VLB ARRAY MEMO No. 96

# ARRAY DYNAMIC RANGES

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# Array Dynamic Ranges

The following procedure was used to determine the dynamic ranges for sample arrays for the High Angular Resolution Telescope . It is a good method for ranking the quality of a given array, but only gives an approximate value for the dynamic range that can be actually be achieved.

## I Test Source and Data

Dynamic ranges were determined using one of two artifical test sources, named DAISY and AMOEBA (see Table 1). For the source under consideration, an artifical data file was created. This file consisted of observations of visibility amplitude and interferometer phase for all times during a twelve hour period when the source was visible from at least 3 stations. For all positive declinations, this included the full 12 hour period. At -06 and -18 degrees declination, observing times were reduced to ~11.5 and ~9 hours, respectively. Artificial noise was added to each data point to simulate the noise for the following interferometer: 25m diameter antennae, 55% aperture efficiency, 600 second coherent integration, Tsys of 50 degrees, and 56 MHz bandwidth. This implies an actual statistical rms error of 0.005 Jy (as per MHC). Note that NO systematic errors were included in the data; this is equivalent to assuming near-perfect station calibration.

In the actual command procedures used, for convenience the noise level was scaled rather than changing the test source file. For example, the signal-to-noise ratio equivalent to a 0.5 Jy source (100:1 on zero length baseline) is correctly simulated using a 20 Jy DAISY and a statistical error of 0.2 Jy.

All things considered, I feel that DAISY is not a completely adequate test source. The extreme regularity in DAISY tends to create problems in gridding and interpolation that make for dificulties in measuring the quality of an array. These problems are easily solved, but at the expense of larger amounts of computer time because larger (finer) arrays and lower loopgains are needed to get the maximum dynamic range. A second problem is that DAISY has no large areas of very low, approximately constant surface brightness, so that dynamic ranges above ~150 may become less meaningful. If many more of these dynamic range measurements are needed in the future, I suggest that a new source be created that is similar to DAISY or AMOEBA, but with a much smoother brightness distribution and larger areas of low brightness.

## II Beam Determination

Because the half-width of the dirty beam is a function of the exact way that the data is gridded into the UV plane, there is no "true" restoring beam. As a guide, however, a beam should not be too much smaller that $\lambda/d$ . A uniformly weighted, filled array will give a FWHM of 1.02 $\lambda/d$; if a 30% Guassian taper is applied to a uniform array, the FWHM is 1.28 $\lambda/d$.

To find the beams used, a dirty beam was produced using uniform weighting with a 30% Guassian taper. The 50% level of this beam was assumed to be elliptical and used to define the FWHM and rotation of the restoring beam. The beams used for array 13 were found to be comparable to $\lambda/d$ , in both dimensions. An alternative procedure for determining the beam might be to measure the raw FWHM of the dirty beam (from uniform, un-tapered weighting) and then scale that beam up until the shortest dimension equaled a factor times $\lambda/d$ ; a typical factor might be 1.0

III Inversion and Cleaning

For the actual fourier inversion of the data, uniform weighting was used to avoid any complications in convolution of the map before cleaning. The dirty map was cleaned with the appropriate beam (uniform weighting of the UV points). A loopgain of 0.4 for 2500 iterations was used for the cleaning; I suspect that a lower loopgain (say, ~0.1) and more iterations (~5000?) would have given higher dynamic ranges in some cases.

Both sources had the brightest component centered at the origin. For the DAISY source, a window 20 mas on a side centered on +5,+5 was cleaned; for the AMOEBA source, the same size window was cleaned, but centered on the brightest component. The large array sizes were needed especially at the lower declinations to prevent spurious components from appearing near the edges of the clean map. The default XYINT and MAPSIZE were used in invert; this resulted in a MAPSIZE of 256 and an XYINT of 0.198 mas for IDIM=256. For declinations greater than 18 degrees, IDIM=128 gave results essentially identical to those from IDIM=256, and only took ~1/6 the elapsed time on the VAX. For this latter case, it is necessary to shift the DAISY before inversion so that the brightest component lies at -5,-5 mas.

## IV Dynamic Range Calculation

The set of delta functions resulting from clean was subtracted from the original model, to produce a difference model. This difference model was then convolved with the restoring beam and plotted. If a perfect map were possible, the difference map would be of zero brightness level everywhere. Because of errors in the clean map, the difference maps all had positive and negative regions, corresponding to deficits or excesses on the clean map. The absolute value of the peak brightness on the difference map was determined (outside of the "core" region on the original map). Then, the dynamic range for a given map was defined as the ratio of the peak brightness of the original map (after convolution with the restoring beam) to the peak brightness of the difference map.

## V Tables

### Table 1: Test Sources

DAISY:

| Flux | R | Theta | Axis | Ratio | P. A. |
|---|---|---|---|---|---|
| 0.0 | 7.071 | -135.0 | 0.9 | 1.0 | 0.0 |
| 0.5 | 5.831 | -149.036 | 1.0 | 1.0 | 0.0 |
| 0.5 | 5.099 | -168.690 | 1.0 | 1.0 | 0.0 |
| 0.5 | 5.099 | 168.690 | 1.0 | 1.0 | 0.0 |
| 0.5 | 5.831 | 149.036 | 1.0 | 1.0 | 0.0 |
| 0.5 | 7.071 | 135.000 | 1.0 | 1.0 | 0.0 |
| 0.5 | 5.165 | -140.752 | 1.0 | 1.0 | 0.0 |
| 0.5 | 3.370 | -152.889 | 1.0 | 1.0 | 0.0 |
| 0.5 | 2.010 | 174.399 | 1.0 | 1.0 | 0.0 |
| 0.5 | 2.172 | 117.412 | 1.0 | 1.0 | 0.0 |
| 0.5 | 3.660 | 90.0 | 1.0 | 1.0 | 0.0 |
| 0.5 | 5.165 | -129.248 | 1.0 | 1.0 | 0.0 |
| 0.5 | 3.370 | -117.111 | 1.0 | 1.0 | 0.0 |
| 0.5 | 2.010 | -84.399 | 1.0 | 1.0 | 0.0 |
| 0.5 | 2.172 | -27.412 | 1.0 | 1.0 | 0.0 |
| 0.5 | 3.660 | 0.0 | 1.0 | 1.0 | 0.0 |
| 0.5 | 5.831 | -120.964 | 1.0 | 1.0 | 0.0 |
| 0.5 | 5.099 | -101.310 | 1.0 | 1.0 | 0.0 |
| 0.5 | 5.099 | -78.690 | 1.0 | 1.0 | 0.0 |
| 0.5 | 5.831 | -59.036 | 1.0 | 1.0 | 0.0 |
| 0.5 | 7.071 | -45.0 | 1.0 | 1.0 | 0.0 |

AMOEBA:

| Flux | R | Theta | Axis | Ratio | P.A. |
|---|---|---|---|---|---|
| 10.000 | 0.000 | 0.000 | 0.800 | 1.000 | 0.000 |
| 2.500 | 5.000 | 0.000 | 6.000 | 0.500 | 90.000 |
| 2.500 | 5.000 | 30.000 | 6.000 | 0.500 | 120.000 |
| 2.500 | 5.000 | 60.000 | 6.000 | 0.500 | 150.000 |
| 2.500 | 5.000 | 90.000 | 6.000 | 0.500 | 0.000 |

### Table 2: Station Lists for Arrays Tested

| Array# | # of Stations | Station List |
|---|---|---|
| [illegible]3 | 10 Stations | HNLU,HSTK,ANCH,LRDO,IOWA,DSS13,BLDR,BOISE,OVRO,SALEM |
| 15 | 9 Stations | HNLU,HSTK,ANCH,LRDO,IOWA,DSS13,BLDR,BOISE,PASC |

Table 3: Dynamic Ranges for Array 13, for DAISY source

| [redacted]lux | Declination, Degrees --> 64 | 44 | 30 | 18 | 06 | -06 | -18 |
|---|---|---|---|---|---|---|---|
| 10 Jy | 339 | | | 266 | | | 88 |
| [redacted] | 327 | | | 265 | | | 88 |
| 0.5 | 204 | 205 | 206 | 168 | 95 | 66 | 73 |
| [redacted]2 | 103 | | | 105 | | | 65 |
| [redacted]1 | 61 | | | 60 | | | 38 |

Table 4: Dynamic Ranges for Array 13 for AMOEBA

| [redacted]ux | Declination, Degrees --> 64 | 44 | 30 | 18 | 06 | -06 | -18 |
|---|---|---|---|---|---|---|---|
| [redacted]5 Jy | 231 | | | 155 | | | 90 |

Table 5: Beams for Array 13

| [redacted]eclination | Short Axis | Long axis | Theta |
|---|---|---|---|
| 64. | .77 mas | .80 mas | -32. degrees |
| [redacted]. | .76 | .85 | -22. |
| [redacted]. | .76 | .94 | -16. |
| 18. | .80 | 1.07 | -13. |
| [redacted]. | .85 | 1.24 | -14. |
| [redacted]6. | .80 | 1.52 | -10. |
| -18. | .70 | 2.10 | -12. |

## Table 6: Dynamic Ranges for Array 15 for DAISY

| F[redacted]x | Declination, Degrees --> 64 | 44 | 30 | 18 | 06 | -06 | -18 |
|---|---|---|---|---|---|---|---|
| 0[redacted]5 Jy | 147 | 128 | 177 | 144 | 95 | 78 | 76 |

## Table 7: Beams for Array 15

| D[redacted]clination | Short Axis | Long axis | Theta |
|---|---|---|---|
| 64. | .72 mas | .78 mas | -17. degrees |
| 44. | .75 | .84 | -15. |
| 3[redacted] | .73 | .91 | -18. |
| 1[redacted]. | .81 | 1.03 | -17. |
| 06. | .82 | 1.20 | -13. |
| -[redacted]. | .80 | 1.49 | -10. |
| -[redacted]. | .70 | 1.96 | -11. |

## VI Command Procedures

The following are samples of command procedures that were used to determine beams and produce clean maps for array 13. Each is more or less self contained, so that the correct version of any particular file is used. To actually measure the peak on the difference map, program MODPLOT was used, using the options: PIXELS=200 DEGREES LRTB=-15,5,15,-5 and CONTOURS For the AMOEBA source, a window of LRTB=-10,10,10,-10 was used. Both sources had the brightest component centered at the origin.

### A Beam Command Procedure:

```
$ ASSIGN [RSS]1364.LOG SYS$PRINT
$ SET WORKINGSET/LIMIT=256
$ SET DEF [VLB.RSS.DAISY]
$ ASSIGN/U 1364.LIS  FOR006
$ ASSIGN/U [VLB]STATIONS.DAT STATIONS
$ ASSIGN/U [VLB]SOURCES.DAT SOURCES
$ RUN [VLB]FAKE
  1364.MRG
  DAISY.N03
RA 00:00:01  DEC 64:00:00
START=19:00:00 STOP=06:50:00  NUP=3
  FREQ 10650  INTEG 600  SOURCE 'DAISY.N03'
NOCLOSE
STATIONS 'HNLU',
'HSTK','OVRO','BOISE','ANCH','LRDO','IOWA','DSS13','BLDR','SALEM'
TIMESCALE 40  ERRADD=0.20  /
$ ASSIGN/U [SCRATCH]1364INVP.RSS PLOTOUT
$ ASSIGN/U [SCRATCH]1364INVL.RSS FOR006
$ ON ERROR THEN GOTO END
$ INVERT/IDIM=256/MAXP=4000
FROM '[VLB.RSS.DAISY]1364.MRG'
MAPFILE 'NL:'
BEAMFILE 'NL:'
CONTOUR=-13,-11,-9,-7,-5,-3,-1,1,3,5,7,9,11,13,50
UVTAPER=.30  NOMAP
FLUX 20    PRINTUV  PLOTMAP=10 PLOTBEAM=1.0
$ RUN [VLB]UVPLOT
1364.MRG
[SCRATCH]1364.RSS

    PRINT/NOFEE/NOFLAG/DEL/HOLD/QUE=LPA0: [SCRATCH]1364INVL.RSS,-
    [SCRATCH]1364INVP.RSS,-
    [SCRATCH]1364.RSS,-
    [VLB.RSS.DAISY]1364.BM/NODELETE
```

```
$ END:
$ SEND TTA0: JOB 1364 HAS NOW FINISHED
```

B Invert and Clean Command Procedure:

```
_ ASSIGN [RSS]1364.LOG SYS$PRINT
$ SET WORKINGSET/LIMIT=512
  SET DEF [VLB.RSS.DAISY]
  ASSIGN/U 1364.LIS  FOR006
$ ASSIGN/U [VLB]STATIONS.DAT STATIONS
$ ASSIGN/U [VLB]SOURCES.DAT SOURCES
  RUN [VLB]FAKE
  1364.MRG
  DAISY.N04
 A 00:00:01  DEC 64:00:00
 TART=19:00:00 STOP=06:50:00  NUP=3
  FREQ 10650  INTEG 600  SOURCE 'DAISY.N04'
 OCLOSE
 TATIONS 'HNLU',
'HSTK','OVRO','BOISE','ANCH','LRDO','IOWA','DSS13','BLDR','SALEM'
  TIMESCALE 40  ERRADD=0.20   ERRMULT=0.00
  ASSIGN/U [SCRATCH]1364INVP.RSS PLOTOUT
  ASSIGN/U [SCRATCH]1364INVL.RSS FOR006
$ ON ERROR THEN GOTO END
  INVERT/IDIM=512/MAXP=4000
 ROM '[VLB.RSS.DAISY]1364.MRG'
MAPFILE '[SCRATCH]MAP1364.RSS'
 EAMFILE '[SCRATCH]BEAM1364.RSS'
 ONTOUR=-5,-3,-1,1,3,5,7,9,11,13,50
FLUX 20   PRINTUV  PLOTMAP=20 PLOTBEAM=1.0
$ ASSIGN/U [SCRATCH]1364CLNL.RSS FOR006
  ASSIGN/U [SCRATCH]1364CLNP.RSS PLOTOUT
  ON ERROR THEN GOTO END
$ CLEAN/SIZE=256/MAXIT=2500
 EAM=.77,.80,-32.
 OOPGAIN = 0.40 NITER = 2500
MAPFILE = '[SCRATCH]MAP1364.RSS'
 EAMFILE = '[SCRATCH]BEAM1364.RSS'
 ODEL = '[VLB.RSS.DAISY]1364.MAP'
LRTB -15,5,15,-5 PLOTWINDOW
 RINTRES  NORESTORE PLOTMAP
  PURGE [SCRATCH]*.RSS
  RUN [VLB]MODSUM
DAISY.N04
 .
 364.MAP
-1.

 364.SUB
N
$ ON ERROR THEN GOTO END
  RUN [VLB]MODPLOT
DAISY.N04
TTB4
 0650.
 6
BEAM=.77,.80,-32.
 RTB -15,5,15,-5 CONT -1,-.5,.5,1,1.5,2,2.5,3,3.5,4,4.5,5,5.5,6,6.5,7,
 0,50  TITLE 'DAISY.N04, DEC64 BEAM, 1364 STA  ARRAY' PIXEL 200 PPRINT
Y
 ODFILE '1364.MAP' TITLE '1364.MAP, DEC64 BEAM, 1364 STA ARRAY'
```

```
M[redacted]DFILE '1364.SUB' TITLE 'DAISY.N04-1364.MAP, 1364 STA ARRAY'
LRTB -15,5,15,-5  DEGREES  CONT (-8*7.53),
([redacted]*7.53),(-6*7.53),(-5*7.53),(-4.5*7.53),(-4*7.53),(-3.5*7.53),(-3*7.53),
([redacted].5*7.53),(-2*7.53),(-1.5*7.53),(-1*7.53),(-.5*7.53),
(.5*7.53),(1*7.53),(1.5*7.53),(2*7.53),(2.5*7.53),(3*7.53),(3.5*7.53),
([redacted]*7.53),(4.5*7.53),(5*7.53),(6*7.53),(7*7.53),(8*7.53)  /
N[redacted]
$ RENAME MODPLOT.LIS [SCRATCH]1364PLOT.RSS
$ [redacted]UN [VLB]UVPLOT
1[redacted]4.MRG
[SCRATCH]1364.RSS

$ [redacted]  PRINT/NOFEE/NOFLAG/DEL/HOLD/QUE=LPA0: [SCRATCH]1364INVL.RSS,-
    [SCRATCH]1364INVP.RSS,1364CLNL,1364CLNP,-
    1364PLOT,1364.RSS,-
[redacted]  [VLB.RSS.DAISY]1364.HYB/NODELETE
$ [redacted]ND:
$ SET PROTECTION=(O:RWED,S:RE,W:RE,G:RE) [SCRATCH]*.RSS
$ [redacted]END TTA0: JOB 1364 HAS NOW FINISHED
```