

VLA Computer Memorandum No. 187

VLAPLAN

VLA OBSERVING STRATEGY PLANNER

Version 2.0
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PREFACE

This document is a User's Guide for VLAPLAN and VLAUVPL -- MS-DOS PC software to help continuum and line observers design VLA proposals and observing strategies. It supersedes VLA Computer Memorandum No. 179.

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").

Some VLA users have asked for an "expert system" to design observations. This is not such a system. You must still decide for yourself how to trade off image quality, observing time and data volume when planning an observation. VLAPLAN seeks only to make it easier to assess such tradeoffs, by monitoring the most important consequences of any proposed change in your imaging parameters.

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`.

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THE DISTRIBUTION FILES

The distribution files available by anonymous-ftp from the */pub/vlaplan* subdirectory on the server *zia.aoc.nrao.edu* in Socorro are:

VLAPLAN2.ZIP	Lotus 1-2-3 WK1 format worksheet for VLAPLAN in ZIP compressed format. Needs separate spreadsheet program to run.
VLAPL2XE.ZIP	Stand-alone executable version of the VLAPLAN spreadsheet, also in ZIP compressed format.
VLAPLTX.T.ZIP	ZIPped version of this document as ASCII text.
VLAPLPS.ZIP	ZIPped version of this document as PostScript.
VLAUVPL3.ZIP	VLAUVPL in Lotus 1-2-3 WK1 format, ZIPped.
VLAUV3XE.ZIP	Stand-alone executable version of VLAUVPL, ZIPped.

This software can be run on any MS-DOS PC or clone with a graphics board. MS-Windows users with a 386 or above should run it in a DOS window under 386 enhanced mode.

If you do not have a spreadsheet program (Lotus 1-2-3, Borland *Quattro*, etc.) that can read and execute worksheets in Lotus 1-2-3 .WK1 format, then you must use the stand-alone executable versions of VLAPLAN and VLAUVPL. With the stand-alone version, only the appearance of the programs' text and graphics outputs can be changed, not their underlying calculations.

If you have a suitable spreadsheet program to host VLAPLAN and VLAUVPL, you may prefer to use the worksheets in directly in .WK1 format, as you can then modify or extend them to perform other calculations or to use different parameters.

The distribution files have been ZIPped with PKWare's Zip Version 2.04g, and may be unZIPped with any DOS or Unix UNZIP utility compatible with this. If you do not have such a utility already, download and run UNZIPPER.EXE from */pub/vlaplan* to acquire a freeware UNZIP and its documentation.

HOW TO INSTALL THE PROGRAM AND CHECK SETTINGS

A. Stand-alone executable VLAPLAN.EXE

This runs directly under MS-DOS (without a host spreadsheet program). Only the input data fields may be edited. The formulas and internal macros used by the program are invisible. You may save your input data to disk as .WKB files for later editing, or to serve as defaults for other observing runs. In a PC without EMS, VLAPLAN requires about 490k of conventional RAM. If EMS is available, this is reduced to 442k. If you normally run TSR's that reduce the available conventional memory below these levels, un-install them before running VLAPLAN.

First unZIP VLAPL2XE.ZIP to get VLAPLAN.EXE and VLAPLAN.WKB.

Copy VLAPLAN.EXE and VLAPLAN.WKB to the disk and directory in which you want to run VLAPLAN. To start the program, enter the command VLAPLAN at the DOS prompt from this directory, or with this directory in your search path.

You should see a banner screen while the program is loading, and a "title screen" with basic instructions about VLAPLAN's menus once the program has loaded. A "READY" message should be present at the bottom right corner.

The top row of the screen should show VLAPLAN's "system menu", with entries for **File**, **Graph**, **System**, **Video** and **Quit**. Type / to access this menu. Items from this and other menus may be selected either with the cursor arrow keys or by typing their high-lighted letter, or with a mouse if you have one. Use the **ENTER** key or left mouse button to enter a selection, the **ESC** key or right mouse button to move back (up) a level in the menu. (See page 10 for details about the system menu).

If VLAPLAN's default colors are hard to read on your display, adjust them as follows. The **Video** menu lets you select any of three palettes. Use the **Color** palette for normal color monitors, the **LCD/BW** palette for laptop LCD displays, and the **Mono/Herc** palette for monochrome or Hercules adapters. You may change the color settings (background, foreground, blinking) of 32 elements of VLAPLAN's displays in each palette. Once you find suitable settings, use the **File Save** option in the **Video** menu to save them to disk as a named .VID file. (The current state of all three palettes is saved). Use **Video File Load** to retrieve these settings when VLAPLAN is run again.

Read VLAPLAN's title screen, then press **Home** to reach the **Continuum Summary** Screen with the pre-loaded data from VLAPLAN.WKB. In this and other screens, highlighted items show parameters that you must specify. The **ALT** keys referred to by each item will invoke windows or menus that will let you specify the associated parameter. All other variable values shown are calculated "on the fly" as soon as you change any input parameter.

To check that your graphics display is compatible with VLAPLAN's graphs, press **ALT-T** to view the time-average smearing graph with VLAPLAN's default input parameters. VLAPLAN is designed to query your hardware and adjust its displays accordingly. I have tested it on PC's ranging from bargain-basement notebooks with LCD displays and CGA graphics to desktop 486's with Super-VGA cards. I have also tested it with the SoftPC/VGA emulator for SPARC stations. The number of hardware combinations available to me is limited, however. So if VLAPLAN does not draw graphs satisfactorily on your PC hardware, please contact me (see Appendix B).

After this initial check-out, you are ready to get to work with VLAPLAN. Move on to the section on "How to use this program".

B. Lotus 1-2-3 worksheet VLAPLAN2.WK1

The main VLAPLAN code is contained in a Lotus 1-2-3 Version 2 format worksheet file VLAPLAN2.WK1. Run under a host spreadsheet program, this provides the same functionality as VLAPLAN.EXE if you leave its global protection enabled. The formulas and macros will also be visible if you access them via the spreadsheet program's utilities. Unlike the stand-alone version, which is secure, or "frozen", all aspects of VLAPLAN's program -- text, formulae, tables and macros -- can be modified (wittingly or otherwise!) if you turn off worksheet's global protection.

First unZIP VLAPLAN2.ZIP to obtain the worksheet VLAPLAN2.WK1.

Copy VLAPLAN2.WK1 to the disk and directory where you normally keep Lotus worksheets, and start 1-2-3 in its 25-line display mode. When you use the 1-2-3 **File Retrieve** command (**/FR VLAPLAN2**) to load the worksheet, VLAPLAN's title screen (cell AA101) should appear as soon as the file has loaded.

Press **HOME** to view the *Continuum Summary* screen. Some cells should be highlighted (unprotected) if you have a color monitor or a color-compatible LCD display. If you have color capability but no cells are highlighted, you may have received a copy of the worksheet from which the global protection has been removed. In this case, use **Worksheet Global Protect Enable (/WGPE)** to protect it, and **File Save (/FS VLAPLAN2)** to save the protected version, before proceeding.

If you see the top few lines of the *Line Summary* screen when you press **HOME**, re-adjust your screen set-up to give a 25-line display. All VLAPLAN's calculation screens and help files are 20 lines deep, so they will be confusing to read if you display more than 20 spreadsheet lines at once.

Press **ALT-T** to view the *Time Average Smearing Graph*. Check that axis labeling is legible and sensible. The settings stored in the worksheet work reasonably well on CGA, Hercules and VGA graphics boards that I have used. But if those you have received are inappropriate, use the 1-2-3 **/G (Graph)** menu to define new setups for the named graphs AVTIME, BANDWIDT, GAUSSVIS, PBCOR and RFILBAND, save your settings with **/GNC AVTIME**, etc., and then save the worksheet to disk with **File Save (/FS VLAPLAN2)**.

After this initial check-out, you are ready to get to work with VLAPLAN. Move on to the section on "How to use this program".

VLAUVPL3.ZIP delivers VLAUVPL3.WK1, an optional extra worksheet for plotting u,v tracks (see the section below on VLAUVPL).

Borland Quattro Users

As a stand-alone version of VLAPLAN is now available, I will only prepare the worksheet in the old but portable (Lotus Version 2.2) .WK1 format which can be used with many versions of Quattro.

The VLAPLAN and VLAUVPL .WK1 worksheets contain macros that must be used with Quattro in its 1-2-3 command mode. Most early versions of Quattro that support this mode can run the .WK1 worksheets "as is". But recent versions do not support 1-2-3 command mode, as a result of a lawsuit. If you have such a later version, you should run the stand-alone version of VLAPLAN unless you are willing to convert the worksheet as described below.

The .WK1 format does not support Quattro graphics setup commands. You

should therefore load VLAPLAN2.WK1 "as is" under *Quattro*, then look at the displays produced by the default settings. Whether or not they are agreeable may depend both on your taste and on your version of *Quattro*. If necessary, set your own colors, grid and axis defaults for each of the named graphs: AVTIME, BANDWIDT, GAUSSVIS, PBCOR and RFILBAND. To do this, type **/GNU** followed by the graph name, and use the *Quattro* Graph Menu to adjust the displays to your satisfaction (you may need, for example, to reset *Quattro's* Y-axis scaling of PBCOR to *Manual*, with a lower limit of 1). After adjusting each graph, store its settings with **/GNC** followed by the graph name. Finally, save the modified spreadsheet in .WKQ format with **File Save (/FS VLAPLAN2.WKQ)**, and work with the .WKQ file rather than the .WK1 file in future.

If you decide to use VLAPLAN2.WK1 with *Quattro* in its native (not 1-2-3) mode, you must modify other macros to handle differences between the graph and print menu commands in 1-2-3 and in *Quattro*. For example, the macros invoked by **ALT-B**, **ALT-P**, **ALT-Q**, **ALT-T** and **ALT-V** in VLAPLAN2.WK1 use the Lotus 1-2-3 command **Graph Name Use (/GNU)** to load named graphs. You must remove cell protection in *Quattro* with **/DPD (Default Protection Disable)** and change these macros (at locations AB13, AD13, AF13, AH13 and AJ13) to the *Quattro* equivalent: **Graph Name Display (/GND)**. Then set colors and axis defaults for *Quattro* as described above. If you also wish to use the **ALT-Y** feature of VLAPLAN to print out parts of the spreadsheet, you must convert the macros in AB79-81, AC79-83, AD79-82 and AE79-82 to their default *Quattro* equivalents (see the *Quattro* Reference Manual for the syntax). This is a tedious job, so I strongly recommend running in 1-2-3 command mode if your *Quattro* supports it. But if you do it, do not forget to protect the worksheet with **/DPE (Default Protection Enable)** and save it as VLAPLAN2.WKQ before executing further commands under *Quattro*! Do not save it in .WK1 format, in case you mistakenly load it into 1-2-3 later; for example, 1-2-3 interprets **/GND** as **Graph Name DELETE!**

To run VLAUVPL3.WK1 under native *Quattro*, you should change **/GNU** to **/GND** at locations B114, B119, B124 and D124, then re-save this worksheet, for similar reasons.

HOW TO USE THIS PROGRAM

This program makes calculations to assist planning of VLA observing strategies. It is intended for use when writing VLA proposals and/or when beginning to design a VLA observing program in detail. It will help you to choose observing parameters to minimize image distortions, observing time and total data volume in ways that meet the restrictions imposed by the VLA hardware.

The *Continuum Summary* and *Line Summary* screens prompt you for the basic VLA observing parameters, and compute various important quantities from them. Changing any input parameter recalculates all related quantities.

Input parameters are changed by using the **ALT**-keys, as indicated on the screens that display the parameters. Use the *Summary* screens to explore options and to get a feel for how the project strategy depends on your input choices. Watch for warning messages about your parameters (press **ALT-W** for a summary of warnings). **ALT-K** can be used at any *READY* prompt (see below) to review the current settings of all of your input parameters.

Other screens give details of subsidiary calculations. Press **ALT-M** for a menu of such calculations. Other **ALT**-keys are used to change input values or to plot useful graphs while reviewing these subsidiary calculations. **ALT-K** lists the special keys and menus.

Unless you have used *Lotus 1-2-3* or *Quattro*, you may need to allow yourself a little time to explore VLAPLAN's menu and command system before planning your first observing session with this program. First-time users should watch the "indicator light" (top right under *1-2-3*, bottom right in the stand-alone VLAPLAN or under *Quattro*) carefully. It shows important program status information, including:

- READY** -- Program is ready for the next data entry or command
- MENU** -- A command menu is being displayed; you must make a selection or press **ESC** to leave a menu level
- VALUE** -- You are entering a number; use **backspace** to edit, **<CR>** to enter, **CTRL-BREAK** to abort.
- ERROR** -- An error has occurred; press **ESC** or **<CR>** to clear it

Beginners should select menu items by using the arrow keypad to point at (highlight) items, then hitting **<CR>**. A one-line explanation appears immediately above the spreadsheet as each item is highlighted. If you use the stand-alone program with a mouse, you may also select items from the current menu by pointing at them with the mouse cursor and tapping the left mouse button once. (The right mouse button is equivalent to the **ESC** key). Experienced users may prefer to select familiar items directly by typing their initial letters.

The *Help* menu (**ALT-H**) can be used to access various levels of text that should make the program self-documenting. As well as the text you are now reading, there are explanatory pages for each input parameter (**ALT-H,I**), and for each major element of observing strategy (**ALT-H,S**). (**ALT-H,N**) tells you how to get information from NRAO about VLA proposals, hardware and software.

ORDER OF ATTACK

A. Overview

1. Enter parameters in the order in which they are listed on the *Continuum Summary* and *Line Summary* screens (key **HOME** and **PgDn** to see these screens). Watch for warning messages as you enter values, and by using **ALT-W**.

2. Use **ALT-M** to see further details of critical calculations, **ALT-H** to get advice about inputs. Watch for warning messages while iterating parameters.

3. Review your final parameter choices on the *Summary* screens and check again for warning messages with **ALT-W**.

The next five sections outline the main calculations, each of which corresponds to a screen in the **ALT-M** menu. The program's **ALT-H** menu gives much more detailed advice than is given here.

B. Choose VLA configuration(s)

Three main parameters are needed:

1. *Observing Frequency*

For continuum work, choose this from astrophysical considerations, e.g. for polarimetry, or choose it for optimum sensitivity or phase stability. For line work, choose it from the rest frequency and systemic velocity.

2. *HPBW of Synthesized Beam*

Choose this to balance the resolution of fine detail against the detection of extended emission. The HPBW sets the *longest* baseline you must use at a given frequency, and hence the *widest* VLA configuration in which you must take data.

3. *Largest Angular Structure to be Imaged*

This sets the *shortest* baseline you must use, and thus the most compact VLA configuration in which you must take data. The baseline used by the program to recommend the configuration(s) is that by which a Gaussian with $FWHM=LAS$ falls to half its peak amplitude in the u,v plane. Use **ALT-M,R** to see details of the *Resolution and Configuration* calculation and/or **ALT-V** to see the visibility of the Gaussian as a function of baseline length. The declination dependence of the VLA's shortest baseline is conservatively accounted for by assuming that the baseline is that of a meridian snapshot. To explore baseline foreshortening at large Hour Angles, use the *VLAUVPL* worksheet.

C. Balance Field of View Restrictions

Point sources away from the delay tracking center are attenuated and smeared by finite IF bandwidth (chromatic aberration). Both effects increase with bandwidth and with angle from the delay tracking center. You specify an acceptable loss of point source amplitude at a maximum field radius (*MAX*); the program recommends a maximum bandwidth. Time averaging also smears and attenuates remote point sources by amounts depending on baseline, Hour Angle, and Declination. The program estimates (a) the averaging time that will, on average, distort the image at *MAX* radius as much as your chosen IF bandwidth, and (b) the averaging time that meets your "acceptable distortion" parameters. Estimate (a) is usually reasonable for continuum work; (b) is usually better for line work. Use **ALT-M,F** to review details.

D. Specify Sensitivity and Find Total Integration Time

Once bandwidth and averaging time are set, the target rms noise level sets the total on-source integration time, and thus the size of the data base. Use **ALT-M,S,C** to review details.

E. Spectral Line Observing

There are three screens specific to spectral line observing.

1. *Line Summary*

This screen can be invoked with **ALT-M,L** or with **PgDn** from the *Continuum Summary*. It shows the primary observing parameters and displays the restrictions on the numbers of channels and on averaging time, given the values of parameters already specified. It is possible to specify all line observing parameters from this screen alone, but also useful are the screens for:

2. *Spectral Line Channels*

This screen explicitly lists the options for spectral line channelization, given a choice of total bandwidth. It calculates the total velocity span and channel velocity resolution for your input parameters. It also warns of VLA computer rules that restrict the choice of averaging time. It is invoked with **ALT-M,N,L**.

3. *Spectral Line Sensitivity*

This screen examines both the "continuum" (all channels combined) and individual channel sensitivities and integration times, including surface brightness sensitivity. It is invoked with **ALT-M,S,L**.

F. Bandwidth Synthesis (optional)

ALT-M,N,B invokes a screen to assist design of continuum experiments that use the spectral line correlator to image wide fields of view at high total IF bandwidth with minimal distortion. It lists the hardware restrictions on the number of channels; it also gives data on bandwidth smearing per channel, on the averaging time equivalent to the per-channel smearing, and on the total integration time needed to reach the target rms with the full bandwidth (summing all channels).

SPECIAL KEYS AND MENUS

A. ALT-keys

The following can be used at any *READY* prompt:

1. Data entry keys (use **CTRL-BREAK** to abort data entry)

Key	Parameter name (units)
ALT-A	prompts for Vis. averaging time (sec)
ALT-C	calls a menu for Number of line channels
ALT-D	prompts for Distortion limit (%)
ALT-E	prompts for Source declination (degrees)
ALT-F	prompts for Observing frequency (GHz)
ALT-G	prompts for Largest Gaussian FWHM (")
ALT-I	calls a menu for IF Bandwidth (MHz)
ALT-J	prompts for Self-cal flux density (mJy)
ALT-L	prompts for Rms (line channel, mJy)
ALT-R	prompts for Rms (continuum, mJy)
ALT-S	prompts for Self-cal averaging time (sec)
ALT-X	prompts for Maximum field radius (")
ALT-Z	prompts for Synthesized HPBW (")

2. Menu Keys (use **ESC** to abort menu selection)

ALT-H calls a menu to select HELP text
ALT-M calls a menu to select CALCULATION screens
ALT-Y calls a menu to select PRINTOUTS

3. Direct Screen Selection Keys

HOME shows *Continuum Summary*; then **PgDn/PgUp** --> *Line/Cont Summary*
ALT-K displays first page of two-page KEY listing
ALT-W displays a summary of WARNING messages about your parameters

4. Graph Selection Keys (hit any key to resume once graph displayed)

ALT-B graphs the BANDWIDTH smearing effect with current parameters
ALT-P graphs the PRIMARY beam correction out to 2*MAX radius
ALT-Q graphs known L-Band RFI signals and the chosen Observing Band
ALT-T graphs the TIME-average smearing effect with current parameters
ALT-V graphs the VISIBILITY of a Gaussian (FWHM=LAS) vs baseline (km)

B. System menu

In both the stand-alone and spreadsheet-hosted versions of VLAPLAN, a "system menu" can be invoked by pressing the / key at any *READY* prompt. The system menu does not access calculations or present any results that cannot be accessed more simply by using the ALT-keys described above. VLAPLAN is designed to be used without invoking the system menu while actually planning an observation.

In the stand-alone version, you will need the system menu only when saving inputs or settings to disk, when modifying the appearance of VLAPLAN's displays, or when exiting VLAPLAN. In the spreadsheet-hosted version, you can use the system menu to alter VLAPLAN's program (after removing the global

protection). To do so, you will need to understand Lotus 1-2-3 formulas and macro language, topics that are beyond the scope of this document!

The stand-alone version of VLAPLAN has the following facilities in its system menu. Once the system menu is activated by the / key, these items can be accessed either by moving the cursor with the arrow keys or by typing their first letters, as indicated beside each command below. Use the **ENTER** key to enter a selection, the **ESC** key to go back (up) a level in the menu.

File	/F	
Get	/FG	loads inputs to VLAPLAN from a file on disk
Save	/FS	saves inputs to VLAPLAN to a file on disk
Dir	/FD	changes directory used to save/get such files
Graph	/G	
View	/GV	displays currently selected named graph (function key F10 at <i>READY</i> prompt also does this)
Options	/GO	invokes menu to change graphing options
Titles	/GOT	changes titles above graph
Grid	/GOG	changes display of horizontal/vertical grids
Scale	/GOS	changes scaling and display of axes vis sub-menu
Color	/GOC	displays graphs using color to distinguish points
BW	/GOB	displays graphs entirely in black-and-white
Name	/GN	invokes menu to store/restore named graph set-ups
Use	/GNU	to use a previously named graph set-up
		AVTIME gives result of ALT-T (averaging-time loss)
		BANDWIDT gives result of ALT-B (bandwidth smearing)
		GAUSSVIS gives result of ALT-V (visibility plot)
		PBCOR gives result of ALT-P (primary beam corr.)
		RFILBAND gives result of ALT-Q (L Band RFI plot)
Create	/GNC	to save current graph set-up under a new name e.g. after changing parameters with Graph Options menu
Quit	/GQ	return to <i>READY</i> mode
System	/S	exit temporarily to MS-DOS system, return later
Video	/V	
Color	/VC	invokes menu to adjust items on color displays
LCD/BW	/VL	invokes menu to adjust items on LCD displays
Mono/Herc	/VM	invokes menu to adjust items on monochrome displays
File	/VF	invokes menu to load/save above three video palettes
Quit	/VQ	return to <i>READY</i> mode
Quit	/Q	exit permanently to MS-DOS system

The spreadsheet-hosted version offers the above facilities without (in general) the Video items. It also offers more detailed customization options that can be used to redesign all aspects of the program.

Note that in the stand-alone version the **File Save (/FS)** command saves only the numerical inputs and graph set-ups for VLAPLAN, in a .WKB file that is in .WK1 format but which is not a fully functioning worksheet. In the spreadsheet-hosted version, the File Save option saves the entire worksheet structure, in the format selected by the host spreadsheet program.

Note also that if you create new graph set-ups that you wish to re-use in future runs of VLAPLAN, they must be saved to disk using **File Save (/FS)**. "Creating" a named graph set-up with **/GNC** does not save it to disk. It merely lets you refer to the set-up by name during the current VLAPLAN session. All graph set-ups are saved in the file written by the **File Save** command, however.

DETAILS ABOUT INPUTS

The following sections repeat *Help* screens from the spreadsheet.

*Observing Frequency (GHz)***(ALT-F)**

The frequency bands for which the VLA is (almost) fully instrumented are tabulated below, with their VLA band designations and *S* -- the rms noise per correlator in 10 seconds, referred to a nominal 50 MHz bandwidth). For 40-50 GHz information, see the Q Band menu **(ALT-H,Q)**.

Frequency Range	Band	<i>S</i>
0.298 - 0.345 GHz	P Band	87 <--- N.B. only 3 MHz usable band
1.25 - 1.80 GHz	L Band	15 <--- for new (1994) receivers
4.25 - 5.1 GHz	C Band	21
7.55 - 9.05 GHz	X Band	14.5
14.25 - 15.7 GHz	U Band	53
21.7 - 24.5 GHz	K Band	112 <--- (1988 upgrade)

"Frequency range" is for 3db loss of sensitivity. P and L Bands may be affected by strong interfering signals, especially in the more compact VLA configurations. Consult the VLA Frequency Coordinator before making final frequency choices in these bands. Interference is rarely detected or suspected at the higher frequencies.

*Synthesized Half-Power Beamwidth - HPBW (arc seconds)***(ALT-Z)**

Enter the HPBW that you will use at the MAXIMUM resolution for which you need to collect data. Lower HPBW's may be obtained by tapering the data. UNIFORM weighting in the *u,v* plane and dense *u,v* coverage is assumed. Snapshot observations may have beamwidths that are 20% or more larger than those of full coverage. The HPBW also depends on declination, but this can be ignored to first order when planning an observing strategy.

Note that you will separately enter *LAS*, the largest angular size of structure that you wish to image. If HPBW and *LAS* are very different, the program may suggest the use of more than one VLA configuration. You may wish to adjust parameters so that the project can be done in one configuration (and thus in one observation). Consult the *Resolution and Configuration* screen **(ALT-M,R)** for assistance.

The program will claim that you need VLBI if you input a smaller HPBW than the VLA can provide at your frequency. Check the *Resolution and Configuration* screen if this occurs; your HPBW may not be far off!

*Largest Angular Scale to be Imaged - LAS (arcsec)***(ALT-G)**

Enter the full width to half maximum of the largest circular Gaussian emission region that you need to image. The program calculates the baseline length (km) at which the visibility function of such a region falls to half its maximum value at your observing frequency, and uses this to estimate the shortest baseline that should be present in your data. If you prefer another criterion, press **ALT-V** to plot visibility against baseline length in km, then adjust criterion accordingly.

The program estimates the most compact configuration quite conservatively from the shortest baseline at H.A. 0 at the next-lowest 10-degree Dec. to your source; it does not account for baseline foreshortening off the meridian. To do this, examine VLA u,v plots for your H.A. range and Dec. (e.g. via VLAUVPL). Then ask if foreshortened baselines in the next widest configuration provide the "Shortest Baseline" estimated (a) by the *Resolution* screen (**ALT-M,R**), or (b) by you from an **ALT-V** plot.

Note: *LAS* is the diameter of the largest structural scale to be imaged, not the field over which you wish to image point sources correctly.

*Maximum Radius of Field with Minimal Distortion***(ALT-X)**

Enter the radius in arcsec from the delay tracking center to which you will need to image point sources with minimal distortion by bandwidth smearing (chromatic aberration) or time-average smearing.

This parameter, together with the "acceptable distortion" parameter, will determine the maximum IF bandwidth and data averaging time for many continuum observations. You may wish to consider displacing the delay tracking center away from your prime target toward other interesting sources in order to minimize the value of *MAX*.

Note that *MAX* will normally be greater than about $0.5 \cdot LAS$, the radius of the largest structural scale that you need to image in your target source. (An exception to this rule occurs when the outer parts of your target source contain no structure whose scale is smaller than the broadened response, so are not noticeably distorted by the additional smearing).

Acceptable Distortion - % reduction in point source response (ALT-D)

This parameter specifies how much distortion due to bandwidth smearing (chromatic aberration) or time-average smearing you can accept at the angular radius from your image center specified by *MAX*. These two parameters together determine the maximum IF bandwidth and data averaging time for many continuum observations.

The distortions produced by bandwidth and time-average smearing reduce and broaden the responses to point sources (preserving the integrated flux densities so long as the effects remain fairly small). Bandwidth smearing broadens the point source response radially away from the delay tracking center. Time average smearing acts azimuthally round the phase tracking center for a source at the pole.

The program measures the effect by the reduction in amplitude of the point source response. You specify an acceptable percentage loss, *m*%, so that the peak response $I = I_0 * (1 - m/100)$ where *I₀* would be the peak response in the absence of bandwidth or time-average smearing. Values in the range 1-10% are tolerable for many applications.

IF Bandwidth (MHz) (ALT-I)

You must select a standard VLA bandwidth, in MHz (ALT-I gives a menu).

The choice of bandwidth is a tradeoff between sensitivity needs (which call for large bandwidths), bandwidth smearing effects (which may call for small bandwidths in continuum work) and velocity coverage in line work. You are likely to experiment with balancing your choices of IF bandwidth, data averaging time, and total integration time against VLA observing restrictions and overall data set size.

The *Continuum Summary* screen recommends an IF bandwidth based on your field of view and distortion parameters. Continuum observers should normally begin by entering this recommended bandwidth.

The *Line Summary* screen does not recommend an IF bandwidth because in most line projects the effects of chromatic aberration are determined by the single-channel bandwidth, so are small. The total IF bandwidth is determined by the need to span line profiles and to include off-line continuum, balanced against correlator and computing restrictions.

*Data Averaging Time (sec)***(ALT-A)**

This specifies how long the visibility data are averaged before being recorded. The choice of averaging time is a tradeoff between minimizing distortions far from the phase-tracking center, preserving the ability self-calibrate atmospheric fluctuations, and keeping the total number of visibility records within reasonable bounds. The first two criteria ask for short averaging times; the last for long ones. The program will warn you if you set the averaging time > your expected selfcal time.

For continuum work, the averaging time will usually be set by the need to minimize distortions. Averaging times longer than 60 sec are rarely appropriate, as they restrict the ability to edit calibrator scans, which are often only about a minute long for sensitivity reasons.

For line work, the averaging time may need to be longer than desirable to reduce distortion and to follow atmospheric fluctuations, because of limits to data set sizes that can be processed in off-line computers. Limits set by the VLA correlator depend on the number of line channels, and are shown (and checked) in the *Line Summary* and *Warning* screens.

*Number of Spectral Line Channels***(ALT-C)**

The number of line channels must be a power of two and should be chosen from the menu invoked by **ALT-C**. The VLA correlator hardware couples the options for numbers of line channels to (a) the total IF bandwidth, (b) the number of separate IF's recorded and (c) whether or not on-line Hanning smoothing is performed. Use the *Spectral Line Channels* screen (invoked by **ALT-M,N,L**) to review the range of choices. N.B. the program tells you the number of channels for a Single-IF experiment. The VLA correlator also allows this total to be split evenly among 2 or 4 IF's. The VLA correlator also imposes some restrictions on the choice of averaging time as a function of the number of line channels. Your final selection will be a compromise between these practical restrictions and the astronomical requirements for (a) adequate resolution per channel, (b) adequate spanning of the line profile, and (c) adequate sensitivity (consult the screen invoked by **ALT-M,S,L**).

Use the *Line Summary* and *Spectral Line Channels* screens to experiment with different choices and their consequences. The *Line Summary* screen will warn of "illegal" choices.

*Self-calibration parameters*1. *Self-cal Flux Density (mJy)* **(ALT-J)**

Enter the total flux density that you expect to be able to include in a model when self-calibrating the antenna gains. This will often be the flux density in the brightest point-like components, but may also include contributions from bright extended structure.

2. *Self-cal Averaging Time (seconds)* **(ALT-S)**

Enter the time for which you expect to average each solution for the antenna gains when self-calibrating. This should not exceed the expected atmospheric phase coherence time, and cannot be less than the visibility averaging time. A warning appears if you specify a self-cal averaging time less than the visibility averaging time!

The program will calculate the rms of the gain solutions in amplitude and phase within each self-cal averaging time. Use these to judge whether self-calibration can improve your data.

Bandwidth Synthesis parameters **(ALT-M,N,B)**

In the present context, "bandwidth synthesis" refers to using the VLA spectral line correlator to observe continuum sources in a number of narrow channels simultaneously. In this mode, the distortions produced by chromatic aberration are governed by the IF bandwidth of the single channels, whereas the sensitivity of the final image (assuming that it is made by summing over all the channels) is determined by the total IF bandwidth. Bandwidth synthesis thus lets you decouple the field of view and sensitivity constraints for continuum work, *subject to the same constraints on number of channels and averaging time as in spectral line work.* It is useful for wide field imaging at high sensitivity.

The *Bandwidth Synthesis Summary* screen, invoked by **ALT-M,N,B**, lists (a) the distortion due to chromatic aberration at the specified *MAX* radius on the individual channel images, (b) the constraints on the number of channels for the selected total bandwidth, (c) the constraints on the visibility averaging time from image distortion and from VLA computer rules (given the other selected parameters), and (d) the integration time and data set size required for your specified final sensitivity.

Q BAND (40-50 GHz) SYSTEM

By the end of 1994, 10 VLA antennas should be equipped with Q Band receivers. Current plans are to use these antennas on the inner pads of the more extended VLA configurations. The efficiencies of VLA antennas at Q Band are still being determined, but are expected to be about 17% at 43 GHz and much less at 50 GHz. The sensitivity calculations done in VLAPLAN assume that 10 antennas are in use, and adopt the 43 GHz sensitivity parameters.

The resolution calculations done in VLAPLAN assume that the antennas are on the inner pads of each configuration. If this is not true for your observing, you should use only the sensitivity and channelization parts of VLAPLAN, not those dealing with resolution.

Because the VLA Q Band system is new and under development, its status for observations, and the calculations that you should do to plan for them, may change from what is assumed in VLAPLAN. Be vigilant!

For the latest status of the VLA Q Band system, users should consult the document *qband.txt* in the */doc/vla/obstatus* directory on *zia.aoc.nrao.edu*. This document is available over the World-Wide-Web by connecting to the URL <http://zia.aoc.nrao.edu/doc/vla/obstatus/qband.txt>. For detailed advice on using Q Band, contact Doug Wood (dwood@nrao.edu) at the AOC.

SAVING YOUR WORK

You may save your input data at any time by using **/FS** to invoke the **File Save** item. You may retrieve a previously-saved set of inputs by using **/FG** to invoke the **File Get** menu item. (These commands are the same under either the stand-alone or spreadsheet-hosted versions of VLAPLAN.)

The data are saved in a worksheet file whose default name is VLAPLAN. It is this default filename whose contents will be loaded as inputs the next time you run VLAPLAN, so you may want to rename it as you save it, e.g. to L BANDCON for an L-Band continuum set-up, etc. Under the stand-alone program, the extension part of the output filename is **.WKB**. It saves the inputs as a Lotus 1-2-3 worksheet with only the changeable (input) fields filled in. Under a spreadsheet host, the entire worksheet (input data, output fields, formulas, text, macros etc.) is saved every time.

If your computer is connected directly to an ASCII printer, you can get hard (paper) copy of your inputs and their results, and parts of VLAPLAN's on-line documentation, using the printer menu invoked by **ALT-Y**.

VLAUVPL

VLAUVPL is a useful adjunct to VLAPLAN if your project is sensitive to the fine details of the inner or outer u,v coverage at large Hour Angles. Over much of the sky, baseline lengths may be significantly foreshortened by projection at large Hour Angles. You may therefore be able to use a single VLA configuration for a full synthesis observation of an extended source even when the shortest baseline on the meridian is a factor of two or three too long to sample the largest angular scale properly. In such cases, VLAPLAN may recommend multi-configuration observations because it is designed to be conservative, and considers only the baseline lengths that are available on the meridian. Realize, however, that the elevation is low when baselines are heavily foreshortened, and data quality at low elevations may be compromised by atmospheric phase fluctuations and attenuation (especially above 5 GHz).

VLAUVPL is used in the same way as VLAPLAN (either as the MS-DOS stand-alone VLAUVPL.EXE calling VLAUVPL.WKB or as a .WK1 worksheet under a host spreadsheet program). It has only one screen. This asks you whether to plot the u,v tracks of the innermost or outermost three VLA antennas, and for a specific VLA configuration, source declination and elevation limits.

Once you have specified the inputs, you must press **F9** to recalculate the baselines for your source as a function of Hour Angle. (Automatic baseline recalculation is turned off because it takes a while in the slowest models of PC and would otherwise be done as you enter every new parameter).

ALT-P graphs the tracks in the u,v plane on an absolute (km) scale.

ALT-H graphs u,v distance versus Hour Angle, labeling each point with the arms that contribute the plotted baselines.

ALT-V graphs u,v distance versus Hour Angle, labeling each point with its elevation angle.

ALT-L plots elevation angle versus Hour Angle.

The "system menu" for the stand-alone VLAUVPL parallels that for VLAPLAN (see page 10). Note however that the graphs in VLAUVPL are named UVPLOT, UVDIST, UVDIHAEL and ELEVHA respectively.

More complete VLA coverage plots can be generated in AIPS (see task UVSIM).

USEFUL REFERENCES

The following publications give more detail about VLA observing strategy and hardware. Recent updates of #2, #3 and #4 should be consulted for any changes to the VLA capabilities and observing restrictions. #5 is a general treatment of radio interferometry.

1. R.A.Perley, F.R.Schwab and A.H.Bridle (eds.), the NRAO Summer School on SYNTHESIS IMAGING, last published in 1989 by the Astronomical Society of the Pacific (Conference Series, Vol.6). Treats imaging issues in detail, both theoretically and practically.

Particularly relevant are Lecture 24, "Synthesis Observing Strategies", p.443-476, Lecture 13, "Bandwidth and Time-Average Smearing", p.247-258 Lecture 7, "Sensitivity", p.139-165 and Lecture 9, "Self-Calibration", p.185-197.

2. "VLA Observational Status Report", a summary of VLA capabilities, updated annually. Distributed by NRAO Socorro.
3. "NRAO NEWSLETTER", distributed quarterly by NRAO Charlottesville. Configuration Schedules, Proposal Deadlines, Hardware changes, etc.
4. "Spectral Line Users' Guide", distributed by NRAO Socorro. Users' manual for VLA Spectral Line System.
5. A.R.Thompson, J.M.Moran and G.W.Swenson, "Interferometry and Synthesis in Radio Astronomy", general text published by Wiley 1988.
6. The VLA World-Wide-Web home page. Using your WWW browser (e.g. Mosaic), connect to URL <http://zia.aoc.nrao.edu/doc/vla/html/VLA.html>

Acknowledgments

The stand-alone versions of VLAPLAN and VLAUVPL have been prepared from Lotus 1-2-3 originals using the Baler XE 2.0g spreadsheet compiler.

I thank Rick Perley, Bill Cotton, Tim Cornwell and Doug Wood for valuable comments and suggestions about VLAPLAN in its various incarnations.

APPENDIX A. Known Bugs in This Program

None known yet (but I'm waiting !)

APPENDIX B. How to Reach Me (Alan H.Bridle)
To Report Bugs, Make Comments, Etc.

Write to me at:

National Radio Astronomy Observatory
520 Edgemont Road
Charlottesville
VA 22903-2475, USA

Call me at:

804-296-0375 (always answered, either by me or machine)

Send E-mail to me at:

abridle@nrao.edu (InterNet)

FAX to me at:

804-296-0278

Please note that my support of this program does not imply that I will assume any responsibility for your VLA observing run itself! I offer this program without warranty, as an aid only. Use at your own risk! Bug reports and other comments/suggestions are most welcome, however.

APPENDIX C. Audit Trail

Version 1.0 (July 1988)

Tested by Charlottesville staff. Not generally released.

Version 1.1 (September 1988)

Added:

1. Built-in comparison of averaging time and self-cal time, with warnings.
2. Display maximum averaging time for distortion in *Continuum Summary*.
3. Dec-dependent minimum baseline on meridian for configuration selection based on LAS (look-up table derived from **VLAUVPL**).

Changed:

1. **ALT-P** does not plot PBCOR when Rots/Napier approximation < 1.000 .
2. Formulae for time average smearing (to Bridle-Schwab 1988 Synthesis Imaging Summer School formulae from 1985/1982 Summer School formulae).
3. Warning messages for bandwidth, averaging time errors.
4. Look-up tables for illegal bandwidths < 0.195 MHz, so that warning messages, not just ERR codes, appear if bandwidth set too low.
5. Correlator codes in *Spectral Line Channels* screen to the Aug 1988 allowed varieties.
6. Various *Help* and *Inputs* text screens to account for above.
7. Format of *Resolution* screen to improve readability, show minimum baseline lengths.

Version 1.2 (October 1988)

Added:

1. All parameters are now input with **ALT**-keys.
2. Documentation for self-calibration parameters.
3. **ALT-K** display for data entry keys also gives current values.
4. **ALT-Q** display of RFI at L-Band, plus RFI table below Observing Frequency Strategy help text; from VLA Test Memo 139 and the GLONASS satellite frequencies.
5. **ALT-H**: added NRAO menu and sub-menus.

Changed:

1. Format of both *Continuum Summary* and *Line Summary* screens, to improve readability.
2. **ALT-K** display to two pages.
3. Labeling and location of "hidden" baseline tables.
4. **ALT-H** *Help* screens to reflect the above.
5. *Line Summary* screen was reading out total integration time for natural weighting, but calling it uniform; it now says and does the uniform weighting case. *Sensitivity* screen has been correct since Version 1.0.

Demonstrated to VLA staff in this version. Detailed comments from Bill Cotton and Rick Perley.

Version 1.3 (December 1988)

Added:

1. **ALT-Y**: printout options for summaries, detailed calculations, keys and menus, and help text on inputs.
2. Calculates bandwidth effect at channel bandwidth in *Field of View* screen, to help plan bandwidth synthesis observing.
3. *Bandwidth Synthesis Summary* screen and related strategy text.
4. *Quit_Menu* option to all sub-menus (quick return to *READY* mode).

Changed:

1. *Spectral line sensitivity* calculation now uses single IF (was 2 IF's -- as in continuum -- but single IF is more relevant here).
2. Title screen and **ALT-K** display now advertise **CTRL-BREAK** option for escaping from data entry macros.
3. Tidied up *Field of View* screen and bandwidth smearing look-up tables, to improve readability and to allow channel bandwidth smearing calculation for bandwidth synthesis.
4. *HELP Strategy* menu (**ALT-H,S**): *MAX Radius*, *Distortion*, and *Bandwidth Synthesis* help text put under one *Field of View* item.
5. All New Mexico telephone numbers to new AOC numbers.
6. Data set size calculation in B20, B40 to sum widest and closest arrays; also removed 1000-block approximation for line data (D40).

Version 1.31 (April 1989)

Changed:

1. Fixed bug in RFI test giving ERR code for bands fully below 1.35 GHz
2. Updated projected VLA configuration schedule to end of 1993; revised text on proposal deadlines.

Version 1.32 (April 1990)

Changed:

1. Updated VLA configuration schedule to end of 1994; revised lists of NRAO contact people; minor help text revisions.

Version 2.0 (May 1994)

Added:

1. Q-Band menu item, data and help, hooks for calculations with <27 antennas to accommodate future developments.
2. References to VLA World-Wide-Web documentation servers.
3. Stand-alone version of program.
4. Formal correlator limits to averaging times in spectral line mode. (all references to artificial computer restrictions should have disappeared by this version!).

Changed:

1. Data set size calculations again in Mbytes.
2. Updated lists of NRAO contacts, documentation, services.
3. Updated L-band RFI table.
4. L Band sensitivity calculation to upgraded system.
5. Small tweaks throughout documentation.