VLA TEST MEMO # 140

VLA SENSITIVITY AT STANDARD BANDS

R. A. PERLEY

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1. Introduction.

It is often very useful to have at hand measurements of the VLA sensitivity in order to aid in such endeavors as estimating required observing time. In this memo we outline the results of a simple experiment made to determine the system sensitivity, and to define a parameter which will enable an easy estimate of the noise on a synthesis map.

2. Observations.

A blank field located at $\alpha = 02^h\ 12^m\ 50^s.0$, $\delta = 74°\ 36'\ 00''$ was observed for a total of ~100^m at all four default observing bands with 50 MHz bandwidth. Calibration was effected by observing the nearby point source 0212+735, whose fluxes are regularly bootstrapped to 3C286 or 3C48. The calibrated data was carefully examined, and antennas whose performance was noticeably worse than average were purged. The resulting data were taken to the VAX, where maps were made in Stokes parameters I, Q, and U with the AIPS system.

The maps were made with natural weighting, and with a cellsize sufficient to ensure that all data were utilized for the map. The noise in the resulting fields was measured by the rms of the intensities in the central quarter of the map, except at 20 cm, where the Stokes I map was dominated by background sources. This map was not used.

At the time of the observations, 12 antennas had new FET amplifiers installed at 2 cm. The data thus gave a look at the performance of the new system. Antenna 9, which has a K-band maser, was not utilized at 1.3 cm.

Below is given the table listing the observing parameters and the resulting rms noise for each Stokes parameter.

Table 1

Observing Parameters

Band	Frequency (MHz)	C	T (sec)	σ_I (mJy)	σ_Q (mJy)	σ_U (mJy)
20 cm	1465	650	1380	(0.43)	0.13	0.13
6 cm	4885	651	1440	0.10	0.088	0.096
2 cm (new)	14965	132	1470	0.50	0.47	0.46
2 cm (old)	14965	196	1470	0.93	0.91	0.91
1.3 cm	22485	625	1490	1.16	1.11	1.11

C = # of correlators, T = integration time

In what follows, we use the noises on the Q and U maps.

3. Discussion

From Equation 3.52 in the publication from the NRAO Synthesis Mapping workshop, we find the noise in the map, ΔI, is given by:

$$\Delta I = \frac{\sqrt{2}\, k_b\, T_{sys}}{\eta_a\, \eta_c\, A \sqrt{CT\Delta\nu}} \qquad (1)$$

where
- k_b = 1.38×10^{-23} (MKS)
- η_a = antenna efficiency
- η_c = correlator efficiency
- C = number of complex correlators
- T = integration time (sec)
- $\Delta\nu$ = bandwidth (Hz)
- T_{sys} = system temperature (K)
- A = geometrical antenna aperture (m^2)

We can define a system dependent parameter, S, by:

$$S \equiv \Delta I \sqrt{C\Delta\nu T} = \frac{\sqrt{2}\, k_b\, T_{sys}}{A\, \eta_a\, \eta_c} \qquad (2)$$

Our data then give the following values for S:

BAND	S	
20	15	mJy(correlators.MHz.Hr)$^{\frac{1}{2}}$
6	9.8	"
2 (old)	55	"
2 (new)	23	"
1.3	120	"

To estimate the map noise, divide the appropriate value of S by $\sqrt{TC\Delta\nu}$, where C is the number of correlators (count AA and CC correlators are separate), T is the integration time in hours, and $\Delta\nu$ is the bandwidth in MHz.

Equation 1 can also be used to estimate the system temperature at any band presuming we know the value at one band, and the antenna efficiencies. If the subscripts 1 and 2 denote two different bands, then from Eq. 1,

$$T_{sys2} = T_{sys1} \cdot \left(\frac{\Delta I_2 \eta_{A2} C_2 T_2}{\Delta I_1 \eta_{A1} C_1 T_1} \right)^{\frac{1}{2}}$$

where we have presumed the bandwidths to be the same. Taking T_{sys} = 50K at 6 cm, we obtain the following:

BAND	T_{sys}
20	56
2 (old)	260
2 (new)	108
1.3	670

where we have used the antenna efficiencies listed in the NRAO Green Book.

4. Caveat

Use of equation 2 to estimate map noise is only applicable to natural weighting, with all measured points located within the u-v plane, and near the map centers. Using uniform weighting increases the noise in a complicated way which will be taper-dependent. Furthermore, effects of aliasing, sidelobes of nearby strong sources, grid correction, bad data, interference, non-standard bands, etc., will cause the actual noise to differ, perhaps substantially, from the expected values.

RP/bmg