Antenna # 4 upgrade
VLA Test Memo # 173

M.Kesteven

September 10, 1993

This note describes the improvement to antenna # 4 as a result of the subreflector shift and the surface resetting. The improvement is tested against the efficiencies of all the VLA antennas.

1 The adjustments

B. Broilo has described the adjustment operation in some detail in VLA test memo # 174.

The adjustment log is given in Table 1.

Table 1 -The Adjustment Log

Move FRM	18 June
Trial: panels in ring 6	8 July
panels 1-1 to 4-33	26 July
panels 4-33 to 5-25 (inner)	29 July
panels 5-25 to 6-20	3 Aug
panels 6-20 to 6-40	4 Aug

Figures 1 and 2 show the surface error maps of antenna # 4 taken in july, before the surface adjustments, and in august, after the adjustments. The improvement is clear. It is pertinent, however, to check that the changes were translated to an improvement in the gain.

2 The antenna gain

Several different procedures were used to assess the improvement in antenna # 4's gain.

1. Holography

   K-band (22.235 GHz) holography images were taken in march, july and august. These provide two indicators of the antenna's performance, listed in table 2. From these we can predict the antenna gain improvement.

   Table 2 - Holography results

date	Surface rms (mm)	Subreflector offset (mm)
25 March	.7	16.
1 July	.6	3.
8 July	.6	6.
24 August	.43	3

   The subreflector shift was measured to be 16 mm parallel to the elevation axis, and 1-2 mm in the focal plane, normal to the elevation axis.

   The surface rms appears to have improved from ~ 0.65 mm to < 0.5 mm.

   We expect that the subreflector shift should improve the gain by :

   $$\Delta\eta = C\left(\frac{shift}{\lambda}\right)^2$$

   C depends on the details of the reflector surface shaping, and is expected to be ~ 1; thus we expect: $\Delta\eta \sim 1.4\,dB$.

   From Ruze's formula relating the surface error to the antenna gain, we expect that improving the surface from 0.65 to 0.5 mm should yield better than 0.6 dB.

2. Holography calibration

   A number of calibration scans were taken during the course of the holography survey. We converted the visibilities to raw correlations in order to bypass the on-line calibration machinery. We then compute, for each baseline, the ratio

   $$r_{ij} = \frac{C_{ij}(August)}{C_{ij}(March)}$$

and a similar set for July-August. We find that over the entire array r_{ij} is bi-modal, with the subset which excludes antenna #4 significantly smaller than the set r_{4j}. (The actual values of r differ from 1.0 as different sources were involved, as well as different elevations).

We find:

August-March	all antennas, excluding # 4	3.8 ± 0.1
	antenna # 4	5.0 ± 0.2
August-July	all antennas, excluding # 4	8.2 ± 0.05
	antenna # 4	9.6 ± 0.1

Since we are dealing with the raw correlations, we have :

$$C_{ij} = \sqrt{\frac{T_i(ant)T_j(ant)}{T_i(sys)T_j(sys)}}$$

and

$$< r(4) > / < r(excluding4) > \sim \sqrt{(\eta(august)/\eta(march)}$$

Thus:

march $- >$ august : $\Delta\eta = 2.4 \pm .1\,dB$

july $- >$ august : $\Delta\eta = 1.4 \pm .1\,dB$

3. On-line calibration tables

Approximately every week the VLA operators run a procedure (MODCAL) to derive the parameters that convert raw correlations to "Jy". These are expressed as two factors, one relating to the system temperature (noise cal, switched power, total power); and the second (α) which relates to the antenna gain. The specific values of α will vary from week to week depending on the cal source chosen, and the elevation at the time. However, the ensemble should rise and fall together. The ratio $r = \alpha(4)/ < \alpha(\neq 4) >$ should therefore track the changes in antenna # 4. we find:

Table 3 - The On-line normalised calibration factor for antenna # 4

< 8 april	1.1
8 april	1.1
22 april	1.1
13 may	1.2
1 july	0.86
7 july	0.70
15 july	0.73
22 july	0.71
29 july	0.75
5 august	0.68
12 august	0.58
26 august	0.56

The quantity tabulated (r) is inversely related to the antenna gain. Thus the improvements are :

march $->$ august : $1.1/0.56$: $\Delta\eta = 2.9\,dB$

june $->$ august : $0.86/0.56$: $\Delta\eta = 1.9\,dB$

4. Direct measurements of the gain

   In 1992 D. Wood made a series of total power measurements to determine the antenna gains at K-band. In september 1993 a set of interferometer measurements were made from which the antenna gains were derived. The results are given in Table 4.

   Table 4 - Antenna # 4 gain

Total power (1992)	25 ± 3 %
Interferometer (1993)	47 ± 3

   This indicates an improvement of 2.7 dB

3 Gain of all VLA antennas

Several of the methods described above measured the gains of all the antennas. For completeness therefore we present the full complement here. Table 5 contains the results which are also shown in figure 3.

The agreement is excellent. We can expect some scatter to result from the different elevations at which the data were acquired; for example, the interferometer observations were made at > 60 deg, while the holography observations were < 40 deg. The gain-elevation function for most antennas is peaked near 40 deg, but several differ significantly from this: antenna # 27 peaks near the horizon; antennas 1, 2 and 13 near 90 deg. (See Test memo 164 (Wrobel) and 171 (Kesteven)).

There are four antennas where the total power results (from 1992) differ significantly from the 1993 results:

1. antenna 4

   The discrepancy here illustrates the dramatic improvement due to the upgrade.

2. antenna 9

   This antenna is now known to have a defective azimuth bearing. Since the total power observations explicitly search for the peak amplitude they should be somewhat less sensitive to pointing problems.

3. antenna 20

   The RF connector in the RCP channel has been deteriorating over the past year; it failed in august and was replaced.The holography results are Tsys independent; the interferometer and MODCAL results used the LCP data alone. A close examination of the total power data shows that indeed the RCP results are too low. Using the LCP data alone gives concordant results.

4. antenna 22

   This is still a mystery. In effect, T_{ant}/T_{sys} has improved between october 1992 and 1993. The resetting of the panels was completed in early 1992, so no significant change in the antenna gain is likely. The interferometer, holography and MODCAL data are currently all consistent with excellent antenna. It is possible that something in antenna # 22 is "loose", as the MODCAL record for this antenna suggests a period (april-july) with a 30 % reduction in gain.

Table 5 - VLA antenna gains (%)

antenna	Interferometer (sep 1993)	holography	MODCAL (aug 1993)	Total power (1992)
1	37		39	38
2		34		35
3	45	42	44	46
4	47	60	47	25
5	38	41	40	37
6	39	32	34	35
7		31	35	29
8	43	45	46	47
9	40	37	41	48
10	39	40	36	36
11	40	31	36	36
12		50	48	50
13	41	43	42	45
14	45	45	49	48
15	32	28	30	34
16	43	41	38	44
17	39	43	38	40
18	44	39	36	42
19	41	39	42	42
20	38	38	38	30
21	41	38	44	37
22	46	46	49	30
23	44	41	40	45
24	36	35	38	42
25	41	40	36	44
26	41	38	38	45
27	35	42	45	44
28	41		43	

Notes:

1. Interferometer

   We use a variant of the procedure described by P. Crane in VLA test memo 141. (We derive the efficiency, given the system temperature, rather than deriving the system temperature assuming some efficiency). A strong point source is observed in the mode which disables the on-line conversion of visibilities to "Jy". ANTSOL will then produce T_{ant}/T_{sys}, from which the antenna gains can be deduced. We used the system temperatures given in VLA test memo 170 (Bagri and Lilie). X-band reference pointing ensured that pointing errors should not contribute. A focus check was also made.

There are no hidden "fudge" factors, but several scale factors were needed. Let V_{ij} be the reported visibility for the baseline between antennas i and j. Then:

$$C_{ij} = 0.81 \frac{V_{ij}}{256 * 0.541}$$

We then run ANTSOL (CALIB in AIPS) to obtain ρ_i; with $T_{ant} = T_{sys}\rho$ we obtain the efficiency from:

$$\eta_i = \frac{2kT_{ant}}{SA}$$

for flux density S and area A.

The observations were made at an elevation of 60 deg. The results for antenna # 17 were scaled up by 15 %, since this antenna's gain-elevation function is significantly offset compared to all the others.

2. Holography

   A number of holography runs were made between march and august. The results presented here are an average of the data, with the corrections for subreflector offset and focus disabled.

3. MODCAL

   The MODCAL procedure assumes an antenna efficiency of 43 % (at k-band), so the factors give the actual antenna efficiency relative to 43 %, along with the difference between the actual noise source temperature and the assumed temperature. The temperatures from test memo 171 were used here.

4. Total power

   This column presents D. Wood's efficiency data, based on total power measurements of Jupiter.

4 summary

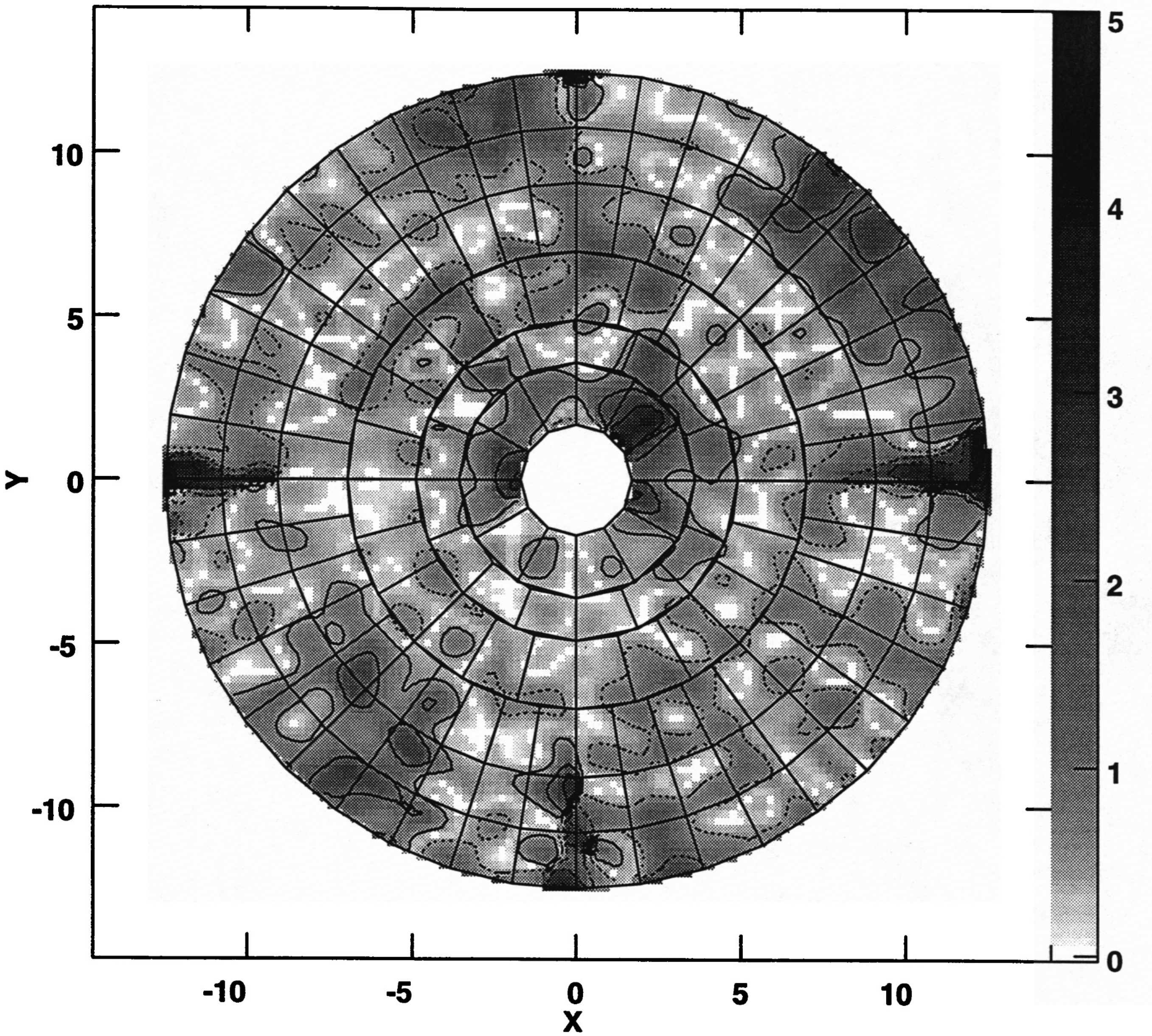
Gain improvement in antenna # 4

Method	Subreflector shift	Surface Adjust	Total
Holography	1.4 dB	> 0.7 dB	2.1 dB
Holography cal scans	1.0 dB	1.4 dB	2.4 dB
On-line cal factors	1.0 dB	1.9 dB	2.9 dB
Direct gain measurements			2.7 dB

The evidence is fairly convincing that the gain of antenna # 4 has improved as a result of the adjustments - by about 2.5 dB.

The results indicate that antenna # 4 has improved from the worst to one of the best performing antennas.

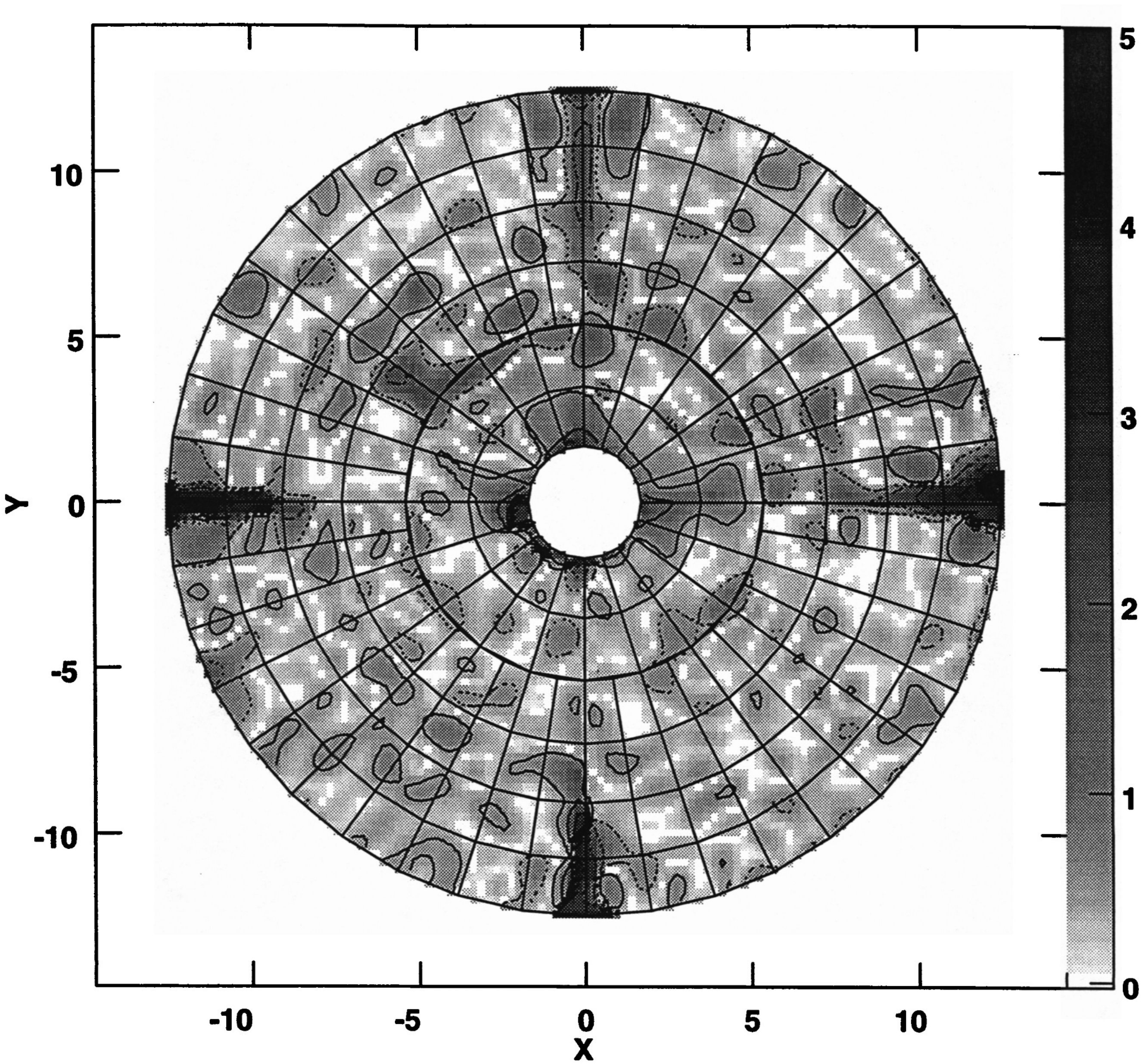
Antenna 4 before adjustment



Surface weighted rms = 0.65 mm

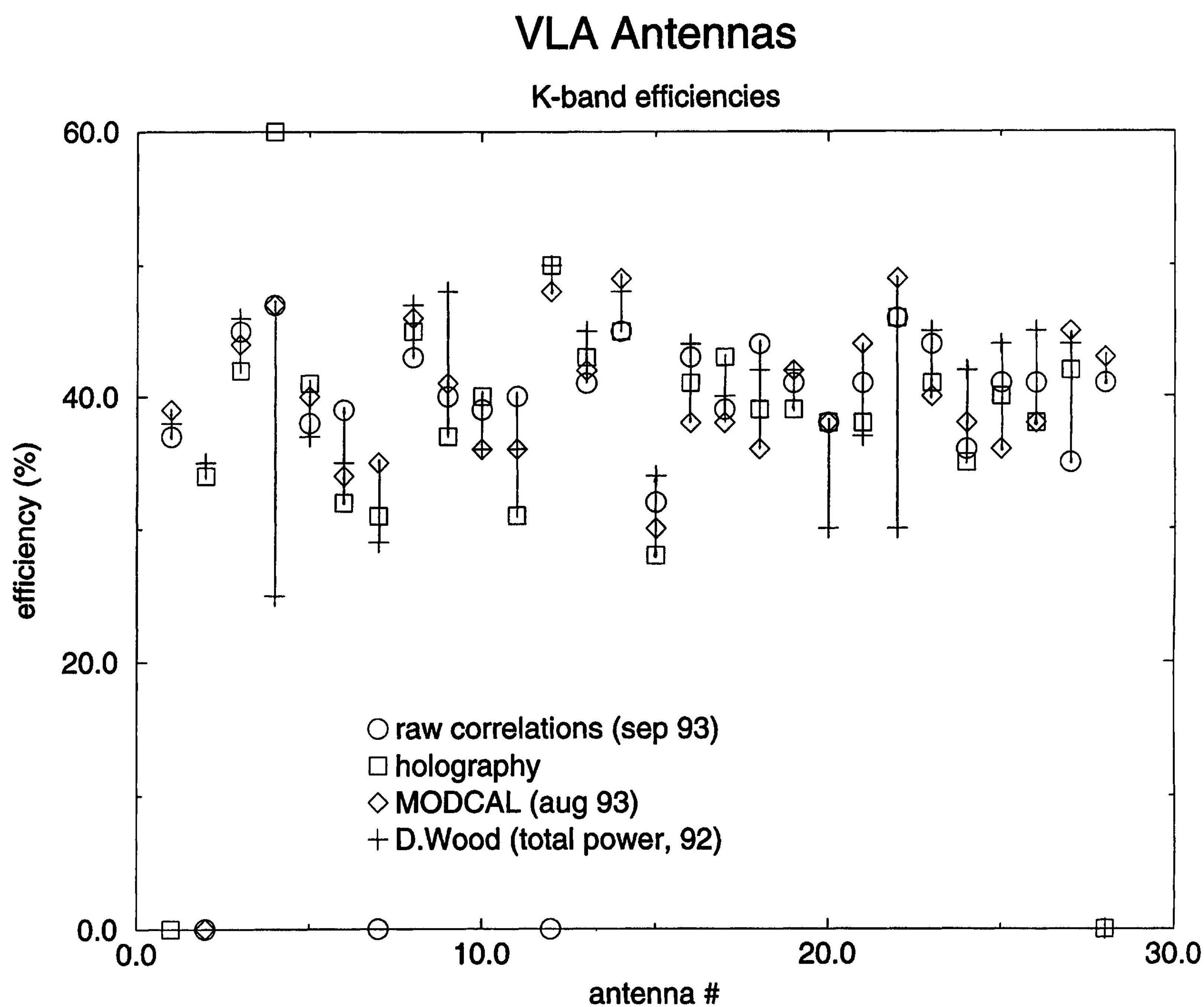
Contours at 1 mm spacing; -4.5 to + 4.5 mm

Antenna 4 after adjustment



Surface weighted rms = 0.43 mm

Contours at 1.0 mm spacing. -4.5 to + 4.5 mm


VLA Antennas
K-band efficiencies
60.0
40.0
20.0
0.0
efficiency (%)
0.0
10.0
20.0
30.0
antenna #
raw correlations (sep 93)
holography
MODCAL (aug 93)
D.Wood (total power, 92)