CARMA

Combined Array for Research in Millimeter-Wave Astronomy

CARMA Memorandum Series #51

Antenna Shadowing in E array

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ABSTRACT

We simulated CARMA E-array configuration observations with sources between declinations of -30 and 85 degrees to determine the extent of shadowing in this most compact configuration. The percentage of shadowed visibilities for various hour angle ranges at each source declination is presented. We find that shadowing only becomes significant for a standard four-hour track, centered on transit, for sources below a declination of 0 degrees. The shadowing ramps up for larger hour angles, especially for lower declination sources. The percentage of shadowed visibilities we obtained uses the full antenna diameters, when in practice, one might be able to get better performance from the actual system by including visibility data where the antenna dish was only slightly shadowed at the edge of the dish. We suggest the use of MIRIAD task, `csflag`, to flag shadowed antennas. However, users should be aware that shadowing does not seem to have a detrimental effect on the data, as unflagged shadowed data have not shown a drop in amplitude or scattering in phase coherence, as might have been expected. Shadowing is not a serious concern in the less compact configurations: A, B, C and D, although users may still want to run `csflag` to see the extent of shadowing themselves and to compare their maps with and without this data.

Change Record

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1.0	2009-Jun-16	Peter J. Teuben, B. Ashley Zauderer	1-101
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1. Simulating E array data: Model parameters

CARMA memorandum 20 describes how the E array configuration was designed to optimize desired parameters and minimize shadowing. The shadowing was described to be significant for sources with a declination of -30 degrees, with as many as 69-77 per cent of visibilities shadowed, but not as problematic for sources with a declination of 0 degrees. We have considered a much finer grid of source declinations and hour angles in order to guide the choice of target sources in E array by observers, and the optimal hour angle range for scheduling.

This memorandum should also serve as a guide for observers to be aware of at what declinations they should know that their data includes shadowed data. Users should use CSFLAG to flag these data and compare their data with and without the flagged visibilities.

We used the MIRIAD task, `uvgen`, to generate the simulated visibility data. We used the 2007 E array position file, an observatory latitude of 37.3 and declinations ranging from -30 to 85, in steps of 5 degrees. At each declination, we considered 6 hour angle ranges: -1,1; -2,2; -3,3; -4,4; -5,5; and -6,6.

2. Shadowing Math

A right handed Cartesian coordinate system (X, Y, Z) is normally used to designate the positions of the antennae in the array (see *e.g.* SMT91, Section 4.2). In these coordinates X and Y are parallel to the earth's equator, X points to the (local) meridian, Y towards the east, and Z measured towards the north pole. In MIRIAD you can find these in the `antpos` UV-variable, measured in nano-seconds. Note that antenna position files in MIRIAD (e.g. `$MIRCAT/carma_E.ant`) are often in a local (topocentric) coordinate system and using MIRIAD's `uvgen` program need to be converted to a geocentric system. See the description of its `baseunit=` and `ant=` keywords.

For given hour hangle (H) and declination (δ) of a source being tracked during an observation, the (u, v, w) coordinates are computed as followed (see SMT91, eq. 4.15):

$$u = X \sin H + Y \cos H \quad (1)$$

$$v = (X \cos H + Y \sin H) \sin \delta + Z \cos \delta \quad (2)$$

$$w = -(X \cos H + Y \sin H) \cos \delta + Z \sin \delta \quad (3)$$

For any antenna pair (i, j) we then compute if difference vector $(u_i, v_i) - (u_j, v_j)$ is within a distance of $(D_i + D_j)/2$ to cause shadowing. The computation has to be done twice, depending on the sign of $w_i - w_j$ which one shadows which.

A standard UV selection in miriad is available to select shadowed visibilities, e.g. `select=shadow(10)` would select visibilties that are shadowed within 10m. For OVRO=10m and BIMA=6m it was found that for mapping programs a BIMA-OVRO baseline corresponds fairly closely to an 8m "dish".

You will thus find that such baselines are labeled with telescope type CARMA. However, the current MIRIAD visibility data format does not know about individual antenna sizes, which causes inaccuracies in the shadowing computations. Hence the `csflag` program that knows about the peculiar CARMA array with its 10m and 6m dishes.

CAVEAT: the algorithm silently assumes that all antennae are in the array pointing at the same object and are always present.

3. Flagged visibilities

To determine the amount of shadowing, we used the new MIRIAD task `csflag` (See the CARMA MIRIAD Cookbook). This task includes the ability to determine shadowing with a heterogenous array, and takes into account both differing antenna diameters and differing antenna heights. The antenna diameters were conservatively entered to be the actual full diameter of each antenna type (10.4 m and 6.1 m). In reality, these values may be able to be pushed a bit smaller, leading to a slight decrease in visibilites flagged because there is some small and insignificant portion of the dish shadowed. The determination of the optimal antenna diameter values to use will require observational tests.

4. Results and Example Script

We present the results of our simulation in Figure 1.

The following combination of MIRIAD commands create a simulation of a point source observed in E array, at an RA of 0, declination of -20, over an hour angle range of -2,2. The baseunit conversion factor is for the purpose of changing the antenna position file into the correct units for `uvgen`. Then, the output from `csflag` will be the total number of records in the visibility file, and the number of visibilities where shadowing occurs.

```
% uvgen source=$MIRCAT/point.source ant=$MIRCAT/carma_E.ant baseunit=-3.33564 \
  telescop=carma corr=0 radec=0,-20 harange=-2,2 ellim=20 lat=37.3  out=EarrayPoint.mir
  ...
  4200 records written to file: EarrayPoint.mir

% csflag vis=EarrayPoint.mir carma=true \
  antdiam=10.4,10.4,10.4,10.4,10.4,10.4,6.1,6.1,6.1,6.1,6.1,6.1,6.1,6.1,6.1
  ...
  Processed  4200 records, flagged  1795 O/H/C:  10 936 849
```

See Table 2 for the specific E antenna configuration file we used for our simulation.

CARMA users can modify this example to create predictions of shadowing tailored to their specific observations, using the correct antenna configuration file, and their source specifics. `csflag` can be run with defaults, shadowing all visibilities where there was any shadowing, or it can be run with a smaller antenna diameter size, to only flag those visibilities where a large fraction of the dish was shadowed by another.

REFERENCES

Teuben, P. 2007. MIRIAD CARMA Cookbook.

Helfer, Tamara T. 2004. Version 2 CARMA Configurations for Cedar Flat. Memo. 20.

Thompson, A.R., Moran, J.M. & Swenson, Jr. G.W.. 1991. Interferometry and Synthesis in Radio Astronomy (Krieger publishing company) [SMT91]

Table 1. Flagged visibilitiesas a function of declination

A - Dec	B - HA	C - Elevation	D - Flagged Records	E - Total Records	F - Shadowing
-30	1	21	1381	2100	66
-30	2	17	3100	4200	74
-30	3	11	5077	6405	80
-25	1	26	991	2100	47
-25	2	22	2414	4200	57
-25	3	15	4168	6405	65
-20	1	31	802	2100	38
-20	2	26	1795	4200	43
-20	3	19	3369	6405	53
-20	4	10	5171	8505	61
-15	1	36	409	2100	19
-15	2	31	831	4200	20
-15	3	23	2015	6405	31
-15	4	13	3636	8505	43
-10	1	41	126	2100	6
-10	2	35	385	4200	9
-10	3	27	1304	6405	20
-10	4	17	2866	8505	34
-5	1	45	0	2100	0
-5	2	39	28	4200	1
-5	3	30	765	6405	12
-5	4	20	2093	8505	25
0	1	50	0	2100	0
0	2	44	0	4200	0
0	3	34	426	6405	7
0	4	23	1609	8505	19
5	1	55	0	2100	0
5	2	48	0	4200	0
5	3	38	277	6405	4
5	4	27	1067	8505	13
5	5	15	2592	10605	24
10	1	60	0	2100	0

Table 1—Continued

A - Dec	B - HA	C - Elevation	D - Flagged Records	E - Total Records	F - Shadowing
10	2	52	0	4200	0
10	3	41	140	6405	2
10	4	30	702	8505	8
10	5	18	2134	10605	20
15	1	64	0	2100	0
15	2	55	0	4200	0
15	3	44	42	6405	1
15	4	33	526	8505	6
15	5	21	1779	10605	17
20	1	68	0	2100	0
20	2	59	0	4200	0
20	3	47	0	6405	0
20	4	36	271	8505	3
20	5	24	1423	10605	13
25	1	72	0	2100	0
25	2	62	0	4200	0
25	3	50	0	6405	0
25	4	38	152	8505	2
25	5	26	930	10605	9
25	6	15	2517	12705	20
30	1	76	0	2100	0
30	2	64	0	4200	0
30	3	52	0	6405	0
30	4	40	98	8505	1
30	5	29	718	10605	7
30	6	18	2143	12705	17
35	1	78	0	2100	0
35	2	66	0	4200	0
35	3	54	0	6405	0
35	4	42	84	8505	1
35	5	31	640	10605	6
35	6	20	1990	12705	16
40	1	78	0	2100	0
40	2	67	0	4200	0
40	3	55	0	6405	0

Table 1—Continued

A - Dec	B - HA	C - Elevation	D - Flagged Records	E - Total Records	F - Shadowing
40	4	44	70	8505	1
40	5	33	553	10605	5
40	6	23	1794	12705	14
45	1	76	0	2100	0
45	2	66	0	4200	0
45	3	56	0	6405	0
45	4	45	56	8505	1
45	5	35	459	10605	4
45	6	25	1567	12705	12
50	1	73	0	2100	0
50	2	65	0	4200	0
50	3	56	0	6405	0
50	4	46	14	8505	0
50	5	37	329	10605	3
50	6	28	1211	12705	10
55	1	70	0	2100	0
55	2	63	0	4200	0
55	3	55	0	6405	0
55	4	46	0	8505	0
55	5	38	223	10605	2
55	6	30	955	12705	8
60	1	65	0	2100	0
60	2	60	0	4200	0
60	3	54	0	6405	0
60	4	46	0	8505	0
60	5	39	84	10605	1
60	6	32	666	12705	5
65	1	61	0	2100	0
65	2	57	0	4200	0
65	3	52	0	6405	0
65	4	46	0	8505	0
65	5	40	14	10605	0
65	6	33	390	12705	3
70	1	56	0	2100	0
70	2	54	0	4200	0

Table 1—Continued

A - Dec	B - HA	C - Elevation	D - Flagged Records	E - Total Records	F - Shadowing
70	3	50	0	6405	0
70	4	45	0	8505	0
70	5	40	28	10605	0
70	6	35	168	12705	1
75	1	52	0	2100	0
75	2	50	0	4200	0
75	3	47	0	6405	0
75	4	43	0	8505	0
75	5	40	112	10605	1
75	6	36	252	12705	2
80	1	47	0	2100	0
80	2	46	0	4200	0
80	3	44	0	6405	0
80	4	42	98	8505	1
80	5	39	238	10605	2
80	6	37	502	12705	4
85	1	42	280	2100	13
85	2	42	560	4200	13
85	3	41	854	6405	13
85	4	40	1134	8505	13
85	5	38	1414	10605	13
85	6	37	1824	12705	14

[a]Source Declination. RA=0

[b]Hour angle range: -p1,p1

[c]Elevation of source at maximum hour angle in range

[d]Number of flagged visibilities. CSFLAG output

[e]Total number of visibilities in simulated data

[f]The percentage of flagged visibilities based on shadowing, using full antenna diameters

Table 2. E array configuration file

north	east	zenith	station	ant
-16.880	-2.270	0.000	49/70	10m
25.170	24.000	0.000	71	10m
33.420	6.800	0.000	72	10m
36.070	-18.600	0.000	73	10m
15.730	-29.230	0.000	74	10m
-22.370	12.620	0.000	75	10m
10.500	-0.850	0.000	61	6m
13.230	8.580	0.000	62	6m
3.050	-7.750	0.000	63	6m
4.460	7.150	0.000	64	6m
0.000	0.000	0.000	32/47/65	6m
3.620	19.700	0.000	66	6m
-0.370	-20.020	0.000	48/67	6m
-7.310	-11.540	0.000	46/68	6m
-9.060	12.000	0.000	69	6m

[a]Topocentric coordinates in meters

[b]baseunit=-3.33564 to convert to equatorial system measured in nanoseconds

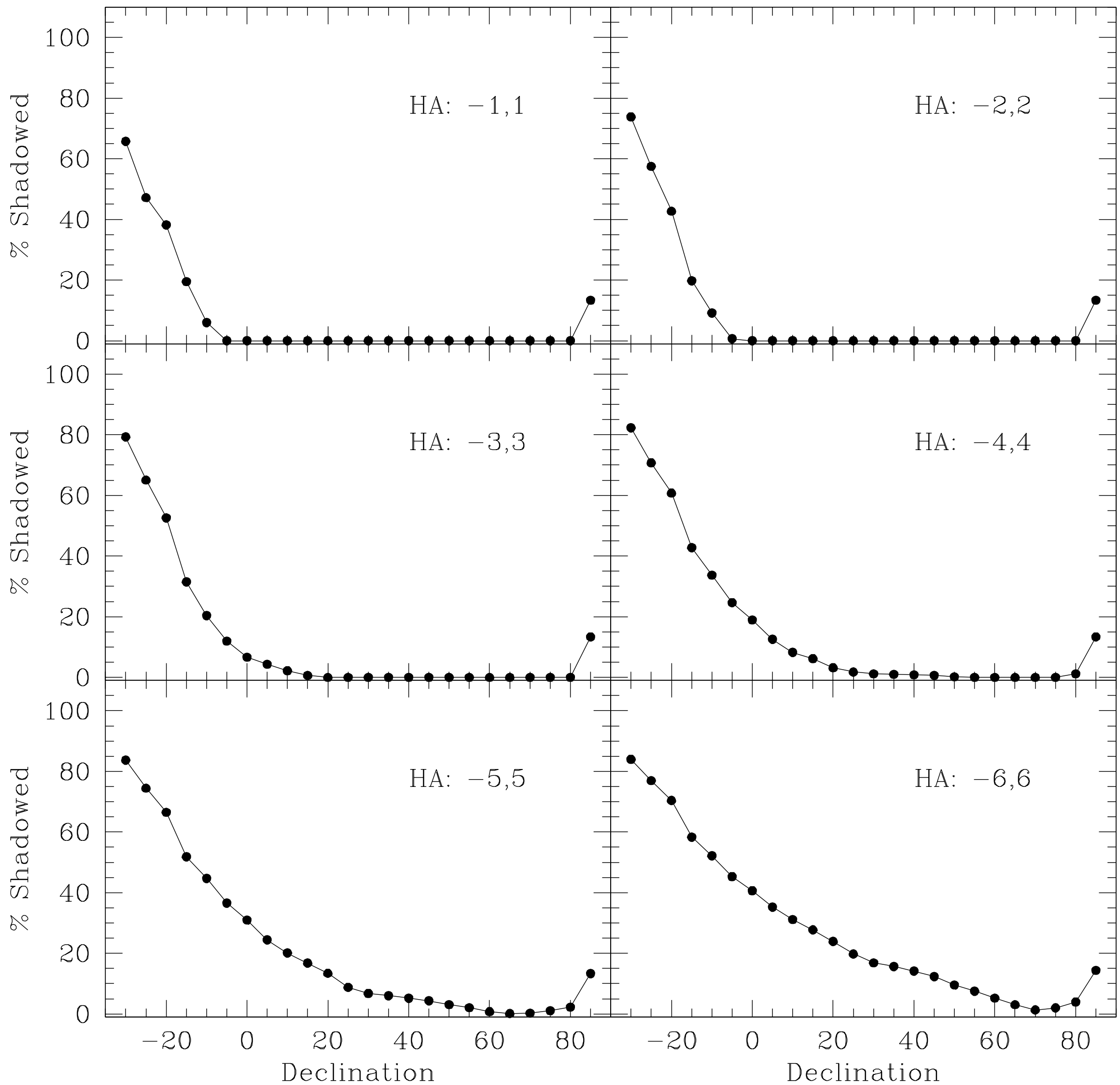

Fig. 1.— Percentage of flagged visibilites due to shadowing by hour angle range and declination.

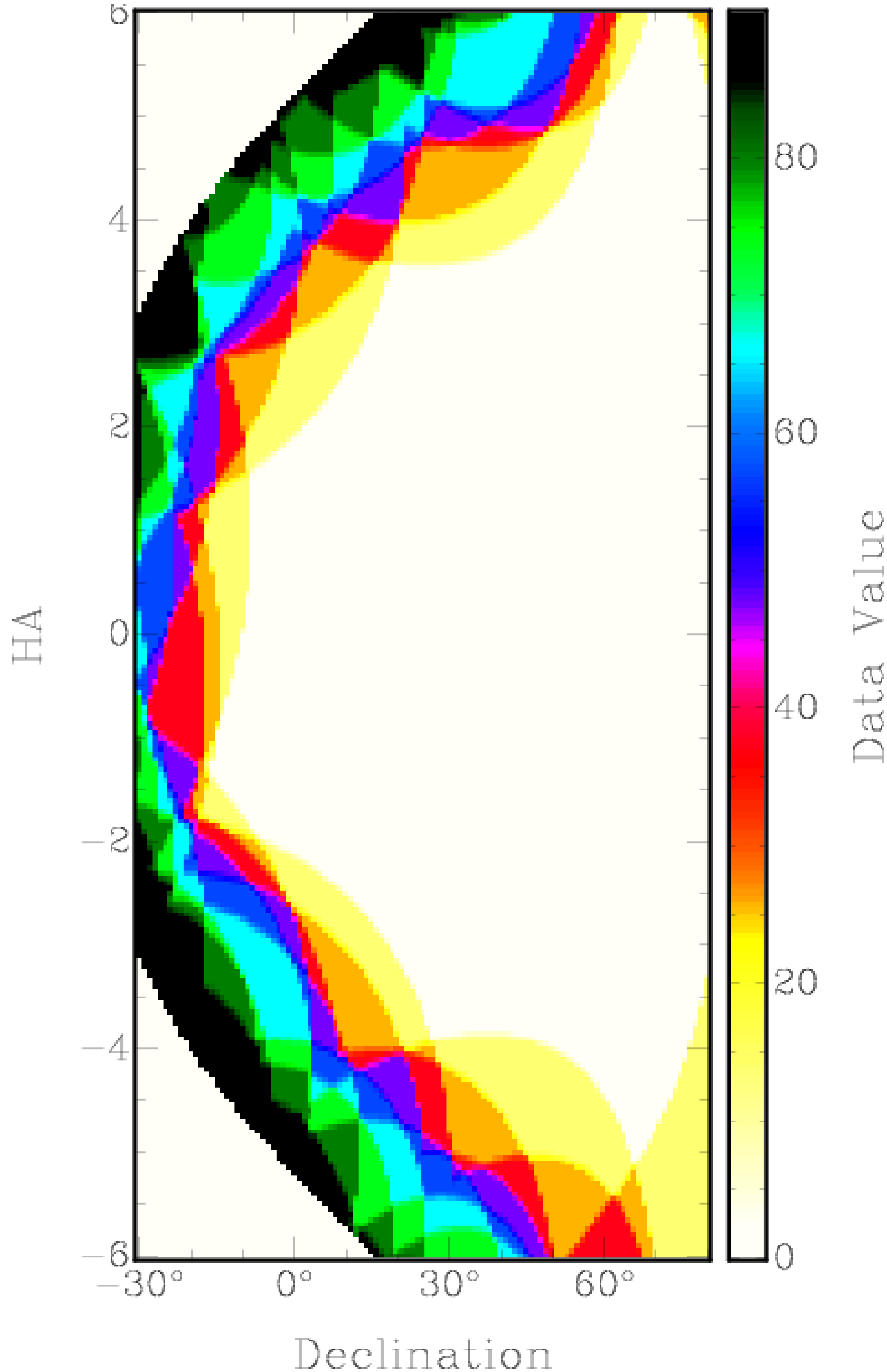

Fig. 2.— CARMA percentage shadowing diagram : E-array configuration