Star and T Configurations for an 8-element Array

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This report summarizes a study of Star and T configurations for an 8-element array. The objective of this report is to show beams and uv coverages obtained with an 8-element array which is constrained to the star-array station layout proposed for the 16-element array. T-configurations with 8-elements are compared to the Star configuration results.

Assumptions and Goals:

The following assumptions were made:

- Star array configurations were restricted to the pad locations determined in the study of the 16-element star-array. All pads from the D, C, and B arrays were assumed to be available.

- The T-array configurations were restricted to a N-S/E-W oriented T. Current OVRO configurations were used as starting points for T-configurations.

- In the compromise between the number of configurations utilized to map a source at a given resolution and the quality of the uv coverage, this study is bias toward utilizing the fewest configurations to achieve acceptable uv coverage.

- Antennas cannot be place closer together than 15m.

The following are treated as design goals to be achieved:

- Good uv coverage in both 4 hour "snapshots" and in full tracks.

- Minimum redundancy in baseline lengths.

- Minimum sidelobes in the synthesized beam for source declinations from +55 to -20 degrees.

- Three primary configurations which achieve resolutions of 5", 2", and <1" at a frequency of 100 GHz with NATURAL weighting.

Star-Configurations

Tables 1 , 2, and 3 list the antenna locations for the proposed D, C, and B Star-configurations. Figures 1 through 6 show beams and uv coverages for these configurations. The two sets of figures for each configuration show the results for hour angle coverages of ± 5 and ± 2 hours from transit, restricted to elevations above 17 degrees. Each figure is divided into two columns; the left column shows the synthesized beam and the right column the uv coverage. The four panels in each column refer to four specific source declinations: -20, -5, 18, and 55 degrees.

East	North
36.0	-36.5
-35.8	236.7
84.9	42.5
152.9	76.6
90.0	-91.3
162.1	-164.4
-114.1	-220.1
-98.4	16.3

Table 1: Star D-Configuration Antenna Locations in nanoseconds

East	North
-35.8	236.7
-89.4	591.8
84.9	42.5
530.9	265.8
405.2	-411.0
-158.5	-305.7
-177.1	29.3
-442.8	73.4

Table 2: Star C-Configuration Antenna Locations in nanoseconds

Tables 4, 5, and 6 report the beam sizes and sidelobe levels for each of the beams presented. The beam size is the Gaussian fitted FWHM. The sidelobe levels are in percentages of the main beam with the first number corresponding to the largest negative sidelobe and the second the largest positive sidelobe.

As can be seen from the beam sizes as a function of source declination, the configurations were designed to have circular beam for a source declination around 0 degrees. Consequently, higher declination sources have elliptical beams with the long axis running E-W and lower declination sources have N-S oriented elliptical beams. This follows the philosophy of the original star which is more extended N-S than E-W to allow for more nearly circular beams on southern sources.

East	North
-124.2	821.9
-223.6	1479.4
530.9	265.8
955.7	478.4
1013.0	-1027.4
-396.3	-764.3
-713.3	-1375.8
-1107.1	183.4

Table 3: Star B-Configuration Antenna Locations in nanoseconds

Decl.	HA = syn beam	± 5 hours sidelobes	HA = syn beam	± 2 hours sidelobes
-20	7.1 x 5.0	-13,16	7.0 x 4.8	-14,20
-5	5.1 x 5.1	-14,25	4.9 x 4.6	-14,41
18	5.0 x 4.0	-13,14	4.6 x 3.8	-14,25
55	4.8 x 3.7	-11,10	4.5 x 3.6	-13,17

Table 4: Star D Configuration Beams

Now let's look at the individual configurations. The D configuration provides good coverage and reasonable sidelobe levels. The average synthesized beam sizes range from 6.0" at decl=-20 to 4.2" at decl=55. The axis ratios of the beams range from 1.0 to 1.4. Sidelobes levels are good, except around declination 0 degrees. The large sidelobes in the δ=-5 beam are beyond 30" from phase center, hence not present in Figure 1. Figure 2 show that the ±2 hours track also gives fairly reasonable results for most declinations. Sidelobe levels increase dramatically only for source declinations between -10 and +20 degrees; the sidelobes are tolerable for mapping except near declination 0 degrees.

The C-array has beam sizes ranging from 2.2" at decl=-20 to 1.6" at decl=55. The axis ratios of the beams range from 1.0 to 1.9 with the strongly elongated beams occurring for southern sources. The sidelobe level for the C-array is generally a little higher than for the D-array but still acceptable, except around declination 0 degrees. As shown in Figure 3, the sidelobes for decl=-5 now appear relatively close to the main lobe and have a more complicated structure. As shown in Figure 4, the sidelobe structure becomes significantly stronger and more complicated in the ±2 hours tracks.

The B-array has beam sizes ranging from 0.56" to 0.78" and axis ratios of 1.0 to 1.5.

Decl.	HA = syn beam	± 5 hours sidelobes	HA = syn beam	± 2 hours sidelobes
-20	3.0 x 1.7	-12,18	3.0 x 1.6	-13,22
-5	2.2 x 1.8	-14,29	2.2 x 1.6	-14,40
18	1.8 x 1.7	-11,16	1.7 x 1.5	-13,32
55	1.8 x 1.5	-9,12	1.6 x 1.5	-12,24

Table 5: Star C Configuration Beams

Decl.	HA = syn beam	± 5 hours sidelobes	HA = syn beam	± 2 hours sidelobes
-20	0.96 x 0.66	-14,17	0.96 x 0.64	-14,25
-5	0.72 x 0.66	-14,28	0.69 x 0.63	-16,47
18	0.68 x 0.55	-13,16	0.63 x 0.52	-14,30
55	0.66 x 0.52	-12,11	0.62 x 0.50	-14,22

Table 6: Star B Configuration Beams

The scale of the B-array was determined by populating the most distant pad on each arm so it represents the highest resolution available on the star. The sidelobe levels for the B-array are similar to the C-array.

These arrays *do not* represent the result of an exhaustive search but are the product of some thought and testing. It may be possible to make small improvements to the sidelobe levels through further modeling.

Finally, I have looked into using multiple configurations to improve the uv coverage and beam for sources near decl=0. The idea is to observe the source in two of the proposed configurations to provide supplemental uv coverage, for example the B-array to fill-in and improve the C-array. Figure 7 show the results for combinations of D+C and B+C configurations. For each combination, I show the two array data with appropriate tapering to generate a beams comparable to the lower resolution array, and I should the data with no taper. Table 7 summarizes the beam characteristics. By comparing to Tables 4, 5, and 6, it can be seen that there are improvements in the sidelobe levels, but the levels are still higher than for most other declinations.

Conf.	HA = syn beam	± 5 hours sidelobes	HA = syn beam	± 2 hours sidelobes
D+C Tapered to D	4.9 x 4.8	-13,19	4.8 x 4.5	-15,30
C+D No Taper	3.9 x 3.8	-13,15	3.7 x 3.5	-14,24
C+B Tapered to C	2.0 x 1.8	-14,26	2.0 x 1.6	-15,30
B+C No Taper	1.7 x 1.5	-12,26	1.7 x 1.3	-14,28

Table 7: Dual Star Configuration Beams for Source δ=-5

T-array Configurations

For comparison, I have created 8-element T-configurations with similar resolution to the D and C star arrays presented in the previous section. The T-array D configuration is based on the current OVRO low resolution configuration, with the addition of one new antenna to the E-W arm and one to the N-arm. The T-array C configuration is based on the OVRO high resolution configuration, again with one antenna added to the E-W and the N-S arms. The locations of the antenna in the T-configurations are listed in Table 8 and 9.

East	North
36.0	-36.5
-35.8	236.7
84.9	42.5
152.9	76.6
90.0	-91.3
162.1	-164.4
-114.1	-220.1
-98.4	16.3

Table 8: T-array D-Configuration Antenna Locations in nanoseconds

The beams and uv coverages for the T-configurations are shown in Figures 8 through 11. The two set of figures for each configuration show the results for hour angle coverages of ±5 and ±2 hours from transit. Each figure has a left column displaying the synthesized beam and a right column with the corresponding uv coverage. The four panels in each column correspond to the same four source declinations as for the star-configurations.

Table 10 and 11 report the beam sizes and sidelobe levels for each of the beams presented. For the ±5 hour tracks, the sidelobe levels for the T configurations are generally slightly higher than for the Star configurations (Tables 4 and 5). The difference is more significant for the ±2 hours tracks, especially around declination 0 degrees. The uv coverage

East	North
-35.8	236.7
-89.4	591.8
84.9	42.5
530.9	265.8
405.2	-411.0
-158.5	-305.7
-177.1	29.3
-442.8	73.4

Table 9: T-array C-Configuration Antenna Locations in nanoseconds

in the star array is better than the T due to the 5-arm morphology of the star array compared to the 3-arms of the T-array, as discussed in Mel Wright's earlier memo.

Decl.	HA =	± 5 hours	HA =	± 2 hours
	syn beam	sidelobes	syn beam	sidelobes
-20	8.3 x 4.5	-12,20	8.3 x 4.3	-13,24
-5	6.4 x 4.4	-12,37	6.1 x 4.1	-17,44
18	5.5 x 4.1	-9,18	5.1 x 3.7	-13,25
55	5.0 x 3.8	-13,11	4.9 x 3.5	-18,20

Table 10: T-array D Configuration Beams

I have not spent much time optimizing the T-configurations so the sidelobe levels could be improved somewhat. The bottom line is that the star configurations yield uv coverages and beams that are at least as good as standard T configurations.

Decl.	HA = syn beam	± 5 hours sidelobes	HA = syn beam	± 2 hours sidelobes
-20	2.5 x 1.9	-11,25	2.5 x 1.8	-13,31
-5	2.0 x 1.8	-12,57	1.9 x 1.7	-13,69
18	2.0 x 1.5	-11,23	1.8 x 1.4	-13,50
55	1.9 x 1.4	-8,10	1.8 x 1.3	-13,21

Table 11: T-array C Configuration Beams

Summary

The following points summarize the important results:

- The proposed pads for the 16-element star array can be utilized to create 8-element configurations which have reasonable uv coverages and beams.

- 8-element star configurations yield uv coverages and beams for ± 5 hours tracks that are comparable to, or slightly better than, the corresponding coverages and beams for T-array configurations.

- 8-element star configurations yield uv coverages and beams for ± 2 hours tracks that are typically better than the corresponding coverages and beams for T-array configurations.

- 8-element star configurations produce reasonable beams except for sources around decl$\sim$0. The synthesized beams from a single star configuration for decl$\sim$0 source can be improved by either adding observations from the next larger star configuration, or from a special equatorial configuration.

Important caveats:

No attempt has been made to generate a star array layout which is optimized for an 8-element array. Many of the pads in the 16-element star layout are not utilized in the 8-element configurations. In addition, it is very likely that other pads could be placed at more optimal positions. It is mostly likely that repositioning pads in the inner part of the star array would have the most impact. One defensive strategy would be to mark out the entire inner 100 meter radius of the array layout for possible use.

The proposed D-array has shortest uv spacings of $\sim$4.5kλ at ν=100 GHz for source declinations from 18 to 50 degrees. The corresponding largest visible structure will be 20"(λ/3mm). Good sampling of the uv plane occurs for $\geq$6kλ, corresponding to structure $\leq$15"(λ/3mm). An array smaller than proposed D-array will be desirable for some projects.

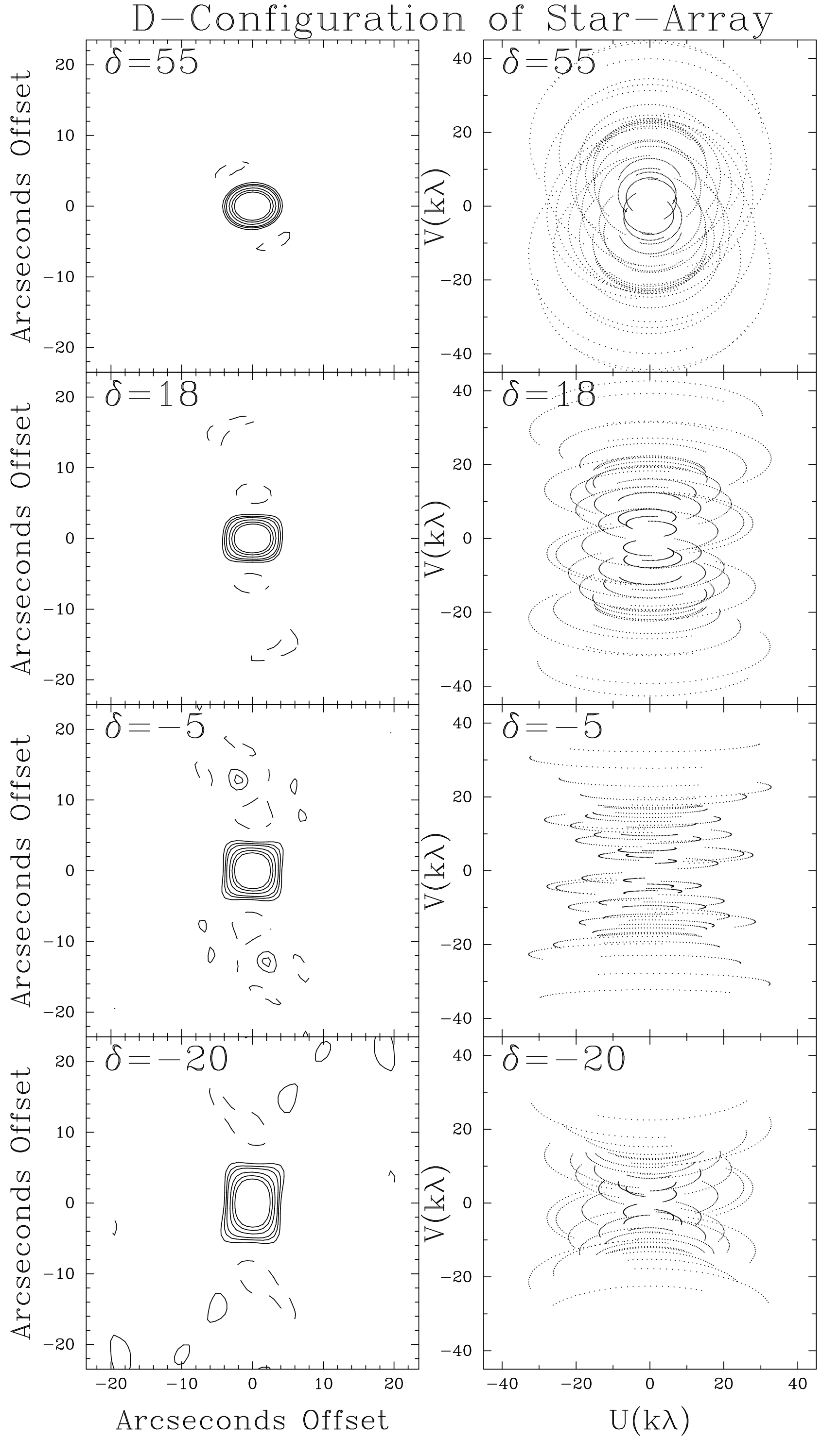

Fig. 1.— Plots of the beams and uv coverages for the proposed D-array configuration for ±5 hours from transit. The contour levels in the beam panels are -30, -20,-15,-10,10,15,20,30,40,and 50 percent of the peak. The source declinations for each panel is given in the upper-left corner.

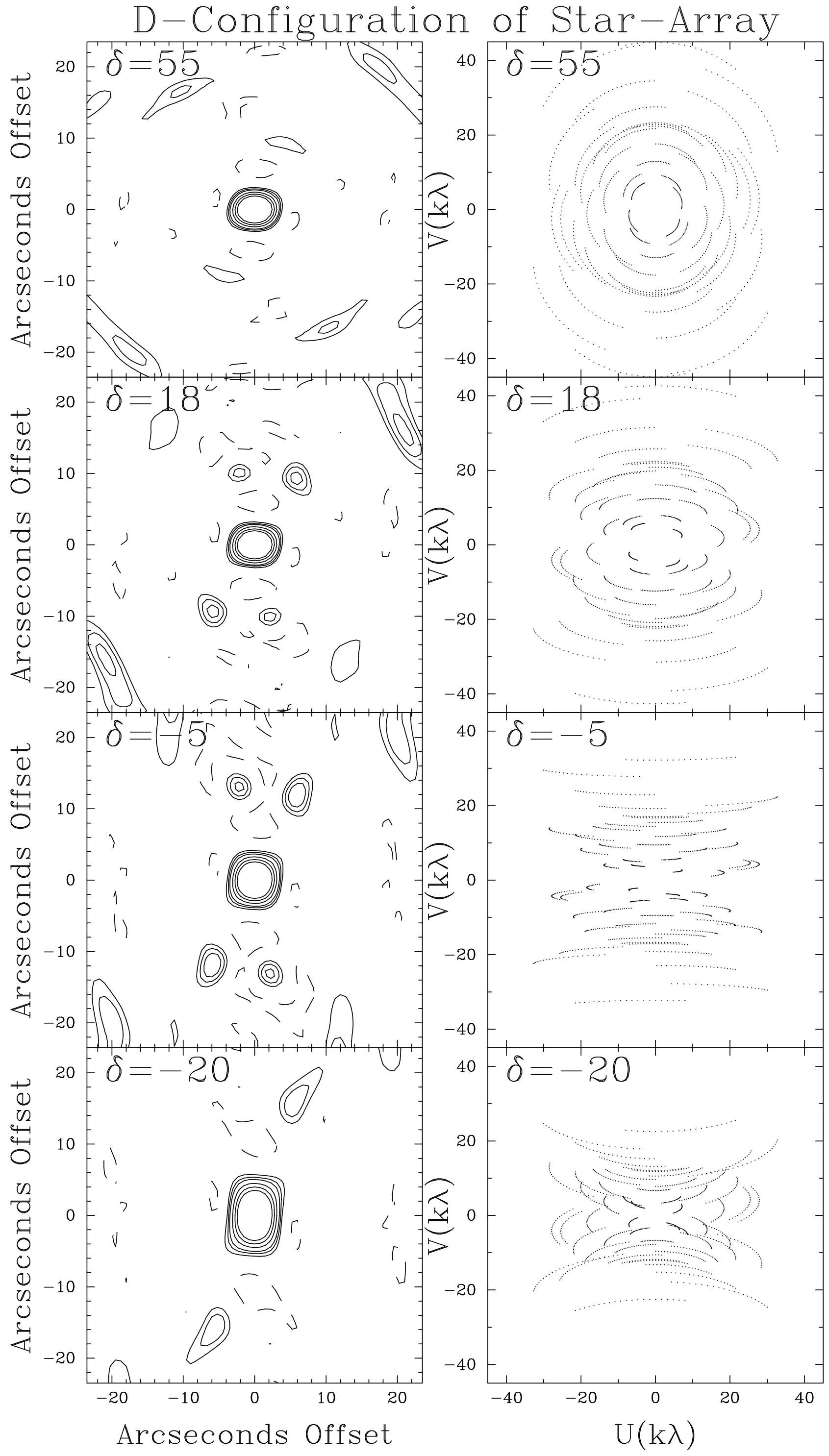

Fig. 2.— Plots of the beams and uv coverages for the proposed D-array configuration for ±2 hours from transit. The contour levels in the beam panels are -30, -20,-15,-10,10,15,20,30,40,and 50 percent of the peak. The source declinations for each panel is given in the upper-left corner.

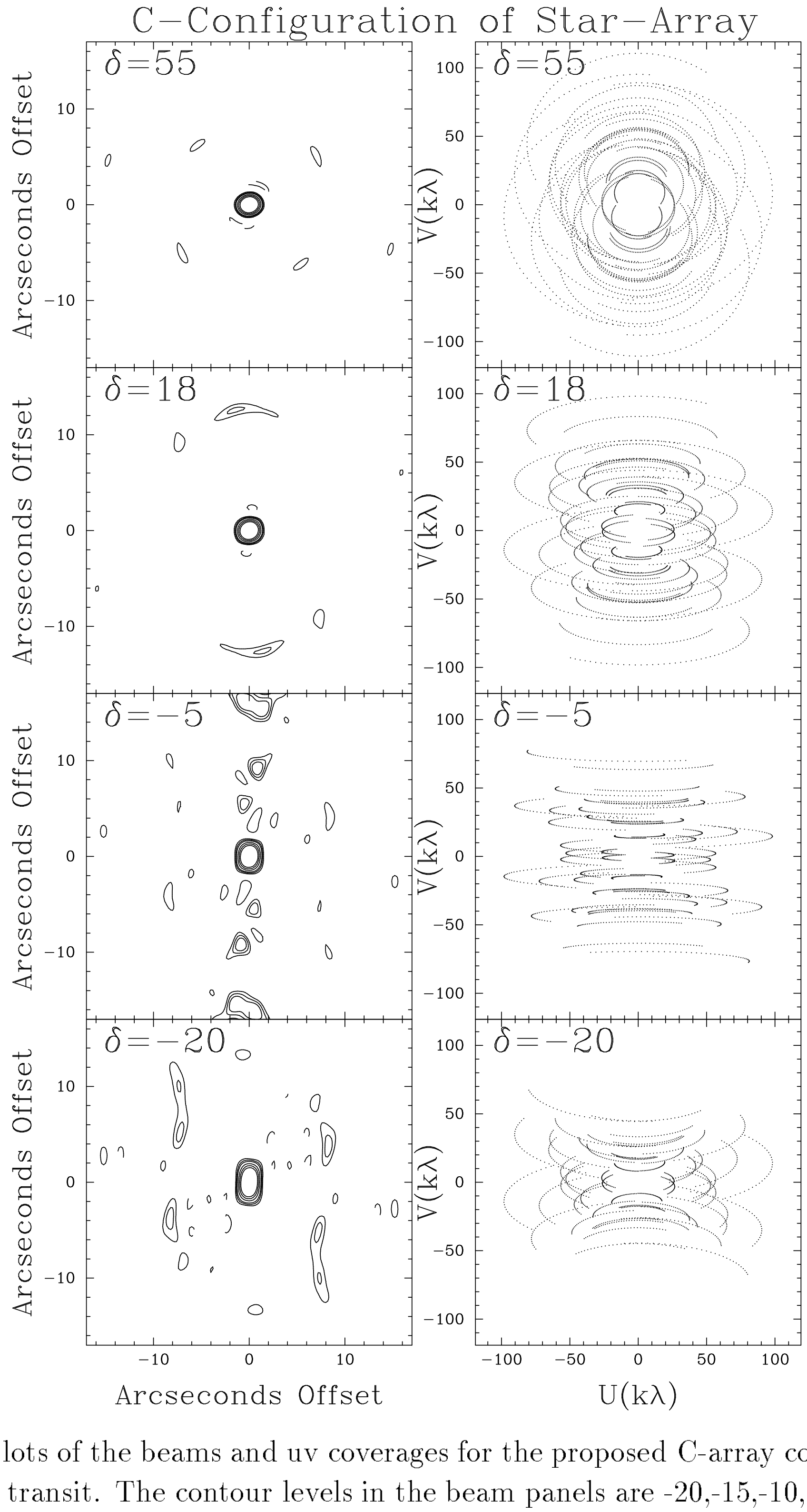

Fig. 3.— Plots of the beams and uv coverages for the proposed C-array configuration for ±5 hours from transit. The contour levels in the beam panels are -20,-15,-10,10,15,20,30,40,and 50 percent of the peak. The source declinations for each panel is given in the upper-left corner.

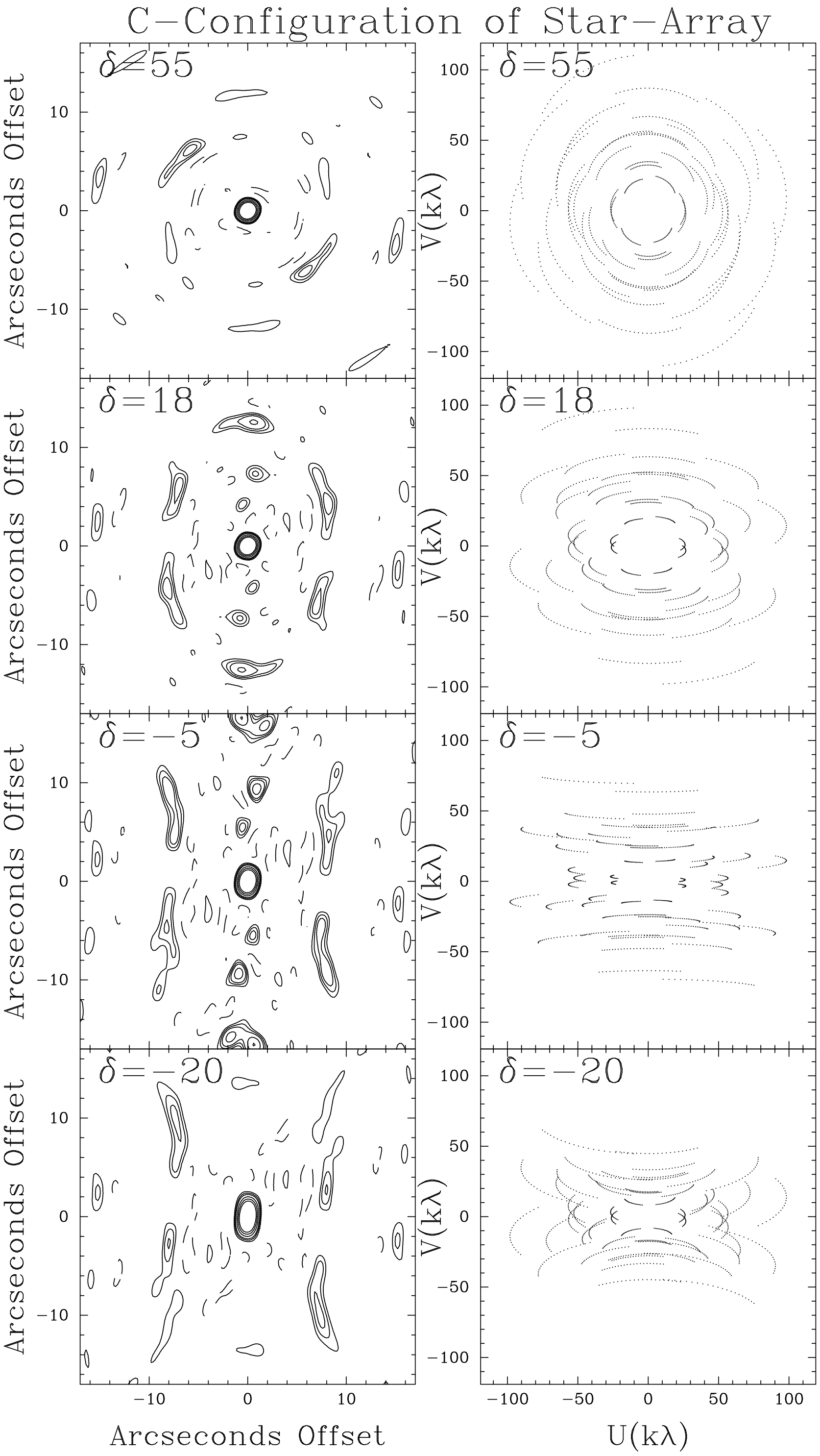

Fig. 4.— Plots of the beams and uv coverages for the proposed C-array configuration for ±2 hours from transit. The contour levels in the beam panels are -20,-15,-10,10,15,20,30,40,and 50 percent of the peak. The source declinations for each panel is given in the upper-left corner.

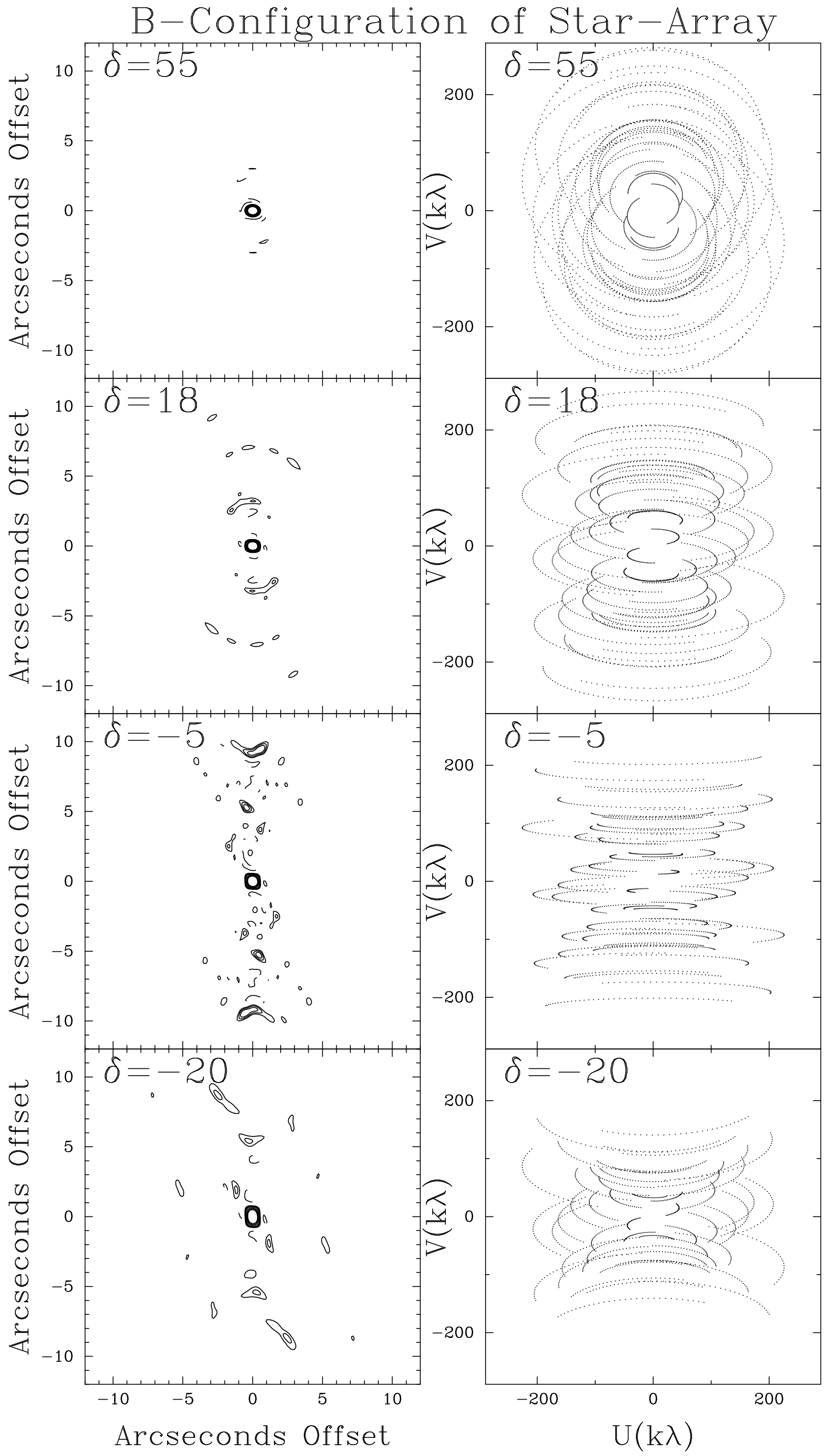

Fig. 5.— Plots of the beams and uv coverages for the proposed B-array configuration for ± 5 hours from transit. The contour levels in the beam panels are -20,-15,-10,10,15,20,30,40,and 50 percent of the peak. The source declinations for each panel is given in the upper-left corner.

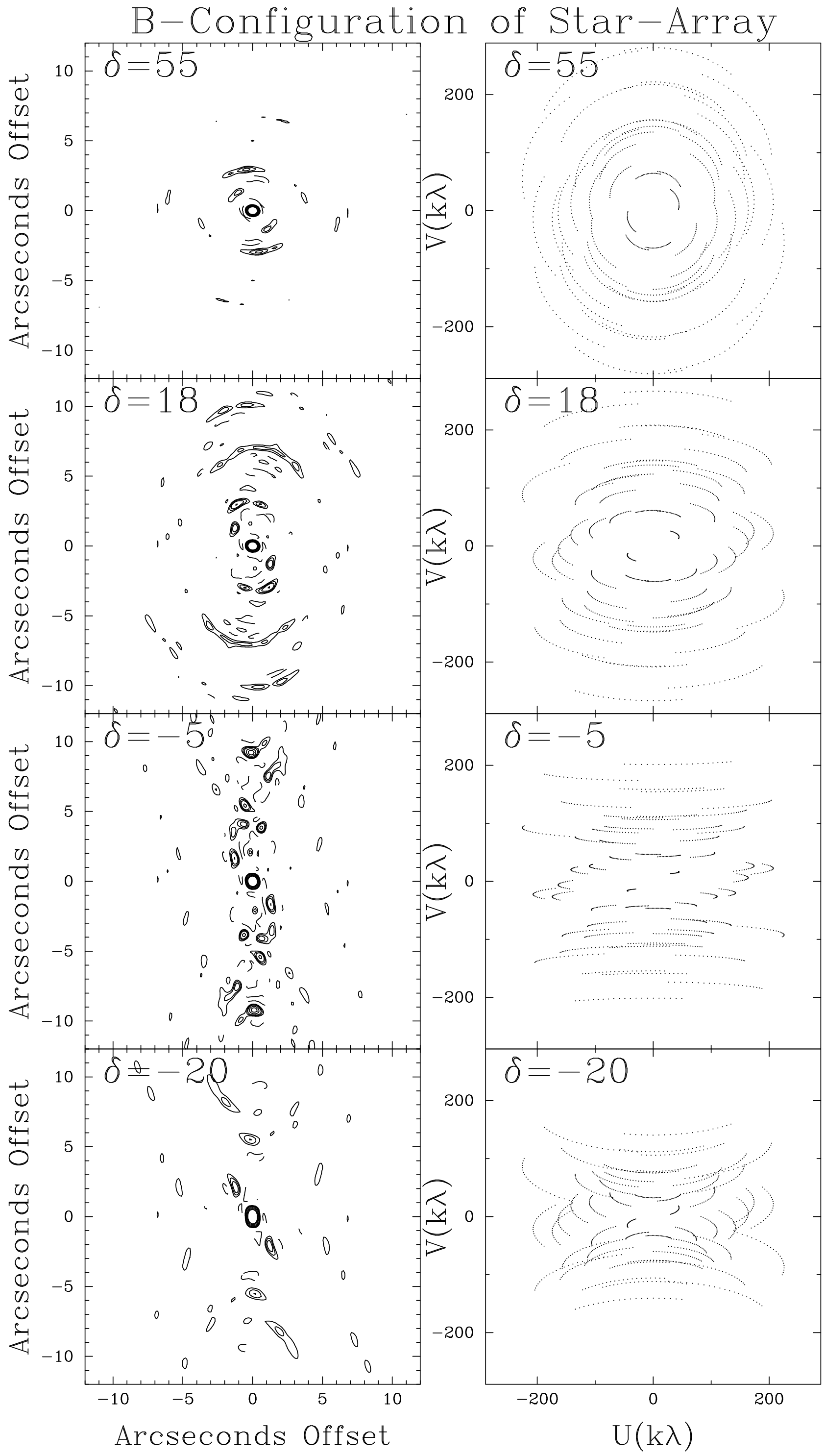

Fig. 6.— Plots of the beams and uv coverages for the proposed B-array configuration for ±2 hours from transit. The contour levels in the beam panels are -20,-15,-10,10,15,20,30,40,and 50 percent of the peak. The source declinations for each panel is given in the upper-left corner.

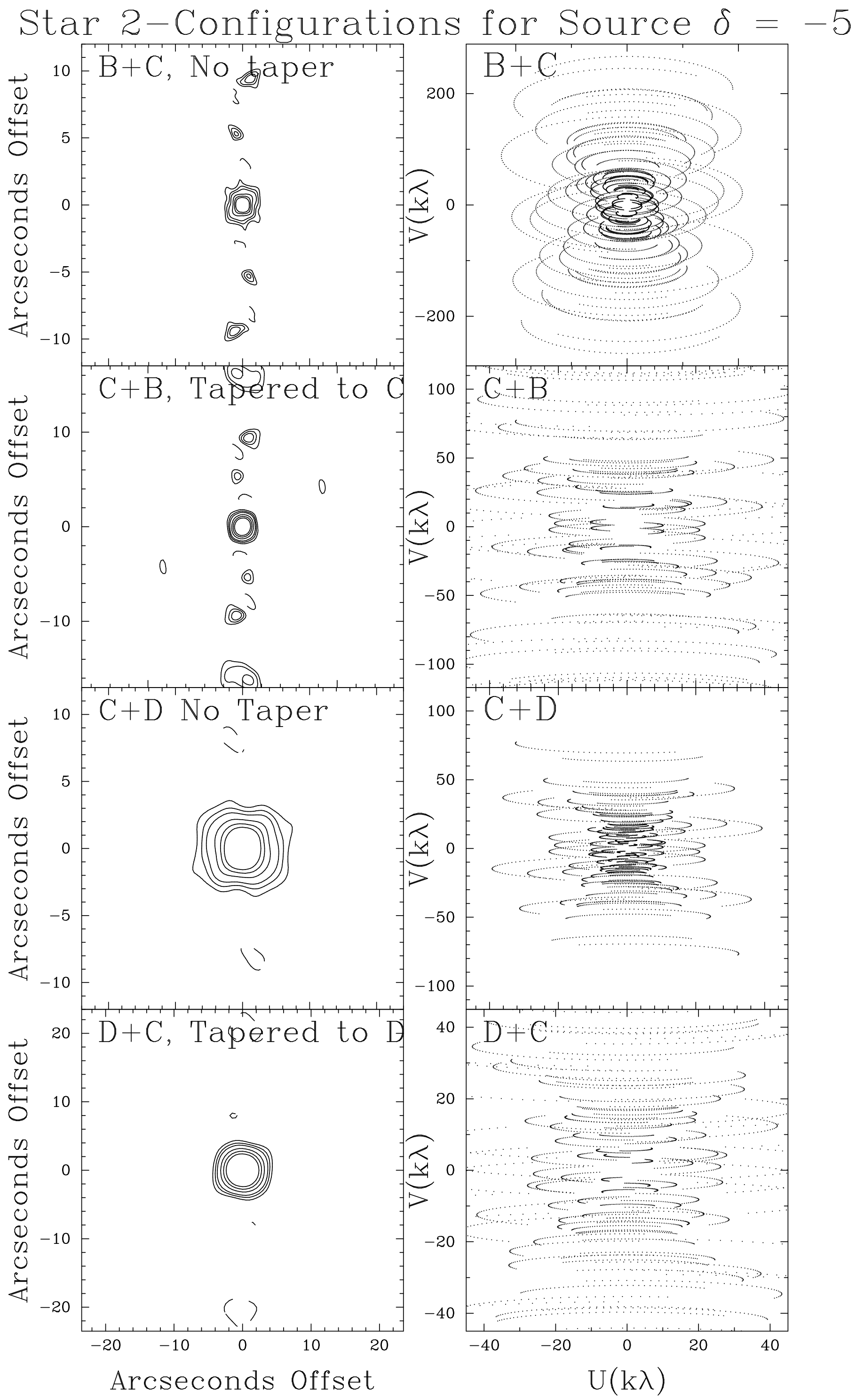

Fig. 7.— Plots of the beams and uv coverages for two configuration combinations of the star array for δ=-5 source. The upper left corner of each plot lists the arrays used. The uv data were either tapered to match the beam of the lower resolution array or not tapered as all, as indicated. The contour levels in the beam panels are -20,-15,-10,10,15,20,30,40,and 50 percent of the peak.

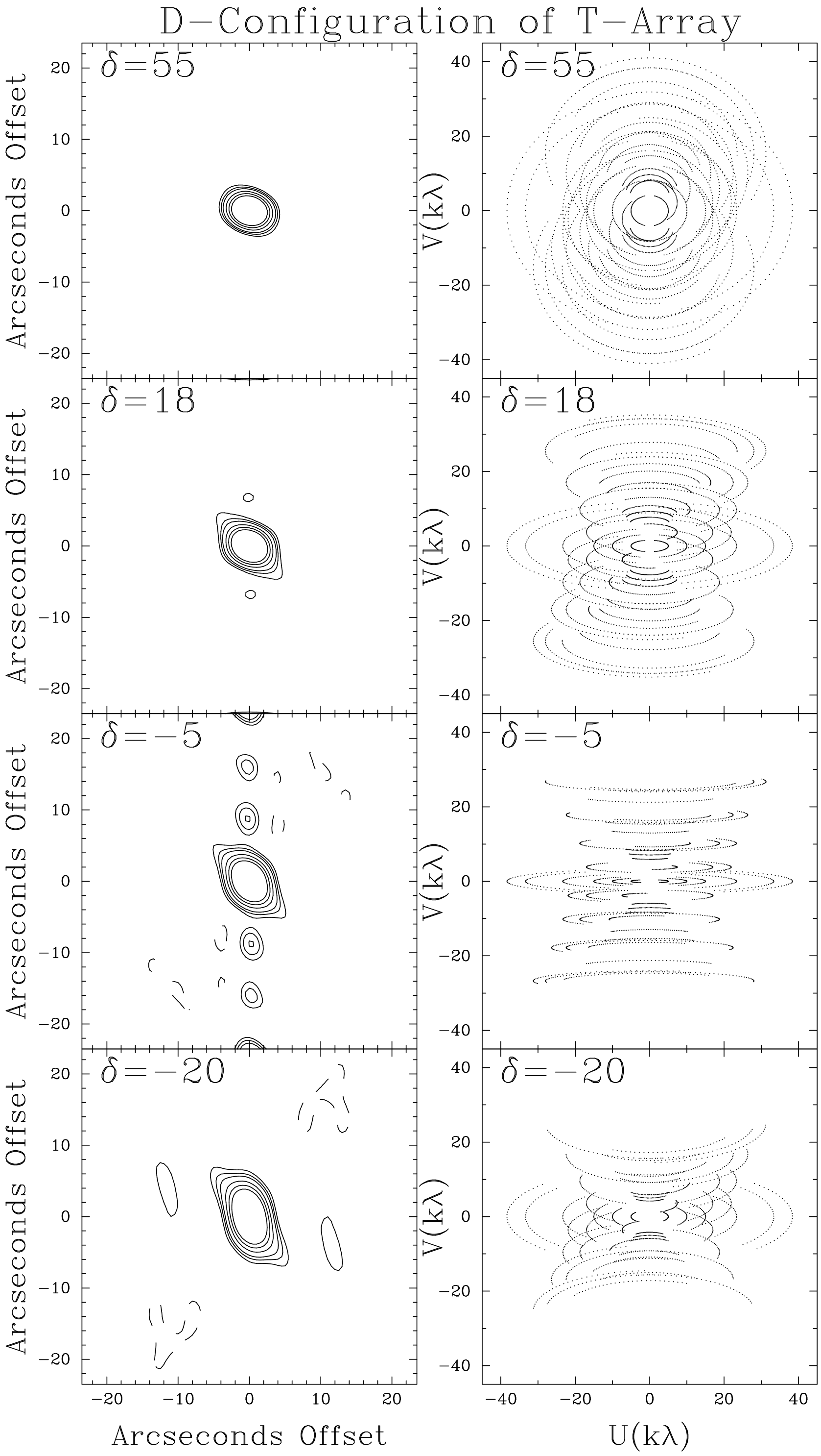

Fig. 8.— Plots of the beams and uv coverages for the T-array D configuration for ±5 hours from transit. The contour levels in the beam panels are -30, -20,-15,-10,10,15,20,30,40,and 50 percent of the peak. The source declinations for each panel is given in the upper-left corner.

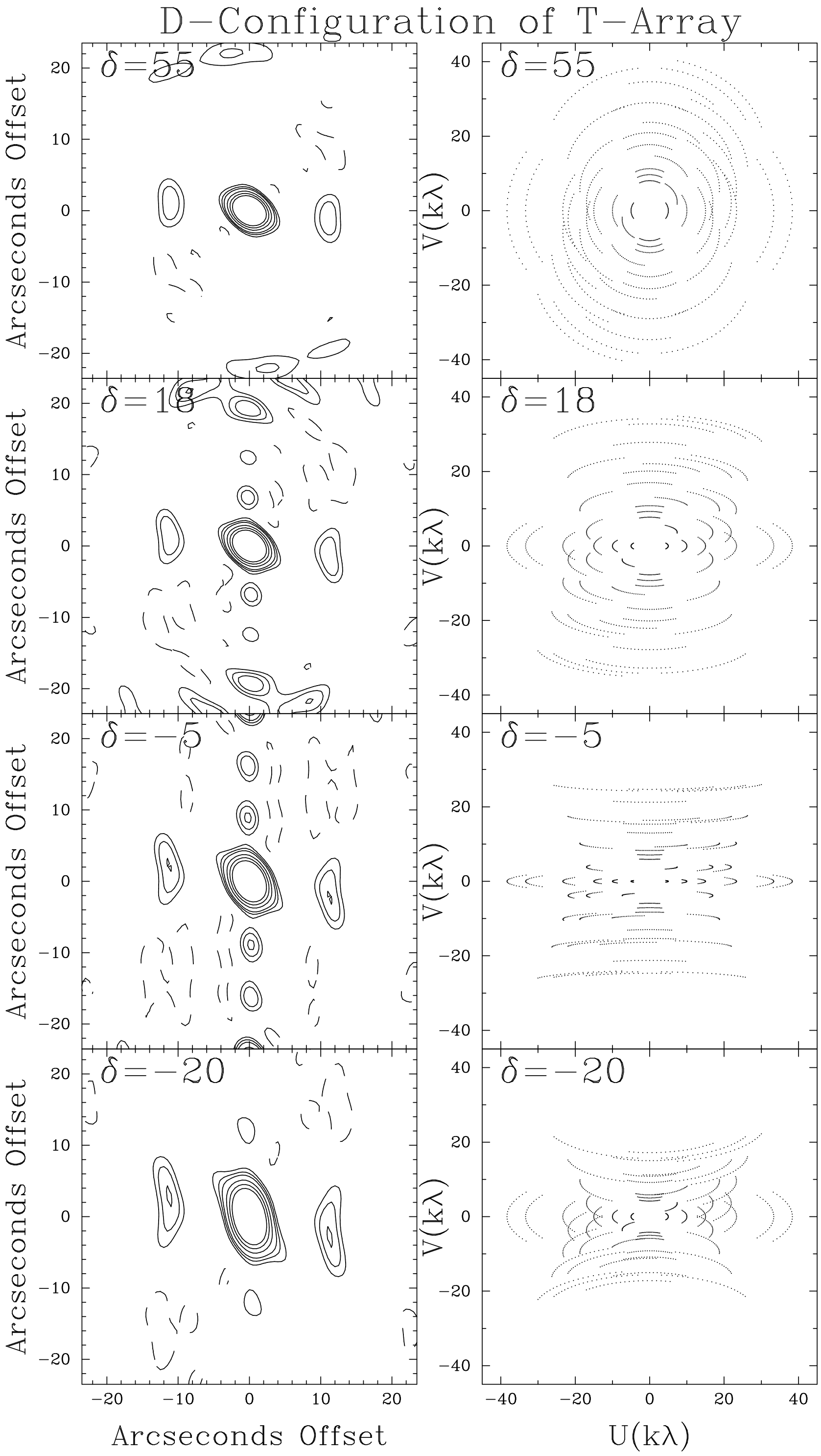

Fig. 9.— Plots of the beams and uv coverages for the T-array D configuration for ±2 hours from transit. The contour levels in the beam panels are -30, -20,-15,-10,10,15,20,30,40,and 50 percent of the peak. The source declinations for each panel is given in the upper-left corner.

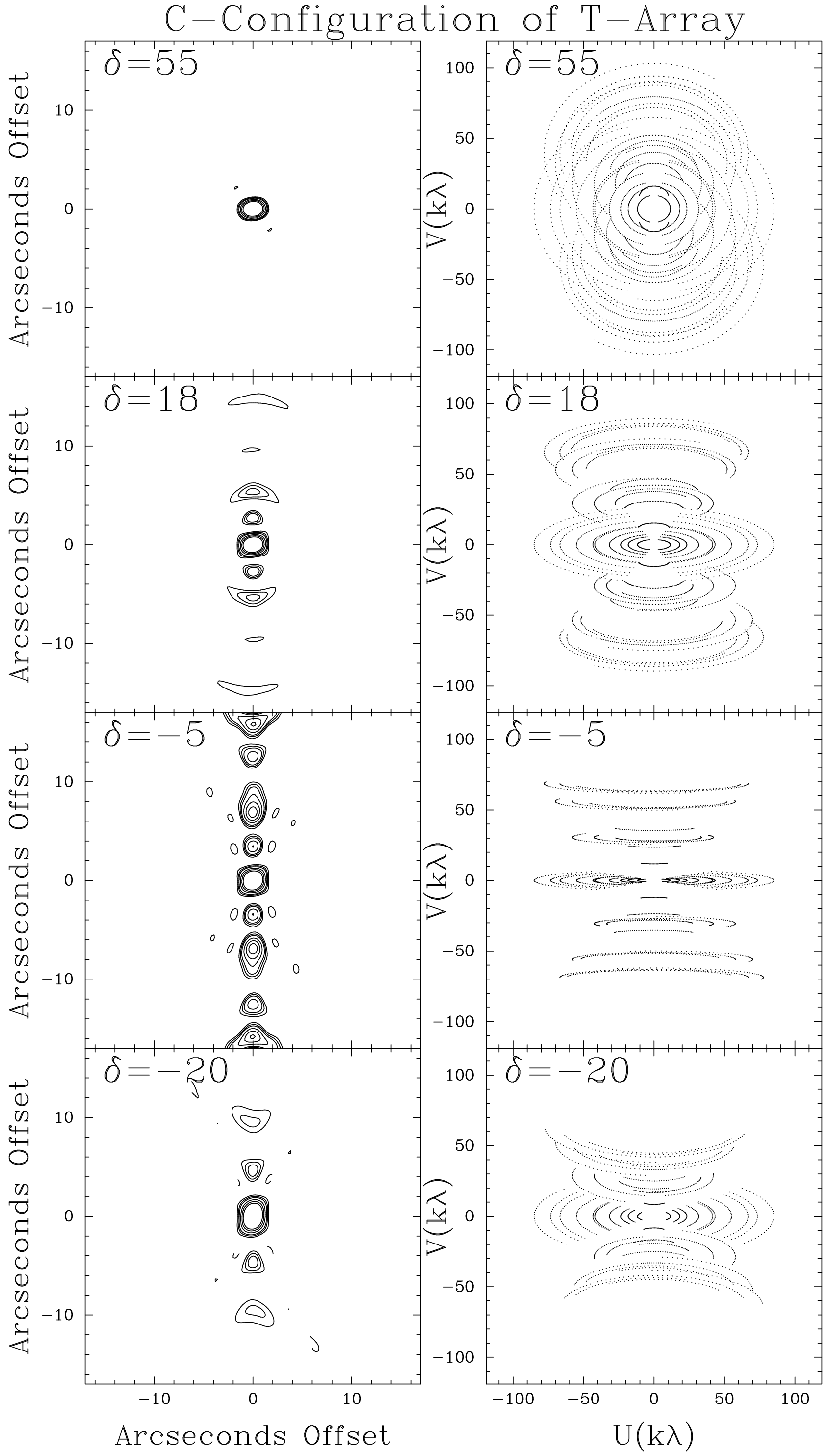

Fig. 10.— Plots of the beams and uv coverages for the T-array C configuration for ±5 hours from transit. The contour levels in the beam panels are -20,-15,-10,10,15,20,30,40,and 50 percent of the peak. The source declinations for each panel is given in the upper-left corner.

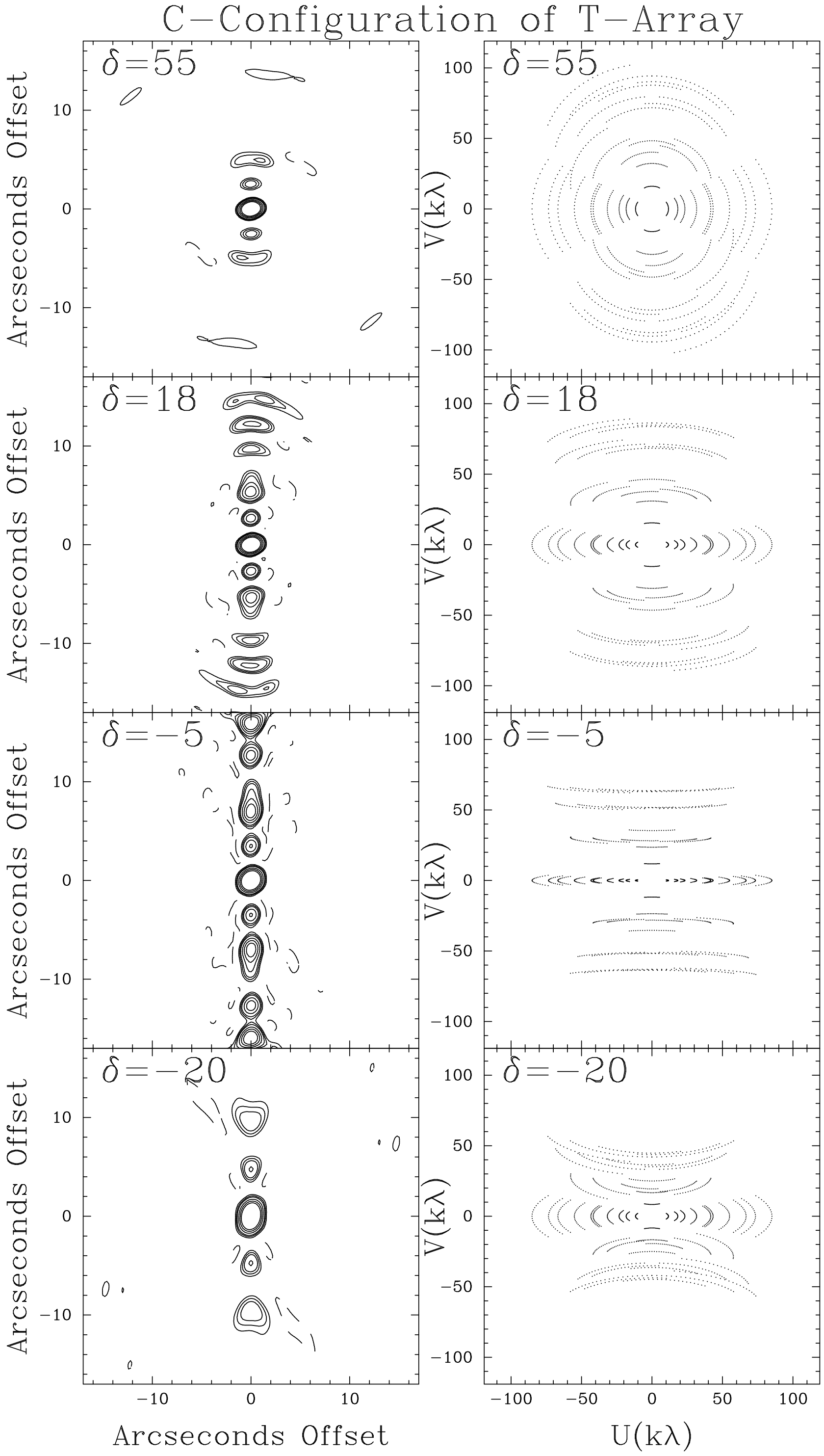

Fig. 11.— Plots of the beams and uv coverages for the T-array C configuration for ±2 hours from transit. The contour levels in the beam panels are -20,-15,-10,10,15,20,30,40,and 50 percent of the peak. The source declinations for each panel is given in the upper-left corner.