VLA TEST MEMORANDUM # 152

# THE SENSITIVITY OF THE VLA.

R. A. Perley

January, 1988

Since the last tests of the VLA's sensitivity were made, many changes have been made to the VLA's receiver system. Amongst these have been the appearance of P-band (327 MHz), the replacement of the L-band paramps by FETs, the appearance of X-band (8.4 GHz), and the new FET or HEMP receivers at both U and K-bands. It seems obvious that some attempt should be made to calibrate the system sensitivity. This memorandum describes such an attempt.

I used 3 hours of test time on 28 Dec, 1987, while the array was in the 'B'-configuration, to observe a blank piece of sky centered at 10 hours in Right Ascension, and 40 degrees in Declination. Data were calibrated with a nearby phase calibrator, with the flux density scales set by observations of 3C286. I assumed the Baars et al. scale at all bands. All data were of good quality, with little editing required. No calibration of polarization was possible, but the absence of such corrections will have negligible effect on the derived sensitivies, provided there are no bright sources in the fields imaged. This is a potential problem only at 327 MHz.

Before imaging, the data were carefully examined to eliminate bad values. In many cases, unduly noisy antennas were noted and removed, while occasional transient points were identified and purged. Images were then made in Stokes' parameters I, Q, and U at all bands, using natural weighting. The 1.3cm receiver retrofit was not yet completed, so I ran two tests at this band, the first with exclusively the old system antennas, and the second with exclusively new system antennas.

The rms noise on an output image can be written

$$\delta I = S/\sqrt{C\Delta\nu T}$$

where $\delta I$ is the output noise in mJy/beam, and $S$ is the sensitivity parameter, dependent on system temperature, effective antenna collecting area and on system efficiency. $C$ is the number of complex correlators (i.e., the number of RR, LL, RL or LR correlators), $\Delta\nu$ is the bandwidth in MHz, and $T$ is the integration time in hours. Below are given the derived values of $S$, the sensitivity parameter, in units of mJy(correlators · MHz · hours)$^{1/2}$/beam, and a derived effective system temperature, based on assuming 50K at 6cm.

| Band | S | $T_{nom}$ |
|---|---|---|
| 90 | 31 | 208 |
| 20 | 10 | 67 |
| 6 | 7.4 | 50 |
| 3.6 | 5.2 | 35 |
| 2 | 19 | 130 |
| New 1.3 | 40 | 270 |
| Old 1.3 | 105 | 700 |

In using this table, recall that two correlators are used in the formation of any Stokes' image (I,Q,U, or V), so the number of correlators is related to the number of antennas by $C = N(N-1)$, where $N$ is the number of antennas.

At 90 cm, the noise in the 'I' image was nearly 10 times that in 'Q' or 'U'. I presume this difference is the effect of the uncleaned background sources. With so little data (about 20 minutes), no effective removal of these objects was possible. The sky temperature at this frequency at this location is very low, about 20K, so the rather high apparent system temperature must be due to low antenna effective collecting area, or some other system inefficiency.

At 20cm, the noise in the 'I' image was about 3 times higher than in 'Q' or 'U'. In this case, some of the responsible background sources were clearly visible. No attempt was made to remove them. The quoted figures come from the 'Q' and 'U' images. At all other bands, the 'I', 'Q', and 'U' images had similar rms noises (to within 10%).

There was a wide variation in receiver sensitivities at 1.3cm, amongst both the old receivers, and the new ones. For both entries, I used only those antennas whose noise powers were in reasonable agreement with each other. The sensitivity with the new receivers at 1.3cm is poorer than expected. The observations were taken in very cold weather, $T = -13$C, at high elevation. I calculate the atmospheric contribution to be less than 25K under these conditions.

I estimate that errors in the listed quantities due to incorrect flux scaling and other errors should not exceed 10%.