NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO
VERY LARGE ARRAY

VLA OBSERVATIONAL STATUS REPORT
March 15, 1987

This report summarizes the current observational parameters of the VLA. It contains the essential information needed to prepare an observing program with the VLA. More technical information is also available from the following general books and publications:

a) Course notes from the NRAO Summer School on "Synthesis Imaging" (August 5-9, 1985) are now available and may be purchased from C. Ziegler at NRAO/Green Bank or A. Patrick at NRAO/VLA. The cost is $10.00 per copy.

b) An Introduction to the NRAO, Very Large Array (Green Book - available from A. Patrick, VLA). Sections on computers are out of date.

c) The Very Large Array: Design and Performance of a Modern Synthesis Radio Telescope, Napier, P.J., Thompson, A.R., and Ekers, R.D., Proc. IEEE, 71, 1295, 1983 (available from A. Patrick, VLA).

d) Other specific manuals and documentation available at the VLA are listed in Section 5.0.

1.0 HARDWARE CONFIGURATIONS

Continuum, polarization and spectral line observations are supported at the six separate wavelengths 1.3 cm, 2 cm, 3.6 cm, 6 cm, 18-20 cm and 90 cm. There are currently 15 antennas outfitted with 90 cm and an additional antenna will be outfitted every 2 months (see Table IV(a)). 90 cm can be tuned in one IF pair and 20, 6, 2 or 1.3 cm can be tuned separately and simultaneously in the other IF pair. At the moment we only support the 20/90 cm calibrations principally because the focus and pointing at the other bands is significantly different from 20 and 90 cm. There are currently 6 antennas outfitted with 3.6 cm. Observations at seven different bandwidths (50 MHz/2^n, where n = 0,1,2...6) are possible in each of the two separate IF pairs. It is possible to have separate bandwidths on the different IFs. These pairs are separately tuneable within a 500 MHz band. Pairs of orthogonal, circularly polarized feeds are used at all bands.

The array is cycled through its four main configurations (A,B,C, D) during a 15 month period. The reconfiguration schedule for the next year, and the approximate long-term schedule are outlined in Table IV. Updates to this table are published in the NRAO and AAS Newsletters.

2.0 OBSERVATIONAL LIMITATIONS

Tables I and V summarize the sensitivity and resolution of the VLA. Note that the sensitivities in Table I and Section 2.1 refer to the naturally weighted data (maximum sensitivity), whereas the resolutions quoted in Table V refer to uniformly weighted data (maximum resolution).

2.1 Sensitivities

The sensitivity parameters listed in Table I are based on theoretical estimates, using the quoted system temperature and are for the most part confirmed from observations. The rms system noise can be calculated approximately using the formulae (for natural weighting):

$$\Delta S_{rms} \simeq \frac{a}{\sqrt{n(n-1)\, h\, i\, \Delta f}} \text{ mJy / beam area}$$

where:

- n = number of antennas
- h = integration time on source, in hours
- Δf = bandwidth in MHz
- i = number of IF pairs
- a $\simeq$ 37, 14, 9, 6, 25, 91 for bands 90, 20, 6, 3.6, 2, 1.3 cm
  $\sim 0.3\, T_{sys}$ (T_{sys} = system temperature)

Use of uniform weighting will decrease the sensitivity by a factor of 1.5 - 2.5 depending on the image size.

The brightness temperature (for the uniformaly weighted case) is given by approximately

$$T_b \sim FS \,^\circ K$$

where S is flux density in mJy and F = 298, 33, 3.7, .30 for configurations A, B, C, D respectively. The F values depend on u,v coverage and source structure and should be used with caution.

A more detailed description of noise formulae, including uniform weighting and tapering, is given in Chapter 6 of the second "Synthesis Imaging" workshop.

The sensitivity degrades near the band edges. Dynamic range, interference and confusion (particularly at 20 and 90 cm) may prevent one from reaching the sensitivity limits quoted in Table I.

There are currently two antennae with improved 1.3 cm receivers (about a factor of 3 improvement). There will be an attempt to outfit one additional antenna per month until all antennas have been retrofitted with new 1.3 cm receivers.

2.2 Large Scale Structures

Imaging of large sources is restricted by the smallest spacings of the array. Table V indicates approximately the largest scale structure "visible" to the VLA at the five standard bands and the four standard configurations. Sources with extended regions larger than these limits will be missing major fractions of flux density and images may seriously misrepresent the large-scale structures. See Chapter 8 of the notes on the

"Synthesis Imaging" workshop held at Socorro, NM for more details.

2.3 Dynamic Range

The dynamic range, which is the ratio of the maximum image brightness to the minimum believable image brightness (defined as the rms in the blank part of the image), is limited mainly by atmospheric and ionospheric phase stability. Many of the synthesized images generated from VLA observations are limited by dynamic range (typically 100:1) and not by noise (Table I). Self-calibration can improve the dynamic ranges up to 10000:1, depending strongly upon source structure, u,v coverage, signal-to-noise levels and data quality. Self-calibration of VLA data is done within the AIPS image processing system. To obtain the highest dymanic range it may be necessary to use closure corrections. See Section 2.5 of the 15OCT85 edition of the AIPS Cookbook for advice on using the self-calibration software. See Chapter 9 of the notes from the Second Synthesis Imaging Workshop for details of the principles of self-calibration.

If spectral line dynamic range is defined as the weakest believable line to continuum ratio, then the spectral line dynamic range achievable will depend on bandwidth. Applying the on-line autocorrelation can result in a 20:1 dynamic range. Better than 1000:1 is possible when proper bandpass calibration is used.

2.4 Pointing

Large daytime antenna pointing errors of 1 arcminute or more occur occasionally when the sun shines upon the yoke and pedestal under calm conditions (dawn to dusk period). At 2 cm this could affect the sensitivity by as much as 30 percent.

Installation of antenna thermal insulation is in progress and will be completed by mid-1987. This will significantly reduce the large pointing errors on calm days. The rms pointing error is 15 arc seconds for all antennas during the night and for all insulated antennas during the day. Degradation in sensitivity is only about 10 percent at 2 cm for insulated antennas. Consult the on-duty operator for a list of insulated antennas. Pointing errors due to wind continue to be a problem. Noticeable degradation at high frequencies occurs at wind velocities above three meters per second (7 mph).

Observations within 1.5 degrees of the zenith should be avoided due to both pointing errors and hardware limits. Observations with antennas 8 and 12 at 90 cm within about 9 degrees of zenith should also be avoided because of large offsets in their feeds.

2.5 Interference

The bands within the frequency range of the VLA that are allocated exclusively to radio astronomy are the following: 1400-1427 MHz, 4990-5000 MHz, 15.35-15.4 GHz, and 23.6-24.0 GHz. There should be no interference within these bands. Some interference (White Sands radar, meteorological balloons, airborne drones, Russian satellites which broadcast at 1600 to 1620 MHz, etc.) can be expected outside of these bands, particularly at 20 cm (1340-1730 MHz). The results of an interference study in the 20 cm band from 1350 to 1730 MHz are available in VLA Test Memorandum No. 139. In summary:

(1) There are birdies every 50 MHz at frequencies of 1300+ n50 (n=1,...) MHz over the whole tuneable range. These are of moderate strength, could interfere with narrow-band continuum observations, and they should be avoided. It is most important to avoid the 1600 MHz birdie as it is exceptionally strong.

(2) Strong signals which are always present are listed in VLA Test Memorandum No. 139. Plots showing interference history in the 20 cm band are available in the VLA Control Room.

(3) Located within the range 1670 to 1700 MHz are the frequencies used by meteorologists to receive weather data from balloons. These are released from nearby South Baldy during thunderstorm season. Thus, one is "probably" safe during the winter and spring in this frequency range -- but summer observations, especially in the daytime, are likely to be affected.

(4) The band from 1610 MHz to 1660 MHz formerly devoid of any measurable interference, is now quite unsuitable for broadband observations. In particular, the frequencies between 1603 and 1620.2 MHz now commonly harbor very strong interference. Between 1620.2 and 1669.2 MHz, the band remains rather good for continuum observations.

Two standard bands have been set up at 20 cm to help avoid interference. The HH code places the observing frequency within the protected band and should be used with observing bandwidths of 25 MHz or less. The LL code should be used with 50 MHz bandwidths.

2.6 Bandwidth and Time Averaging Smearing

A. Effects Due to Bandwidth

Observing with a finite bandwidth causes a radial smearing of the image which increases with separation from the phase center. There is a corresponding reduction in the peak response and hence point source sensitivity.

The distance dependence of the effect scales inversely with bandwidth. The loss in gain is tabulated in Table II(a) for an untapered observation at 50 MHz. $\Delta\nu/\nu$ is the ratio of the bandwidth to the observing frequency and $\chi/\chi_{\frac{1}{2}}$ is the ratio of the radial distance from the phase center to the FWHP of the synthesized beam.

The increase in the beamwidth in the radial direction is proportional to the loss in peak intensity (i.e., radial beamwidth is approximately equal to FWHP [Table V] divided by the loss in sensitivity [Table II(a)]). The integrated flux density remains constant with a modest amount of smearing.

A more detailed discussion of this effect is found in the Green Book (An Introduction to the NRAO Very Large Array) and in Chapter 2 of the notes on the second "Synthesis Imaging" workshop.

B. Effects Due to Time Averaging

Time averaging over intervals for which the visibility changes significantly causes loss of amplitude similar to that due to the bandwidth effect. However, the analysis of the time effects is more complicated. A simple case exists for the North Pole, where the losses are equivalent to bandwidth losses except that the smearing is in the azimuthal, rather than the radial direction. A guideline for keeping time averaging losses small in broadband continuum observations is to keep them less than the corresponding bandwidth losses. Table II(b) gives the averaging times for which, at $\delta = 90^{\circ}$, time averaging losses equal bandwidth losses.

2.7 Confusion

As indicated in Table I, the presence of sources in the primary antenna beam, but outside the useful or practical imaging area, can limit image quality. These sources produce unwanted sidelobes in the images and can lead to aliasing problems. Although bandwidth and time smearing in the larger configurations will suppress some of the effects from confusing sources in the primary beam, they are a major concern especially at 20 and 90 cm and for observations near the galactic plane using the compact arrays. The brightest source expected in the primary antenna beam pointing away from the galactic plane is listed in Table I for each of the observing bands.

2.8 Strong Source Interference

The presence of very strong sources in the sky may lead to interference problems. For example, the sun is such a strong source that the far sidelobes of the antenna are not able to suppress its signal entirely. For broad continuum bandwidths the correlated signal from the sun is bandwidth smeared down to negligibly low levels. However, this is not true for the narrow bandwidth spectral-line observations of weak sources in the more compact configuration during the daytime which may be degraded even when the sun is far away from the source. The problems are especially severe at 90 cm, where observations of weak sources within several degrees of Cyg A, Cas A, Tau A, and Virgo A are also not possible.

2.9 Positions

The absolute positional accuracy obtained is generally about 0.1 arcsec in the A array (at 20 cm and 90 cm wavelengths, careful correction for ionospheric effects are necessary to attain this accuracy). The main limitations are the phase errors caused by the ionosphere and the troposphere. Positional accuracy of 0.03 arcseconds can be obtained in good weather by using only the class B calibrators and checking antenna baseline parameters. Position errors in declination are about a factor of 2 worse for sources at -20 degrees declination and will deteriorate at more southern declinations.

The VLA supports the J2000 epoch ephemeris, preferred for accurate astrometric work, as well as the 1950.0 epoch.

2.10 Flux Density Scale

The VLA staff has compiled a list of sources which are sufficiently unresolved and unconfused to permit gain calibration at all bands to a few percent. This list currently contains about 400 sources and it is readily available at the VLA site. Although the primary flux density calibrator is 3C286, 3C48 is also used. 3C48 is known to be variable. In January 1986 the observed flux density of 3C48 at 330, 1465, 4885 and 14905 MHz was 43.1±1, 15.76±.05, 5.59±.05 and 1.95±.05 Jy respectively (using 3C286 as the standard and adopting 26.85, 14.51, 7.41 and 3.45 Jy respectively). Our previously adopted (from Baars et al) values for 3C48 were 44.51, 15.37, 5.36 and 1.72 respectively.

The flux density of 3C48 and 3C147, measured at 22485 MHz in December 1985, were found to be 1.28(±.01) and 1.83(±.01) respectively. These values are 16 and 9 percent, respectively, higher than the extrapolation of Baar's scale to 22485 MHz when compared to 3C286.

2.11 Polarization

Circular polarization measurements are limited by large circularly polarized sidelobes and are restricted to sources with very large degrees (>10%) of circular polarization or to point sources located at the center of the primary beam. This limitation is due to the offset of the two oppositely polarized beams.

Linear polarization observations are possible at all bands. The on-axis instrumental polarization can usually be determined to an accuracy of much better than 0.5 percent at 6 and 20 cm. At 2 and 1.3 cm the accuracies are usually about a factor of 2 worse. The limit of this accuracy is partly a result of pointing errors. Imaging the polarization of sources more than 10 percent of the half-power beam width away from the beam center at 6 cm may be subject to uncertainties greater than one percent because of the large, linearly polarized sidelobes. This limitation is also present at the other bands; the location of the polarized sidelobes scales with wavelength.

Polarization observations in the 20 cm band and in the 90 cm band are always hampered by ionospheric Faraday rotation. The amount of Faraday rotation has been occasionally larger than 35 degrees at 20 cm and will probably continue to be a factor in observations at 20 cm even during the minimum of the solar cycle. Ionospheric Faraday rotation will always be a problem at 90 cm. More information can be obtained from the Linear Polarization Measurements document in the VLA COOKBOOK and a general discussion is available in the "Synthesis Imaging--Course Notes from an NRAO Summer School Held in Socorro, New Mexico August 5-9, 1985".

In general the instrumental polarization can be calculated from observations of the calibrator normally used to obtain the amplitude and phase of the instrument, provided that there are enough observations to ensure both a high signal-to-noise ratio in the cross hands and reasonable change in parallactic angle ($\gtrsim 90^{\circ}$). Absolute position angles are determined by observing a strong, linearily polarized source whose polarization is known. The two main calibrators used are 1328+307 (3C286) and 0518+165 (3C138).

2.12 Spectral-Line Capabilities

Spectral-line observations are currently supported in only a single polarization mode (right or left circular polarization). The permitted number of baseline channels is currently 10240. The system temperature correction is applied on-line.

In general, a channel-to-channel stability of about 30:1 can be achieved easily, but achieving 100:1 at wide bandwidths is very hard. Stabilities better than 100:1 require special treatment and cannot be guaranteed (discussed in greater detail in Chapter 12 of the "Synthesis Imaging--Course Notes from an NRAO Summer School Held in Socorro, New Mexico August 5-9, 1985".

The basic combination of bandwidth channels and antennas are listed in Table III. Further trade offs between the number of channels and antennas by bandwidth are possible. See "A Short Guide for VLA Spectral Line Observers" or the course notes from the NRAO Summer Workshop on "Synthesis Imaging", or the Green Book for more information.

UVFITS tapes may now be written on SORTER or from the DEC-10. Use of the DEC-10 version for the spectral-line data is more convenient than the SORTER version because of the 8 channel grouping limitations on SORTER, especially when dealing with large data bases. However UVFITS on the DEC-10 is very slow and should be avoided if possible. These make it possible to use the full 3-D structure in AIPS.

For spectral line mapping where self-calibration is not needed we encourage the use of the PIPELINE (GRIDER). Mapping is quite fast and there is no need for uv data to be written to tape. The data can be looked at using the PIPELINE display system on OUTBAX including the Image Storage Unit.

Spectral-line observations at 1.3 cm will be limited to the practical range over which the receiver may be tuned (see Figure 1 at the end of this report).

2.13 VLBI Observations

VLBI observations using the VLA and the Mark II or Mark III backend are possible either using phased array mode or a single antenna. There is one antenna (23) which has a HEMT amplifier at 22 GHz in the CD side (system temperature = 125 K, frequency = 22-24 GHz). There is a VLBI cookbook available (in the COOKBOOK manual). See comments under 3.0 (VLA REMOTE OBSERVING PROGRAM) for the support available for in-absentia VLBI observing.

2.14 Snapshop Mode

When signal-to-noise is not critical, and a source is not very extended, adequate observations of small sources can be made in short periods of time.

Single snapshots with good phase stability should give dynamic ranges of about 50 to 1 for sources whose angular size does not exceed the numbers listed in Table V for "Largest Scale Structure Visible". Snapshots do not give as good protection against the sidelobes of distant confusing sources as full imaging. This is especially true at 20 cm in the C and D arrays. A single snapshot at 20 cm will give an rms noise of 1 mJy due to confusing sidelobes. This level can be reduced either by making multiple snapshots, with at least 1 hour separating the observations, or by imaging and cleaning the entire beam with the AIPS program MX, or by doing both.

2.15 Shadowing

Observations at low elevations taken in the C and D arrays may be affected by antenna shadowing (see VLA Scientific Memorandum No. 134). The OBSERV program will indicate when shadowing will occur and on what antennas. After the observations, the program SHADOW or GTBCOR (with FLAGER) can be used to find out what antennas have been shadowed and to flag shadowed antennas. There are no automatic on-line shadowing corrections applied to the data. Observations using a hybrid array with a longer north arm (see Section 6.0) will be preferable for sources with declinations $<-15^{o}$.

2.16 Combining Configurations

It is useful to combine data from different configurations when there is a large range of structure scales in the source. This can be done by using software in AIPS. Because of software limitations it is preferable to use the same position, bandwidth and averaging time for such observations.

2.17 Weak Source Detections

DC offsets in the correlators may occasionally lead to artifacts in the center of the field. It is advisable to offset the source positions from the field center in weak source detection experiments.

2.18 Imaging Large Objects

Imaging of objects larger than a VLA primary beam is now possible using AIPS software developed by Tim Cornwell and Robert Braun. To image a large object one must obtain the VLA observations at a number of pointing centers spanning the object, and optionally, single dish observations of the same object, spanning the same region.

For further details and advice, those interested should contact either Tim Cornwell or Robert Braun.

2.19 Use of a Supercomputer for VLA Data Reduction

Projects requiring very large amounts of computer time for data reduction may be eligible for processing on a supercomputer under the NRAO supercomputer access program. Typical suitable problems are deconvolutions of large images (2048 to 4096 pixels on a side), repetitive processing of a large number of objects, as in a survey, or spectral line processing of many channels. Those interested should contact either Ed Fomalont in Charlottesville or Ron Ekers at the VLA.

3.0 VLA REMOTE OBSERVING

3.1 Observing File Preparation

The observing file can be prepared for standard VLA observing programs. The observer is required to specify the detailed source list, sequences and observing options at least two weeks in advance. The observing files for any complicated programs generally must be completed by the observer himself. In particular, the observer must take responsibility for setting frequencies for line programs. The preparation of VLBI observing files is the responsibility of the observer. If the VLBI observer is unable to prepare his source file he should contact Ina Cole at least two weeks before the start of the Network run.

3.2 Absentee Observing

Observers may be absent during the observations provided that advance notice (at least two weeks) has been given. For standard VLA continuum or spectral-line programs and all standard Mark II VLBI programs which need very little operator interaction, the observer is generally not required to be present at the VLA site. However, for any complicated or unusual Mark II or III VLBI programs the presence of an observer on-site may be required.

3.3 Editing and Calibration of VLA Data and Related Tasks

(a) Any standard VLA continuum observing program can be edited and calibrated. Complicated calibration of continuum data or calibration of spectral-line data may be possible but must be checked out well in advance.

(b) Calibrated visibility tapes (Export or UVFITS tapes), backup tapes and copies of archive tapes can be prepared.

(c) In general, images will not be produced.

3.4 DEC-10 Dial-Up Line

The DEC-10 has four dial-up lines which may be used for preparing observing files or the calibration of a DEC-10 database. One telephone number, (505) 772-4346, will access all lines. Modem protocols allowed include Bell 103j (300 baud), Bell 212A (1200 baud) and Racal-Vadic (1200 baud). Eight bits and no parity are the usual settings.

All requests for remote calibration MUST be made through the Data Analysts (see Section 3.6(b) below) at least 10 days in advance in order to obtain disk space. Data will be filled on a first-come, first-served basis. In general, a five day limit will be imposed on disk space usage for a given project.

NRAO will pay for the call. Dial (505) 772-4011 and request to be called back on FTS and transferred to the computer (DEC-10).

3.5 On-Site Help

The Data Analysts who normally carry out the tasks listed under 3.1 and 3.2 will be available on weekdays to on-site observers for direct assistance in matters related to the remote observing program.

3.6 How to Make Use of Remote Observing Services

(a) Check the appropriate box on the observing cover sheet for your proposal.

(b) Contact either Dave Wunker (505-772-4359) or Peggy Perley (505-772-4239) or Ina Cole (505-772-4414) and pass on the details well in advance (>2 weeks). The advance notice is required to enable us to schedule all the requests efficiently.

(c) For VLBI observations, contact Ina Cole at least 2 weeks before the start of the VLBI Network session. Complicated observing files must be prepared by the observer.

4.0 SOFTWARE

The current on-site VLA software capabilities for converting raw visibility data into well-calibrated images are best summarized by briefly listing the various tasks presently implemented at the different stages of data processing. No attempt is made to list the complete set of either the software options or its limitations.

The on-line computers, the Modcomps, automatically (a) change the LO phase to compensate for differential atmospheric refraction; and (b) correct the visibility phases for variations in the effective electrical length of the waveguide and some of the antenna LO paths. (This latter correction is often termed the "round-trip phase correction"). In addition, gain variations caused by changes in the system temperature are corrected by using real-time measured system temperatures. (This correction is applied to both continuum and spectral line data.) The latter correction may be turned on or off at the astronomer's option and by default is turned on at all bands. The current on-line system (both hardware and software) will be upgraded to include new hardware (ModComp Classics) and new control system software in the fall of 1987.

Processing required to take the initially corrected visibility data from the Modcomps through calibration is accomplished using the DEC-10 general-purpose computer. The software is quite extensive and employs an antenna-based calibration technique. For the calibration of data, there exist programs to (a) flag data good or bad, (b) correct phases for known source position errors, antenna position errors and time errors, and (c) correct amplitudes for general, zenith angle, dependent effects such as atmospheric absorption. The antenna gain, phase and polarization characteristics are calculated from calibrator source observations, interpolated in time, and stored with the visibility data. The data may then be written on an UVFITS or EXPORT tape.

Conversion of calibrated u,v data to images can be done using either PIPELINE or the post-processing system (AIPS) which consists of two VAXs and a CONVEX at the VLA and one VAX and one CONVEX in Charlottesville. On both systems the tasks for conversion of calibrated data to images include sorting, gridding, fast Fourier transform, source subtraction in the u,v plane, and the clean algorithm. Both u,v plane convolution (to aid in reducing the aliasing problems) and tapering are supported. Self-calibration is only available on AIPS.

The PIPELINE system handles a large volume of data efficiently and, in particular, accommodates a substantial increase in spectral-line processing. SORTER can write UVFITS tapes that can be read on the VAX for transfer of visibility data (continuum or spectral-line). Images made in the PIPELINE can be displayed on OUTBAX (VAX 11/750) after transfer to that system.

Image display formats include: character display on computer terminals, line printer output (DEC-10), Versatec (VAX) and Laser printer (VAXes and CONVEX); contours with or without polarization on the Tektronix storage tube terminal (DEC-10), ZETA pen plotter (VAX), the QMS laser printer (on the VAX and CONVEX), and the Versatec dot matrix plotter (DEC-10 and VAX); gray scale and color images in two dimensions (2-D) on the IIS video terminal (VAX and CONVEX); and Dicomed film recorder. The image storage unit attached to OUTBAX allows the storage of multiple images and replay of these images in a "movie" mode. This is most used for spectral line observations.

The AIPS post-processing system includes options to edit and display u,v data, to make and deconvolve images using a variety of algorithms including CLEAN and MEM, self-calibration, display 2-D images on a TV monitor, contour images on the Versatec printer and QMS laser printers, source fitting, polarization, optical depth, etc. Input is images (FITS) or u,v data (EXPVIS or UVFITS). Spectral-line capabilities are available. This system is currently running on the two VAX 11/780s, one VAX 11/750 and one CONVEX at the VLA and on a VAX 11/780 and a CONVEX in Charlottesville. Visibility data can be displayed in baseline time format on OUTBAX using the PIPELINE. Spectral line data may be processed on OUTBAX using GIPSEY. One AIPS system at the VLA has dismountable disk packs for temporary use by observers. These packs are available from Computer Operations Group.

All computers support image data exchange using the FITS and UVFITS format.

One return visit to Charlottesville or the VLA for further VLA reduction is supported by NRAO. Contact Jim Condon in Charlottesville (804-296-0322) or Carl Bignell at the VLA (505-772-4242).

5.0 DOCUMENTATION

Documentation for VLA data reduction, image making, observing preparation, etc., can be found in various manuals. Some, but not all, of these manuals can be mailed out. Manuals which can be mailed are marked with an asterisk (*). Direct your requests to A. Patrick at the VLA.

*INTRODUCTION TO THE NRAO VERY LARGE ARRAY (Green Book): This manual has general introductory information on the VLA. Topics include theory of interferometry, hardware descriptions, observing preparation, data reduction, image making and display. Parts of the 1983 manual are now out of date.

*NRAO-VLA WORKSHOP: Synthesis theory and technical information and observing strategies can be found in: "Synthesis Imaging -- Course Notes from an NRAO Summer School Held in Socorro, New Mexico" (August 5-9, 1985). There is a $10.00 charge for this manual and it must be ordered on a payment accompanying order basis. Contact either A. Patrick at the VLA or C. Ziegler, NRAO-GB, P. O. Box 2, Green Bank, WV 24944.

THE OBSERVERS REFERENCE MANUAL: This is a reference manual which contains all the information on individual computer programs and utilities run from the DEC-10. There is a separate volume for the PIPELINE system (ORM Vol. II). This manual is available for use on-site only.

VLA COOKBOOK: The Cookbook contains some observing stratagies and recipes on the initial data reduction of continuum, polarization, spectral line, solar observations, and guides to self-calibration. This manual is available on-site only.

*A SHORT GUIDE FOR VLA SPECTRAL-LINE OBSERVERS: This is an important document for those wishing to carry out spectral-line observations at the VLA. This guide can also be found in the VLA Cookbook.

*AIPS COOKBOOK: The "Cookbook" description for the AIPS image processing system can be found in the AIPS terminal room in the VAX building. You may obtain your own copy from A. Patrick at the VLA, or by writing to Nancy Weiner at NRAO, Edgemont Road, Charlottesville. The latest version, for the 15OCT86 release of AIPS, has expanded descriptions of imaging, cleaning, self-calibration, spectral line reduction, VLBI reductions and a new section for CONVEX users. The AIPS COOKBOOK is now produced in a ring binder format for greater ease of updating. Custom binders are available from A. Patrick at the VLA or N. Wiener in Charlottesville for $5.00.

*GOING AIPS: This is a two-volume programmers manual for those wishing to write programs to interface with AIPS.

VLA CALIBRATOR BOOK: This manual contains the list of VLA Calibrators in both 1950 and J2000 epoch and a discussion of gain and phase calibration. This is available on-site only. There exists an IBM PC computer program which can be used to search the calibrator list. The program and data files can be ordered from A. Patrick at the VLA.

*GUIDE TO VLBI AT THE VLA: This manual describes VLBI observing procedures and requirements when the VLA is one of the NUG stations.

PIPELINE REFERENCE AND USER'S MANUAL (OBSERVER'S REFERENCE MANUAL VOL.II): The detailed descriptions of, and "how to use", the PIPELINE system is described in this manual. The USER'S MANUAL part may be requested separately.

*A STEP BY STEP GUIDE TO VLA DATA CALIBRATION: This is a guide (found in the VLA COOKBOOK) to facilitate calibration of visibility data on the DEC-10. Familiarity with the DEC-10 programs is assumed.

The Very Large Array: Design and Performance of a Modern Synthesis Radio Telescope, Napier, Thompson, and Ekers, Proc. of IEEE, 71, 295, 1983.

6.0 VLA OBSERVING REQUESTS

Observing requests should be sent to the NRAO Director:

Dr. Paul A. Vanden Bout
Director
NRAO
Edgemont Road
Charlottesville, VA 22903-2475

Requests should be concise (less than 1000 words) and emphasize the scientific justification. Sufficient thought should be given to instrumental capabilities to enable filling out the attached observing application form, which should be submitted with the proposal.

Closing dates for receipt of observing requests are listed in Table IV. Prospective users are advised to submit their proposals well in advance of the change to the required configuration and certainly no later than the appropriate deadlines listed in the Table. Proposals submitted requiring a specific configuration other than the one for the next quarter will be refereed but final evaluation and scheduling will not occur until the appropriate quarter.

The basic reconfiguration cycle is spread over one and a quarter years in order to slide the sidereal times available at night through each configuration. The proposed long-term schedule is given in Table IV(b), but it may be subject to changes.

The duration of each configuration will be varied in response to proposal pressure. We will support observations during the reconfiguration. Suitable observations are point-source monitoring and detection programs for which the configuration is not critical. During reconfiguration we will pause in the hybrid configuration with the north arm in the next larger configuration. For declinations $<-15^{\circ}$ the longer north arm hybrid gives a more circular beam and reduces shadowing.

Configurations and proposal deadlines for 1987/88 are listed in Table IV(a).

VLA observers are also urged to arrange their travel as soon as possible after scheduling and no later than two weeks before you are scheduled to arrive at the site. Both rooms and vehicle reservations (Albuquerque to VLA site) can be made by dialing (505) 772-4357, or FTS 476-8357.

7.0 VLA ARCHIVE DATA

A directory of the VLA archive data back to September, 1981 is available in six reports, covering the six years 1981 (09/81-12/81), 1982, 1983, 1984, 1985 and 1986. There is also available a cumulative report covering all years (09/81-12/86), but only containing observations longer than one hour on source (ACCUM.SRT). Users with access to the VLA DEC-10 can find computer readable versions (1981.SRT[13,542], etc.) of these reports and of all completed quarters in the current year in user area [13,542]. Hardcopy versions are available from A. Patrick and in all NRAO libraries. There is now an IBM PC program that can be used to search the archive source list (it also searches the calibrator list as well). Currently it only handles the ACCUM.SRT file. The data and program are available from A. Patrick.

NRAO has the following policy on the extent to which an observing team has exclusive use of the raw data obtained as part of their VLA observations. This policy is:

> Eighteen months after the end of a VLA observaion the raw (uncalibrated visibility) data will be made available to other users on request. The end of an observation is defined to be after the last VLA configuration requested, either in the original proposal or in a direct extension of the proposal. Data taken for VLBI observations are immediately available.

8.0 PUBLICATION GUIDELINES

Any papers using observational material taken with NRAO instruments (VLA or otherwise) or papers where a significant portion of the work was done at NRAO, should include the following acknowledgement to NRAO and NSF:

> "The National Radio Astronomy Observatory is operated by Associated Universities, Inc., under contract with the National Science Foundation."

Preprints

NRAO requests that you submit four copies of all papers which include observations taken with any NRAO instrument or have NRAO author(s) to Ellen Bouton in the Charlottesville Library. NRAO authors may request that their papers be included in the official NRAO preprint series. Multiple author papers will not be included in the series if they are being distributed by another institution. All preprints for distribution should have a title page that conforms to the window format of the NRAO red preprint covers. Note that preprints will be distributed ONLY when the NRAO author so requests; inclusion in the series is not automatic. This action will also cause the paper to be included in NRAO's publication lists.

Reprints

NRAO no longer purchases reprints from the major astronomical journals for distribution. However, NRAO will purchase and distribute reprints in the following cases:

1. The paper is in a publication less likely to be readily available to other astronomers (i.e., IAU symposia/colloquia, IEEE and SPIE proceedings, commercial journals).
2. The paper is likely to be in great demand (i.e., comprehensive catalogs, detection of ETI, etc.).

In such cases, please send copies of the order forms supplied by the publisher to Ellen Bouton in the Charlottesville Library.

NRAO will also order 50 reprints for the personal use of the NRAO author(s) if reprints are requested at the time of submission of page charge information. Orders at a later date should be avoided in order to minimize administrative hassle. Normally, the first author should be responsible for reprint orders and share reprints as appropriate with collaborators. Do not ask NRAO to order reprints in those cases where reprints will be received from a non-NRAO first author.

TABLE I

VLA SENSITIVITY AND RESOLUTION

Frequency (GHz)	0.3 - 0.35	1.34 - 1.73	4.5 - 5.0	8.0 - 8.8	14.4 - 15.4	22.0 - 24.0
Band Name (approximate wavelength)	90 cm	20 cm	6 cm	3.6 cm	2 cm	1.3 cm
System Temperature (°Kelvins)	125	60	50	30	116	350+
Antenna Effeciency (%)	40	51	65	58	52	43
*RMS Sensitivity (mJy) in 10 minutes (50 MHz bandwidth - 27 antennas)	1.4 (3 MHz bw)	.13	.09	.06	.24	.88
*RMS Sensitivity (mJy) in 12 hours (50 MHz bandwidth - 27 antennas)	0.2 (3 MHz bw)	.016	.010	.007	.028	.10
#*Untapered brightness (mKelvins) temperature (D configuration)	27 (3 MHz bw)	2.1	1.3	0.9	3.7	13.3
**Dynamic Range without Self-Calibration	10-500++	50	70	?	10 - 20?	10?
Antenna Primary Beam Size (FWHP)	156'	30'	9'	5'.4	3'	2'
Brightest Source (mJy) Expected in Antenna Primary Beam after correction for beam.	5 Jy	100	2.3	?	.1	.01

* Table entries are sensitivities for a point source using both parallel hand correlator outputs of one pair of IFs. Sensitivities will be a factor of $\sqrt{2}$ better when B and D IFs are also used. See text for discussion of formula used. Calculations based on natural weighting.

** Extremely dependent on weather and frequency of calibration. C and D arrays give the highest dynamic range.

\+ The ammonia lines are located near the band edge where sensitivities are about a factor of 2 worse. The 1.3 cm receivers will be retrofitted with new FET amplifiers. Two antennas have been outfitted with the others to be completed at a rate of one per month. The sensitivity of the new receivers should be 2 to 4 times better than the present ones.

++ All A, B and C array images may require self-calibration for the ionospheric errors.

\# Calculations base on 12 hours integration with 50 MHz bandwidth.

TABLE III(a)

AVAILABLE BANDWIDTHS AND NUMBER OF FREQUENCY CHANNELS

Normal Mode

BW Code	Bandwidth MHz	Single IF Mode(1) No. Channels(4)	Single IF Mode(1) Freq. Separ. kHz	Two IF Mode(2) No. Channels(4) per IF	Two IF Mode(2) Freq. Separ. kHz	Four IF Mode(3) No. Channels(4) per IF	Four IF Mode(3) Freq. Separ. kHz
0	50	16	3125	8	6250	4	12500
1	25	32	781.25	16	1562.5	8	3125
2	12.5	64	195.313	32	390.625	16	781.25
3	6.25	128	48.828	64	97.656	32	195.313
4	3.125	256	12.207	128	24.414	64	48.828
5	1.5625	512(5)	3.052	256	6.104	128	12.207
6	0.78125	512(5)	1.526	256	3.052	128	6.104
8	0.1953125	256	0.763	128	1.526	64	3.052
9	0.1953125	512(5)	0.381	256	0.763	128	1.526

Notes:

(1) Observing Modes 1A and 1C
(2) Observing Modes 2A and 2C
(3) Observing Modes 4 and 4A
The observing mode determines how the hardware combination of the correlator and the four IFs are to be used to handle the data. It is possible to use the output from one, two or four IFs in such a way as to obtain different combinations of number of frequency channels and channel separation. It should be noted that (a) the practical limitation on the minimum and maximum number of channels is 8 and 256 respectively, (b) the product of the number of frequency channels and baselines is a maximum of 10240 and (c) no polarization measurements are possible.
(4) These are the numbers of frequency channels produced in the AP. Any number of channels that is a power of 2, that is less than or equal to the number in the table (with a maximum of 256; see note (5)), and that is greater than or equal to 8 may be selected using the data selection parameters on the LI card.
(5) Although 512 frequency channels are produced in the AP, only 256 channels may be sent to CORA (this may change with the new on-line system. Data selection must be used to meet this limitation.

TABLE III(b)

AVAILABLE BANDWIDTHS AND NUMBER OF FREQUENCY CHANNELS

On-Line Hanning Smoothing Option(5)

BW Code	Bandwidth MHz	Single IF Mode(1) No. Channels(4)	Single IF Mode(1) Freq. Separ. kHz	Two IF Mode(2) No. Channels(4) per IF	Two IF Mode(2) Freq. Separ. kHz	Four IF Mode(3) No. Channels(4) per IF	Four IF Mode(3) Freq. Separ. kHz
0	50	8	6250	4	12500	2	25000
1	25	16	1562.5	8	3125	4	6250
2	12.5	32	390.625	16	781.25	8	1562.5
3	6.25	64	97.656	32	195.313	16	390.625
4	3.125	128	24.414	64	48.828	32	97.656
5	1.5625	256	6.104	128	12.207	64	24.414
6	0.78125	256	3.052	128	6.104	64	12.207
8	0.1953125	128	1.526	64	3.052	32	6.104
9	0.1953125	256	0.763	128	1.526	64	3.052

Notes:

(1) Observing Modes 1A and 1C
(2) Observing Modes 2A and 2C
(3) Observing Modes 4 and 4A
(4) These are the numbers of frequency channels produced in the AP. Any number of channels that is a power of 2, that is less than or equal to the number in the table, and that is greater than or equal to 8 may be selected using the data selection parameters on the LI card.
(5) Data selection HAS to be used.

TABLE IV(a)

VLA CONFIGURATIONS FOR 1987/88

Quarter	Configuration	Antennas Available 327 MHz	8.4 GHz	23 GHz*	Proposal Deadline
1987 Q3	A	21+	13	7+	March 15, 1987
1987 Q4	A/B, B	22+	15	10+	June 15, 1987
1988 Q1	B, B/C	25	21	13	Sept. 15, 1987
1988 Q2	C	27	22	16	Dec. 15, 1987

Mixed configurations with a longer North arm will be available during each change between contiguous configurations.

Maximum antenna separation for the four VLA configurations are: A-36km, B-11km, C-3km, D-1km.

* All 27 antennas are equipped with 23 GHz receivers; the number given is the number of antennas with new receivers, approximately three times more sensitive than current ones.

+ Subject to budgetary limitations.

TABLE IV(b)

APPROXIMATE LONG TERM VLA CONFIGURATION SCHEDULE

	Q1	Q2	Q3	Q4
1987	C	D	A	B
1988	B	C	D#	A
1989	A+	B	C*	D
1990	D	A	B	C

All antennas equipped for 327 MHz operation.

+ All antennas equipped for 8.4 GHz operation.

* Voyager-Neptune encounter.

TABLE V

CONFIGURATION SUMMARY

	A	B	C	D
Maximum Antenna Pair Separation (km)	36.4	11.4	3.4	1.03
(ns)	121,250	36,740	11,431	3,429
Minimum Antenna Pair Separation (km)	.68	.21	.063	.040
(ns)	2,267	700	210	133
Approximate Synthesized Half-Power Beamwidth* (arcseconds):				
90 cm	6	17	56	200
20 cm	1.4	3.9	12.5	44
6 cm	.4	1.2	3.9	14
3.6 cm	.24	.7	2.3	8.4
2 cm	.14	.4	1.2	3.9
1.3 cm	.08	.3	.9	2.8
Approximate Largest Scale Structure "Visible" to VLA ** (arcseconds):				
90 cm	110	360	1080	4000
20 cm	25	80	240	900
6 cm	7	25	80	240
3.6 cm	4	15	48	144
2 cm	2	7	25	80
1.3 cm	2	5	15	50

* These numbers are estimates for a uniformly weighted and untapered map produced from full synthesis observations of a high declination source which passes near the zenith.

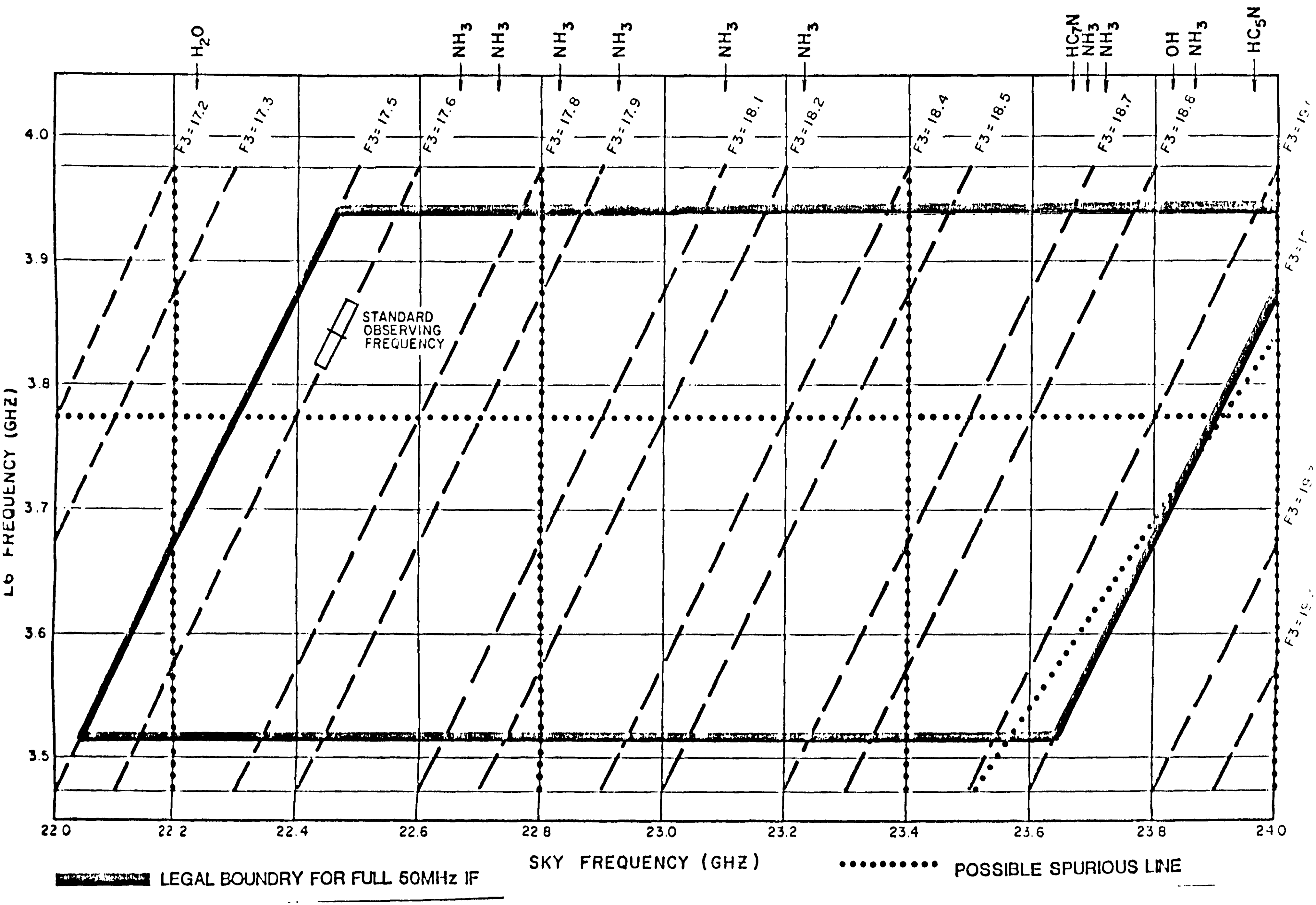
North-South resolution degrades for southern sources. Sources below -15 degrees declination observed with the long north arm hybrid configuration will have resolutions similar to those of the smaller configurations.

The approximate resolution for natural weighted map is about 1.5 times these numbers.

The approximate resolution of snapshots is about 1.3 times the above values.

**These numbers do not represent the maximum field of view but are the largest source size (anywhere in the image) which can be reasonably well imaged in full synthesis observations. For single snapshot observations these numbers should be divided by 2.

1.3 cm – BAND FREQUENCY CHART



VLA OBSERVING APPLICATION

A

received:

SEND TO: Director NRAO Edgemont Rd. Charlottesville, Va. 22901

DEADLINES: 15th of Mar., June, Sept., Dec. for Q 3, 4, 1, 2 respectively

(1) Date:

(2) Title of Proposal:

(3) Authors	Institution	Who will observe?	For Grad Students Onl: Observations for PhD Thesis?	Anticipate PhD Year

(4) Related previous VLA proposal number:

(5) Contact author for scheduling:

Address:

(6) Telephone:

-TWX:

(7) Scientific category: ☐ planetary, ☐ solar, ☐ stellar, ☐ galactic, ☐ extragalactic

(8) Configuration(s) (A, B, C, D, A/B, B/C, C/D, Any)					
(9) Wavelength (90 20 18 6 2 1.3 cm)					
(10) Time requested (hours or days)					

(11) Type of observation: ☐ mapping, ☐ point source, ☐ monitoring, ☐ continuum, ☐ lin poln, ☐ circ poln, ☐ spectral line, ☐ solar, ☐ VLBI, ☐ phased array, ☐ other __________

(12) ABSTRACT (do not write outside this space):

NRAO use only

(13) Observing style: ☐ Will be present ☐ Will prepare files & return to reduce ☐ Will use modem ☐ Absentee (NRAO prepares OBSERV file & sends calibrated data)

(14) Reduction: Number of maps ________ Maximum size of maps ______________ Self-cal maps ________ Private disk pack _____

(15) Off-site reduction: ☐ none, ☐ post map, ☐ post calibration, ☐ everything.

(16) Help required: ☐ none, ☐ consultation, ☐ friend (extensive help), ☐ staff collaborator.

(17) Spectral line only:

	line 1	line 2	line 3		line 1	line 2	line 3
transitions to be observed				number of channels (N)			
channel bandwidth (KHz) (Δ)				number of antennas			
observing frequency (±NΔ/2)				rms noise after 1 hour (mJy)			

(18) Number of sources _____ (If more than 10 sources please attach list. If more than 30 give only selection criteria and LST range(s).)

Name	Epoch 1950☐ 2000☐ RA hh mm	Dec ±xx°.x	Config.	Band (cm)	Band width (MHz)	Total Flux line (Jy)	Total Flux cont. (Jy)	Largest ang. size	Weakest signal (mJy/beam)	Required dynamic range	Possible LST range hh - hh	Time requested

(19) Special hardware, software, or operating requirements:

(20) Preferred range of dates for scheduling:

(21) Dates which are not acceptable:

(22) Please attach a self-contained Scientific Justification not in excess of 1000 words.

When your proposal is scheduled, the contents of this cover sheet become public information. (Any supporting documents are for refereeing only)