NATIONAL RADIO ASTRONOMY OBSERVATORY

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A STUDY OF AN EIGHT-ELEMENT CORRELATOR ARRAY

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INTRODUCTION

A computer study has been made of the performance of a possible multielement interferometer containing eight antennas. The beam pattern of such an array depends upon the locations of the elements, the declination of the source being observed, and the total time for which the source is tracked. The beam pattern is obtained from the transfer function by taking the Fourier Transform of the latter. For this purpose the spatial frequency plane (u-v plane) is divided into a number of cells. The array is treated as a large number of two-element interferometers. The computer computes the spatial frequency corresponding to each pair of elements at each minute of the observation time. The cell corresponding to this spatial frequency is then given one minute of integration time. Thus finally one obtains the transfer function which shows the distribution of integration time over the cells. The Fourier Transform of this transfer function is then obtained using the Cooley-Tukey algorithm. Information about the maximum and RMS sidelobes is obtained and printed out. Cross sections through the center of the beam in right ascension and declination are plotted by using a Calcomp plotter.

THE TRANSFER FUNCTION

The layout and various parameters of the proposed array are shown in Figure 1. The field of view as governed by the beamwidth of the elements (130 ft. dishes operating at 0.1 m wavelength) is 10' minutes of arc. In order that no grating lobes appear within this field, the sampling interval should be (1/10') = 344 cycles/radian.

The size of the transfer function has been chosen to correspond to the longest East-West baseline available. For the layout as shown in Figure 1, this is 9000 ft. or 2743 m. Thus the longest East-West baseline is 27430 wavelengths for a wavelength of 0.1 m.

With a sampling interval of 344 cycles/radian, there are (27430/344) = 80 cells in the radius of 27430 wavelengths.

The computer program gives the integration time of each cell of a 81 x 161 cell transfer function. The number of minutes of integration (in a coded form) are printed out. Each unsampled cell is marked by a dot (·). Only one-half of the transfer function is printed out because of the symmetry about the center.

THE BEAM

The beam is computed directly from the transfer function. The beamwidth and sidelobes can be controlled somewhat by weighting the transfer function appropriately. However, this cannot suppress the sidelobes caused by the holes (unsampled cells). In the computations made, equal weighting is given to all the sampled cells, ignoring the integration times. A guassian taper, decreasing to 15 db at the edge, is superposed on the whole transfer function.

PERFORMANCE IN THE PROPOSED MODES

The array is proposed to be used in the following modes:

(a) Fan Beams for short observations (of a few minutes at transit),

(b) Narrow pencil beams for sources north of declination 30°. This is obtained by using 12 hours of observation,

(c) Instantaneous pencil beams obtained by using a crossed grating or T-Configuration.

Beams have been obtained for these three modes. Figure 2 shows the configurations for which beams have been computed. Figures 2(a), 2(b), and 2(c) show east-west arrays using the minimum redundancy locations of Leech with unit spacings of 140 ft. (43 m), 250 ft. (76 m), and 387 ft. (118 m), respectively. The unit spacing of 387 ft. is the largest that can be accommodated on a 9000 ft. track. Figure 2(d) is a T-Configuration which provides north-south baselines also. It has a unit spacing of 250 ft.

The transfer functions and beam patterns for these arrays for declinations of 0°, 30°, and 90° are shown in Figures 3 - 14. Short observations of about 10 minutes are used with the configurations of Figures 2(a) and 2(d) and 12 hours of observation time is used with the configurations of figures 2(b) and 2(c). The beam patterns show east-west and north-south cross sections through the beam center. The maximum and RMS sidelobe levels within the field of view are summarized in Table I. In all beam patterns, the total width of the pattern is 10' and one small division corresponds to 3.92 seconds of arc.

OTHER POSSIBLE CONFIGURATIONS

Several other configurations have been tried using 12 hours of tracking time. Figure 15 shows the configurations which give good beams. The configuration of Figure 15(a) gives good performance at declinations of 30° and 90°. To get a good coverage at the equator, north-south baselines are needed. Figures 15(b) and 15(c) show configurations which have good performance at a declination of 0°. The transfer functions and beams corresponding to these configurations are shown in Figures 16 - 19, and the sidelobe levels are summarized in Table I.

DISCUSSION

The performance of the proposed 8-element array for a few configurations has been given in this report. The transfer function depends upon the element configuration, the declination of the source and time for which the source is observed. It also depends upon the sampling interval in the u-v plane. The sampling interval governs the distance of the grating lobes from the main lobe and has been taken to correspond to a grating lobe separation of 10 minutes of arc. The beam pattern depends upon the transfer function and the weighting given to various cells of the transfer function. As mentioned earlier, equal weighting has been given to all sampled cells and an overall gaussian taper, decreasing to 15 db at the edge of the transfer function, has been superposed on the whole transfer function. This tapering has been found to effectively suppress the sidelobes without unduly broadening the beam.

It should be emphasized that no attempt at optimising the array configuration has been made in this report. However, the results given will help in finding the best element arrangement for given conditions of observation. While the minimum redundancy array of Leech is optimum for a linear array used in the transit mode, this is not necessarily so for a two-dimensional array used in the tracking mode.

TABLE I

PERFORMANCE OF THE PROPOSED 8-ELEMENT ARRAY

Model No.	Declination	Tracking Time	Half-Power Beamwidth (R.A. x Decl)	Maximum Sidelobe Level*					RMS Sidelobe Level				
				Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
140EW004	0.0	10^m	12.6 x fan	- 0.0	- 0.0	- 0.0	- 0.0	- 0.0	- 5.3	- 7.9	-10.1	-10.9	-11.1
140EW305	30.0	10^m	12.6 x fan	- 0.0	- 0.0	- 0.0	- 0.0	- 0.0	- 5.3	- 7.9	-10.1	-10.9	-11.1
140EW906	90.0	10^m	10.2 x fan	- 0.0	- 0.0	- 0.1	- 0.2	- 0.6	- 5.3	- 6.9	- 8.8	-10.6	-11.5
250EW004	0.0	12^h	8.6 x fan	- 0.0	- 0.0	- 0.0	- 0.0	- 0.0	- 7.8	-10.4	-13.1	-15.8	-18.5
250EW305	30.0	12^h	9.4 x 15.7	- 6.6	- 7.4	-11.4	-15.4	-15.2	-14.0	-18.6	-22.0	-23.9	-23.9
250EW906	90.0	12^h	8.6 x 8.6	-11.9	-16.2	-15.9	-18.2	-12.2	-17.6	-21.6	-23.9	-24.8	-21.6
250T-004	0.0	10^m	58.8 x 61.2	- 0.4	- 1.3	- 5.0	- 4.3	- 1.0	- 1.1	- 4.3	- 9.5	-11.2	- 9.9
250T-305	30.0	10^m	58.8 x 50.2	- 0.5	- 1.5	- 5.6	- 6.1	- 1.0	- 1.3	- 5.3	-11.7	-11.8	- 9.7
250T-906	90.0	10^m	62.0 x 85.5	- 0.2	- 0.7	- 2.6	- 5.3	- 0.8	- 0.8	- 3.0	-10.2	-11.6	-11.2
TEE--321	30.0	12^h	11.0 x 12.6	- 8.9	- 9.8	-10.8	-13.2	-14.3	-12.8	-17.1	-19.1	-20.6	-22.4
TEE--922	90.0	12^h	8.6 x 8.6	- 9.3	-13.3	-15.9	-15.6	-13.2	-15.5	-18.3	-21.0	-21.5	-21.2
NS---012	0.0	12^h	22.0 x 7.8	- 3.7	- 8.0	- 8.3	-10.1	- 2.7	- 8.8	-13.1	-16.7	-21.5	-21.5
EQTROPT5	0.0	12^h	22.0 x 47.8	- 0.6	- 2.2	- 6.9	- 7.7	- 2.7	- 4.4	-11.0	-13.1	-18.3	-18.2
118EW001	0.0	12^h	7.8 x fan	- 0.0	- 0.0	- 0.0	- 0.0	- 0.0	- 8.8	-11.6	-14.5	-17.4	-20.4
118EW302	30.0	12^h	7.8 x 10.2	- 7.8	-11.7	-14.5	-16.2	-10.3	-17.0	-22.4	-25.0	-23.4	-22.0
118EW903	90.0	12^h	7.8 x 7.8	-15.9	-17.2	-19.1	-10.6	-10.4	-20.8	-24.0	-25.5	-20.6	-21.6

* The field of view (10' x 10') is divided into five zones. The zones are square annuli lying at the following distances from the center of the main beam:

Zone 1- 10".9 - 20".5
Zone 2- 20".5 - 40"
Zone 3- 40" - 77".5
Zone 4- 77".5 - 155"
Zone 5- 155" - 300"

Proposed 8-element Array

Nominal Operating Wavelength	0.1 m
Dish Size	130 ft = 39.624 m
Number of Dishes	8
Site Latitude	30.5° N

Rail Network: 9000 ft x 16000 ft (2743 m x 4877 m) cross as shown below

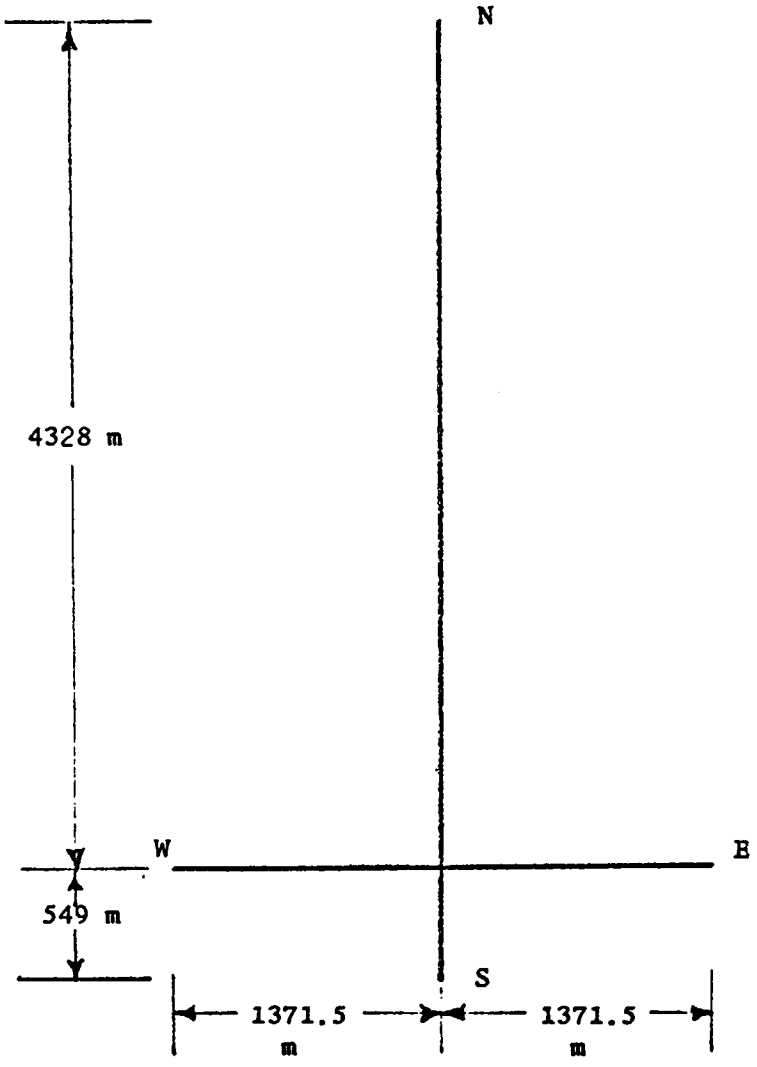
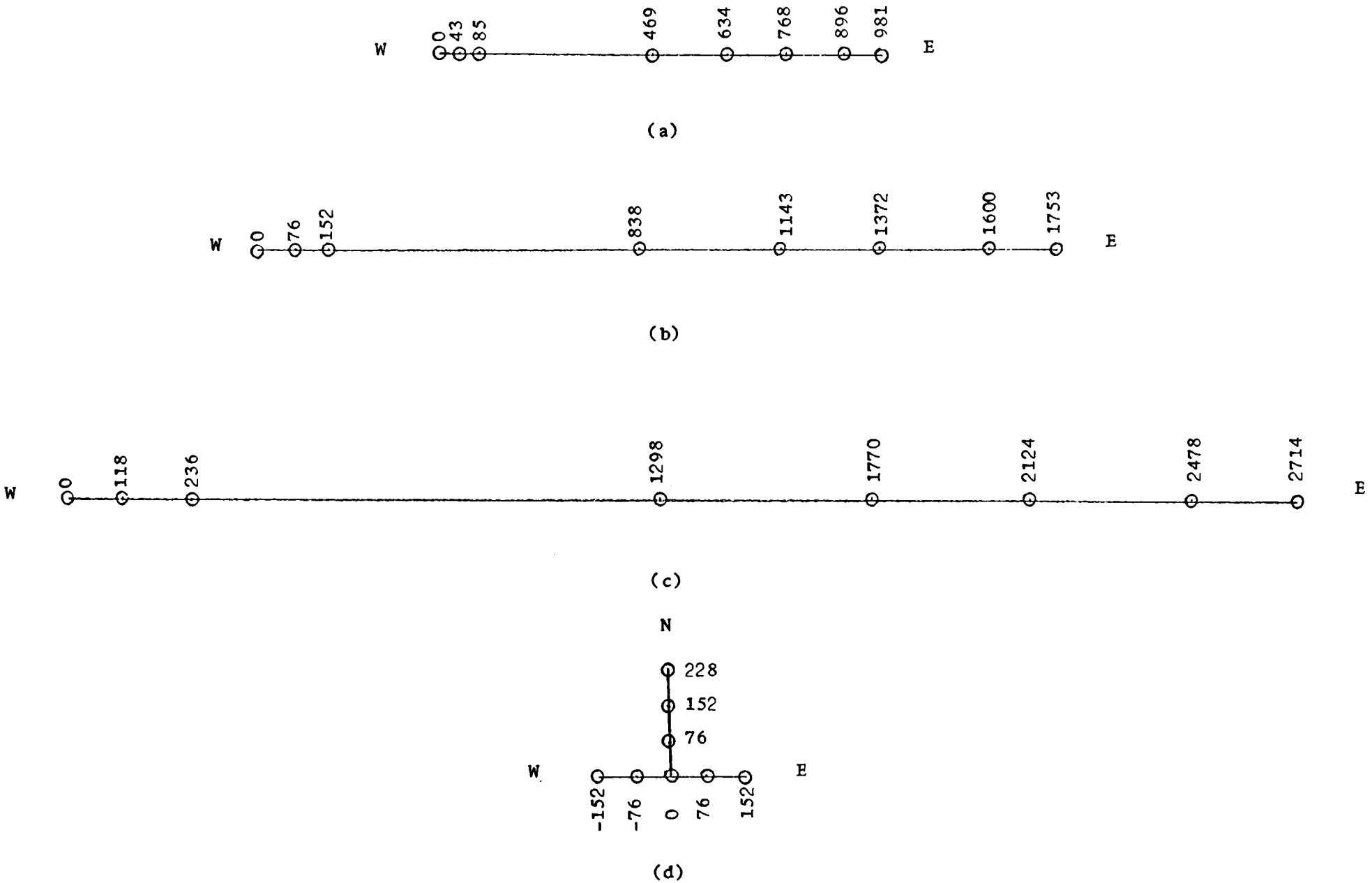
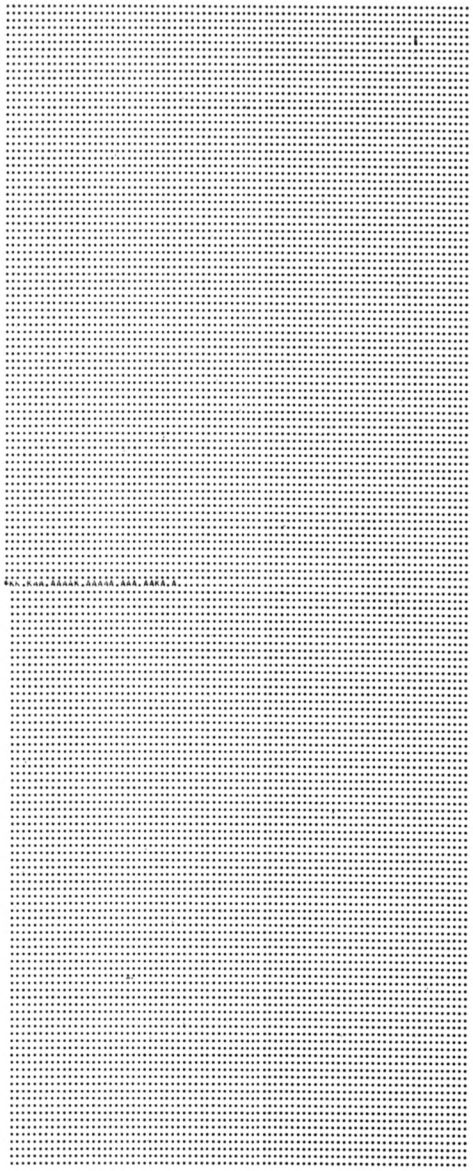


Figure 1



All dimensions in meters

Figure 2



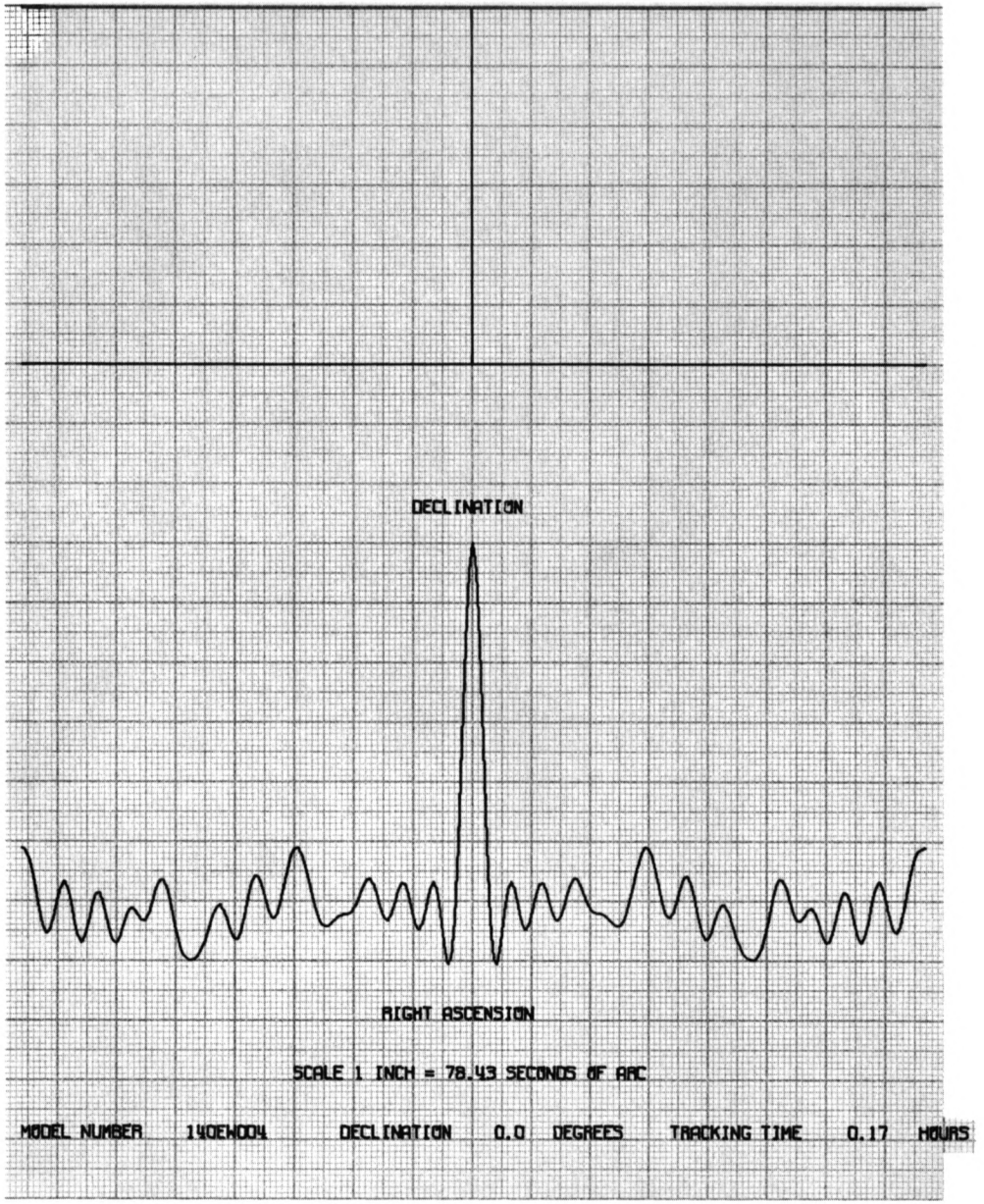
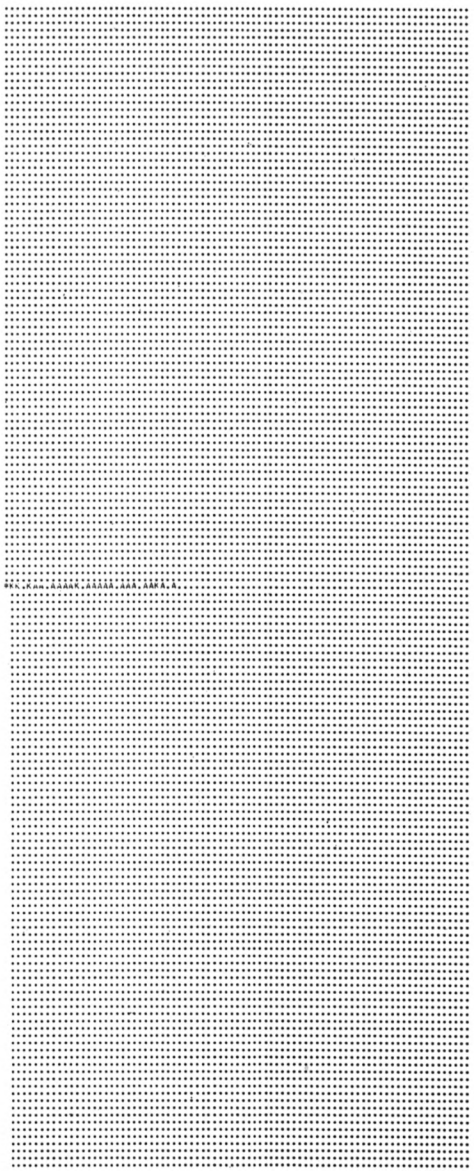


Figure 3. East-West Array with 140 ft (43m) unit spacing
Declination 0°, Tracking Time 10^m



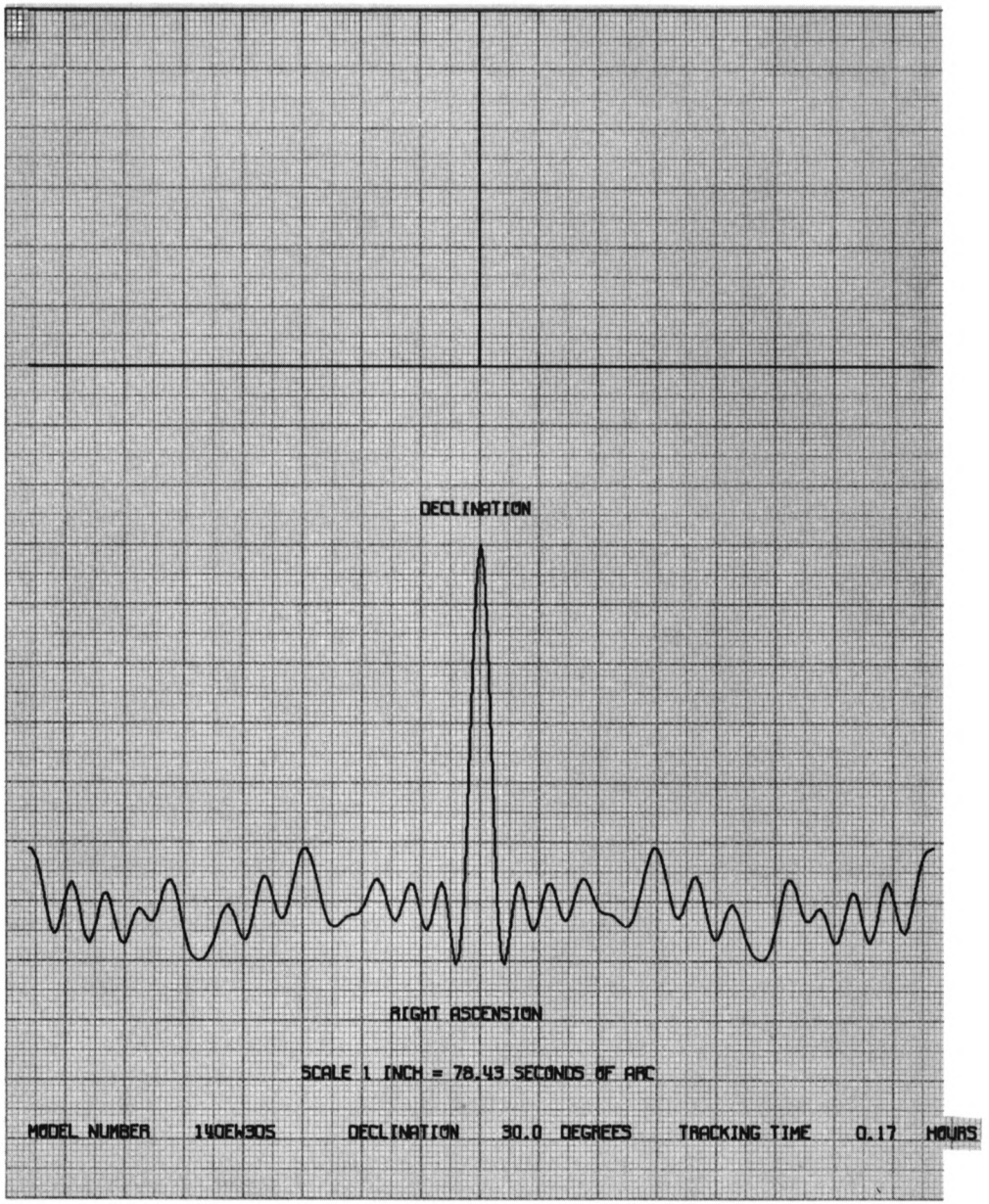


Figure 4. East-West Array with 140 ft (43m) unit spacing
Declination 30°, Tracking Time 10^{m}

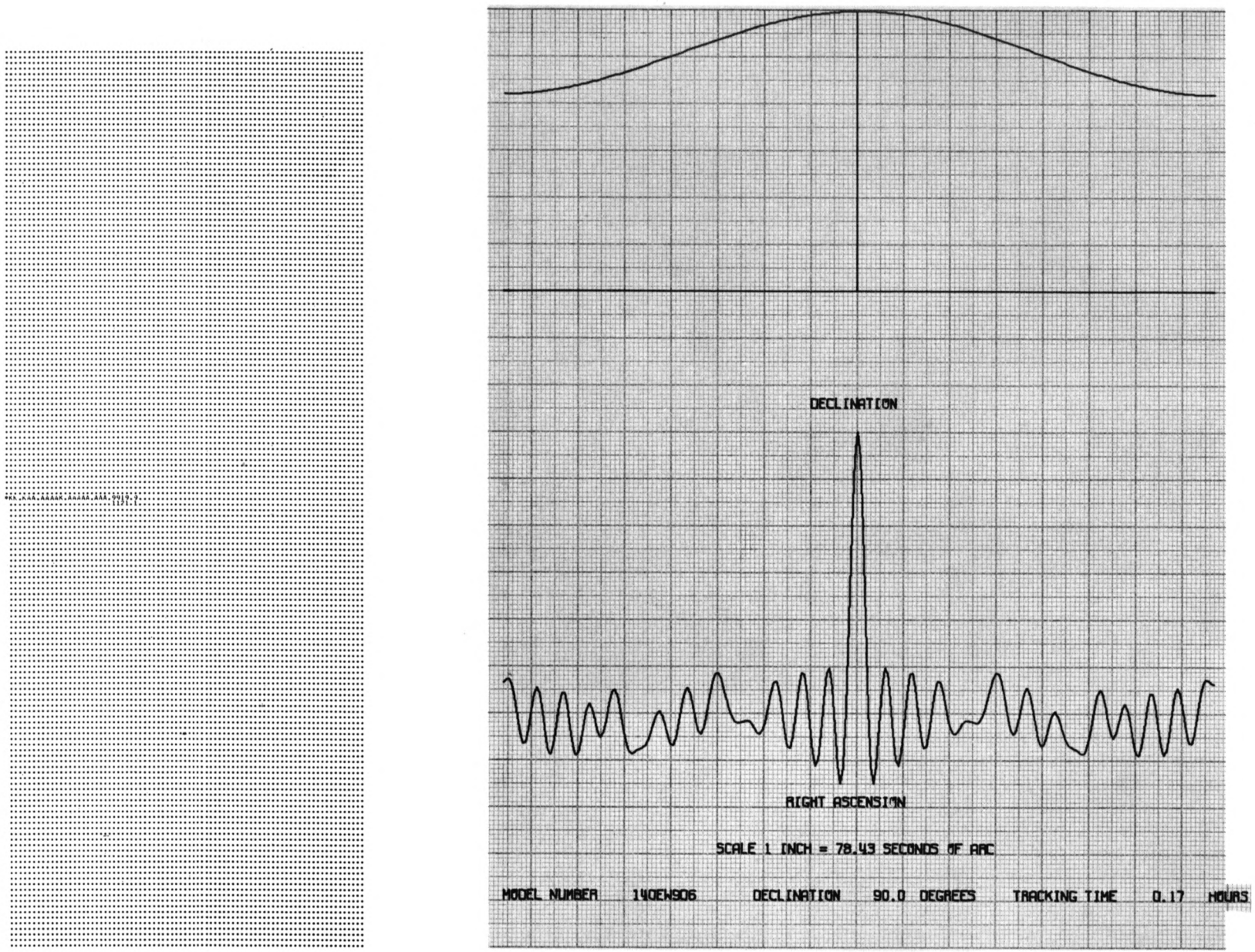
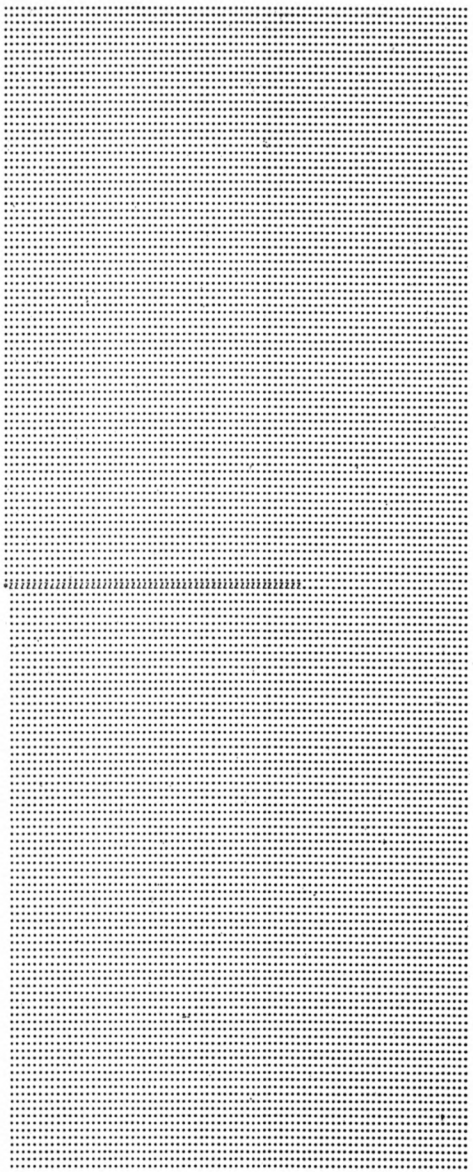


Figure 5. East-West Array with 140 ft (43m) unit spacing
Declination 90°, Tracking Time 10^{m}



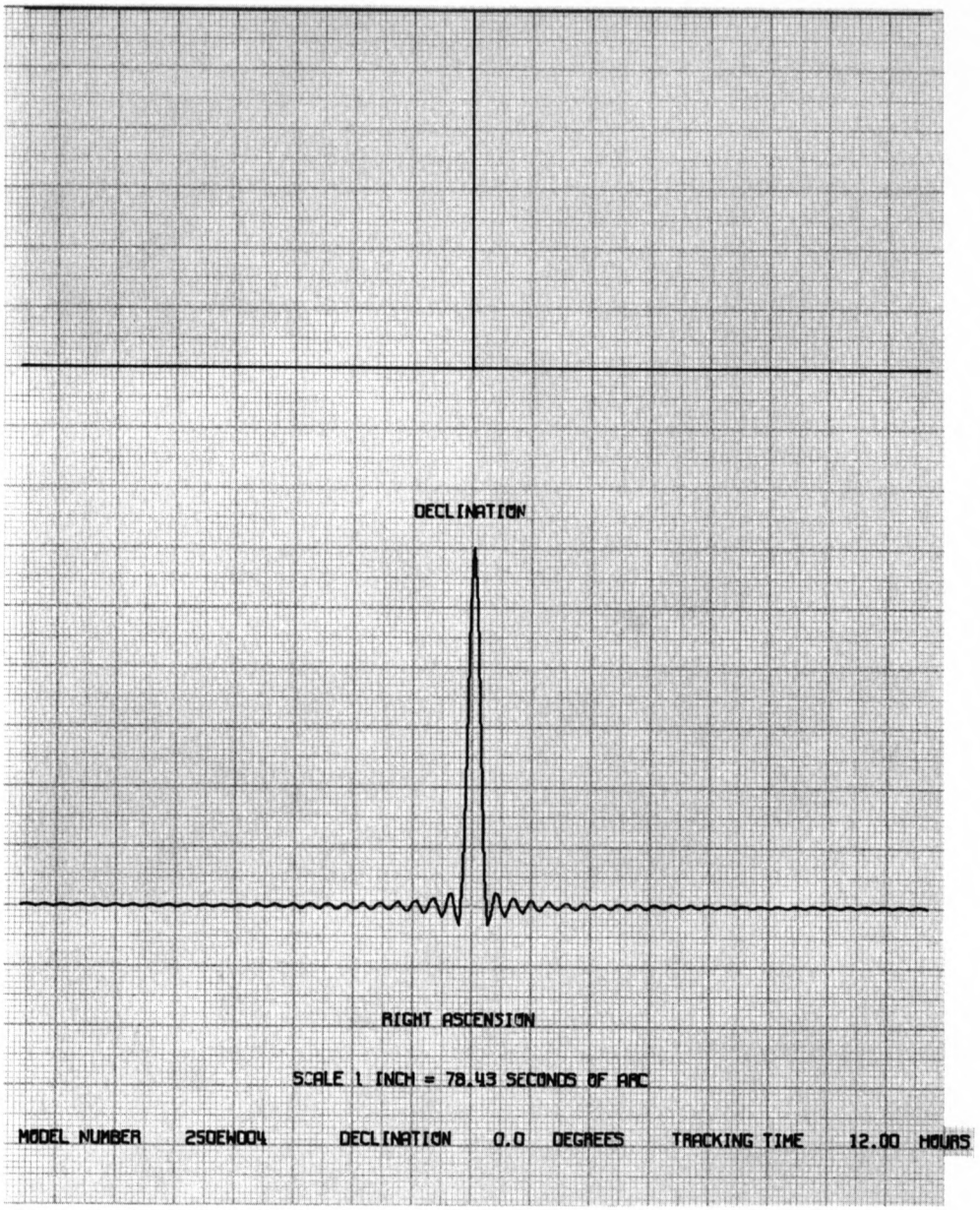
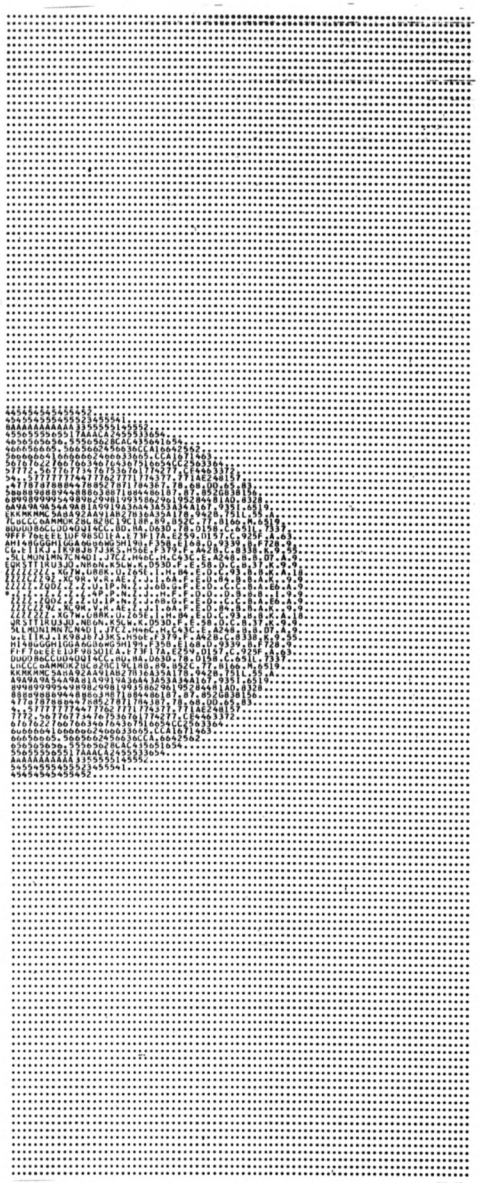


Figure 6. East-West Array with 250 ft (76m) unit spacing
Declination 0°, Tracking Time 12^h



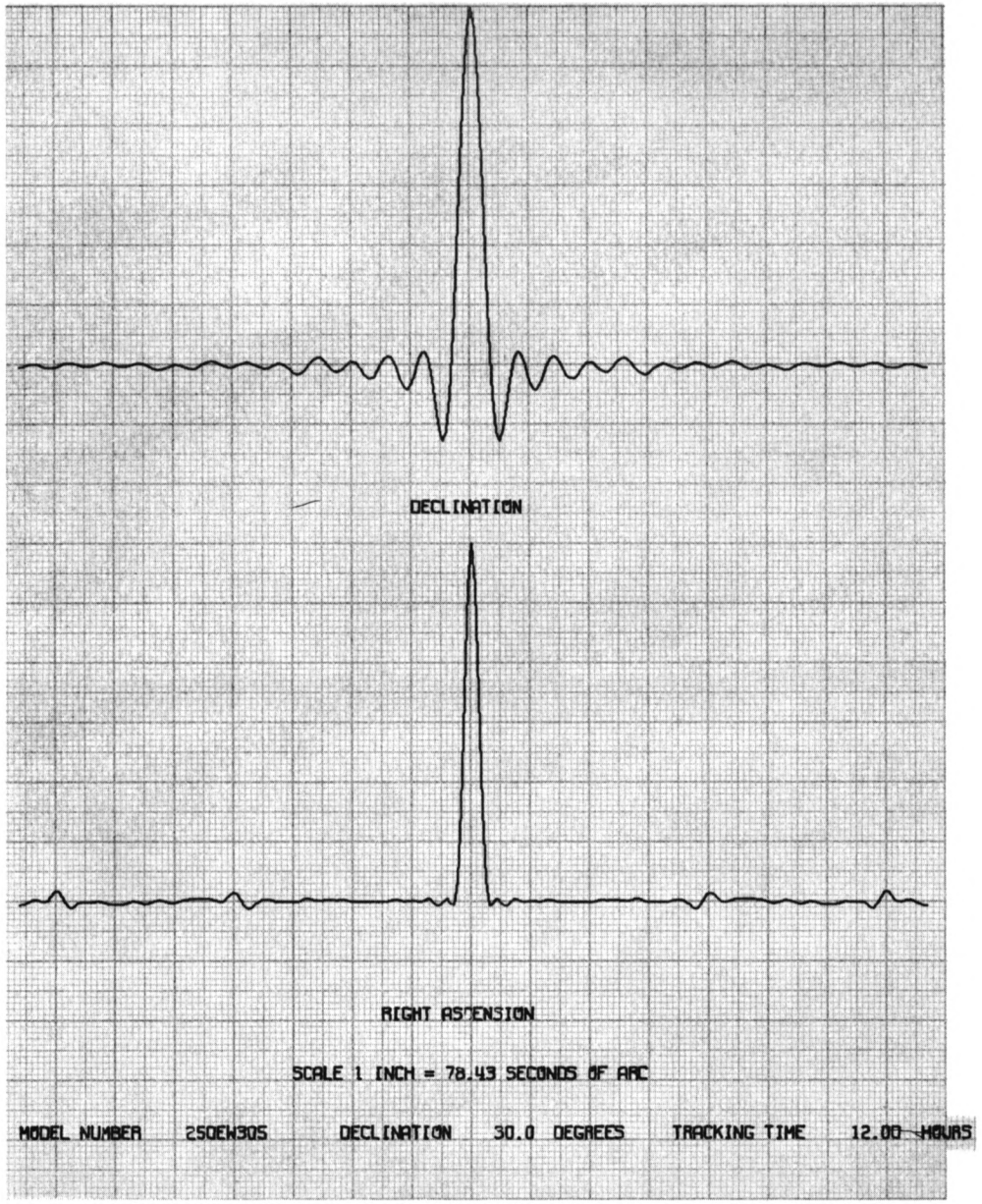
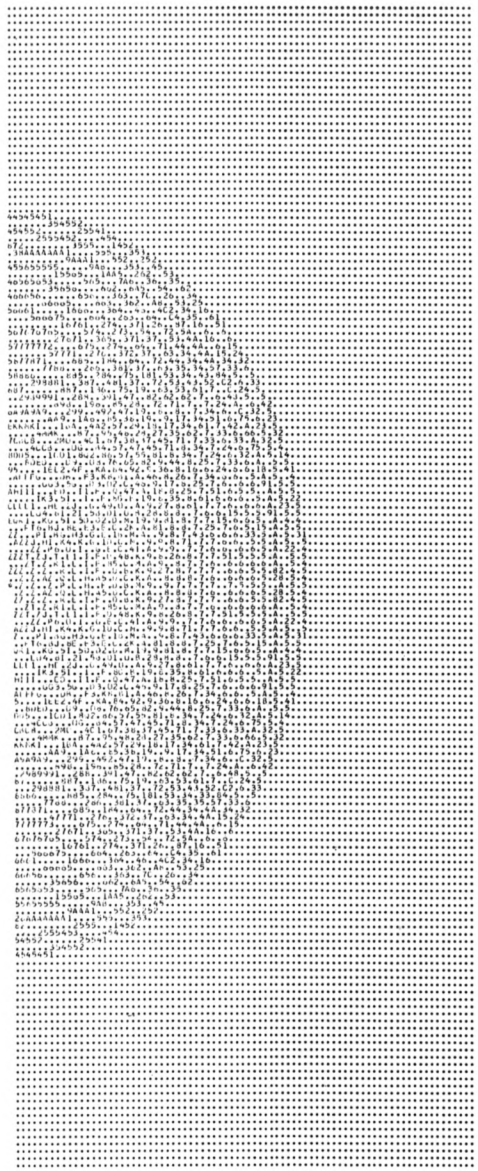


Figure 7. East-West Array with 250 ft (76m) unit spacing
Declination 30°, Tracking Time 12^h



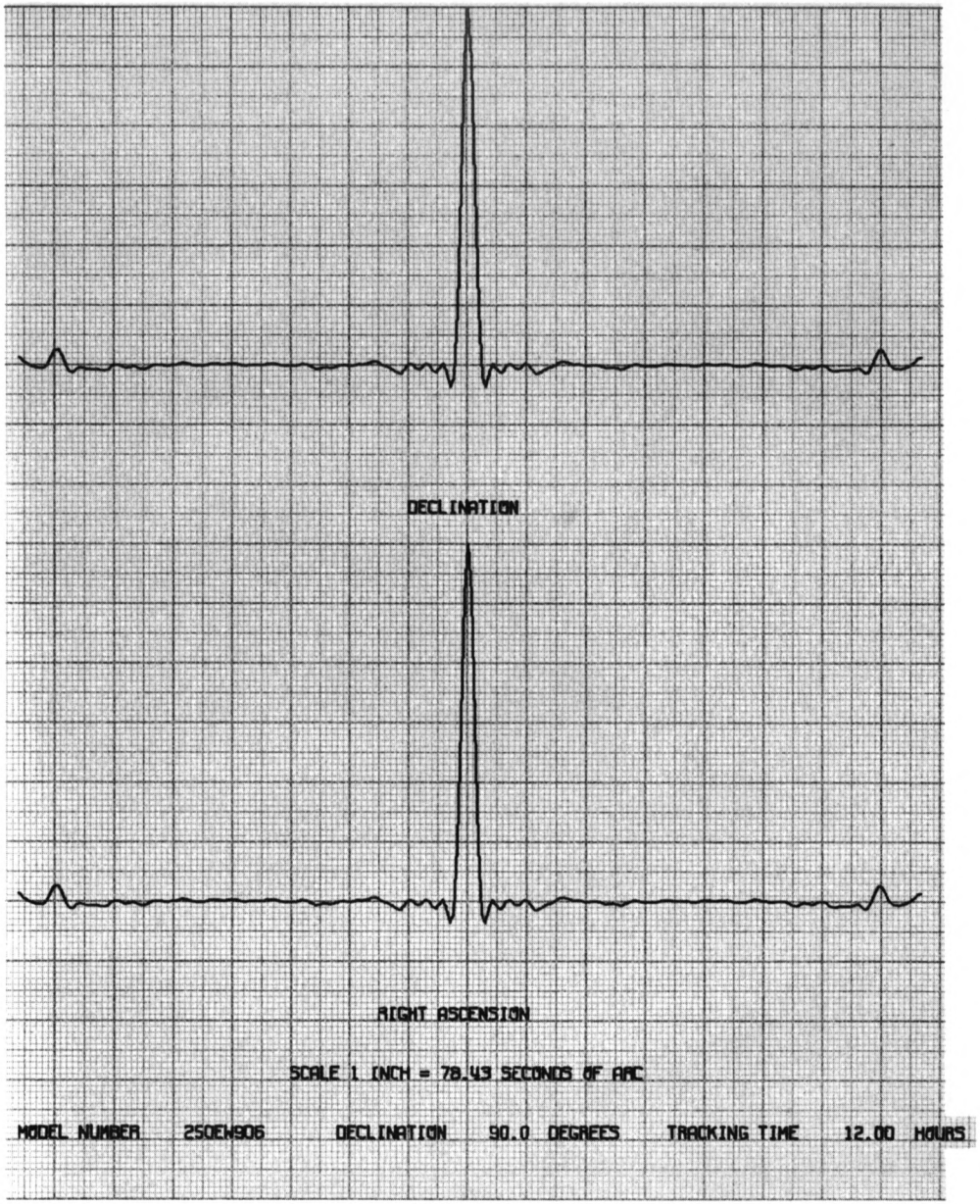
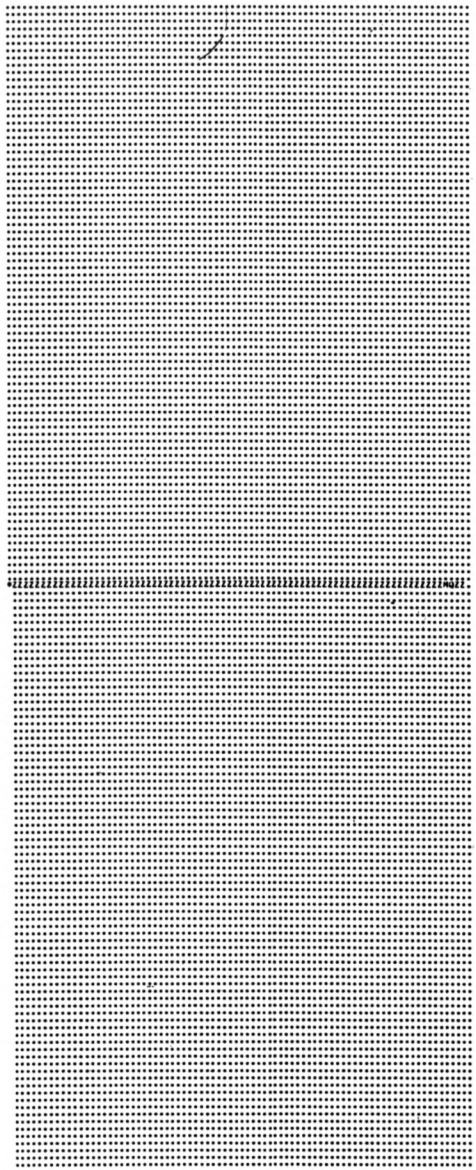


Figure 8. East-West Array with 250 ft (76m) unit spacing
Declination 90°, Tracking Time 12^h



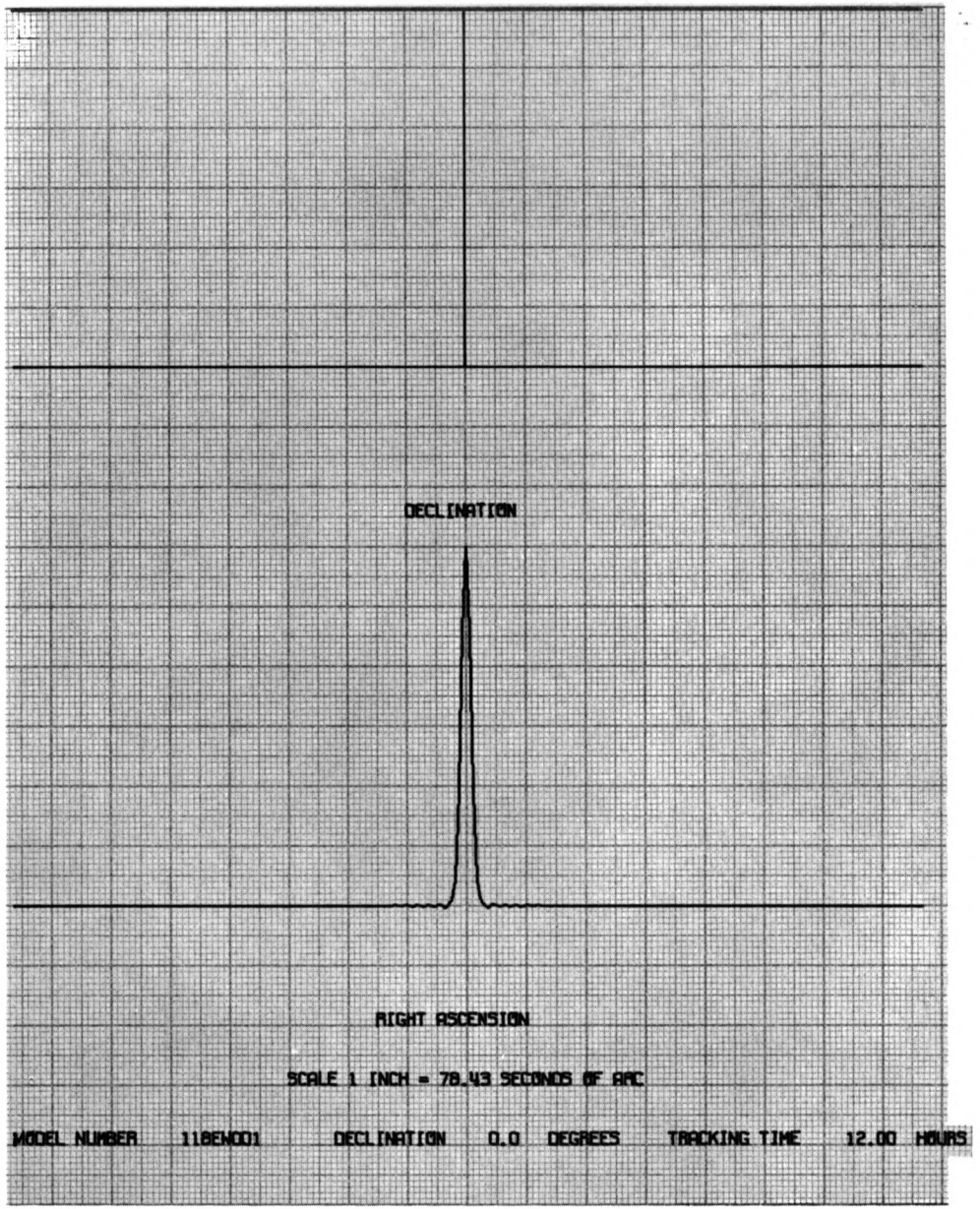


Figure 9. East-West Array with 387 ft (118m) unit spacing
Declination 0°, Tracking Time 12^h

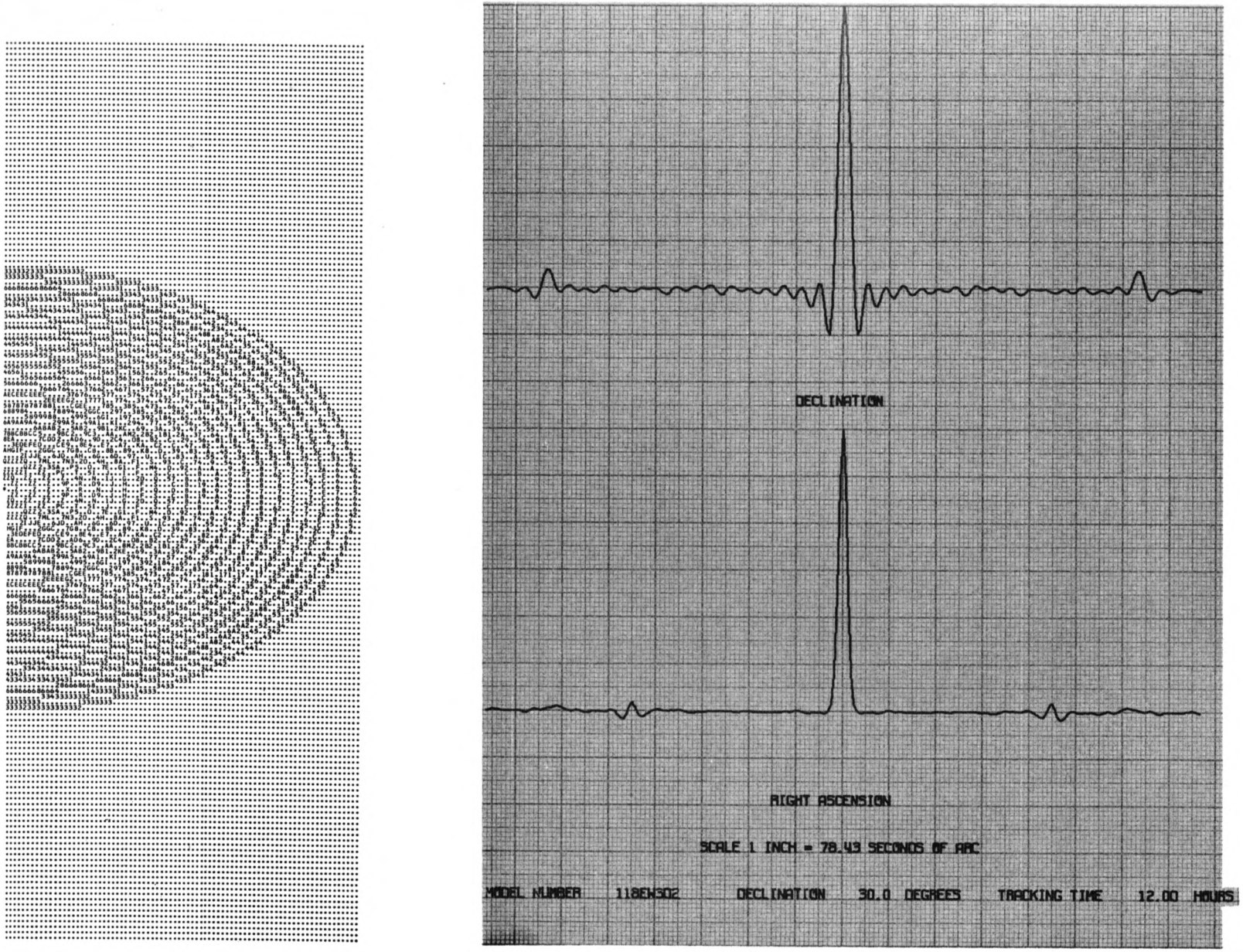
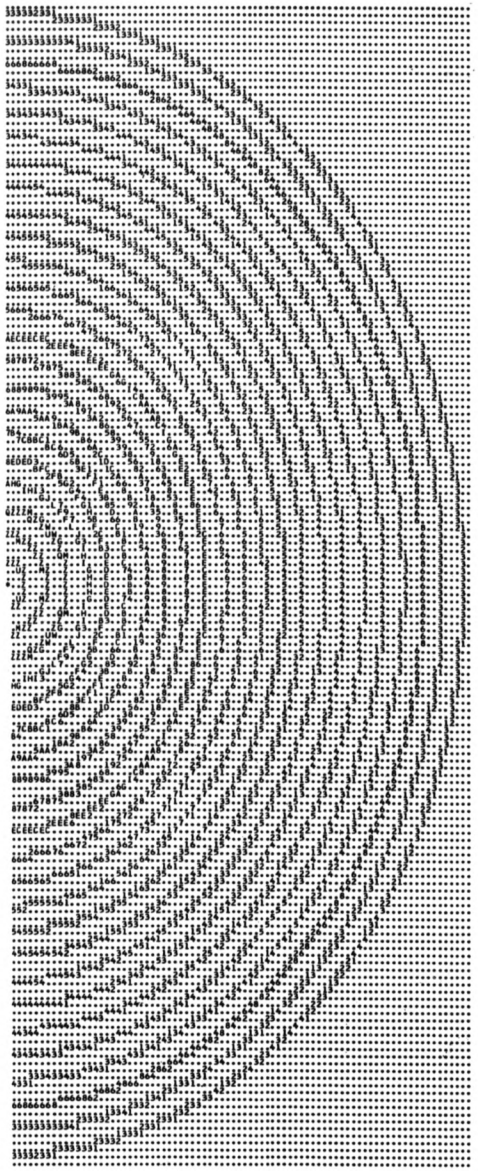


Figure 10. East-West Array with 387 ft (118m) unit spacing
Declination 30°, Tracking Time 12^h



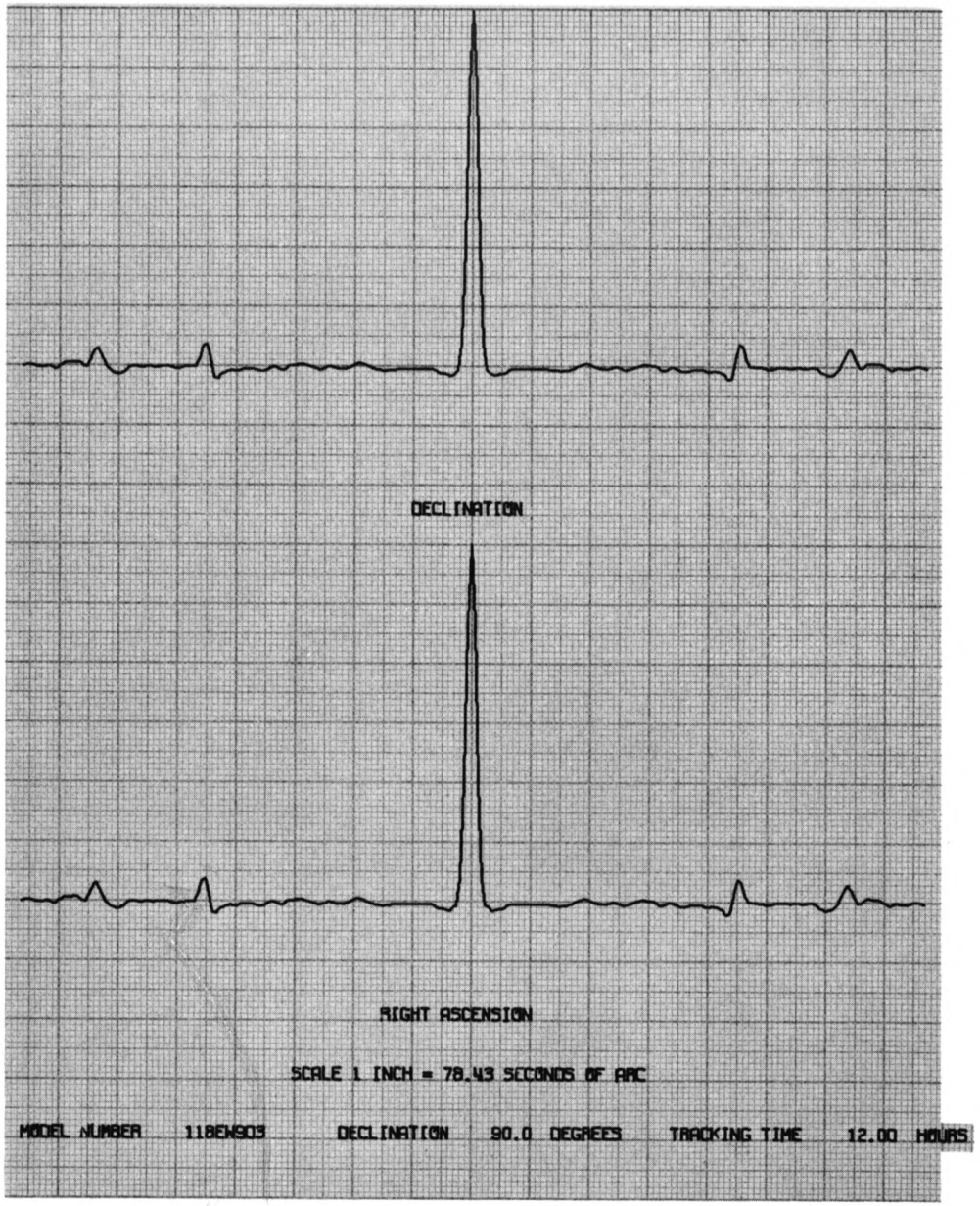


Figure 11. East-West Array with 387 (118m) unit spacing
Declination 90°, Tracking Time 12^h

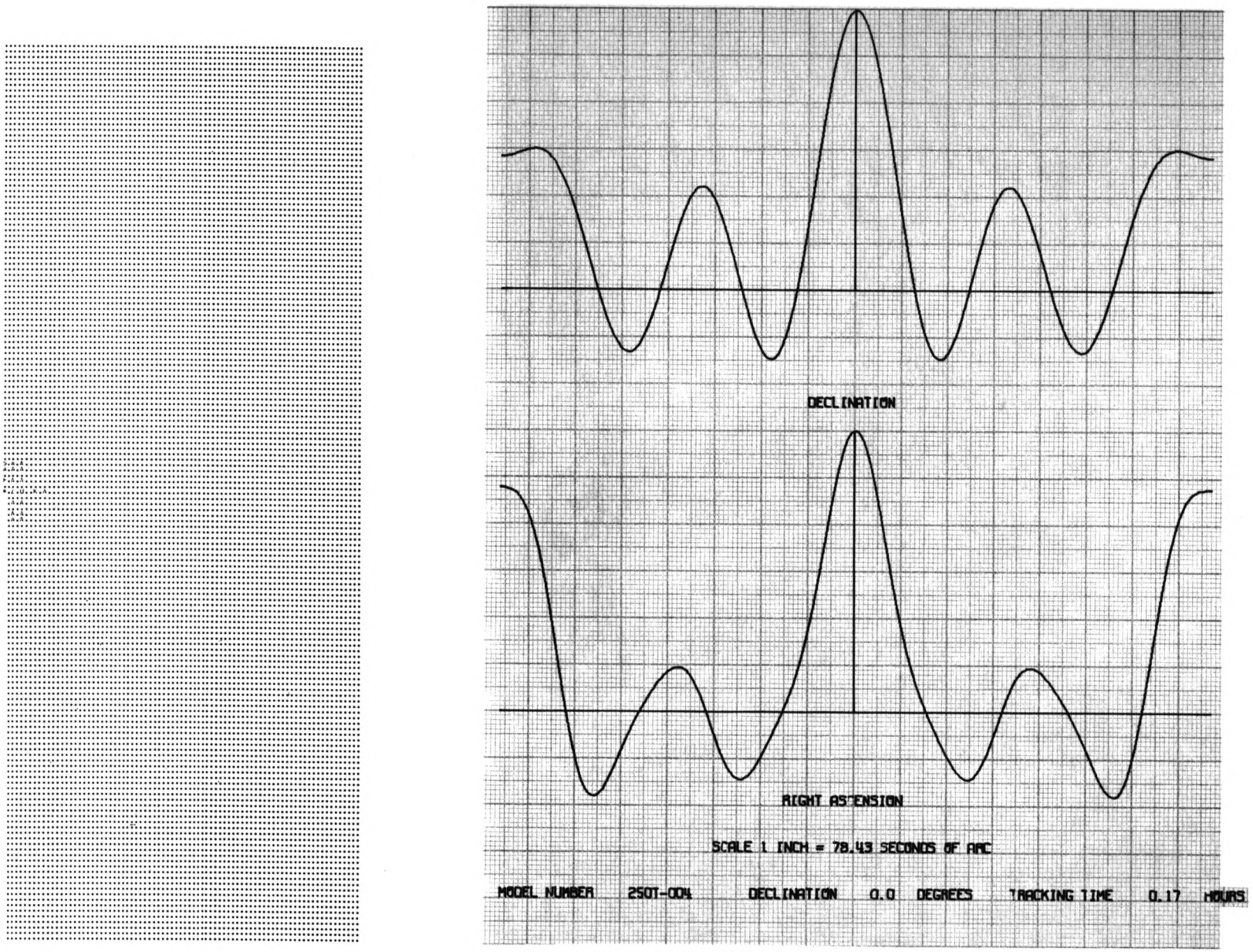
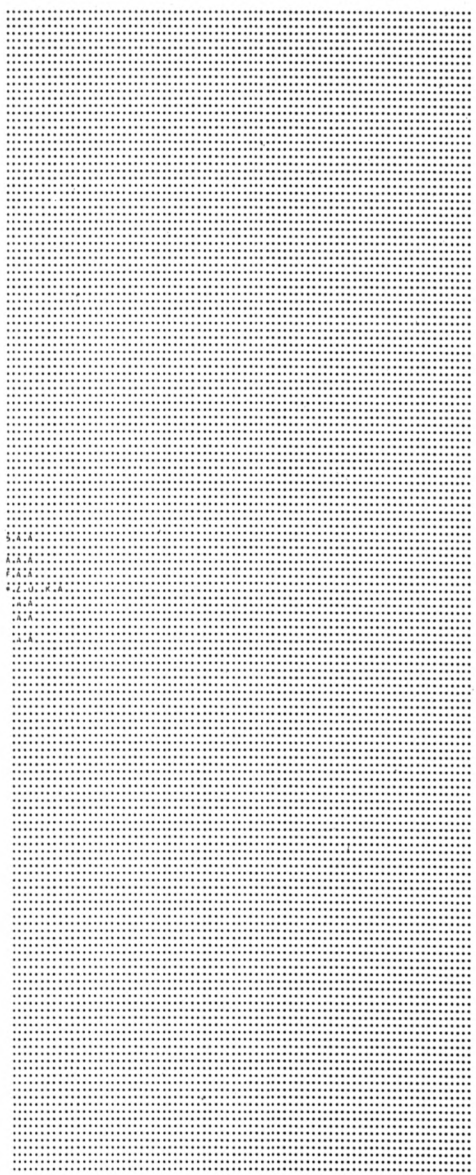


Figure 12. T-Configuration as shown in Figure 2(d)
Declination 0°, Tracking Time 10^m



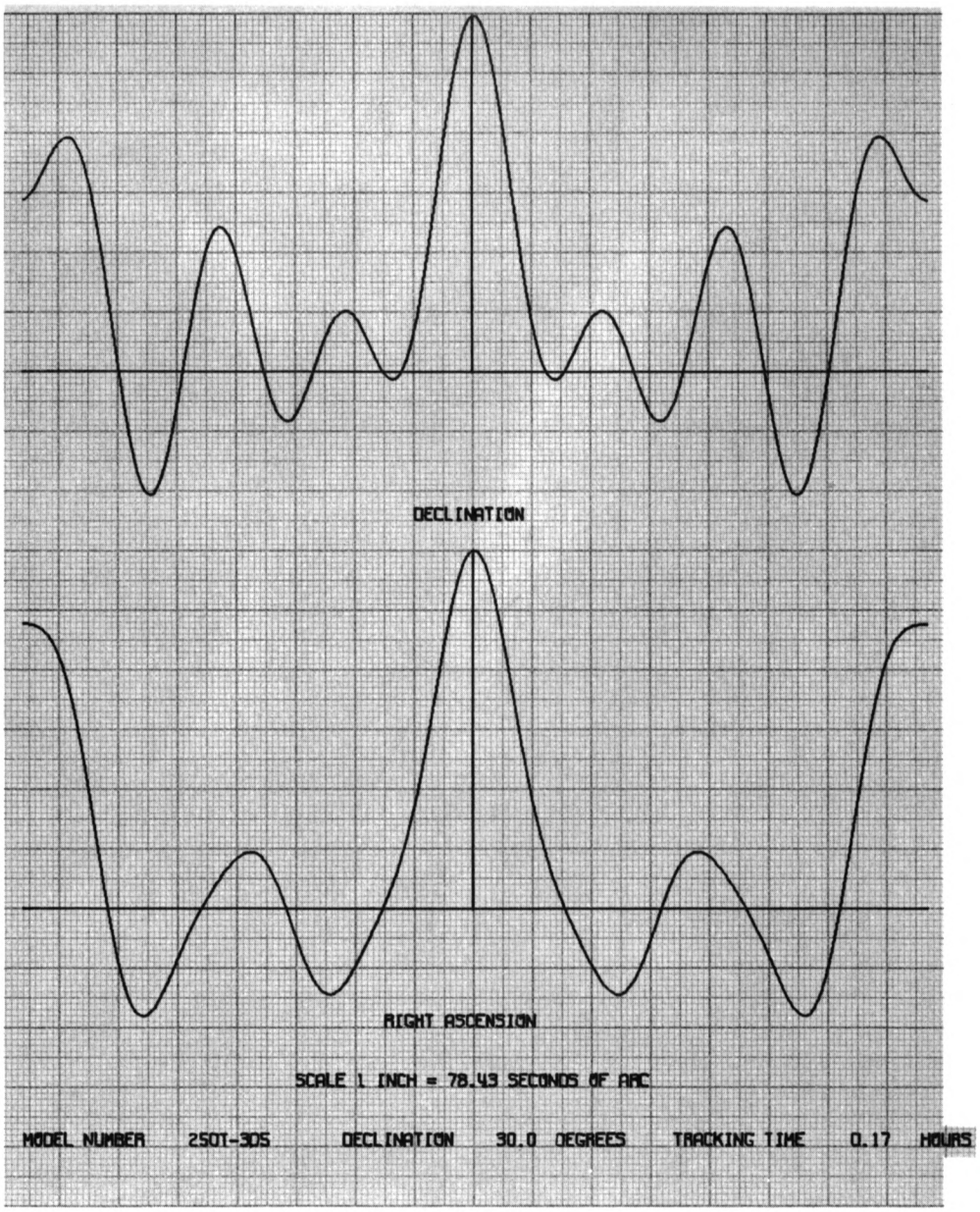


Figure 13. T-Configuration as shown in Figure 2(d)
Declination 30°, Tracking Time 10^m

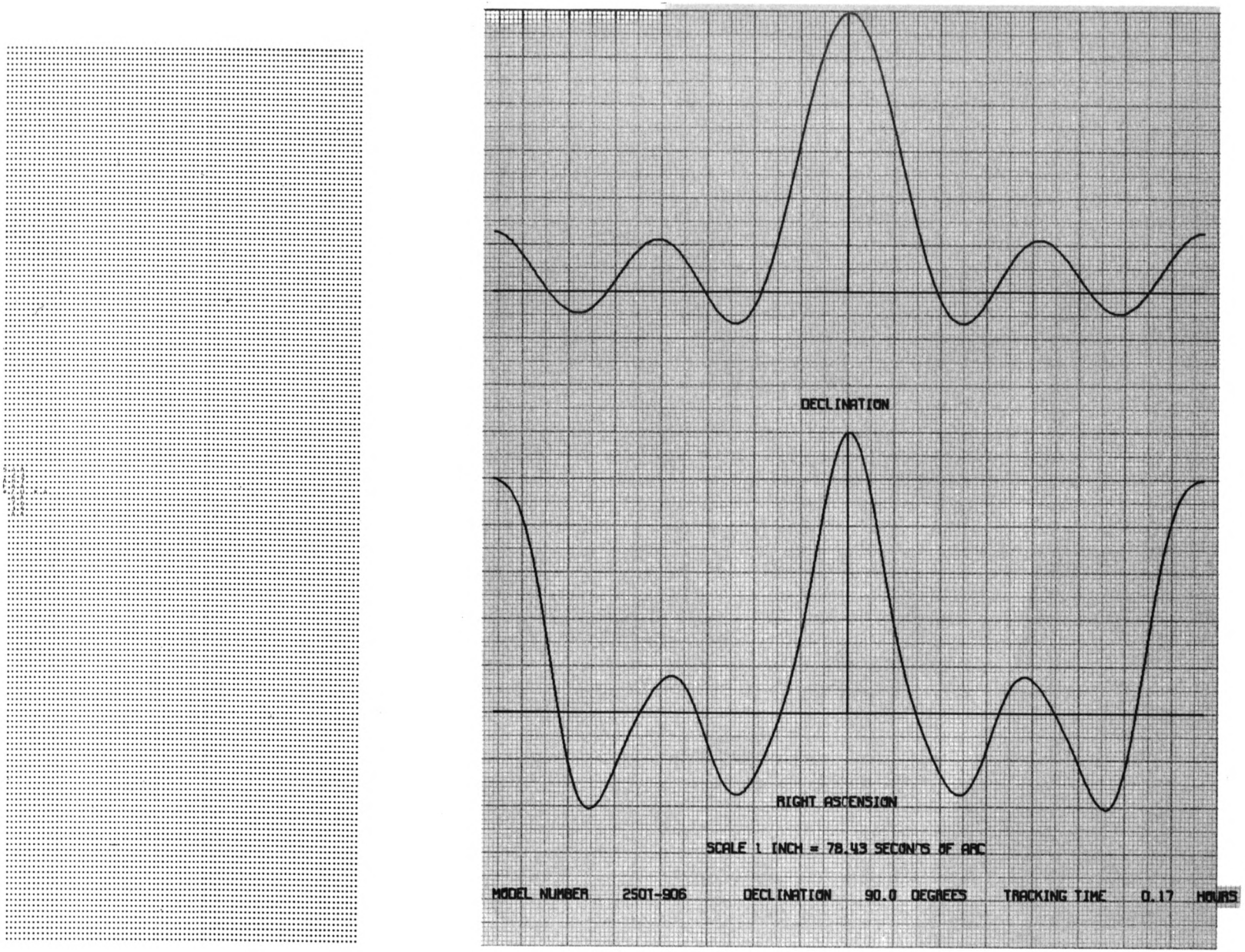
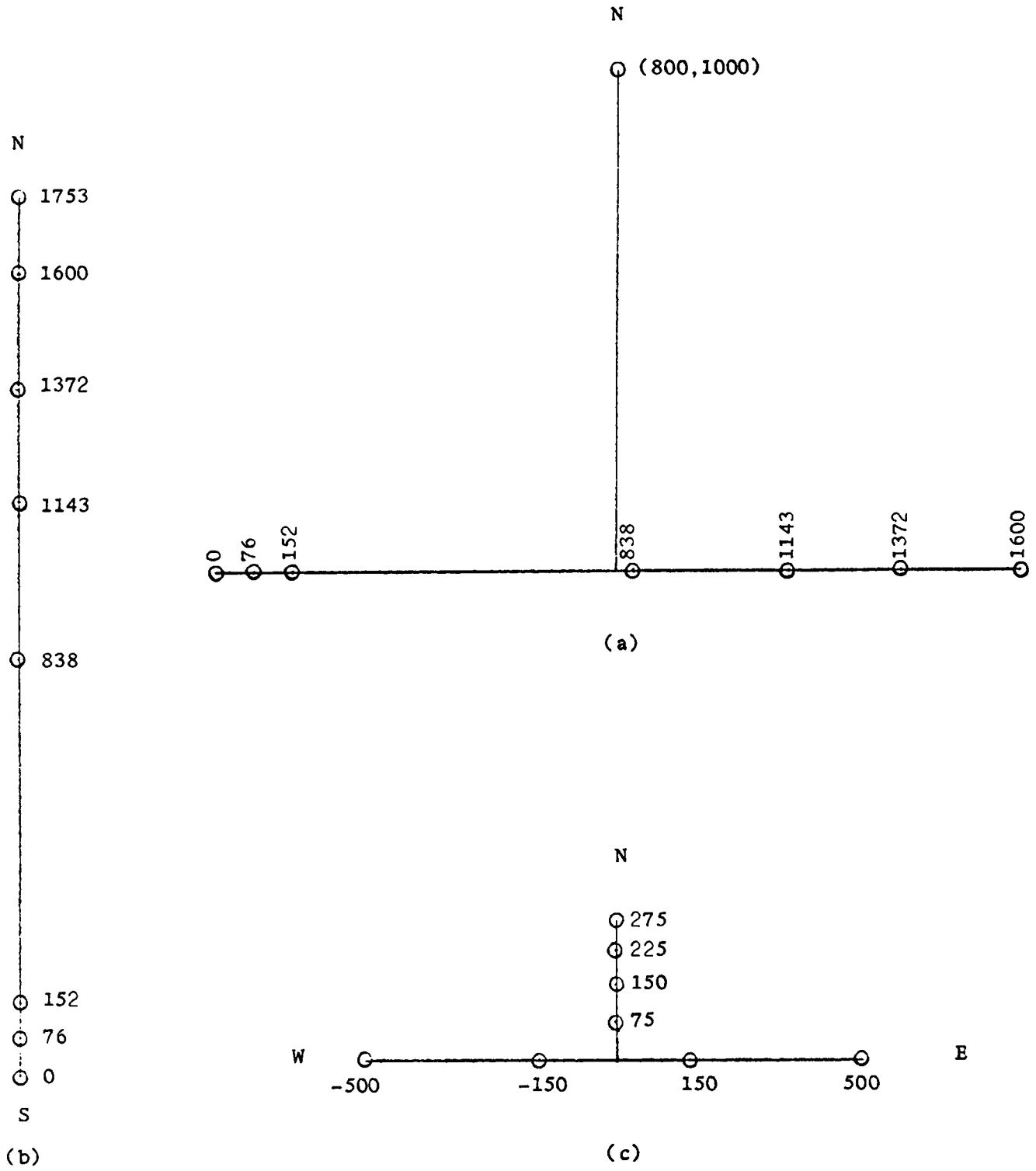
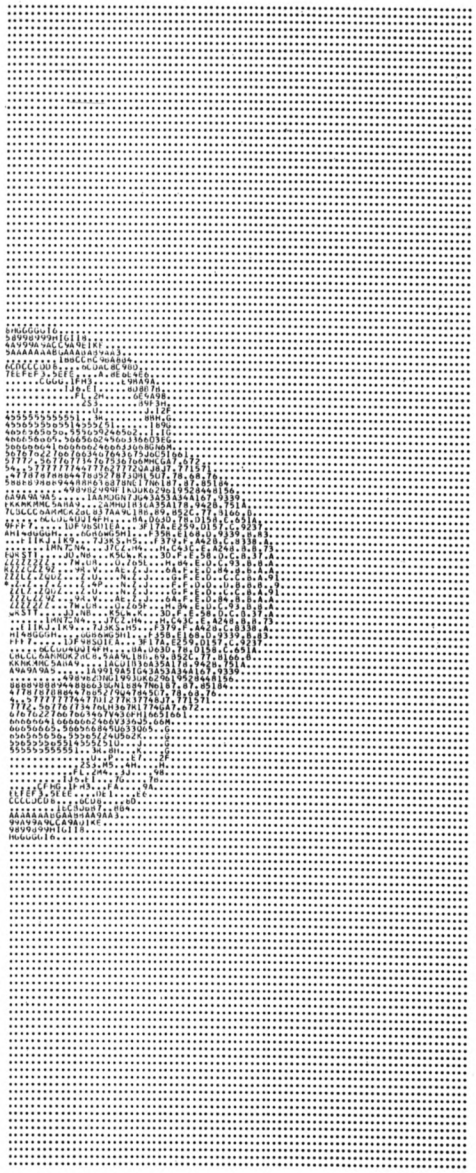


Figure 14. T-Configuration as shown in Figure 2(d)
Declination 90°, Tracking Time 10^m



All dimensions in meters

Figure 15



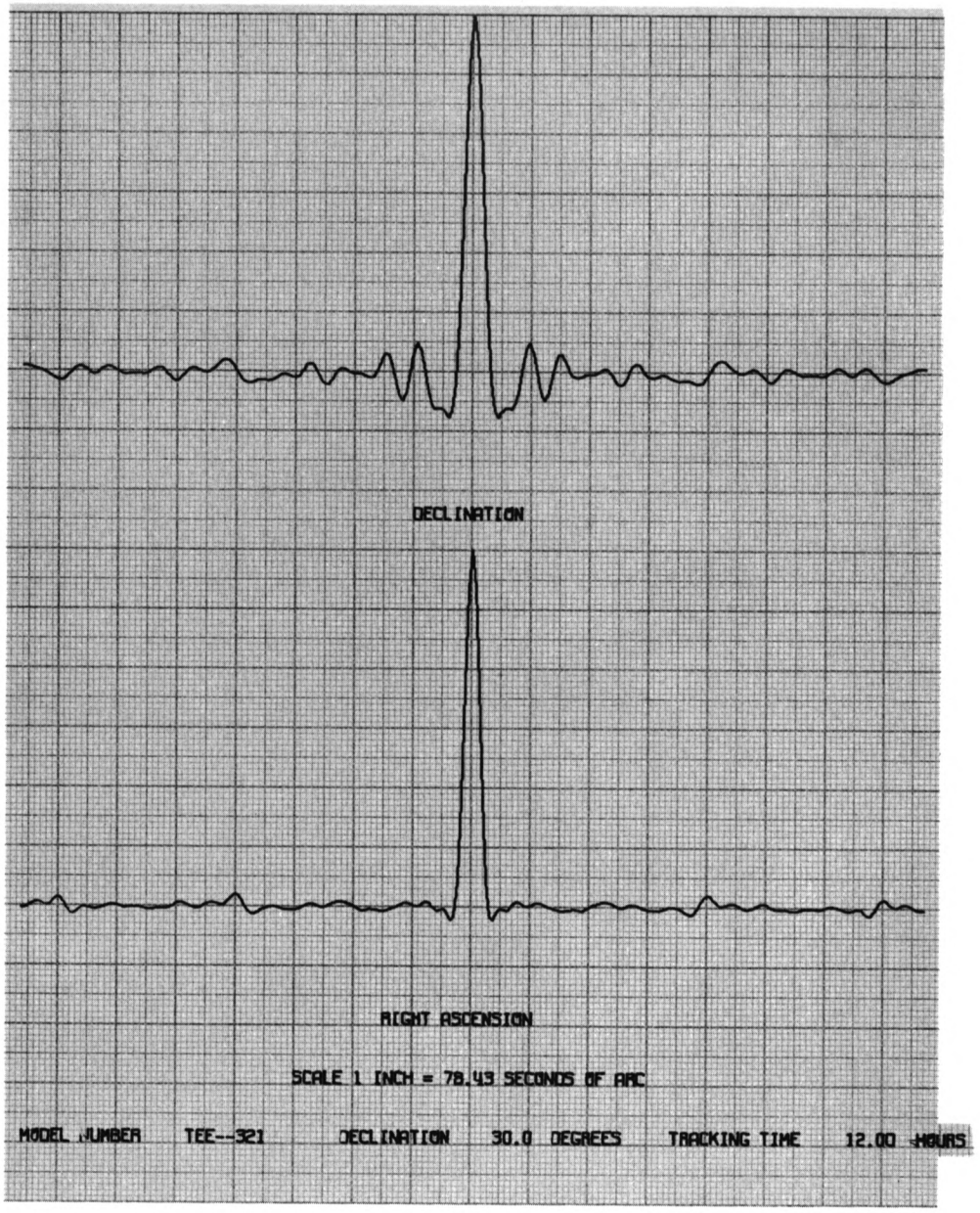
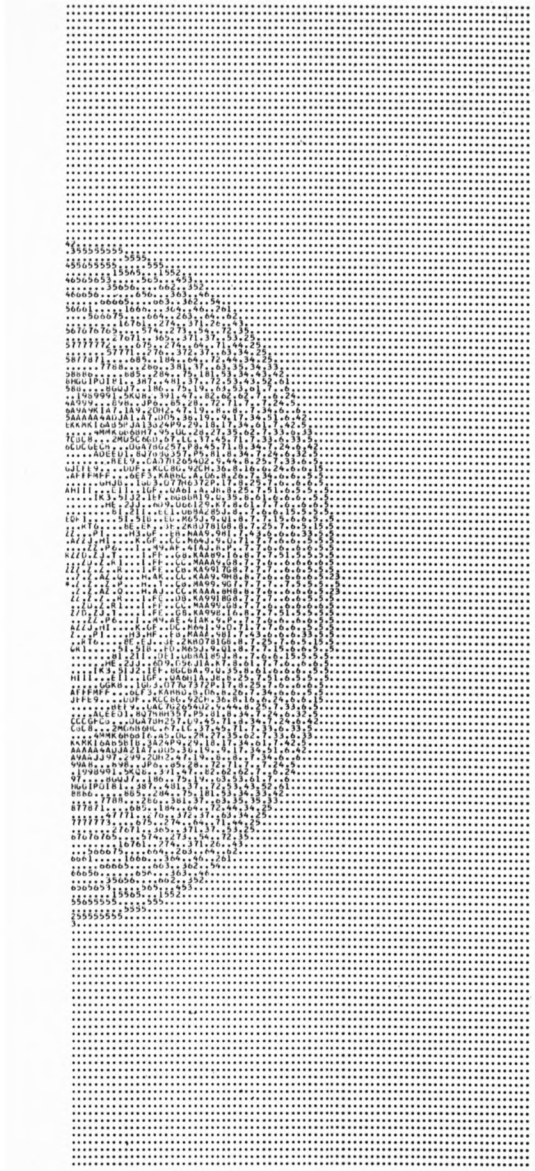


Figure 16. T-Configuration as shown in Figure 15(a)
Declination 30°, Tracking Time 12^h



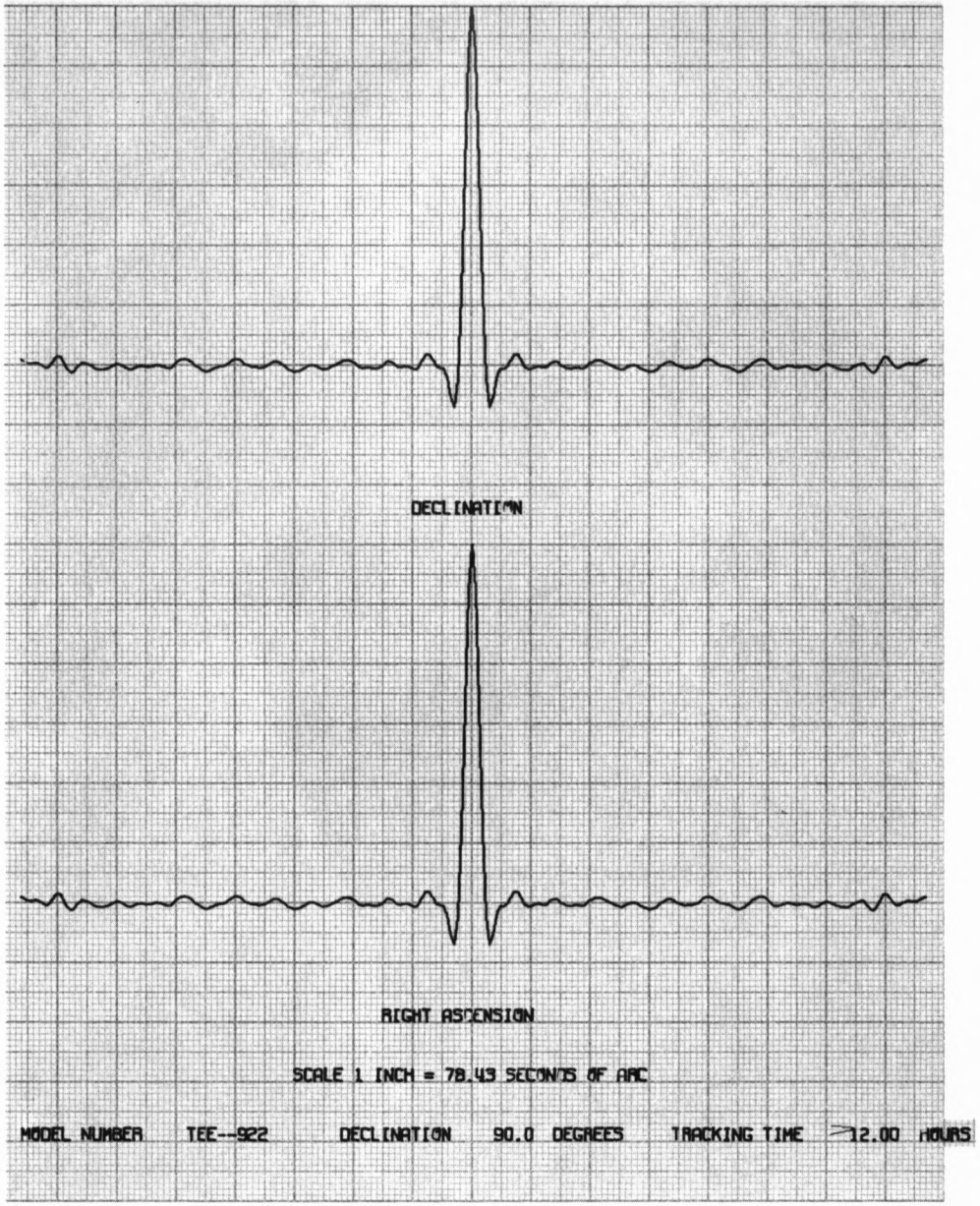
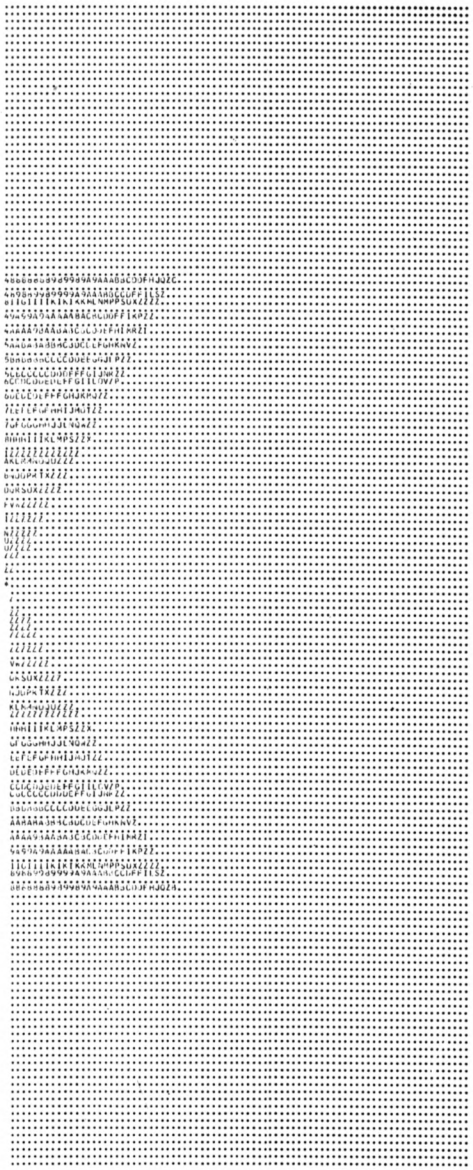


Figure 17. T-Configuration as shown in Figure 15(a)
Declination 90°, Tracking Time 12^h



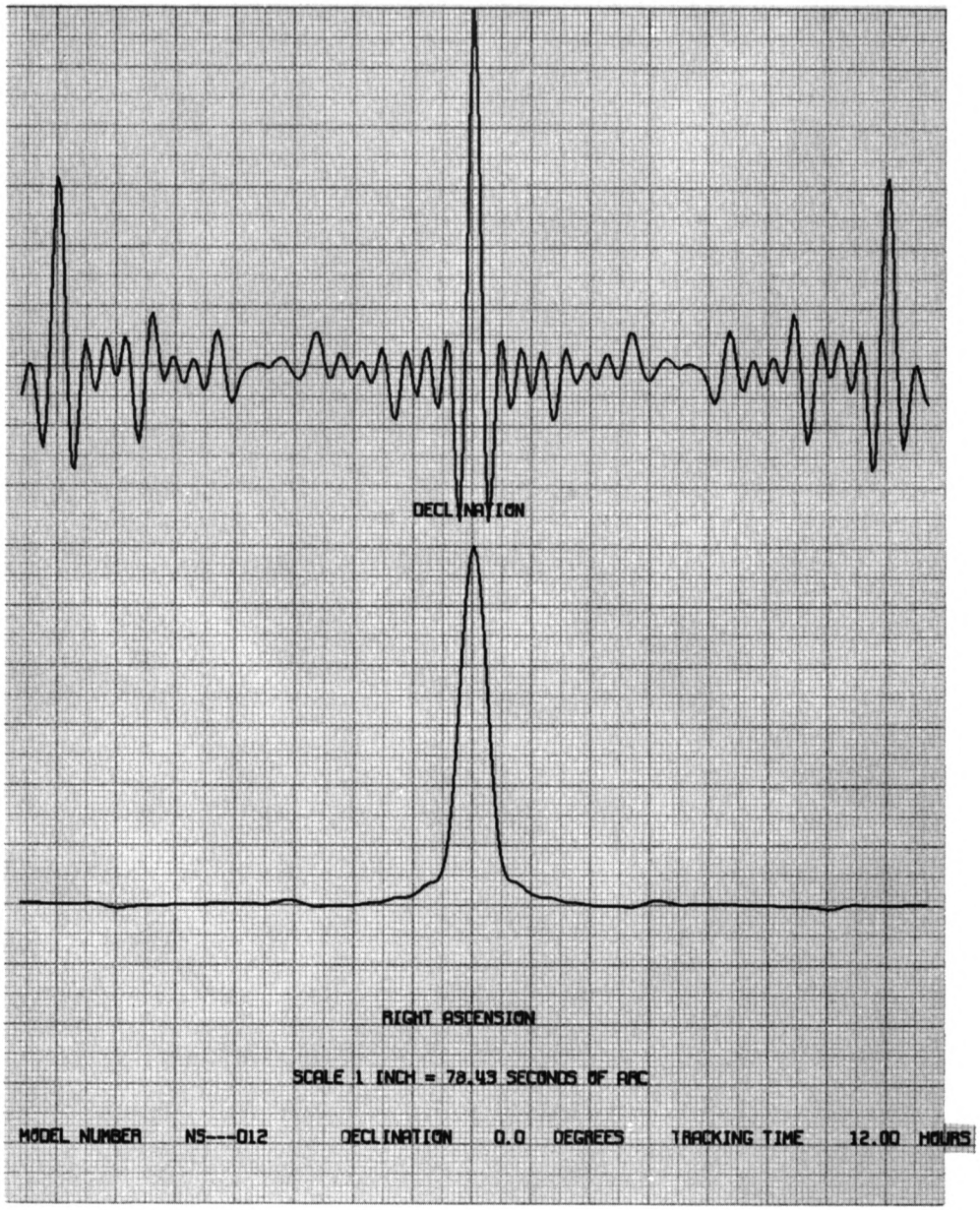
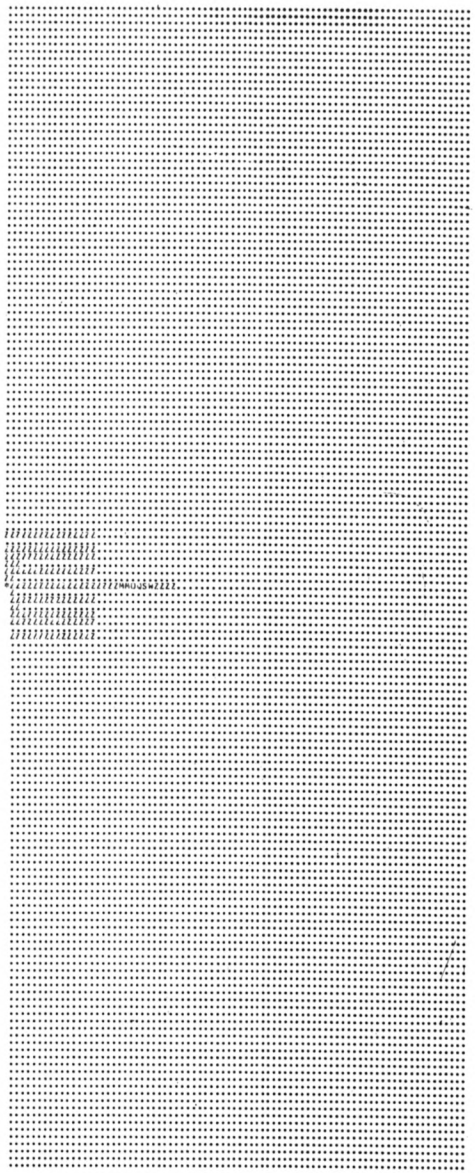


Figure 18. North-South Array with 250 ft (76m) unit spacing
Declination 0°, Tracking Time 12^h



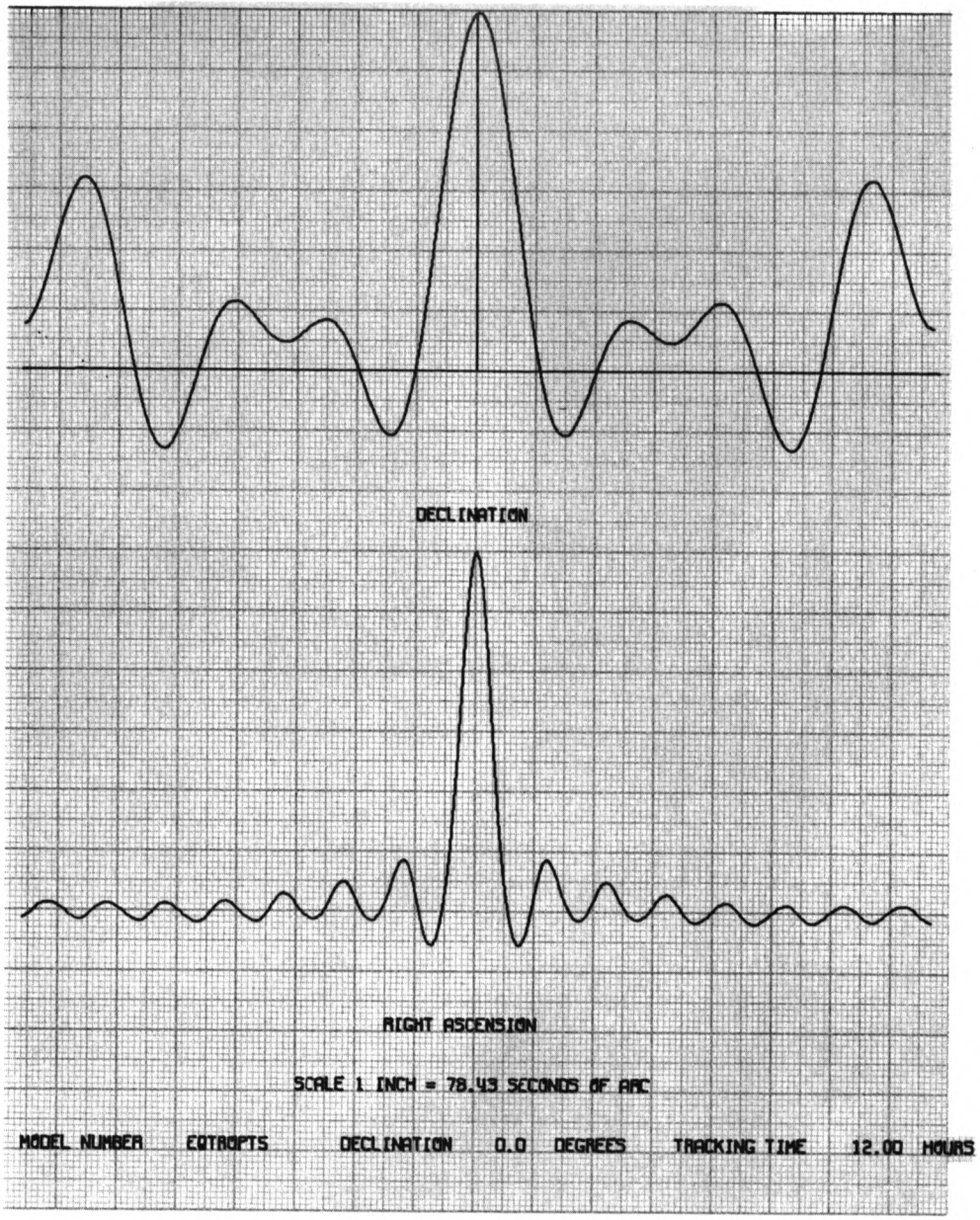


Figure 19. T-Configuration as shown in Figure 15(c)
Declination 0°, Tracking Time 12^h