Concept for an "Observation Builder" for Array and Correlator Configuration

NRC-EVLA Memo# 012

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ABSTRACT

The WIDAR correlator design for the EVLA is very flexible and, as such, it has a vast parameter space within which it can operate. This is advantageous in that it provides astronomers with a flexible instrument that can be used to maximize the science output from a particular observation given the system's hardware resource limitations. However, it is problematic in that the high degree of flexibility provided by the correlator can make it difficult for end-users (astronomers) and software designers to use and implement the almost unlimited number of "modes" that the correlator provides. This memo is an attempt to present an initial concept that may allow the end-users to take advantage of the full flexibility of the correlator and allow software designers to envision ways in which all of the modes the correlator provides can be programmed. Since the correlator is intimately linked with the entire array, a representative concept for array configuration is presented that is admittedly simplistic in nature and should be judged accordingly.

Introduction

The WIDAR correlator design [1] for the EVLA provides a large parameter space within which an almost unlimited number of modes or combinations of modes can be envisioned. Each station/antenna input to the correlator can handle eight, 2 GHz analog bands. Each analog band can be sliced up into 16 digital sub-bands and each of these sub-bands can be any width and placement[1] in the analog band. Anti-aliasing techniques ensure that adjacent sub-band results can be seamlessly "stitched" together with no systematic biases but with some SNR degradation in the overlap region. If desired, overlap can be eliminated by changing the sub-band's digital filter shape, but at the cost of loss of bandwidth at the sub-band edge. The correlator contains 16 "sub-band correlators"[2] that can be used to correlate each sub-band, or that can be used in concert to correlate less than 16 sub-bands, but with more spectral points per sub-band. Each sub-band, depending on bandwidth, can be correlated to produce anywhere from 64 spectral points to ¼ million spectral points. Multiple independent and/or overlapping sub-arrays can also be defined. The advantages and problems associated with this kind of flexibility have been stated informally by various people on a number of occasions. The "Observation Builder" concept in this memo demonstrates that it should be possible to

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[1] Within the integer sub-band constraints imposed by the signal-processing design.

[2] In the current (as yet "un-Memo'd") design, up to 18 sub-band correlators are defined for redundancy.

easily configure and use the correlator (and thus the entire array) anywhere within the vast parameter space available.

Context

Figure 1 is a diagram that defines the context within which the Observation Builder concept defined in this memo resides.
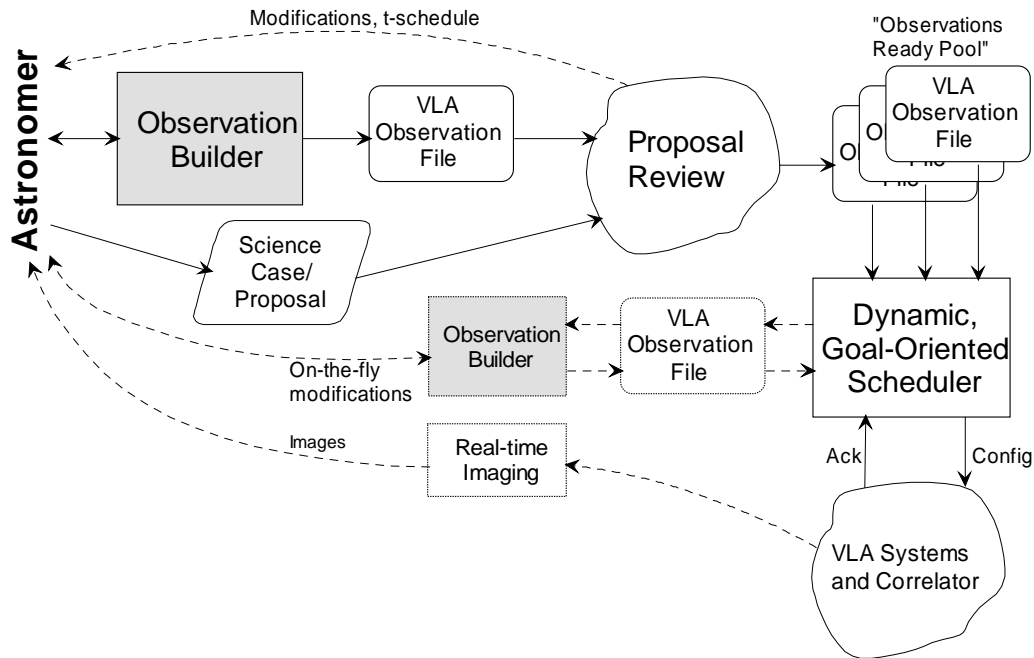
Figure 1 Diagram illustrating the context within which the "Observation Builder" described in this memo resides.

In the diagram, the astronomer who wishes to use the VLA uses an "Observation Builder"[3] to create a "VLA observation file". In this concept, the observation file should contain all of the information necessary to completely configure the array and the correlator (antenna pointings, receivers, local oscillators, sub-band digital filters, correlator chips etc.). This builder should be platform independent[4], be usable by any astronomer, and should not require the user to have specialized knowledge of VLA systems. Indeed, in the builder concept presented, the word "correlator" is never even used. The VLA observation file is included with the astronomer's science case for review[5]. Once the observation is approved, the file goes into the "Observations ready pool"—a pool of observations that are ready to be executed by the "dynamic goal-oriented scheduler"[6]. A possibility (shown with dashed lines in the diagram) is that the astronomer could change an observation's parameters "on-the-fly" while her observation is in progress. This would entail reading the observation file into the builder, making

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[3] Definitely not a new concept. However, the astronomer's view of the VLA necessarily requires that this builder contain details of the correlator's capabilities and that is why it is being described.

[4] "On a laptop", "over the web" etc. etc.

[5] This is not new, is speculative, and is only one possible model.

[6] The scheduling concept intended by NRAO for the EVLA.

allowed modifications, and writing it back out for reconfiguration by the scheduler. It may be impractical to do this with a dynamic scheduler since it may not be possible to give the astronomer enough advance notice to allow her to be involved.

Straw-Man Observation Builder

A straw-man Observation Builder GUI (Graphical User Interface) screen is shown in Figure 2. It contains four major components: the "Reference Image" window; the "Array Settings" window; the "Spectrum Allocator" window; and the "Spectrum Planner" window.
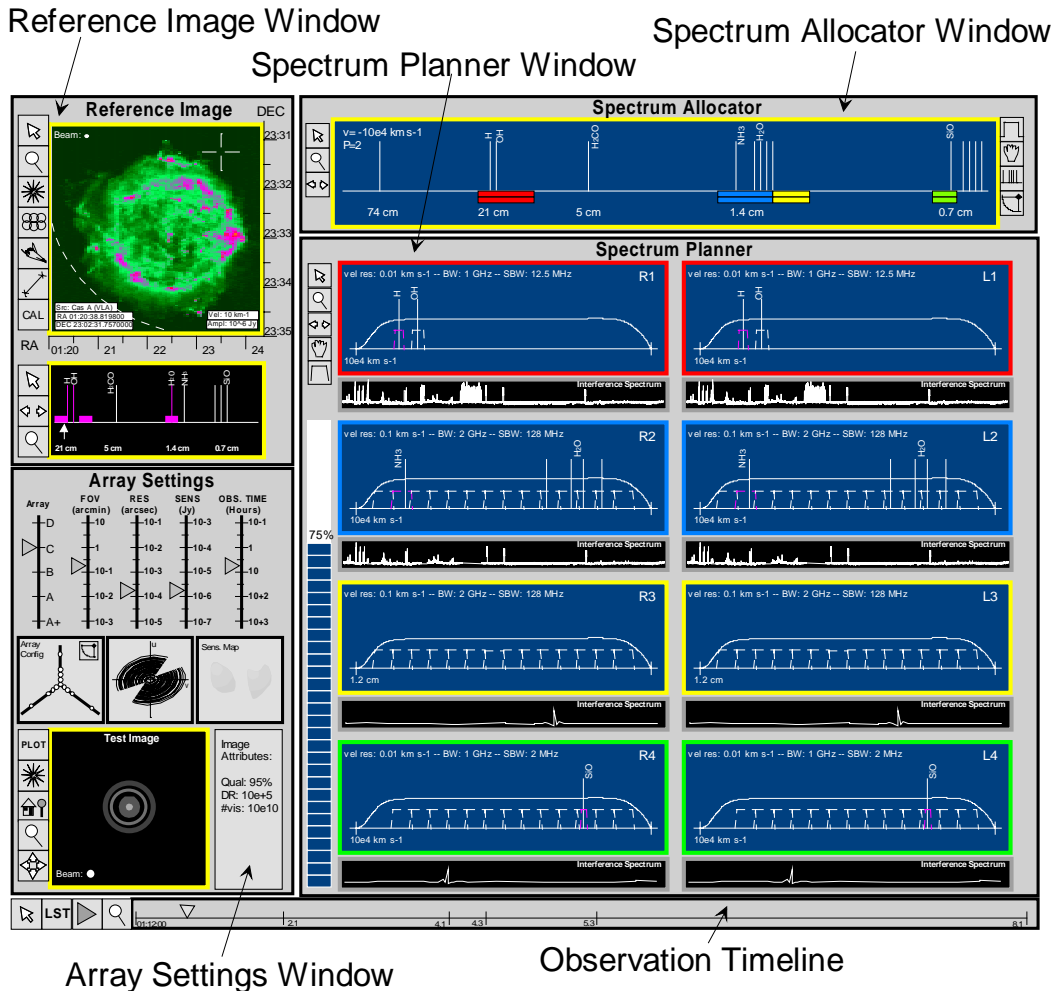
Figure 2 Straw-man Observation Builder GUI showing the four main windows and the Observation Timeline. The Reference Image and Array Settings windows are representative of what might be required for a complete package. The Spectrum Allocator and Spectrum Planner windows are where the astronomer decides how to use bandwidth—effectively setting the desired correlator configuration. The Observation Timeline allows for different array and bandwidth usage during the course of the observation and is not described in any more detail in this memo.

The Reference Image and Array Settings windows are not specifically required to configure the correlator but are concepts that it is believed are required for a complete package. The Spectrum Allocator and Spectrum Planner windows are where the

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astronomer decides what to do with available "spectrum resources"—effectively configuring the correlator. The Spectrum Allocator and Spectrum Planner could be implemented independent of the Reference Image and Array Settings windows with an appropriate interface. The bottom window is an Observation Timeline that allows different array and spectrum configurations to be defined within the desired observing time. Not shown (and something that could go in a generic top-of-the-screen tool bar) is an "observation wizard" which, when implemented, should allow any astronomer to configure the array and spectrum usage (correlator) to meet desired science requirements. Full-scale implementation of this wizard may require utilization of artificial intelligence algorithms.

The following figures describe each of these windows in more detail. The Reference Image and Array Settings windows are included since they are representative of what might be required for a complete package. The Spectrum Allocator and Spectrum Planner windows are where the available bandwidth and correlator resources are planned in detail. There are many places where there is considerable coupling between windows. For example, grabbing a spectral line in the Spectrum Planner window and moving it will cause the entire associated analog band to be moved accordingly in the Spectrum Allocator.
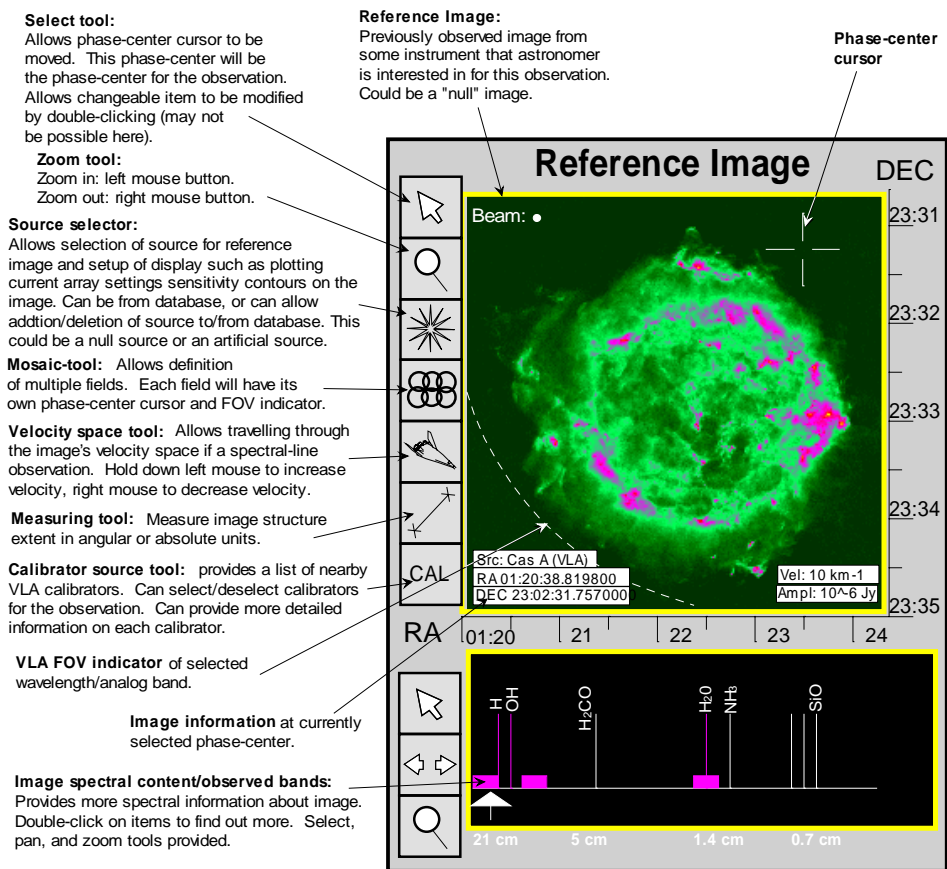
Figure 3 Details of a representative Reference Image window. This window is intended to provide the astronomer with information sufficient for planning the VLA observation. This is representative only of what might be required in a complete package and is probably somewhat simplistic.

Sensitivity Map: Brightness temperature sensitivity over the current Test Image. Affected by Array Settings sliders, band-width etc. etc. Could display other maps such as resolution/beam shape/size?

Array Settings window: Allows control/setup of array parameters and testing of those settings on test images.

Sliders for array configuration, field-of-view, resolution, sensitivity, and observing time. These are all interlocked and interlocked with observing bandwidth (i.e. changing one necessarily changes the others). Settings are for currently selected analog band(s). May want a slider for hardware integration time as well.

Array config indicator: Shows array configuration and selected antennas. Click the "select antennas" button to select antennas for a sub-array. This may be a time-variable function, so allows selection of sub-arrays on a time scale. Double-click in window to enlarge or change display.

u-v tracks indicator: Plots u-v tracks for the array configuration, selected analog bands, spectral resolution, and observing time.

PLOT: Left-clicking this causes the Test Image to be generated.

Select Test Source for the Test Image: Allows selection from a catalog of test sources for the Test Image. Could allow selection of the Reference Image (or part of the reference image) as well.
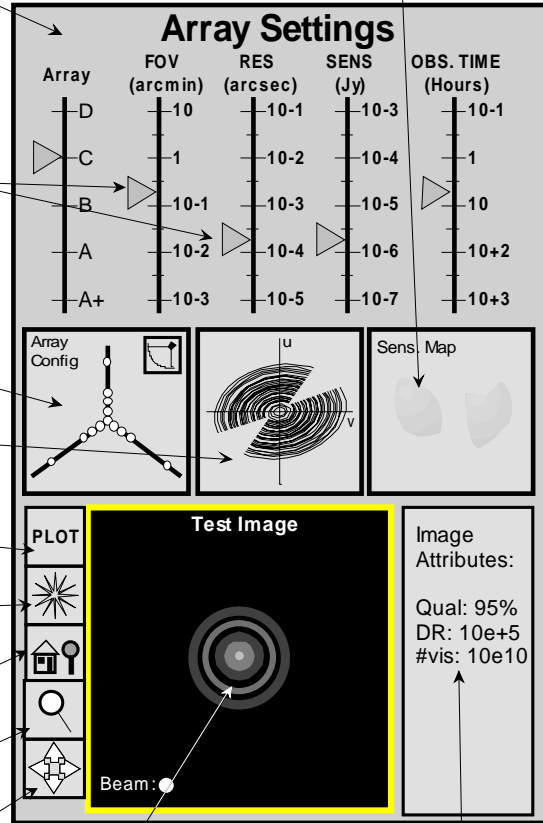
Select image processing attributes such as contrast/enhance, (clean/self-cal algorithms??) etc. etc.

Zoom tool: Zoom in: left mouse button. Zoom out: right mouse button.

Pan tool: hold left mouse button to pan through the image.

Array Settings

Array	FOV (arcmin)	RES (arcsec)	SENS (Jy)	OBS. TIME (Hours)
D	10	10-1	10-3	10-1
C	1	10-2	10-4	1
B	10-1	10-3	10-5	10
A	10-2	10-4	10-6	10+2
A+	10-3	10-5	10-7	10+3

Array Config

u / v

Sens. Map

PLOT

Test Image

Beam: ●

Image Attributes:

Qual: 95%
DR: 10e+5
#vis: 10e10

Test image attributes: Some measure of image quality compared to the ideal image; image dynamic range; # of visibilities used in generating the image (and expected # of visibilities out of the correlator).

Test Image: this is a test image when the PLOT button is hit. This is an indicator of how the array configuration etc. affects the image. (Right-click in image to toggle between display of VLA image and the ideal image??)

Figure 4 Details of a representative Array Settings window. This window is intended to provide the astronomer with the ability to configure the array and test that configuration's effect on a Test Image. This is only representative of what might be required in a complete package and is probably somewhat simplistic.

Spectral-line palette: Click to add pre-defined or custom spectral lines and widths to the diagram. Also add/remove reference (v=0) lines.

Grab tool: Use this to grab bandwidth and move it around. Grabbing a spectral line is the same as panning.

Bandwidth tool: Hold left button and drag to define required bandwidth region. To delete bandwidth, select it and hit the 'delete' key.

Spectrum Allocator window: Allows definition of what part of the spectrum to observe. Double-click in blank part of window to enlarge. **Right-click on any parameter to lock it** to change or lock to reference image.

Select antennas: Allows selection of antennas for this particular spectrum allocation. Antennas different than the VLA antennas could have different analog baseband characteristics. New antennas' spectrum allocations automatically sync. with current allocations.

Velocity or z indicator: Indicates the object's velocity or z-shift so lines are shifted in wavelength accordingly. Double-click to change or lock to reference image.

Bandwidth indicator: (E.g.) These Green indicators apply to the Green band in the Spectrum Planner. Top is R; bottom is L. If P=2 or 4, then locked together. Can be moved or deleted. "Lights up" when selected. Double-click to change attributes (BW, #quant bits etc). Shift-click to select more than one. Affects indicators in Ref. Image window and Array Settings window.

Spectrum Allocator

Spectral-lines of interest: Click to select; use delete key to delete.

Wavelength/frequency indicator: Double click to change showing wavelength or sky frequency or band designator (e.g. 'L')

Selector: Double-clicking allows a changeable item to be modified. Single-click allows an item (such as a line, a band) to be selected).

Zoom tool: Zoom in: left mouse button. Zoom out: right mouse button.

Pan tool: Hold left mouse button to pan in frequency/wavelength.

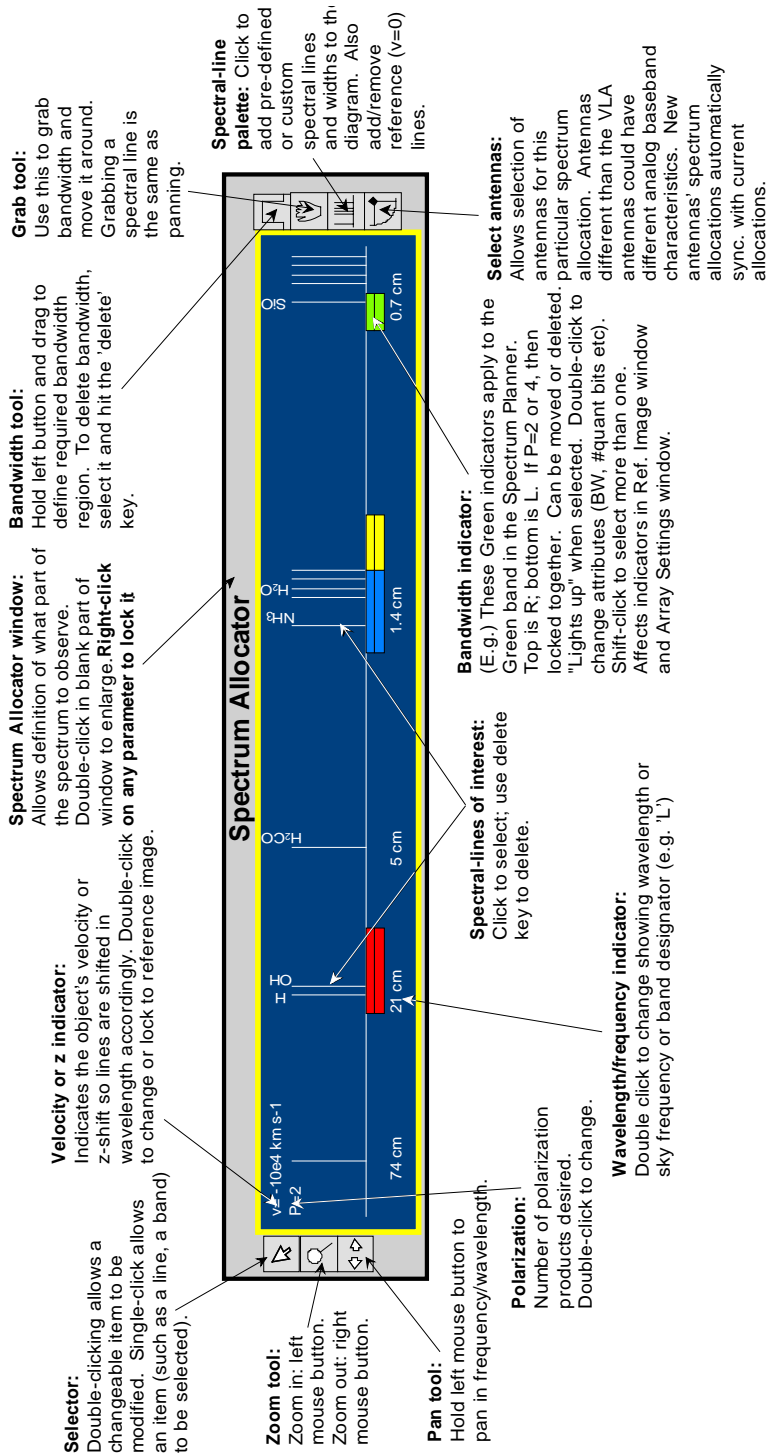**Polarization:** Number of polarization products desired. Double-click to change.

SiO — 0.7 cm

H_2O — 1.4 cm
NH_3 —

H_2CO — 5 cm

OH / H — 21 cm

v=-10e4 km s-1
P=2 — 74 cm

Figure 5 Details of the Spectrum Allocator window. This window is used to perform overall planning of where the eight available analog bands will be placed within the observing capability of the VLA. Pre-defined spectral lines, and user-defined spectral lines can be placed in this window with a user-defined velocity shift. The user can then place the analog bands for optimum coverage of the spectral lines of interest. Analog band placement will be reflected in more detail in the Spectrum Planner window (next Figure) along with correlator sub-band and spectral resources.

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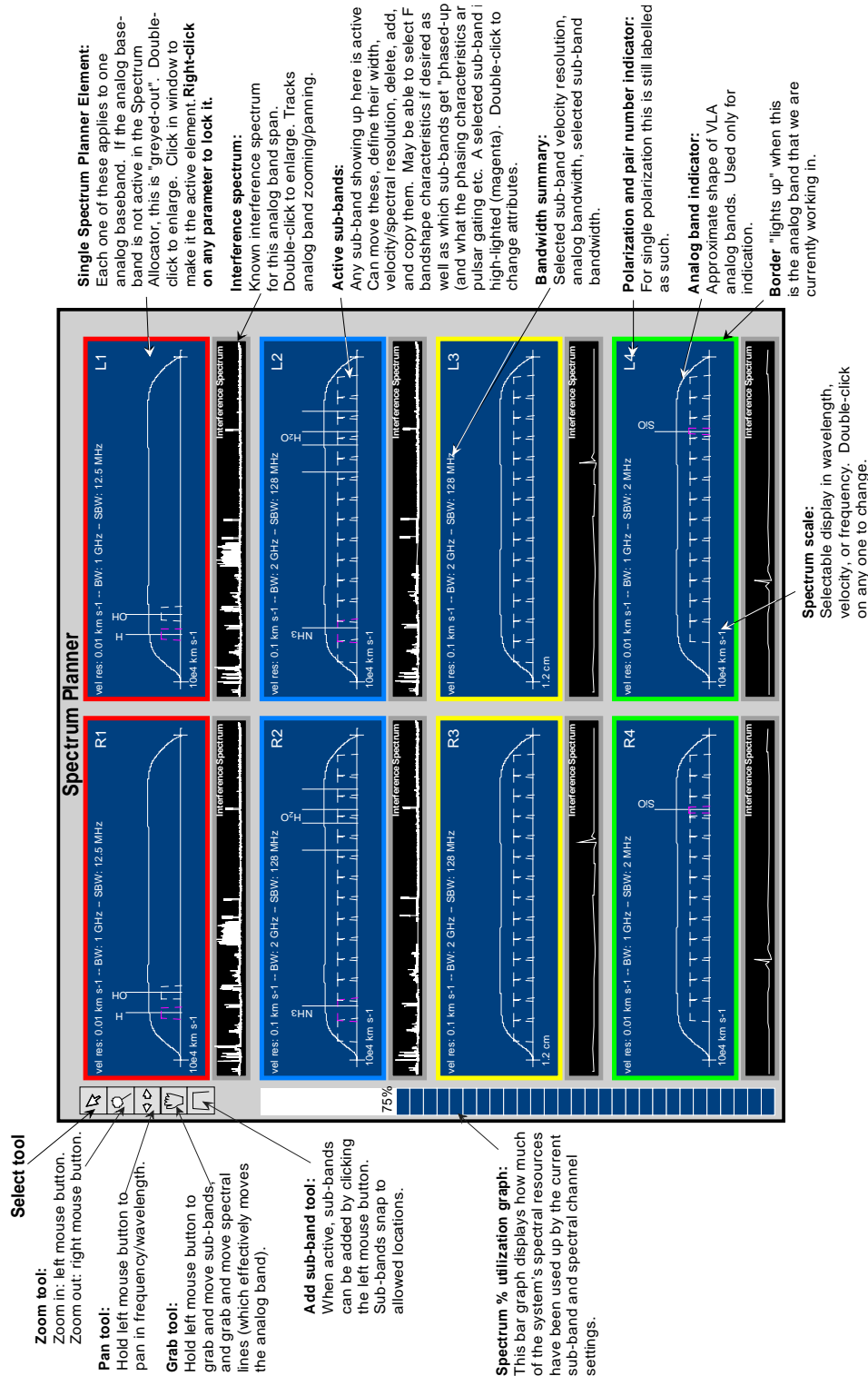
Figure 6 Details of the Spectrum Planner window. This is the window within which the correlator configuration is really mapped out. This window allows definition and placement of sub-bands as well as the number of spectral channels allocated to sub-bands and analog bands. As can be seen, there are virtually an unlimited number of ways that sub-bands can easily be defined in this window—completely matching the correlator's flexibility.

Some important functions in the Spectrum Planner window are:

- Grabbing a spectral line and moving it causes the entire analog band to move (i.e. changes the local oscillator frequency) and is reflected by appropriate movement in the Spectrum Allocator window. This feature can be used to prevent spectral lines of interest from ending up in the overlap region between sub-bands where there is additional SNR degradation.

- The interference spectrum window will help astronomers decide if the spectral line of interest will be clobbered by interference. If so, hardware integration and back-end image processing may have to be adjusted accordingly.

- To change or view more detail on some item in any sub-window, double-click on it. To view a larger version of a sub-window, double-click in a blank part of the sub-window.

- Right-click on items to lock them (or unlock them if they are locked) so they can't be disturbed. This allows important parameters to be set and locked before modifying or experimenting with less important parameters.

- The current displayed capability is always within the correlator's capability. If the user tries to define something outside of the correlator's capability then an error message is generated (if it just can't be done), or a warning message is generated if it will have a detrimental effect on some other parameter's setting.

Conclusions

This document presented a concept for an "Observation Builder". This builder contains a "Reference Image" window, an "Array Settings" window, a "Spectrum Allocator" window, a "Spectrum Planner" window, and an "Observation Timeline". The Reference Image and Array Settings windows are only representative of what might be required for a complete package. The Spectrum Allocator and Spectrum Planner windows are where the full flexibility of the correlator can be easily explored and utilized by an astronomer planning an observation. The Observation Builder generates a VLA observation file that completely describes how the correlator (and the array) are configured for the observation.

References

[1] Carlson, B., A Proposed WIDAR Correlator for the Expansion Very Large Array Project: Discussion of Capabilities, Implementation, and Signal Processing, NRC-EVLA Memo# 001, May 18, 2000.

Acknowledgements