VERY LARGE ARRAY OBSERVATIONAL STATUS SUMMARY

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Contents

List of Tables

List of Figures

1 INTRODUCTION

This document summarizes the current instrumental status of the Very Large Array. It is intended as a ready reference for those contemplating use of the VLA for their astronomical research. The information contained herein is in summary form – those requiring greater detail should consult one of the VLA's staff members, listed in Section 7 or refer to the manuals and documentation listed in Section 6. A companion document for the VLBA is also available.

The Very Large Array is a large and complex modern instrument. It cannot be treated as a "black box", and some familiarity with the principles and practices of its operation is necessary before efficient use can be made of it. Although the NRAO strives to make use of the VLA as simple as possible, users must be aware that proper selection of observing mode and calibration technique is often crucial to the success of an observing program. Inexperienced and first-time users are especially encouraged to enlist the assistance of an experienced colleague or NRAO staff member for advice on, or direct participation in, an observing program. See Section 4.10 for details. The VLA is an extremely flexible instrument, and we are always interested in imaginative and innovative ways of using it.

2 BASIC PARAMETERS OF THE VLA

The VLA is a 27-element array which will produce images of the radio sky at a wide range of frequencies and resolutions. The basic data produced by the array are the visibilities, or measures of the spatial coherence function, formed by correlation of signals from the array's elements. The most common mode of operation uses these data, suitably calibrated, to form images of the radio sky as a function of sky position and frequency. Another mode of observing (commonly called *phased array*) allows operation of the array as a single element through summation of the individual antenna signals. This mode is commonly used for VLBI observing and for observations of rapidly varying objects.

The VLA can vary its resolution over a range exceeding a factor of 32 through movement of its component antennas. There are four basic arrangements, called configurations, whose scales vary by the ratios 1:3.2:10:32 from smallest to largest. These configurations are denoted D, C, B, and A respectively. In addition, there are 3 "hybrid" configurations labelled BnA, CnB, and DnC, in which the North arm antennas are deployed in the next larger configuration than the SE and SW arm antennas, and which are especially well suited for observations of sources south of $\delta = -15°$ or north of $\delta = +75°$. The array completes one cycle through all four configurations in approximately a 16 month period. The configuration schedule for 1994 and 1995, and the approximate long-term schedule are outlined in Tables 1 and 2. Updates to this table are published in the NRAO and AAS Newsletters. Read Section 4.1 for information on proposal deadlines, and on how to submit an observing proposal.

Note that the 'B' and 'D' configuration durations are considerably longer than those for the 'A' and 'C' configurations – a result of the all-sky surveys currently underway. In order to accommodate these surveys, and not perturb the 16-month configuration cycle, time allotted to the 'A' and 'C' configurations has been sharply reduced. The D-configuration survey will be completed in mid-1996, the B-configuration survey in early 1997, after which approximately equal durations for each configuration should return.

Table 1: **VLA Configurations for 1994/1995**

DATES	CONFIG	Proposal Deadline
11 May 1994 - 31 May 1994	BnA	01 Feb 94
3 Jun 1994 - 19 Sep 1994	B	01 Feb 94
30 Sep 1994 - 17 Oct 1994	CnB	01 Jun 94
21 Oct 1994 - 26 Dec 1994	C	01 Jun 94
6 Jan 1995 - 31 Jan 1995	DnC	01 Oct 95
10 Feb 1995 - 22 May 1995	D	01 Oct 95

Observing projects on the VLA vary in duration from as short as 1/2 hour to as long as several days. Most observing runs have only one, or perhaps a few, target sources. However, since the VLA is a two-dimensional array, images can be made with data durations of less than one minute. This mode, commonly called *snapshot* mode, is well suited to surveys of relatively strong, isolated objects. See Section 3.13 for details.

The VLA can be broken into as many as five sub-arrays, each of which can observe a different object at a different band. This is especially useful for multi-band flux monitoring observations, and for observing compact objects for which the VLA's full imaging capability and sensitivity are not required.

Table 2: **Approximate Long Term VLA Configuration Schedule**

	T1	T2	T3
1994	A	B	C
1995	D	A	B
1996	C	D	A
1997	B	C	D
1998	A	B	C

However, important restrictions apply when multiple sub-arrays are used: all sub-arrays must simultaneously be either in continuum or line mode. And, if in line mode, all subarrays must use 50 MHz bandwidth, or all must use bandwidths less than 50 MHz. Other restrictions apply, and users should call Ken Sowinski for details (for room and phone numbers of selected NRAO staff, see section 7).

All antennas are outfitted with receivers for six wavelength bands centered near λ90, 20, 6, 3.6, 2.0 and 1.3cm. These bands are commonly referred to as P, L, C, X, U, and K bands, respectively. Ten antennas are now equipped with 0.7cm receivers (Q-band). The feeds for the eight antennas equipped at 73.8 MHz have been removed for at least the duration of the all-sky surveys.

The array can tune to two different frequencies from the same receiver (front end) provided the frequency difference does not exceed approximately 450 MHz. Right-hand circular (RCP) and left-hand circular (LCP) polarizations are received for both frequencies. Each of these four data streams is called an *IF channel.* Observations at more widely separated frequencies can be made within the same run by time switching between the frequencies. This operation takes less than 30 seconds. The array can also simultaneously observe one frequency within L band and one within P band (known as LP band). This is the only currently *supported* mode in which frequencies within two different bands can be observed simultaneously (others are possible but not supported).

Observations at seven different bandwidths (given by $50/2^n$ MHz, with $n = 0, 1, \ldots 6$) are possible. A 200 kHz bandpass is also available in spectral line mode. Continuum mode users wishing to use the 200 kHz bandpass should consult VLA staff first. Different bandwidths can be used for each of the two separate frequencies. Wider bandwidths provide better sensitivity, but also increase the chromatic aberration. See Section 3.3.2 for details.

The VLA correlator has two basic modes, Continuum and Line. In Continuum mode, the correlator provides, for each of the two frequencies, the four correlations (RR, RL, LR, LL) needed for full polarimetric imaging. This mode is particularly well suited to high sensitivity, narrow field-of-view projects. The Line mode is a spectrum measuring mode principally intended for observing spectral lines. There are a great many options allowed in this mode. Besides the obvious need for this mode for all spectral line projects, certain continuum projects which require extremely high dynamic range and/or large field-of-view without undue loss of sensitivity will benefit from use of this mode. It is further described in Section 3.11.

3 PERFORMANCE OF THE VLA

This section contains details of the VLA's resolution, sensitivity, tuning range, dynamic range, pointing accuracy, and modes of operation. More detailed discussions of most of the observing limitations are found elsewhere. In particular, see Reference 1, listed in Section 6.

3.1 Resolution

The VLA's resolution is set by the configuration and frequency of observation. It is important to recall that a synthesis array is "blind" to structures on scales both smaller and larger than the range of fringe spacings given by the antenna distribution. For the former limitation, the VLA acts like any single antenna – structures smaller than the diffraction limit are broadened to the resolution of the antenna. The latter limitation is unique to interferometers – it means that structures on angular scales significantly larger than the fringe spacing formed by the shortest baseline are simply unseen. No subsequent processing can fully recover this missing information, which can only be obtained by observing in a smaller configuration, or with an instrument which provides this information.

Table 3 summarizes the relevant information. This table shows the maximum and minimum antenna separations, the approximate synthesized beam size (full width at half-power), and the scale at which severe attenuation of large scale structure occurs.

Table 3: **Configuration Properties**

Configuration	A	B	C	D
B_{Max}(km)	36.4	11.4	3.4	1.03
B_{Min}(km)	0.68	0.21	0.073	0.035
	θ_{syn}(arcsec)			
90 cm	6.0	17.0	56.0	200.0
20 cm	1.4	3.9	12.5	44.0
6 cm	0.4	1.2	3.9	14.0
3.6 cm	0.24	0.7	2.3	8.4
2 cm	0.14	0.4	1.2	3.9
1.3 cm	0.08	0.3	0.9	2.8
0.7 cm	0.05	0.15	0.47	1.5
	θ_{Max}(arcsec)			
90 cm	170.0	540.0	1800.0	4200.0
20 cm	38.0	120.0	420.0	900.0
6 cm	10.0	36.0	120.0	300.0
3.6 cm	7.0	20.0	60.0	180.0
2 cm	4.0	12.0	40.0	90.0
1.3 cm	2.0	7.0	25.0	60.0
0.7 cm	1.3	4.3	13.0	43.0

These numbers are estimates for a uniformly weighted, untapered map produced from full synthesis observations of a source which passes near the zenith.
Notes:

1. B_{Max} is the maximum antenna separation, B_{Min} is the minimum antenna separation, θ_{syn} is the synthesized beam width, and θ_{Max} is the largest scale structure "visible" to the array.
2. The listed resolutions are appropriate for sources with declinations between -15 and 75 degrees. For sources outside this range, the extended north arm hybrid configurations (BnA, CnB, DnC) should be used, and will provide resolutions similar to the smaller configuration of the hybrid, except for declinations south of -30. No double-extended north arm hybrid is provided, however.
3. The approximate resolution for a natural weighted map is about 1.5 times these numbers. The values for snapshots are about 1.3 times the listed values.
4. The largest scale structure is that which can be reasonably well imaged in full synthesis observations (anywhere in the image). For single snapshot observations these numbers should be divided by 2.
5. The listed resolution performance of the 0.7cm system will not be met in general, as the ten antennas with receivers will be preferentially located near the center of the larger configurations.

3.2 Sensitivity

Table 4 shows the VLA sensitivities expected for natural weighting. The values listed in columns 6 and 8 are the expected r.m.s. fluctuations due to

Table 4: **VLA Sensitivity**

Frequency (GHz)	Band Name (approx. wavelength)	(letter code)	System Temperature (K)	Antenna Eff. (%)	RMS (10 min) Sensitivity (mJy)
0.3 - 0.34	90 cm	P	150-180	40	1.4(1)
1.3 - 1.70	20 cm	L	33	51	0.071
4.5 - 5.0	6 cm	C	45	65	0.080
8.1 - 8.8	3.6 cm	X	31	63	0.055
14.6 - 15.3	2 cm	U	108	52	0.25
22.0 - 24.0	1.3 cm	K	158	42	0.43
40.0 - 50.0	0.7 cm	Q	80 - 120	15	1.2(2)
Frequency (GHz)	RMS Sensitivity in 12 hours (mJy)	Untapered Brightness (D-config) (mKelvins)	Antenna Primary Beam Size (FWHP)	Peak Confusing Source in Beam (Jy)	Total Confusing Flux in Primary Beam (Jy)
0.3 - 0.34	0.17(1)	52.0	150'	1.8	15
1.34 - 1.73	0.0084	2.6	3'	0.11	0.35
4.5 - 5.0	0.0094	3.3	9'	0.002	0.02
8.0 - 8.5	0.0065	2.2	5.4'	0.001	—
14.4 - 15.4	0.029	8.4	3'	0.0001	—
22.0 - 24.0	0.051	10.0	2'	0.00001	—
40.0 - 50.0	0.14(2)	40.0	1'	—	—

All sensitivity calculations assume 50 MHz bandwidth, 27 antennas, one IF pair (two IF channels), natural weighting, except for P band where 3 MHz bandwidth is assumed. Performance will be worse for large zenith angles at high frequencies and for sources close to the galactic plane at low frequencies.
Notes:
(1) Needs 3-D imaging to reach this level. Snapshot observations will not usually reach this level, even with 3-D imaging, as the confusion problem is insoluble with only snapshot u,v coverage.
(2) Values listed are for 40 GHz and El = 90, with 10 antennas.

thermal noise on an image made with natural weighting, calculated using the standard formulae with the system temperatures and efficiencies listed. These values are realized in practice except at P-band where the sensitivities are limited by other effects, and in imaging very bright objects where the residual image noise is due to baseline dependent errors.

In general, the expected r.m.s. noise in mJy on an output image, for natural weighting, can be calculated with the following formula:

$$S_{\rm rms} = \frac{K}{\sqrt{N(N-1)(n\Delta t_{\rm hrs}\Delta\nu_{\rm MHz})}} \tag{1}$$

where N is the number of antennas, $\Delta t_{\rm hrs}$ is the on-source integration time in hours, $\Delta\nu_{\rm MHz}$ is the continuum bandwidth or spectral-line channelwidth in MHz, n is the number of IF channels (from 1 to 4) or spectral line channels (from 1 to 512) which will be combined in the output image, and K is a system constant, equal to 40, 7.7, 8.1, 5.6, 25, 44 and 65 for P, L, C, X, U, K, and Q bands respectively. This constant K can also be expressed in terms of system temperature and efficiency as:

$$K = \frac{0.12T_{\rm sys}}{\epsilon} \tag{2}$$

where $T_{\rm sys}$ is the system temperature, and ϵ is the system efficiency. For the more commonly used uniform weighting, the sensitivity will be a factor of 1.5 to 2.5 worse than the listed values.

The L-band retrofit has now been completed, and the table entries reflect these new systems. However, these sensitivites are appropriate for high elevations – recent tests show that feed spillover causes the system temperature to increase significantly at low elevations – a 50% increase is seen at 30° elevation, and a doubling at 15° elevation. (see VLA Test Memo 167). Contact Durga Bagri for more details.

The limiting brightness temperature achievable by an array is a complicated function of the source distribution and array configuration. However, for the simplified case of an object approximately the size of the synthesized beam, the following relation between brightness temperature and flux density can be applied:

$$T_{\rm b} = F \cdot S \tag{3}$$

where T_b is the brightness temperature (Kelvins) corresponding to S mJy per beam, and F is a constant depending only upon array configuration: F = 300, 30, 3, 0.3 for A, B, C, and D configurations, respectively. The limiting brightness can be obtained by substituting the rms noise for S. A more detailed description of the relation between flux density and surface brightness is given in Chapter 7 of Reference 1 in Section 6.

The sensitivity varies across each observing band. Table 5 gives the frequency ranges for each band at which the sensitivity degrades by 10% and by a factor of two. Also included are the maximum ranges over which the VLA receivers remain operative. At these extreme ends, the system sensitivity is typically 10 to 100 times worse than at band center. Furthermore, not all antennas will operate at these frequencies. Consult a VLA staff scientist if you wish to observe near these band edges.

Table 5: **Sensitivity ranges of VLA bands**

Band	0.9 x Nominal	0.5 x Nominal	Extreme Range
90 cm	305 - 335 MHz	298 - 345 MHz	295 - 350 MHz
20 cm	1320 - 1700 MHz	1250 - 1800 MHz	1225 - 1875 MHz
6 cm	4500 - 5000 MHz	4250 - 5100 MHz	4200 - 5100 MHz
3.6 cm	8080 - 8750 MHz	7550 - 9050 MHz	6800 - 9600 MHz
2 cm	14650 - 15325MHz	14250 - 15700 MHz	13500 - 16300 MHz
1.3 cm	22000 - 24000MHz	21700 - 24500 MHz	20800 - 25800 MHz

The VLA's sensitivity at short wavelengths is highly weather-dependent. The values given for 2cm are typical for good conditions – dry and cold. In summer, sensitivities can be degraded by perhaps 20%. For Q-band, the sensitivity is affected strongly by two factors: the atmospheric opacity, and the decrease of antenna efficiency with decreasing wavelength (see reference 10: "The VLA 7mm System").

3.3 Field of View

At least four different effects will limit the field of view. These are: primary beam; chromatic aberration; time-averaging; and non-coplanar baselines. We discuss each briefly:

3.3.1 Primary Beam

The ultimate factor in limiting the field-of-view is the diffraction-limited response of the individual antennas. An approximate formula for the full width at half power in arcminutes is: $\theta_{\mathrm{PB}} = 45/\nu_{\mathrm{GHz}}$. Objects larger than approximately half this angle cannot be directly observed by the array. However, a technique known as "mosaicing", in which many different pointings are taken, can be used to construct images of larger fields. Refer to Reference 1 for details.

3.3.2 Chromatic Aberration (Bandwidth Smearing)

The principles upon which synthesis imaging are based are strictly valid only for monochromatic radiation. When radiation from a finite bandwidth is accepted, aberrations in the image will result. These take the form of radial smearing which worsens with increased distance from the delay-tracking center. The peak response to a point source simultaneously declines in a way that keeps the integrated flux constant. The net effect is a radial degradation in the resolution and sensitivity of the array.

These effects can be parametrized by the product of the fractional bandwidth ($\Delta\nu/\nu$) with the source offset in synthesized beamwidths ($\theta_0/\theta_{\rm syn}$). Table 6 shows the decrease in peak response as a function of this parameter.

Table 6: **Band width smearing: decrease peak response for fractional bandwidth $\Delta\nu/\nu$ and source offset (from delay center in synthesized beams) $\theta_0/\theta_{\rm syn}$**

$\frac{\Delta\nu}{\nu}\frac{\theta_0}{\theta_{\rm syn}}$	Peak Response
0.0	1.0
0.50	0.95
0.75	0.90
1.0	0.80
2.0	0.50

3.3.3 Time Averaging Loss

The measures of the coherence function (visibility) for objects not located at the phase-tracking center are slowly time-variable due to the changing array geometry, so that averaging them will cause a loss of amplitude. The acceptable loss depends on the expected or required image fidelity. Unfortunately, and unlike the bandwidth loss effect described above, the losses due to time averaging cannot be simply parameterized. The only simple case exists for observations at $\delta = 90°$, where the effects are identical to the bandwidth effect except they operate in the azimuthal, rather than the radial, direction. The functional dependence is the same in this case with $\Delta\nu/\nu$ replaced with $\Omega_{\rm Earth}\Delta t$, where $\Omega_{\rm Earth}$ is the Earth's angular rotation rate, and Δt is the averaging interval.

For other declinations, the effects are more complicated and approximate techniques must be employed. Chapter 13 of Reference 1 considers the average reduction in image amplitude due to finite time averaging. The results are summarized in Table 7, showing the time averaging in seconds which results in 1%, 5% and 10% loss in the amplitude of a point source located at the half-power point of the primary beam. If the target source extends a fraction $1/f$ of the half-power from the phase-tracking point, the table entries are multiplied by f.

Table 7: **Time averaging smearing: times (seconds) resulting in various amplitude losses for a point source at the antenna half power point**

	Amplitude loss		
Configuration	1.0%	5.0%	10.0%
A	2.1	4.8	6.7
B	6.8	15.0	21.0
C	21.0	48.0	67.0
D	68.0	150.0	210.0

3.3.4 Non-Coplanar Baselines

The principles by which nearly all images are made in Fourier synthesis imaging are based on the assumption that all the coherence measurements are made in a plane. This is strictly true for E-W interferometers, but is manifestly false for the VLA, with the single exception of snapshots. Analysis of the problem shows that the errors associated with the assumption of a planar array increase quadratically with angle from the phase-tracking center. Serious errors result if the product of the angular offset in radians times the angular offset in synthesized beams exceeds unity. The effects are especially severe at λ90 cm, where standard two-dimensional imaging can only be done for D-configuration data. This effect is noticeable at λ20 cm in certain instances, but can be safely ignored at shorter wavelengths.

The best solution to this problem is to use an algorithm (called `dragon` in the experimental software system SDE) similar to the `MX` algorithm in AIPS, but which images a filled field of view rather than a collection of patches. At this time, data taken in B, C and D configurations at 90 cm can be properly imaged in this way at the AOC. Reaching the theoretical noise (0.2 mJy/beam) of a long integration (8-12 hours) at λ90 cm requires use of this software. For A-conf λ90 cm observations, the only recourse is to use the AIPS `MX` software to subtract the sidelobes of the brightest 16 sources in the field. In combination with band-width smearing, this can result in a noise level of somewhat better than 1 mJy/beam. Contact Tim Cornwell for further details of all of these approaches.

3.4 Time Resolution

The minimum integration time at which all data can be written to tape is a function of the total number of channels of data produced by the correlator. This minimum time varies from 1 1/3 seconds for the continuum mode to 20 seconds for 512 channel spectral line modes. Times less than these can be selected, but only at the cost of removing antennas from the array. Integration times as short as 0.4 seconds are available in continuum, but are appropriate only for solar observing. Contact Ken Sowinski for details on their use.

Users must keep in mind the large data rate of the VLA when planning their observing. The array's maximum data rate of some 3 GByte per day can easily overwhelm most data reduction facilities. This rate can be reduced to manageable levels by increasing the averaging time and/or decreasing the number of spectral channels. Consult your VLA friend for advice.

See Section 3.16 for a description of the High Time Resolution Processor.

3.5 Radio-Frequency Interference

The bands within the tuning range of the VLA which are allocated exclusively to radio astronomy are 1400 – 1427 MHz, 1660 – 1670 MHz, 4990 – 5000 MHz, 15.35 – 15.4 GHz, 22.2 – 22.5 GHz and 23.6 – 24.0 GHz. No external interference should occur within these bands. Experience shows that RFI is a serious problem only within the 20 and 90 cm bands. At 20 cm, interference is most serious to the D configuration, as the fringe rates in other configurations are generally sufficient to reduce interference to tolerable levels.

RFI at the VLA is an increasing problem to astronomical observations. To monitor this increase, and to provide a rough guide to the severity of this interference, Vivek Dhawan monitors the L-band RFI spectrum approximately once monthly, using the VLA correlator system. Table 8 is a convenient summary of eight such observations taken during the 1993/1994 D-configuration. This table lists the "line" frequency, the average equivalent flux density (in mJy) in 50 MHz, and the peak flux density, also reduced to 50 MHz equivalent bandwidth. A significant difference between these columns indicates that the RFI is intermittant. These equivalent flux densities are approximate, and should be used only to give a rough approximation to the severity and likelihood of a problem.

Between 1220 and 1250 MHz, very strong and very broad RFI is always present (apparently due to satellite and radar transmissions). It may be possible to observe in selected, narrow bandwidths in this region. Special tests will to be run to determine whether such observations are possible. Between 1435 and 1530 MHz, aeronautical telemetry from White Sands Missle Range will occasionally interfere with observing. These transmission are very occasional, and unpredictable. In general, it may be possible to observe in spectral regions containing strong RFI provided: (1) That the RFI is not so strong as to cause serious gain compression in the front-end amplifiers, and (2) That the RFI be kept out of the correlator through use of a narrow back-end filter. This latter requirement is particularly important for spectral line correlator modes, although use of Hanning smoothing is very helpful in reducing the Gibbs' ringing. The former condition can be assisted by using a narrower (12.5 or 25 MHz) front-end filter, rather than the default 50 MHz filter. Note that use of these FE filters greatly restricts the range of tunable frequencies.

Note that the listed RFI signal strengths are appropriate for the 'D'-configuration. These signal strengths are considerably reduced in the larger configurations – an average attenuation of perhaps a factor of 100 will be obtained in the 'A'-configuration due to fringe phase winding.

Observers can use Table 8 to assist in deciding which center frequencies and bandwidths are most likely to result in good data. There are very few good combinations for 50 and 25 MHz bandwidths. These are summarized in Table 9, which shows the "statistically" best frequencies to use at L-band with the listed bandwidths. Note that the VLA LO system restricts the selection of frequencies at both 50MHz and 25MHz bandwidths. The restrictions are particularly severe at the former bandwidth. At 25 MHz bandwidth, the centered on 1250, 1300, 1350, ... , 1700 MHz cannot be tuned. For other bandwidths, refer to Table 8

Copies of all RFI plots taken over a 5-year period are posted in the data analysts' room at the AOC (Rm 204). Plots from 1993 onwards are available via the Mosaic system (see Section 4.13). For general information about the

Table 8: **VLA RFI Between 1260 and 1740 MHz**

Frequency	Avg. Flux	Pk. Flux	Source	Comments
1277 MHz	12	20	Aerostat Radar	Sometimes absent
1286	2	5	Farmington Radar	Other weak lines nearby
1300	2	5	Internal RFI	
1310	100	100	ABQ Radar	
1330	45	80	ABQ Radar	Sometimes absent
1381	3	100	GPS L3 IONDS	On $< 3\%$ of the time
1400	60	60	Internal RFI	
1429-1435	15	130	Military	Four separate lines
1444,1453	5	> 100	Hi altitude balloons	NASA/NSBF
1465	6	8	Alias of 1735 MHz	
1486	15	20	Alias of 1714 MHz	
1500	2	5	Internal RFI	
1510	5	40	Alias of 1690	
1515	15	> 100	Balloon, Alias of 1685	
1520	9	30	Alias of 1680	
1525	6	> 100	Balloon, Alias of 1675	
1530-1544	> 130	> 200	INMARSAT	Many 'lines'
1557-1567	10	20	GPS Sidelobe?	Wide spectrum
1570-1580	> 500	> 500	GPS	Wide spectrum
1584-1598	20	20	Alias of GLONASS	
1600	120	120	Internal RFI	
1602-1616	> 500	> 500	GLONASS	Many separate 'lines'
1620	80	300	?	
1625	15	20	Aliased GPS carrier	
1650	13	25	Internal RFI	
1678-1698	50	100	Radiosondes, satellite	> 6 variable 'lines'.
1710	10	10	?	
1714	> 500	> 500	Forest Service	
1725	10	10	" "	
1730	25	25	" "	
1735	> 100	> 100	Forest Service	

RFI environment, consult Bill Brundage. Figure 1 shows a typical result

Table 9: **Recommended Frequency/Bandwidth Combinations for L-Band**

BW	Class A No RFI Expected	Class B Weak/Occas'l RFI	Class C "Tolerable" RFI
50 MHz	none	1364.9,1464.9,1485.1	1335.1,1385.1,1414.9,1435.1
25MHz	1343 – 1347 1353 – 1387 1413 – 1417 1663 – 1665	1290 – 1297 1453 – 1470 1503 – 1517 1637.5	many See Table 8

from the RFI survey.

The rising tide of interference at L-band has recently caused us to designate a number of "standard" L-band frequencies, as shown in table 10.

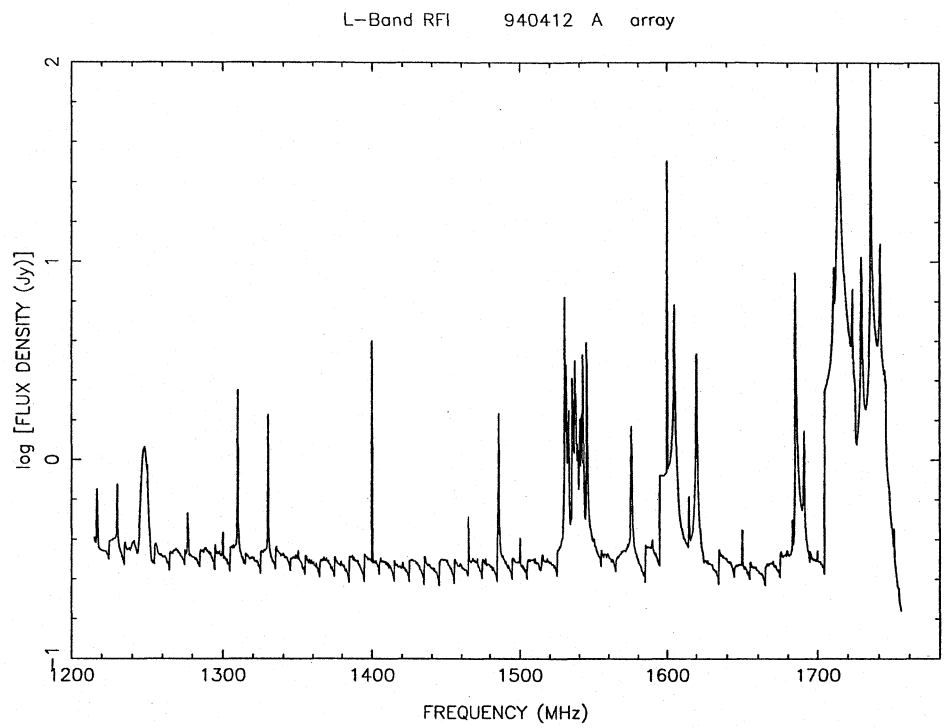
Table 10: `Observe` names of L-band "Standard frequencies"

`Observe` Name	AC Center Frequency	AC Bandwidth	BD Center Frequency	BD Bandwidth
LL	1464.9	50	1385.1	50
L1	1364.9	50	1435.1	50
L2	1515.9	25	1365.1	25
L3	1515.9	25	1435.1	25

At 90 cm, the RFI situation is particularly bad. Interference is relatively infrequent in the evenings and on weekends. However, during the day, very strong interference, sufficient to saturate the receivers, is common. The best advice is to arrange observing to fall outside of regular working hours. Very sensitive spectral line observations require special measures at the site (contact Bill Brundage).

Another important form of RFI consists of signals which are generated by each antenna. These signals are picked up by nearby antennas, or by the generating antenna's feed, and produce correlated signals in the visibility data. This form of RFI is especially important in the 90 cm band when in the C and D configurations. They appear at all multiples of 5 and 12.5 MHz -

Figure 1: Typical L-band interference spectrum



frequencies divisible by these numbers must be avoided. (It is this spectrum of RFI which limits our P-band bandwidth to 3.125 MHz.) Another family of RFI occurs at multiples of 100 kHz - these are much weaker, are incoherent between antennas, and can usually be ignored.

These internally generated signals can only be eliminated through RFI shielding of the electronics producing the signals. Currently, thirteen antennas are shielded, with two more scheduled for installation by the end of June, 1994. We hope to obtain funding to allow completion of this project over the next two or three years.

In the 327 MHz band, use of the spectral line system is recommended for diagnosis and removal of internal and external interference – especially in C and D configurations. Consult with Juan Uson or Durga Bagri for advice.

Within the 6cm band, all observers should avoid using a combination of frequency and bandwidth which includes 4800 MHz, where a strong internal birdie exists. The default frequency combinations at this band avoid this birdie. This birdie can also be seen if the setting of the L6 frequency is 3760 MHz (for 50 MHz bandwidth) or 3790 MHz (for 25 and 50 MHz bandwidth).

3.6 Antenna Pointing

The pointing parameters of the antennas are measured monthly under calm nighttime conditions, and are sufficient, under good weather, to allow pointing accuracy of 10 arcsec rms. The pointing accuracy in daytime is a little worse, due to the effects of solar heating of the antenna structures. To achieve better pointing, we have recently added a capability for repeated calibration of the pointing during astronomical observations. In this observing mode, known as 'referenced pointing', a nearby calibrator must be observed (usually at X-band) in interferometer pointing mode ("IR") every hour or so. The local pointing corrections thus measured can then be applied to subsequent target observations. Tests show that this mode reduces rms pointing errors to typically 2 - 3 arcseconds. The `Observe` program is aware of this observing mode. Use of referenced pointing is highly recommended for all K- and Q-band observations, and for X- and U-band observations of objects whose total extent is a significant fraction of the antenna primary beam. Consult with Rick Perley or Ken Sowinski for more information about this mode.

3.7 Positional Accuracy

The accuracy with which an object's position can be determined is limited by the atmospheric phase stability, the closeness of a suitable (astrometric) calibrator, and the calibrator-source cycle time. Under the best conditions, in A-configuration, accuracies of about 0.05 arcseconds can be obtained. Under more normal conditions, accuracies of perhaps 0.1 arcseconds can be expected. If highly accurate positions are desired, only A or B position code calibrators from the VLA Calibrator List should be used. The positions of these sources are taken from the JPL or Goddard astrometric survey lists.

3.8 Imaging Performance

Imaging performance can be limited in many different ways. Some of the most common are:

Calibration errors: With conventional point-source calibration methods, and even under the best observing conditions, the achieved dynamic range will rarely exceed a few hundred. The limiting factor is the atmospheric phase stability. If the target source contains more than 50 mJy in compact structures (depending somewhat on band), self-calibration can be counted on in improving the images. Dynamic ranges in the thousands can be achieved using these techniques. If the target source is bright enough for dynamic ranges exceeding 10,000 to be conceivable, use of the spectral line correlator mode should be considered.

Invisible structures: An interferometric array acts as a spatial filter, so that for any given configuration, structures on a scale larger than the fringe spacing of the shortest baseline will be completely absent. Table 3 gives the largest scale visible to each configuration/band combination.

Poorly sampled Fourier plane: Unmeasured Fourier components are assigned values by the deconvolution algorithm. While this often works well, sometimes it fails noticeably. The symptoms depend upon the actual deconvolution algorithm used. For the CLEAN algorithm, the tell-tale sign is a fine mottling on the scale of the synthesized beam, which sometimes even organizes itself into coherent stripes. Further details are to be found in Reference 1.

Sidelobes from confusing sources: At 90 and 20 cm, large numbers of background sources are located throughout the primary antenna beam. Sidelobes from these objects will lower the image quality of the target source. Although bandwidth and time-averaging will tend to reduce the effects of these sources, the very best images will require careful imaging of all significant background sources. The AIPS task `MX` is well suited to this task at λ20 cm. The problem at λ90 cm is much worse, and is greatly complicated by the non-coplanar nature of the array, as described in Section 3.3.4. Table 3 gives the highest flux density expected of these background sources, and the total background flux density.

Sidelobes from strong sources: Another image-degrading effect is that due to strong nearby sources. Again, the 20 and 90 cm bands are especially affected. The active Sun will be visible to any D configuration spectral line observation at these bands. Even with 50 MHz bandwidth in continuum mode, the active Sun can ruin the short spacings of observations within about 20 degrees of the Sun. The quiet Sun poses a lesser threat, so the general rule is to go ahead and observe, even if the target source is close to the Sun. At 90 cm, observations within approximately 10 degrees of Cygnus A, Cassiopeia A, Taurus A, and Virgo A will be greatly degraded.

3.9 Calibration and the Flux Density Scale

The VLA Calibrator List contains information on 806 sources sufficiently unresolved and bright to permit their use as calibrators. Copies of the list are distributed throughout the AOC. The list is also available within the `Observe` program and via the mosaic information system (see Section 4.13). An IBM PC program which accesses the VLA Calibrator list can be used to assist in calibrator selection. Copies of these can be obtained by calling Theresa McBride or via anonymous `ftp` from zia.aoc.nrao.edu (or 146.88.1.4).

Accurate flux densities are obtained by observing one of 3C286, 3C147 or 3C48 during the observing run. These sources are slowly variable, so we attempt to monitor and update their flux densities each year when the VLA is in its D-configuration. The VLA's flux density scale is based on the Baars *et al.* values for 3C295 at all bands except K-band (23 GHz). For this band, the situation is still unsettled, but it is likely we will adopt the Baars *et al.* value of NGC7027.

Table 11 shows the flux densities of these sources in December 1989 at our standard bands.

Table 11: **Flux densities of Standard Calibrators for December 1989**

	327.5 MHz	1425 MHz	4866 MHz	8434 MHz	14984 MHz	22460 MHz
3C48	42.7±.3	16.0±.01	5.61±.02	3.29±.01	1.85±.02	1.24±.02
3C147	53.1±.4	21.6±.01	7.78±.02	4.59±.01	2.66±.02	1.80±.02
3C286	26.4±.2	14.7±.01	7.47±.02	5.20±.01	3.42±.03	2.52
3C295	60.4	22.0	6.56	3.42	1.615	——
NGC7027	——	1.40±.01	5.49±.02	6.03±.05	5.72±0.1	——
3C138	19.7±.3	8.41±.01	3.8±.02	2.50±.01	1.59±.02	1.14±.02

3.10 Polarization

The continuum mode always provides full polarimetric information. The polarimetric spectral line modes (PA and PB) are also available for observations of linearly polarized spectral lines, or for observations of continuum objects where large field-of-view or high dynamic range is necessary.

For each observation requiring polarization information, the instrumental polarization should be determined through observations of a bright calibrator source spread over a range in parallactic angle. In nearly all cases, the phase calibrator chosen can double as a polarization calibrator. The minimum condition that will enable accurate polarization calibration is four observations of a bright source spanning at least 90 degrees in parallactic angle. The accuracy of polarization calibration is generally better than 0.5%. The instrumental polarization is not constant across the beam, so that errors in the source polarization exceeding 1% can be expected when imaging at angles exceeding 10% of the primary beam width. At least one observation of 3C286 or 3C138 is required to fix the absolute position angle of polarized emission.

Ionospheric Faraday rotation is always present at 20 and 90 cm. The amount of rotation can exceed 40 degrees at 20 cm at solar maximum, and remains notable even through solar minimum. Approximate correction schemes are available within the AIPS task `FARAD`. This task reads TEC (Total Electron Content) data and computes the appropriate correction. Unfortunately, relevent TEC data has not been available for the last two years. We are currently arranging to obtain the GPS L-band data taken at the VLBA's Pie Town site. At $\lambda 90$ cm, the situation is more difficult. Ionospheric effects are too large to be accurately corrected, and there are no polarized sources which allow fixing the true position angle. The best method to date has been with objects in which strong, compact polarized emission is found. Each scan can then be corrected to remove the ionospheric rotation, allowing an accurate measure of the polarized flux. However, the problem of fixing the true position angle remains.

Circular polarization measurements are limited by the beam squint – the RCP and LCP primary beams are separated by 6 percent of the beamwidth. Since circular polarization is determined from the difference between RCP and LCP signals, there results a large error in all measurements of circular polarization. The effect is large – the apparent circular polarization is $\sim$10% at $\lambda/4D$, and $\sim$20% at $\lambda/2D$. This false circular polarization is antisymmetric with respect to the center of the antenna beam, so 12-hour observations will largely cancel out the effect – however, even so, the residual apparent circular polarization is probably only accurate to a few percent.

High sensitivity polarization imaging may be limited by time dependent instrumental polarization, which can add low levels of spurious polarization near features seen in total intensity and can scatter flux throughout the polarization image, potentially limiting the dynamic range. The instrumental polarization averaged among all baselines can vary by 0.3% on timescales of minutes to hours, limiting the believable fractional polarization to about 0.15%

Wide field polarization imaging will be limited by the instrumental polarization beam. For a snapshot observation, the spurious polarization is $<$ 1% at $\lambda/4D$, 1 – 3% at $\lambda/2D$, and increases sharply beyond this, reaching 10% at $3\lambda/4D$. Since the instrumental polarization beam is directed radially and rotates on the sky, the spurious polarization will tend to average down for long integrations, but flux will be scattered across the polarization image, limiting the polarization dynamic range if an off-axis source is bright enough in total intensity.

3.11 Spectral Line Modes

The VLA correlator is very flexible, and can provide data in many ways. The various spectral line modes currently available are shown in Tables 12 and 13 and described below.

Most modes are distinguished by a code comprising a number followed by zero, one, or two letters. The number refers to the number of spectra being produced, the letters describe which IF channels are involved. Recall that each VLA antenna returns four signals: these are the RCP and LCP for each of two separately tuned frequencies. These signals are referred to as IF channels, and are named A, B, C, and D. The first two represent RCP, and latter two LCP. IF channels A and C are at one frequency; B and D are at another. The spectral line modes can subdivide these IF channels into four to 512 units, evenly spaced in frequency across the bandwidth of the input IF channel or channels. These narrower units are referred to as *spectral line channels*. In addition to these interferometric spectra, autocorrelation spectra for all antennas are produced.

The single-channel modes provided by the spectral line correlator are known as 1A, 1B, 1C, and 1D. In these modes, only one spectrum is produced. These modes give the highest spectral resolution at any given bandwidth. The dual-channel modes are denoted 2AB, 2AC, 2AD, 2BC, 2BD

Table 12: **Available bandwidths and number of spectral line channels in normal mode**

BW	Bandwidth	Single IF Mode[1]		Two IF Mode[2]		Four IF Mode[3]	
		No.	Freq.	No.	Freq.	No.	Freq.
Code	MHz	Channels[4]	Separ. kHz	Channels[4] per IF	Separ. kHz	Channels[4] per IF	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	3.052	256	6.104	128	12.207
6	0.78125	512	1.526	256	3.052	128	6.104
8	0.1953125	256	0.763	128	1.526	64	3.052
9	0.1953125	512	0.381	256	0.763	128	1.526

Notes:
(1) Observing Modes 1A, 1B, 1C, 1D.
(2) Observing Modes 2AB, 2AC, 2AD, 2BC, 2BD, 2CD.
(3) Observing Modes 4, PA, PB. It is possible to use the output from one, two or four IF channels in such a way as to obtain different combinations of number of spectral line channels and channel separation. The minimum and maximum number of channels is 4 and 512 respectively.
(4) These are the numbers of spectral line channels produced in the AP. Any number of spectral line 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 2 may be selected using the data selection parameters on the DS card.

and 2CD, and provide spectral information for the two IF channels named. Linear polarization measurements are not possible with these modes, but circular polarization can be determined using the 2AC and 2BD modes. The four-channel modes are known as 4, PA and PB. The first of these provides spectra for all four IF channels. Circular, but no linear polarization measurements are possible in this mode. The other two modes provide full polarimetric information – PA provides this for the A and C IF channels (that is, it performs the correlations AA, AC, CA, and CC, providing a spectrum for each), PB for the B and D IF channels. Note that for these polarimetric modes, the descriptor 4 is omitted. The characteristics of all of these modes are summarized in Table 13.

It is also possible to use multiple, independent subarrays in spectral line

Table 13: **Available Bandwidths and Number of Spectral Line Channels in Hanning Smoothing Mode**

		Single IF Mode(1)		Two IF Mode(2)		Four IF Mode(3)	
BW Code	Bandwidth MHz	No. Channels(4)	Freq. Separ. kHz	No. Channels(4) per IF	Freq. Separ. kHz	No. Channels(4) per IF	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, 1B, 1C, 1D.
(2) Observing Modes 2AB, 2AC, 2AD, 2BC, 2BD, 2CD.
(3) Observing Modes 4, PA, PB.
(4) These are the numbers of spectral line channels produced in the AP. Any number of spectral line 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 2 may be selected using the data selection parameters on the DS card.

mode. The correlator modes beginning with 2 or 4 will allow the IF channels to be at different bandwidths as well as at different frequencies within the same band. There are other restrictions. Contact Ken Sowinski or Elias Brinks for further details.

Of central interest to observers is the stability of the spectra. Spectral line dynamic range is commonly defined as the ratio of the continuum brightness to the minimum detectable line brightness in an image. This ratio is limited by instrumental effects which must be calibrated out. The spectral dynamic range depends on bandwidth in a poorly understood way. Applying the on-line autocorrelation only should result in about 50:1 dynamic range and is generally discouraged. Values exceeding 10,000:1 at C and X-bands can be achieved but it requires the most careful data editing and bandpass calibration. A more typical limit is around 1,000:1. At L-band spectral dynamic ranges of 1000:1 can be achieved by observing a suitable bandpass calibrator. Consult with Elias Brinks for more details.

See "A Short Guide for VLA Spectral Line Observers" for more information.

3.12 VLBI Observations

The VLA participates in VLBI projects run during Network sessions, as well as in non-Network VLBA projects run outside of Network sessions. The VLA supports VLBI observations in either single-antenna or phased-array modes. Data can be recorded in VLBA, Mark III, or Mark II formats. Each type of recording makes use of the VLA's VLBA data acquisition system. A comprehensive document entitled "VLBI at the VLA" is available.

VLBI at the VLA is overseen by Mark Claussen and Joan Wrobel. Mark is responsible for VLBI hardware readiness. Either Mark or Joan can be consulted for general information regarding matters such as observing in VLBA, Mark III, or Mark II formats; phased-array or single-dish observations; or calibration of the VLA for VLBI. However, each VLBI project involving the VLA, whether run during or outside of a Network session, will be assigned an AOC contact by Barry Clark. Queries from an observer concering specific information about a specific project should be directed to the AOC contact assigned to the project. If the project's principal investigator is an AOC employee, then that person will be assumed to be the AOC contact.

See Section 4.11 for information on absentee observing.

3.13 Snapshots

The two-dimensional geometry of the VLA allows a snapshot mode whereby short observations can be used to image relatively bright unconfused sources. This mode is ideal for survey work where the sensitivity requirements are modest. Due to confusion by background sources, this mode is not recommended at λ90 cm.

Single snapshots with good phase stability should give dynamic ranges of a few hundred. Note that because the snapshot synthesized beam contains high sidelobes, the effects of background confusing sources are much worse than for full syntheses, especially at 20 cm in the C and D configurations for which a single snapshot will give a limiting noise of about 0.2 mJy/beam. This level can be reduced by taking multiple snapshots separated by at least one hour. Use of the AIPS program `MX` is necessary to remove the effects of background sources.

3.14 Shadowing and Cross-Talk

Observations at low elevation in the C and D configurations will commonly be affected by shadowing. It is strongly recommended that all data from a shadowed antenna be discarded. This will automatically be achieved within the AIPS task `FILLM`.

Cross-talk is an effect in which signals from one antenna are picked up by an adjacent antenna, causing an erroneous correlation. At λ20cm, this effect is important prinicipally in the D configuration. At λ90cm, C and even B configurations can also be affected. Careful editing is necessary to identify and remove this form of interference.

3.15 Combining Configurations and Mosaicing

Any single VLA configuration will allow accurate imaging up to a scale approximately 30 times the synthesized beam. Objects larger than this will require multiple configuration observations. Observers only need ensure that the frequencies used are similar for each configuration. It is not necessary that they be identical, but differences greater than 50 MHz could cause errors due to spectral index gradients. Objects larger than the primary antenna pattern may be mapped through the technique of interferometric mosaicing. Consult with Tim Cornwell for details and advice.

3.16 High Time Resolution Processor

The High Time Resolution Processor (HTRP) is a 14-channel polarimeter designed for observations of short timescale phenomena such as pulsars and flare stars. The HTRP has been used successfully in pulsar polarimetry, pulsar searches, and pulsar timing. The HTRP directs two, oppositely polarized input signals from the VLA analog sum ports through a 14-channel filter bank. The bandwidth of each input channel can be set to 0.125, 0.25, 0.5, 1.0, 2.0, or 4.0 MHz. The HTRP provides full polarimetry, producing a total of 56 detected outputs.

The integration times for each output can be set to between 25 and 5000 microseconds. The maximum aggregate sample rate is about 100 kilosamples per second, so the minimum sampling interval for each channel is about (10 microseconds multiplied by number of sampled channels). The HTRP is controlled by an IBM PC compatible, and the sampled data are written to the PC hard disk or Exabyte tape. Current versions of monitor and control software and data acquisition software are adequate for general use. Observers interested in using the HTRP should plan on investing some time in developing their own data analysis software. The Princeton MkIII Timing System, although not supported by the NRAO, is available for general use. It accepts 32 outputs from the HTRP detectors for time-stamped synchronous signal averaging at aggregate sampling rates up to about 2.5 MHz. For further information regarding the HTRP, contact Dale Frail or Tim Hankins.

4 OBSERVING WITH THE VLA

4.1 Getting Observing Time on the VLA

The allocation of observing time on the VLA is based upon the submission of a VLA Observing Application Form obtainable at any NRAO office. The form consists of a cover sheet whereon the proposer must summarize all technical details of the observations, and an appended, self-contained, scientific justification of the project not to exceed 1000 words in length. Once completed the entire observing request (cover sheet plus appended justification) must be submitted to:

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

This form can be obtained in a TEX version via anonymous `ftp` from the `ftp` server zia.aoc.nrao.edu (146.88.1.4). Login as "anonymous", and use your e-mail address as the password. In the subdirectory pub/vlacover are three files: cover1.tex (the front side), cover2.tex (back side) and logo.ps (a PostScript file of the NRAO logo). Copy these and insert the relevant information.

Submission of proposals by e-mail is now encouraged. Simply concatenate the front side, back side, text, and figure files (using, for example, the UNIX cat command), and e-mail to "propsoc@nrao.edu". This e-mailed file must be printable on our systems – if it cannot be printed, it won't be accepted. We will acknowledge the successful printing of received proposals, and will work with proposers to modify those files which are received but did not print successfully, if the file is received at least 5 days before the actual deadline.

Submissions by Fax (804 296 0278), although not encouraged, are permitted but the paper copy must be received at NRAO within 48 hours after the deadline.

The VLA is scheduled on a term basis, with each term lasting 4 months. The proposal deadline for a particular configuration is the 1st of February, June, or October of the preceding term. Table 1 details the deadlines through 1995. It is not necessary to submit a proposal in the preceding term, since all proposals will be refereed immediately following the deadline of submission, regardless of the configuration requested. Early submissions - more than one deadline in advance of the relevant configuration deadline - will benefit from referee feedback and the opportunity for revision and additional review if warranted.

All proposals are externally refereed by several experts in relevant subdisciplines (e.g. solar, stellar, galactic, extragalactic, etc.). The referees' comments and rating are advisory to the internal VLA scheduling committee, and the comments of both groups are passed on to the proposers soon after each meeting of the committee (3 times yearly) and prior to the next proposal submission deadline. Scheduling the telescope is a non-exact science, and because of competition highly rated proposals are not guaranteed to receive observing time. This is particularly true for programs that concentrate on objects in the LST ranges occupied by popular targets such as the galactic center or the Virgo cluster.

Note also the effect of the all-sky surveys. The D-configuration survey will be taken only at nighttime – thus, observing time between 5 and 17 hours LST will be in short supply during the D-configuration of Spring 1995, as will be time from 13 to 01 hours LST during the D-configuration of Summer 1996. The B-configuration is limited to the LST hours of 07 to 17:30, so these LSTs will be difficult to obtain time in during the B-configurations scheduled for late 1995 and early 1997.

4.2 Data Analysts and General Assistance

General assistance of all kinds is available through the Data Analysts, Sue Prewitt (505 835 7238) and Meri Stanley (505 835 7359). They can be considered to be advocates for all VLA users, and should be consulted first when you encounter any problem. Note that they are not available to perform remote data calibration.

4.3 Observing File Preparation

To use the VLA an observing file must be prepared and submitted to the VLA Operators. This file is generated by the NRAO-supplied program `Observe`, which is available to all users and can run on a wide variety of machines. We recommend that all users obtain a copy of this program, and periodically check that they have the latest version.

At this time, `Observe` is available for Sun workstations and IBM RS6000 workstations.

`Observe` can be obtained by one of these routes - listed in order of preference:

1. For users with Internet access; for SUN and IBM versions, use anonymous `ftp` from directory pub/observe on zia.aoc.nrao.edu (or 146.88.1.4).
2. Telephone Theresa McBride and specify the machine type (SUN, IBM) and medium (disc, floppy, standard tape, Exabyte, or DAT), which she will then mail to you.

A considerable training effort is required to become fully conversant with `Observe`. For help, call the Data Analysts, Sue Prewitt, or Meri Stanley, or through E-mail (analysts@nrao.edu).

After your file is prepared, E-mail it to the operators at observe@nrao.edu. Include the program name in the subject line. Always call the operators at 505 772 4251 to confirm receipt of the file. It is in your best interest to complete these operations at least two working days before your observing.

4.4 The Observations and Remote Observing

Observers need not be present at the VLA to obtain VLA data. However, we encourage VLA users to come to Socorro when observing. There is no better way to interact with the data, and to calibrate and to image data quickly. And coming to Socorro is the best way to benefit from discussions with staff members.

We recommend that observers who are coming to and who intend to set up their `Observe` files in Socorro arrive two days before their scheduled observations to allow sufficient time to interact with key staff members. See Section 4.8 for information on coming to and staying in Socorro.

For those who choose to process their data at home, the data analysts will, upon request, mail you a tape (standard 1/2 inch, Exabyte or DAT) containing your uncalibrated data. For short observations requiring fast turnaround, the data analysts will load your data on disk in FITS format, from where you may transfer the data through `ftp` to your computer. Contact the Data Analysts to access these services.

4.5 Data Calibration

The only supported software package for data calibration is AIPS. Remote data calibration by the Data Analysts is no longer provided.

4.6 Real-Time Observing

A Sun Sparc 2 workstation, connected to the on-line computers by an Ethernet link, is now in place at the VLA site. A special version of the AIPS task `FILLM` will fill VLA data into the workstation disks. Each scan is available for editing, calibration, and imaging within a few seconds of the end of that scan. Data can also be written to a local Exabyte tape. All regular AIPS tasks are available on this workstation.

The real-time data pipeline has now been extended to the AOC. Any workstation at the AOC can now receive VLA data as it is produced by the Modcomps. This is an experimental system, and George Martin should be notified of its use at least one day before observing.

4.7 Computing at the AOC

A primary goal of the computing environment at the AOC is to allow every user to have full use of a workstation during his or her visit. There are 15 public workstations available for full-time data reduction by visitors to the AOC. These workstations range from Sparc IPX-class workstations to IBM RS/6000-580 workstations. The former are targeted to VLA continuum observations and small spectral line projects, while the latter are needed for large spectral line projects as well as VLBA processing.

For hardcopy, we have a number of laser printers, a color Postscript laser printer (which can reproduce on both paper and tranparencies), and a Solitaire film recorder.

Visitors may reserve time on these workstations when they make their travel arrangements with the Reservationist, Eileen Latasa (see Section 4.8). Jon Spargo schedules all public computers.

4.8 Reservations for VLA and/or AOC

Advance contact with the Reservationist (Eileen Latasa) at least 1 week prior to your visit to the NRAO/NM is required, and 2 weeks' notice is preferred, in order to optimize the logistics of room occupancy, transportation, computer load, and staff assistance.

First time visiting students will be allowed to come to the NRAO/NM for observations or data reduction only if accompanied by their faculty advisor.

4.9 Staying in Socorro

Visitors to Socorro can now take advantage of the recently completed NRAO Guest House. This facility contains 8 single, 4 double, and 2 two-bedroom apartments, plus a lounge/kitchen, terminal facility, and full laundry facilities. The Guest House is located on the NMIMT campus, a short walk from the AOC. Reservations are made through the Reservationist, Eileen Latasa.

4.10 Help for Visitors to the VLA and AOC

We encourage observers to come to Socorro to calibrate and image their data. This is the best way to ensure the quickest turnaround and best results from their observing. While in Socorro, each observer will interact with members of the AOC staff in accordance with his/her level of experience and the complexity of the observing program. If requested on the original VLA application form, the visiting observer will be guided through the steps of data calibration and imaging by a prearranged staff friend or scientific collaborator. Data Analysts and the computer operations staff are also available for consultation on AIPS procedures and systems questions.

4.11 VLBI Remote Observing

The VLA supports absentee VLBI observations, whether conducted during, or outside of, a Network session. Queries from an absentee observer concerning a specfic project should be directed to the AOC contact assigned to that project (see Section 3.12). VLA schedule file preparation assistance is provided by the Data Analysts (see Section 4.2). Absentee observers must provide the Data Analysts with all necessary scheduling information. For a Network project, this information is due at least two weeks before the start of the appropriate Network session. For a non-Network project, this information is due by the schedule file due date assigned by Barry Clark.

Although VLA Operations fully supports absentee VLBI observing, visits by observers are welcomed and are especially encouraged if the observations are in any way atypical. Included in this category are VLBI spectral line projects regardless of recording format, and any phased-array VLBI projects for which radio frequency interference is expected.

For more information, consult "VLBI at the VLA".

4.12 VLAPLAN

VLAPLAN and VLAUVPL are MS-DOS PC-based tools to help continuum and line observers design VLA proposals and observing strategies.

VLAPLAN does basic calculations needed when designing an observation to produce a given image quality and sensitivity within the restrictions imposed by the VLA hardware. VLAPLAN is a spreadsheet that lets you adjust imaging parameters interactively while seeing their consequences for VLA configuration selection, bandwidth, total integration time and other critical parameters. The program warns of conflicts between the imaging parameters and the VLA's hardware capabilities, and suggests strategies for removing such conflicts. It also plots context-sensitive graphs of the bandwidth and time-average smearing effects, primary beam correction and Gaussian source visibilities. For L Band observing, it warns of conflicts with persistent RFI signals.

VLAPLAN has menu-based documentation to guide your choice of parameters and to help you learn its capabilities. It consolidates numerous graphs and algorithms that are useful when designing observations but which originate from many different documents. These documents include the lecture "Synthesis Observing Strategies" from the NRAO Summer Schools on Synthesis Imaging, VLA Scientific and Test Memoranda, the NRAO Newsletter, the VLA Observational Status Report and the Introduction to the NRAO VLA (the "Green Book").

Starting with Version 2.0 (May 1994), VLAPLAN is available as a stand-alone MS-DOS executable that does not require a separate spreadsheet program as a host. It is still available as a worksheet template that can be run under Lotus 1-2-3, Borland Quattro, or any other spreadsheet program that reads Lotus .WK1 format and macros. The stand-alone and worksheet forms of VLAPLAN use the same menus to lead you through the basic calculations and to document the required input parameters. VLAPLAN can therefore be used without much prior experience of spreadsheets.

VLAPLAN recommends the most compact configuration for your observing based only on the observing frequency and the largest angular size and declination of your source. To do this quickly, it uses a table of the shortest projected baselines in snapshots on the meridian. VLAUVPL is an ancillary program to help you choose configurations and sampling for longer observations. It plots u,v tracks for the innermost and outermost antennas, and other graphs that help you refine your choice of configuration when working off-meridian. It is also available both as a stand-alone program and as a worksheet template.

Both programs and their documentation can be obtained by anonymous-ftp from the /pub/vlaplan directory on zia.aoc.nrao.edu. Paper documentation is available as VLA Computer Memorandum No. 187.

4.13 VLAIS and Mosaic

There are two sources of on-line information about the VLA. First, there is a simple information system, VLAIS, on the Zia computer system in Socorro, New Mexico. The information in the system is oriented towards VLA observers and contains data on baseline corrections, system temperatures, list of VLA calibrators and VLA archive sources and other VLA related items. Access to this system is by Internet (address 146.88.1.4) or through the NRAO Socorro terminal switch (505 835 7010). At the login message for Zia type vlais (no password required). A menu will list the major categories available. Choose VLA to get to the VLA specific information.

Second, NRAO-wide information is available via the NCSA Mosaic program. If you have mosaic available locally, use the URL http://info.aoc.nrao.edu/ to point towards the NRAO Home Page. VLA and AOC specific information is available from the Home Page.

5 MISCELLANEOUS

5.1 VLA Archive Data

A directory of the VLA archive data is available in ten reports, covering the eleven years 1981 (09/81–12/81), through 1992. Hardcopy versions are available from the VLA/VLBA Director's secretary and in all NRAO libraries. There is also an IBM PC program (VLASORS) that can be used to search the archive source list. The data and program are available for IBM PCs, with at least 4MB disk space, from the VLA/VLBA Director's secretary. A version of the archive list is available by anonymous `ftp` to zia.aoc.nrao.edu in the pub/vlasors subdirectory. It is also available on-line in the VLA information system (see Section 4.13).

Archive data taken prior to 1988 cannot be read by the AIPS task `FILLM`. A general-purpose program has been developed to reformat all old data. To obtain reformatted tapes of archive data, call the Data Analysts.

The NRAO is currently converting all old VLA data to the current, modern data format, and archiving it on high density Exabyte tapes. All data taken from 1976 through 1982 have now been converted. It is expected that this project will be complete by the middle of 1997. At that time, and possibly before, a comprehensive catalog of all observations will be available.

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 the following:

> *Eighteen months after the end of a VLA observation the raw (uncalibrated visibility) data will be made available to other users on request. Miller Goss or Barry Clark must first be notified. 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. VLA correlator data taken for VLBI observations are immediately available to all.*

5.2 Publication Guidelines

5.2.1 Acknowledgement to NRAO

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 coöperative agreement with the National Science Foundation.*

5.2.2 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.

5.2.3 Reprints

NRAO no longer distributes reprints, but will purchase the minimum number of reprints for NRAO staff members. The NRAO does not want reprints, and will not pay for any reprint costs for papers with no NRAO staff author.

5.2.4 Page Charge Support

The following summarizes NRAO's policy:

- When requested, NRAO will pay the larger of the following:
  - 50% of the page charges reporting original results made with NRAO instrument(s) when at least one author is at a U.S. scientific or educational institution.
  - 100% of the page charges prorated by the fraction of authors who are NRAO staff members.
- Page charge support is provided for publication of color plates.
- To receive page charge support, authors must comply with all of the following requirements:
  - Include the NRAO footnote in the text: "Operated by Associated Universities, Inc., under cooperative agreement with the National Science Foundation."
  - Send four copies of the paper prior to publication to Ellen Bouton in Charlottesville.
  - Notify Ellen Bouton in Charlottsville of the proposed date of publication and apportionment of page charges so that the necessary purchase orders may be initiated. Convenient ways to do this are to send her copies of the completed page charge form, or send her an e-mail message (library@nrao.edu), or call her by telephone at (804)-296-0254.

When filling out page charge forms, use the following information:

- Contact person for NRAO is Ellen Bouton, 804-296-0254.
- Billing address for both page charges and reprints is NRAO Fiscal Division at the Charlottesville address.
- Shipping address for reprints should be the NRAO author.
- On ApJ and AJ forms, cite the purchase order number as "NRAO blanket PO". For all other publications, call Ellen Bouton for a purchase order number.

6 DOCUMENTATION

Documentation for VLA data reduction, image making, observing preparation, etc., can be found in various manuals. Some manuals are available on-line via the Mosaic system (see Section 4.13). Those manuals marked by an asterisk (*) can be mailed out upon request. Direct your requests to Theresa McBride.

1. PROCEEDINGS FROM THE 1988 SYNTHESIS IMAGING WORKSHOP: Synthesis theory, technical information and observing strategies can be found in: "Synthesis Imaging in Radio Astronomy". This collection of lectures given in Socorro in June 1988 has been published by the Astronomical Society of the Pacific as Volume 6 of their Conference Series. It is currently out of print, and we are unaware of any plans for a second printing.

2. 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. Major sections of the 1983 manual are now out of date, but it nevertheless remains the best source of information on much of the VLA. Copies of this are found at the VLA and in the AOC, but no new copies are available.

3. *A SHORT GUIDE FOR VLA SPECTRAL LINE OBSERVERS: This is an important document for those wishing to carry out spectral- line observations with the VLA.

Table 14: **List of Key VLA Personnel**

Name	Phone	Room	Notes
Dave Adler	835-7272	AOC 208	AIPS Support
Durga Bagri	7216	182	Technical advice, 327MHz observing
Tim Bastian	7259	318	Solar Observing
Carl Bignell	7242	344	Head of Operations
Eli Brinks	7029	206	Spectral Line Observing
Bill Brundage	7120	188	Head of Electronics, RFI
Barry Clark	7268	308	Scheduling
Mark Claussen	7284	268	VLBI, Spectral Line
Tim Cornwell	7333	362	Imaging, Computing, Operations
Vivek Dhawan	7378	310	VLBI, RFI Monitoring
Phil Diamond	7365	306	VLBI, AIPS
Chris Flatters	7209	208	AIPS
Dale Frail	7338	360	Pulsars, HTRP Support
Miller Goss	7300	336	VLA/VLBA Director
Phil Green	7294	252	Networking
Tim Hankins	7326	278	Pulsar Observing, HTRP
Kevin Healey	7359	204	Remote Observing, User support
Phil Hicks	772-4319	VLA 220	VLA Chief Operator
Bob Hjellming	7273	326	Stellar Observing
Mark Holdaway	7306	356	Polarimetry, SDE Package, Imaging
Eileen Latasa	7357	218	Visitor Registration and Accomodations
George Martin	7287	373	Real-time Observing
Theresa McBride	7245	267	Documentation
Ruth Milner	7282	342	Head of Computing Systems
Peter Napier	7218	250	Technical advice
Frazer Owen	7304	320	Polarimetry, High dynamic range
Rick Perley	7312	362	Calibration,Imaging, low-freq.
Michael Prewitt	7213	252	Computing Systems Manager
Sue Prewitt	7238	204	User Assistance
Terry Romero	7315	330	Visitor Support
Ken Sowinski	7299	375	On-Line Systems
Jon Spargo	7305	258	Computer Support, Reservations
Dick Sramek	7394	328	Electronics Problems
Meri Stanley	7359	204	Remote Observing, User support
Juan Uson	7237	358	327MHz, Spectral Line Observing
Jacqueline van Gorkom	7375	300	Spectral Line Observing (Summer Only)
Gustaaf van Moorsel	7396	348	AIPS, Spectral Line, Computing Head
Dave Westpfahl	7225	373	Spectral Line Observing
Doug Wood	7398	309	Spectral Line Observing
Wes Young	7337	378	OBSERVE