Compact Array Holography

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1 Summary

12 GHz receivers were installed in antennas 5 and 6 at the Australia Telescope Compact Array, providing the opportunity to test the holography procedures using the Optus-B1 satellite. Observations were also made using a strong methanol maser.

A number of difficulties were encountered which restricted the number of holography images taken — in the end we were only able to survey antenna 6.

The results show that this antenna has a surface RMS of around 0.35mm, indicating that some adjustments may be advisable. Perhaps the strongest result is a reminder that the subreflector was not in the correct position, and that remote control of the subreflector is highly desirable. A 5mm lateral adjustment of the subreflector is probably also required.

2 Targets

- Optus-B1 is a geostationary satellite at longitude of 160 (E); it is visible at an elevation of 52 degrees from Narrabri. We observed a 4 MHz band centred on 12.750 GHz, in spectral-line mode, with 1024 channels. The analysis is based on 4 channels spanning the the telemetry beacon at 12.749 GHz
- We observed the methanol maser G351.42+0.64 [1]. This has two strong lines ($\tilde{1}200$ Jy) separated by a few arcsecs; the analysis is based on 3 channels spanning the stronger line, at -11 km/sec.

3 Observations

The observations consist of a number of elevations scans, each scan being bracketted by a pair of direct, *"boresight"* observations. These boresights serve as phase calibrators, as well as providing a general indication of the pointing quality.

Optus-B1 has a modest diurnal cycle of approximately 0.25 degrees; we can observe in AZ/EL mode, but the position needs to be updated at regular intervals. The drift rate was typically 1 arcsecond per minute. Whilst this is small compared to the antenna primary beam it is large compared to the synthesised beam of the baseline between antennas 5 and 6 (3.7km). The phase drift rate was typically 20 degrees per integration; during the analysis we computed the drift rate from the satellite ephemerides (provided by A. Belo of Optus).

The observations were made in AZ/EL mosaicing mode — this means that the reference antenna continues to stay on boresight while the other antenna(s) execute the elevation scans. A utility (SCHED_HOLO) is available to prepare the mosaic files and the sched file for the observations.

A 39×39 map took approximately 5 hours, using 10 second integration cycles. The signal to noise ratio is large enough that 5 second cycles would suffice for future observations.

The sampler quantisation machinery of the correlator poses a serious problem for this experiment — in effect, the signal is so strong that the usual correlation procedures fail as far as the amplitude information is concerned. We can overcome these difficulties by using the new digital synchronous demodulators (DSD) to provide amplitude data for the strongest signals (the boresight and the central regions of the elevation scans), merging smoothly to the visibility amplitudes at low signal strengths.

We also offset the two IF channels by 14 dB to extend the dynamic range of the DSDs, hence using the different polarisation channels to measure different signal strengths.

Calibration of the combined visibility and DSD results is not entirely satisfactory in the present software, but the authors are confident that further attention will ensure that this does not compromise further experiments.

4 Analysis

The analysis of the holography data proceeds in four stages:

1. We determine the zero-points of the DSDs by examining histograms of low-signal data. The A polarisation DSD(A) flattened out at a count of 1885 (this is presumably the level where the receiver noise becomes important), while the B polarisation DSD(B), with approximately 14dB attenuation (and gain offsets), flattens out at 85 counts.

2. We then determine the relative gains by comparing two units (DSD(A):DSD(B) and DSD(A):Visibilities) in those regions where both are on scale and not subject to poor signal to noise ratios. We find a S/N ratio of 30:1 between DSD(B) and DSD(A), and $\left(7 * \sqrt{DSD(A)}\right) : 1$ between DSD(A) and the visibilities.

   We also scaled the antenna 6 DSD data by the corresponding antenna 5 data. This ensured that we were not sensitive to satellite power fluctuations. It also shielded us from variations in the DSD integration, which could vary to allow for drive times (blanking due to the dynamic hold).

   The task DSD_CAL was used for this operation. Figures 1 and 2 show the calibration results.

3. The boresight phase data is then "phase-unwrapped" to allow interpolation over each elevation scan. This is accomplished using the INTERPOLATE_HOLO program.

   The phase and amplitude of each scan is referenced to the boresights, and the data is then written to an ASCII file for the AIPS task, HOLGR.

   Figures 3 and 4 show the boresight calibration data, along with a few scans to show the quality of the data.

4. The data is now loaded into AIPS. We grid the data and transform it to yield amplitude and surface deviation maps as well as wide angle beam patterns; Subreflector offsets are determined at this stage and applied as calibration factors to the data.

   The AIPS task that is employed is called HOLGR. The task parameters for its use are listed in the appendix.

5 Results

The results are shown in figures 5 (the aperture illumination function) and figure 6 (the surface deviation map). Figure 7 shows the surface deviation map before correction for the subreflector offsets.

The rms is 0.35mm; the focus was in error by 15mm (axial) and 5mm in the focal plane (in the "y" direction). There are no serious high points, although ring 5 appears to have a number of anomalies.

6 Problems

- Satellite tracking. This needs to be automated, with the Optus predictions accessible directly by CAOBS. The present arrangement relied on SCHED_HOLO predicting the position on the basis of strict adherence to a schedule. For a number of reasons (eg, power glitch in antenna 6; time lost at start up) this was not entirely satisfactory. The Optus predictions are excellent - the computed visibility phase on the $5*6$ baseline stayed within one turn throughout the entire run. (See figure 3).
- It would be useful if CAOBS also performed the phase tracking; on the 3 km. baseline the fringe rate was around 150 degrees/minute.
- DSD/Vis calibration. The overlap between DSD(A) and DSD(B) was quite small. This will improve with the revised pre-scaling factors in the ACC; but it would be useful to run a more extended calibration observation in this mid-range to establish more firmly the relative DSD scaling.

7 Recommendations

- Remote control of the focus is becoming an important issue. An error of 15mm at 12 GHz results in a very serious gain drop (4dB).
- The subreflector's lateral position should be checked — 5mm is at the level of some concern.
- Proper motion phase tracking in AZ/EL mode should be implemented.
- The experiment should be repeated with better control of the calibration procedures. Antenna 5 has one panel offset, which will provide a global calibration, as well as resolving the various sign ambiguities.

8 Conclusion

The observations were brought to a premature end with the failure of the Wiltron synthesiser. In addition, the scheduled VLBI required the 12 GHz receiver to be returned to Mopra. The results are sufficiently encouraging to warrant a further experiment when the conditions permit.

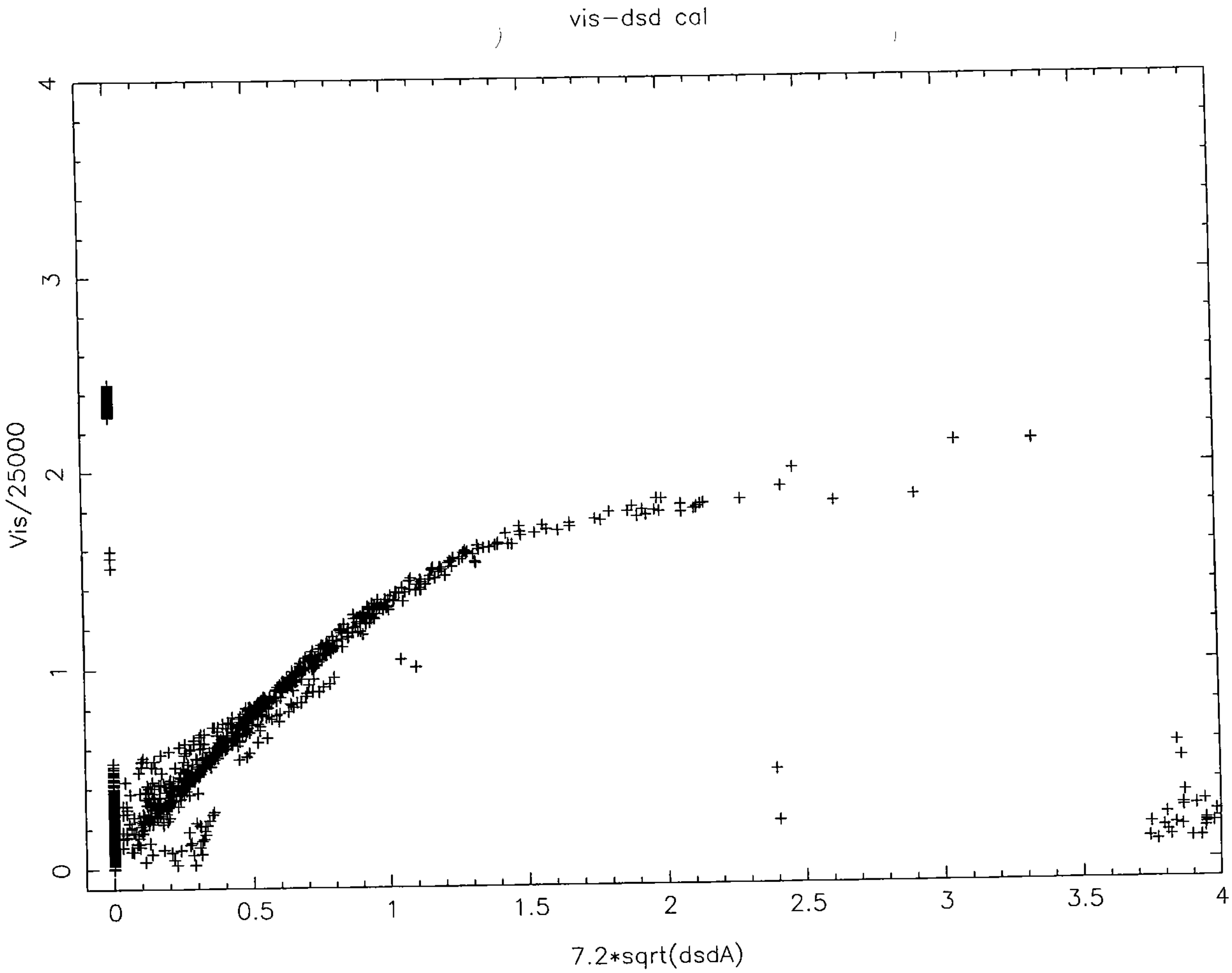
9 References

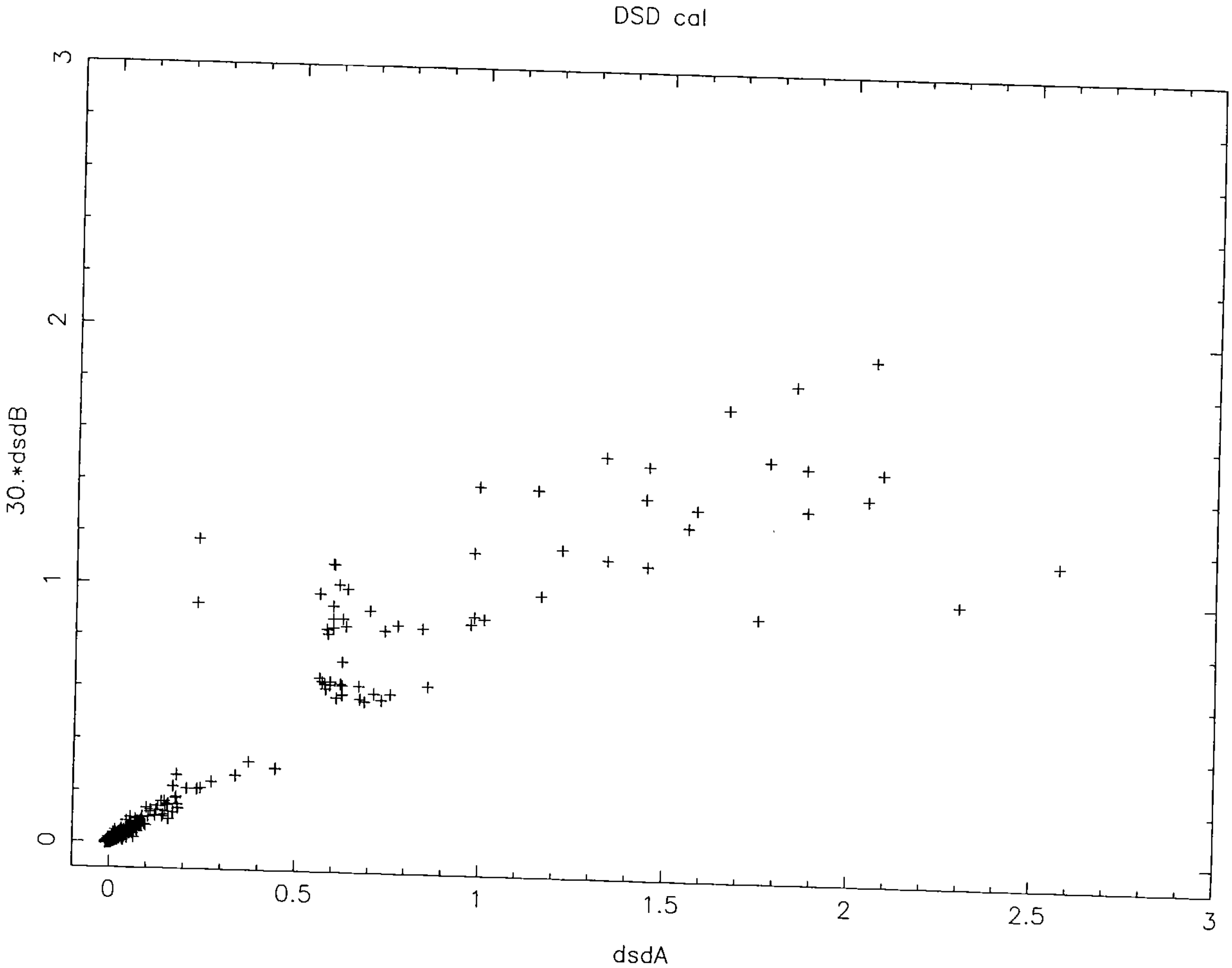
Caswell,J.L., Vaile,R.A., Ellingsen,S.P. and Norris,R.P.
"Galactic Methanol Masers at 12 GHz", MNRAS, 1995

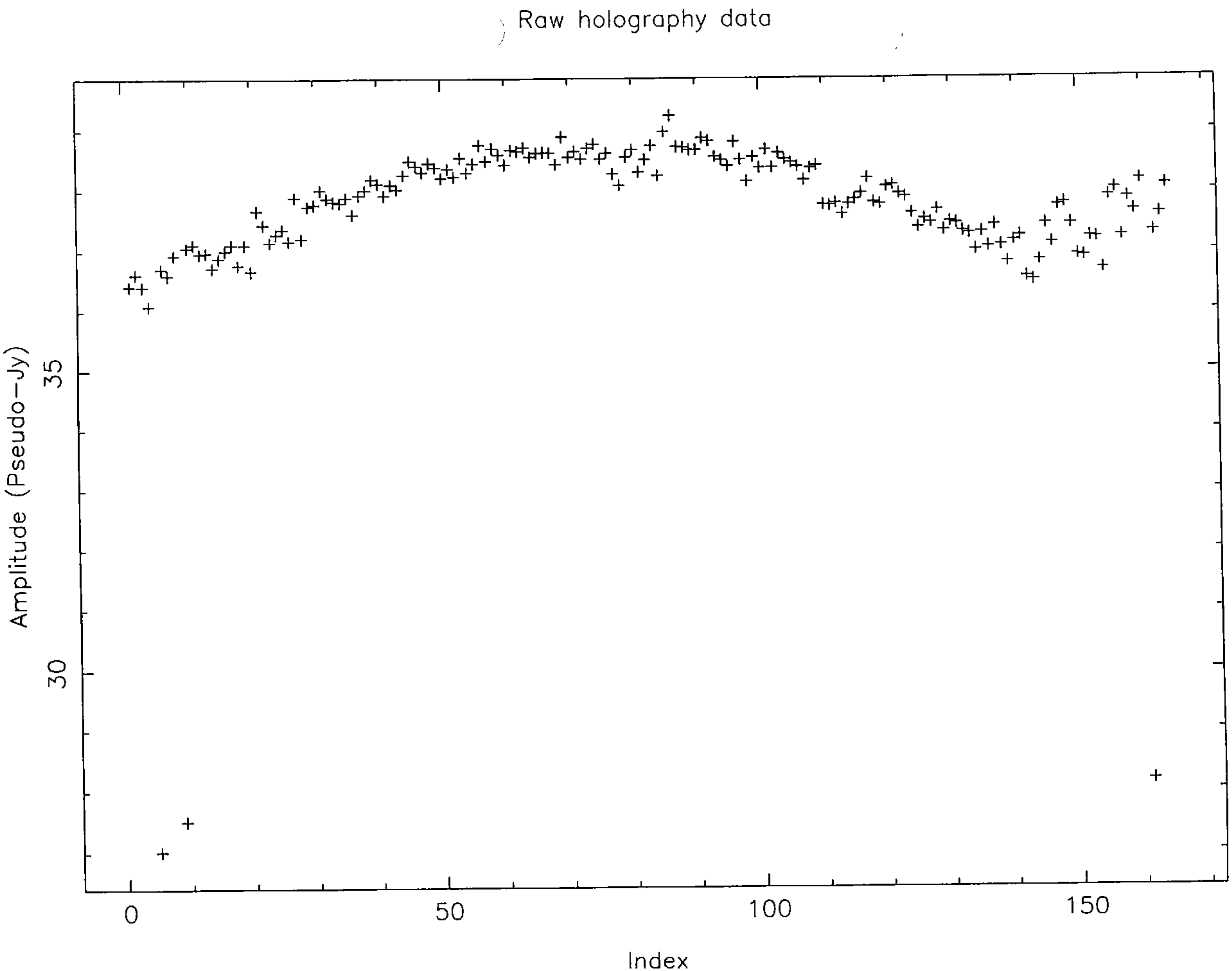
10 Appendix A — HOLGR adverbs

HOLGR: Task to read and process holography visibility data.

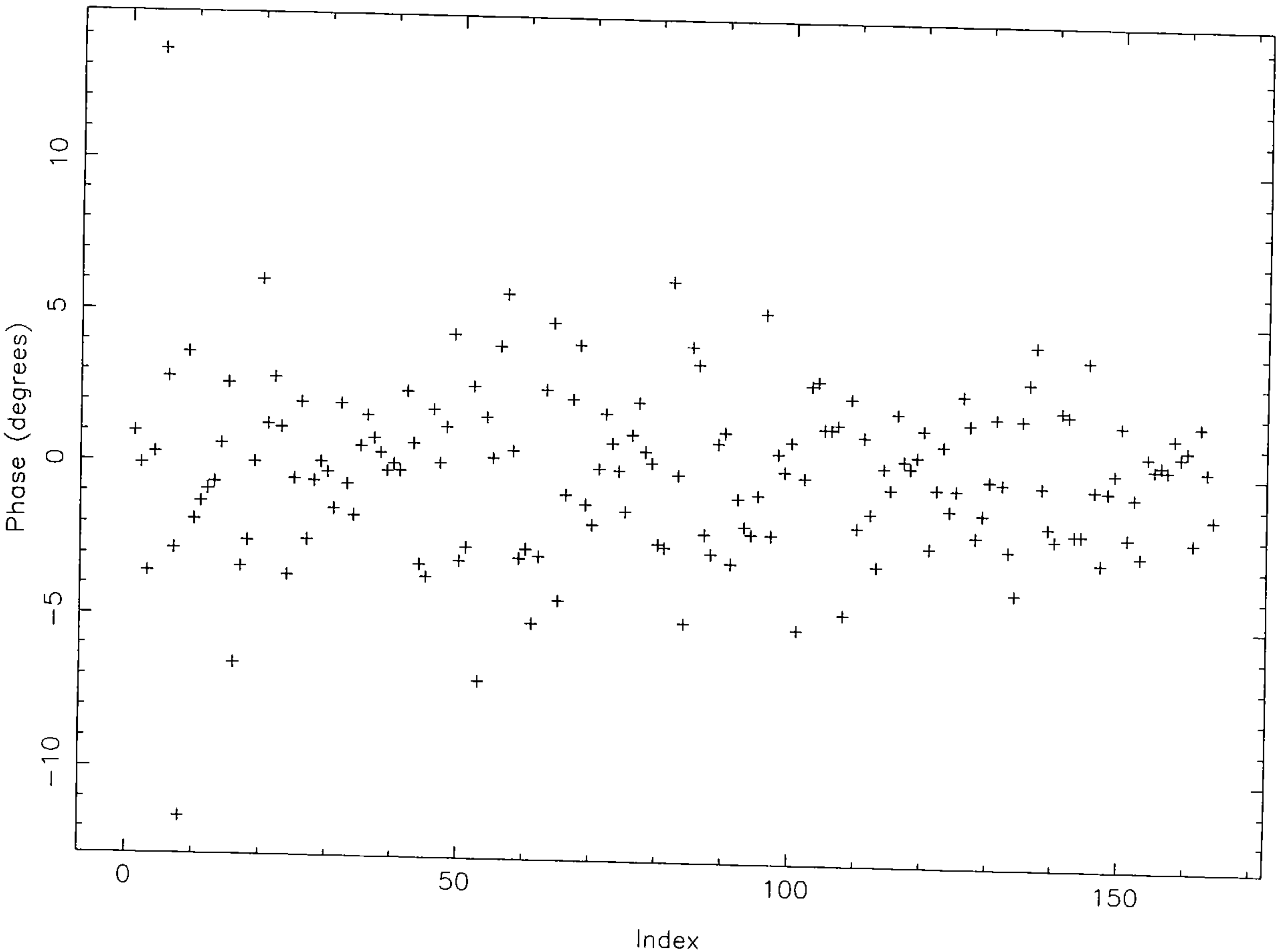
```
Adverbs      Values                          Comments
------------------------------------------------------------------------
INFILE       'HOLO:RESULTS2.23JUN'           Input file name
OUTNAME                                      Output image name.
OUTDISK        1                             Output disk number.

APARM          12.75        1                Operating parameters.
               22           3.35             1: Frequency (GHz).
               7            *rest 0          2: Satellite elevation, deg.
                                             3: Antenna diameter, m.
                                             4: Subreflector diameter, m.
                                             5: Focal length, m.
                                             6: Offset of the antenna
                                                vertex in u, in meters.
                                             7: As for 6 in v.
                                             8: As for 6 in w.
                                             9: Antenna number. see help
                                             10: Stokes [1,2]

BPARM          26           128              Data reduction parameters.
                0             1              1: Required map size, m.
                1             1              2: No. of pixels on a side
                1            24                 of the output map (power
              101            -1                 of 2, maximum 128).
                                             3,4: (u,v) range, see help
                                             5: Amplitude scaling factor
                                             6: Fourier transform control
                                             7,8: (x,y) range, see help
                                             9: Correction control flags
                                             10: logarithmic/linear data

CPARM        *all 0                          Parameters for the regridding
                                             operation (see HELP).

DPARM           0             0              Output option flags..
                0             1              1,2: Regridded amplitude and
                0             0                   phase of the observed
                0             0                   antenna pattern.
                1             1                3: Weights used in the
                                                   regridding procedure.
                                             4,5: Derived amplitude and
                                                  phase of the grading.
                                             6,7: Amplitude and phase of
                                                  the point-spread
                                                  function for 4 and 5.
                                               8: Potential energy map
                                                  for (5).
                                               9: Surface deviation map.
                                              10: Interpolated antenna
                                                  power pattern.
```

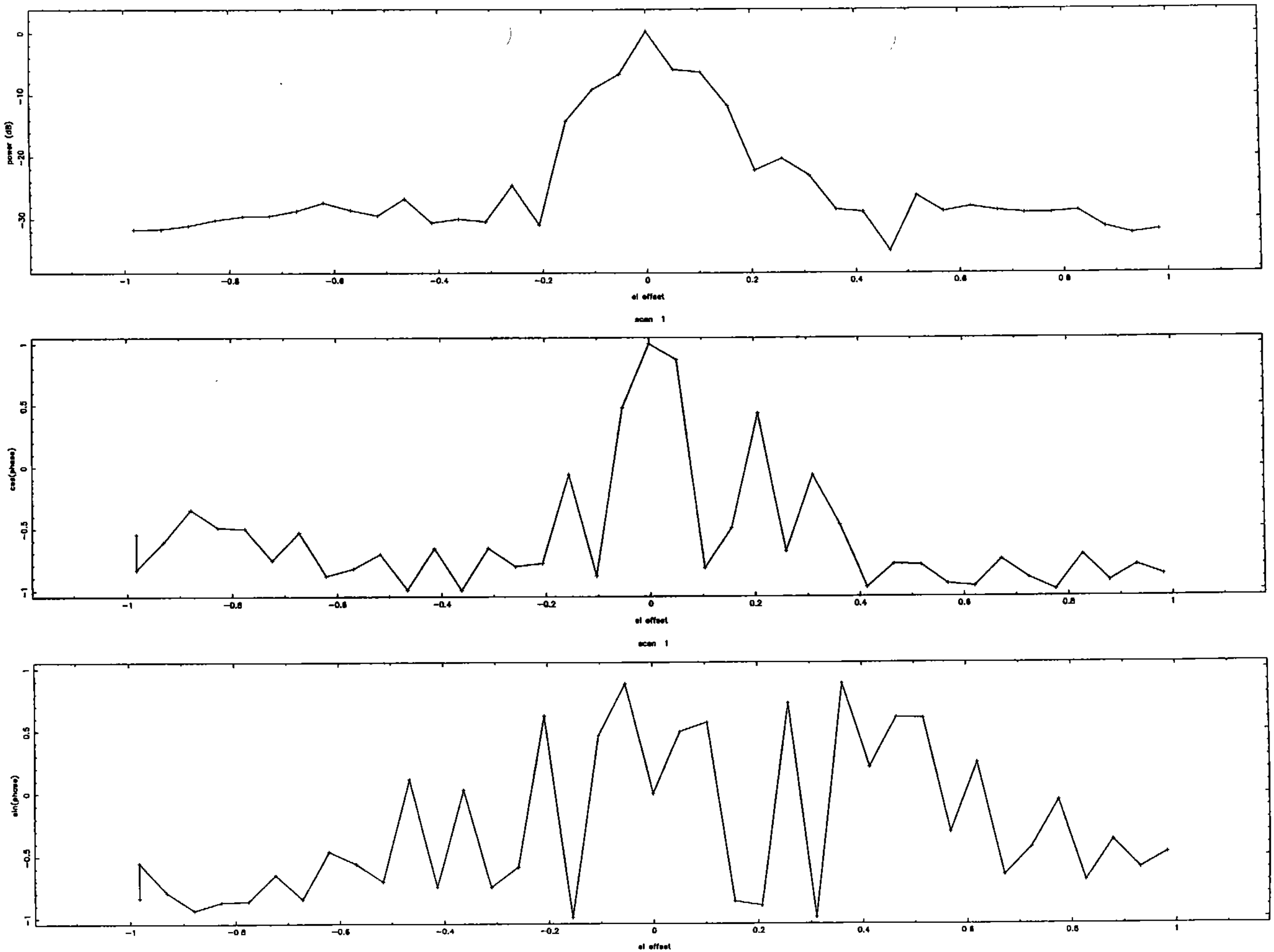

vis-dsd cal
Vis/25000
0
1
2
3
4
0
0.5
1
1.5
2
2.5
3
3.5
4
7.2*sqrt(dsdA)

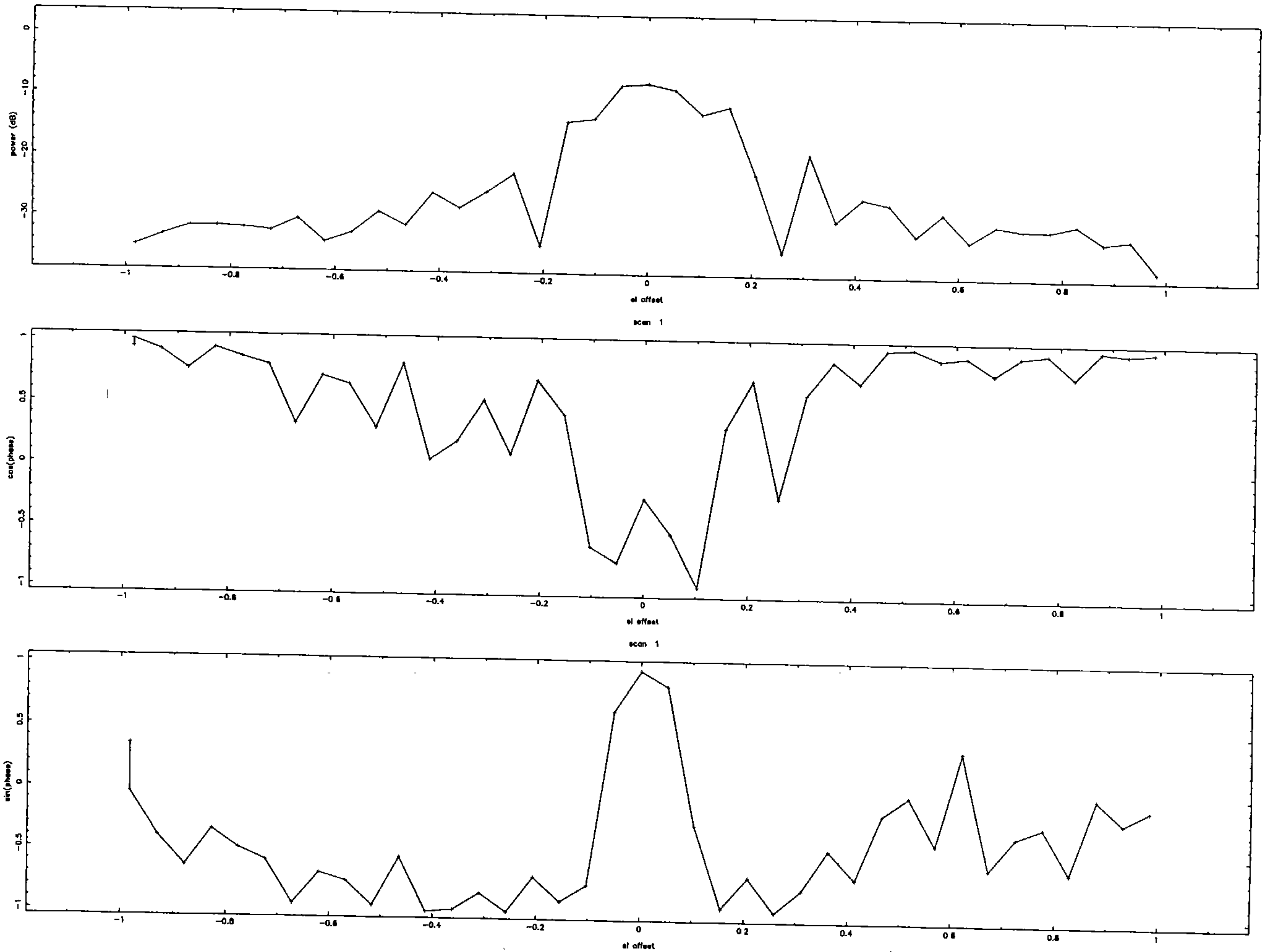

DSD cal
30.*dsdB
dsdA
0
0.5
1
1.5
2
2.5
3
0
1
2
3


Raw holography data
Amplitude (Pseudo-Jy)
35
30
0
50
100
150
Index

Calibrated holography data

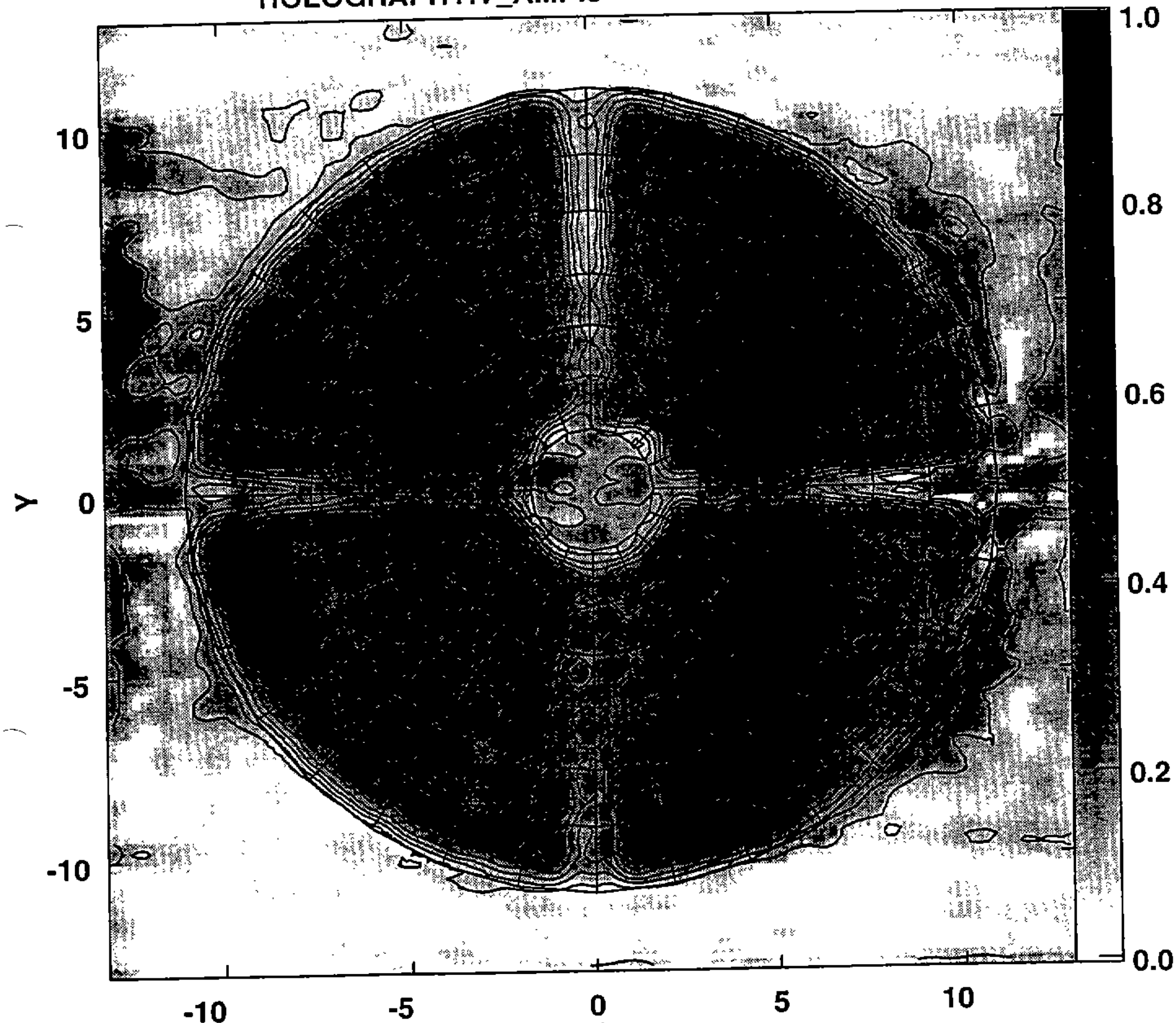



power (dB)
el offset
scan 1
cos(phase)
el offset
scan 1
sin(phase)
el offset


power (dB)
el offset
scan 1
cos(phase)
el offset
scan 1
sin(phase)
el offset

Plot file version 1 created 27-JUN-1995 18:38:36

HOLOGRAPHY.V_AMP.5



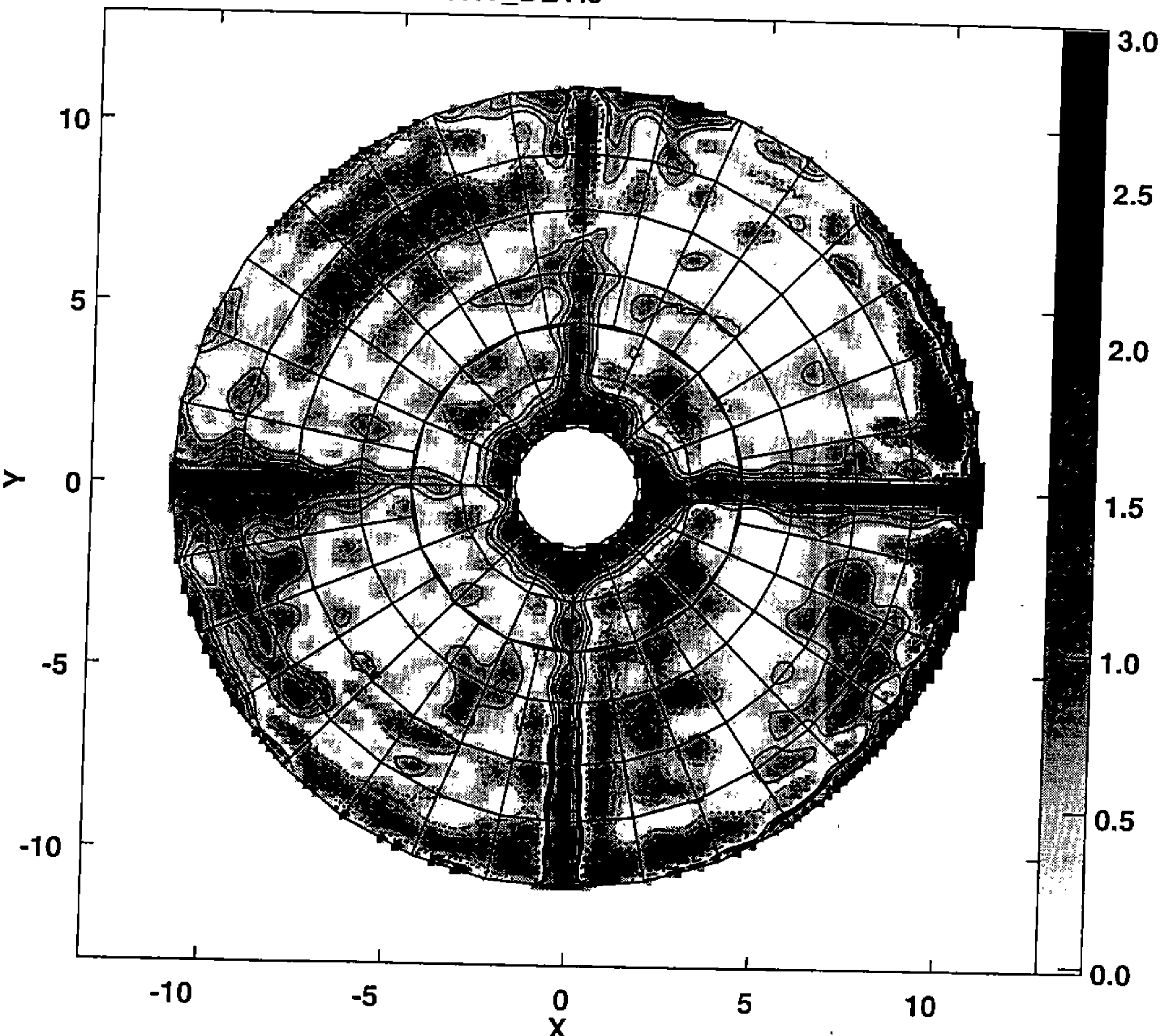
Grey scale flux range= 0.000 1.000 Volt
Peak contour flux = 1.0000E+00 Volt
Levs = 1.0000E-02 * (10.00, 20.00, 30.00, 40.00, 50.00, 60.00, 70.00, 80.00, 90.00)

CAOG

June 23 — corrected for subreflector offset.

Plot file version 3 created 27-JUN-1995 18:42:41

HOLOGRAPHY.V_DEV.5



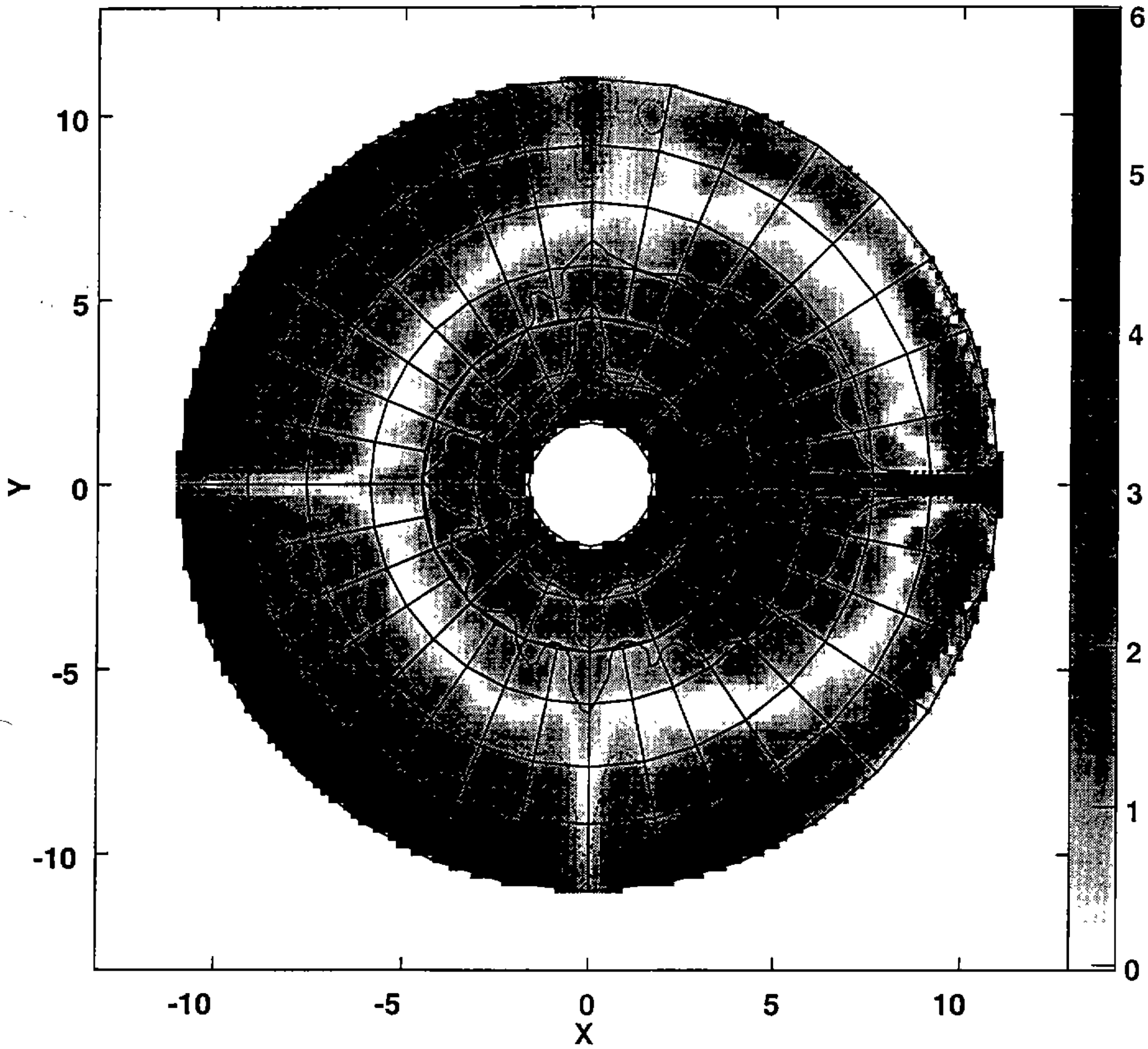
Grey scale flux range= 0.000 3.000 MilliMeter
Peak contour flux = -6.8698E-03 Meter
Levs = 1.0000E-04 * (-5.00, -2.50, 2.500,
5.000, 7.500)

Δx = -2.0 mm
Δy = 4.0 mm
Δz = 15.4 mm

CA06 – June 23 – uncorrected for sub-reflector offset.

Plot file version 5 created 28-JUN-1995 08:09:47

HOLOGRAPHY.V_DEV.7



Grey scale flux range= 0.000 6.000 MilliMeter
Peak contour flux = -8.6771E-03 Meter
Levs = 5.0000E-04 * (-5.00, -2.50, 2.500, 5.000, 7.500)

Reconstructed CA06 beam pattern.