Interoffice

National Radio Astronomy Observatory
Socorro, New Mexico

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To: Scientific Staff

From: Pat Crane

Subject: Future expansion of the VLA

In preparation for the next Future Instrumentation Workshop in October, I have revised my memorandum of 15 August on the future expansion of the VLA. Any plan of future improvements should be compiled with definite priorities in mind; to date the VLA has been able to proceed in a more incremental fashion. It may be possible to combine many features (e.g., new correlator, IF system, additional antennas) of a long-range plan into a single proposal to the NSF to be funded outside NRAO's regular budget. My suggested priorities for the long-range plan are

1. Improve sensitivity
2. Solve short-spacing problem
3. Improve wide-field mapping capability
4. Increase angular resolution
5. Improve frequency coverage
6. Interface to VLBA
7. Improve broadband spectral-line capability
8. Improve capability for high-time-resolution obervations
9. Improve dynamic range

IMPROVED SENSITIVITY: Improved sensitivity is essential for many obervations with the VLA. Spectral-line observations, especially observations of neutral hydrogen at 20cm, require lower system temperatures which can be achieved by improved receivers and better feed designs to reduce spillover, for example. The sensitivity of some spectral-line observations (e.g., hydrogen recombination lines) can be improved by providing additional IF channels. The sensitivity of continuum observations can be improved by lower system temperatures and greater total IF bandwidth.

1. Replacement of existing VLA receivers with new VLBA-design receivers. Such receivers at 20 and 6 cm could reduce system temperatures by about 30 percent and by 60 percent at 2 cm. Further improvement could be achieved at 20cm by redesigning the feed.
   Costs given in RE plan

2. Expansion of VLA IF system to provide a total bandwidth of about 1 GHz is possible, and the waveguide itself probably could allow about 2 GHz. Providing more individual IF channels will improve sensitivity for some spectral-line problems. For discussion, I suggest replacing the existing

VLA IF system with a VLBA-style IF system with 128 8-MHz baseband IFs providing a total IF bandwidth of 1024 MHz. For some projects including some spectral-line observations and self-calibration of weak continuum sources, greater individual IF bandwidths may be desirable.
$10,000,000

3. An E array has been proposed for observations of very-low-surface-brightness objects. One possibility is to arrange the 27 VLA antennas in a scaled-up 235-meter version of the 90-meter pseude-random configuration being discussed for the millimeter array. The two main problems that I foresee are that the If-distribution system may have to use a medium other than the waveguide and that the packing will be too dense and the curves too tight for the present transporters. Such an array will not solve the short-spacing problem discussed below.
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SHORT-SPACING PROBLEM: VLA observations of sources with large angular sizes are greatly by the short-spacing problem which arises because the minimum baseline length is the diameter of a VLA antenna or 25 meters. This problem cannot be solved by the so-called E array or dense configuration of the VLA which still suffers from the same hole in the uv-coverage. One solution would require a 100-m telescope with the same frequency coverage as the VLA; the cost of such a telescope would be comparable to that of the VLBA. An alternative approach is to build a scaled-down version of the VLA: to reduce the magnitude of the problem by a factor of ten, build an array of 2.5-m antennas with a maximum baseline of 100 meters. Such an approach appears to be a combination of the multi-element telescope and compact array proposed for the millimeter array; perhaps they could be used for this purpose during "summer shutdown".

? WIDEFIELD MAPPING: Widefield mapping with high sensitivity requires major modifications to, or replacement of, the existing VLA correlator. I think replacement will be necessary. I do not think the hybrid approach mentioned in the RE plan is satisfactory because of the effects of the Gibbs phenomenon on the individual 4-channel spectra. I think a new correlator should be combined with a proposal to add additional antennas and a new IF system, so I will discuss the particulars below.

HIGHER ANGULAR RESOLUTION: MERLIN observations and VLA observations at high frequencies show that significant structure in radio sources exists on scales of 0.1". The combined VLA/VLBA has a significant gap in uv-coverage on scales between 35 and 200 km. Additional antennas to fill this gap may be regarded as extending the VLA at low frequencies and filling in the short spacings at high frequencies for the VLBA. (At high frequencies such antennas will improve the ability of the VLBA to carry out scaled-array observations at many frequencies.)

1. Expansion of the VLA to include the VLBA antennas at Pie Town and Los Alamos and at least four additional antennas at Dusty, Bernardo, Holbrook, and Roswell. This expansion would require microwave and/or optical-fiber links to transmit local oscillator signals and the broadband IFs.
$25,000,000

2. A new correlator to handle 31 or more antennas. To provide full-field mapping at 20cm with 200-km baselines requires a channel width of 125 kHz

(after Hanning smoothing) or 64 channels per 8-MHz baseband IF; smaller channel widths and smaller total IF bandwidths can be used at lower frequencies. The sampling should be two-bit, four-level, and may need to be done at the antenna to transmit the desired bandwidth through the waveguide-transmission system. The correlator should be able to handle mixed-mode observations and provide full capabilities for polarization - which implies >31*15*64*4*128=15,237,120 complex baseline-channels before Hanning smoothing. The minimum integration time is approximately 0.2 seconds. The minimum of channels per IF channel should be 128 before Hanning smoothing. Also some spectral-line problems may need considerable oversampling in frequency.
$10,000,000

3. Dedicated array operating at 75 MHz with arms extended by a factor of three-four using narrow-band radio links for distant antennas.
$1,000,000

IMPROVED FREQUENCY COVERAGE: Coverage of additional frequency bands by the VLA is essential for the study of many astrophysical problems: the polarization and spectral properties of galactic and extragalactic sources, the study of extended sources like M51 at decimetric wavelengths, studies of additional spectral lines and redshifted spectral lines. The choice of frequency bands to add should be guided by compatibility with the VLBA, the existing radio-astronomical frequency allocations, and particular problems such as the study of redshifted neutral hydrogen and water vapor and of the newly discovered ring molecule.

1. New receivers should include 608-614 MHz, 2.2-2.7 GHz (including the radio astronomy band), 10.6 GHz, and 43-49 GHz. A new receiver to cover 1.00-1.35 GHz should also be added to cover redshifted neutral hydrogen. The coverage of the Kband receiver should be expanded to allow observations of redshifted water vapor, the newly discovered ring molecule, and ammonia; Pat Palmer has suggested covering 19.0-25.9 GHz. (608-614-MHz band should be much wider - e.g., for study of HI absorption at high redshifts.)
Costs for most new receivers given in RE plan

2. Modifying the existing F/R structure to provide access to the prime focus will probably be necessary to obtain satisfactory performance at 608-614 MHz; this would also improve the performance at 300 Mhz. If the prime focus were accessible, a room-temperature receiver with crossed dipoles mounted there could provide good coverage of the band 1.00-1.35 GHz for the study of redshifted neutral hydrogen.
$50,000 per antenna

3. Performance at 43 GHz would be significantly improved by installation of new surface panels and subreflector. Active pointing controls, such as electronic levels, and pointing models may be needed to provide a major improvement in pointing accuracy (5") and stability needed for observations at 43 GHz; perhaps new motors and encoders will be necessary.
$50,000 for subreflector, $240,000 for panels, per antenna

INTERFACE TO VLBA: The above suggestions include most of the requirements for interfacing the VLA and VLBA. The nearby VLBA antennas should be linked to the VLA; at least one VLA antenna should be equipped at all the VLBA frequencies; VLBA recorders and IF systems should be provided for at least three VLA antennas.

BROADBAND SPECTRAL-LINE CAPABILITY: Spectral-line observations at 22 and 43 GHz may need bandwidths of order 80 MHz with 256 channels. A new IF system and correlator may provide this in a hybrid mode.

HIGH-TIME-RESOLUTION OBSERVATIONS: Many astrophysical phenomena are either short-lived, intermittent, periodic, or some combination thereof - e.g, pulsars, Saturn electric discharges, Jupiter or solar bursts, flare stars, etc. Some capability can be provided in software, limited by the minimum integration time of the correlator, but higher time resolution will require special-purpose hardware.

1. Build the analog-sum processor for high-time-resolution, phased-array observations of periodic and intermittent signals. If modeled on the Green Bank spectral processor, such a system could also do spectrometry and de-dispersion and could be used to monitor and record radio-frequency interference.
   $235,000

IMPROVED DYNAMIC RANGE: Hardware improvements may yet be necessary, but so far software has enabled us to reach 40,000-80,000:1.

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