments, and deformations of the telescope structure due to gravity and differential heating by the sun. The apparent coordinates of a celestial source can be found in a straightforward way, but the pointing errors must be known to determine what indicated coordinates should be commanded. The difference between apparent and indicated coordinates is the pointing correction. Since the pointing corrections are small, right ascension and declination pointing corrections are treated separately. The pointing corrections are implemented as functional forms with coefficients that can be varied. The H316 computer, which performs the coordinate transformations, must read the coordinates of these functional forms from cards. This section describes the content and format of those cards. A sample H316 input card deck is shown in Figure 8-1.

A typical H316 input card sequence consists of right ascension pointing curve coefficients (read from an "A" card), declination pointing curve coefficients ("D" card or cards), nominal level curve coefficients ("L" card), and focal length, beam deflection factors, critical angles, and additional beam deflection factors for the travelling feed and Sterling mount ("T" card). There are different sets of declination pointing curve coefficients for different receiver/feed combinations, so there can be a number of "D" cards, each carrying a two character identifying code. Instructions given to the DDP116 computer (on "S" cards, see Chapters 9 and 10), tell which set of declination coefficients the H316 is to use.

Chapter 4 also described pointing corrections called PVALS, and how to determine them. They are used to correct for small feed offsets, which may change when a receiver is re-installed. They may be read into the H316 on a "P" card. IF PVALS ARE NOT USED MAKE SURE THAT A "P" CARD WITH ZEROES IS IN THE H316 INPUT CARD DECK.

8.1.1. RIGHT ASCENSION POINTING CURVE COEFFICIENTS: "A" CARD

The right ascension pointing correction equation is

$$\Delta\alpha = m + n \tan(\delta) + c \sec(\delta) \qquad (8\text{-}1)$$

where δ is the indicated declination, and where $\Delta\alpha$, m, n, and c are in seconds of time. This is the offset equation for a transit circle whose axis is displaced from true east-west and from the horizontal. The current values of m, n, and c are listed in Table 8-1, and are entered into the H316 computer on an "A" card. The "A" card format is given in Table 8-2. A nominal right ascension pointing correction curve is plotted in Figure 8-2.

8.1.2. DECLINATION POINTING CURVE COEFFICIENTS: "D" CARD

The declination pointing correction equation is more complex than the right ascension pointing correction because the dish deformations are not easily modeled. The equation is

$$\Delta\delta = C_0 + C_1\ \delta + C_2\ \delta^2 + C_3\ \delta^3 - \Delta L \qquad (8\text{-}2)$$

where $\Delta\delta$ is in arc seconds, C_0, C_1, C_2, and C_3 are the pointing coefficients for a particular combination of receiver and feed, and ΔL is the level curve correction, described below. Particular sets of declination pointing coefficients are identified by a two character identifier. The most recently determined coefficients are given in Table 8-1. Ask the "Friend" about more recent updates to the pointing coefficients. The declination pointing coefficients are entered via a "D" card. The "D" card format is given in Table 8-3, along with a list of the identifiers recognized by the program. Identifiers listed in Table 8-3 but not in

Table 8-1 correspond to receivers that have not been pointed. Typical declination pointing correction curves are plotted in Figure 8-3.

8.1.3. LEVEL CURVE COEFFICIENTS: "L" CARD

An electronic level mounted on one of the telescope support towers measures the structural tilt in the north-south direction. Part of the tilt as a function of declination is due to the fact that the telescope is not perfectly balanced, and so there is an unavoidable bending of the structure. The level curve is this nominal relationship between the electronic level reading and the indicated declination. The declination pointing correction equation takes this effect into account. However, the telescope also tilts due to the uneven heating by sunlight and due to wind, and these effects are not accounted for in the nominal declination corrections. This extra tilt is the measured level reading minus the nominal level curve:

$$\Delta L = \bar{L} - (L_0 + L_1\delta + L_2\delta^2 + L_3\delta^3) \qquad (8\text{-}3)$$

where ΔL is in arcseconds, δ is the indicated declination, $\bar{L}$ is the ten second average level reading, and L_0, L_1, L_2, and L_3 are the nominal level curve coefficients. The current values of the level curve coefficients are listed in Table 8-1, and are entered into the H316 via an "L" card. The "L" card format is given in Table 8-4. A positive level correction is in the sense of a northward tilt, and so the level correction is subtracted from the declination correction. A typical level curve is plotted in Figure 8-4. Experience has shown that the shape of this curve is quite stable but that the zero point changes with time. It is not known whether these changes consist of a continuous drift or discrete jumps.

8.1.4. BEAM DEFLECTION DATA: "T" CARD

Besides the information on the "A" card, an additional right ascension pointing correction is necessary for observing off axis. The beam deflection factor (BDF) is the ratio of the angular displacement of the beam to the angular displacement of the feed in the east-west direction. At large feed displacements, obtainable only on the travelling feed, the BDF changes abruptly. The critical angle is the angular distance of the feed where the BDF changes. A third parameter tells the computer the change in slope at this critical distance as a fraction of 2^{15}:

$$\Delta BDF = \frac{\Delta T}{T} \times 2^{15} \qquad (8\text{-}4)$$

where ΔT is the pointing error in seconds of time incurred by using the central BDF and T is the time in seconds from the critical angle to the time of observation. The computer uses the focal length of the telescope, 1525.0 inches, to compute the angular displacement of the feed. All of these data are entered on a "T" card, short for travelling feed. The format for the "T" card is given in Table 8-5. Nominal values are given in Table 8-1.

8.1.5. PVALS: "P" CARD

Corrections for small feed offsets may be entered as PVALS, i.e., P_1, P_2, and P_3. These extra coefficients enter the pointing equations as

$$\begin{aligned} \Delta\alpha &= (m + P_2/4) + n \tan(\ \delta\ ) + (c + P_1/4) \sec(\ \delta\ ) \\ \Delta\delta &= (C_0 + 60\ P_3) + C_1\delta + C_2\delta^2 + C_3\delta^3 - \Delta L \end{aligned} \qquad (8\text{-}5)$$

The procedure for determining the PVALS was given in Chapter 4. The PVALS are entered on a "P" card, the format of which is given in Table 8-6.

8.1.6. TRAVELLING FEED RECEIVER OFFSETS: "B" CARD

Although the box offset card, or "B" card, is input into DDP116 rather than the H316, it is worth mentioning at this time because of its effect on pointing and its effect on scheduling. The travelling feed box (0.3-1 GHz) allows two feeds to be installed for observations at 300-500 MHz or 500-700 MHz, and 700-1000 MHz. The two feeds are physically offset from center by ±34 inches, so that the whole box must be moved to get either feed on axis. The 300-700 MHz receiver is located East on the box (-34 inches), and the 700-1000 MHz receiver is located West on the box (+34 inches). These offsets are entered on a "B" card in the observer's setup deck for the DDP116 computer, which passes the value to the H316. The "B" card format is given in Tables 9-3 and 10-5.

The effect of the box offsets on the hour angle limits of this receiver is discussed in Appendix D. The point to remember is that for a tracking scan the source peaks up at the box offset. For example, the two low frequency feeds peak up at -34 inches of travel. This means that a source can be tracked for less time before transit and more time after transit. The 98 inches of travel before transit correspond to 12^m20^s sec δ of right ascension, and the 166 inches of travel after transit correspond to 20^m55^s sec δ. The calculations for the high frequency side of this receiver give the reverse answers. It is advisable to calculate these maximum offsets in beamwidths, heeding the advice of section 3.3.1 that there is little to be gained by tracking more than 5 HPBW's off axis, due to the loss of aperture efficiency.

8.2. SEQUENCING AN OBSERVING PROGRAM: SOURCE CARDS

The DDP116 computer performs the task of implementing an observing program. To do this it reads instructions from cards, and acts on them sequentially. Each source card contains pointing instructions and equally important timing instructions. The computer will record data between the specified start and stop times. There is a variety of source card formats, as shown in Figure 8-5. The format for interpreting source cards is coded onto the card as the position code or pointing mode. Part of the variety in pointing modes is due to the number of different coordinate frames in which pointing and timing instructions can be specified, and part is due to variations on the themes of tracking a position on the sky and scanning across the sky. The different coordinate frames were discussed in Chapter 4, and are reviewed here before going on to sections which discuss in general terms the limitations on tracking and scanning imposed by the telescope hardware itself. The restrictions on tracking are only a subset of those on scanning, and so an observer planning to observe in a scanning mode should first read the section on tracking. A third section describes the available pointing modes, and a fourth section describes computer programs available to assist in preparing decks of source cards.

The telescope position may be commanded in a number of coordinate frames of reference. The H316 computer performs the computations necessary to convert from one frame to another. The four frames that are used are epoch, apparent or true, indicated, and galactic. The epoch coordinate frame consists of positions in equatorial coordinates at a given epoch. The only epoch now available is 1950.0. The apparent coordinate frame consists of positions in equatorial coordinates at the epoch of the observations. The difference between epoch and apparent coordinates is precession, aberration, and nutation from 1950.0 to the epoch of the observations. The indicated coordinate frame consists of positions as indicated by the position encoders on the telescope. Quite literally, the indicated coordinates are "what the dials read." The differences between apparent and indicated coordinates are due to slight misalignments in the telescope axes, encoder offset errors, and deformations of the telescope structure due to gravity and differential heating by the sun. The galactic coordinate frame consists of positions in new galactic coordinates. These coordinates are transformed to 1950.0 equatorial coordinates, and then treated as epoch coordinates. That is, they are precessed to the present epoch and pointing corrections are added.

8.2.1. TRACKING MODES

The most fundamental limitation on tracking, of course, is that the 300 foot was designed as a transit instrument. Tracking in right ascension is accomplished by moving the feed in the focal plane. There are two feed carriage systems. One is a 14 m, fixed focus east-west set of rails, called the travelling feed, used for frontends below 1 GHz. The other, called the Sterling mount, is a more accurate mount for radiometers above 1 GHz and is capable of focusing, rotation and east-west translation up to 45 cm on either side of the telescope axis.

Hour angle limits are ±15 inches or about $\pm 2^m \sec \delta$ around the telescope's meridian on the Sterling mount (used above 1 GHz) and are ±275 inches or about $\pm 28^m \sec \delta$ on the travelling feed carriage. Hour angle limits using the 300-1000 MHz carriage on the travelling feed are ±132 inches (reference: Appendix D), allowing a total tracking time of about $33^m \sec \delta$, but the feeds are offset from the center of the box making the tracking limits asymmetrical (see section 4.2.3). The limits in terms of time are very slightly dependent on frequency and aperture illumination as explained in the section on beam deflection factor. Here again it should be remembered that precession and pointing corrections will make these limits asymmetric about the true or 1950 meridian.

The primary indicated declination limits are nominally +89°50' and -18°30' but may vary by a few arcminutes depending on temperature. Indicated coordinates are those indicated by the position encoders on the telescope structure, but they are quite close to the actual position on the sky. Beyond these limits the telescope can be driven manually to back-up limits of +91°04' and -19°30' with the variable speed motor. When operating in card control mode, it should be remembered that these limits are indicated and a 1950 or true position may be beyond the limits after precession and/or pointing corrections are applied. If a primary limit will be encountered, the telescope will not move under computer control from the current position.

Another important limitation on the scheduling of an observing program is the time it takes to move from one source to the next. When a series of cards is read into the computer, the first card is acted upon immediately and the second takes control at the stop time of the first and so forth. Sufficient time must be allowed for movement of the telescope in declination at 10°/minute plus about 5 seconds for position trim, and in hour angle at the rate of 30 inches per minute (240^s H.A./min at the equator) on the Sterling mount and 90 inches per minute (720^s H.A./min at declination = 0°) on the travelling feed [32], plus 4 or 5 seconds for trim. The trim time may be reduced if a position error of a few arc minutes can be tolerated at the start of a scan. Two motors are used for declination drive. One provides continuously variable speeds from 0 to 2°.25/minute (0 to 135'/minute), and the slew motor has a fixed nominal speed of 10°/minute. A three second time delay is built into the declination drive system to allow for telescope deceleration before reversal of direction of travel or speed change. A rule of thumb for slewing to a new position is to add five seconds to the time required to slew at 10°/min for deceleration and position trim. Additional time may also be required for receiver adjustments.

There are two pointing modes available for tracking. Both require source positions in epoch 1950.0. The difference between them is that in one mode (mode 8), start and stop times are specified as local sidereal times (LST) at the epoch of the observations. In the other mode (mode 18), start and stop times are specified as 1950.0 LST times. This choice of start and stop time frames of reference is available for declination scans as well.

The advantage of scheduling start and stop times in 1950.0 LST times is that it is very simple to set up the maximum length observation. The declination gives the maximum length of time that a particular source can be tracked. Subtracting half of this time from the 1950.0 right ascension gives the earliest possible start time, and adding half of the scan length to the right ascension gives the latest possible stop time. There may be other restrictions on the scan length, for example those imposed by the autocorrelator, but it is still easier to schedule a single scan in mode 18, with 1950.0 start and stop times.

The advantage of scheduling start and stop times in current LST times becomes apparent in a schedule with many sources closely spaced in right ascension. The scheduling of such as observing program will very much depend on the time it takes to get from one source to the next. These computations are easy if start and stop times are in current LST times, but not if they are in 1950.0 LST times because of the need to precess and nutate the commanded positions to recover current start and stop times.

There are some computer programs available for preparing an observing program which make the choice of timing mode less momentous. A program called LINE300 prepares source cards with current LST start and stop times, for ease of scheduling, but also with start and stop times computed to allow for the maximum scan length. Another program, PLAN300, scans a deck of source cards, computing the time required to move to the next source, skipping down through the deck until it finds the next source that it can get to in time. These programs are described in a separate section in this chapter.

8.2.2. SCANNING MODES

All of the available pointing modes make provisions for scanning across the sky. Right ascension scanning rates may be specified for the two tracking modes described in the previous section. In the other modes, right ascension scanning is at the sidereal rate as the sky drifts by with the telescope at zero hour angle. Declination scanning rates can be specified in most of the other pointing modes.

The simplest scanning mode is the drift scan, where the telescope remains motionless while the source drifts through the beam (or beams). Ground pick-up in the sidelobes is unchanged during a drift scan, which results in good baselines for continuum observing, necessary for accurate flux determinations. The declination for a drift scan may be commanded in epoch (mode 3), apparent (mode 2), or indicated (mode 1) coordinate frames, with start and stop times specified as current LST. If an epoch declination is specified, start and stop times may also be specified as 1950.0 LST times. As was the case with the tracking modes, there is a program, PREP300, which calculates current LST start and stop times centered on the right ascension of the source, where the right ascension is given in the 1950.0 coordinate frame.

Scanning rates may be specified in most of the observing modes. The DDP116 computer sequences operations so that the computer is at the position specified on the card, moving at the specified rate, at the specified start time. The position at later times can then be determined from the initial position, time from the start of the scan, and scanning rate. This is not true if the telescope is still moving to get on source when data taking begins. In continuum observations it is possible to avoid this problem by setting a flag to delay data taking until the telescope is within 20 arcseconds of being on source by placing a "1" in column 56 on the source cards.

Source cards are acted upon sequentially, as they are read. If the time between scans is long, the computer may try to back the telescope into a limit so that the specified scanning rate will put the telescope on source at the specified start time. To avoid this problem, there is a dummy pointing mode (mode 0). When a dummy card is encountered, the telescope moves to the commanded declination and waits. The time specified in the start time field is actually a release time: at that time the computer looks at the next source card and acts upon it.

A right ascension scanning rate may be specified on cards in the two tracking modes. This allows scanning at rates other than the sidereal rate. This mode of observing is limited by the hour angle coverage of the receiver mount in use and by the drive rates of the motors. Maximum hour angle drive rates on the movable feed systems are 0.5 inches/sec (about 1°/min) on the Sterling mount and 1.5 inches/sec (about 3°/min) on the travelling feed carriage. Note that hour angle and right ascension rates are not the same due to the apparent motion of the sky.

A declination scanning rate can be specified in most observing modes. Observations to determine declination pointing are usually made while simultaneously tracking in right ascension (modes 8 and 18). Declination scans without hour angle motion can be made in pointing modes 1, 2, 3, and 13. A dummy card may be necessary to avoid commanding a position outside the telescope limits if there is a long time between scans. Any declination rate up to 130'/min may be specified in steps of 1'/min. A fast slew rate of 600'/min can be used, but the motion is less predictable because the single speed slew motor is used with no provision for vernier rate trim. If this high rate is to be used, it is best to specify a rate of about 620'/min to prevent the computed position from getting ahead of the actual position and momentarily shutting down the slew motor. One other consequence of not having rate trim at high speed is that the acceleration time of the telescope causes a lag of about 50' behind the 600'/min computed position which cannot be made up.

Wobbles (mode 6) provide a capability for alternately scanning north and south at a specified rate between two specified declination limits. One use for wobbles is to measure efficiency vs. hour angle by scanning across a continuum source a number of times, giving both the source deflection and baseline. There is a delay of 6 seconds between passing out of the declination range and re-entering it travelling in the opposite direction to allow time for reversal. Data is taken continuously, even during reversal, however.

Dummy card (0). The dummy card is used to hold the telescope at a particular declination in anticipation of further commands. Parameter 1 (Figure 8-5) is read as an indicated declination, and the time in the start time block is interpreted as a release time to execute the commands of the next card. The dummy card is useful for setting up near the start position of a variable declination scan, thus preventing the telescope from encountering a declination limit by picking up a computed track long before the start of data taking. It may also be used to set the telescope for a drift scan through a calibration source to be recorded on a chart record. No data is put on tape with this card, and the feed is automatically driven to center track.

Indicated declination card (1). This card drives the telescope to the indicated declination specified by parameter 1, and data is put on tape between the current LST start and stop times. A declination rate entered as parameter 3 in arcminutes per minute may be used to drive the telescope at a constant rate with the feed at center track. This motion is closed-loop, meaning that the commanded declination is computed at frequent intervals so that the position of the telescope at any given time is completely predictable. Any declination rate up to 130'/min may be specified in steps of 1'/min. A fast slew rate of 600'/min can be used, but the motion is less predictable because the single speed slew motor is used with no provision for vernier rate trim. If this high rate is to be used, it is best to specify a rate of about 620'/min to prevent the computed position from getting ahead of the actual position and momentarily shutting down the slew motor. One other consequence of not having rate trim at high speed is that the acceleration time of the telescope causes a lag of about 50' behind the 600'/min computed position which cannot be made up.

A feed rotation angle may also be specified on the indicated declination card as parameter 4. This angle is measured eastward from north on the sky. Slew rate for rotation angle on the Sterling mount is 13.3 degrees/second and limits are ±200°. No rotation is provided on the travelling feed mount. The position and polarization angle of the beam(s) at zero rotation angle may be found in the electronics division reports on the individual feeds, or front end boxes, or on receiver installation sheets.

True declination (2). This card has exactly the same function and controls as the indicated declination card except that parameter #1 is interpreted as true declination. The difference between true and indicated position is the declination pointing correction.

1950 declination (3). This card is identical to the indicated declination card except that parameter 1 is interpreted as 1950.0 declination. The difference between indicated and 1950.0 declination at the 300 foot is the declination pointing correction plus precession, aberration and nutation.

Constant galactic latitude (4). Position code 4 provides for scanning at a constant galactic latitude (new galactic coordinates) by moving the declination of the telescope at a slowly varying rate with the feed box at center track. The feed box is continuously rotated during the observation so as to maintain a constant galactic rotation angle. The latitude is specified by parameter 1 in decimal degrees and the angle by parameter 4. Galactic rotation angle is defined for this purpose as the angle measured counterclockwise on the sky from the direction of the north galactic pole. By pointing the center of a receiver box at a constant latitude and maintaining a constant galactic rotation angle, each beam of a multibeam frontend system follows a constant latitude. The chosen value of rotation angle should allow for variation during the observation without impinging on the rotation limits of ±200° with respect to the direction of the north celestial pole. Note that in pointing modes 4 and 5 there are problem areas in the sky where lines of constant latitude or longitude, respectively, are almost parallel to lines of constant right ascension.

Constant galactic longitude (5). With this card a constant galactic longitude (new galactic coordinates) is maintained by continuously varying the telescope declination with the feed at center track. No provision is made for automatically maintaining a constant galactic rotation angle. The coordinate l^{II} is entered as parameter 1 in decimal degrees.

Wobbles (6). The wobble card initiates a zig-zag track in the sky by driving the telescope at a rate specified by parameter 3 alternately north and south with the feed at center track. The motion is closed loop, and all of the rates and limitations outlined in this and the previous section apply here. The sign on the declination rate is ignored, and the first track is always northward. A dummy card (0) is useful in setting up just south of the south limit to allow a smooth start.

Parameters 1 and 2 are the south and north indicated declination limits, respectively, between which the wobbles are performed. There is a delay of 6 seconds between passing out of the declination range and reentering it travelling in the opposite direction to allow time for reversal. Data is taken continuously, even during reversal, however. No provision is made for card control of rotation angle.

Celestial coordinates (8). This is one of two card types which allow computer control of hour angle. Within the hour angle limits of the travelling feed or Sterling mount, a position in the sky can be tracked or scanned in right ascension and/or declination. Positions in parameters 1 and 2 are in 1950.0 coordinates, which means that the on-line computer will apply pointing corrections, precession, aberration and nutation.

Parameter 4 specifies a declination rate, and all of the limitations outlined in the indicated declination card section apply here. The right ascension rate is entered as parameter 3 in arcminutes per minute on the equator in 1'/min increments. The maximum east-west tracking rate of either the travelling feed or Sterling mount is 0.25 inches/s or about +3 and -1 minute of time per minute in right ascension depending on the BDF. For the travelling feed, the travel limits are ±275 inches (about 9°), the maximum slew rate is 2.0 inches/s, and the maximum position error in the east-west direction is

±0.5 inches or about ±1 arcminute. For the Sterling mount, the travel limits are ±15 inches (about $0\overset{\circ}{.}5$), the maximum slew rate is 0.5 inches/s, and the maximum system position error is ±0.086 inches or ±10 arcseconds.

In specifying start and stop times on the position code 8 card, one must keep in mind that these times must be centered on the indicated source position if the source is to be tracked for an equal time on either side to the feed track center, while the source position itself is in 1950.0 coordinates.

1950 Declination (13). This card is identical to the 1950 declination (3) card except that start and stop times are referenced to 1950 coordinates. These times are converted to LST by adding precession, aberration, nutation, and pointing corrections. Caution must be used to avoid start and stop time conflicts when source scheduling due to the fact that precession and pointing corrections are different at different declinations.

Celestial coordinates (18). This card is identical to position code (8) except that start and stop times are referenced to 1950 coordinates. These times are converted to LST's by adding precession, aberration, nutation, and pointing corrections. This card is more convenient for producing scans symmetric about the telescope meridian from 1950 coordinates, but because precession is different at different declinations, one must be careful to avoid stop and start time conflicts when scheduling sources in close succession.

8.2.4. COMPUTER PROGRAMS FOR PRODUCING SOURCE CARDS

There are a number of computer programs available which facilitate the production of source card decks. There is also a program which reads in observing decks and simulates the observing sequence to help optimize the timing of the observations. This program is useful for any observing deck, not just those produced with the aid of the computer programs that are described here. If many sources are observed in an identical manner, or nearly so, these programs may help reduce the drudgery of punching up observing decks. The programs run on the Charlottesville IBM computer and can do the actual card punching on a remote punch in Green Bank. The programs can do the transformations from 1950.0 coordinates to the present so that start and stop times can be specified in current LST for ease of scheduling. One need supply only the 1950.0 coordinates of the sources to be observed and parameters of the observing procedure such as positioning mode, scan length, integration time, etc., and the programs will precess the positions, add in pointing corrections, compute start and stop times, and punch the cards. There is a feature whereby well-known calibration sources (such as VLA calibrators) can be specified by name only, and the program will look up the positions. The purpose of this section is simply to make the observer aware of these programs. Here we describe in general terms what these programs do and where to find them. Complete instructions for running these programs are found within the program listings, which are given in Appendix C.

The programs described here were originally written to assist the staff with the kinds of observations necessary to maintain telescope performance, such as pointing and gain calibration, and therefore they are not completely general in their application. For example, pointing in galactic coordinates (pointing modes 4 and 5) is not currently supported by a card producing program. The programs reside on the Pandora data set with logon GBOPER (for Green Bank Operations). If you are unfamiliar with the Pandora system on the Charlottesville computers, the "friend" or a computer programmer can help you get started. The details of running the programs can be found in a descriptive comment at the beginning of each program listing. The program comments can be found in Appendix C to this manual, or in Pandora members with names corresponding to the program names. Most of the JCL has been hidden away in catalogued procedures, simplifying the job of running these programs. Listings of the calibrator files can also be found in this manual, in Appendix B. These files contain the sources that the programs recognize by name, and are excellent sources of suitable calibrators.

There are three programs which produce punched cards. Programs POINT300 and PREP300 punch cards for continuum declination scans and drift scans or wobbles, respectively. Program POINT300 prepares cards for positioning codes 3, 8, 13, and 18, observing with a pulsed cal. The scan length and scanning rate may be specified provided that they do not violate constraints imposed by the Sterling mount. The program needs to be supplied with the coefficients of the right ascension pointing correction curve, which can be found in Table 8-1 of this manual. Program POINT300 is primarily intended for preparing observations to check the declination pointing of the telescope. Program PREP300 prepares cards for positioning codes 13 and 18. Cards for wobbles may also be produced, but they are somewhat different from positioning code 6, including provisions for offset feeds and multiple feeds. Drift scans of any length can be set up. High declination drift scans are automatically lengthened. Declination scanning rates can be applied. A series of declination offsets can be applied to cards for use on successive days for mapping or for measuring beam shapes. This program also requires certain input numbers found in Table 8-1 of this manual. A version of PREP300 with a slightly different input format, in use before July 1982, is still available under the name OLDPREP.

The third card producing program is LINE300. Program LINE300 is for preparing observing cards for spectral line observations in pointing modes 8 and 18. The program is essentially the same as POINT300 in these two pointing modes except that the timing of scan lengths and intervals between scans is adjusted to conform with peculiarities of the autocorrelator, and that a series of scans is produced for each source, with off source scans symmetrically arranged about an on source scan for total power observing. The number of off source scans on each side of the on source scan can be specified, and can be set to zero for switched power observing. The default value for the scan length is the maximum amount of time that the Sterling mount can track, rounded down to a multiple of 20 seconds. The program could be used to prepare source cards for any observing program that involved tracking.

The scheduling program is PLAN300. The straightforward way of using it is to take cards produced by the programs just described, or by hand at the keypunch, add a few cards that invoke program PLAN300 and submit the deck via the remote card reader next to the line printer in the Jansky lab (rm. 234). The required card images can be found in the program listing in the GBOPER Pandora member named PLAN300. The source cards should be arranged in order of start time. The current version of PLAN300 assumes that start and stop times on source cards are current LST time, i.e. this program cannot do precession. The program goes through the input source cards calculating the time necessary to move and set up for the next source. If that time comes after the specified start time, then that source is set aside temporarily. All of the sources that are kept make up the observing schedule for the first day. Then the process is repeated with all of the sources that were skipped, yielding schedules for successive days until all of the input sources are scheduled.

There are other, more highly specialized programs that run off-line. These include programs for measuring the level curve, pointing curves, and gain curves. Observers who intend to make extensive pointing and calibration observations should ask the "Friend" about these programs.

```
P ZERO      0.00   0.00   0.00
T         1525.0 0.865   3.1504004.90 0.865    0.000    0.00
L                   47.50  00.35  0.0093 -0.000087
D  TF  T.F. COEFF.    -113.98    2.83 -0.0018  0.000010
D  UP  UPC COEFF.        0.00    0.00  0.0000  0.000000
D  25  25CM COEFF.       0.00    0.00  0.0000  0.000000
D  21  21CM COEFF.    -214.05    3.91  0.0282 -0.000311
D  18  18CM COEFF.       0.00    0.00  0.0000  0.000000
D  11  11 CM COEFF.   -153.54    5.08 -0.0204  0.000010
D   9  9CM COEFF.     -179.36    4.88 -0.0064  0.000010
D  6F  6CM COEFF.     -171.60    6.35 -0.0374  0.000340
D  6N  6CM COEFF.     -201.93    3.56  0.0530 -0.000500
A ALPHA   7.83 -14.30   4.99
```

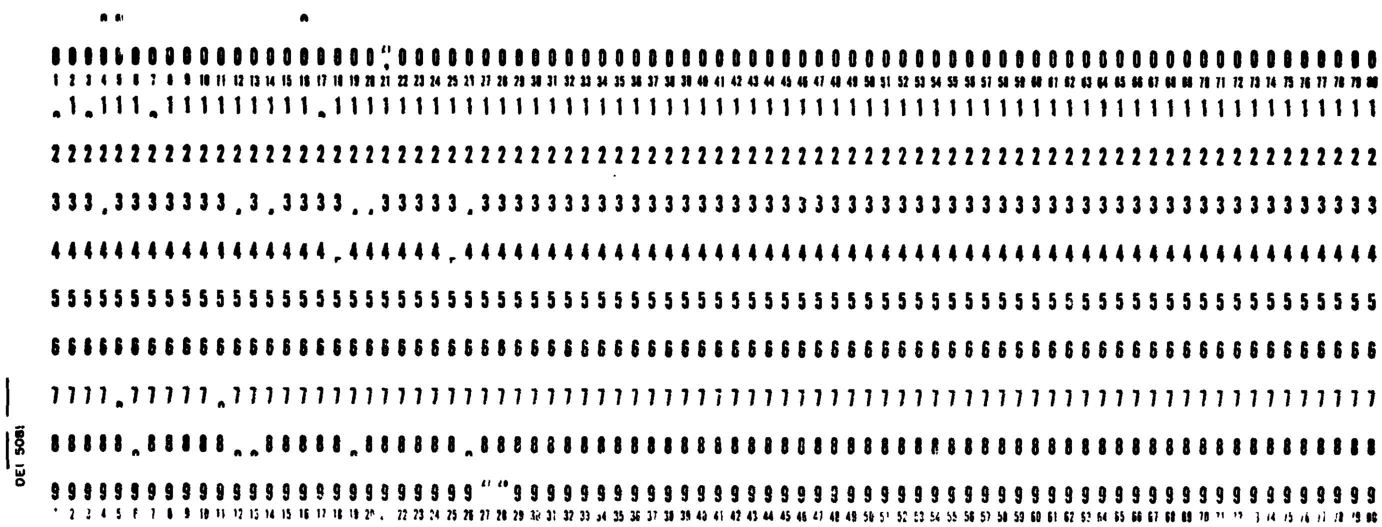

Figure 8-1. Sample H316 input card deck. This is a copy of the deck in use at the telescope in January 1983.

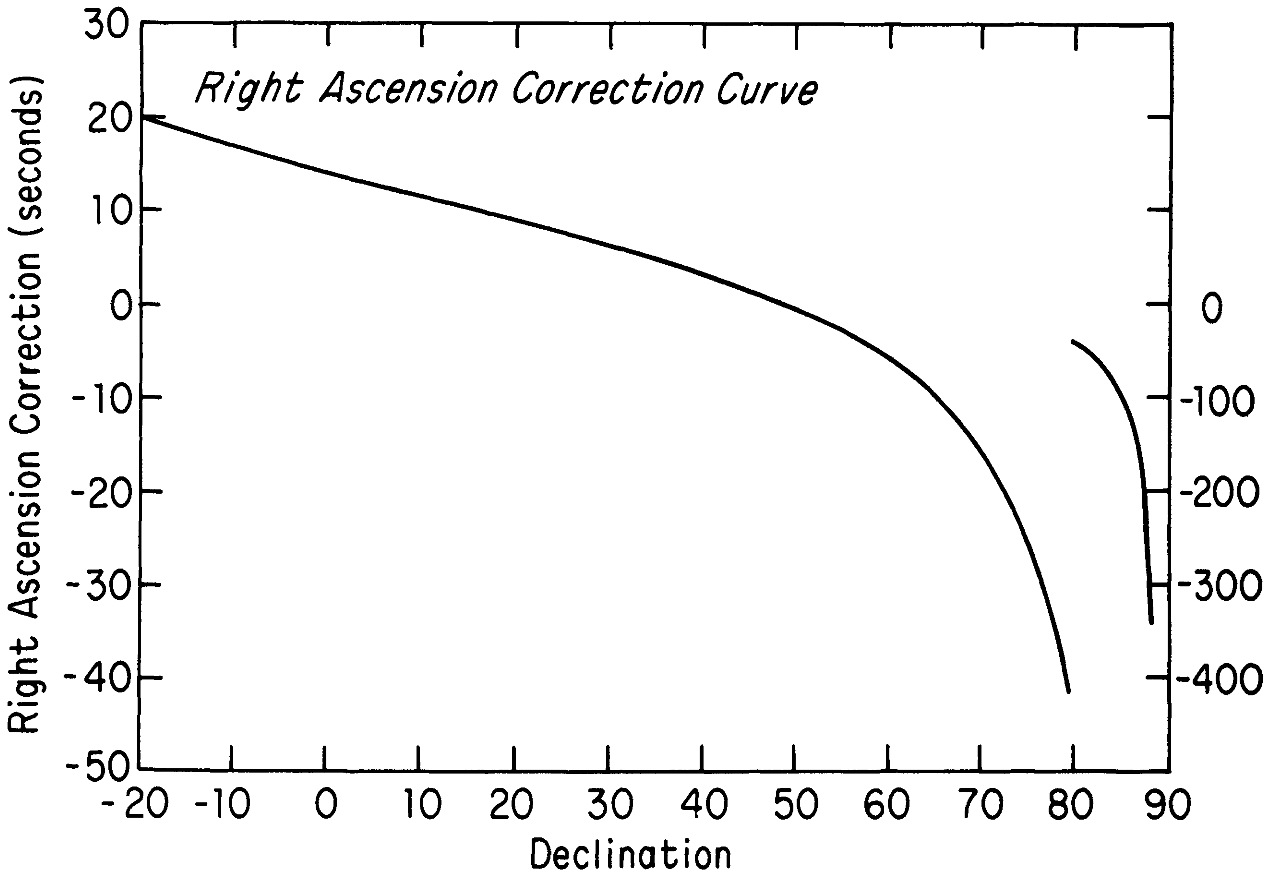

Figure 8-2. Nominal right ascension pointing curve. The curve above 80° is plotted on a scale reduced by a factor of 10.

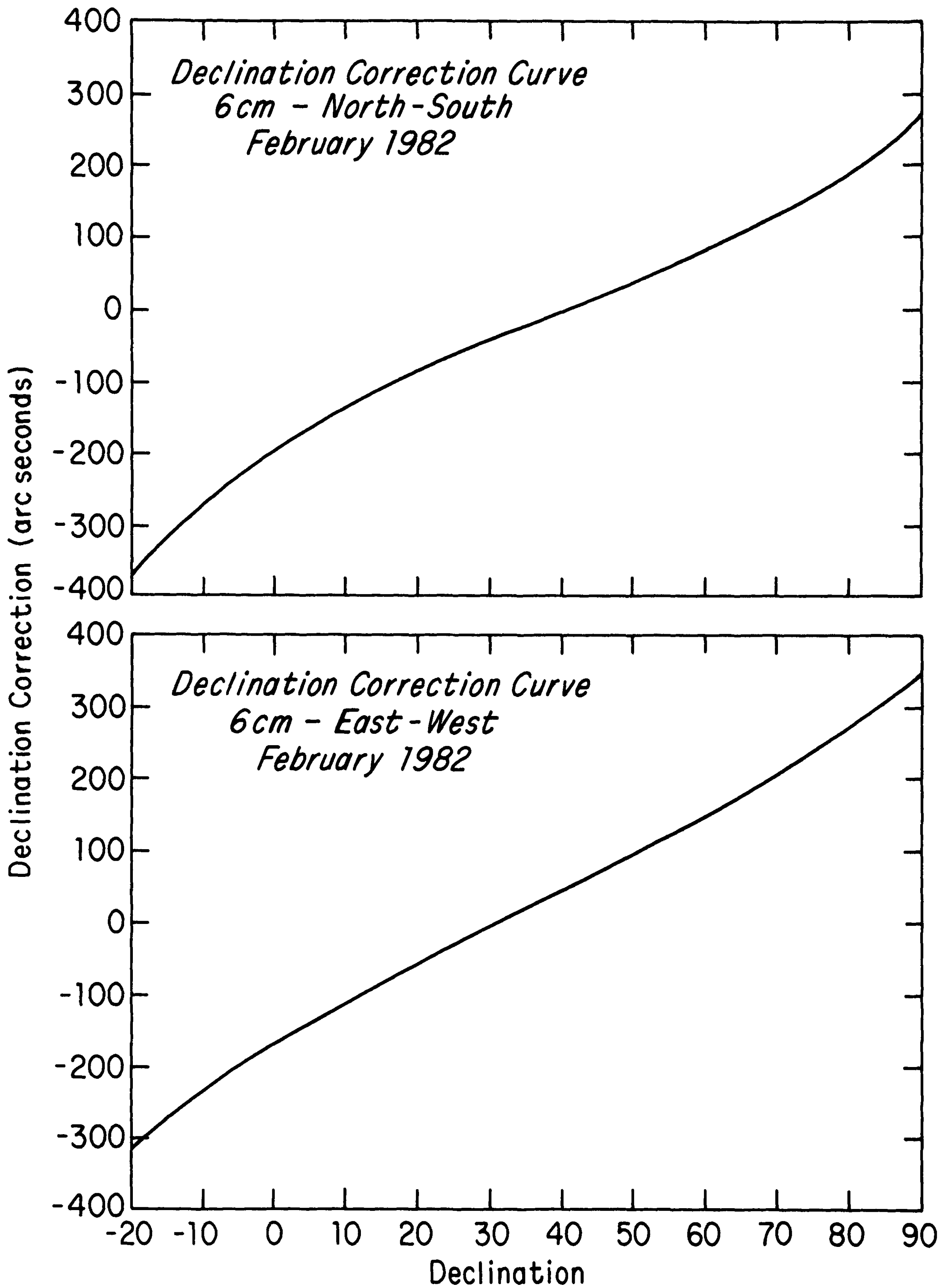

Figure 8-3. Typical declination pointing correction curves: (a) 6 cm receiver with the two feeds along a north-south line, and (b) 6 cm receiver with the two feeds along an east-west line.

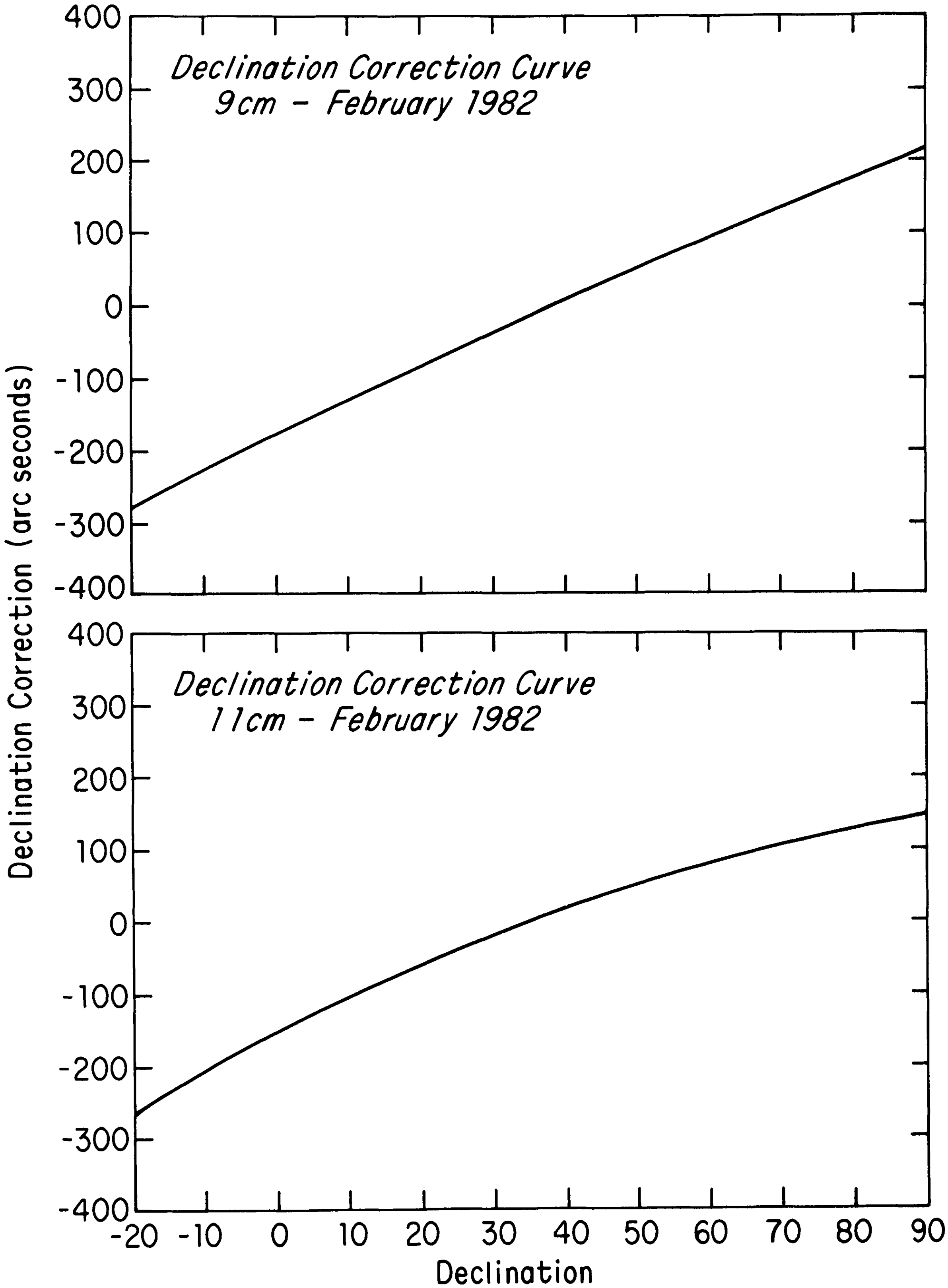

Figure 8-3 (Cont.) Typical declination pointing correction curves: (c) 9 cm receiver, and (d) 11 cm receiver.

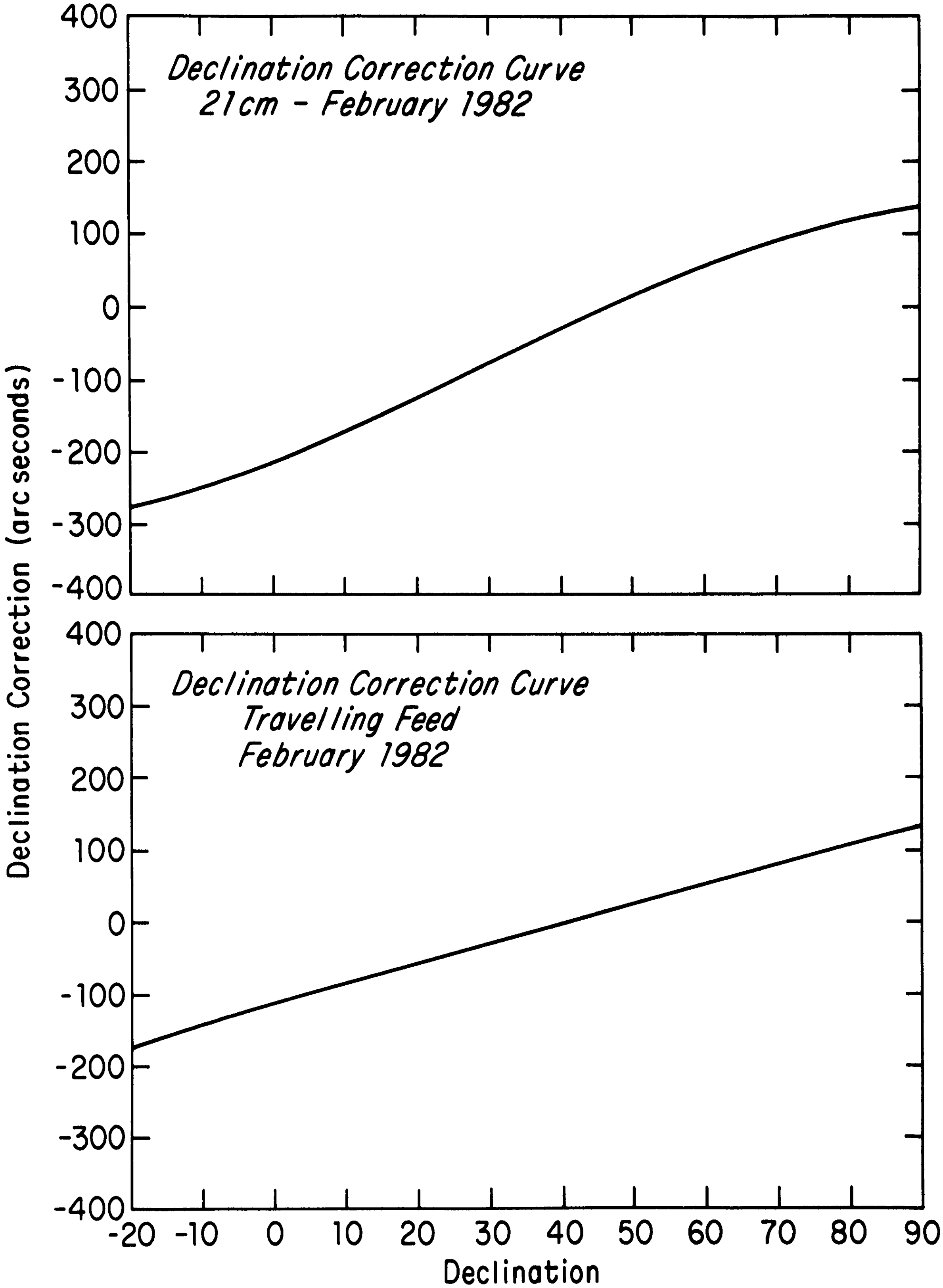

Figure 8-3 (Cont.) Typical declination pointing correction curves: (e) cooled 21 cm receiver, and (f) travelling feed box.

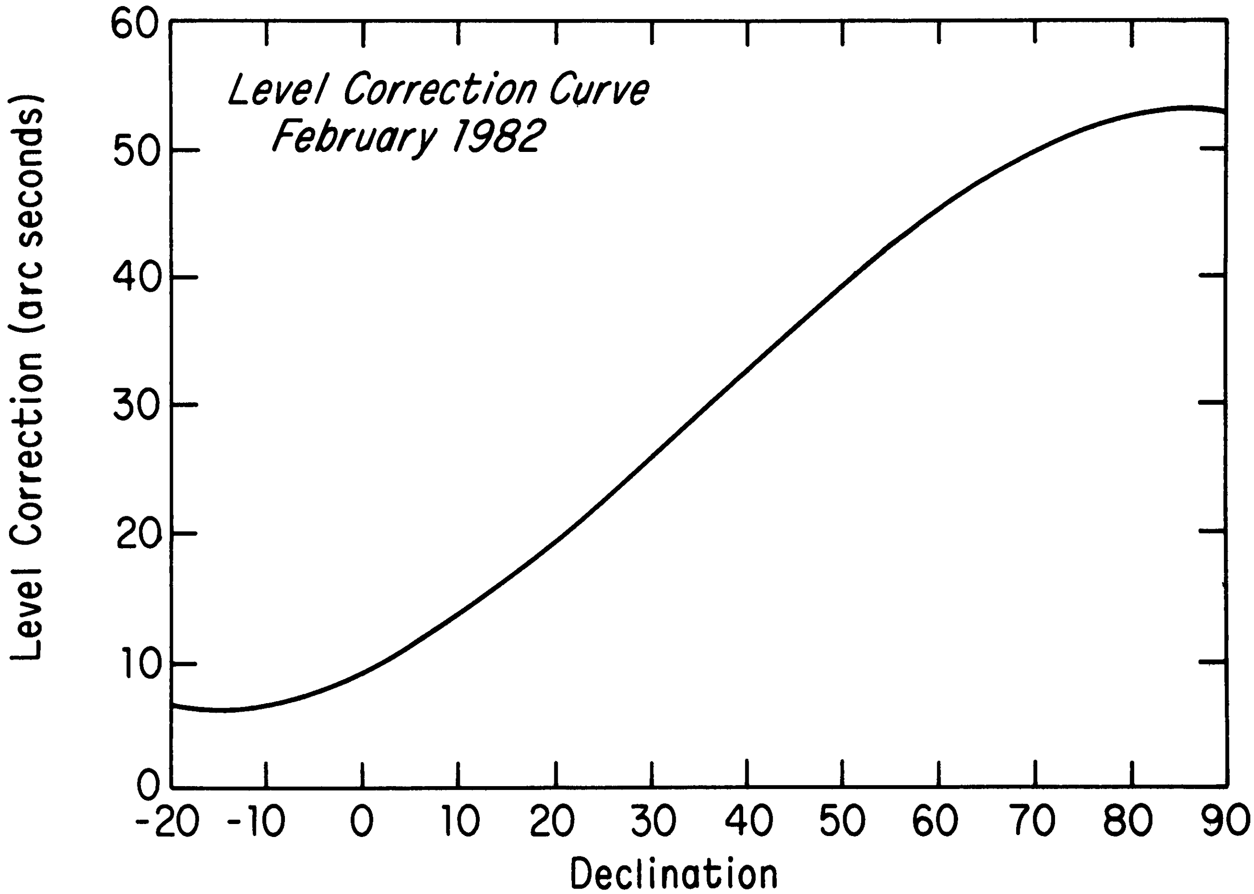

Figure 8-4. Typical level curve, not the level correction as drawn. A positive level correction corresponds to a northward tilt. This is the intrinsic tilt built into the pointing correction. Experience shows the shape of this curve to be stable but the intercept is not.

Figure 8-5

Source Card Format

```
COLUMN                   1         2         3         4         5         6         7         8
                12345678901234567890123456789012345678901234567890123456789012345678901234567890

ALL MODES                          NN .......................................................... Position code, right justified
                                                                         NNNN .................. Observer code, right justified
                                                                             AAAAAAAAAAAA ...... Source Name, any combination of alphanumeric
                                                                                                 or special characters
                .........:.........:.........:.........:.........:.........:.........:.........:
DUMMY (0)         HH MM SS          0±DD MM SS                           NNNNAAAAAAAAAAAA

                  HH MM SS ..................................................................... Time computer releases and goes to next card.
                                     ±DD MM SS ................................................. Indicated declination

                .........:.........:.........:.........:.........:.........:.........:.........:
INDICATED         HH MM SS HH MM SS 1±DD MM SS              ±RRR ±DDD    NNNNAAAAAAAAAAAA
DECLINATION (1)
                  HH MM SS ..................................................................... Current LST start for data taking
                           HH MM SS ............................................................ Current LST stop for data taking
                                     ±DD MM SS ................................................. Indicated declination
                                                            ±RRR ............................... Declination scanning rate in '/min
                                                                 ±DDD .......................... Frontend box rotation angle

                .........:.........:.........:.........:.........:.........:.........:.........:
APPARENT          HH MM SS HH MM SS 2±DD MM SS              ±RRR ±DDD    NNNNAAAAAAAAAAAA
DECLINATION (2)
                  HH MM SS ..................................................................... Current LST start for data taking
                           HH MM SS ............................................................ Current LST stop for data taking
                                     ±DD MM SS ................................................. Apparent or true declination
                                                            ±RRR ............................... Declination scanning rate in '/min
                                                                 ±DDD .......................... Frontend box rotation angle

                .........:.........:.........:.........:.........:.........:.........:.........:
1950              HH MM SS HH MM SS 3±DD MM SS              ±RRR ±DDD    NNNNAAAAAAAAAAAA
DECLINATION (3)
                  HH MM SS ..................................................................... Current LST start for data taking
                           HH MM SS ............................................................ Current LST stop for data taking
                                     ±DD MM SS ................................................. Epoch 1950.0 declination
                                                            ±RRR ............................... Declination scanning rate in '/min
                                                                 ±DDD .......................... Frontend box rotation angle

                .........:.........:.........:.........:.........:.........:.........:.........:
CONSTANT          HH MM SS HH MM SS 4±DDD.DDD                    ±DDD    NNNNAAAAAAAAAAAA
GALACTIC
LATITUDE (4)      HH MM SS ..................................................................... Current LST start for data taking
                           HH MM SS ............................................................ Current LST stop for data taking
                                     ±DDD.DDD .................................................. Galactic latitude to track
                                                                 ±DDD .......................... Galactic rotation angle of frontend box
```

LEGEND: A-Alphanumeric, D-Degrees, H-Hours, M-Minutes of time or arc, S-seconds of time or arc, N-Number, R-Rate
Where + is indicated, a blank will suffice. For declinations between -10° and 0° the leading zero(s) must be punched.

Figure 8-5 (Cont.)

Source Card Format

```
COLUMN                 1         2         3         4         5         6         7         8
              12345678901234567890123456789012345678901234567890123456789012345678901234567890

              .........:.........:.........:.........:.........:.........:.........:.........:
CONSTANT        HH MM SS HH MM SS 5±DDD.DDD                            NNNNAAAAAAAAAAAAA
GALACTIC
LONGITUDE (5)   HH MM SS .................................................................... Current LST start for data taking
                         HH MM SS ........................................................... Current LST stop for data taking
                                   ±DDD.DDD ................................................. Galactic longitude to track

              .........:.........:.........:.........:.........:.........:.........:.........:
WOBBLES (6)     HH MM SS HH MM SS 6±DD MM SS  ±DD MM SS  ±RRR          NNNNAAAAAAAAAAAAA

                HH MM SS .................................................................... Current LST start for data taking
                         HH MM SS ........................................................... Current LST stop for data taking
                                   ±DD MM SS ................................................ South indicated declination limit
                                              ±DD MM SS ..................................... North indicated declination limit
                                                         ±RRR ............................... Declination scanning rate in '/min

              .........:.........:.........:.........:.........:.........:.........:.........:
CELESTIAL       HH MM SS HH MM SS 8 HH MM SS  ±DD MM SS  ±RRR  ±RRR    NNNNAAAAAAAAAAAAA
COORDINATES (8)
                HH MM SS .................................................................... Current LST start for data taking
                         HH MM SS ........................................................... Current LST stop for data taking
                                    HH MM SS ................................................ Epoch 1950.0 right ascension
                                              ±DD MM SS ..................................... Epoch 1950.0 declination
                                                         ±RRR ............................... Right ascension scanning rate on the equator
                                                                                                  in '/min
                                                               ±RRR ......................... Declination scanning rate in '/min

              .........:.........:.........:.........:.........:.........:.........:.........:
1950            HH MM SS HH MM SS13±DD MM SS             ±RRR  ±DDD    NNNNAAAAAAAAAAAAA
DECLINATION (13)
                HH MM SS .................................................................... Epoch 1950.0 LST start for data taking
                         HH MM SS ........................................................... Epoch 1950.0 LST stop for data taking
                                   ±DD MM SS ................................................ Epoch 1950.0 declination
                                                         ±RRR ............................... Declination scanning rate in '/min
                                                               ±DDD ......................... Frontend box rotation angle

              .........:.........:.........:.........:.........:.........:.........:.........:
CELESTIAL       HH MM SS HH MM SS18 HH MM SS  ±DD MM SS  ±RRR  ±RRR    NNNNAAAAAAAAAAAAA
COORDINATES (18)
                HH MM SS .................................................................... Epoch 1950.0 LST start for data taking
                         HH MM SS ........................................................... Epoch 1950.0 LST stop for data taking
                                    HH MM SS ................................................ Epoch 1950.0 right ascension
                                              ±DD MM SS ..................................... Epoch 1950.0 declination
                                                         ±RRR ............................... Right ascension scanning rate on the equator
                                                                                                  in '/min
                                                               ±RRR ......................... Declination scanning rate in '/min
```

LEGEND: A-Alphanumeric, D-Degrees, H-Hours, M-Minutes of time or arc, S-seconds of time or arc, N-Number, R-Rate
Where + is indicated, a blank will suffice. For declinations between -10° and 0° the leading zero(s) must be punched.

TABLE 8-1

NOMINAL DECLINATION CORRECTION COEFFICIENTS
December 1982 - Inductosyn

Receiver	C_0	C_1	C_2	C_3
6 cm (N-S Polar.)	-201.93	3.56	0.0530	-0.000500
6 cm (E-W Polar.)	-171.60	6.35	-0.0374	0.000340
9 cm	-179.36	4.88	-0.0064	0.000010
11 cm	-153.54	5.08	-0.0204	0.000010
21 cm	-214.05	3.91	0.0282	-0.000311
T.F. (31 cm)	-113.98	2.83	-0.0018	0.000010

NOMINAL LEVEL CURVE COEFFICIENTS
December 1982 - East Tower

East Tower Level	L_0	L_1	L_2	L_3
Coefficients	47.50	0.35	0.0093	-0.000087

NOMINAL R.A. CORRECTION COEFFICIENTS

Equation	M	N	C
Coefficients	7.83	-14.30	4.99

NOMINAL BEAM DEFLECTION DATA

	BDF	Critical Angle	ΔBDF x 2^{15}
Travelling Feed	0.865	3.150	4004.90
Sterling Mount	0.865	0.000	0.00

TABLE 8-2

"A" CARD FORMAT (H316 Computer)

COLUMN	CONTENTS	FORMAT
1	"A"	A
2-8	Comments	AAAAAAA
9-14	m (seconds of time)	SNN.FF
15	Blank	b
16-21	n (seconds of time)	SNN.FF
22	Blank	b
23-28	c (seconds of time)	SNN.FF
29-80	Blank	bbb...

Read formats as follows:

A - Alphanumeric character
N - Integer
S - Sign
b - Blank
F - Integers after decimal place

H316 display option #6 displays the current "A" card in use

TABLE 8-3

"D" CARD FORMAT (H316 Computer)

COLUMN	CONTENTS	FORMAT
1	"D"	A
2-3	Blank	bb
4-5[1]	Pointing Coefficient Identifier	AA
6-20	Comments	15 A's
21	Blank	b
22-28	C_0 (arc seconds)	SNNN.FF
29	Blank	b
30-35	C_1 ("/degree)	SNN.FF
36	Blank	b
37-43	C_2 ("/degree^2)	SN.FFFF
44	Blank	b
45-53	C_3 ("/degree^3)	SN.FFFFFF
54-80	Blank	bbb...

NOTES:

1. Pointing coefficient identifiers are:

   6N - 6 cm Receiver (North-South Polarization)
   6E - 6 cm Receiver (East-West Polarization)
   9 - 9 cm Receiver
   11 - 11 cm Receiver
   18 - 18 cm Receiver
   21 - 21 cm Receiver
   25 - 25 cm Receiver
   TF - Travelling Feed Receivers
   UP - Up-converter Receivers

TABLE 8-4

"L" CARD FORMAT (H316 Computer)

COLUMN	CONTENTS	FORMAT
1	"L"	A
2	Level in use indicator	N
	0 - use level correction	
	1 - do not use level correction	
3-15	Blank	bbb...
16-22	L_0 (arc seconds)	SNNN.FF
23	Blank	b
24-29	L_1 ("/degree)	SNN.FF
30	Blank	b
31-37	L_2 ("/degree^2)	SN.FFFF
38	Blank	b
39-47	L_3 ("/degree^3)	SN.FFFFFF
48-80	Blank	bbb...

TABLE 8-5

"T" CARD FORMAT (H316 Computer)

COLUMN	CONTENTS	FORMAT
1	"T"	A
2-8	Comments	AAAAAAA
9-14	Focal Length (inches)	NNNN.N
15-20	Trav. Feed Beam Deflection Factor (BDF)	SN.FFF
21-28	Trav. Feed Critical Distance (Degrees)	SNNN.FFF
29-35	Trav. Feed Additional BDF	NNNN.FF
36-41	Sterling Mount BDF	SN.FFF
42-49	Sterling Mount Critical Distance (Deg.)	SNNN.FFF
50-56	Sterling Mount Additional BDF	SNNN.FF
57-80	Blank	bbb...

The focal length of the 300 foot is nominally 1525.0 inches and need not be changed for different feeds.

TABLE 8-6

"P" CARD FORMAT (H316 Computer)

COLUMN	CONTENTS	FORMAT
1	"P"	A
2-8	Comments	AAAAAAA
9-14	P_1 (RA Box Offset) Arc Minutes	SNN.FF
15-20	P_2 (RA Dial Error) Arc Minutes	SNN.FF
21-26	P_3 (Dec Dial Error) Arc Minutes	SNN.FF
27-80	Blank	bbb...

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9. SPECTRAL LINE OBSERVING

The purpose of this chapter is to describe the on-line computer programs for spectral line observing that run on the DDP116 computer, and the setup cards necessary for each. These setup cards contain information that the computer uses to check the configuration of the autocorrelator, to command the L.O. system, and to point the telescope, among other things. Setup cards followed by source cards constitute an observing deck. Source cards were discussed in Chapter 8, except for certain options pertaining particularly to spectral line observing.

The basic component of the spectral line system is the Model III autocorrelator, discussed in detail in Chapter 6. The autocorrelator is the digital equivalent of a filter bank with detectors and analog-to-digital converters. The autocorrelator also sends signals which control various schemes to stabilize against gain fluctuations and to allow automatic determination of the system temperature.

The autocorrelator contains 384 spectrometer channels, but this total can be broken up to accommodate from one to four receivers. The breakdown is into quadrants of 96 channels each. In the three receiver mode, the channels are allocated to spectra of 96, 96, and 192 channels. The on-line computer reads setup parameters for the autocorrelator from cards.

Stability against gain fluctuations is achieved by comparing two spectra which are presumed to be affected equally by any gain drifts. The two spectra will be referred to as the signal and reference spectra. The two modes of observing that are currently supported are referred to as "switched power" and "total power", and the difference between them is the way the reference spectrum is obtained. In the switched power mode, the observing time is equally (usually) divided between the signal band and a reference band of frequencies, with the reference band centered on a different frequency ("frequency switching"). In the total power mode, the signal and reference spectra are summed in separate scans taken at different positions on the sky, flagged as "on" source or "off" source, with no frequency switching.

There are three on-line spectral line programs. SPOWR3 and MPOWR3 are switched power programs. The major difference between them is how often data accumulated in the DDP116 computer are written to tape. SPOWR3 is normally used where long integrations are taken at a single point in the sky. The integration time is set at the control console and is usually a compromise between keeping the off-line data averaging to a manageable amount and having the ability to eliminate interference in one or more records (integration periods) without losing too much data. The integration time must be set to an <u>even</u> multiple of the correlator dump time, which is typically 10 seconds. MPOWR3 is normally used for spectral line mapping, and spectra are recorded on tape every correlator dump cycle. Both signal and reference spectra are recorded on tape in both of these programs, although only the final switched difference spectrum is available in the on-line analysis computer. TPOWR3 is the total power program. It records a single spectrum on tape at the chosen integration period, which must be an even multiple of the correlator dump time. A code on the source cards can be used to indicate whether a scan is a signal or "on source" spectrum or whether it is a reference or "off source" spectrum. For reasons associated with the on-line analysis program POPS, this feature simplifies the processing of total power data, provided that the "off" is obtained before the "on" spectrum.

All three programs require the same types of setup cards, and so sections of this chapter describe the types of input cards rather than the three programs. A sample setup card deck for spectral line observing is shown in Figure 9-1. The "S" card contains information pertaining to a single receiver channel, such as noise tube value and information required to set the L.O. frequencies correctly. There must always be four "S" cards, as if four receivers were in use. Besides the "S" cards, pointing cards, and source cards, the input deck may contain "L" cards, which set and check the automatic L.O. system output as desired, and an "E" card, which changes the equation relating L.O. frequencies and sky frequency to accommodate receivers with up-converters.

The spectral line system has some limitations which should be kept in mind when making up source cards:

NOTE:

> Because of computer-autocorrelator timing requirements, the difference between start and stop times on the observing cards should be at least 1^s more than an integral multiple of integration periods, otherwise the last integration may not get on tape. Successive start times should not differ by multiples of 10^s (e.g., 22 39 56, 22 46 16). This can occasionally cause autoorrelator sequence errors. Also, the time between the end of one scan and the beginning of the next scan must be at least 11^s.

9.1. SETUP CARDS: "S" CARD

Each setup "S" card contains information for a particular receiver. The information required on each "S" card, and the card format are shown in Table 9-1. Four "S" cards are required (one each with A, B, C, and D in column 31) no matter which receiver configuration is used. The comment in columns 11-30 must agree exactly on all setup cards. The pointing coefficient identifier (columns 6 and 7) is transmitted to the H316 computer in order to select the proper declination pointing curve for the observations, as described in section 8.1.2. Table 8-3 lists the available identifiers. The pointing code (columns 34 and 35) specifies which of the feed offsets on the "F" card (described below) applies to the channel specified by the "S" card.

The inversion indicator (column 37) controls whether the velocity or sky frequency increases with increasing channel number, both on the on-line display scope and as the data are written on tape. To make the velocity increase from left to right on the display scope, the inversion indicator should be 0 if the first local oscillator is lower than the sky frequency (upper sideband) and 1 if it is higher than the sky frequency (lower sideband).

The noise tube temperature (columns 38-43) is used to assign a vertical scale and system temperature to the off-line spectrum. Normally, nominal values from the receiver installation data sheets are entered here in Kelvins, with corrections for aperture efficiency and so forth to be done in a later stage of data reduction. The decimal point must be in column 41.

The spectral line rest frequency, f_o, (columns 47-55) is used both on and off line in the radial velocity calculations and is expressed in Hz with no decimal. The center frequency formula (columns 56-73) is a FORTRAN expression for off-line computing of the center sky frequency from the IF and local oscillator frequencies. The symbol convention is as follows: L1 is the ULO primary frequency, F_0; L2 is the corresponding frequency if a second LO is used; and LA, LB, LC, and LD are the IF's dialed into the IF processor in channels A, B, C and D, respectively. Typical equations would be 4*L1 + 150.0 or 4*L1 + LA. If the L.O. is under computer control, the sign before the IF frequency should be a plus. To indicate that the lower sideband of the L.O. frequency is to be observed, a negative IF frequency should be specified on the "L" card (described below). If the L.O. is in manual control, which means that there <u>cannot</u> be an "L" card, then the sign in front of the IF in the sky frequency equation can be used to select the proper sideband. In the manual mode, the IF frequency assumed by the computer is the output of the counter in the IF processor, which is always positive. Proper sideband selection can also be affected by the "E" card used with up-converter receivers.

The multipliers M and N (columns 74-77) from the first "S" card are used in the automatic computation of L.O. frequencies, as explained below. M is the factor by which the synthesizer frequency is multiplied before the L.O. signal is sent up to the frontend box, and N is the multiplication factor in the front end. The ULO has a built in multiplier, so for almost all setups using the ULO, M is 4. The value of N depends on the front end box in use, and both M and N can be obtained from the receiver installation information sheet, or from the receiver engineer.

The velocity reference indicator (column 78) specifies the rest frame in which radial velocities are computed off-line. The same rest frame is used in interpreting velocities in the automatic L.O. computations. Zero (0) causes no radial velocity corrections to be made, 1 refers radial velocities to the local standard of rest (LSR), 2 refers them to the sun, and 3 to the center of the earth. The velocity definition (column 79) indicates whether the velocities are to be interpreted by the radio ($v = c\ \Delta f/f_o$) (1) or optical ($v = c\ \Delta\lambda/\lambda_o$) (2) definition.

Each "S" card could have its own velocity and inversion indicators, noise tube temperature, rest frequency, and/or center frequency formula depending on how the receiver is divided to observe different lines or velocity ranges with one or more receiver frontend channels.

9.2. FEED OFFSET CARD: "F" CARD

The feed offset card, or "F" card, specifies positions of beams in multi-feed systems with respect to the axis of receiver box rotation in polar coordinates, ρ and θ. These are in decimal degrees with θ measured eastward from north when the box is at zero rotation angle as indicated at the control console. The sole purpose of the "F" card is to provide beam position information to the off-line programs via the telescope tape header. It has no effect on the actual position of the receiver on the telescope. Table 9-2 shows the "F" card format along with nominal feed offsets for multi-feed receivers currently in use on the 300 foot. Trailing zeroes must be punched on the "F" card.

9.3. TRAVELLING FEED RECEIVER OFFSETS: "B" CARD

The travelling feed box (0.3-1 GHz) allows two feeds to be installed for observations at 300-500 MHz or 500-700 MHz, and 700-1000 MHz. The two feeds are physically offset from center by ±34 inches, so that the whole box must be moved to get either feed on axis. The 300-700 MHz receiver is located East on the box (-34 inches), and the 700-1000 MHz receiver is located West on the box (+34 inches). These offsets are entered on a "B" card in the observer's setup deck for the DDP116 computer, which passes the value to the H316. The "B" card format is shown in Table 9-3.

9.4. AUTOMATIC L.O. CARD: "L" CARD

The automatic local oscillator "L" card is used to specify Model III autocorrelator and synthesizer settings. Autocorrelator settings must be done manually by the operator and are only checked against the contents of the "L" card. Data taking cannot start until all autocorrelator checks are satisfied. If the observer chooses, the L.O. synthesizer can be under computer control. If there is an "L" card in the DDP116 deck, then the program demands that the L.O. be in computer control. In automatic control the synthesizer settings on the "L" card are recorded on tape. The "L" cards go in the source card sequence, and each card controls receiver settings for all subsequent source cards until another "L" card is encountered.

There are 3 modes of L.O. control. In Mode 1, L.O. settings are made by commanding the ULO frequency F_0 directly. In Mode 2, the center frequency in the source frame of reference is specified. The choice of reference frame is taken from the "S" card, and there is no provision for velocity offsets. In Mode 3, the center of the band is set to a commanded velocity in the source frame of reference. The rest frequency and choice of reference frame are taken from the "S" card. In Modes 2 and 3, Doppler corrections are made in the transformation between the chosen frame of reference and the telescope frame; L.O. settings are updated every 10 seconds to track the changing Doppler corrections. In all three modes, the L.O. settings for the two reference frequency bands are computed from commanded offsets from the center of the observed band. That is, if the observer wishes the center of the reference band to be 1 MHz higher than the signal band, then the offset should be set to 1 MHz, without worrying about multipliers or Doppler corrections.

The three card formats for "L" cards are shown in Table 9-4. Many of the parameters are codes, elaborated upon in the notes to Table 9-4. In mode 3, columns 4-17 are often used for a descriptive comment. These columns are not read by the program. Nearly all operations use only one L.O., so column 2 usually contains a 1. A separate card would be used for each of multiple L.O.'s. F_0 is the primary L.O. frequency (first receiver L.O. frequency divided by the multipliers, i.e. the frequency synthesizer output), and $F_{ref\ 1}$ and $F_{ref\ 2}$ are the frequency offsets used in frequency switching. In modes 2 and 3 the reference frequencies are derived by applying specified offsets to the calculated F_0. F_0 is normally in the 250 to 500 MHz range. LA through LD are the IF values set into the IF processor rack. The IF frequencies should be entered with a sign to indicate the desired sideband of the L.O. frequency to be observed. A positive IF is specified if the L.O. is below the sky frequency (upper sideband). The front end switch indicator (column 77) only has effect if a switch (such as a Dicke switch) in the front end is being controlled by the autocorrelator. Otherwise this number may be any of those allowed in note 4. The standard time mode is one of three preset autocorrelator duty cycles available if front panel control is not assumed. The switch rate and duty cycle refer to a switched receiver system (SPOWR3 or MPOWR3). The duty cycle is the signal time to reference time proportion. Time mode 3, with a 90/10 duty cycle, is usually used only when an average of many reference spectra is going to be taken off-line. In note 5 to Table 9-4, DT is the dump time, BT is the blanking time to suppress switching transients, for which 10 milliseconds is often sufficient, ST and RT are signal and reference times, and C/D is the number of switching cycles per correlator dump. With an unswitched system (TPOWR3), time mode 1 is always used.

The automatic L.O. system provides continuous frequency counter checking of the synthesizer output and IF frequencies to be sure that they agree with the specified frequencies on the "L" card. During scans, the synthesizer output frequencies are averaged over each integration period and then checked. Between scans they are averaged for 10 seconds, and then checked. If a discrepancy between frequencies or excessive jitter between successive measurements is detected, the result is a ULO error. ULO error messages are printed on the teletype when encountered. Data taking continues in spite of a ULO error. A two-digit code is used and can be cross-referenced to the codes found in Table 9-5.

9.5. UP-CONVERTER RECEIVER L.O. CONTROL: "E" CARD

Most receivers at the 300 foot can be treated as single conversion (one L.O. and one IF) systems where the simple frequency equation

$$F_{sky} = F_0 * M * N + IF \tag{9-1}$$

is assumed by the computer in the L.O. computations. However, this is not the case with receivers incorporating up-converters, so provision has been made through an "E" card to specify constants in the following equation to be used by the computer:

$$F_0 = D * (F_{sky} - (C + E * LA + F * LB))/(M * N) \qquad (9\text{-}2)$$

where M and N are specified on the "S" card. The "E" card enters values for C, D, E, and F through the format shown in Table 9-6.

The "E" card could be entered at any time, but would normally go into the DDP116 with the "S" and "F" cards. If no "E" card is read after the on-line program is loaded, default values of C = 0, D = +1, E = +1, and F = 0 are assumed. This reduces the L.O. equation to the simpler single conversion receiver equation, equation (9-1). Once an "E" card is entered, the default values are lost until the on-line program is reinitialized. As an example, if the following values were entered: C = 812500, D = +1, E = -1 and F = 0, M = 4 and N = 1, the equation would read:

$$F_0 = (F_{sky} - 3250 \text{ MHz} - LA)/4 \qquad (9\text{-}3)$$

The "E" card would have no effect on the operation of a mode 1 "L" card.

If the observer chooses the L.O. frequency can still be set manually by switching the synthesizer out of computer control. In this case and "L" card is not used, and the frequency recorded on tape is the checking counter value, which has an accuracy of ±100 Hz.

9.6. SOURCE CARDS

Besides the telescope positioning and scheduling information on the source cards, described in Chapter 8, there is only one additional parameter connected with spectral line programs. When making total power observations (TPOWR3), a scan will automatically be flagged as an "off" or reference scan if a "1" is punched in source card column 57. A command in the POPS data analysis program (FETCH) will look back through the data to find the most recent scan flagged as an "off" before the "on" that it simultaneously loads into the work areas. For this reason, analysis is somewhat simplified if the "off" for a particular object is obtained before the "on" scan.

Observers are hereby reminded for the last time about the timing requirements imposed by computer-autocorrelator timing idiosyncrasies, as described on page 9-2.

9.7. ON-LINE DATA REDUCTION

The on-line MODCOMP analysis computer is available to the observer during the course of scheduled observations. Although data from all programs is recorded on 9-track telescope tapes for off-line reduction, the data are simultaneously transmitted from the DDP116 to the MODCOMP for inspection and reduction. The <u>On-site Spectral Line Data Reduction</u>

manual contains the information necessary to use the POPS analysis program, and that information is not repeated here.

Data records received from the DDP116 are accumulated to form a single spectrum for each receiver in each scan. This accumulated scan is stored on a disk associated with the analysis system. The total number of scans that can be held on disk is 2560. When the disk storage area is full, storage "wraps around" so that the most recent scan overwrites the data at the front of the area. It is useful to estimate how often the disk will fill up in those cases where the observer is trying to reduce all of the data on-line so that no data is overwritten before it is reduced. It is not a disaster if some data is overwritten, but the procedure for recovering from this situation is somewhat cumbersome. The recovery procedure involves reading the telescope tape onto the MODCOMP in the Jansky Lab, which is a clone of the one at the telescope, and completing reduction on that computer.

The KEEP area on disk and KEEP tapes are a way to store and transport reduced or partially reduced scans, in contrast to telescope tapes, which record raw data record by record. The KEEP command in POPS is fully described in the POPS manual. Basically, the POPS analysis program can read data from a disk area for processing. An auxiliary disk area, the KEEP area, can be written sequentially from POPS. The KEEP area can be used to store completely reduced data, intermediate steps, partial averages, or simply to keep only scans instead of individual records. The KEEP area can be dumped onto a tape and subsequently read into the data file for further processing. The KEEP area can hold 143 scans, and must be dumped to tape when it is full. The KEEP tape format can be found in the POPS manual.

9.8. OFF-LINE DATA REDUCTION

The standard NRAO spectral line data reduction programs are completely described in the TPOWER-SPOWER manual so they will not be discussed here. It may be useful, however, to briefly describe the information on tape and the steps taken in doing the basic spectral scaling. For one reason or another, the observer may want to do some or all of the data handling, but in any case the procedures involved should be understood.

Tables A-1, A-2, A-3 of Appendix A give the 9-track telescope tape formats for MPOWR3, SPOWR3, and TPOWR3, respectively. The various word formats are also described. The observer can read the 9-track telescope tape with his or her own program, read the 9-track user tape generated by the IBM TPOWER/SPOWER programs as described in their manual, or read the 9-track telescope tape back into the analysis system in the Jansky Lab. The instructions for starting up the Jansky Lab analysis computer are taped to the front of the unit. The telescope tape may be loaded by typing the following commands:

```
$JOB
$TPR
```

Then the POPS program can be invoked just as at the telescope. For observers writing their own programs, once the word formats are understood, the interpretation of the time and position information in the tape record is fairly straightforward. The calculations required to interpret the spectral numbers were described in Chapter 6. Telescope tapes and KEEP tapes are usually written at 1600 BPI, but the MODCOMP can produce 800 BPI tapes if desired.

```
  10 15 06 10 20 51 8 10 16 00   46 43 00                        0394  U 5565OM
  10 08 11 10 13 56 8 10 09 05   46 43 00                       10094  U 5565X1
L13                    0.000  0.000  1762.00   -150000-157500-165000-172500111401
  09 59 44 10 06 23 8 10 01 00   53 38 00                        0394  U 5417OM
  09 51 55 09 58 34 8 09 53 11   53 38 00                       10394  U 5417X1
L13                    0.000  0.000  7200.00   -150000-150000-150000-150000111201
F
S    21    GIOVHNES                 D  0001  7.20   355101450 L1*4-LD           4 122
S    21    GIOVHNES                 C  0001  7.20   355101450 L1*4-LC           4 122
S    21    GIOVHNES                 B  0001  5.50   355101450 L1*4-LB           4 122
S    21    GIOVHNES                 A  0001  5.50   355101450 L1*4-LA           4 122
```

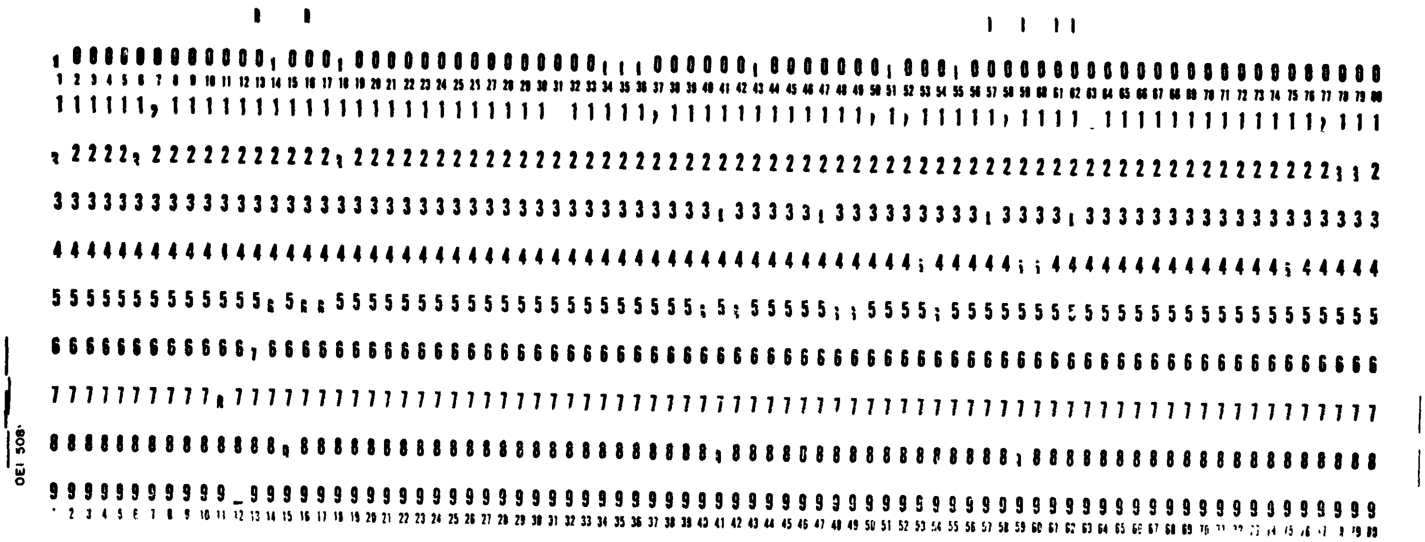

Figure 9-1. Sample DDP116 input card deck for spectral line observing. This deck is for observing HI in galaxies in total power, using "L" cards to set up the receiver for the velocity of each galaxy. The setup changes from two receivers for galaxies with known redshifts to four receivers with different IF frequencies to search for galaxies with unknown redshifts. The receiver changes are actually made manually by the telescope operator and checked by the computer.

TABLE 9-1

SETUP CARD FORMAT - MPOWR3, SPOWR3, TPOWR3 (DDP116 Computer)

COLUMN	CONTENTS	FORMAT
1	"S"	A
2-5	Blanks	bbbb
6-7	Pointing Coefficient Identifier	AA (Table 8-3)
8-10	Blanks	bbb
11-30	Comment	2ØA's
31	"A", "B", "C", or "D"	A
32-33	Blanks	bb
34-35	Pointing Code	NN
36	Calibration Code (=0 or 1)	N
37	Inversion Indicator (=0 or 1)	N
38-43	Noise Tube Value (XXX.XX)	NNN.FF
44-46	Blanks	bbb
47-55	Rest Frequency/(M*N) (Hz)	NNNNNNNNN
56-73	Center Frequency Formula	18A's
74-75	Multiplier M(Synthesizer)	NN
76-77	Multiplier N(Front-End)	NN
78	Velocity Reference Indicator	N
79	Velocity Definition Indicator	N
80	Blank	b

TABLE 9-2

"F" CARD FORMAT (DDP116 Computer)

COLUMN	CONTENTS	FORMAT
1	'F'	A
2	Number of OFFSET Feed Values	A
3-8	Blank	bbbbbb
9-17	RHO for Feed 1 OFFSET	NNNN.FFFF
18-26	THETA for Feed 1 OFFSET	NNNN.FFFF
27-35	RHO for Feed 2 OFFSET	NNNN.FFFF
36-44	THETA for Feed 2 OFFSET	NNNN.FFFF
45-53	RHO for Feed 3 OFFSET	NNNN.FFFF
54-62	THETA for Feed 3 OFFSET	NNNN.FFFF
63-71	RHO for Feed 4 OFFSET	NNNN.FFFF
72-80	THETA for Feed 4 OFFSET	NNNN.FFFF

Feed offset values for multi-feed systems on the 300 foot

		Feed	ρ	θ
21 cm, 4-feed		1	$0^{\circ}.2863$	$226^{\circ}.4000$
		2	$0^{\circ}.2440$	$302^{\circ}.2000$
		3	$0^{\circ}.2389$	$121^{\circ}.1000$
		4	$0^{\circ}.2856$	$46^{\circ}.3000$
11 cm, 3-feed		1	$0^{\circ}.0000$	$0^{\circ}.0000$
		2	$0^{\circ}.0000$	$0^{\circ}.0000$
		3	$0^{\circ}.1642$	$270^{\circ}.0000$
		4	$0^{\circ}.1642$	$90^{\circ}.0000$
6-cm, Beam Switched)				
AlL and		1 (Sig)	$0^{\circ}.0600$	$0^{\circ}.0000$
TRG		2 (Ref)	$0^{\circ}.0600$	$180^{\circ}.0000$
	or	1 (Sig)	$0^{\circ}.0000$	$0^{\circ}.0000$
		2 (Ref)	$0^{\circ}.1200$	$180^{\circ}.0000$

TABLE 9-3

"B" CARD FORMAT (DDP116 COMPUTER)

COLUMN	CONTENTS	FORMAT
L	"B"	A
2-7	Blanks	bbbbbbbb
10-16[1]	Feed offset (inches)	SNN.FFF

NOTES:

1. A plus-offset defines the feed physically offset West on the traveling feed carriage.

   A minus-offset defines the feed physically East on the feed carriage.

TABLE 9-4

MODEL III CORRELATOR
"L" CARD DESCRIPTION (DDP116 Computer)

I. Mode 1 "L" Card

COLUMN	CONTENTS	FORMAT	NOTES
1	"L"	A	
2	ULO Number	N	
3	Mode = 1	N	
4-6	Blank	bbb	
7-15	F_o in Hz	NNNNNNNNN	
16-18	Blank	bbb	
19-27	$F_{ref.\ 1}$ in Hz	NNNNNNNNN	
28-30	Blank	bbb	
31-19	$F_{ref.\ 2}$ in Hz	NNNNNNNNN	
40-43	Blank	bbbb	
44-50	+LA in kilohertz	SNNNNNN	1
51-57	+LB in kilohertz	SNNNNNN	1
58-64	+LC in kilohertz	SNNNNNN	1
65-71	+LD in kilohertz	SNNNNNN	1
72	Bandwidth Rx. A Indicator	A	2
73	Bandwidth Rx. B Indicator	A	2
74	Bandwidth Rx. C Indicator	A	2
75	Bandwidth Rx. D Indicator	A	2
76	Mode of Operation Indicator	A	3
77	Front End Switch Indicator	A	4
78	Standard Time Mode Indicator	A	5
79-80	Blank	bb	

A = Alphanumeric character, N = number, S = sign, b = blank,
F = numbers after decimal.

TABLE 9-4 (Cont.)

II. Mode 2 "L" Card

COLUMN	CONTENTS	FORMAT	NOTES
1	"L"	A	
2	ULO Number	N	
3	Mode=2	N	
4-6	Blank	bbb	
7-15	F_{source} / (M*N) in Hz	NNNNNNNNN	
16-17	Blank	bb	
18-24	$\pm$ Ref. Freq. 1 Offset in MHz	SNN.FFF	6,7
25-31	$\pm$ Ref. Freq. 2 Offset in MHz	SNN.FFF	6,7
32-43	Blank, or comment	12 b's	
44-80	Same as Mode 1 "L" Card		

III. Mode 3 "L" Card

COLUMN	CONTENTS	FORMAT	NOTES
1	"L"	A	
2	ULO Number	N	
3	Mode=3	N	
4-17	Comment	14 b's	
18-24	$\pm$Ref. Freq. 1 Offset in MHz	SNN.FFF	6,7
25-31	$\pm$Ref. Freq. 2 Offset in MHz	SNN.FFF	6,7
32-40	$\pm$Velocity Offset km/sec	SNNNNN.FF	7
41-43	Blank	bb	
44-80	Same as Mode 1 "L" Card		

TABLE 9-4 (Cont.)

NOTES:

1. The sign of the IF's should indicate the desired direction of the offset. ONLY LA and LC are checked on-line.

2. Bandwidth Indicators Are:

1 ----	10 MHz	6 ----	312.5 kHz
2 ----	5 MHz	7 ----	156.25 kHz
3 ----	2.5 MHz	8 ----	78.125 kHz
4 ----	1.25 MHz	9 ----	39.0625 kHz
5 ----	625 MHz		

3. Mode of Indicators Are:

1 ---- 1 ea. 384 ch. A/C

2 ---- 2 ea. 192 ch. A/C

3 ---- 2 ea. 96 ch. and 1 ea. 192 ch. A/C

4 ---- 4 ea. 96 ch. A/C

5 ---- Not allowed

6 ---- Not allowed

7 ---- Not allowed

8 ---- 1 ea. 192 ch. A/C double frequency

4. Front-end Switch Setting Indicators:

0 ---- Signal

1 ---- Reference

2 ---- Modulate

5. Standard Time Mode Indicators Are:

0 ----Use the digi-system settings on the A/C panel

	BT	ST	RT	C/D
1 ----	10000	04900	04900	010
2 ----	30000	04700	04700	010
3 ----	10000	08900	00900	010

TABLE 9-4 (Cont.)

These modes produce the following conditions:

	DT	BT	SW RATE	DUTY
1 ----	10 sec.	10 ms.	1 Hz	50 / 50
2 ----	10 sec.	30 ms.	1 Hz	50 / 50
3 ----	10 sec.	10 ms.	1 Hz	90 / 10

6. The sign of the reference frequency offsets should indicate the desired direction of the offset.

7. Decimal point must be punched in the proper column in the field followed by numeric characters.

NOTE: In all sign fields, a blank may be used to indicate positive values.

TABLE 9-5

AUTOMATIC ULO ERROR MESSAGES
MODEL III AUTOCORRELATOR

All error messages related to the ULO are of the following format:

ULO ERROR XX

where XX is a one or two digit code whose meaning may be found in the following table:

1	F_0
2	F_1
3	F_0 and F_1
4	F_2
5	F_0 and F_2
6	F_1 and F_2
7	F_0, F_1, and F_2
8	LA
9	LA and F_0
10	LA and F_1
11	LA, F_0, and F_1
12	LA and F_2
13	LA, F_0, and F_2
14	LA, F_1, and F_2
15	LA, F_0, and F_1, and F_2
16	LC
17	LC and F_0
18	LC and F_1
19	LC, F_0, and F_1
20	LC and F_2
21	LC, F_0, and F_2
22	LC, F_1, and F_2
23	LC, F_0, F_1, and F_2
24	LC, LA
25	LC, LA, and F_0
26	LC, LA, and F_1
27	LC, LA, F_0, and F_1
28	LC, LA, and F_2
29	LC, LA, F_0, and F_2
30	LC, LA, F_1, and F_2
31	LC, LA, F_0, F_1, and F_2
98	Bands indicator in read-out of F_0, F_1, F_2 was not equal to 1, 2, 4 or 8.
99	Jitter error in read-out of F_0, F_1, or F_2 (Jitter means a variation of greater than 100 Hz was detected between 2 consecutive read-outs of F_0, F_1, F_2).

TABLE 9-6

"E" FORMAT (DDP116 Computer)

COLUMN	CONTENTS	FORMAT
1	"E"	
2-8	C value (kHz/(M*N))	SNNNNNN
9-10	D value (+1 or -1)	SN
11-12	E value (+1, 0, or -1)	SN
13-14	F value (+1, 0, or -1)	SN

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10. CONTINUUM OBSERVING

10.1. OBSERVING PROGRAMS

The purpose of this chapter is to describe the on-line computer programs for continuum observing that run on the DDP116 computer, and the setup cards necessary to use them. The setup cards contain information that the computer uses to sample the correct analog-to-digital converters, to calibrate the data, and to command the L.O. system. The card input to the DDP116 computer consists of setup cards followed by source cards. Besides the telescope pointing and scheduling information on the source cards discussed in Chapter 8, there are a few additional parameters on source cards for continuum observing. This section gives a general description of the on-line observing programs.

For moderate sampling rates, the choice of observing program is governed by a decision to use the "standard" continuum receiver or the digital continuum receiver (DCR). The square law detectors in the autocorrelator are also used for continuum observations intended to calibrate line observations. The continuum receivers are described in Chapter 5, where it is pointed out that the "standard" designation should simply be read as "analog", to contrast it with the digital receiver. The digital receiver is equally "standard" in the sense of being used routinely. The program for the standard continuum receiver is called CONDAR. The program for the digital receiver is CONINT. The setup cards for the two programs are identical, but since many parameters are entered manually into the digital receiver, a number of fields in the setup cards are ignored in CONINT. The calibration modes are somewhat different between the two receivers. Data from the digital receiver are received by the DDP116 computer as already calibrated numbers. Data from the standard receiver are received as arbitrary units which must be calibrated in a later stage of analysis, which requires somewhat more care to make sure that there are enough measurements of the internal noise source to stabilize against gain fluctuations.

A fast-sampling program, FSAMP2, is intended for high data rates, such as in pulsar observations. 1, 2, or 4 receiver channels can be sampled at a 1 sidereal millisecond rate. 1, 2, 4, or 8 receiver channels can be sampled at multiples of 5 sidereal milliseconds. A large amount of computer tape is used by this program. At the 1 ms sampling rate a 2400' tape lasts about 15 minutes, so arrangements should be made well in advance if more than 3 or 4 tapes are to be consumed. In the past, program FS6 was available for sampling 50 channels at a 30 millisecond rate, but it has fallen into disuse and is no longer maintained. A special effort on the part of the Green Bank programmers would be required to resurrect it, so the computer division should be contacted before considering its use. Also, there are no standard off-line programs for handling data from FSAMP2 or FS6, so observers should generally expect to provide their own data reduction programs. To assist this effort, 9-track telescope tape formats are given in Appendix A.

A 4096 channel Fabri-Tek signal averager is available for use at the 300 foot for synchronously integrating repetitive signals such as those from pulsars. The complexity and variety of timing and synchronization schemes employable with this system are beyond the scope of this manual, however. There is an on-line program, SAVG2, which will record data sent from the signal averager onto a 9-track tape. Once a scan is initiated by an observing card, the signal averager controls the integration times and data transfers. The details of the electronics setup at the telescope for this type of program have been the result of close cooperation between pulsar observers and the Green Bank electronics staff. New observers should plan on considerable preparation before the observing begins. No standard off-line programs are supported for the signal averager tapes.

In spite of the differences between observing programs, the setup cards required are basically similar, and so this chapter is organized by type of card rather than by program, except for the first section, which discusses the difference between calibration modes of CONDAR and CONINT. The emphasis of this chapter is on the basic programs CONDAR and CONINT.

10.2. GAIN STABILIZATION AND CALIBRATION

The Digital Continuum Receiver Manual [57] contains a discussion of sources of unwanted signals in continuum observations, and various schemes for minimizing them. Parts of that discussion will be summarized in this section. The digital continuum receiver is quite flexible in terms of calibration and switching modes, but the standard continuum receiver is less flexible, and the available calibration modes for the standard receiver are also discussed. Although gain stabilization and gain calibration are separate problems, as discussed in the DCR manual, both topics are jumbled together in this section.

If receiver/detector systems were stable enough, continuum observations would be made in the total power mode, where the output of the detector is simply sampled during an observation, and calibration is done before or after the observation. No calibration noise source degrades the system temperature or decreases the integration time during an observation in the total power mode, making this the most sensitive observing technique, in principle. This technique has been seldom used, however, because it relies on a total system stability of a part in 10^4 or better over time scales of an observation, typically a minute or more. On the other hand, receivers are more stable now that GaAsFET amplifiers are replacing parametric amplifiers, so total power observing should at least be considered, particularly for fast scanning of small sources. Programs to measure the fluxes of moderately strong (1 Jy) point sources with total power drift scans have been performed successfully at the 300 foot with certain receivers.

Both digital and standard continuum receivers can operate in the total power mode. The digital receiver automatically computes the gain and system temperature between scans, and applies the last measured values to the data during a scan, sending calibrated data to the computer. With the standard receiver, the CONDAR program makes provision for specifying a timed cal scan, which is a separate calibration scan. The parameters of a timed cal scan are set at the control panel. In the on-line analysis program, the calibration factors derived from a timed cal scan are applied to all subsequent total power scans until another timed cal scan is run.

Assuming that receivers and properties of the telescope/feed combination are not sufficiently stable to measure weak radio sources in the total power mode, a number of switching and gain stabilization schemes have been devised. As discussed more extensively in the DCR manual [57], different observing conditions call for different stabilization methods. For example, beam switching is commonly used for continuum observations above 3 GHz to compensate for atmospheric fluctuations. The other basic stabilization schemes are load switching and noise adding radiometry (NAR).

In noise adding radiometry, a strong noise signal is periodically injected into the receiver input, and the receiver output is integrated in signal and reference integrators, which are connected to the detector in synchronism with the noise source being off and on, respectively. The radiometer output is proportional to the signal integrator divided by the reference minus signal difference. The advantage of NAR over load or beam switching is that a lossy switch does not have to be put in the signal path ahead of the low noise amplifier. A disadvantage is that NAR only compensates for receiver gain fluctuations and does not cancel changes in receiver or sky noise temperature. If possible, the noise switching frequency should be faster than any gain instabilities in the receiver. If this is not possible, the switching frequency should at least avoid any narrowband features in the receiver's post-detection spectrum, such at the 1.2 Hz feature associated with the refrigeration systems used on NRAO receivers and the 60 Hz power line feature.

The maximum sensitivity NAR has a very strong noise source and spends about equal times on signal and reference. The DCR is programmed to provide equal signal and reference integration times for sensitive observations. Program CONDAR for the standard continuum receiver has a somewhat limited form of NAR conveniently provided for in a mode referred to as pulsed cal. In the pulsed cal mode, the calibration noise source is turned on every 15th integration period, beginning with the 3rd. The on-line analysis computer uses two integrations on each side of this noise spike as a baseline for the reference minus signal difference, and simply averages all of these differences, computing a single calibration factor for an entire scan, so the gain is no more stable than in total power. However, the calibration may be more accurate, as well as more convenient, since it is made during the actual observations rather than before or after. An observer could provide a more sophisticated analysis program but it would have to involve reading the 9-track telescope tape. In the pulsed cal mode, program CONDAR imposes $0^{s}.2$ of blanking time at the beginning and end of the calibration period, and so the pulsed cal mode cannot be used with integration times shorter than $0^{s}.6$.

Load switching is one of the oldest methods of receiver stabilization in radio astronomy, and is often called Dicke switching after one of its first users, R.H. Dicke. As the name implies, the receiver input is switched between the antenna feed and a stable resistive load. The radiometer output is the difference between signal and reference integrators. Immunity from gain fluctuations depends on a balance between signal and reference levels in their respective integrators. In the DCR this can be accomplished by a multiplicative factor applied to the reference integrator count. In the analog system, an attenuator would have to be switched into the reference path ahead of the synchronous detector. One penalty of using gain modulation to compensate for unequal reference and antenna temperatures is that the system will respond to variations in the noise temperature of the receiver behind the load switch in proportion to the compensating gain imbalance. In the worst case of a very hot reference load, any receiver temperature variation would show up as an equivalent synchronous detector output signal. Normally the gain imbalance is not required to be so severe, and receiver temperature is usually more stable than receiver gain. For some radiometers incorporating the DCR, balancing is accomplished manually by setting a fixed signal-to-reference ratio in the calculator. Radiometers which are automatically balanced by the DCR retain the signal-to-reference ratio measured just before a scan begins for the duration of that scan. The synchronous detector in the standard analog receiver is balanced manually.

In beam switching the receiver gain variation immunity advantages of load switching plus substantial cancellation of atmospheric noise fluctuations can be achieved by replacing the reference load with an offset antenna beam. Since the noise received by the front end will be very nearly equal in the signal and reference halves of the switch cycle the system is intrinsically nearly balanced. However, there are two sometimes conflicting balance conditions in a beam switched radiometer. To cancel atmospheric fluctuations, the amount of power received from the atmosphere in the general direction of the main beam should be the same in the signal and reference beams. If there were higher resistive or reflective losses in the reference beam path than in the signal beam path, the gain would want to be increased in the reference half-cycle to compensate for the loss in atmospheric noise power. On the other hand, higher resistive losses in the reference path would produce a higher noise input to the front end which would call for a gain reduction in the reference half-cycle to maintain receiver gain fluctuation immunity. One way around this conflict is to balance the gain for equal power from the atmosphere and balance the noise input level by adding noise or resistive attenuation to the signal beam path. However, it is often difficult to decide when the atmospheric noise contribution is equal in the two halves of the switch cycle.

To summarize the gain stabilization discussion, total power observing should be considered as a possibility with the newer receivers. If total power observing is not feasible, then beam switching is desirable at the higher frequencies, if multiple feed receivers are available, to reduce the effect of atmospheric fluctuations. NAR and load switching are available for single feed receivers. In the standard analog receiver setup, these switching schemes require a synchronous detector to be balanced manually and sampled by the DDP116 computer. Using the DCR as a digital synchronous detector, automatic balancing is available in some setups. The DCR is rather more flexible in setting up a gain stabilization scheme, and has the advantage that its integrators are ideal integrators rather than RC integrators with a finite time constant.

To summarize the gain calibration discussion, gain calibration with the DCR is necessarily but automatically taken care of as data is acquired and before data is passed to the DDP116 computer. Further processing is possible in some switched modes by passing continuously computed gain data to the DDP116 for recording on tape. On the other hand, observations with the standard analog receiver are calibrated in the on-line analysis computer or off-line. In this case one must keep in mind that the only monitor of system performance may be the calibrations specifically invoked and recorded on tape. The calibrations must therefore be frequent enough to correct for receiver instabilities and readjustments. For this reason, and the fact that the data reduction is somewhat simplified, the pulsed cal mode is most frequently used, where possible. The alternative is to run a separate timed cal scan, preferably before an observation rather than after, for convenience in analysis, and before <u>and</u> after for accuracy.

10.3. SETUP CARDS: "S" CARDS

For the continuum programs, the setup cards are used to specify the channels in the analog-to-digital converter to be sampled and to pass along some information to the automatic L.O. and the off-line programs by way of the tape header. There must be one "S" card for each receiver channel.

The "S" card format for CONDAR and CONINT is shown in Table 10-1. Column 31 contains an "X" on the first card only and is blank on all others. The first channel to be read from the analog-to-digital converter is identified in columns 32-33, with these columns blank on subsequent "S" cards. All of the channels to be read must be in a continuous sequence, and the number to be read is controlled by the number of "S" cards (up to 8). The observer should consult the receiver engineer in charge or the receiver installation sheet to be certain which channels the receiver is connected to. "S" card data is associated with the A/D channels in the order of the cards in the setup deck, i.e. the data on the second "S" card are associated with the A/D channel immediately following that specified on the first "S" card. Since there is no numbering on the cards, it is important not to shuffle the "S" cards in the input deck. Sample setup decks for CONDAR or CONINT are shown in Figure 10-1.

The declination pointing coefficient identifier (see Section 8.1.2 and Table 8-3) is punched in columns 6 and 7. This code enables the H316 computer to select the proper coefficients in the declination pointing equations for the receiver in use. The pointing code (columns 34-35) specifies which of the beam offsets on the feed offset card ("F" card) apply to the channel represented by the "S" card. The observing wavelength in centimeters (columns 36-39) is used by the off-line programs to scale the beam offsets in beamwidths. The noise source value (columns 40-45) is used to apply a calibration to the data off-line or in the on-line analysis computer. A decimal point must be punched in column 43.

If the digital continuum receiver is being used, then the A/D channel information and noise source values on the "S" cards are ignored, and must be entered manually at the calculator keyboard.

The information on the setup cards for FSAMP2 is basically the same as on those for CONDAR and CONINT, except that the observing wavelength is omitted. The "S" card format for FSAMP2 is given in Table 10-2. A decimal point must be punched in column 39.

Only one setup card is needed for program SAVG2, and the only things it contains are an "S" in column 1, the observer name(s) in columns 11-30, and the synthesizer and front end multipliers as shown in Table 10-3.

10.4. FEED OFFSET CARD: "F" CARD

The feed offset card, or "F" card, specifies positions of beams in multi-feed systems with respect to the axis of receiver box rotation in polar coordinates, ρ and θ. These are in decimal degrees with θ measured eastward from north when the box is at zero rotation angle as indicated at the control console. The sole purpose of the "F" card is to provide beam position information to the off-line programs via the telescope tape header. It has no effect on the actual position of the receiver on the telescope. Table 10-4 shows the "F" card format along with nominal feed offsets for multi-feed receivers currently in use on the 300 foot. Trailing zeroes must be punched on the "F" card.

10.5. TRAVELLING FEED RECEIVER OFFSETS: "B" CARD

The travelling feed box (0.3-1 GHz) allows two feeds to be installed for observations at 300-500 MHz or 500-700 MHz, and 700-1000 MHz. The two feeds are physically offset from center by ±34 inches, so that the whole box must be moved to get either feed on axis. The 300-700 MHz receiver is located East on the box (-34 inches), and the 700-1000 MHz receiver is located West on the box (+34 inches). These offsets are entered on a "B" card in the observer's setup deck for the DDP116 computer, which passes the value to the H316. The "B" card format is shown in Table 10-5.

10.6. AUTOMATIC L.O. CARD: "L" CARD

With most continuum observations, only one L.O. frequency is used during an entire run, with the L.O. settings made in the manual mode. However, automatic L.O. control is available through an "L" card similar to the mode 1 card described in Section 9.4. In this mode, frequency synthesizer settings are specified directly. The use of an "L" card may be desirable, even in the manual setting mode, to minimize the chance of a discrepancy between desired and actual synthesizer settings. The format for the continuum "L" card is shown in Table 10-6. FREF 1 and FREF 2 (columns 19-39) usually have no use in a continuum program. F_o is the frequency synthesizer setting and is calculated from the desired sky frequency and the L.O. multipliers M and N, taken from the "S" cards. In CONDAR and CONINT, F_o is continuously checked with a frequency counter to see that the synthesizer output agrees with the specified value. A discrepancy results in a ULO error message at the DDP116 teletype, but data taking is not affected. ULO error codes and their meanings are listed in Table 9-5. In the fast sampling program FSAMP2 and the signal averager program SAVG2 there is no frequency checking. In the fast sampling program FSAMP2 there cannot be an "L" card. The presence of an "L" card in the input deck will result in an error. Programs CONDAR and CONINT will support the presence of an "E" card, to allow automatic setting of the L.O. for up-converter receivers. The "E" card is very rarely used in continuum programs, and so the discussion of the "E" card in Section 9.5 and Table 9-6 is not repeated in this chapter.

10.7. SOURCE CARDS

Besides the telescope pointing and scheduling information on the source cards described in Chapter 8, there are a few additional parameters pertinent to continuum observations.

In CONDAR, the pulsed cal calibration mode is invoked by a blank or "0" in source card column 54. This causes the calibration noise source to be turned on every 15^{th} integration period beginning with the third. Since there is $0^s.2$ of blanking time at the beginning and the end of the calibration period, the timed cal mode cannot be used with integration times less that $0^s.6$. The timed cal mode is invoked by a "1" in column 54. This is a single shot calibration sequence, the total duration of which is set on the telescope control console. If, for example, a 30^s timed cal duration is set with a $1^s.0$ integration time, the computer will start taking data with the noise source off at the start time on the observing card. After 15^s the noise source will be turned on for 30^s, then off again for 15^s, at which time the scan will end even if the stop time has not been encountered. A separate source card must be used for the timed calibration. It is convenient to run a timed cal scan before a total power scan. The total power mode, with no calibration superposed on the data, is invoked by a 2 in source card column 54. The console switch for calibration has no effect in card control except that it cannot be left in the MANUAL position.

Data taking by the continuum programs can be delayed until the position error in declination is less than 20 arcseconds by placing a "1" in column 56.

10.8. ON-LINE DATA REDUCTION

The on-line MODCOMP analysis computer is available to the observer during the course of scheduled observations. Although data from all programs is recorded on 9-track telescope tapes for off-line reduction, the data are simultaneously transmitted from the DDP116 computer to the MODCOMP for inspection and reduction. The program for analyzing data is CONDAR, which is completely described in a separate manual. The data retrieval and data manipulation is very much the same as it is in POPS, the spectral line analysis program.

The number of data points in a continuum scan depends on the sample rate and the scan length, and is arbitrary. However, there is a maximum number of data points transferred from the DDP116 computer to the MODCOMP in a single scan. The maximum number of data points is 1190. This amounts to 19^{m} 50^{s} at a 1 Hz sample rate. All of the data is recorded on tape, but only this number of points can be examined on-line. The analysis disk can hold 1560 continuum scans of this maximum length, and more if the scans have fewer points. When the disk storage area is full, storage "wraps around" so that the most recent scan overwrites the data at the front of the area. It is useful to estimate how often the disk will fill up in those cases where the observer is trying to reduce all of the data on-line so that no data is overwritten before it is reduced. It is not a disaster if some data is overwritten, but the procedure for recovering from this situation is somewhat cumbersome. The recovery procedure involves reading the telescope tape onto the MODCOMP in the Jansky Lab, which is a clone of the one at the telescope. This may involve recalling tapes from the library in Charlottesville, resulting in further delay.

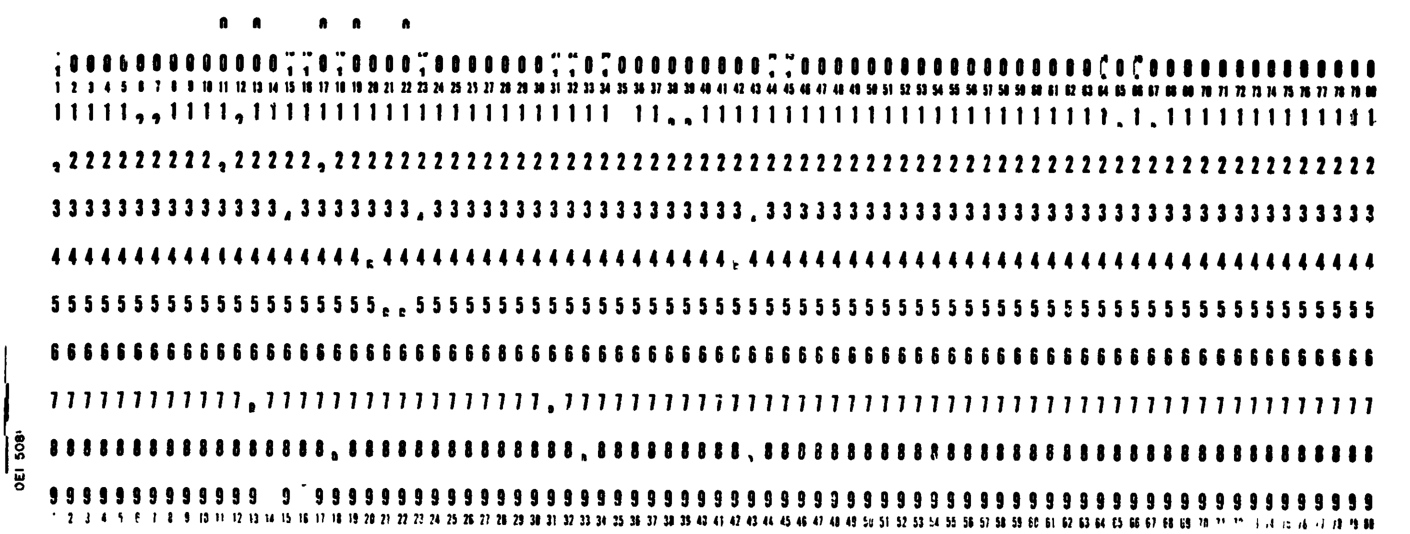
Data reduced on-line can be saved in a number of ways. Some observers take away only hard copies of scans reduced with their own custom-made procedures, which print all of the desired information on the screen. The parameters of Gaussian fits to the data can be stored at the end of a disk area set aside for that purpose by invoking the GPUNCH verb in CONDAR. This area can be copied onto a tape. A program in Charlottesville will take such a tape and produce punched cards for the observers' own reduction programs. Processed scans themselves can be saved on a KEEP tape for transport to the off-line analysis system in the Jansky Lab or elsewhere. The KEEP area on disk and KEEP tapes are a way to store and transport reduced or partially reduced scans, in contrast to telescope tapes, which record raw data record by record. The KEEP command in CONDAR is fully described in the CONDAR manual. Basically, the CONDAR analysis program can read data from a disk area for processing. An auxiliary disk area, the KEEP area, can be written sequentially from CONDAR. The KEEP area can be used to store completely reduced data, intermediate steps, partial averages, or simply to keep only scans instead of individual records. The KEEP area can be dumped onto a tape and subsequently read into the data file for further processing. The KEEP area can hold 143 scans, and must be dumped to tape when it is full. The KEEP tape format can be found in the CONDAR manual.

Only CONDAR/CONINT data can be examined by the CONDAR analysis program. There are no supported programs -- on-line or off-line -- for the analysis of FSAMP2 or SAVG2 data.

10.9. OFF-LINE DATA REDUCTION

A continuum data reduction system called CONDARE is available for use on the IBM 4341 computer in Charlottesville. This system is described in its own manual. For observers who would like to work directly with the telescope tapes, the formats for tapes written by CONDAR, CONINT, FSAMP2, and SAVG2 are given in Appendix A. No matter how the data are reduced, consider the fact that the receiver outputs written on tape by CONDAR, FSAMP2, and SAVG2 are in arbitrary units, and some reference calibrations must also be put on the same tape. Since the output of the A/D converters contains fewer bits than a computer word, the data words are padded out so that the least significant bit is zero when the calibration noise source is off, and one when the calibration noise source is on. Of course the data written on tape by CONINT is already calibrated. Telescope tapes are normally written at 1600 BPI but the MODCOMP can also write 800 BPI tapes, if desired.

```
F4      0000.00000000.00000000.00000000.0000   0.1642 270.0000   0.1642  90.0000
S    11    KAPITZKY-DENT          04   11   6.30                    0101
S    11    KAPITZKY-DENT          03   11   4.20                    0101
S    11    KAPITZKY-DENT          02   11   4.20                    0101
S    11    KAPITZKY-DENT       X0801   11   4.00                    0101
```



```
B        +34.000
F
S    TF    BRODERICK DENNISON      00   33   5.68                 4 3
S    TF    BRODERICK DENNISON   X0800   33   5.35                 4 3
```

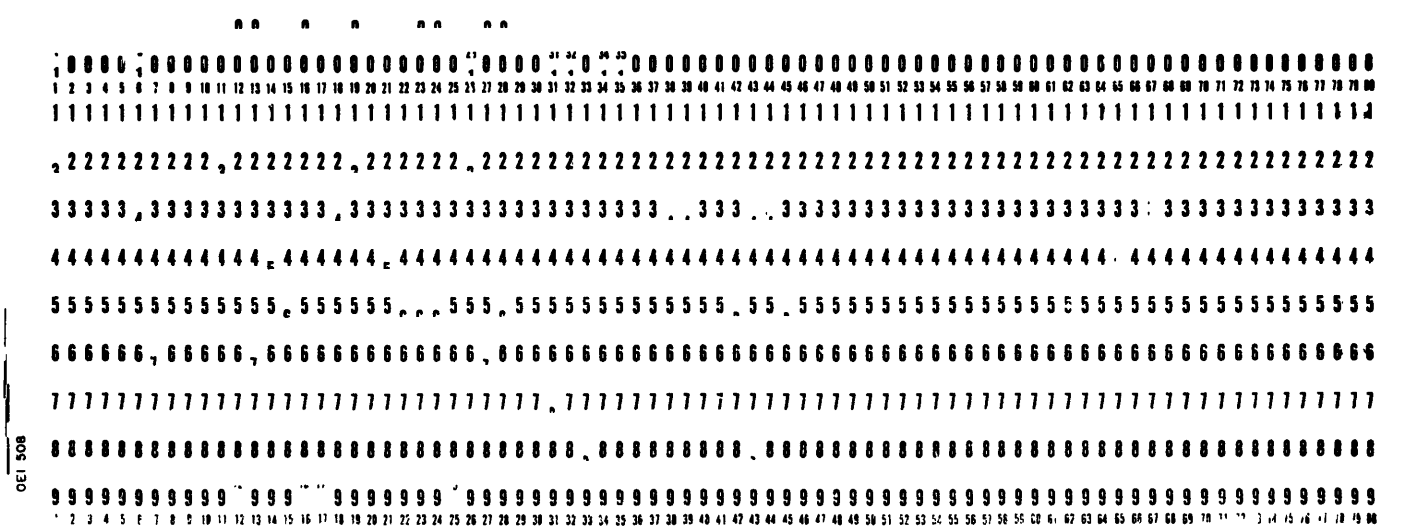


Figure 10-1. Two sample DDP116 setup card decks for CONDAR or CONINT continuum programs. The top deck uses an "F" card to specify the offsets of the four feeds on the 11 cm receiver. The bottom deck uses a "B" card to select the 700-1000 MHz feed on the travelling feed box.

TABLE 10-1

SETUP CARD FORMAT - CONDAR, CONINT

COLUMN	CONTENTS	FORMAT
1	"S"	A
2-5	Blanks	bbbb
6-7	Pointing Coefficient Identifier	AA (Table 8-3)
8-10	Blanks	bbb
11-30	Comment	20A's
31	"X" (First card only - must be blank on subsequent cards)	A
32-33	Starting Multiplexer Channel (First Card only, blank on all others)	NN
34-35	Pointing Code	NN
36-39	Lambda (in centimeters)	NNNN
40-45	Noise Tube Value	NNN.FF
64-65	Multiplier M (Synthesizer)	NN
66-67	Multiplier N (Front End)	NN
68-80	Blank	bbb...

TABLE 10-2

SETUP CARD FORMAT-FSAMP2 (DDP116 Computer)

COLUMN	CONTENTS	FORMAT
1	"S"	A
2-5	Blank	bbbb
6-7	Pointing coefficient identifier	AA (Table 8-3)
8-10	Blank	bbb
11-30	Comment	20A
31	"X" on first card Blank on all others	A
32-33	First channel of A/D converter to be sampled. Blank on all others.	NN
34-35	Pointing code for channel	NN
36-41	Noise source value for channel	NNN.FF
42-80	Blank	bbb...

TABLE 10-3

SETUP CARD-SAVG2 (DDP116 Computer)

COLUMN	CONTENTS	FORMAT
1	"S"	A
2-5	Blanks	bbbb
6-7	Pointing coefficient identifier	AA (Table 8-3)
8-10	Blanks	bbb
11-30	Comment	20 A's
31-32	Synthesizer Multiplier (M)	NN
33-34	Front-End Multiplier	NN
35-80	Blank	bbb...

NOTE" One "S" card only is required to make this program operate. No "F" card is required since only one input channel is allowed.

TABLE 10-4

"F" CARD FORMAT (DDP116 Computer)

COLUMN	CONTENTS	FORMAT
1	'F'	A
2	Number of OFFSET Feed Values	A
3-8	Blank	bbbbbb
9-17	RHO for Feed 1 OFFSET	NNNN.FFFF
18-26	THETA for Feed 1 OFFSET	NNNN.FFFF
27-35	RHO for Feed 2 OFFSET	NNNN.FFFF
36-44	THETA for Feed 2 OFFSET	NNNN.FFFF
45-53	RHO for Feed 3 OFFSET	NNNN.FFFF
54-62	THETA for Feed 3 OFFSET	NNNN.FFFF
63-71	RHO for Feed 4 OFFSET	NNNN.FFFF
72-80	THETA for Feed 4 OFFSET	NNNN.FFFF

Feed offset values for multi-feed systems on the 300 foot

		Feed	ρ	θ
21 cm, 4-feed		1	$0\overset{\circ}{.}2863$	$226\overset{\circ}{.}4000$
		2	$0\overset{\circ}{.}2440$	$302\overset{\circ}{.}2000$
		3	$0\overset{\circ}{.}2389$	$121\overset{\circ}{.}1000$
		4	$0\overset{\circ}{.}2856$	$46\overset{\circ}{.}3000$
11 cm, 3-feed		1	$0\overset{\circ}{.}0000$	$0\overset{\circ}{.}0000$
		2	$0\overset{\circ}{.}0000$	$0\overset{\circ}{.}0000$
		3	$0\overset{\circ}{.}1642$	$270\overset{\circ}{.}0000$
		4	$0\overset{\circ}{.}1642$	$90\overset{\circ}{.}0000$
6-cm, Beam Switched)				
A1L and		1 (Sig)	$0\overset{\circ}{.}0600$	$0\overset{\circ}{.}0000$
TRG		2 (Ref)	$0\overset{\circ}{.}0600$	$180\overset{\circ}{.}0000$
	or	1 (Sig)	$0\overset{\circ}{.}0000$	$0\overset{\circ}{.}0000$
		2 (Ref)	$0\overset{\circ}{.}1200$	$180\overset{\circ}{.}0000$

TABLE 10-5

"B" CARD FORMAT (DDP116 COMPUTER)

COLUMN	CONTENTS	FORMAT
L	"B"	A
2-7	Blanks	bbbbbbbb
10-16[1]	Feed offset (inches)	SNN.FFF

NOTES:

1. A plus-offset defines the feed physically offset West on the traveling feed carriage.

   A minus-offset defines the feed physically East on the feed carriage.

TABLE 10-6

"L" CARD DESCRIPTION - CONDAR, CONINT

COLUMN	CONTENTS	FORMAT
1	"L"	A
2	ULO Number	N
3	Mode = 1	A
4-6	Blank	bbb
7-15	F_o in Hz	NNNNNNNNN
16-18	Blank	bbb
19-27	FREF1 in Hz	NNNNNNNNN
28-30	Blank	bbb
31-39	FREF2 in Hz	NNNNNNNNN
40-80	Blank	bbb...

NOTE: Modes 2 and 3 are not usable due to the lack of rest frequency input.

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Parameter / Radiometer	ε_A	ε_B	Beam width and shape	Sidelobes	Pointing	Baselines	Coma lobe	BDF	Polarization
50-80 MHz									
110-240 MHz	6,25,26								
250-500 MHz	6,12,13				6,8,9				
500-750 MHz	37		37						
740-1000 MHz	6				6,32				
Cooled 21 cm	4		4,40,53	40	4,54			4	
21 cm Zeeman									
21 cm scalar					22				
21 cm four feed	2,23	2	2	2	17,21	15			
11 cm three feed	3,24,29,34				3,29,30,42				3,19
6 cm AIL Dual beam	1,50				1,50				
6 cm AIL Orthog									
6 cm TRG									
General	16	16		16					

Focus: 21 cm 4 feed [21,23] 21 cm scalar [22]

TABLE OF TABLES

APPENDIX A

NINE-TRACK TELESCOPE TAPE FORMATS

For the benefit of observers who choose to or must write their own data reduction programs, the 9-track telescope tape formats are given in this appendix. The individual word formats are described after the last tape format table, and notes unique to particular data groups are included with each tape format. As new features are added to the on-line programs, it may be necessary to change tape formats, so the programmer should be sure he has the latest one. Hopefully, they will not have to be changed more than once every year or two.

Effective Date: Feb. 1982

TABLE A-1

FORMAT 55, MPOWR3

WORD	FORMAT	CONTENTS
1	2	*Scan Number
2	2	Zero
3-12	1	Observer Name
13-18	1	Source Name
19	2	Zero
20-21	5BB17	Julian Date (-2400000 Days)
22	6B1	Orientation Angle (Turns)
23	6B1	Orientation Angle (Turns)
24-25	4	*L.S.T.
26-27	4	*E.S.T.
28	2	*Month
29	2	*Day
30	2	*Year
31	2	Type of Observing (55)
32	2	*Observer Number
33	2	Integration Period (.1 Sec)
34	2	Telescope
35	2	Position Code
36	2	Zero
37-38	5BB15	R.A. Rate (Epoch)
39-40	5BB15	Dec. Rate (Epoch)
41-42	5BB15	Epoch Observed In
43	6B10	Focus (Millimeters)
44	6B10	Focus (Millimeters)
45-46	4	Level Reading
47-48	4	*R.A. Indicated
49-50	4	*Dec. Indicated
51-83	Note 1	Rx. A Descriptor Block
84-116	Note 1	Rx. B Descriptor Block
117-149	Note 1	Rx. C Descriptor Block
150-182	Note 1	Rx. D Descriptor Block
183-214	Note 2	L.O. Data Block
215-598	Note 3 (6B3)	Signal Spectrum
599-982	Note 3 (6B3)	Reference Spectrum
983-998	Note 4	Signal Power Counters
999-1014	Note 4	Reference Power Counters
1015-1030	4	Chan. Zero Words
1031-1034	4	Chan. 385 Words
1035-1066	Note 5	A/C Control Words (1572-1603)
1067-1068	4	Spectral Scaling Factor
1069-1095	----	Reserved Words

* At dump from autocorrelator

See notes at the end of the TPOWR3 format.

TABLE A-2

FORMAT 56, SPOWR3

WORD	FORMAT	CONTENTS
1	2	*Scan Number
2	2	Zero
3-12	1	Observer Name
13-18	1	Source Name
19	2	Zero
20-21	5BB17	Julian Date (-2400000 Days)
22	6B1	Orientation Angle (Turns)
23	6B1	Orientation Angle (Turns)
24-25	4	*L.S.T.
26-27	4	*E.S.T.
28	2	*Month
29	2	*Day
30	2	*Year
31	2	Type of Observing (56)
32	2	*Observer Number
33	2	Integration Period (.1 Sec)
34	2	Telescope
35	2	Position Code
36	2	Zero
37-38	5BB15	R.A. Rate (Epoch)
39-40	5BB15	Dec. Rate (Epoch)
41-42	5BB15	Epoch Observed In
43	6B10	Focus (Millimeters)
44	6B10	Focus (Millimeters)
45-46	4	Level Reading
47-48	4	*R.A. Indicated
49-50	4	*Dec. Indicated
51-83	Note 1	Rx. A Descriptor Block
84-116	Note 1	Rx. B Descriptor Block
117-149	Note 1	Rx. C Descriptor Block
150-182	Note 1	Rx. D Descriptor Block
183-214	Note 2	L.O. Data Block
215-1750	4 Note 3	Signal and Reference Spectra
1751-1782	4 (B30) Note 4	Power Counters
1783-1798	4	Chan. Zero Words
1799-1802	4	Chan. 385 Words
1803-1834	Note 5	A/C Words 1572-1603
1835-1836	4	Spectral Scaling Factor
1837-1850	----	Reserved Words

* At midpoint in time of the integration

See notes at the end of TPOWR3 format.

Effective Date: Feb. 1982

TABLE A-3

FORMAT 57, TPOWR3

WORD	FORMAT	CONTENTS
1	2	*Scan Number
2	2	Off Scan Number
3-12	1	Observer Name
13-18	1	Source Name
19	2	Zero
20-21	5BB17	Julian Date (-2400000 Days)
22	6B1	True Orientation Angle (Turns)
23	6B1	True Orientation Angle (Turns)
24-25	4	*L.S.T.
26-27	4	*E.S.T.
28	2	*Month
29	2	*Day
30	2	*Year
31	2	Type of Observing (57)
32	2	*Observer Number
33	2	Integration Period (.1 Sec.)
34	2	Telescope
35	2	Position Code
36	2	Zero
37-38	5BB15	R.A. Rate (Epoch)
39-40	5BB15	Dec. Rate (Epoch)
41-42	5BB15	Epoch Observed In
43	6B10	True Focus (Millimeters)
44	6B10	Ind. Focus (Millimeters)
45-46	4	Level Reading
47-48	4	*R.A. Indicated
49-50	4	*Dec. Indicated
51-83	Note 1	Rx. A Descriptor Block
84-116	Note 1	Rx. B Descriptor Block
117-149	Note 1	Rx. C Descriptor Block
150-182	Note 1	Rx. D Descriptor Block
183-214	Note 2	L.O. Data Block
215-982	4 Note 3	Spectrum
983-998	4 (BB30) Note 4	Signal Power Counters
999-1014	4 (BB30) Note 4	Reference Power Counters
1015-1030	4	Chan. Zero Words
1031-1032	4	Chan. 385S Words
1033-1034	4	Chan. 385R Words
1035-1066	Note 5	A/C Words 1572-1603
1067-1068	4	Spectral Scaling Factor
1069-1095	----	Reserved Words

* At midpoint in time of the integration

NOTES: For Formats (55, 56, 57)

1. Format of Rx. Descriptor Block

WORD	FORMAT	CONTENTS
1	2	Pointing Code
2	2	Calibration Code
3	2	Inversion Indicator
4-5	5BB15	Noise Tube
6-7	5BB30	Rest Freq. (Hz)
8-16	1	Center Freq. Formula
17-18	5BB30	Center Freq./M*N (FSKY)
19-20	5BB19	Radial Velocity of System
21	2 (BYTE1 = REF) (BYTE2 = DEF)	Velocity Indicator (REF. & DEF.) REF = 1, NO DEF = 1, RADIO 2, LSR 2, OPTICAL 3, SUN 4, EARTH
22-23	4	*Apparent R.A.
24-25	4	*Apparent Dec
26-27	4	*1950 R.A.
28-29	4	*1950 Dec
30-31	4	RHO for Feed
32-33	4	Theta for Feed

2. L.O. Data Block - For Formats (55, 56, 57)

WORD	FORMAT	CONTENTS	
1-2	5BB30	L1	Signal L.O. (Hz)
3-4	5BB30	L1F1	First Ref. L.O. (Hz)
5-6	5BB30	L1F2	Second Ref. L.O. (Hz)
7	2B15	M	Front End Multiplier
8	2B15	N	Syn. Multiplier
9-10	5BB30	LA	I.F. Offsets
11-12	5BB30	LB	I.F. Offsets
13-14	5BB30	LC	I.F. Offsets
15-16	5BB30	LD	I.F. Offsets
17-18	5BB30	L2	Second L.O. Data
19-20	5BB30	L2F1	Second L.O. Data
21-22	5BB30	L2F2	Second L.O. Data
23	2B15	M2	Second L.O. Data
24	2B15	N2	Second L.O. Data
25-26	5BB30	L3	Third L.O. Data
27-28	5BB30	L3F1	Third L.O. Data
29-30	5BB30	L3F2	Third L.O. Data
31	2B15	M3	Third L.O. Data
32	2B15	N3	Third L.O. Data

3. 384 channels of relative spectral intensities are contained here. In MPOWR3 and SPOWR3 the set of signal channels appear first followed by 384 reference channels. The spectral intensities in MPOWR3 are contained in single 16 bit interger words. In SPOWR3 and TPOWR3, however, 2-16 bit words are used in series and must be combined off-line to produce a 32-bit integer. (See the sample program.)

4. The power counters are integrated for the period of time indicated in word 33. They are recorded in the same order as A/C words 770-785 and 1556-1571 as described in Appendix I of ref. [31].

5. See Appendix I of ref. [31] for the order and format of these words.

TABLE A-4

FORMAT 61, CONDAR

WORD	FORMAT	CONTENTS
1	2	Scan Number
2	2	Zero
3-12	1	Observer Name in ASCII
13-18	1	Source Name in ASCII
19	2	Number of Channels
20-21	5BB17	Julian Date (-2400000 Days)
22	6B1	Orientation Angle (Turns)
23	6B1	Orientation Angle (Turns)
24-25	4	**L.S.T.
26-27	4	**E.S.T.
28	2	Month
29	2	Day
30	2	Year
31	2	Type of Observing (61)
32	2	Observer Number
33	2	Integration Period (.1 Sec)
34	2	Telescope Number
35	2	Position Code
36	2	Calibration Mode
37-38	5BB15	RA Rate (Epoch Observed)
39-40	5BB15	Dec Rate (Epoch Observed)
41-42	5BB15	Epoch Observed In
43	6B10	Focus (Millimeters)
44	6B10	Focus
45	2	Zero
46	2	Subblock Counter
47-48	4	**Indicated R.A.
49-50	4	**Indicated Dec
51-66	Note 1	Rec. Descriptor Block 1
67-82	Note 1	Rec. Descriptor Block 2
83-98	Note 1	Rec. Descriptor Block 3
99-114	Note 1	Rec. Descriptor Block 4
115-130	Note 1	Rec. Descriptor Block 5
131-146	Note 1	Rec. Descriptor Block 6
147-162	Note 1	Rec. Descriptor Block 7
163-178	Note 1	Rec. Descriptor Block 8
179-184	5BB30	L.O. Data (Hertz)
185	2	Multiplier M
186	2	Multiplier N
187-188	4	Level Reading
189-192	2	Reserved
193-204	Note 2	Data Subblock 1
205-216	Note 2	Data Subblock 2
--	--	--
589-600	Note 2	Data Subblock 34

** Center of integration

Note 1: (Format 61) Receiver Descriptor Block (At center of integration of 1st data point of record)

WORD	FORMAT	CONTENTS
1	2	Pointing Code
2	2	Lamda (centimeters)
3-4	5BB15	Noise Tube Value
5-6	4	*Apparent RA
7-8	4	*Apparent Dec
9-10	4	*1950 RA
11-12	4	*1950 Dec
13-14	4	RHO
15-16	4	Theta

* Stored in first descriptor block only at the time of moving header for record. This corresponds to words 47-48 and 49-50 of header less pointing corrections.

Note 2: Data Subblock

WORD	FORMAT	CONTENTS
1-2	4	**Observed H Coordinate
2-4	4	**Observed V Coordinate
5	2	Radiometer 1 Output
6	2	Radiometer 2 Output
7	2	Radiometer 3 Output
8	2	Radiometer 4 Output
9	2	Radiometer 5 Output
10	2	Radiometer 6 Output
11	2	Radiometer 7 Output
12	2	Radiometer 8 Output

Effective Date: Feb. 1982

TABLE A-5

FORMAT 26, FSAMP2

WORD	FORMAT	CONTENTS
1	2	Scan
2	2	Zero
3-12	1	Observer Name in ASCII
13-18	1	Source Name
19-32	1	Blanks
33	2	# of Channels
34	3	Orientation Angle
35	3	Orientation Angle
36-37	4	L.S.T. first sample in block
38-39	4	E.S.T. first sample in block
40	2	Month
41	2	Day
42	2	Year
43	2	Type of Observing
44	2	Observer Number
45	2	Sample Rate in Milliseconds
46	2	Telescope
47-49	2	Zero's
50	2	Subscan Counter
51-52	4	R.A. Indicated
53-54	4	Dec. Indicated
55-1078	2	See next page

FORMAT 26 (Cont.)

Layout of Words 55-1078

This layout varies according to the number of channels being recorded. The table below illustrates the variation. The entries give the channel number and the sample number.

WORD	1 Channel Recording	2 Channel Recording	4 Channel Recording	8 Channel Recording
55	1/1	1/1	1/1	1/1
56	1/2	2/1	2/1	2/1
57	1/3	1/2	3/1	3/1
58	1/4	2/2	4/1	4/1
59	1/5	1/3	1/2	5/1
60	1/6	2/3	2/2	6/1
61	1/7	1/4	3/2	7/1
62	1/8	2/4	4/2	8/1
63	1/9	1/5	1/3	1/2
65	1/11	1/6	3/3	3/2
66	1/12	2/6	4/3	4/2
	.	.	.	.
	.	.	.	.
	.	.	.	.
	.	.	.	.
1075	1/1021	1/511	1/256	5/128
1076	1/1022	2/511	2/256	6/128
1077	1/1023	1/512	3/256	7/128
1078	1/1024	2/512	4/256	8/128

For example, for 2 channel recording, word 65 contains the sixth sample of the first channel.

The program requires that the number of channels be 1, 2, 4 or 8.

Effective Date: Feb. 1982

TABLE A-6

FORMAT 62, CONINT

WORD	FORMAT	CONTENTS
1	2	Scan Number
2	2	Zero
3-12	1	Observer Name (ASCII)
13-18	1	Source Name (ASCII)
19	2	Number of Channels
20-21	5BB17	Julian Date (-2400000 days)
22	6B1	Orientation Angle (Turns)
23	6B1	Orientation Angle (Turns
24-25	4	L.S.T.
26-27	4	E.S.T.
28	2	Month
29	2	Day
30	2	Year
31	2	Type of Observing (62)
32	2	Observer Number
33	2	Integration Period (Milliseconds)
34	2	Telescope Number
35	2	Position Code
36	2	Calmode (No-Cal)
37-38	5BB15	RA Rate
39-40	5BB15	Dec Rate
41-42	5BB15	Epoch of Observation
43	6B10	Focus
44	6B10	Focus
45	2	Posparm 8
46	2	Subblock Counter
47-48	4	Indicated R.A.
49-50	4	Indicated Dec.
51-66	Note 1	Rec. Descriptor Block 1
67-82	Note 1	Rec. Descriptor Block 2
83-98	Note 1	Rec. Descriptor Block 3
99-114	Note 1	Rec. Descriptor Block 4
115-178	Note 2	Digital Receiver Header Info.
179-184	5BB30	L.O. Data (Hertz)
185	2	Multiplier M
186	2	Multiplier N
187-188	4	Level Reading
189-192	2	Reserved
193-204	Note 3	Data Subblock 1
205-216	Note 3	Data Subblock 2
---	---	---
589-600	Note 3	Data Subblock 34

FORMAT 62 (Cont.)

Note 1: (Format 62) Receiver Descriptor Block

WORD	FORMAT	CONTENTS
1	2	Pointing Code
2	2	Lambda (centimeters)
3-4	5BB15	Noise Tube Value
5-6	4	*Apparent RA
7-8	4	*Apparent Dec
9-10	4	*1950 RA
11-12	4	*1950 Dec
13-14	4	RHO
15-16	4	Theta

* Stored in first descriptor block only at the time of moving header for record. This corresponds to words 47-48 and 49-50 of header less pointing corrections.

Note 2: (Format 62) Digital Receiver Header Info.

WORD	CONTENTS
1	Host data scale factor (counts/K)
2	Receiver balance time factor (# switch cycles)
3	Receiver balance time (centiseconds)
4	Integration period (milliseconds)
5	Interrupt delay time
6	Blanking time parts (4096 x Blanking time/phase per.
7	Phase period (milliseconds)
8	Blanking time (milliseconds)
9	Number of receiver channels in use
10	Input status word
11	Summation time for statistics data (sec)
12	Gain Modulation factor for chan. 1 x 10^3
13	System Temperature for chan. 1 (decikelvins)
14	Relative gain for chan. 1 x 10^3
15	Measured output RMS for chan. 1
16	Theoretical output RMS for chan. 1
17	U/F counter scale factor for chan. 1
18	Calibration noise source for chan. 1
19	System temperature for chan. 1
20	Channel 2 bandwidth
21	Gain modulation for chan. 2 x 10^3

.
.
.
.

etc. for as many channels used
repeating 12 through 20

FORMAT 62 (Cont.)

Note 3: (Format 62) Data Subblock

WORD	FORMAT	CONTENTS
1-2	4	**Observed H Coordinate
3-4	4	**Observed U Coordinate
5	2	Radiometer 1 output
6	2	Radiometer 2 output
7	2	Radiometer 3 output
8	2	Radiometer 4 output
9		Reserved
10		Reserved
11		Reserved
12		Reserved

** Center of Integration

Effective Date: Feb. 1982

TABLE A-7

FORMAT 51, SAVG2

WORD	FORMAT	CONTENTS
1	2	Scan Number
2	2	Zero
3-12	1	Observer Name
13-18	1	Source Name
19	1	Zero
20-21	5BB17	Julian Date (-2400000)
22	3	Orient. Angle
23	3	Orient. Angle
24-25	4	*L.S.T.
26-27	4	*E.S.T.
28	2	Month
29	2	Day
30	2	Year
31	2	Type of Observing (51)
32	2	Observer Number
33	2	Zero
34	2	Telescope
35	2	Position Code
36	2	Zero
37-38	5BB15	G.C. Rate
39-40	5BB15	L.C. Rate
41-42	5BB15	Epoch
43	6B10	Focus
44	6B10	Focus
45-46	2	Zero
47-48	4	*R.A. Indicated
49-50	4	*Dec. Indicated
51-52	2	Zero
53	2	Multiplier (Synthesizer)
54	2	Multiplier (Front-End)
55	2	# of Signal Ave. Words
56-57	5BB30	L1 (Hertz)
58-59	5BB30	L1F1 (Hertz)
60-61	5BB30	L1F2 (Hertz)
62-104	2	Spare Words
105-4200	2	Signal Averager Words

* Start Time of Integration of Signal Averager

Word Formats for all Programs

1 - This is an alphanumeric format in ASCII code with two characters per word.

2 - This is a standard 16-bit integer which ranges from -32768(-2^{15}) to 32767.

4 - This format is used where double precision is required. It uses 2 16-bit words in series, the first containing the sign and 15 highest order bits, and the second contains a zero in the sign bit and the 15 low order bits. To handle this in FORTRAN, use the equation

```
IFOUR = ID(24) * 32768 + ID(25),
```

where IFOUR is an INTERGER*4 word and ID(24) and ID(25) are examples from the MPOWR3 format.

Unless otherwise noted, all of the time and angle measures (e.g. R.A., Dec, E.S.T., L.S.T., and Polarization angle) are in turns time 2^{30}. To convert the above example into decimal hours, the following statements would be needed:

```
REAL*8  C,HLST
C = 2.**30
HLST = DFLOAT(IFOUR)/C
```

Double word spectral values and power counters could best be handled by converting them to REAL*4 since they are only relative numbers and must be used in ratios.

5 - These are also sets of double 16-bit words like word format 4, but the decimal may be specified to be anywhere in the bit sequence as specified in the BB--notation. For example, BB17 would indicate that the decimal is 17 places from the left in a 30-bit word.

For example, to convert the Julian date in the CONDAR format to a decimal number, the following numbers would be required:

```
REAL*8  JD,C
C = 2.**13
JD = DFLOAT(ID(20)*32768+ID(21))/C
```

This could also be done in single precision if all of the accuracy were not required.

By definition, the time and angle measure in word format 4 are BBO.

6 - Same as 5 except that it applies to a single 16-bit word, i.e. 6BB10 would indicate the decimal is 10 bits from the right of a 16-bit word.

APPENDIX B

SOURCE LIST (Calibrators)

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
0003-066	00 03 40.293	-06 40 17.30	VLA
0003-003	00 03 48.84	-00 21 06.0	ADGIE ET AL. 1972
0007+171	00 07 59.383	17 07 37.50	VLA
0008-421	00 08 21.318	-42 09 49.70	VLA
0008-264	00 08 28.882	-26 29 14.80	VLA
0012+610	00 12 07.930	61 01 04.00	VLA
0013+790	00 13 35.09	79 00 12.9	HOGBOM AND CARLSSON 1974
0013-005	00 13 37.347	-0C 31 52.50	VLA
0016+731	00 16 54.198	73 10 51.46	VLA
0019-000	00 19 51.650	-00 01 41.77	VLA
0019+058	00 19 58.020	05 51 26.40	VLA
0022-423	00 22 15.417	-42 18 40.70	VLA
0022+390	00 22 46.668	39 02 59.00	VLA
0023-263	00 23 18.914	-26 18 49.25	VLA
0024+348	00 24 02.786	34 52 06.40	VLA
0026+346	00 26 34.834	34 39 57.70	VLA
0030+196	00 30 01.24	19 37 19.4	FOMALONT AND MOFFET 1971
0034-014	00 34 30.49	-01 25 36.7	MCEWAN ET AL. 1975
0035+413	00 35 41.572	41 20 37.10	VLA
0035-024	00 35 47.13	-02 24 07.7	BRANDIE AND BRIDLE 1974
0036-216	00 36 00.439	-21 36 33.10	VLA
0038+328	00 38 13.830	32 53 41.20	VLA
0038+097	00 38 14.57	09 46 56.1	FOMALONT AND MOFFET 1971
0038-020	00 38 24.233	-02 02 59.25	VLA
0039+230	00 39 25.713	23 03 34.70	VLA
0039-445	00 39 47.280	-44 30 42.00	VLA
0040+517	00 40 18.00	51 47 12.8	KUHR 1979
0042-357	00 42 16.500	-35 47 06.00	VLA
0048+509	00 48 04.88	5C 55 45.0	FOMALONT AND MOFFET 1971
0048-097	00 48 09.983	-09 45 24.25	VLA
0048-071	00 48 36.200	-07 06 20.50	VLA
0051-038	00 51 35.67	-03 50 13.5	FOMALONT AND MOFFET 1971
0052+681	00 52 44.9	68 06 06.2	FOMALONT AND MOFFET 1971
0055+300	00 55 05.634	30 04 57.05	VLA
0056-001	00 56 31.755	-00 09 18.75	VLA
0102+480	01 02 55.460	48 03 00.50	VLA
0104-408	01 04 27.575	-40 50 21.20	VLA
0106+013	01 06 04.523	01 19 01.06	VLA
0107+562	01 07 53.796	56 16 20.70	VLA
0108-079	01 08 19.000	-07 57 37.60	VLA
0108+388	01 08 47.254	38 50 32.80	VLA
0109+224	01 09 23.611	22 28 44.10	VLA
0111+021	01 11 08.570	02 06 24.75	VLA
0112-017	01 12 43.920	-01 42 54.95	VLA
0113-118	01 13 43.217	-11 52 04.50	VLA
0114-211	01 14 25.954	-21 07 55.00	VLA
0116+082	01 16 25.04	08 14 30.4	CONDON ET AL. 1975
0116-219	01 16 32.404	-21 57 15.20	VLA
0116+319	C1 16 47.249	31 55 05.83	VLA
0117-155	01 17 59.700	-15 35 59.60	VLA
0118-272	01 18 09.531	-27 17 07.35	VLA
0119+115	01 19 03.083	11 34 09.30	VLA
0119+041	01 19 21.393	04 06 44.00	VLA
0119+247	01 19 54.284	24 46 52.10	VLA

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
0003-066							
0003-003	3.54	0.12	2.33	0.02	1.41	0.04E	3C2
0007+171							
0008-421							
0008-264							
0012+610							
0013+790	3.39	0.09D	1.86	0.04A	1.04	0.04E	3C6.1
0013-005							
0016+731							
0019-000	2.73	0.07	1.84	0.02	1.05	0.04E	
0019+058							
0022-423							
0022+390							
0023-263							
0024+348							
0026*346							
0030+196	1.72	0.06L	1.25	0.05	0.82	0.03H	3C12
0034-014							3C15
0035+413							
0035-024	6.25	0.17	3.94	0.04	2.72	0.07E	3C17
0036-216							
0038+328	3.12	0.08	1.86	0.02	1.26	0.09E	3C19
0038+097	4.26	0.14	2.68	0.05	1.73	0.06E	3C18
0038-020							
0039+230							
0039-445							
0040+517	10.79	0.31	6.53	0.18	4.18	0.16E	3C20
0042-357							
0048+509	2.27	0.15	1.23	0.03	0.76	0.03E	3C22
0048-097							
0048-071							
0051-038	2.11	0.09	1.17	0.01	0.61	0.04E	3C26
0052+681	7.10	0.27	4.36	0.12	2.48	0.06E	3C27
0055+300							
0056-001	2.16	0.07	1.93	0.03	1.46	0.05E	P0056-00
0102+480							
0104-408							
0106+013							P0106+01
0107+562	1.88	0.07	1.29	0.02	0.90	0.09N	
0108-079							
0108+388							
0109+224							
0111+021							
0112-017	1.20	0.11C	1.11	0.04	1.16	0.04F	
0113-118							
0114-211							
0116+082	2.38	0.06	1.66	0.03	1.18	0.04H	
0116-219							
0116+319	2.54	0.07	1.98	0.03	1.46	0.04H	
0117-155	4.95	0.13D	2.74	0.23	1.42	0.07E	3C38
0118-272							
0119+115							
0119+041							
0119+247							

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
0122-003	01 22 55.177	-00 21 31.25	VLA
0123+329	01 23 54.82	32 57 35.6	FOMALONT AND MOFFET 1971
0125+287	01 25 42.89	28 47 29.3	FOMALONT AND MOFFET 1971
0127+233	01 27 15.080	23 22 52.70	VLA
0130-171	01 30 17.689	-17 10 12.10	VLA
0132-097	01 32 06.405	-09 46 23.30	VLA
0132+079	01 32 37.51	07 55 46.4	FOMALONT AND MOFFET 1971
0133-203	01 33 13.631	-20 24 04.30	VLA
0133+206	01 33 39.96	20 41 55	FOMALONT 1968, BDFL
0133+476	01 33 55.105	47 36 12.80	VLA
0134+329	01 34 49.832	32 54 20.52	VLA
0135-247	01 35 17.110	-24 46 08.65	VLA
0138+136	01 38 28.530	13 38 20.10	VLA
0138-097	01 38 56.860	-09 43 51.65	VLA
0142-278	01 42 44.991	-27 48 35.40	VLA
0145+532	01 45 15.33	53 17 45	FOMALONT AND MOFFET 1971
0146+056	01 46 45.523	05 41 00.70	VLA
0147+187	01 47 05.584	18 42 28.60	VLA
0149+218	01 49 31.736	21 52 20.70	VLA
0150-334	01 50 56.987	-33 25 10.65	VLA
0153+744	01 53 04.350	74 28 05.65	VLA
0154+286	01 54 19.3	28 37 03	BDFL
0159-117	01 59 30.400	-11 47 00.00	VLA
0201+113	02 01 05.997	11 20 22.85	VLA
0201-440	02 01 39.850	-44 04 13.00	VLA
0202+149	02 02 07.403	14 59 50.95	VLA
0202+319	02 02 09.656	31 58 10.35	VLA
0202-172	02 02 34.515	-17 15 39.43	VLA
0206+355	02 06 39.11	35 33 43.0	S4
0212+735	02 12 49.925	73 35 40.10	VLA
0213-026	02 13 09.870	-02 36 51.50	VLA
0216+011	02 16 32.457	01 07 13.35	VLA
0218+357	02 18 04.131	35 42 32.00	VLA
0218-021	02 18 21.900	-02 10 35.50	VLA
0220+397	02 20 36.78	39 47 16	FOMALONT AND MOFFET 1971
0220-349	02 20 49.580	-34 55 04.60	VLA
0221+276	02 21 18.060	27 36 38.20	VLA
0221+067	02 21 49.960	06 45 50.40	VLA
0223+341	02 23 09.75	34 08 01.6	ADGIE ET AL. 1972
0224+671	02 24 41.175	67 07 39.70	VLA
0229+132	02 29 02.527	13 09 40.60	VLA
0229+341	02 29 27.06	34 10 55.4	ADGIE ET AL. 1972
0229-398	02 29 51.975	-39 48 58.70	VLA
0234+285	02 34 55.593	28 35 11.35	VLA
0235+164	02 35 52.630	16 24 03.98	VLA
0237-027	02 37 13.717	-02 47 32.93	VLA
0237+040	02 37 14.407	04 03 29.65	VLA
0237-233	02 37 52.789	-23 22 06.42	VLA
0238-084	02 38 37.356	-08 28 08.95	VLA
0239+108	02 39 47.093	10 48 16.15	VLA
0240-217	02 40 19.329	-21 45 09.80	VLA
0248+430	02 48 18.490	43 02 56.95	VLA
0250+178	02 50 46.319	17 53 30.10	VLA
0256+075	02 56 46.990	07 35 45.20	VLA

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
0122-003							
0123+329	3.49	0.10	2.24	0.03	1.46	0.05E	3C41
0125+287	2.64	0.08	1.59	0.02	0.84	0.04E	3C42
0127+233	2.78	0.08	1.76	0.02	1.09	0.04E	3C43
0130-171							
0132-097							
0132+079	2.33	0.07	1.29	0.02	0.78	0.03H	3C45
0133-203							
0133+206	3.68	0.09	2.02	0.04	1.10	0.05E	3C47
0133+476							
0134+329	15.29	0.35	9.15	0.14	5.37	0.07E	3C48
0135-247							
0138+136							3C49
0138-097							
0142-278							
0145+532	3.72	0.10	2.31	0.03	1.48	0.06E	3C52
0146+056							
0147+187							
0149+218							
0150-334							
0153+744							
0154+286	2.50	0.12	1.21	0.01	0.88	0.10E	3C55
0159-117	3.24	0.14B	2.00	0.10	1.25	0.04E	3C57
0201+113							
0201-440							
0202+149							NRAO91
0202+319							
0202-172							
0206+355	2.15	0.06	1.38	0.02	0.87	0.03I	
0212+735							
0213-026							
0216+011							
0218+357							
0218-021	3.32	0.08	1.65	0.04	1.09	0.06E	3C63
0220+397	3.13	0.21	1.59	0.03	0.77	0.05E	3C65
0220-349							
0221+276	2.94	0.23	1.70	0.03	0.91	0.05E	3C67
0221+067							
0223+341	2.17	0.06	1.71	0.03	1.20	0.04H	
0224+671							D0224+67
0229+132							
0229+341	2.42	0.16	1.42	0.01	0.83	0.03E	3C68.1
0229-398							
0234+285							
0235+164							
0237-027							
0237+040							
0237-233							P0237-23
0238-084							
0239+108							
0240-217							
0248+430							
0250+178							
0256+075							

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
0258+350	02 58 35.3	35 00 30	S4
0300+471	03 00 10.110	47 04 33.70	VLA
0300+162	03 00 27.10	16 14 31.0	KUHR 1979
0306+102	03 06 20.920	10 17 51.90	VLA
0307+169	03 07 11.4	16 54 34	BDFL
0309+390	03 09 12.20	39 05 17.7	KUHR 1979
0316+161	03 16 09.138	16 17 40.45	VLA
0316+413	03 16 29.569	41 19 51.94	VLA
0317+188	03 17 00.043	18 50 41.90	VLA
0319+121	03 19 08.206	12 10 31.60	VLA
0320+053	03 20 41.49	05 23 34.5	FOMALONT AND MOFFET 1971
0327-241	03 27 43.868	-24 07 22.90	VLA
0331-013	03 31 41.8	-01 21 21	MCEWAN ET AL. 1975
0332+078	03 32 12.103	07 50 16.65	VLA
0332-403	03 32 25.238	-40 18 23.85	VLA
0333+321	03 33 22.400	32 08 36.67	VLA
0333+128	03 33 40.57	12 52 40.1	FOMALONT AND MOFFET 1971
0336-019	03 36 58.954	-01 56 16.92	VLA
0338-214	03 38 23.281	-21 29 07.85	VLA
0340+048	03 40 51.60	04 48 24.4	FOMALONT AND MOFFET 1971
0345+337	03 45 35.720	33 44 06.30	VLA
0346-279	03 46 34.032	-27 58 20.70	VLA
0347+057	03 47 07.32	05 42 34	FOMALONT 1968, BDFL
0355+508	03 55 45.256	50 49 20.29	VLA
0400+258	04 00 03.589	25 51 46.50	VLA
0400-319	04 00 23.609	-31 55 41.90	VLA
0402-362	04 02 02.598	-36 13 11.75	VLA
0403-132	04 03 13.962	-13 16 18.80	VLA
0404+428	04 04 35.1	42 52 27	BDFL
0405-123	04 05 27.461	-12 19 32.50	VLA
0405-331	04 05 38.548	-33 11 42.00	VLA
0405-385	04 05 12.070	-38 34 24.70	VLA
0406+387	04 06 01.360	38 40 41.70	VLA
0406+121	04 06 35.476	12 09 49.25	VLA
0406-127	04 06 45.328	-12 46 39.00	VLA
0409+229	04 09 44.670	22 57 27.60	VLA
0411+141	04 11 41.19	14 08 42	FOMALONT 1968, BDFL
0411+054	04 11 58.29	05 27 13.4	ADGIE ET AL. 1972
0413-210	04 13 53.621	-21 03 51.10	VLA
0414-189	04 14 23.354	-18 58 29.65	VLA
0420+417	04 20 28.7	41 43 12	BDFL
0420+347	04 20 41.090	34 44 52.00	VLA
0420-014	04 20 43.540	-01 27 28.66	VLA
0421+019	04 21 32.673	01 57 32.70	VLA
0422+004	04 22 12.520	00 29 16.65	VLA
0422+178	04 22 31.044	17 48 37.40	VLA
0422-380	04 22 56.168	-38 03 09.10	VLA
0423+051	04 23 57.232	05 11 37.30	VLA
0426-380	04 26 54.710	-38 02 52.05	VLA
0427-366	04 27 52.600	-36 37 17.00	VLA
0428+205	04 28 06.861	20 31 09.13	VLA
0429+415	04 29 07.899	41 32 08.55	VLA
0430+052	04 30 31.600	05 14 59.50	VLA
0433+295	04 33 55.24	29 34 14.0	FOMALONT AND MOFFET 1971

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
0258+350	1.88	0.06	1.29	0.02	0.93	0.04H	
0300+471							
0300+162	2.60	0.07	1.82	0.03	1.31	0.04E	3C76.1
0306+102							
0307+169	4.59	0.40	2.41	0.04	1.31	0.04E	3C79
0309+390	1.73	0.05	1.13	0.02	0.73	0.01J	
0316+161	7.60	0.16	4.96	0.04	2.86	0.05E	CTA21
0316+413							3C84
0317+188							
0319+121	1.82	0.06	1.27	0.02	1.10	0.04H	
0320+053	2.86	0.07	1.51	0.03	0.88	0.03E	
0327-241							
0331-013	2.72	0.07	1.30	0.02	0.81	0.06E	3C89
0332+078							
0332-403							
0333+321							NRAO140
0333+128							3C90
0336-019							CTA26
0338-214							
0340+048	2.84	0.07	1.56	0.03	0.89	0.04E	3C93
0345+337	2.25	0.14	1.27	0.02	0.75	0.04E	3C93.1
0346-279							
0347+057	3.25	0.08	1.94	0.01	1.23	0.04H	
0355+508							NRAO150
0400+258	1.82	0.06	1.61	0.03	1.79	0.05H	
0400-319							
0402-362							
0403-132							
0404+428	5.22	0.37	2.43	0.04	1.41	0.04E	3C103
0405-123	3.03	0.31B	2.42	0.11	1.85	0.05E	
0405-331							
0405-385							
0406+387							
0406+121							
0406-127							
0409+229							
0411+141	2.15	0.06	1.37	0.03	0.89	0.03I	
0411+054	1.71	0.05	1.08	0.02	0.70	0.03I	
0413-210							
0414-189							
0420+417							
0420+347							
0420-014							
0421+019							
0422+004							
0422+178							
0422-380							
0423+051							
0426-380							
0427-366							
0428+205	3.81	0.09	3.04	0.04	2.31	0.06H	
0429+415							3C119
0430+052							3C120
0433+295							3C123

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
0434-188	04 34 48.967	-18 50 48.15	VLA
0435+487	C4 35 14.085	48 42 52.10	VLA
0438-436	04 38 43.184	-43 38 53.10	VLA
0439-337	04 39 41.968	-33 45 44.00	VLA
0440-003	04 40 05.293	-00 23 20.60	VLA
0444+634	04 44 42.375	63 26 56.00	VLA
0448-392	04 48 00.456	-39 16 15.30	VLA
0450+314	04 50 10.55	31 24 31.7	FOMALONT AND MOFFET 1971
0451-282	04 51 15.133	-28 12 29.30	VLA
0453-206	04 53 14.160	-20 39 00.90	VLA
0453+227	04 53 42.42	22 44 42.2	FOMALONT AND MOFFET 1971
0454-463	04 54 24.520	-46 20 44.00	VLA
0454+066	04 54 26.407	06 40 30.05	VLA
0454+844	04 54 57.190	84 27 52.99	VLA
0454-234	04 54 57.300	-23 29 28.30	VLA
0457+024	04 57 15.543	C2 25 05.60	VLA
0458+476	04 58 41.100	47 41 47.70	VLA
0458-020	04 58 41.347	-02 03 34.00	VLA
0459+135	04 59 43.843	13 33 56.30	VLA
0459+252	04 59 54.23	25 12 11.5	FOMALONT AND MOFFET 1971
0500+019	05 00 45.176	01 58 53.82	VLA
0502+049	05 02 43.814	04 55 40.50	VLA
0506+101	05 06 42.048	10 07 59.40	VLA
0507+290	05 07 30.4	29 05 11	BDFL
0509+152	05 09 49.457	15 13 51.90	VLA
0511+008	05 11 32.3	00 53 13	MCEWAN ET AL. 1975
0511-220	05 11 41.815	-22 02 41.20	VLA
0514-161	05 14 01.076	-16 06 22.60	VLA
0515+508	05 15 37.97	5C 51 30.0	FOMALONT AND MOFFET 1971
0516+276	C5 16 27.0	27 40 55	BDFL
0517+454	05 17 07.000	45 25 36.50	VLA
0518+165	05 18 16.532	16 35 26.90	VLA
0519-208	05 19 30.140	-20 50 29.00	VLA
0519+011	05 19 42.346	C1 10 41.40	VLA
0528-250	05 28 05.205	-25 05 44.55	VLA
0528+134	05 28 06.760	13 29 42.20	VLA
0528+064	05 28 48.00	06 28 16.4	FOMALONT AND MOFFET 1971
0529+075	05 29 56.494	07 30 38.10	VLA
0530+040	05 30 25.41	04 03 50.9	FOMALONT AND MOFFET 1971
0531+194	05 31 47.357	19 25 24.75	VLA
0534-340	05 34 39.565	-34 02 58.10	VLA
0537+531	05 37 13.520	53 10 54.25	VLA
0537-158	05 37 17.155	-15 52 04.60	VLA
0537-441	05 37 20.921	-44 06 38.40	VLA
0537-286	05 37 56.931	-28 41 27.95	VLA
0538+498	05 38 43.507	49 49 42.78	VLA
0539-057	05 39 10.993	-05 43 15.10	VLA
0540+187	05 40 30.9	18 44 23	BDFL
0548+165	05 48 25.1	16 35 51	BDFL
0550+032	05 50 12.607	C3 12 50.00	VLA
0552+398	05 52 01.418	39 48 21.84	VLA
0600+412	06 00 56.850	41 14 10.80	VLA
0601+204	06 C1 30.010	20 21 34.99	VLA
0602-319	06 02 22.450	-31 55 40.00	VLA

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
0434-188							
0435+487							
0438-436							
0439-337							
0440-003							NRAO190
0444+634							
0448-392							
0450+314	2.90	0.15	1.49	0.03	0.86	0.04E	3C131
0451-282							
0453-206							
0453+227	3.25	0.09	1.91	0.03	1.05	0.04E	3C132
0454-463							
0454+066							
0454+844							
0454-234							
0457+024							
0458+476							
0458-020							
0459+135							
0459+252	5.55	0.14	3.34	0.04	2.16	0.06E	3C133
0500+019	2.21	0.06	2.31	0.04	1.83	0.05H	
0502+049							
0506+101							
0507+290	1.90	0.06	1.09	0.02	0.65	0.06N	
0509+152							
0511+008							3C135
0511-220							
0514-161							
0515+508	2.22	0.14	1.05	0.02	0.57	0.04E	3C137
0516+276	1.84	0.06	1.16	0.03	0.75	0.08N	
0517+454							
0518+165							3C138
0519-208							
0519+011							
0528-250							
0528+134							
0528+064	3.61	0.33	1.65	0.01	1.02	0.04E	3C142.1
0529+075							
0530+040	1.93	0.06	1.19	0.04	0.71	0.02B	
0531+194	6.73	0.14	3.98	0.03	2.53	0.05B	
0534-340							
0537+531							
0537-158							
0537-441							
0537-286							
0538+498							3C147
0539-057							
0540+187	2.24	0.06	1.27	0.05	0.63	0.05B	
0548+165	2.13	0.06	1.42	0.01	0.97	0.10N	
0550+032							
0552+398							
0600+412							
0601+204							3C152
0602-319							

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
0602+673	06 02 38.890	67 21 18.40	VLA
0602-424	06 02 52.500	-42 25 14.80	VLA
0605-085	06 05 36.027	-08 34 20.30	VLA
0605+480	06 05 44.450	48 04 49.00	VLA
0606-223	06 06 53.379	-22 19 46.20	VLA
0607-157	06 07 25.982	-15 42 03.30	VLA
0609+607	06 09 50.866	60 47 14.82	VLA
0614-349	06 14 48.810	-34 55 05.60	VLA
0615+820	06 15 32.752	82 03 56.50	VLA
0618+145	06 18 50.10	14 33 41.1	ADGIE ET AL. 1972
0620+389	06 20 51.529	38 58 27.30	VLA
0621+400	06 21 34.30	40 05 32.2	FOMALONT AND MOFFET 1971
0621+321	06 21 41.88	32 06 47.1	BROSCHE ET AL.1973
0622+147	06 22 54.770	14 42 06.00	VLA
0624-058	06 24 43.177	-05 51 11.60	VLA
0627-199	06 27 14.122	-19 57 16.10	VLA
0629+104	06 29 29.430	10 24 16.80	VLA
0636+680	06 36 47.622	68 01 27.24	VLA
0637-337	06 37 31.192	-33 43 11.90	VLA
0640+233	06 40 04.9	23 22 08	BDFL
0642+214	06 42 24.76	21 24 57.1	ELSMORE AND MACKAY 1969
0642-349	06 42 37.454	-34 56 31.80	VLA
0642+449	06 42 53.014	44 54 30.85	VLA
0646+600	06 46 04.107	60 05 14.20	VLA
0646-306	06 46 19.215	-30 40 54.30	VLA
0646+692	06 46 29.261	69 14 46.20	VLA
0648-165	06 48 10.296	-16 34 05.85	VLA
0650+371	06 50 35.281	37 09 27.10	VLA
0651+542	06 51 10.81	54 12 50.0	FOMALONT AND MCFFET 1971
0653+694	06 53 20.520	69 24 52.36	VLA
0655+699	06 55 56.83	69 56 04.9	S4
0658+380	06 58 56.39	38 01 44.5	ADGIE ET AL. 1972
0659+445	06 59 16.41	44 35 36.3	S4
0702+749	07 02 47.4	74 54 12	FOMALONT AND MOFFET 1971
0704-231	07 04 27.310	-23 06 58.60	VLA
0707+476	07 07 02.540	47 37 07.80	VLA
0710+439	07 10 03.350	43 54 26.00	VLA
0711+356	07 11 05.607	35 39 52.51	VLA
0711+146	07 11 14.300	14 41 33.00	VLA
0715-250	07 15 13.500	-24 59 26.00	VLA
0716+714	07 16 13.302	71 26 15.25	VLA
0722+145	07 22 26.967	14 31 11.90	VLA
0723+679	07 23 03.68	67 54 52.5	EDWARDS ET AL. 1975
0723-008	07 23 17.837	-00 48 55.40	VLA
0724-019	07 24 33.5	-01 58 36	MCEWAN ET AL. 1975
0725+147	07 25 20.350	14 43 46.30	VLA
0727-115	07 27 58.100	-11 34 52.62	VLA
0731+479	07 31 20.690	47 56 44.80	VLA
0732+332	07 32 41.79	33 13 50	CONDON ET AL. 1975
0733-174	07 33 31.417	-17 29 06.23	VLA
0733+705	07 33 58.890	70 30 00.20	VLA
0735+178	07 35 14.126	17 49 09.30	VLA
0736-303	07 36 21.770	-30 18 11.00	VLA
0736+017	07 36 42.513	01 44 00.20	VLA

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
0602+673							
0602-424							
0605-085							
0605+480	4.01	0.09	2.30	0.04	1.35	0.06E	3C153
0606-223							
0607-157							
0609+607							
0614-349							
0615+820							
0618+145							3C158
0620+389							
0621+400	1.96	0.06	1.23	0.03	0.70	0.01J	3C159
0621+321							
0622+147							
0624-058	19.03	0.13B	11.19	0.07	6.73	0.09E	3C161
0627-199							
0629+104							
0636+680							
0637-337							
0640+233	2.40	0.20	1.28	0.03	0.77	0.03E	3C165
0642+214							3C166
0642-349							
0642+449							
0646+600							
0646-306							
0646+692							
0648-165							
0650+371							
0651+542	3.66	0.14	2.00	0.03	1.22	0.04E	3C171
0653+694							
0655+699	1.70	0.11	1.07	0.05	0.69	0.01J	
0658+380							3C173
0659+445	2.47	0.07	1.15	0.01	0.54	0.01J	
0702+749	2.60	0.13A	1.36	0.09	0.77	0.06E	3C173.1
0704-231							
0707+476							
0710+439							
0711+356							
0711+146	2.04	0.06	1.07	0.02	0.56	0.05E	3C175.1
0715-250							
0716+714							
0722+145							
0723+679	2.38	0.06	1.72	0.07	1.31	0.07E	3C179
0723-008							
0724-019	2.65	0.07	1.65	0.06	0.94	0.03E	3C180
0725+147	2.29	0.06	1.24	0.02	0.66	0.05E	3C181
0727-115							
0731+479							
0732+332	2.32	0.06	1.40	0.05	0.91	0.01G	
0733-174							
0733+705	2.49	0.10D	1.17	0.04A	0.60	0.04E	3C184
0735+178							
0736-303							
0736+017							

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
0738+313	07 38 00.178	31 19 02.07	VLA
0738+272	07 38 20.906	27 13 48.45	VLA
0740+380	07 40 56.75	38 00 31.3	ADGIE ET AL. 1972
0741-063	07 41 54.700	-06 22 20.00	VLA
0742+103	07 42 48.465	10 18 32.64	VLA
0742+318	07 42 30.738	31 50 16.25	VLA
0743-006	07 43 21.050	-C0 36 55.75	VLA
0745-191	07 45 18.100	-19 10 17.40	VLA
0745-330	07 45 24.934	-33 03 17.30	VLA
0745+241	07 45 35.726	24 07 55.50	VLA
0746+483	07 46 39.930	48 22 30.50	VLA
0748+126	07 48 05.060	12 38 45.35	VLA
0748-440	07 48 06.180	-44 04 51.00	VLA
0748+333	07 48 41.052	33 21 03.55	VLA
0754+100	07 54 22.568	10 04 39.70	VLA
0758+143	07 58 45.010	14 23 03.90	VLA
0759+183	07 59 55.286	18 18 15.45	VLA
0802+103	08 02 03.780	10 23 56.50	VLA
0802-276	08 02 47.877	-27 40 34.60	VLA
0804-267	08 04 07.861	-26 43 51.30	VLA
0804+499	08 04 58.396	49 59 23.10	VLA
0805+410	08 05 33.635	41 01 33.10	VLA
0806+426	08 06 37.98	42 36 55.8	FOMALONT AND MOFFET 1971
0808+019	08 08 51.127	01 55 51.20	VLA
0809+483	08 09 59.410	48 22 07.20	VLA
0812+367	08 12 10.712	36 44 27.45	VLA
0812-355	08 12 20.820	-35 29 15.00	VLA
0812+020	08 12 47.13	02 04 20.6	MCEWAN ET AL. 1975
0814+425	08 14 51.672	42 32 07.73	VLA
0818+472	08 18 01.110	47 12 11.00	VLA
0818-128	08 18 36.249	-12 49 24.70	VLA
0818+179	08 18 52.64	17 57 56.0	ADGIE 1974
0820+225	08 20 28.57	22 32 44.7	ADGIE ET AL. 1972
0820+560	08 20 53.206	56 02 27.45	VLA
0823+033	08 23 13.537	03 19 15.33	VLA
0823-223	08 23 50.074	-22 20 34.80	VLA
0824+294	08 24 21.64	29 28 41.1	ELSMORE AND MACKAY 1969
0825-202	08 25 03.380	-20 16 31.00	VLA
0826-373	08 26 12.005	-37 21 06.13	VLA
0827+243	08 27 54.400	24 21 07.65	VLA
0827+378	08 27 55.09	37 52 16.9	FOMALONT AND MOFFET 1971
0828+493	08 28 47.970	49 23 33.00	VLA
0829+046	08 29 10.893	04 39 50.80	VLA
0829+187	08 29 24.508	18 42 25.40	VLA
0831+557	08 31 04.379	55 44 41.32	VLA
0833+585	08 33 23.757	58 35 30.30	VLA
0834-201	08 34 24.603	-20 06 30.35	VLA
0834+250	08 34 42.316	25 04 54.30	VLA
0835+580	08 35 09.94	58 04 47.2	HOGBOM AND CARLSSON 1974
0836+710	08 36 21.560	71 04 22.45	VLA
0837+035	08 37 12.372	C3 30 32.80	VLA
0838+133	08 38 01.980	13 23 08.10	VLA
0839+187	08 39 14.086	18 46 27.25	VLA
0843-259	08 43 51.580	-25 59 53.40	VLA

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
0738+313							
0738+272							
0740+380							3C186
0741-063							
0742+103	3.17	0.08	3.87	0.11	3.84	0.07E	
0742+318							
0743-006	0.80	0.08C	1.37	0.04	1.93	0.07F	
0745-191	2.34	0.11D	1.12	0.11	0.46	0.04E	
0745-330							
0745+241							
0746+483							
0748+126							
0748-440							
0748+333							
0754+100							
0758+143	2.47	0.07	1.37	0.02	0.82	0.06E	3C190
0759+183							
0802+103							3C191
0802-276							
0804-267							
0804+499							
0805+410							
0806+426	2.05	0.06	1.12	0.02	0.61	0.03E	3C194
0808+019							
0809+483	13.85	0.28	7.64	0.08	4.36	0.06E	3C196
0812+367							
0812-355							
0812+020							
0814+425							
0818+472	1.87	0.07	1.01	0.03	0.86	0.06E	3C197.1
0818-128							
0818+179	2.05	0.19B	1.06	0.02	0.61	0.03E	
0820+225	2.31	0.06	1.89	0.02	1.61	0.04I	
0820+560							
0823+033							
0823-223							
0824+294							3C200
0825-202							
0826-373							
0827+243							
0827+378	2.22	0.06	1.40	0.04	0.93	0.01J	
0828+493							
0829+046							
0829+187							
0831+557	8.04	0.17	7.49	0.08	5.60	0.06J	DA251
0833+585							
0834-201							
0834+250							
0835+580	2.34	0.07	1.11	0.03	0.67	0.04E	3C205
0836+710							
0837+035							
0838+133	2.46	0.08	1.63	0.02	1.44	0.05E	3C207
0839+187							
0843-259							

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
0850-206	08 50 44.990	-20 36 05.00	VLA
0850+140	08 50 22.980	14 04 18.90	VLA
0850+581	08 50 50.153	58 08 55.70	VLA
0851+142	08 51 53.30	14 17 20.0	ADGIE ET AL. 1972
0851+202	08 51 57.253	20 17 58.44	VLA
0855+143	08 55 55.740	14 21 25.80	VLA
0858+292	08 58 05.16	29 13 33.2	FOMALONT AND MOFFET 1971
0859+681	08 59 23.031	68 09 16.20	VLA
0859+470	08 59 39.990	47 02 56.90	VLA
0859-140	08 59 54.950	-14 03 38.85	VLA
0900+428	09 00 58.736	42 50 01.20	VLA
0905+380	09 05 41.140	38 00 29.60	VLA
0906+430	09 06 17.34	43 05 59.2	FOMALONT AND MOFFET 1971
0906+015	09 06 35.193	01 33 48.10	VLA
0913+391	09 13 39.513	39 07 02.10	VLA
0917+624	09 17 40.314	62 28 38.60	VLA
0917+449	09 17 41.919	44 54 39.60	VLA
0919-260	09 19 16.706	-26 05 54.55	VLA
0920-397	09 20 48.289	-39 46 42.80	VLA
0922+005	09 22 33.760	00 32 12.20	VLA
0923+392	09 23 55.316	39 15 23.51	VLA
4C39.25	09 23 55.316	39 15 23.51	VLA
0925-203	09 25 33.545	-20 21 44.95	VLA
0926+793	09 26 30.64	79 19 42.4	HOGBOM AND CARLSSON 1974
0927+362	09 27 29.98	36 14 36.2	ADGIE ET AL. 1972
0929+533	09 29 13.316	53 19 51.10	VLA
0931+834	09 31 11.260	83 28 55.90	VLA
0938+399	09 38 18.0	39 58 20	S4
0941-080	09 41 08.646	-08 05 44.03	VLA
0941+522	09 41 30.081	52 16 22.70	VLA
0941+100	09 41 36.20	10 00 08.0	FOMALONT AND MOFFET 1971
0945+664	09 45 14.900	66 28 57.70	VLA
0945+408	09 45 50.075	40 53 43.35	VLA
0947+145	09 47 27.65	14 34 00.0	FOMALONT AND MOFFET 1971
0949+246	09 49 10.2	24 36 35	ADGIE 1974
0949+002	09 49 24.94	00 12 40.5	MCEWAN ET AL. 1975
0951+699	09 51 44.30	69 54 58.9	FOMALONT AND MOFFET 1971
0952+179	09 52 11.807	17 57 44.60	VLA
0953+254	09 53 59.742	25 29 33.55	VLA
0954+556	09 54 14.38	55 37 17.3	ADGIE ET AL. 1972
0954+658	09 54 57.853	65 48 15.55	VLA
0955+476	09 55 08.530	47 39 28.25	VLA
0955+326	09 55 25.406	32 38 23.00	VLA
0959-443	09 59 58.764	-44 23 29.75	VLA
1003+351	10 03 05.39	35 08 48.1	BROSCHE ET AL. 1973
1003+830	10 03 25.843	83 04 56.70	VLA
1004-018	10 04 31.710	-01 52 30.85	VLA
1004+141	10 04 59.789	14 11 10.90	VLA
1005+077	10 05 22.020	07 44 58.60	VLA
1008+066	10 08 23.08	06 39 28.5	ADGIE ET AL. 1972
1010+350	10 10 54.783	35 00 44.10	VLA
1011+250	10 11 05.636	25 04 10.10	VLA
1012+232	10 12 00.505	23 16 12.10	VLA
1013+208	10 13 59.413	20 52 46.30	VLA

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
0850-206							
0850+140	2.29	0.06	1.12	0.02	0.54	0.05E	3C208
0850+581							
0851+142	2.06	0.06	1.25	0.03	0.71	0.04E	3C208.1
0851+202							OJ287
0855+143	2.47	0.07	1.42	0.03	0.89	0.04E	3C212
0858+292	1.89	0.07	1.27	0.03	0.84	0.03E	3C213.1
0859+681							
0859+470							
0859-140	3.43	0.09B	2.71	0.13	2.44	0.07E	
0900+428							
0905+380	2.12	0.06	1.00	0.01	0.48	0.06E	3C217
0906+430	3.76	0.09	2.38	0.03	1.81	0.04E	3C216
0906+015							
0913+391							
0917+624							
0917+449							
0919-260							
0920-397							
0922+005							
0923+392	2.52	0.07	4.78	0.05	7.57	0.13E	DA267
4C39.25							
0925-203							
0926+793	2.20	0.11A	1.04	0.07	0.54	0.03E	3C220.1
0927+362							3C220.2
0929+533							
0931+834							3C220.3
0938+399							3C223.1
0941-080							
0941+522							
0941+100	2.25	0.06	1.07	0.03	0.64	0.05E	3C226
0945+664							
0945+408	1.96	0.06	1.31	0.03	1.39	0.02J	
0947+145	3.47	0.08	1.97	0.03	1.14	0.06E	3C228
0949+246							3C229
0949+002							3C230
0951+699	7.94	0.17	5.43	0.14			3C231
0952+179							
0953+254							
0954+556	3.52	0.08	2.60	0.05	2.27	0.03J	
0954+658							
0955+476							
0955+326							3C232
0959-443							
1003+351	3.24	0.08	2.09	0.03	1.34	0.08E	3C236
1003+830							
1004-018							
1004+141							
1005+077	6.25	0.15	3.57	0.05	2.01	0.06E	3C237
1008+066							3C238
1010+350							
1011+250							
1012+232							
1013+208							

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
1015+359	10 15 16.228	35 57 41.30	VLA
1015-314	10 15 53.388	-31 29 11.33	VLA
1018-426	10 17 55.940	-42 36 35.00	VLA
1019+309	10 19 39.882	30 56 15.00	VLA
1021-006	10 21 56.200	-00 37 41.55	VLA
1030+415	10 30 07.803	41 31 34.45	VLA
1030+398	10 30 27.505	39 51 19.80	VLA
1030+611	10 30 32.674	61 06 36.50	VLA
1031+567	10 31 55.964	56 44 18.15	VLA
1032-199	10 32 37.366	-19 56 02.15	VLA
1034-293	10 34 55.833	-29 18 26.95	VLA
1036-154	10 36 39.478	-15 25 28.10	VLA
1039+029	10 39 04.18	02 58 14.7	MCEWAN ET AL. 1975
1039+811	10 39 27.788	81 10 23.70	VLA
1040+123	10 40 05.730	12 19 15.10	VLA
1044+719	10 44 49.750	71 59 26.86	VLA
1045-188	10 45 40.094	-18 53 44.20	VLA
1048-313	10 48 43.390	-31 22 18.50	VLA
1049+215	10 49 07.192	21 35 48.45	VLA
1053+704	10 53 27.720	70 27 47.90	VLA
1053+815	10 53 36.220	81 30 35.60	VLA
1055-242	10 55 29.936	-24 17 44.60	VLA
1055+201	10 55 37.2	20 08 10	ADGIE 1974
1055+018	10 55 55.316	01 50 03.45	VLA
1056+432	10 56 08.160	43 17 28.00	VLA
1059-010	10 59 30.75	-01 00 10.1	MCEWAN ET AL. 1975
1059+282	10 59 31.436	28 13 17.30	VLA
1100+772	11 00 25.000	77 15 11.00	VLA
1100+223	11 00 42.495	22 19 47.60	VLA
1101+384	11 01 40.577	38 28 42.80	VLA
1103-208	11 03 54.650	-20 52 46.00	VLA
1104-445	11 04 50.417	-44 32 51.90	VLA
1108+201	11 08 41.034	20 11 54.20	VLA
1110-217	11 10 21.723	-21 42 09.60	VLA
1111+408	11 11 53.110	40 53 41.10	VLA
1113+295	11 13 53.9	29 31 36	BDFL
1116+128	11 16 20.777	12 51 06.65	VLA
1117-248	11 17 40.923	-24 51 41.40	VLA
1117+146	11 17 50.992	14 37 21.08	VLA
1119+183	11 19 52.246	18 21 53.90	VLA
1123+264	11 23 14.874	26 26 49.95	VLA
1124-186	11 24 34.023	-18 40 46.50	VLA
1127-145	11 27 35.673	-14 32 54.40	VLA
1128+385	11 28 12.516	38 31 51.50	VLA
1128+455	11 28 56.38	45 31 24.9	EDWARDS ET AL. 1975
1128-047	11 28 57.502	-04 43 46.05	VLA
1137+660	11 37 10.830	66 04 23.90	VLA
1138+015	11 38 34.38	01 30 56.0	MCEWAN ET AL. 1975
1140+223	11 40 49.19	22 23 34.8	ADGIE ET AL. 1972
1142-225	11 42 50.233	-22 33 51.55	VLA
1143+500	11 43 04.220	50 02 47.60	VLA
1143-245	11 43 36.373	-24 30 52.90	VLA
1143-287	11 43 54.849	-28 42 38.60	VLA
1144+542	11 44 04.582	54 13 22.80	VLA

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
1015+359							
1015-314							
1018-426							
1019+309							
1021-006							
1030+415							
1030+398							
1030+611							
1031+567							
1032-199							
1034-293							
1036-154							
1039+029	2.84	0.07	1.59	0.02	0.99	0.06B	
1039+811							
1040+123	3.06	0.08	2.11	0.02	1.39	0.04E	3C245
1044+719							
1045-188							
1048-313							
1049+215							
1053+704							
1053+815							
1055-242							
1055+201	2.19	0.06	1.49	0.05	1.09	0.06B	
1055+018							
1056+432	2.82	0.12	1.59	0.03	0.95	0.06E	3C247
1059-010	2.56	0.07	1.32	0.04	0.61	0.09E	3C249
1059+282							
1100+772	2.36	0.09D	1.40	0.04A	0.78	0.03E	3C249.1
1100+223							
1101+384							
1103-208							
1104-445							
1108+201							
1110-217							
1111+408	3.05	0.13	1.46	0.05	0.79	0.05E	3C254
1113+295	1.97	0.06	1.22	0.02	0.87	0.03H	
1116+128	2.25	0.06	1.70	0.03	1.64	0.07E	
1117-248							
1117+146	2.35	0.06	1.58	0.04	1.03	0.04I	
1119+183							
1123+264							
1124-186							
1127-145	6.63	0.21B	6.43	0.35	7.31	0.15E	
1128+385							
1128+455	2.00	0.06	1.13	0.01	0.65	0.01J	
1128-047							
1137+660	2.98	0.11	1.75	0.05	1.04	0.04E	3C263
1138+015	2.47	0.07	1.54	0.05	0.93	0.03E	
1140+223	2.96	0.07	1.50	0.02	0.78	0.03E	3C263.1
1142-225							
1143+500							3C266
1143-245							
1143-287							
1144+542							

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
1144+402	11 44 21.024	40 15 14.15	VLA
1144-379	11 44 30.870	-37 55 30.60	VLA
1145-071	11 45 18.300	-07 08 00.75	VLA
1147+130	11 47 22.1	13 04 00	BDFL
1147+245	11 47 44.000	24 34 34.60	VLA
1148-001	11 48 10.130	-00 07 13.30	VLA
1150+812	11 50 23.502	81 15 10.25	VLA
1150+497	11 50 48.005	49 47 50.00	VLA
1151-348	11 51 49.443	-34 48 47.15	VLA
1153+317	11 53 44.13	31 44 46.4	ADGIE ET AL. 1972
1155+251	11 55 51.645	25 06 59.81	VLA
1156-221	11 56 37.789	-22 11 54.90	VLA
1156+295	11 56 57.791	29 31 25.65	VLA
1157-215	11 57 18.330	-21 32 11.60	VLA
1157+732	11 57 45.5	73 17 27.5	FOMALONT AND MOFFET 1971
1201-041	12 01 28.52	-04 06 00.2	FOMALONT AND MCFFET 1971
1203+645	12 03 54.090	64 30 18.70	VLA
1203-262	12 02 58.861	-26 17 22.60	VLA
1204+281	12 04 55.102	28 11 40.20	VLA
1206-238	12 06 27.670	-23 49 38.80	VLA
1206+439	12 06 41.980	43 55 59.90	VLA
1213-172	12 13 11.674	-17 15 05.25	VLA
1213+350	12 13 24.826	35 04 54.95	VLA
1214+588	12 14 44.925	58 52 05.70	VLA
1215-457	12 15 28.830	-45 43 29.00	VLA
1216+487	12 16 38.570	48 46 34.90	VLA
1218+339	12 18 03.84	33 59 46.6	CONDON ET AL. 1975
1219+285	12 19 01.120	28 30 36.45	VLA
1222+037	12 22 19.100	03 47 27.05	VLA
1225+368	12 25 30.773	36 51 47.00	VLA
1226+023	12 26 33.248	02 19 43.29	VLA
1229-021	12 29 25.91	-02 07 31.9	MCEWAN ET AL. 1975
1232-416	12 32 59.330	-41 36 42.00	VLA
1236+077	12 36 52.310	07 46 45.35	VLA
1237-101	12 37 07.287	-10 07 00.65	VLA
1239-044	12 39 44.800	-04 29 52.80	VLA
1241+166	12 41 27.56	16 39 18.0	ADGIE ET AL. 1972
1242+410	12 42 26.396	41 04 30.00	VLA
1243-412	12 43 12.533	-41 12 22.20	VLA
1243-072	12 43 28.793	-07 14 23.55	VLA
1244-255	12 44 06.729	-25 31 27.00	VLA
1245-197	12 45 45.218	-19 42 57.51	VLA
1250+568	12 50 15.224	56 50 36.20	VLA
1251+278	12 51 46.02	27 53 47.5	FOMALONT AND MOFFET 1971
1252+119	12 52 07.717	11 57 20.82	VLA
1253-055	12 53 35.838	-05 31 08.04	VLA
1254+476	12 54 41.030	47 36 32.10	VLA
1255-316	12 55 15.182	-31 39 05.03	VLA
1256-220	12 56 13.937	-22 03 20.40	VLA
1302-102	13 02 55.854	-10 17 16.45	VLA
1306-095	13 06 02.03	-09 34 31.5	FOMALONT AND MOFFET 1971
1306+660	13 06 31.910	66 00 10.50	VLA
1308+326	13 08 07.567	32 36 40.30	VLA
1308-220	13 08 57.356	-22 00 46.30	VLA

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
1144+402							
1144-379							
1145-071							
1147+130	2.16	0.07	1.23	0.02	0.59	0.07E	3C267
1147+245							
1148-001	3.06	0.08	2.51	0.05	1.97	0.04E	
1150+812							
1150+497							
1151-348							
1153+317	2.77	0.07	1.73	0.01	0.95	0.04H	
1155+251							
1156-221							
1156+295							
1157-215							
1157+732	6.60	0.33A	3.91	0.26	2.62	0.06E	3C268.1
1201-041	2.10	0.06	1.44	0.02	1.00	0.03E	
1203+645							3C268.3
1203-262							
1204+281							
1206-238							
1206+439	2.04	0.09	1.05	0.01	0.60	0.03E	3C268.4
1213-172							
1213+350							
1214+588							
1215-457							
1216+487							
1218+339	2.50	0.07	1.53	0.04	0.87	0.04E	3C270.1
1219+285							
1222+037							
1225+368	2.06	0.06	1.46	0.01	0.77	0.01J	
1226+023							3C273
1229-021	1.76	0.05	1.29	0.06	1.32	0.07E	
1232-416							
1236+077							
1237-101	1.93	0.11B	1.51	0.06	1.53	0.05E	
1239-044							3C275
1241+166							3C275.1
1242+410							
1243-412							
1243-072							
1244-255							
1245-197							
1250+568	2.42	0.12	1.32	0.07	1.05	0.04E	3C277.1
1251+278	2.89	0.08	1.88	0.03	1.24	0.04E	3C277.3
1252+119							
1253-055							3C279
1254+476	5.08	0.11	2.86	0.02	1.53	0.06E	3C280
1255-316							
1256-220							
1302-102							
1306-095	4.49	0.16B	2.95	0.05	2.00	0.05E	
1306+660	2.24	0.08	1.11	0.04	0.57	0.06N	3C282
1308+326							
1308-220							3C283

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
1311+678	13 11 45.036	67 51 42.31	VLA
1313-333	13 13 20.054	-33 23 09.65	VLA
1318+113	13 18 49.67	11 22 29.0	FOMALONT AND MOFFET 1971
1320-446	13 20 07.395	-44 36 53.40	VLA
1322+835	13 22 34.451	83 31 51.70	VLA
1323+799	13 23 30.986	79 58 27.60	VLA
1323+321	13 23 57.916	32 09 43.00	VLA
1328+254	13 28 15.924	25 24 37.58	VLA
1328+307	13 28 49.657	30 45 58.64	VLA
1330+022	13 30 21.3	02 16 04	MCEWAN ET AL. 1975
1334-127	13 34 59.815	-12 42 09.90	VLA
1335-061	13 35 31.390	-06 11 54.80	VLA
1336-260	13 36 32.480	-26 05 17.30	VLA
1336+391	13 36 38.36	39 06 22.3	FOMALONT AND MOFFET 1971
1340+053	13 40 12.42	05 19 38.8	FOMALONT AND MOFFET 1971
1340+606	13 40 29.760	60 36 47.90	VLA
1341+144	13 41 57.370	14 24 17.03	VLA
1343+500	13 43 27.520	50 01 32.50	VLA
1344-078	13 44 23.470	-07 48 26.40	VLA
1345+125	13 45 06.170	12 32 20.30	VLA
1346-391	13 46 52.520	-39 07 57.00	VLA
1347+539	13 47 42.570	53 56 08.35	VLA
1349-145	13 49 10.751	-14 34 27.00	VLA
1349-439	13 49 52.539	-43 57 55.30	VLA
1350+316	13 50 03.23	31 41 32.6	ADGIE ET AL. 1972
1351-018	13 51 32.033	-01 51 20.05	VLA
1353-341	13 53 09.800	-34 06 29.30	VLA
1354-174	13 54 22.038	-17 29 25.20	VLA
1354+013	13 54 28.45	01 19 16.9	MCEWAN ET AL. 1975
1354-152	13 54 28.600	-15 12 51.85	VLA
1354+196	13 54 42.086	19 33 43.95	VLA
1357+769	13 57 42.129	76 57 53.30	VLA
1358+624	13 58 58.360	62 25 06.70	VLA
1402-012	14 02 11.293	-01 16 01.80	VLA
1402+044	14 02 29.973	04 29 55.10	VLA
1402+660	14 02 48.393	66 05 57.45	VLA
1404+344	14 04 34.48	34 25 40.1	FOMALONT AND MOFFET 1971
1404+286	14 04 45.613	28 41 29.22	VLA
1406-076	14 06 17.920	-07 38 16.10	VLA
1406-267	14 06 58.430	-26 43 26.50	VLA
1409+524	14 09 33.490	52 26 13.00	VLA
1413+135	14 13 33.910	13 34 17.40	VLA
1413+349	14 13 56.270	34 58 29.35	VLA
1415+463	14 15 13.429	46 20 55.55	VLA
1416+067	14 16 38.860	06 42 19.40	VLA
1418+546	14 18 06.188	54 36 58.00	VLA
1419+419	14 19 06.460	41 58 29.90	VLA
1420+198	14 20 40.77	19 49 28	FOMALONT 1968, BDFL
1422-297	14 22 32.900	-29 46 23.50	VLA
1422+202	14 22 37.48	20 13 52.9	ADGIE 1974
1424-418	14 24 46.706	-41 52 56.10	VLA
1425-011	14 25 56.56	-01 10 45.8	MCEWAN ET AL. 1975
1427+109	14 27 43.703	10 56 44.60	VLA
1427+543	14 27 44.055	54 19 29.70	VLA

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
1311+678							
1313-333							
1318+113	2.18	0.06	1.33	0.02	0.77	0.03B	
1320-446							
1322+835							
1323+799							
1323+321	4.56	0.10	3.29	0.04	2.31	0.06H	
1328+254	6.72	0.14	4.61	0.02	3.26	0.06E	3C287
1328+307	14.78	0.30	10.22	0.11	7.48	0.09E	3C286
1330+022							3C287.1
1334-127							
1335-061	3.39	0.14B	1.86	0.04	1.06	0.04E	
1336-260							
1336+391	3.32	0.09	1.77	0.03	0.99	0.06E	3C288
1340+053	1.73	0.11B	1.09	0.07	0.79	0.05B	
1340+606							3C288.1
1341+144							
1343+500	2.28	0.07	1.21	0.02	0.60	0.03E	3C289
1344-078							
1345+125	5.01	0.11	3.79	0.02	2.71	0.04E	
1346-391							
1347+539							
1349-145							
1349-439							
1350+316	4.42	0.11	2.89	0.04	1.87	0.04E	3C293
1351-018							
1353-341							
1354-174							
1354+013	2.47	0.15	1.29	0.01	0.72	0.02B	
1354-152							
1354+196							
1357+769							
1358+624	4.32	0.13	2.73	0.07	1.77	0.02J	
1402-012							
1402+044							
1402+660							
1404+344							3C294
1404+286	0.71	0.07M	1.88	0.02	2.90	0.07H	OQ208
1406-076							
1406-267							
1409+524	22.18	0.39	12.08	0.14	6.53	0.08E	3C295
1413+135							
1413+349	2.09	0.09	1.67	0.04	1.35	0.14N	
1415+463							
1416+067	5.66	0.15	2.78	0.03	1.46	0.05E	3C298
1418+546							
1419+419	2.95	0.10	1.67	0.06	0.90	0.05E	3C299
1420+198	3.44	0.08	1.94	0.02	1.10	0.04E	3C300
1422-297							
1422+202	1.72	0.05	1.03	0.02	0.60	0.03I	
1424-418							
1425-011	3.30	0.17	1.61	0.02	0.94	0.06E	3C300.1
1427+109							
1427+543							

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
1430-178	14 30 10.650	-17 48 24.30	VLA
1430-155	14 30 36.135	-15 35 35.50	VLA
1434+235	14 34 25.407	23 34 03.15	VLA
1434+036	14 34 25.87	03 37 11.3	MCEWAN ET AL. 1975
1435-218	14 35 18.686	-21 51 58.30	VLA
1437-153	14 37 11.349	-15 18 59.50	VLA
1437+624	14 37 32.021	62 24 47.00	VLA
1441+522	14 41 23.60	52 14 19.2	FOMALONT AND MOFFET 1971
1442+101	14 42 50.484	10 11 12.10	VLA
1443-162	14 43 06.702	-16 16 27.40	VLA
1444+175	14 44 15.451	17 33 39.65	VLA
1447+771	14 47 49.500	77 08 46.10	VLA
1448+634	14 48 17.450	63 28 33.50	VLA
1451-375	14 51 18.284	-37 35 22.25	VLA
1451-400	14 51 20.643	-40 00 24.20	VLA
1452-041	14 52 24.7	-04 09 20	BDFL
1453-109	14 53 12.25	-10 56 51.5	FOMALONT AND MOFFET 1971
1458+718	14 58 56.650	71 52 11.15	VLA
1502+106	15 02 00.159	10 41 17.71	VLA
1502+036	15 02 35.700	03 38 07.50	VLA
1504+377	15 C4 12.958	37 42 23.30	VLA
1504-167	15 04 16.419	-16 40 59.25	VLA
1508-055	15 08 14.94	-05 31 49.0	KUHR 1979
1509+015	15 09 52.92	01 32 21.7	MCEWAN ET AL. 1975
1510-089	15 10 08.903	-08 54 47.55	VLA
1511-100	15 11 02.265	-10 00 50.90	VLA
1511-210	15 11 03.949	-21 03 48.40	VLA
1511+238	15 11 28.286	23 49 43.75	VLA
1511+263	15 11 31.0	26 18 37	BDFL
1514+072	15 14 16.97	07 12 16.6	FOMALONT AND MOFFET 1971
1514-241	15 14 45.275	-24 11 22.55	VLA
1517+204	15 17 50.628	20 26 53.10	VLA
1518+046	15 18 44.73	04 41 05.5	ADGIE ET AL. 1972
1519-273	15 19 37.249	-27 19 30.25	VLA
1523+033	15 23 18.12	03 18 54.9	MCEWAN ET AL. 1975
1524-136	15 24 12.875	-13 40 34.90	VLA
1529+242	15 29 40.83	24 12 47.9	MACKAY 1969
1532+016	15 32 20.173	01 41 01.65	VLA
1533+557	15 33 46.3	55 46 50	S4
1535+004	15 35 42.560	00 28 50.80	VLA
1538+149	15 38 30.231	14 57 21.80	VLA
1540-077	15 40 20.313	-07 47 37.90	VLA
1543+005	15 43 36.252	00 35 41.80	VLA
1545+210	15 45 31.30	21 01 38.5	FOMALONT AND MOFFET 1971
1546+027	15 46 58.293	02 46 06.05	VLA
1547+215	15 47 37.360	21 34 41.90	VLA
1547+507	15 47 52.272	50 47 09.23	VLA
1548+056	15 48 06.933	05 36 11.25	VLA
1549+628	15 49 14.33	62 50 20.1	HOGBOM AND CARLSSON 1975
1551+130	15 51 12.032	13 05 41.25	VLA
1553+202	15 53 57.30	20 13 00.5	ADGIE ET AL. 1972
1555+001	15 55 17.694	00 06 43.54	VLA
1555-140	15 55 33.766	-14 01 26.50	VLA
1600+335	16 00 11.910	33 35 09.60	VLA

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
1430-178							
1430-155							
1434+235							
1434+036	2.86	0.07	1.83	0.01	1.28	0.02B	
1435-218							
1437-153							
1437+624							
1441+522	2.46	0.07	1.53	0.03	0.94	0.06E	3C303
1442+101							OQ172
1443-162							
1444+175							
1447+771							3C305.1
1448+634	2.94	0.09	1.62	0.04	0.92	0.04E	3C305
1451-375							
1451-400							
1452-041	1.86	0.11	1.09	0.04	0.75	0.06E	3C306.1
1453-109	3.90	0.08D	2.48	0.03	1.57	0.05E	
1458+718	7.90	0.34A	5.47	0.30	3.76	0.06E	3C309.1
1502+106							OR103
1502+036							
1504+377							
1504-167							
1508-055							
1509+015	2.12	0.06	1.21	0.03	0.68	0.05B	
1510-089							
1511-100							
1511-210							
1511+238							
1511+263	3.87	0.10	2.26	0.05	1.27	0.04E	3C315
1514+072	5.35	0.14	2.08	0.03	0.87	0.04E	3C317
1514-241							
1517+204	2.50	0.07	1.35	0.01	0.75	0.03E	3C318
1518+046	4.01	0.09	2.32	0.03	0.99	0.03B	
1519-273							
1523+033	1.86	0.06	1.12	0.02	0.68	0.04E	
1524-136							
1529+242							3C321
1532+016							
1533+557							3C322
1535+004							
1538+149							
1540-077							
1543+005	1.71	0.05	1.15	0.10	0.88	0.05B	
1545+210	2.49	0.07	1.33	0.03	0.92	0.07E	3C323.1
1546+027							
1547+215	2.28	0.06	1.27	0.03	0.61	0.03E	3C324
1547+507							
1548+056							
1549+628	3.62	0.12	1.88	0.06	0.83	0.04E	3C325
1551+130							
1553+202	2.35	0.06	1.25	0.01	0.86	0.06E	3C326.1
1555+001							
1555-140							
1600+335							

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
1602+014	16 02 12.93	C1 25 58.9	MCEWAN ET AL. 1975
1603+001	16 03 39.18	00 08 31.5	MCEWAN ET AL. 1975
1604+315	16 04 10.612	31 32 47.70	VLA
1604-333	16 04 22.201	-33 23 09.80	VLA
1606+106	16 06 23.397	10 36 59.75	VLA
1607+268	16 07 09.289	26 49 18.60	VLA
1608+331	16 08 09.8	33 06 26	BDFL
1609+660	16 09 16.2	66 04 31	S4
1611+343	16 11 47.917	34 20 19.82	VLA
1614+051	16 14 09.086	05 06 54.40	VLA
1615+029	16 15 19.113	02 54 00.10	VLA
1615+324	16 15 47.19	32 29 54	FOMALONT 1968, BDFL
1616+063	16 16 36.537	06 20 14.25	VLA
1618+177	16 18 06.81	17 43 37.7	FOMALONT AND MOFFET 1971
1622+238	16 22 32.47	23 52 06.5	FOMALONT AND MOFFET 1971
1622-253	16 22 44.110	-25 20 51.50	VLA
1622-297	16 22 57.246	-29 44 41.15	VLA
1624+416	16 24 18.253	41 41 23.50	VLA
1626+396	16 26 55.3	39 39 31	S4
1627+444	16 27 19.73	44 25 37.4	FOMALONT AND MOFFET 1971
1627+234	16 27 29.80	23 26 43.6	FOMALONT AND MOFFET 1971
1629+120	16 29 24.56	12 02 24.0	ADGIE 1974
1629+680	16 29 50.817	68 03 38.85	VLA
1633+382	16 33 30.628	38 14 10.05	VLA
1634+628	16 34 01.063	62 51 41.83	VLA
1636+473	16 36 19.150	47 23 28.55	VLA
1637+575	16 37 17.432	57 26 15.70	VLA
1637+626	16 37 55.305	62 40 34.30	VLA
1637+826	16 37 56.970	82 38 18.50	VLA
1638-025	16 38 03.25	-02 33 57.1	MCEWAN ET AL. 1975
1638+124	16 38 27.923	12 25 46.32	VLA
1638+398	16 38 48.172	39 52 30.08	VLA
1641+399	16 41 17.608	39 54 10.82	VLA
1641+173	16 41 34.59	17 21 20.7	ADGIE ET AL. 1972
1642+690	16 42 18.076	69 02 13.20	VLA
1643-223	16 43 04.860	-22 22 38.00	VLA
1643+022	16 43 11.12	02 17 09.2	MCEWAN ET AL. 1975
1645+174	16 45 27.94	17 25 27.2	ADGIE ET AL. 1972
1648+015	16 48 31.580	01 34 25.65	VLA
1652+398	16 52 11.732	39 50 25.10	VLA
1654+866	16 54 31.400	86 37 07.21	VLA
1655+077	16 55 43.948	07 45 59.70	VLA
1656+053	16 56 05.620	05 19 47.05	VLA
1656+347	16 56 12.270	34 47 59.80	VLA
1656+477	16 56 39.600	47 42 19.60	VLA
1657-261	16 57 47.720	-26 06 29.25	VLA
1658+471	16 58 05.06	47 07 08.5	S4
1704+608	17 04 04.48	60 48 50.3	FOMALONT AND MOFFET 1971
1705+456	17 05 50.410	45 40 01.90	VLA
1709+460	17 09 17.930	46 05 06.30	VLA
1714+219	17 14 03.743	21 55 28.55	VLA
1716+686	17 16 27.838	68 39 48.30	VLA
1716+006	17 16 49.86	00 40 11.3	MCEWAN ET AL. 1975
1717+178	17 17 00.322	17 48 08.50	VLA

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
1602+014							3C327.1
1603+001	2.26	0.06	1.48	0.04	0.93	0.03B	
1604+315							
1604-333							
1606+106							
1607+268	4.43	0.10	2.94	0.04	1.58	0.06H	CTD93
1608+331							3C329
1609+660	6.98	0.16	3.82	0.21	2.35	0.08E	3C330
1611+343	2.92	0.07	2.44	0.03	2.67	0.06H	DA406
1614+051							
1615+029							
1615+324	2.40	0.06	1.48	0.02	0.83	0.03E	3C332
1616+063							
1618+177	2.12	0.13	1.07	0.03	0.57	0.03E	3C334
1622+238	2.71	0.07	1.38	0.02	0.69	0.06E	3C336
1622-253							
1622-297							
1624+416	2.08	0.06	1.65	0.02	1.31	0.02J	
1626+396	3.53	0.09	1.26	0.02	0.49	0.03E	3C338
1627+444	2.97	0.07	1.66	0.03	0.91	0.03E	3C337
1627+234	2.38	0.06	1.37	0.02	0.69	0.03E	3C340
1629+120	1.76	0.08	1.05	0.03	0.68	0.03I	
1629+680							
1633+382							
1634+628	5.17	0.14	2.72	0.07	1.49	0.04E	3C343
1636+473							
1637+575							
1637+626	4.66	0.10	2.28	0.07	1.20	0.04E	3C343.1
1637+826							
1638-025	1.76	0.05	1.05	0.04	0.57	0.05B	
1638+124	2.08	0.06	1.51	0.03	1.04	0.04I	
1638+398							NRAO512
1641+399							3C345
1641+173	3.64	0.14	2.27	0.04	1.63	0.10E	3C346
1642+690							
1643-223							
1643+022	1.94	0.10	1.10	0.01	0.71	0.02C	
1645+174	2.08	0.08	1.36	0.01	1.20	0.05E	
1648+015							
1652+398							
1654+866							
1655+077							
1656+053							
1656+347							
1656+477							
1657-261							
1658+471	3.18	0.08	1.90	0.03	1.14	0.04E	3C349
1704+608	3.52	0.10	1.92	0.05	1.21	0.05E	3C351
1705+456							
1709+460							3C352
1714+219							
1716+686							
1716+006	2.18	0.06	1.26	0.01	0.77	0.05B	
1717+178							

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
1719+356	17 19 23.035	35 45 08.80	VLA
1725+123	17 25 47.656	12 18 03.40	VLA
1725+044	17 25 56.336	04 29 27.90	VLA
1726+455	17 26 01.199	45 33 04.55	VLA
1726+318	17 26 27.0	31 48 25	BDFL
1730-130	17 30 13.534	-13 02 45.78	VLA
1732+389	17 32 40.487	38 59 46.90	VLA
1732+094	17 32 35.630	09 28 53.50	VLA
1734+063	17 34 47.355	06 22 48.20	VLA
1738+499	17 38 12.678	49 56 35.70	VLA
1738+476	17 38 36.314	47 39 28.60	VLA
1739+522	17 39 29.005	52 13 10.45	VLA
1741-312	17 41 09.340	-31 15 20.70	VLA
1741-038	17 41 20.619	-03 48 48.88	VLA
1743+173	17 43 22.236	17 21 09.15	VLA
1748-253	17 48 45.789	-25 23 17.43	VLA
1749+701	17 49 03.400	70 06 39.60	VLA
1749+096	17 49 10.386	09 39 42.80	VLA
1751+288	17 51 45.404	28 48 36.60	VLA
1751+441	17 51 53.715	44 10 17.80	VLA
1756+134	17 56 13.35	13 28 43.9	ADGIE 1974
1756+237	17 56 55.932	23 43 55.80	VLA
1758+388	17 58 44.695	38 48 32.50	VLA
1800+440	18 00 03.191	44 04 18.30	VLA
1801+010	18 01 43.386	01 01 18.80	VLA
1802+110	18 02 45.670	11 01 14.40	VLA
1803+784	18 03 39.179	78 27 54.30	VLA
1807+698	18 07 18.544	69 48 56.98	VLA
1808-209	18 08 07.400	-20 55 44.60	VLA
1817-098	18 17 52.820	-09 48 41.20	VLA
1819+396	18 19 42.39	39 41 13.8	ADGIE ET AL. 1972
1820+179	18 20 09.0	17 58 34	BDFL
1820+397	18 20 21.239	39 44 27.00	VLA
1821+017	18 21 32.4	01 46 44	BDFL
1821+107	18 21 41.655	10 42 43.90	VLA
1823+568	18 23 14.949	56 49 18.05	VLA
1826+796	18 26 43.190	79 37 00.00	VLA
1827-360	18 27 36.841	-36 04 37.90	VLA
1828+487	18 28 13.460	48 42 41.00	VLA
1829+290	18 29 17.94	29 04 57.2	FOMALONT AND MOFFET 1971
1829-106	18 29 34.700	-10 37 27.00	VLA
1830+285	18 30 52.378	28 31 17.05	VLA
1831-126	18 31 30.590	-12 40 04.80	VLA
1832+474	18 32 24.51	47 25 13	FOMALONT 1968, BDFL
1832+315	18 32 25.2	31 34 00	BDFL
1833+653	18 33 33.50	65 19 12.0	HOGBOM AND CARLSSON 1974
1835+134	18 35 12.7	13 28 04	BDFL
1842+455	18 42 35.49	45 30 22.4	FOMALONT AND MOFFET 1971
1842+681	18 42 43.385	68 06 19.70	VLA
1843+098	18 43 15.35	09 50 29.3	FOMALONT AND MOFFET 1971
1843+400	18 43 32.544	40 04 38.70	VLA
1843+356	18 43 48.341	35 38 02.40	VLA
1848+283	18 48 29.070	28 21 38.45	VLA
1849+670	18 49 16.504	67 02 07.90	VLA

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
1719+356							
1725+123							
1725+044							
1726+455							
1726+318							3C357
1730-130							NRAO530
1732+389							
1732+094							
1734+063							
1738+499							
1738+476							
1739+522							
1741-312							
1741-038							
1743+173							
1748-253							
1749+701							
1749+096							
1751+288							
1751+441							
1756+134							
1756+237							
1758+388							
1800+440							
1801+010							
1802+110							3C368
1803+784							
1807+698							3C371
1808-209							
1817-098							
1819+396	3.39	0.08	1.77	0.03	0.97	0.01J	
1820+179	1.76	0.05	1.08	0.02	0.67	0.05B	
1820+397							
1821+017	2.53	0.09	1.46	0.02	0.87	0.09N	
1821+107							
1823+568							
1826+796							
1827-360							
1828+487	14.11	0.29	9.44	0.07	7.50	0.09E	3C380
1829+290	2.84	0.07	1.87	0.02	1.15	0.04H	
1829-106							
1830+285	1.74	0.05	1.28	0.02	1.07	0.04H	
1831-126							
1832+474	3.79	0.18	2.26	0.03	1.29	0.05E	3C381
1832+315	2.06	0.06	1.42	0.03	1.16	0.04K	
1833+653	2.38	0.23	1.36	0.04	0.80	0.01J	3C383
1835+134	2.00	0.06	1.18	0.02	0.72	0.07N	
1842+455	5.57	0.23	3.18	0.02	1.77	0.04E	3C388
1842+681							
1843+098							3C390
1843+400							
1843+356							
1848+283							
1849+670							

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
1855+529	18 55 35.90	52 54 04.0	KUHR 1979
1856+737	18 56 06.999	73 47 19.40	VLA
1901+319	19 01 02.309	31 55 13.91	VLA
1905+190	19 05 11.120	19 51 36.00	VLA
1908-202	19 08 12.465	-20 11 55.10	VLA
1914+302	19 14 00.00	30 14 23	BDFL
1921-293	19 21 42.238	-29 20 26.42	VLA
1923+210	19 23 49.788	21 00 23.20	VLA
1926+611	19 26 49.646	61 11 20.70	VLA
1928+738	19 28 49.348	73 51 44.90	VLA
1933-400	19 33 51.118	-40 04 46.80	VLA
1936-155	19 36 36.024	-15 32 38.75	VLA
1937-101	19 37 12.646	-10 09 39.50	VLA
1938-155	19 38 24.480	-15 31 34.20	VLA
1939+605	19 39 38.83	60 34 31.2	HOGBOM AND CARLSSON 1974
1940+504	19 40 21.4	50 28 47	S4
1947+079	19 47 40.160	07 59 35.53	VLA
1949+023	19 49 44.13	02 22 41.5	MCEWAN ET AL. 1975
1953-325	19 53 48.368	-32 33 49.50	VLA
1953-425	19 53 49.000	-42 30 21.00	VLA
1954+513	19 54 22.469	51 23 46.40	VLA
1954-388	19 54 39.056	-38 53 13.25	VLA
1955-357	19 55 48.270	-35 42 44.00	VLA
1958-179	19 58 04.605	-17 57 16.90	VLA
2000-330	20 00 13.021	-33 00 12.50	VLA
2003-025	20 03 32.22	-02 32 15.2	MCEWAN ET AL. 1975
2004-447	20 04 25.143	-44 43 27.45	VLA
2005+403	20 05 59.560	40 21 01.80	VLA
2007+249	20 07 17.740	24 56 55.20	VLA
2007+776	20 07 20.435	77 43 58.10	VLA
2008-159	20 08 25.914	-15 55 38.25	VLA
2008-068	20 08 33.699	-06 53 01.75	VLA
2010+723	20 10 16.207	72 20 20.75	VLA
2012+234	20 12 18.16	23 25 41.5	FOMALONT AND MOFFET 1971
2018+295	20 18 04.17	29 32 40.6	ADGIE ET AL. 1972
2018+231	20 18 53.180	23 09 01.00	VLA
2019+098	20 19 44.36	09 51 32.9	FOMALONT AND MOFFET 1971
2021+614	20 21 13.297	61 27 18.12	VLA
2021+317	20 21 18.950	31 43 19.00	VLA
2022+542	20 22 37.630	54 17 49.00	VLA
2022+031	20 22 38.861	03 06 55.70	VLA
2023+336	20 23 12.960	33 33 11.00	VLA
2023+760	20 23 40.854	76 01 40.60	VLA
2029+121	20 29 32.679	12 09 28.70	VLA
2030+547	20 30 29.150	54 44 49.00	VLA
2030+257	20 30 42.90	25 42 06.0	BDFL
2032-350	20 32 37.450	-35 04 33.60	VLA
2032+107	20 32 58.558	10 45 42.20	VLA
2033+181	20 33 18.032	18 46 40.05	VLA
2037+511	20 37 07.460	51 08 35.71	VLA
2037-253	20 37 10.759	-25 18 26.35	VLA
2044-168	20 44 30.816	-16 50 09.70	VLA
2045+068	20 45 44.36	06 50 09.8	FOMALONT AND MOFFET 1971
2047+098	20 47 20.779	09 52 02.00	VLA

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
1855+529							3C393
1856+737							
1901+319							3C395
1905+190							
1908-202							
1914+302							3C399.1
1921-293							
1923+210							
1926+611							
1928+738							
1933-400							
1936-155							
1937-101							
1938-155	7.17	0.15B	3.93	0.32	2.31	0.06E	
1939+605	4.75	0.14	2.72	0.03	1.37	0.05E	3C401
1940+504							3C402
1947+079							
1949+023							3C403
1953-325							
1953-425							
1954+513							
1954-388							
1955-357							
1958-179							
2000-330							
2003-025	2.01	0.06	1.51	0.04	0.93	0.05B	
2004-447							
2005+403							
2007+249							
2007+776							
2008-159							
2008-068							
2010+723							
2012+234	13.04	0.27	6.46	0.08	3.12	0.05E	3C409
2018+295							3C410
2018+231	1.75	0.05	1.33	0.03	1.20	0.06B	
2019+098	3.18	0.08	1.70	0.01	0.87	0.06E	3C411
2021+614							
2021+317							
2022+542							
2022+031							
2023+336							
2023+760							
2029+121							
2030+547							
2030+257	1.81	0.06	1.01	0.04	0.60	0.05B	3C414
2032-350							
2032+107							
2033+181							
2037+511							3C418
2037-253							
2044-168							
2045+068	2.04	0.12	1.22	0.02	0.65	0.03E	3C424
2047+098							

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
2044-027	20 44 34.207	-02 47 25.80	VLA
2047+039	20 47 35.946	03 56 35.50	VLA
2050+364	20 50 54.460	36 24 11.69	VLA
2051+745	20 51 57.449	74 30 18.20	VLA
2055+508	20 55 45.150	50 46 38.50	VLA
2058-297	20 58 00.914	-29 45 15.00	VLA
2058-425	20 58 42.073	-42 31 03.60	VLA
2059+034	20 59 08.010	03 29 41.45	VLA
2104+763	21 04 46.11	76 21 03.2	HOGBOM AND CARLSSON 1974
2105+420	21 05 09.390	42 02 03.10	VLA
2106-413	21 06 19.391	-41 22 33.35	VLA
2111+620	21 11 39.47	62 02 35.0	HOGBOM AND CARLSSON 1974
2111-259	21 11 44.770	-25 54 17.20	VLA
2113+293	21 13 20.576	29 21 06.70	VLA
2117+605	21 17 01.88	60 35 34	FOMALONT AND MOFFET 1971
2121+053	21 21 14.799	05 22 27.45	VLA
2121+248	21 21 30.57	24 51 17.9	FOMALONT AND MOFFET 1971
2126-158	21 26 26.775	-15 51 50.40	VLA
2126-185	21 26 33.899	-18 34 32.60	VLA
2126+073	21 26 37.55	07 19 51.4	FOMALONT AND MOFFET 1971
2128+048	21 28 02.614	04 49 04.35	VLA
2128-208	21 28 12.280	-20 50 10.00	VLA
2128-123	21 28 52.673	-12 20 20.52	VLA
2131-021	21 31 35.126	-02 06 39.95	VLA
2134+004	21 34 05.205	C0 28 25.08	VLA
2135-209	21 35 01.323	-20 56 03.70	VLA
2135-248	21 35 45.400	-24 53 28.50	VLA
2136+141	21 36 37.411	14 10 00.63	VLA
2140-048	21 39 59.964	-04 51 27.80	VLA
2141+279	21 41 58.0	27 56 33	BDFL
2143-156	21 43 38.872	-15 39 37.30	VLA
2144+092	21 44 42.473	09 15 51.15	VLA
2145+151	21 45 01.29	15 06 45.5	FOMALONT AND MOFFET 1971
2145+067	21 45 36.076	06 43 40.90	VLA
2146-133	21 46 46.350	-13 18 28.00	VLA
2146+608	21 46 48.090	60 53 07.00	VLA
2147+145	21 47 59.298	14 35 44.66	VLA
2148+143	21 48 20.80	14 19 30.6	ADGIE ET AL. 1972
2149-306	21 49 00.592	-30 42 00.15	VLA
2149+069	21 49 02.703	06 55 20.90	VLA
2149+056	21 49 07.696	05 38 06.85	VLA
2149-287	21 49 10.530	-28 42 35.10	VLA
2150+173	21 50 02.229	17 20 29.80	VLA
2153+377	21 53 45.55	37 46 13.4	FOMALONT AND MOFFET 1971
2154+482	21 54 43.100	48 16 09.00	VLA
2155-152	21 55 23.238	-15 15 30.15	VLA
2200+420	22 00 39.363	42 02 08.57	VLA
2201+315	22 01 01.440	31 31 05.85	VLA
2201+624	22 01 50.110	62 26 01.00	VLA
2203-188	22 03 25.730	-18 50 17.05	VLA
2203+292	22 03 49.17	29 14 45.8	FOMALONT AND MOFFET 1971
2209+081	22 09 32.10	08 04 25.8	FOMALONT AND MOFFET 1971
2209+236	22 09 45.690	23 40 50.00	VLA
2210+016	22 10 05.133	01 37 59.50	VLA

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
2044-027							3C422
2047+039							
2050+364							
2051+745							
2055+508							
2058-297							
2058-425							
2059+034							
2104+763	3.70	0.18A	1.99	0.12	0.96	0.06E	3C427.1
2105+420							NGC7027
2106-413							
2111+620	2.53	0.08	1.39	0.04	0.79	0.08N	3C429
2111-259							
2113+293							
2117+605							3C430
2121+053							
2121+248	11.68	0.27	6.51	0.04	3.74	0.07E	3C433
2126-158							
2126-185							
2126+073	2.01	0.06	1.07	0.02	0.56	0.03E	3C435
2128+048	3.98	0.09	2.94	0.02	1.97	0.05I	
2128-208							
2128-123	1.85	0.09B	1.78	0.11	2.15	0.05E	
2131-021							
2134+004							P2134+00
2135-209							
2135-248							
2136+141							
2140-048							
2141+279	3.26	0.09	1.80	0.09	0.99	0.03E	3C436
2143-156							
2144+092							
2145+151	2.84	0.07	1.54	0.01	0.88	0.06E	3C437
2145+067							
2146-133							
2146+608							
2147+145	2.42	0.11	1.37	0.02	0.72	0.03I	
2148+143	2.13	0.08	1.30	0.06	0.78	0.03I	
2149-306							
2149+069							
2149+056							
2149-287							
2150+173							
2153+377	6.70	0.14	3.25	0.03	1.54	0.06E	3C438
2154+482							
2155-152							
2200+420							BLLAC
2201+315							
2201+624	2.96	0.09	1.68	0.07	1.07	0.07E	3C440
2203-188	6.32	0.20B	5.11	0.42	4.62	0.12E	
2203+292	2.51	0.08	1.38	0.02	0.92	0.03E	3C441
2209+081	1.80	0.06	1.27	0.03	1.09	0.04H	
2209+236							
2210+016	2.60	0.07	1.67	0.01	1.02	0.04H	

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
2210-257	22 10 14.131	-25 44 22.50	VLA
2214+350	22 14 07.016	35 03 15.20	VLA
2215+020	22 15 15.587	02 05 09.00	VLA
2216-038	22 16 16.380	-03 50 40.65	VLA
2218+395	22 18 21.15	39 33 40.1	KUHR 1979
2223-052	22 23 11.087	-05 12 17.90	VLA
2223+210	22 23 14.6	21 02 51	BDFL
2226-411	22 26 22.230	-41 06 52.00	VLA
2227-088	22 27 02.337	-08 48 17.58	VLA
2227-399	22 27 44.980	-39 58 16.75	VLA
2229+695	22 29 11.651	69 31 02.65	VLA
2230+114	22 30 07.812	11 28 22.72	VLA
2233-148	22 33 53.979	-14 48 56.70	VLA
2234+282	22 34 01.727	28 13 23.20	VLA
2239+096	22 39 19.846	09 38 09.90	VLA
2240-260	22 40 41.834	-26 00 15.80	VLA
2243-123	22 43 39.796	-12 22 40.25	VLA
2244+366	22 44 12.52	36 40 34.7	KUHR 1979
2245-328	22 45 51.502	-32 51 44.28	VLA
2247+140	22 47 56.83	14 03 56.3	FOMALONT AND MOFFET 1971
2248+712	22 48 58.530	71 13 23.90	VLA
2249+185	22 49 07.79	18 32 44.0	FOMALONT AND MOFFET 1971
2250+644	22 50 13.28	64 24 13.3	HOGBOM AND CARLSSON 1974
2251+158	22 51 29.521	15 52 54.31	VLA
2251+244	22 51 44.6	24 29 28	BDFL
2252-089	22 52 27.493	-09 00 04.60	VLA
2252+129	22 52 34.55	12 57 35.7	FOMALONT AND MOFFET 1971
2253+417	22 53 19.837	41 46 51.30	VLA
2255+416	22 55 04.65	41 38 13.6	ADGIE ET AL. 1972
2255-282	22 55 22.467	-28 14 25.80	VLA
2259-375	22 59 37.010	-37 34 17.00	VLA
2305-418	23 05 06.800	-41 48 58.00	VLA
2309+090	23 09 56.60	09 03 09.4	FOMALONT AND MOFFET 1971
2314+038	23 14 02.24	03 48 55.2	MCEWAN ET AL. 1975
2318+049	23 18 12.129	04 57 23.45	VLA
2318+235	23 18 59.89	23 30 23.6	ELSMORE AND MACKAY 1969
2319+272	23 19 31.990	27 16 19.10	VLA
2320-035	23 20 57.522	-03 33 33.60	VLA
2323-407	23 23 51.710	-40 43 46.00	VLA
2324-023	23 24 20.34	-02 18 47.6	MCEWAN ET AL. 1975
2324+405	23 24 30.71	40 31 38.3	FOMALONT AND MOFFET 1971
2325-150	23 25 11.597	-15 04 27.30	VLA
2328+107	23 28 08.787	10 43 45.50	VLA
2329-162	23 29 02.397	-16 13 30.85	VLA
2331-240	23 31 17.950	-24 00 16.00	VLA
2335-027	23 35 23.230	-02 47 35.00	VLA
2337-334	23 37 16.672	-33 26 54.80	VLA
2337+220	23 37 51.89	22 04 14.2	FOMALONT AND MOFFET 1971
2337+264	23 37 58.275	26 25 18.95	VLA
2341+535	23 41 21.500	53 32 01.00	VLA
2343+657	23 43 10.300	65 40 39.50	VLA
2344+092	23 44 03.773	09 14 05.45	VLA
2345-167	23 45 27.687	-16 47 52.59	VLA
2347-026	23 47 51.50	-02 41 23.7	MCEWAN ET AL. 1975

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
2210-257							
2214+350							
2215+020							
2216-038							
2218+395							
2223-052							3C446
2223+210							
2226-411							
2227-088							
2227-399							
2229+695							
2230+114							CTA102
2233-148							
2234+282							
2239+096							
2240-260							
2243-123							
2244+366	2.03	0.06	1.19	0.02	0.70	0.01J	
2245-328							
2247+140	2.10	0.06	1.46	0.03	1.03	0.06E	
2248+712							3C454.1
2249+185	2.06	0.07	1.21	0.01	0.79	0.03E	3C454
2250+644	2.21	0.08D	1.29	0.04A	0.76	0.03E	3C454.2
2251+158							3C454.3
2251+244	1.88	0.06	1.22	0.02	0.87	0.03H	
2252-089							
2252+129	2.93	0.12	1.41	0.01	0.93	0.10E	3C455
2253+417							
2255+416	2.21	0.06	1.44	0.03	0.99	0.01J	
2255-282							
2259-375							
2305-418							
2309+090	2.51	0.08	1.36	0.02	0.67	0.03E	3C456
2314+038	4.17	0.10	2.30	0.04	1.36	0.04E	3C459
2318+049							
2318+235							3C460
2319+272							
2320-035							
2323-407							
2324-023							
2324+405	2.38	0.12	1.54	0.03	1.12	0.10E	3C462
2325-150							
2328+107							
2329-162							
2331-240							
2335-027							
2337-334							
2337+220	2.13	0.07	1.31	0.03	0.75	0.05B	3C466
2337+264							
2341+535							
2343+657							
2344+092							
2345-167							
2347-026	1.75	0.05	1.02	0.08	0.48	0.02C	

SOURCE NAME	RIGHT ASCENSION (1950)	DECLINATION	REFERENCE
2348+643	23 48 27.450	64 23 37.00	VLA
2349-014	23 49 22.50	-01 25 58.6	MCEWAN ET AL. 1975
2351+456	23 51 49.976	45 36 22.80	VLA
2351-154	23 51 55.883	-15 29 53.00	VLA
2352+495	23 52 37.790	49 33 26.76	VLA
2354-117	23 54 57.211	-11 42 21.40	VLA
2356+437	23 56 02.42	43 47 01.3	FOMALONT AND MOFFET 1971

SOURCE NAME	21 CM FLUX	ERR MEAS	11 CM FLUX	ERR MEAS	6 CM FLUX	ERR MEAS	OTHER NAME
2348+643	4.80	0.20D	1.94	0.04A	0.87	0.03E	3C468.1
2349-014	1.63	0.12C	1.00	0.02	0.70	0.03I	
2351+456	2.12	0.06	1.51	0.05	1.41	0.02J	
2351-154							
2352+495							
2354-117							
2356+437	1.88	0.06	1.03	0.02	0.55	0.03E	3C470

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APPENDIX C

IBM PROGRAMS FOR PRODUCING SOURCE CARD DECKS

```
//PREP300 JOB (532,300),GBOPER,MSGLEVEL=(2,0),CLASS=C
/*ROUTE  PRINT REMOTE1
// EXEC FORTGCL,ERROR=E,PARM.FORT='ID'
//FORT.SYSIN DD *
C
C  PROGRAM PREP300                 VERSION 2.0   1 JULY 82
C                                  PREVIOUS VERSION SAVED AS 'OLDPREP'
C
C       PROGRAM PREP300 IS USED TO PREPARE OBSERVING CARDS FOR DRIFT
C  SCANS AT THE 300-FOOT TELESCOPE.  CARDS FOR WOBBLES CAN ALSO BE
C  PRODUCED.  THE PROGRAM CAN PRODUCE CARDS FOR OBSERVATIONS IN
C  POSITIONING CODES 1-3 AND 13.  CARDS FOR DECLINATION SCANS WITH
C  POSITIONING CODES 3, 8, 13, OR 18 ARE PRODUCED BY A COMPANION
C  PROGRAM CALLED POINT300.  PARAMETERS THAT ALLOW THE PROGRAM TO TAKE
C  ACCOUNT OF PRECESSION, POINTING CORRECTIONS, AND FEED OFFSETS, AS
C  WELL AS THE CHOSEN MODE OF OBSERVING --SCAN LENGTH, INTEGRATION TIME,
C  ETC.-- ARE READ FROM THE FIRST EIGHT CARDS ON THE CARD INPUT FILE OR
C  STREAM (SYSIN).  THE REST OF THE INPUT CARDS ARE SOURCE CARDS,
C  CONTAINING THE SOURCE NAME AND 1950.0 RIGHT ASCENSION AND DECLI-
C  NATION.  THE PROGRAM WILL PUNCH AN OBSERVING CARD (OR PERHAPS MORE
C  THAN ONE CARD) FOR EACH SOURCE.
C
C       THE DIFFERENCE BETWEEN THIS VERSION AND THE PREVIOUS VERSION,
C  SAVED AS OLDPREP, IS THE WAY THE DECLINATION POINTING CORRECTION IS
C  IMPLEMENTED.  IN THE PREVIOUS VERSION A TABLE OF OFFSETS TAKING UP
C  TWO INPUT CARDS WAS READ N, AND THE PROGRAM INTERPOLATED BETWEEN
C  VALUES IN THE TABLE.  IN THIS VERSION, THE COEFFICIENTS OF A POLY-
C  NOMIAL FIT ARE READ FROM A SINGLE CARD.  THE DIFFERENCE IN THE
C  NUMBER OF SETUP CARDS BETWEEN THE TWO VERSIONS SHOULD CAUSE A FATAL
C  RUN-TIME ERROR, PREVENTING THE USE OF THE WRONG VERSION.
C
C       PROGRAM PREP300 ASSUMES THAT YOU WILL BE DOING DRIFT SCANS.
C  TO SWITCH FROM DRIFT SCANS TO WOBBLES, INSERT A CARD CONTAINING
C  'WOBBLE' IN COLUMNS 1-6 INTO THE INPUT STREAM.  TO REVERT BACK TO
C  DRIFT SCANS, INSERT A CARD CONTAINING 'DRIFT' IN COLUMNS 1-5 INTO
C  THE JOB STREAM.  THIS SWITCHING CAN BE PERFORMED ANY NUMBER OF
C  TIMES.  DRIFT SCANS ARE OBSERVED WITH A PULSED CAL, AND WOBBLES
C  ARE OBSERVED WITH NO CAL.
C
C       PROGRAM PREP300 HAS TWO IMPORTANT CONVENIENCE FEATURES:
C  COORDINATE LOOKUP AND DECLINATION OFFSETS.  IF THE CONTENTS OF
C  COLUMNS 39-40 ON A SOURCE CARD ARE NOT ZERO (I.E. BLANK) THEN THE
C  PROGRAM WILL SCAN THE CONTENTS OF A LOOKUP FILE FOR AN EXACT MATCH
C  TO THE SOURCE NAME ON THE CARD.  IF A MATCH IS FOUND THEN THE
C  PROGRAM USES THE COORDINATES READ FROM THE DISK FILE.  IF NOT, THEN
C  IT USES THE COORDINATES ON THE CARD.  THIS PROVIDES A CONVENIENT WAY
C  TO USE UPDATED COORDINATES FROM THE STAFF MAINTAINED LOOKUP FILE.
C  IF THE RA AND DEC FIELDS ON A SOURCE CARD ARE BLANK THEN THE PROGRAM
C  WILL ALSO LOOK FOR COORDINATES ON THE LOOKUP FILE, BUT IF IT DOES
C  NOT FIND ANY IT PRINTS A MESSAGE AND GOES ON TO THE NEXT SOURCE CARD.
C  A LISTING OF THE CONTENTS OF THE SUPPLIED LOOKUP FILE CAN BE FOUND
C  IN APPENDIX B OF THE 300-FOOT MANUAL.
C
C       THE DECLINATION OFFSET FEATURE PROVIDES A CONVENIENT WAY TO
C  OBSERVE THE SAME SOURCE WITH DIFFERENT DECLINATION OFFSETS ON
C  SUCCESSIVE DAYS, UP TO A LIMIT OF 20 DAYS (I.E. 20 OFFSETS).
C  THE NUMBER OF OFFSETS (I4) IS PUNCHED ON INPUT CARD 6, FOLLOWED
C  BY A LIST OF OFFSETS IN ARCMINUTES (F7.3), WHICH MAY CONTINUE
```

```
C   ONTO A SECOND CARD.
C
C        TO RUN PROGRAM PREP300 YOU SHOULD CREATE A PANDORA MEMBER
C   CONTAINING IMAGES OF THE INPUT CARDS TO BE READ BY THE PROGRAM, IN
C   THE FORMATS GIVEN BELOW, AND SAVE IT.  THEN CREATE A MEMBER WITH
C   THE NECESSARY JCL STATEMENTS.  IF ALL OF YOUR SOURCES ARE SUPPLIED
C   WITH COORDINATES ON THE SOURCE CARDS OR CAN BE FOUND IN THE STAFF
C   MAINTAINED LOOKUP FILES, THEN THE FOLLOWING WILL SUFFICE:
C
C   //PREP300 JOB (<USER#>,300),<YOURNAME>,CLASS=B,MSGLEVEL=(2,0)
C   /*ROUTE  PRINT REMOTE1
C   /*ROUTE  PUNCH REMOTE1
C   // EXEC PREP300
C   //SYSIN DD *
C
C   TAKE NOTE OF THE TWO SPACES AFTER 'ROUTE' ON THE SECOND AND THIRD
C   CARDS.  TO SUBMIT THIS JOB, TYPE
C
C   SUB <NAME OF JCL MEMBER> <NAME SYSIN MEMBER>
C
C        IF YOU ARE SUPPLYING YOUR OWN LOOKUP FILE, THEN YOU NEED YET
C   ANOTHER PANDORA MEMBER, OF WHICH THE FIRST LINE IS:
C
C   //SOURCES DD *
C
C   FOLLOWED BY LINES OF SOURCE NAMES AND POSITIONS IN THE SAME FORMAT
C   AS FOR SOURCE CARDS.  TO SUBMIT THIS JOB, TYPE
C
C   SUB <NAME JCL MEMBER> <NAME SYSIN MEMBER> <NAME SOURCES MEMBER>
C
C   YOUR LOOKUP FILE WILL BE THE FIRST ONE SEARCHED, BUT IF A SOURCE
C   IS NOT FOUND THERE, THE SEARCH WILL CONTINUE ON TO THE SUPPLIED
C   LOOKUP FILE.  SCANNING STOPS WHEN A MATCH IS FOUND, SO IF A SOURCE
C   COULD BE FOUND ON BOTH YOUR LOOKUP FILE AND THE SUPPLIED LOOKUP
C   FILE, THE PROGRAM WILL ALWAYS TAKE THE INFORMATION FROM YOUR FILE.
C
C
C   INPUT CARDS
C
C     COLUMN       ITEM(S)                                  FORMAT
C
C   1         MEDIAN OBSERVING DATE, OBSERVER NUMBER
C        1           DAY                                       I5
C        6           MONTH                                     I5
C       11           YEAR                                      I5
C       16           OBSERVER NUMBER                           I5
C   2         UP TO 4 FEED OFFSETS IN ARCMINUTES
C        1,11        RA1, DEC1                              2F10.5
C       21,31        RA2, DEC2                              2F10.5
C       41,51        RA3, DEC3                              2F10.5
C       61,71        RA4, DEC4                              2F10.5
C   3         COEFFICIENTS OF RA POINTING CURVE:
C               DRA = M + N*TAN( DEC ) + C/COS( DEC )
C               (SEE TABLE 8-1 IN THE 300-FOOT MANUAL)
C        1           M                                       F10.5
C       11           N                                       F10.5
C       21           C                                       F10.5
C   4         COEFFICIENTS OF DEC POINTING CURVE:
```

```
C             CDEC = C1 + C2*DEC + C3*DEC**2 + C4*DEC**3
C             (SEE TABLE 8-1 IN THE 300-FOOT MANUAL)
C        1          D1                                       F10.5
C       11          D2                                       F10.5
C       21          D3                                       F10.5
C       31          D4                                       F10.5
C   5         UP TC 2C DECLINATION OFFSETS IN ARCMINUTES
C        1          NUMBER OF OFFSETS                         I4
C        5          OFFSET(1)                                F7.3
C       12          OFFSET(2)                                F7.3
C      ...           ...
C       68          OFFSET(10)                               F7.3
C        1          OFFSET(11)                               F7.3
C                     (CONTINUES ON SECCND CARD)
C      ...           ...
C   6         DETAILS CF OBSERVING PROCEDURE (SEE 300' MANUAL)
C        1          SCAN LENGTH IN ARCMINUTES                F10.4
C       11          ADDITIONAL BASELINE LENGTH (SECONDS)     F10.4
C       24          PCSITIONING CCDE (ONLY 1-3 AND 13,        I2
C                     SEE PROGRAM POINT300 FOR OTHERS)
C       26          DECLINATION SCANNING RATE                 I5
C                     ARCMINUTES/MINUTE
C       31          RCTATION ANGLE                            I5
C       36          INTEGRATION PERIOD IN SECONDS            F5.1
C       41          WAIT CODE.  IF=1 THEN DATA TAKING         I1
C                     IS DELAYED FROM THE INDICATED
C                     START TIME UNTIL THE DEC ERROR
C                     IS LESS THAN 20 ARCSECONDS.
C   7         WOBBLE LIMITS ABOUT SPECIFIED POSITION
C       1,11        NCRTH, SOUTH LIMITS IN ARCMINUTES       2F10.5
C      21,31        EAST, WEST LIMITS IN SECONDS            2F10.5
C   8         SOURCE CARDS
C        1          SOURCE NAME                              A8,A2
C       11          RIGHT ASCENSION (1950.0)                 R14.4 *
C       25          DECLINATION (1950.0)                     S14.4 *
C       39          IREAD, FLAG TC LOOK CN FILE 9 IF          I2
C                     IREAD .NE. ZERO
C       41          FLUX (OPTIONAL, I.E. NOT PUNCHED)        F6.1
C       47          SOURCE WIDTH IN ARCMIN                   F3.1
C       51          NCTE                                      A6
C
C   * FORMAT FCR R14.4 IS SHH MM SS.SSSS
C     FORMAT FCR S14.4 IS SDD MM SS.SSSS
C
C
C        THE DURATION OF THE DRIFT SCANS IS TAKEN FROM THE INFORMATION
C   ON BCTH  THE SETUP CARDS AND INDIVIDUAL SOURCE CARDS.  THE TOTAL
C   DURATION OF A SCAN IN SECONDS OF TIME IS GIVEN BY THE FORMULA
C
C        SCAN DURATICN = 4*(SCAN LENGTH + WASTE + WIDTH )/COS( DEC )
C                            + 2*BASELINE LENGTH
C
C   'WASTE' IS CCMPUTED IN THE PROGRAM FROM THE FEED OFFSETS ON CARD 2,
C   'SCAN LENGTH' AND 'BASELINE LENGTH' ARE TAKEN FRCM CARD 6, AND
C   'WIDTH' IS TAKEN FRCM THE SOURCE CARDS.  IF A PULSED CAL WOULD
C   OCCUR IN THE LAST OR SECOND-TO-LAST DATA POINT CF A SCAN, THEN
C   THE SCAN IS LENGTHENED TO AVOID THIS.
C
```

```
//POINT300 JOB (533,300),GBOPER,MSGLEVEL=(2,0),CLASS=Q
/*ROUTE  PRINT REMOTE1
// EXEC FORTGCL,PARM.FORT=ID,ERROR=E
//*FORT.SYSPRINT DD DUMMY
//FORT.SYSIN DD *
C
C   PROGRAM POINT300                    VERSION 2.0   20 JULY 1982
C
C        PROGRAM POINT300 IS A COMPANION PROGRAM TO PROGRAM PREP300.
C   PROGRAM POINT300 PREPARES OBSERVING CARDS FOR DECLINATION SCANS
C   AT THE 300-FOOT TELESCOPE IN POSITIONING MODES 3, 8, 13, OR 18.
C   SEE PROGRAM PREP300 FOR MODES 1-3 AND 13.  PROGRAM POINT300 IS
C   PRIMARILY INTENDED FOR PREPARING OBSERVATIONS TO CHECK THE DECLI-
C   NATION POINTING OF THE 300-FOOT TELESCOPE.  THERE ARE RELATIVELY
C   FEW PARAMETERS WHICH CAN BE SPECIFIED BY THE USER, AND THESE ARE READ
C   FROM THE FIRST TWO CARDS ON THE CARD INPUT FILE.  THE REMAINING CARDS
C   ON THE CARD INPUT FILE ARE SOURCE CARDS, CONTAINING THE NAME
C   AND 1950.0 COORDINATES OF A SOURCE.  TWO OBSERVING CARDS ARE
C   PRODUCED FOR EACH SOURCE CARD:  ONE MARKED 'NS' SCANS THE TELESCOPE
C   FROM NORTH TO SOUTH, AND ANOTHER MARKED 'SN' SCANS FROM SOUTH TO
C   NORTH.  THESE PAIRS ARE SEGREGATED INTO TWO SEPARATE OBSERVING DECKS
C   WHICH ARE PRODUCED AT THE END OF THE COMPUTATIONS.  THE DECKS ARE
C   FOR USE ON SUCCESSIVE DAYS.  IN BOTH DECKS, SUCCESSIVE SCANS
C   ALTERNATE BETWEEN 'NS' AND 'SN' SCANS BUT THE TWO DECKS ARE 'OUT OF
C   PHASE', ONE GOING NORTH WHERE THE OTHER GOES SOUTH.
C
C        PROGRAM POINT300 PREPARES CARDS FOR SCANS DRIVEN IN DECLI-
C   NATION SO THAT THE SOURCE SHOULD PEAK AT THE CENTER OF THE SCAN.
C   FOR THOSE POSITIONING MODES IN WHICH THE TELESCOPE IS SIMULTANEOUSLY
C   TRACKING IN RIGHT ASCENSION (8 AND 18), THE SOURCE SHOULD PEAK AT
C   TRANSIT.  ALL OF THE OBSERVING CARDS CONTAIN A CODE FOR PULSED CAL
C   OBSERVATIONS (0 IN COLUMN 54).  IF A PULSED CAL WOULD OCCUR IN THE
C   LAST OR SECOND TO LAST DATA POINT THE SCAN IS LENGTHENED.
C
C        LEAVING THE DECLINATION RATE FIELD ON INPUT CARD 1 BLANK
C   INVOKES THE DEFAULT DECLINATION RATE OF 15 ARCMINUTES PER MINUTE
C   OF TIME. IF THE SECANT( DEC ) INDICATOR IS ZERO THEN THE SCAN
C   RATE IS ALWAYS 15 ARCMIN/MIN, BUT IF THE SECANT( DEC ) INDICATOR
C   IS 1 THEN THE SCAN RATE IS SLOWED BY COS( DEC ) AND THE SCAN IS
C   LENGTHED BY SECANT( DEC ) TO TAKE ADVANTAGE OF THE THE ABILITY OF
C   THE STERLING MOUNTED RECEIVERS TO TRACK A GIVEN RIGHT ASCENSION
C   FOR A LONGER PERIOD OF TIME AT HIGHER DECLINATIONS.  THE INTEGRATION
C   PERIOD, OR SAMPLING RATE REMAINS CONSTANT SO THE HIGHER DECLINATION
C   SCANS HAVE MORE DATA POINTS THAN LOW DECLINATION SCANS.
C
C        PROGRAM POINT300 DOES NOT HAVE THE FEATURE ALLOWING SCANS AT
C   GIVEN OFFSETS FROM THE NOMINAL SOURCE POSITION, BUT IT DOES HAVE THE
C   SAME COORDINATE LOOKUP FEATURE AS PROGRM PREP300.  THAT IS, IF
C   COLUMNS 39-40 ON A SOURCE CARD ARE NOT ZERO (I.E. BLANK) THEN THE
C   PROGRAM WILL SCAN THE CONTENTS OF A LOOKUP FILE, LOOKING FOR
C   AN EXACT MATCH TO THE SOURCE NAME ON THE CARD.  IF A MATCH IS FOUND
C   THEN THE PROGRAM USES THE COORDINATES READ FROM THE DISK FILE.  IF
C   NOT, IT USES THE COORDINATES ON THE CARD.  THIS PROVIDES A CONVEN-
C   IENT WAY TO USE UPDATED COORDINATES FROM A MAINTAINED LOOKUP FILE.
C   IF THE RA AND DEC FIELDS ON A SOURCE CARD ARE BLANK THEN THE PROGRAM
C   WILL ALSO SCAN THE LOOKUP FILE, BUT IF IT DOES NOT FIND
C   ANY, IT PRINTS A MESSAGE AND GOES ON TO THE NEXT SOURCE CARD.
C
```

```
C        TO RUN PROGRAM POINT300 YOU SHOULD CREATE A PANDORA MEMBER
C   CONTAINING IMAGES OF THE INPUT CARDS TO BE READ BY THE PROGRAM, IN
C   THE FORMATS GIVEN BELOW, AND SAVE IT.  THEN CREATE A MEMBER WITH
C   THE NECESSARY JCL STATEMENTS.  IF ALL OF YOUR SOURCES ARE SUPPLIED
C   WITH COORDINATES ON THE SOURCE CARDS OR CAN BE FOUND IN THE STAFF
C   MAINTAINED LOOKUP FILES, THEN THE FOLLOWING WILL SUFFICE:
C
C   //POINT300 JOB (<USER#>,300),<YOURNAME>,CLASS=B,MSGLEVEL=(2,0)
C   /*ROUTE  PRINT REMOTE1
C   /*ROUTE  PUNCH REMOTE1
C   // EXEC POINT300
C   //SYSIN DD *
C
C   TAKE NOTE OF THE TWO SPACES AFTER 'ROUTE' ON THE SECOND AND THIRD
C   CARDS.  TO SUBMIT THIS JOB, TYPE
C
C   SUB <NAME OF JCL MEMBER> <NAME SYSIN MEMBER>
C
C        IF YOU ARE SUPPLYING YOUR OWN LOOKUP FILE, THEN YOU NEED YET
C   ANOTHER PANDORA MEMBER, OF WHICH THE FIRST LINE IS:
C
C   //SOURCES DD *,DCB=BLKSIZE=80
C
C   FOLLOWED BY LINES OF SOURCE NAMES AND POSITIONS IN THE SAME FORMAT
C   AS FOR SOURCE CARDS.  TO SUBMIT THIS JOB, TYPE
C
C   SUB <NAME JCL MEMBER> <NAME SYSIN MEMBER> <NAME SOURCES MEMBER>
C
C   YOUR LOOKUP FILE WILL BE THE FIRST ONE SEARCHED, BUT IF A SOURCE
C   IS NOT FOUND THERE, THE SEARCH WILL CONTINUE ON TO THE SUPPLIED
C   LOOKUP FILE.  SCANNING STOPS WHEN A MATCH IS FOUND, SO IF A SOURCE
C   COULD BE FOUND ON BOTH YOUR LOOKUP FILE AND THE SUPPLIED LOOKUP
C   FILE, THE PROGRAM WILL ALWAYS TAKE THE INFORMATION FROM YOUR FILE.
C
C
C   INPUT CARDS
C
C     COLUMN       ITEM(S)                                   FORMAT
C
C   1         MEDIAN OBSERVING DATE, OBSERVER NUMBER,
C               DETAILS OF OBSERVING PROCEDURE
C        1         DAY                                         I5
C        6         MONTH                                       I5
C       11         YEAR                                        I5
C       16         OBSERVER NUMBER                             I5
C       21         POSITIONING CODE (ONLY 3,8,13,              I5
C                     AND 18.  SEE PREP300 FOR OTHERS)
C       26         INTEGRATION PERIOD IN SECONDS              F5.1
C       31         SCAN LENGTH IN SECONDS                     F5.1
C                     MAXIMUM OF 240 FOR CODE 8 OR 18
C       36         SECANT( DEC ) LENGTHENING OF SCAN           I5
C                     0 FOR NO, 1 FOR YES
C       41         WAIT CODE.  IF=1 THEN DATA TAKING           I5
C                    IS DELAYED FROM THE INDICATED
C                    START TIME UNTIL THE DEC ERROR
C                    IS LESS THAN 20 ARCSECONDS.
C       46         ROTATION ANGLE IN DEGREES                   I5
C       51         DECLINATION RATE IN ARCMIN/MIN.             I5
```

```
C                     DEFAULT IS 15 ARCMIN/MIN
C   2        COEFFICIENTS OF RA POINTING CURVE:
C              DRA = M + N*TAN( DEC ) + C/COS( DEC )
C              (SEE TABLE 8-1 IN THE 300-FOOT MANUAL)
C        1          M                                          F10.5
C       11          N                                          F10.5
C       21          C                                          F10.5
C   3        SOURCE CARDS
C        1          SOURCE NAME                                A8,A2
C       11          RIGHT ASCENSION (1950.0)                   R14.4 *
C       25          DECLINATION (1950.0)                       S14.4 *
C       39          IREAD, FLAG TO LOOK ON FILE 9 IF            I2
C                     IREAD .NE. ZERO
C
C   * FORMAT FOR R14.4 IS SHH MM SS.SSSS
C     FORMAT FOR S14.4 IS SDD MM SS.SSSS
C
C
C      SUBROUTINES USED
C         CCREAD
C         DJL
C         DMAP
C
      IMPLICIT REAL*8 (A-H,O-Z), INTEGER*4 (I-N)
C
      INTEGER*2 SECDEC, NS, SN
      REAL*4 MONTH,MO(12)
      REAL*8 DAYMO(12), DELRA(12), DECD(12), M2R, NSDEC, SOURCE(2),
     +       T2R, TWOPI
C
      DATA  MO    /' JAN', ' FEB', ' MAR', ' APR', ' MAY', ' JUN',
     +              ' JUL', ' AUG', ' SEP', ' OCT', ' NOV', ' DEC'/,
     +      DAYMO /    0.,     31.,     59.,     90.,    120.,    151.,
     +               181.,    212.,    243.,    273.,    304.,    334./,
     +      M2R / 2.908882087D-4 /,
     +      T2R / 7.272205218D-5 /,
     +      TWOPI / 6.283185308 /,
     +      NS / 'NS' /,
     +      SN / 'SN' /,
     +      DECD  / -20.0, -10.0,  0.0,  10.0,  20.0,  30.0,
     +               40.0,  50.0, 60.0,  70.0,  80.0,  89.0 /
C
C      READ IN THE SETUP CARDS
C
      READ (5,1000) ID,IM,IY,IOBCOD,IPCSCO,IPOSC1,ENTP,SCLEN,SECDEC,
     * IWAIT,IROTAN,IRATE
 1000 FORMAT(4I5,3X,2I1,2F5.1,4I5)
C
C      MAXIMUM SCAN LENGTH FOR STERLING MOUNT IS 240 SEC
C
      IF (IPOSC1.EQ.8.AND.SCLEN.GT.240.0D0) SCLEN=240.0D0
C
C      FOR IPOSC1=8 COMPUTER SETS IROTAN=0
C
      IF (IPOSC1.EQ.8) IROTAN=0
C
C      FOR IRATE<=0 SET DEFAULT IRATE=15
C
```

```
//LINE300 JOB (532,300),GBOPER,MSGLEVEL=(2,0),CLASS=Q
/*ROUTE  PRINT REMOTE1
// EXEC FORTGCL,ERRCR=E,PARM.FORT='ID'
//*FORT.SYSPRINT DD DUMMY
//FORT.SYSIN DD *
C
C   LINE300                VERSION 2.0          20 JULY 1982
C
C        PROGRAM LINE300 PREPARES OBSERVING CARDS FOR SPECTRAL LINE
C   OBSERVATIONS ON THE 300-FOOT TELESCOPE IN POSITIONING CODES 8 OR
C   18.  THE PROGRAM PRODUCES CARDS FOR A SERIES OF SCANS FOR EACH
C   SOURCE, WITH OFF SOURCE SCANS SYMMETRICALLY ARRANGED ABOUT A SINGLE
C   ON SOURCE SCAN.  THE NUMBER OF OFF SOURCE SCANS ON EACH SIDE OF THE
C   ON SOURCE SCAN CAN BE SPECIFIED, FOR TOTAL POWER OBSERVING, OR CAN
C   BE SET TO ZERO FOR SWITCHED POWER OBSERVING.
C
C        BESIDES THE NUMBER OF OFFS, THE ONLY OBSERVING PARAMETERS THAT
C   CAN BE SET BY THE USER ARE THE POSITIONING CODE AND THE SCAN LENGTH.
C   THE SCAN LENGTH WILL BE ROUNDED DOWN TO A MULTIPLE OF 20 SECONDS
C   TO SATISFY TIMING REQUIREMENTS OF THE AUTOCORRELATOR.  IF THE SCAN
C   LENGTH FIELD ON A SOURCE CARD IS LEFT BLANK, THEN THE PROGRAM
C   SUPPLIES A DEFAULT SCAN LENGTH OF 240*SECANT( DEC ) SECONDS,
C   ROUNDED DOWN TO A MULTIPLE OF 20 SECONDS.  THIS IS THE MAXIMUM SCAN
C   LENGTH ALLOWED BY THE STERLING MOUNT.
C
C        THE INTERVAL BETWEEN SCANS IN A SEQUENCE IS 64 SECONDS.  THIS
C   IS THE TIME REQUIRED FOR THE STERLING MOUNT TO RETURN TO ITS EAST-
C   ERNMOST POSITION.  THE PROGRAM ALSO ADDS ONE SECOND TO THE SCAN
C   LENGTH TO AVOID A TIMING PECULIARITY BETWEEN THE CORRELATOR AND
C   THE COMPUTER.
C
C        PROGRAM LINE300 SHARES WITH PROGRAM PREP300 THE FEATURE OF
C   SCANNING A LOOKUP FILE FOR SOURCE COORDINATES.  THAT IS, IF
C   COLUMNS 39-40 ON A SOURCE CARD ARE NOT ZERO (I.E. BLANK) THEN THE
C   PROGRAM WILL SCAN THE CONTENTS OF A LOOKUP FILE, LOOKING FOR
C   AN EXACT MATCH TO THE SOURCE NAME ON THE CARD.  IF A MATCH IS FOUND
C   THEN THE PROGRAM USES THE COORDINATES READ FROM THE DISK FILE.  IF
C   NOT, IT USES THE COORDINATES ON THE CARD.  THIS PROVIDES A CONVEN-
C   IENT WAY TO USE UPDATED COORDINATES FROM A MAINTAINED LOOKUP FILE.
C   IF THE RA AND DEC FIELDS ON A SOURCE CARD ARE BLANK THEN THE PROGRAM
C   WILL ALSO SCAN THE LOOKUP FILE, BUT IF IT DOES NOT FIND
C   ANY, IT PRINTS A MESSAGE AND GOES ON TO THE NEXT SOURCE CARD.
C
C        TO RUN PROGRAM LINE300 YOU SHOULD CREATE A PANDORA MEMBER
C   CONTAINING IMAGES OF THE INPUT CARDS TO BE READ BY THE PROGRAM, IN
C   THE FORMATS GIVEN BELOW, AND SAVE IT.  THEN CREATE A MEMBER WITH
C   THE NECESSARY JCL STATEMENTS.  IF ALL OF YOUR SOURCES ARE SUPPLIED
C   WITH COORDINATES ON THE SOURCE CARDS OR CAN BE FOUND IN THE STAFF
C   MAINTAINED LOOKUP FILES, THEN THE FOLLOWING WILL SUFFICE:
C
C   //LINE300 JOB (<USER#>,300),<YOURNAME>,CLASS=B,MSGLEVEL=(2,0)
C   /*ROUTE  PRINT REMOTE1
C   /*ROUTE  PUNCH REMOTE1
C   // EXEC LINE300
C   //SYSIN DD *
C
C   TAKE NOTE OF THE TWO SPACES AFTER 'ROUTE' ON THE SECOND AND THIRD
C   CARDS, WHICH SEND THE OUTPUT TO GREEN BANK.  TO SUBMIT, TYPE
```

```
C
C   SUB <NAME OF JCL MEMBER> <NAME SYSIN MEMBER>
C
C        IF YOU ARE SUPPLYING YOUR OWN LOOKUP FILE, THEN YOU NEED YET
C   ANOTHER PANDORA MEMBER, OF WHICH THE FIRST LINE IS:
C
C   //SOURCES DD *
C
C   FOLLOWED BY LINES OF SOURCE NAMES AND POSITIONS IN THE SAME FORMAT
C   AS FOR SOURCE CARDS.  TO SUBMIT THIS JOB, TYPE
C
C   SUB <NAME JCL MEMBER> <NAME SYSIN MEMBER> <NAME SOURCES MEMBER>
C
C   YOUR LOOKUP FILE WILL BE THE FIRST ONE SEARCHED, BUT IF A SOURCE
C   IS NOT FOUND THERE, THE SEARCH WILL CONTINUE ON TO THE SUPPLIED
C   LOOKUP FILE.  SCANNING STOPS WHEN A MATCH IS FOUND, SO IF A SOURCE
C   COULD BE FOUND ON BOTH YOUR LOOKUP FILE AND THE SUPPLIED LOOKUP
C   FILE, THE PROGRAM WILL ALWAYS TAKE THE INFORMATION FROM YOUR FILE.
C
C
C   INPUT CARDS
C
C     COLUMN       ITEM(S)                                      FORMAT
C
C   1         MEDIAN OBSERVING DATE, OBSERVER NUMBER,
C               DETAILS OF OBSERVING PROCEDURE
C        1            DAY                                          I5
C        6            MONTH                                        I5
C       11            YEAR                                         I5
C       16            OBSERVER NUMBER                              I5
C       21            POSITIONING CODE (ONLY 8 OR 18)              I5
C       26            NUMBER OF OFFS ON EACH SIDE OF ON            I5
C
C   2         COEFFICIENTS OF RA POINTING CURVE:
C               DRA = M + N*TAN( DEC ) + C/COS( DEC )
C               (SEE TABLE 8-1 IN THE 300-FOOT MANUAL)
C        1            M                                          F10.5
C       11            N                                          F10.5
C       21            C                                          F10.5
C
C   3         SOURCE CARDS
C        1            SOURCE NAME                                A8,A2
C       11            RIGHT ASCENSION (1950.0)                   R14.4 *
C       25            DECLINATION (1950.0)                       S14.4 *
C       39            IREAD; FLAG TO SCAN LOOKUP FILE FOR         I2
C                       COORDINATES IF IREAD.NE.ZERO
C       41            SCAN LENGTH IN SECONDS                     F7.1
C                       SHOULD BE A MULTIPLE OF 20 SECONDS
C
C   * FORMAT FOR R14.4 IS SHH MM SS.SSSS
C     FORMAT FOR S14.4 IS SDD MM SS.SSSS
C
C
C      SUBROUTINES USED
C         COREAD
C         DJL
C         DMAP
C
```

```
//PLAN300 JCB (532,300),GBCPER,MSGLEVEL=(0,0),CLASS=C
/*ROUTE  PRINT REMCTE1
// EXEC FCRTGCL,ERRCR=E,PARM.FCRT='IC'
//*FORT.SYSPRINT CD CUMMY
//FORT.SYSIN CD *
C
C  PLAN300                 VERSION 2.0          27 JULY 1982
C
C      PURPCSE
C
C         PLAN300  ASSISTS IN OPTIMIZING A 300-FOOT CBSERVING
C         PROGRAM BY CCMPUTING FOR EACH OBSERVATION WHICH AMONG THE
C         NEXT TEN CBSERVATIONS WOULD ALLOW SUFFICIENT SLEW AND SETUP
C         (10 SEC) TIME.  THE RESULT IS EXPRESSED AS A POSITIVE CR
C         NEGATIVE 'ICLE TIME'.  PREP300, POINT300, AND LINE300 CARDS
C         MAY BE USEC AS INPUT, AS WELL AS CARCS PUNCHEC BY HAND.
C         CARDS CTHER THAN SOURCE CARDS WILL BE IGNORED, SO YOU NEED
C         NCT REMCVE THEM FRCM YOUR DECK.
C
C         THEREAFTER THE PRCGRAM SCHEDULES THE ENTIRE SET OF OBSERVATION
C         BY SELECTING THE NEXT POSSIBLE SOURCE IN EVERY CASE.
C
C         PLAN300 CCES NCT MAKE ANY ALLCWANCE FOR PRECESSION, ETC.
C         IF MOCES 13 ANC 18 ARE USED, BOTH PRECESSION AND POINTING
C         CCRRECTIONS CAN SCREW THINGS UP.
C
C         TC RUN THE PRCGRAM PUNCH THESE CARDS WHICH PROCEED YOUR
C         OBSERVING DECK:
C
C         //PLAN300 JCB (<USER#>,300),<YOURNAME>,CLASS=Q,MSGLEVEL=(2,0)
C         /*ROUTE  PRINT REMOTE1
C         // EXEC PLAN300
C         //SYSIN CD *
C
C         TAKE NOTE CF THE TWO SPACES AFTER 'ROUTE' CN THE SECOND CARC,
C         WHICH SENDS THE OUTPUT TO GREEN BANK.  ALSC, PUNCH AN END-OF-
C         FILE CARC TO FCLLCW YOUR CBSERVING DECK:
C
C         /*EOF
C
C         SUBMIT THE RESULTING DECK VIA A REMOTE CARD READER.
C
C      CAPACITY
C      UP TC 2000 CBSERVING CARDS
C
       IMPLICIT REAL*8 (A-H,O-Z), INTEGER*4 (I-N)
       LOGICAL*1 DONE(2010)/2010*.FALSE./
       INTEGER*2 POSCOD,KOUNT(10)/0,1,2,3,4,5,6,7,8,9/,
     *           RNUM(10)/'0','1','2','3','4','5','6','7','8','9'/,
     *           PLOT(71)/71*' '/,ISEC(10),ID(2010)/2010*0/,
     *           CARC(80),BLANK/'  '/
       INTEGER*4 ICAY2S/86400/
       REAL*4    SOURCE(2010,3),TSTART(2010),TSTOP(2010),
     *           SIX/6.0/,SETUP/10.0/,SM(2010)/2010*0.0/
       REAL*8    DEC(2010),DEC8,DAY2S/86400.0D0/,R2S/13750.98708/,
     *           R2D/57.2957795100/
C
C      SET UP THE NUMBERING SYSTEM
```

APPENDIX D

EXPECTED PERFORMANCE OF THE 300-1000 MHz RECEIVER ON THE 300 FOOT TRAVELLING FEED

EXPECTED PERFORMANCE OF THE 300-1000 MHz RECEIVER ON THE 300-FOOT TRAVELING FEED

General

Users should be aware of the expected changes in beam shape and reduced gain caused by the lateral displacement of the feed during normal operation of the tracking mechanism. As the feed is moved off axis, the beam is scanned in the opposite direction. The ratio of the angle of the beam to the angle of the feed measured from the vertex of the antenna is the beam deviation factor. As the beam is scanned, the gain is reduced and the beam is broadened on the side away from the antenna axis. Also, the side lobe level on the axis side of the main beam increases in amplitude.

Beam Deviation Factor

The beam deviation factor is dependent upon the f/D ratio for the antenna, the the edge illumination provided by the feed, and the displacement off axis [1]. The 300-1000 MHz receiver feeds provide 12 to 15 dB edge illumination. On the 300-foot the computed beam deviation factor varies from .847 at one foot displacement to .850 at eleven feet displacement.

Tracking Range

With the cooled 300-1000 MHz receiver installed, the traveling carriage range is restricted to plus or minus eleven feet. The feeds are offset 34 inches on either side of the center of the carriage. With a beam deviation factor of .85, the beam angle is 1.89 minutes per inch of travel. The maximum displacement of the feed that is on the side of the box away from the antenna axis would be 132 + 34 or 166 inches. This should scan the beam 314 minutes in one direction. The feed on the side of the box toward the antenna axis would have a beam shift of 185 minutes.

The number of half-power beamwidths corresponding to these angular shifts in the beam are tabulated below for 300 and 1000 MHz.

Frequency	Half Power Beamwidth	Beam Angles	
		314 Minutes	185 Minutes
300 MHz	46.0 minutes	6.8 HPBW	4.0 HPBW
1000 MHz	13.8 minutes	22.8 HPBW	13.4 HPBW

Beam Gain Reduction and Sidelobe Level

The predicted gain reduction is 2 dB at a 6 HPBW beam angle [2]. This value is based on the movement of the feed along a maximum gain curve which requires increasing the focal distance at larger scan angles. Since the traveling feed movement is restricted to the focal plane, a somewhat larger gain reduction may occur at 6 HPBW. In fact, measurements made with the old tracking feed show 3 dB gain reduction at 6 HPBW.

The sidelobe level (coma lobe) is expected to be only 10 dB below the main beam angles of 4 HPBW [3]. If the usable scanning range is determined to be 4 HPBW, then the tracking range should be limited to:

$$\text{4 HPBW Tracking Range} = \pm 29.1/f_{GHz} \text{ inches} + (\mp 34'' \text{ feed offset})$$

$$= -63 \text{ to } +131 \text{ inches at } 300 \text{ MHz}$$

$$+5 \text{ to } +63 \text{ inches at } 1 \text{ GHz}.$$

Depolarization Effects

Studies of off-axis-fed paraboloids indicate an increase in the cross-polarization for linearly polarized antennas and beam separation for circularly polarized antennas which increase with offset angle [4]. The maximum traveling feed angular offset of about five degrees may cause some degradation of the polarization properties of the 300-foot antenna feed system.

References

[1] Y. L. Lo, "On the Beam Deviation Factor of a Parabolic Reflector." In: Reflector Antennas, edited by A. W. Love, pp. 252-254 (IEEE Press, 1978).

[2] W. V. T. Rusch and A. G. Ludwig, "Determination of the Maximum Scan-Gain Contours of a Beam-Scanning Paraboloid and Their Relation to the Petzval Surface." In: Reflector Antennas, editec by A. W. Love, pp. 268-274 (IEEE Press, 1978).

[3] J. Ruze, "Lateral-Feed Displacement in a Paraboloid." In: Reflector Antennas, edited by A. W. Love, pp. 255-260 (IEEE Press, 1978).

[4] T. Chu and R. H. Turrin, "Depolarization Properties of Offset Reflector Antennas." In: Reflector Antennas, edited by A. W. Love, pp. 212-218 (IEEE Press, 1978).

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3-27-81