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APERTURE SYNTHESIS WITH THE GREEN BANK ARRAY

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INTRODUCTION

This report considers the performance of the 3-element array operated by the National Radio Astronomy Observatory at Green Bank, West Virginia. The array is used as a correlator array and its performance has been analyzed in the supersynthesis mode. The basic parameters of the array are summarized below.

The array consists of three 85-foot diameter, steerable antennas lcoated on a horizontal baseline of length 2700 meter and azimuth 63°, at Green Bank, West Virginia, (latitude 38°.5 N). The antennas employ a polar mount and are capable of tracking a source to ±6 hours of the meridian. One of the antennas (designated 85-1) is fixed, while the other two, (designated 85-2 and 85-3), can be moved and placed on any of seven possible observing stations along the baselines as shown in Figure 1. The array thus provides all the baselines from 100m to 900m at 100m intervals and from 900m to 2700m at 300m intervals and, in addition, a baseline of 1900m. The operating frequency is 2695 MHz (with a corresponding wavelength of 11 cm. This enables the array to achieve a limiting resolution of about 9 seconds of arc. Each pair of antennas is connected to a correlation receiver.

The radiation pattern of the array has been computed for various source declinations using the IBM 360/50 computer. The computation of the radiation pattern is done in two steps. First the transfer function is computed. For this, the east-west and north-south components of the effective baseline, u and v, are computed at each minute of the tracking time for every available baseline. The u-v plane is then divided into a large number of cells by a rectangular grid. The elliptical tracks pass through some of these cells (the sampled cells) and do not pass through the others (unsampled cells or "holes"). Holes represent the spatial frequencies which are not sampled by the array. In the second step, the radiation pattern is obtained by taking the Fourier Transform of the Transfer Function. Before taking the Fourier Transform, a uniform weighting is given to each sampled cell, irrespective of the multiplicity of sampling received by the cell due to the crisscrossing of the elliptical tracks. A gaussian taper, decreasing to -15 db at the edge of the transfer function is superposed on the whole transfer function to keep down the sidelobes.

The discrete sampling in the transfer function plane results in a radiation pattern that is periodic, i.e., there are grating lobes of the same intensity as the main beam. The separation of the grating lobes from the main beam is defined as the field of view. It is inversely proportional to the sampling interval. The distant grating lobes are rendered harmless by the limited beamwidth of the individual antennas. But the nearer grating lobes are as strong as the main beam and, for extended sources, should be kept off the source. Thus, the field of view should be at least as large as the extent of the largest source to be observed. In general, very large fields of view can only be achieved at the cost of higher and more numerous sidelobes within the field of view. Fortunately the choice of the field of view is made in the post-observation data reduction and thus it is possible to analyze a given set of data with several different beam patterns. In this report, fields of view of 5, 10 and 17 minutes of arc have been considered. We consider the performance with the existing facilities and also investigate the improvements possible with additional antennas and/or observing stations.

Performance with Existing Stations

The existing 8 observing stations provide 16 distinct baselines ranging from 100m to 2700m, each with an azimuth of 63°. Unlike an East-West baseline, a skewed baseline produces a transfer function which is not symmetrical about the u-axis, although the source is tracked for equal time on either side of the meridian. Also, the limited time for which sources with negative declination are visible and the limited tracking range of the antennas causes the transfer function to be highly unsymmetrical and poorly sampled. These two factors cause the beam to be elliptical with the major axis inclined to the East-West line. Also, high sidelobes appear both in isolated locations, and as spiral arms originating at the center of the beam. This is true for low declinations. For declinations above about 50°, the transfer function is more symmetrical and so is the beam. Figure 2 compares the beams at 40° and 80° declinations with a field of view of

10'. The percentage of holes as a function of source declination is shown in figure 3 for fields of view of 5', 10' and 17'. Details of sidelobe levels are given in Tables I, II, and III, and the maximum sidelobes are shown in Figure 4. Computer plots of the beam pattern for a field of view of 10' are given in the Appendix for declinations ranging from -10° to 90°. These plots serve as contour diagrams of the beam and can be used to determine the beamwidth (approximately) and the shape and orientation of the beam as explained in the Appendix. The beamwidths quoted in the tables are determined in this manner and are only approximate.

A comparison of Tables I, II, and III shows that the sidelobes for a 17 minutes field of view are not very different in magnitude from those for a 5 minutes field. In a wider field of view, sidelobes tend to be more numerous. Figure 5 compares the beam plot for a declination of 40° for fields of view of 5' and 17'.

As mentioned earlier, the existing observing stations provide 16 distinct baselines, all similarly oriented. With the existing three antennas, nine configurations will be needed to get all the 16 baselines. This means that nine days of observation of the same source is needed to achieve the array performance described earlier.

Performance with Additional Facilities

It is interesting to consider the performance assuming the availability of additional observing stations and/or antennas. First let us consider two additional stations located at distances of 100m and 200m southwest of 85-1 along the same baseline as the other observing stations. With the total of ten observing stations thus available, we would get 27 distinct baselines--all the way from 100m to 2700m at 100m intervals, all similarly oriented. The transfer function corresponding to the 10 stations (and 27 distinct baselines) is much better filled than that with 8 stations. Figure 6 compares the percentage of holes for the two cases. Tables I, II, and III also include sidelobe information for the case of 10 stations. It is assumed throughout that the antennas occupying the two additional stations have the same tracking facilities as the above. The improvement in performance with 10 stations is quite marked.

It should be mentioned here that the limited tracking ability (±6 hours from the meridian) of the antennas is a severe limitation for the skewed baselines. Had the antennas been capable of tracking the source from horizon-to-horizon for all declinations, the beam would be considerably improved.

The coordinates of the point sampled in the spatial frequency plane are given by

$$u = B_2 \sin (H-h)$$

$$v = B_1 \cos \delta - B_2 \sin \delta \cos (H-h)$$

Where B_1 and B_2 are the components of the baseline, respectively parallel to and perpendicular to the earth's rotation axis, H and δ are the hour angle and declination of the source and h is the hour angle of the baseline pole. For a horizontal east-west baseline $B_1 = 0$ and $h = 0$. This reduces the above equations to

$$u = B_2 \sin H$$

$$v = B_2 \sin \delta \cos H$$

This clearly shows that any tracking beyond ±6 hours of the meridian will not lead to the sampling of new cells in the u-v plane. This is not so with a skewed baseline. With a skewed baseline, tracking beyond ±6 hours will improve the sampling of the u-v plane.

The sidelobe levels for the case of 10 stations and fully tracking antennas and a 10' field of view are given in Table IV. A comparison of Table IV with Table II shows the marked improvement. An interesting feature can be seen by a comparison of these two tables. Introduction of additional antennas and/or an increase in the observing time can only result in a reduction of the percentage of unsampled cells and an over all improvement in the beam. This is borne out by the two tables. However, because of the Fourier Transform relationship between the transfer function and the beam pattern, additional sampling in the transfer function plane will not guarantee an improvement in the beam at every point in the field of view. Thus, though the mean sidelobe level decreases, the peak sidelobes may actually increase at some points. This is brought out very clearly in Figure 7 where the maximum sidelobe level is plotted as a function of declination for the three cases considered in Tables II and IV. (It may be mentioned here that in considering the maximum sidelobe, the central portion of the field containing the main beam is neglected. This means neglecting Zone 1 for a 10' field and Zones 1 and 2 for a 5' field). The beam pattern at 40° declination is shown in Figure 8.

We next consider the saving in observation time that can be achieved by additional antennas. As already mentioned, nine configurations are needed to achieve the 16 baselines available with the present set up using 85-1, 2, and 3. The 42-foot mobile antenna is already being used in conjunction with the array. It has a limited tracking range of 4.5 hours maximum (somewhat smaller range at low declinations). If this antenna is correlated with all the other antennas then in three configurations we get 18 distinct baselines covering the range from 100m to 1200m at 100m intervals and from 1200m to 2700m at 300m intervals. This enables a saving by a factor of 3 in time. However, the limited tracking range of the 42-foot telescope leaves a lot of unsampled spatial frequencies.

Computations have also been done using five antennas. The fifth antenna is taken as another mobile 42-foot antenna capable of tracking within ±4 hours of the meridian and correlated with all the other antennas. The configurations and the available baselines are shown in Table V. It is seen that two configurations with 5 antennas give all the baselines now available. The percentage of holes and the maximum sidelobes are plotted in Figures 9 and 10 as a function of declination for the cases discussed above. The field of view has been taken as 5'. The details of the sidelobes are given in Table VI.

CONCLUSIONS

The analysis presented in this report shows that the three element array at Green Bank can be effectively used for synthesis of sources north of 40° declination. A nearly circular beam with a half power beamwidth of about 10" can be produced by using all the available baselines (this involves nine configurations), utilizing maximum possible tracking in each configuration. The synthesized beam has no sidelobes greater than -9 db. The sidelobe level can be improved somewhat by employing a smaller field of view. An improvement of about two dbs will result in going from a 17' field of view to one of 5'. At lower declinations the beam becomes more elliptical and the sidelobe level also rises. For a source at the equator, the beam is elliptical, about 10" x 25" and sidelobes as high as -5 db appear within a field of view of 5'.

It is found that the spatial frequency sampling can be considerably improved if two additional stations are provided. These stations, located at 100m and 200m from 85-1, reduce the mean sidelobe level by about 4 db.

The time required for the synthesis of a source can be considerably shortened by employing additional antennas and correlators. For example, the use of the mobile 42' telescope with the three others can produce, in three configurations, a beam which is almost as good as that produced by the three antennas alone in nine configurations. With two additional antennas the same beam characteristics can be achieved in two configurations.

The resolution of the array can be improved by increasing the maximum baseline. Thus an antenna located 2700m north-east of 85-1 at the same azimuth of 63° will improve the resolution by almost a factor of two. Although detailed analysis of such configurations has not been carried out, a few cases considered show that this improvement in resolution is achieved without a marked increase in the sidelobe levels.

A few configurations were studied using antennas placed off the 63° azimuth baseline in an effort to improve the beam at low declinations. However, no substantial improvement was achieved and the results are not included in this report.

TABLE I

COMPARISON OF PERFORMANCE WITH 8 AND 10 STATIONS: 5' FIELD OF VIEW

ZONES: (1) 5.8" - 10.5" (2) 10.5" - 19.8" (3) 19.8" - 38.4" (4) 38.4" - 75.7" (5) 75.7" - 150.0"

Model	N	Decli-nation	Tracking Time (Hours)	Holes (%)	Half-Power Beamwidth (Seconds)	Relative Gain	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
N0810S12	8	-10°	10.04	89.38	10 x 50	47	-0.4	-1.1	-4.3	-7.7	-10.6	-4.4	-7.2	-10.9	-15.9	-18.3
N1010S12	10	-10°	10.04	85.95	8 x 50	54	-0.4	-1.2	-4.6	-9.5	-11.6	-5.0	-8.0	-11.4	-16.8	-19.9
N0800N12	8	0°	11.15	88.28	10 x 25	57	-1.3	-3.8	-5.1	-9.4	-6.4	-4.5	-7.8	-13.1	-17.4	-19.5
N1000N12	10	0°	11.15	85.28	8 x 27	72	-1.4	-3.8	-5.5	-9.1	-12.7	-4.7	-8.0	-13.7	-18.6	-21.7
N0810N12	8	10°	12.0	82.90	10 x 18	72	-2.1	-5.5	-6.7	-9.0	-5.7	-5.8	-9.5	-13.3	-18.0	-19.2
N1010N12	10	10°	12.0	75.08	8 x 18	95	-2.1	-4.3	-9.3	-12.0	-14.2	-5.9	-9.8	-15.2	-20.2	-23.3
N0820N12	8	20°	12.0	78.37	10 x 16	80	-2.5	-6.1	-7.4	-9.4	-8.3	-6.3	-9.7	-13.8	-17.7	-19.2
N1020N12	10	20°	12.0	63.89	8 x 16	109	-2.7	-5.7	-10.0	-12.3	-15.5	-6.7	-11.2	-16.1	-21.1	-24.2
N0830N12	8	30°	12.0	72.27	10 x 15	94	-2.5	-5.2	-9.2	-10.6	-9.4	-6.7	-10.4	-15.3	-18.4	-20.1
N1030N12	10	30°	12.0	51.55	9 x 14	123	-3.4	-8.6	-11.1	-14.6	-16.7	-7.9	-13.2	-17.3	-21.9	-24.9
N0840N12	8	40°	12.0	67.79	10 x 13	89	-2.8	-6.0	-9.6	-12.1	-11.6	-6.9	-11.8	-16.4	-18.1	-19.6
N1040N12	10	40°	12.0	41.35	9 x 13	126	-3.9	-9.8	-11.6	-14.0	-16.7	-9.3	-15.1	-18.5	-22.1	-24.1
N0850N12	8	50°	12.0	64.46	11 x 13	84	-3.1	-7.0	-10.1	-11.4	-11.5	-6.8	-12.8	-17.5	-17.7	-19.7
N1050N12	10	50°	12.0	32.97	9 x 11	120	-4.3	-11.4	-13.2	-14.7	-16.8	-10.3	-17.2	-21.0	-22.1	-23.8
N0860N12	8	60°	12.0	62.32	11 x 12	94	-3.3	-8.0	-11.7	-12.1	-12.0	-6.7	-13.1	-17.5	-17.8	-19.9
N1060N12	10	60°	12.0	26.73	9 x 11	127	-4.7	-13.3	-15.6	-16.1	-16.8	-10.9	-19.2	-22.6	-23.0	-24.1
N0870N12	8	70°	12.0	60.31	10 x 11	91	-3.6	-8.6	-11.7	-11.6	-11.9	-6.7	-13.0	-17.6	-17.5	-20.2
N1070N12	10	70°	12.0	21.20	9 x 11	121	-5.1	-16.0	-17.4	-17.4	-17.5	-11.3	-21.3	-24.2	-24.0	-24.5
N0880N12	8	80°	12.0	59.55	11 x 11	99	-3.7	-8.7	-11.7	-11.5	-12.5	-6.6	-13.0	-17.6	-17.4	-20.4
N1080N12	10	80°	12.0	18.96	10 x 11	130	-5.4	-16.5	-17.4	-17.5	-17.8	-11.5	-22.5	-25.1	-23.7	-25.0
N0890N12	8	90°	12.0	59.60	11 x 11	100	-3.8	-8.7	-12.4	-12.4	-12.4	-6.6	-13.0	-17.2	-17.2	-20.7
N1090N12	10	90°	12.0	18.72	10 x 10	129	-5.5	-17.8	-19.1	-18.5	-18.2	-11.5	-23.2	-26.0	-25.0	-25.6

TABLE II

COMPARISON OF PERFORMANCE WITH 8 AND 10 STATIONS: 10' FIELD OF VIEW

ZONES: (1) 11.7" - 21.0" (2) 21.0" - 39.6" (3) 39.6" - 76.8" (4) 76.8" - 151.5" (5) 151.5" - 300"

Model	N	Declination	Tracking Time (hours)	Holes (%)	Half-Power Beamwidth (Seconds)	Relative Gain	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
T0810S12	8	-10°	10.04	92.94	9 x 50	58	- 1.1	- 3.5	- 6.1	- 9.5	- 8.9	- 7.1	-10.3	-15.1	-18.3	-20.2
T1010S12	10	-10°	10.04	89.10	8 x 50	85	- 1.2	- 4.0	- 6.9	-11.0	-10.3	- 7.8	-10.5	-16.3	-20.4	-22.3
T0800N12	8	0°	11.15	93.48	11 x 25	63	- 4.3	- 6.8	- 6.5	- 5.9	- 3.8	- 7.7	-11.6	-14.8	-18.9	-21.3
T1000N12	10	0°	11.15	86.96	8 x 27	85	- 3.3	- 4.8	- 8.3	-12.7	-14.7	- 7.8	-13.3	-17.6	-22.7	-25.6
T0810N12	8	10°	12.0	89.51	9 x 18	78	- 4.8	- 5.6	- 7.0	- 5.0	- 5.8	- 9.2	-12.2	-16.8	-18.8	-21.1
T1010N12	10	10°	12.0	80.70	8 x 18	99	- 4.2	- 8.9	-11.2	- 9.3	- 9.9	-10.0	-14.9	-19.4	-21.9	-23.1
T0820N12	8	20°	12.0	87.65	9 x 16	89	- 5.3	- 6.8	- 8.2	- 7.7	- 8.8	- 9.4	-13.5	-17.0	-18.4	-19.6
T1020N12	10	20°	12.0	76.45	8 x 16	112	- 6.7	- 9.4	- 9.9	-12.5	- 8.9	-11.6	-15.8	-20.1	-22.0	-21.8
T0830N12	8	30°	12.0	84.32	9 x 15	87	- 4.7	- 8.3	- 9.4	- 9.6	- 7.3	-10.1	-14.4	-17.4	-19.4	-19.8
T1030N12	10	30°	12.0	69.83	9 x 14	122	- 6.6	- 8.4	-13.0	-16.0	- 7.1	-12.4	-16.0	-20.8	-23.9	-22.5
T0840N12	8	40°	12.0	82.66	10 x 13	90	- 5.4	- 9.6	-10.7	-11.4	- 9.8	-11.7	-14.9	-17.0	-19.1	-19.6
T1040N12	10	40°	12.0	64.25	9 x 13	118	- 6.9	-10.1	-13.9	-15.9	-10.9	-12.6	-17.1	-20.9	-23.8	-22.5
T0850N12	8	50°	12.0	81.29	11 x 13	91	- 6.9	-10.2	-11.7	-10.4	-10.5	-12.8	-15.1	-17.2	-18.8	-19.6
T1050N12	10	50°	12.0	60.83	9 x 11	114	- 8.6	-12.0	-13.1	-15.8	-11.2	-14.1	-18.5	-22.4	-22.8	-22.0
T0860N12	8	60°	12.0	80.18	11 x 12	93	- 8.3	-11.1	-11.9	-11.1	-10.3	-13.2	-16.1	-16.1	-19.5	-19.4
T1060N12	10	60°	12.0	58.74	9 x 11	117	-11.0	-14.0	-14.6	-15.9	-11.3	-16.3	-20.3	-23.6	-23.6	-21.7
T0870N12	8	70°	12.0	79.23	10 x 11	92	- 8.9	-11.6	-11.6	-11.3	-10.6	-13.3	-16.6	-17.0	-19.8	-19.4
T1070N12	10	70°	12.0	57.02	9 x 11	117	-13.1	-15.5	-16.8	-16.0	-11.5	-18.0	-22.1	-24.4	-23.5	-21.6
T0880N12	8	80°	12.0	79.18	11 x 11	92	- 9.1	-11.9	-11.7	-12.3	-10.9	-13.2	-16.8	-17.2	-19.7	-19.4
T1060N12	10	80°	12.0	56.53	10 x 11	117	-15.0	-17.3	-18.1	-16.2	-11.7	-19.6	-23.0	-24.8	-23.5	-21.7
T0890N12	8	90°	12.0	79.07	11 x 11	95	- 9.3	-11.4	-12.1	-13.0	-11.4	-13.3	-16.7	-16.9	-20.0	-19.3
T1090N12	10	90°	12.0	56.00	10 x 10	118	-15.9	-16.7	-20.3	-16.1	-12.1	-20.0	-23.8	-26.6	-23.7	-21.7

TABLE III

COMPARISON OF PERFORMANCE WITH 8 AND 10 STATIONS: 17' FIELD OF VIEW

ZONES: (1) 19.9"-35.7" (2) 35.7"-67.3" (3) 67.3"-130.6" (4) 130.6"-257.5" (5) 257.5"-510.0"

Model	N	Declination	Tracking Time (Hours)	Holes (%)	Half-Power Beamwidth (Seconds)	Relative Gain	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
S0810S12	8	-10°	10.04	95.21	9 x 50	63	-3.1	-5.2	-8.5	-9.9	-7.3	-9.1	-13.4	-17.0	-19.5	-21.1
S1010S12	10	-10°	10.04	91.90	8 x 50	84	-3.5	-4.9	-10.0	-12.7	-10.3	-9.1	-14.7	-19.1	-22.8	-24.8
S0800N12	8	0°	11.15	96.08	11 x 25	66	-6.6	-7.2	-9.5	-2.8	-2.7	-10.8	-13.7	-18.8	-20.5	-22.5
S1000N12	10	0°	11.15	91.84	8 x 27	88	-4.5	-8.4	-12.3	-10.3	-3.6	-12.1	-16.6	-21.5	-24.9	-24.9
S0810N12	8	10°	12.0	93.46	9 x 18	83	-4.9	-6.7	-9.6	-6.4	-6.3	-11.5	-15.4	-18.5	-20.3	-21.4
S1010N12	10	10°	12.0	87.79	8 x 18	107	-7.2	-8.2	-11.6	-12.0	-6.2	-13.5	-17.4	-21.5	-23.6	-23.8
S0820N12	8	20°	12.0	92.59	9 x 16	92	-5.7	-7.2	-8.1	-10.0	-6.9	-12.5	-15.8	-17.7	-19.3	-20.8
S1020N12	10	20°	12.0	85.63	8 x 16	117	-7.9	-8.4	-9.8	-11.0	-6.8	-14.7	-18.0	-22.1	-22.8	-22.9
S0830N12	8	30°	12.0	90.67	9 x 15	91	-6.9	-8.5	-8.8	-9.7	-8.5	-13.2	-15.9	-18.3	-19.2	-20.7
S1030N12	10	30°	12.0	81.28	9 x 14	120	-6.7	-9.0	-14.1	-10.4	-9.0	-13.8	-18.5	-22.4	-22.8	-23.5
S0840N12	8	40°	12.0	89.97	10 x 13	93	-9.7	-10.7	-11.2	-9.7	-9.2	-14.2	-16.6	-18.5	-18.6	-20.7
S1040N12	10	40°	12.0	79.15	9 x 13	117	-9.1	-12.9	-16.5	-10.3	-10.2	-15.7	-19.8	-23.6	-22.0	-23.0
S0850N12	8	50°	12.0	89.18	11 x 13	94	-10.1	-11.4	-10.5	-9.9	-10.2	-14.8	-17.2	-18.6	-18.3	-21.0
S1050N12	10	50°	12.0	77.68	9 x 11	120	-12.1	-12.7	-15.8	-10.4	-10.6	-17.8	-21.6	-24.7	-21.2	-23.3
S0860N12	8	60°	12.0	88.72	11 x 12	95	-11.0	-12.8	-10.9	-9.7	-9.9	-15.3	-17.6	-18.8	-17.9	-21.0
S1060N12	10	60°	12.0	76.65	9 x 11	121	-13.8	-14.6	-16.6	-10.2	-10.1	-19.7	-23.2	-25.4	-20.6	-23.4
S0870N12	8	70°	12.0	88.39	10 x 11	96	-11.8	-12.3	-11.2	-9.6	-9.3	-15.9	-17.7	-19.2	-17.8	-21.1
S1070N12	10	70°	12.0	75.83	9 x 11	124	-15.7	-16.5	-16.3	-10.0	-9.7	-21.0	-24.2	-25.4	-20.4	-23.4
S0880N12	8	80°	12.0	88.06	11 x 11	98	-11.9	-11.9	-11.1	-9.8	-12.2	-16.2	-17.5	-19.6	-17.7	-21.2
S1080N12	10	80°	12.0	75.29	10 x 11	125	-18.1	-19.3	-18.3	-10.3	-13.4	-22.7	-25.0	-26.0	-20.2	-23.5
S0890N12	8	90°	12.0	88.08	11 x 11	99	-12.2	-12.7	-12.4	-10.0	-13.0	-16.8	-17.2	-19.7	-17.6	-21.3
S1090N12	10	90°	12.0	75.14	10 x 10	125	-18.7	-19.8	-21.0	-10.4	-13.5	-24.2	-25.8	-26.8	-20.3	-23.8

TABLE IV

PERFORMANCE WITH 10 STATIONS AND HORIZON-TO-HORIZON TRACKING

FIELD OF VIEW 10' ZONES: (1) 11.7"-21.0" (2) 21.0"-39.6" (3) 39.6"-76.8" (4) 76.8"-151.5" (5) 151.5"-300.0"

Model	N	Declination	Tracking Time (Hours)	Holes (%)	Half-Power Beamwidth (Seconds)	Relative Gain	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
Z1010SHH	10	-10°	10.92	87.03	9 x 38	92	-1.9	-5.6	-7.8	-11.4	-10.6	-8.4	-11.3	-16.8	-20.8	-22.8
Z1000NHH	10	0°	12.0	85.46	10 x 22	93	-3.3	-5.0	-8.3	-12.6	-14.7	-8.2	-13.5	-18.0	-23.0	-26.0
Z1010NHH	10	10°	13.08	78.53	10 x 19	106	-4.3	-8.7	-11.5	-9.4	-10.2	-10.2	-15.0	-19.8	-22.1	-23.3
Z1020NHH	10	20°	14.24	72.32	10 x 15	116	-6.5	-9.9	-10.4	-13.2	-9.4	-12.3	-16.3	-20.6	-22.1	-22.0
Z1030NHH	10	30°	15.65	61.66	10 x 12	138	-7.4	-10.0	-13.2	-17.1	-9.4	-14.0	-18.3	-22.6	-24.9	-23.1
Z1040NHH	10	40°	17.58	52.40	10 x 11	143	-8.9	-9.7	-14.5	-17.3	-14.6	-15.9	-20.4	-24.2	-25.8	-24.2
Z1050NHH	10	50°	21.52	40.25	10 x 10	151	-10.7	-14.4	-16.6	-17.5	-14.2	-17.6	-22.3	-25.8	-24.9	-24.5
Z1060NHH	10	60°	24.0	34.59	10 x 10	164	-15.8	-16.0	-17.4	-9.9	-14.2	-20.8	-23.4	-25.9	-24.8	-24.0
Z1070NHH	10	70°	24.0	32.25	10 x 10	165	-18.1	-18.3	-9.6	-11.0	-14.0	-22.7	-24.7	-23.8	-24.8	-23.8
Z1080NHH	10	80°	24.0	32.34	10 x 10	168	-17.5	-8.7	-14.3	-17.1	-13.4	-21.5	-21.1	-26.1	-24.7	-23.6
Z1090NHH	10	90°	24.0	55.00	10 x 10	165	-15.7	-16.9	-20.1	-16.1	-11.8	-19.8	-23.8	-26.4	-23.6	-21.6

TABLE V

Configurations with 4 antennas

Configuration	Location of Antennas				BASELINES AVAILABLE
	85-1	85-2	85-3	42'	
1	0	1800	2700	1200	600, 900, 1200, 1500, 1800, 2700
2	0	2100	2400	1900	200, 300, 500, 1900, 2100, 2400
3	0	1200	1500	800	300, 400, 700, 800, 1200, 1500
4	0	1800	1900	800	100, 800, 1000, 1100, 1800, 1900

Configurations with 5 antennas

Configuration	Location of Antennas					BASELINES AVAILABLE
	85-1	85-2	85-3	42'	Add. 42'	
1	0	2400	2700	1900	1800	100, 300, 500, 600, 800, 900, 1800, 1900, 2400, 2700
2	0	1900	2100	1500	1200	200, 300, 400, 600, 700, 900, 1200, 1500, 1900, 2100
---	---	---	---	---	---	---
1	0	1800	2400	100	200	100, 200, 600, 1600, 1700, 1800, 2200, 2300, 2400
2	0	1200	2100	100	200	100, 200, 900, 1000, 1100, 1200, 1900, 2000, 2100
3	0	1500	2700	100	200	100, 200, 1200, 1300, 1400, 1500, 2500, 2600, 2700
4	0	1500	1900	2000	1200	100, 300, 400, 500, 700, 800, 1200, 1500, 1900, 2000

NOTE: All locations refer to distances southwest from 85-1 on the existing baseline.

[redacted]ABL[redacted]

PERFORMANCE OF THE ARRAY WITH 4 AND 5 ANTENNAS

Field of View 5'

ZONES: (1) 5.8" - 10.5" (2) 10.5" - 19.8" (3) 19.8" - 38.4" (4) 38.4" - 75.7" (5) 75.7" - 150.0"

Model Number	Number of Antennas	No. of Configurations	Declination	Tracking Time (Hours)	Holes (%)	Half-Power Beamwidth (Seconds)	Relative Gain	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
4M310S12	4	3	-10°	10.04	89.85	9 x 23	38	-0.4	-1.1	- 4.3	- 7.1	- 9.3	-4.3	- 7.1	-10.6	-15.7	-18.3
5M210S12	5	2	-10°	10.04	90.76	9 x 38	38	-0.4	-1.2	- 4.1	- 5.8	- 8.7	-4.7	- 7.0	-11.2	-13.8	-17.7
5M410S12	5	4	-10°	10.04	87.71	9 x 43	43	-0.4	-1.1	- 4.2	- 8.4	-10.6	-4.7	- 7.5	-11.0	-16.3	-18.5
4M300N12	4	3	0°	11.15	89.76	9 x 23	46	-1.4	-3.3	- 4.8	- 8.5	- 4.9	-4.9	- 8.0	-14.0	-16.8	-17.8
5M200NL2	5	2	0°	11.15	90.28	9 x 25	45	-1.4	-3.1	- 5.2	- 7.1	- 5.0	-5.0	- 8.2	-11.7	-15.8	-17.6
5M400N12	5	4	0°	11.15	86.47	9 x 25	59	-1.2	-3.6	- 4.9	- 9.7	- 9.1	-4.7	- 7.9	-13.7	-17.6	-19.5
4M310N12	4	3	10°	12.0	84.99	9 x 17	56	-2.5	-4.1	- 6.7	- 7.8	- 3.6	-6.1	-10.1	-14.4	-16.7	-18.1
5M210N12	5	2	10°	12.0	85.76	9 x 19	55	-2.3	-3.9	- 4.2	- 8.2	- 6.9	-5.9	- 9.2	-12.4	-16.0	-17.7
5M410N12	5	4	10°	12.0	79.37	9 x 19	68	-2.2	-4.3	- 7.3	-10.9	- 5.7	-5.9	- 9.7	-14.4	-18.1	-19.3
4M320N12	4	3	20°	12.0	80.90	9 x 16	58	-2.7	-5.8	- 6.4	- 8.3	- 6.4	-6.7	-10.3	-13.5	-16.4	-17.9
5M220N12	5	2	20°	12.0	81.90	9 x 18	63	-2.3	-4.0	- 5.8	- 8.4	- 8.1	-6.3	- 8.7	-13.3	-15.7	-18.1
5M420N12	5	4	20°	12.0	71.18	8 x 18	83	-2.4	-5.7	- 8.0	-10.7	- 7.5	-6.4	-11.1	-15.9	-18.8	-20.4
4M330N12	4	3	30°	12.0	75.61	9 x 15	66	-2.6	-5.1	- 6.8	-10.9	- 7.3	-7.6	-10.0	-14.3	-17.4	-18.4
5M230N12	5	2	30°	12.0	77.18	9 x 18	66	-2.3	-4.3	- 7.2	- 8.9	- 8.9	-7.0	- 8.7	-14.3	-16.2	-18.2
5M430N12	5	4	30°	12.0	61.51	8 x 17	96	-2.5	-5.9	- 9.9	-13.9	- 9.0	-7.4	-11.9	-16.8	-20.2	-20.9
4M340N12	4	3	40°	12.0	72.27	9 x 13	59	-2.9	-6.4	- 8.5	-10.9	- 9.3	-8.4	-10.9	-14.5	-16.6	-17.9
5M240N12	5	2	40°	12.0	73.84	9 x 14	64	-2.7	-5.3	- 6.4	-10.0	-10.1	-7.5	- 9.0	-14.4	-16.3	-18.4
5M440N12	5	4	40°	12.0	53,69	8 x 14	86	-2.9	-7.6	-12.0	-13.7	-11.0	-8.5	-12.9	-18.3	-20.3	-20.3
4M350N12	4	3	50°	12.0	69.75	9 x 12	59	-3.5	-7.4	- 8.2	-10.2	- 9.5	-8.9	-11.3	-14.6	-16.4	-18.1
5M250N12	5	2	50°	12.0	71.27	9 x 13	64	-3.1	-5.1	- 7.3	-10.4	-10.2	-7.4	- 9.2	-14.6	-16.7	-18.3
5M450N12	5	4	50°	12.0	48.26	8 x 13	85	-3.4	-9.4	-13.2	-13.1	-10.9	-9.2	-13.7	-19.6	-19.8	-20.2
4M360N12	4	3	60°	12.0	68.51	9 x 11	62	-4.0	-7.9	- 8.5	- 9.3	- 9.2	-9.3	-11.4	-14.4	-16.1	-18.1
5M260N12	5	2	60°	12.0	69.60	9 x 13	67	-3.2	-4.9	- 8.0	-10.0	-10.3	-7.2	- 9.5	-15.1	-16.2	-18.5
5M460N12	5	4	60°	12.0	44.55	8 x 12	88	-3.7	-9.8	-14.6	-12.8	-10.5	-9.5	-15.0	-19.7	-20.1	-20.1
4M370N12	4	3	70°	12.0	66.65	9 x 11	60	-4.2	-8.0	- 8.2	- 9.2	- 9.1	-9.3	-11.1	-14.5	-15.7	-18.6
5M270N12	5	2	70°	12.0	67.94	9 x 13	63	-3.2	-4.7	- 7.6	-10.3	-10.7	-6.8	- 9.8	-15.2	-16.2	-18.7
5M470N12	5	4	70°	12.0	41.35	8 x 12	85	-3.9	-10.1	-14.6	-11.8	-11.3	-9.7	-15.1	-20.0	-19.6	-20.4
4M380N12	4	3	80°	12.0	66.08	10 x 11	61	-4.3	-8.2	- 8.3	- 8.8	- 9.7	-9.1	-11.0	-14.7	-15.6	-18.7
5M280N12	5	2	80°	12.0	67.32	9 x 12	66	-3.2	-4.8	- 7.6	- 9.9	-10.7	-6.8	-10.1	-15.4	-16.0	-18.6
5M480N12	5	4	80°	12.0	40.35	8 x 12	90	-4.0	-10.0	-13.7	-10.5	-11.5	-9.7	-15.3	-19.8	-19.2	-20.8
4M390N12	4	3	90°	12.0	66.32	10 x 11	68	-4.4	-8.3	- 8.3	- 9.7	- 9.9	-9.2	-11.0	-14.8	-15.5	-18.7
5M290N12	5	2	90°	12.0	67.60	9 x 11	70	-3.2	-4.8	- 7.7	- 9.9	-10.4	-6.8	-10.2	-15.1	-16.0	-18.7
5M490N12	5	4	90°	12.0	40.59	9 x 11	97	-4.0	-9.6	-14.0	-11.7	-12.2	-9.7	-14.8	-19.9	-19.0	-21.1

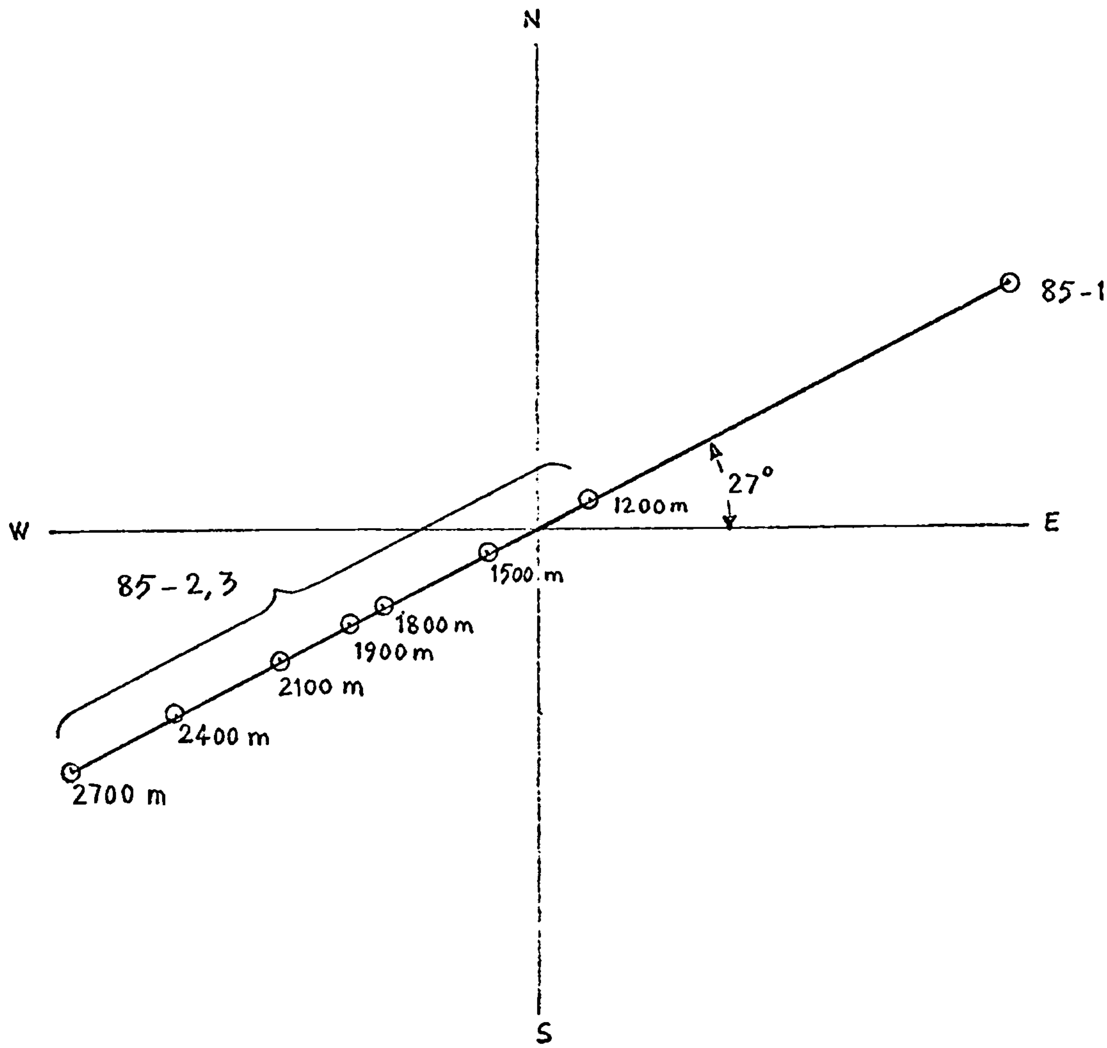
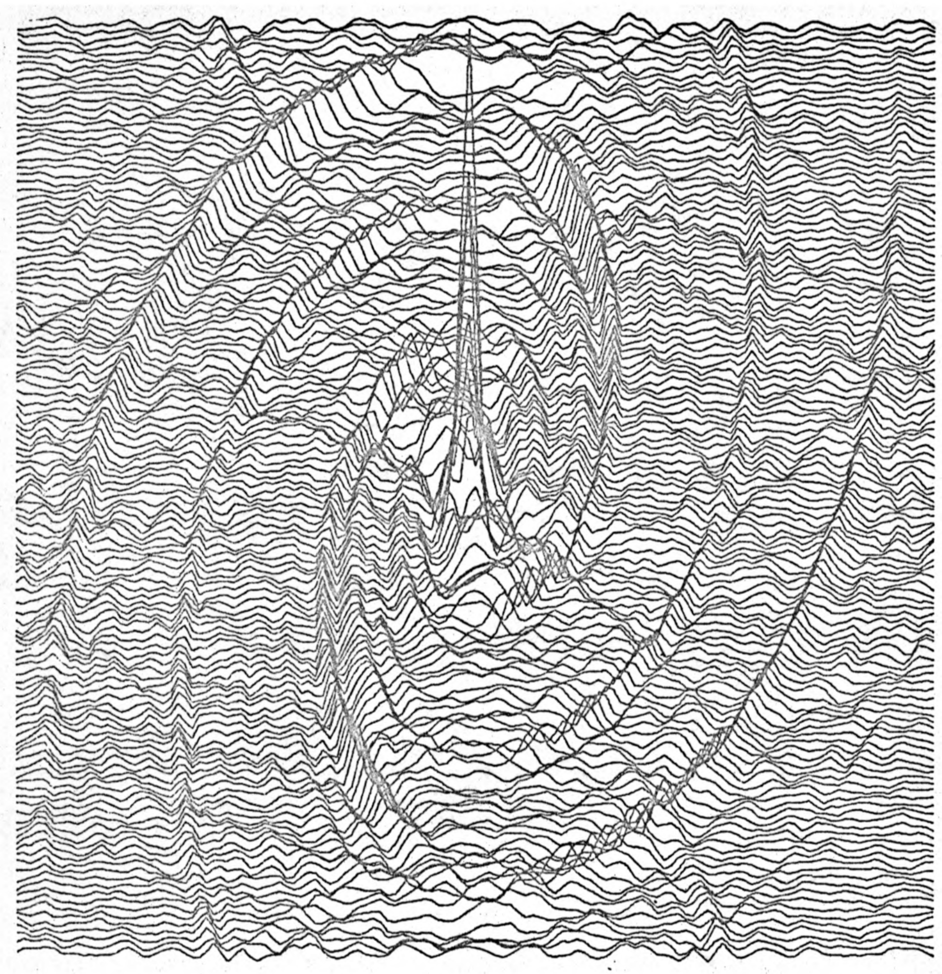
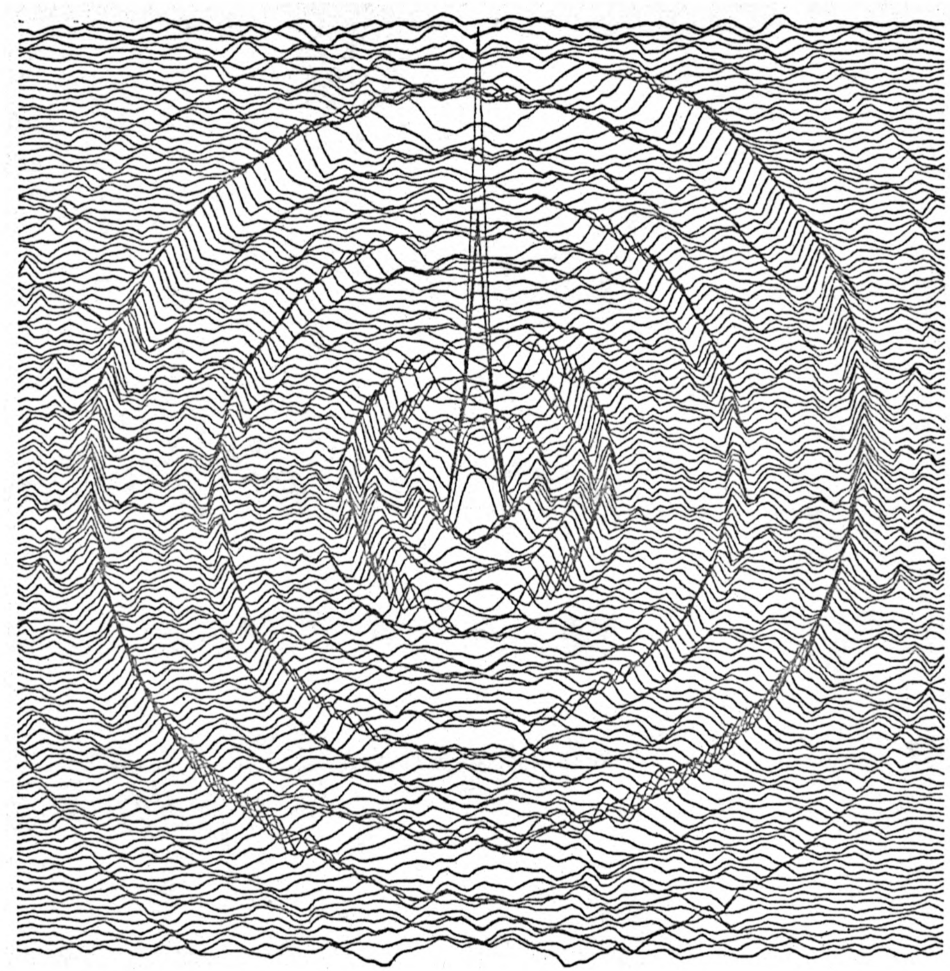


Figure 1. Layout of the Array



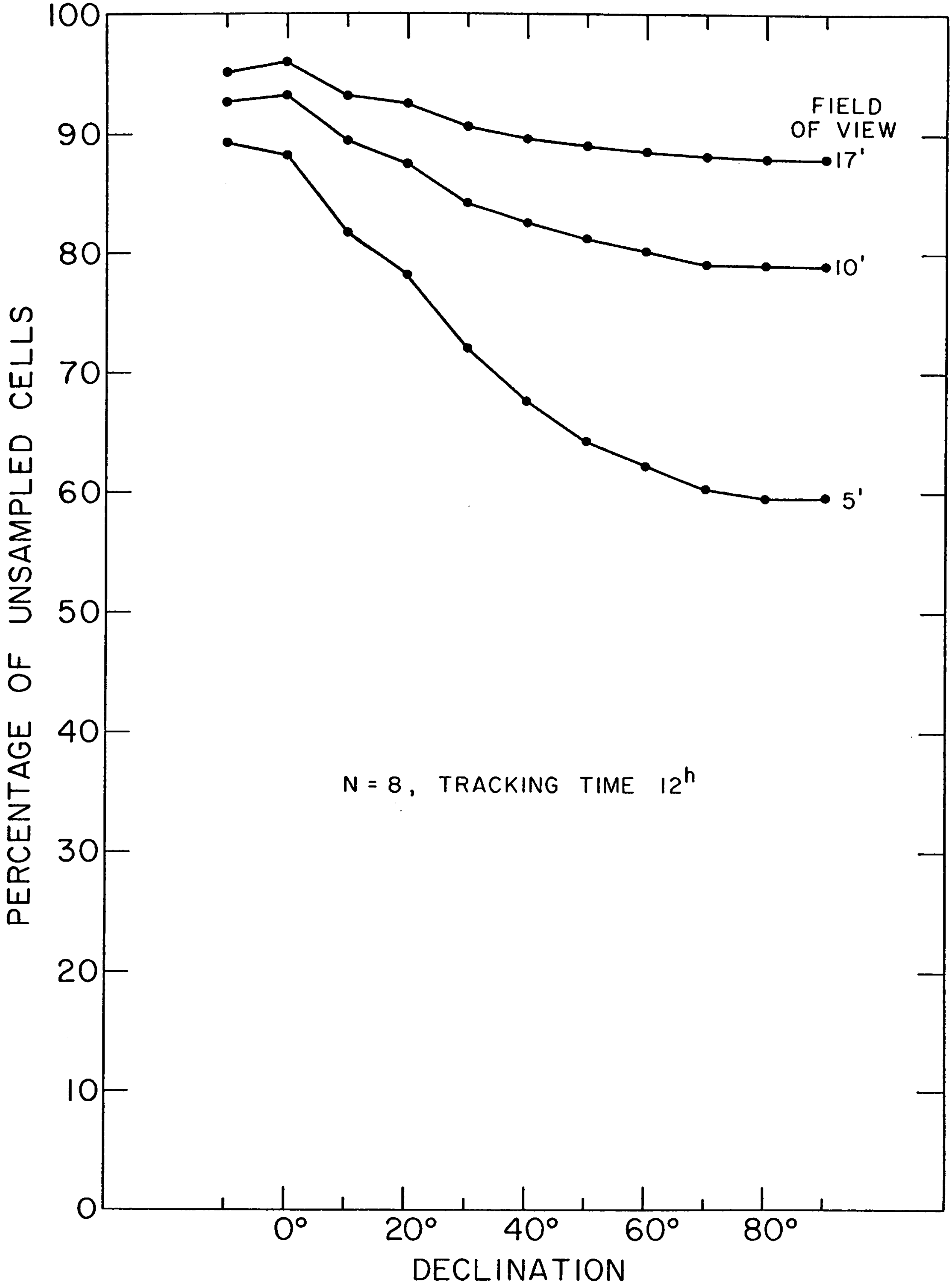
δ = 40°



δ = 80°

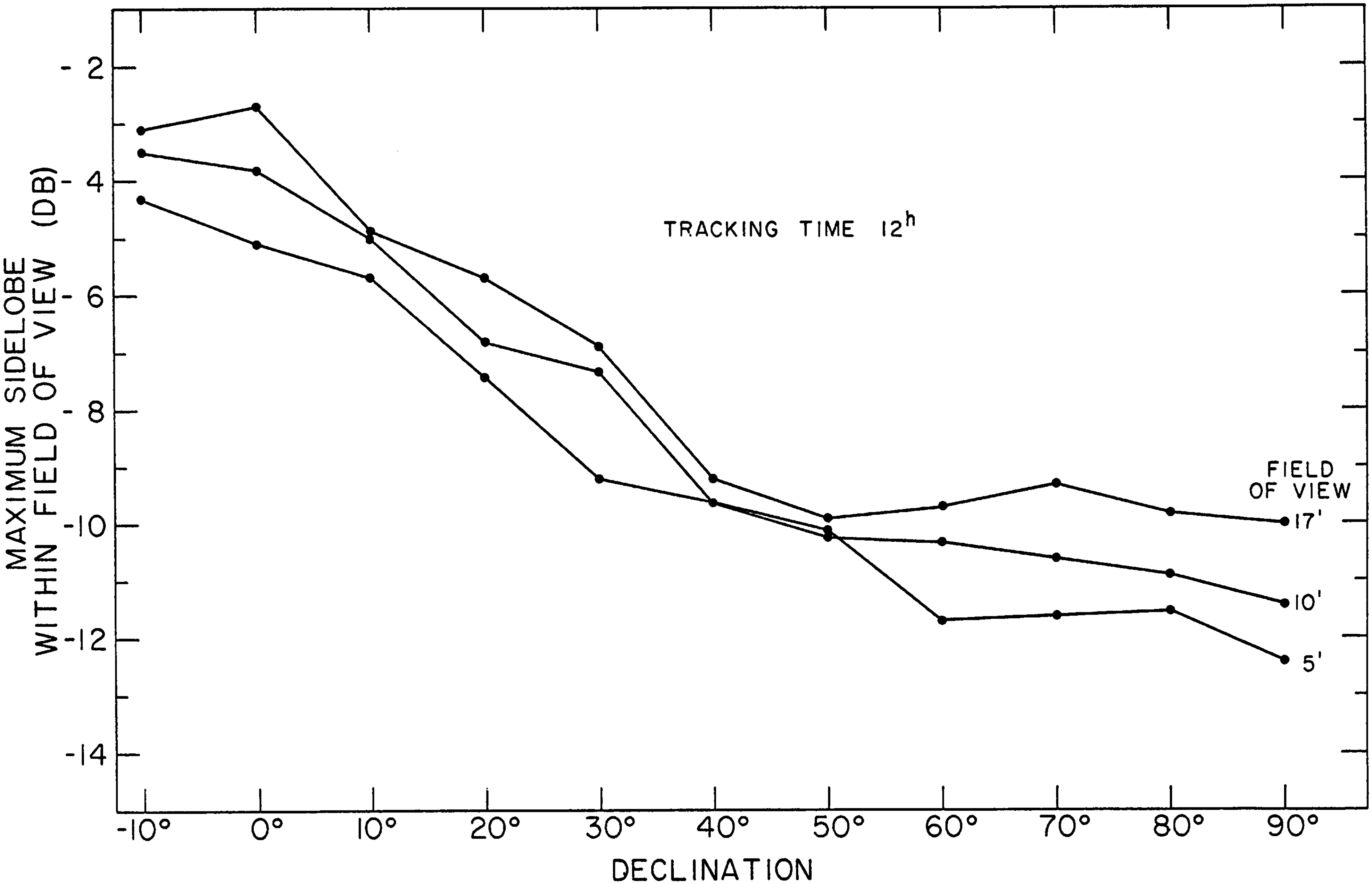
Number of stations = 8, Field of view = 10'

Figure 2



100
90
80
70
60
50
40
30
20
10
0
PERCENTAGE OF UNSAMPLED CELLS
0°
20°
40°
60°
80°
DECLINATION
FIELD OF VIEW
17'
10'
5'
N = 8, TRACKING TIME 12h

Figure 3



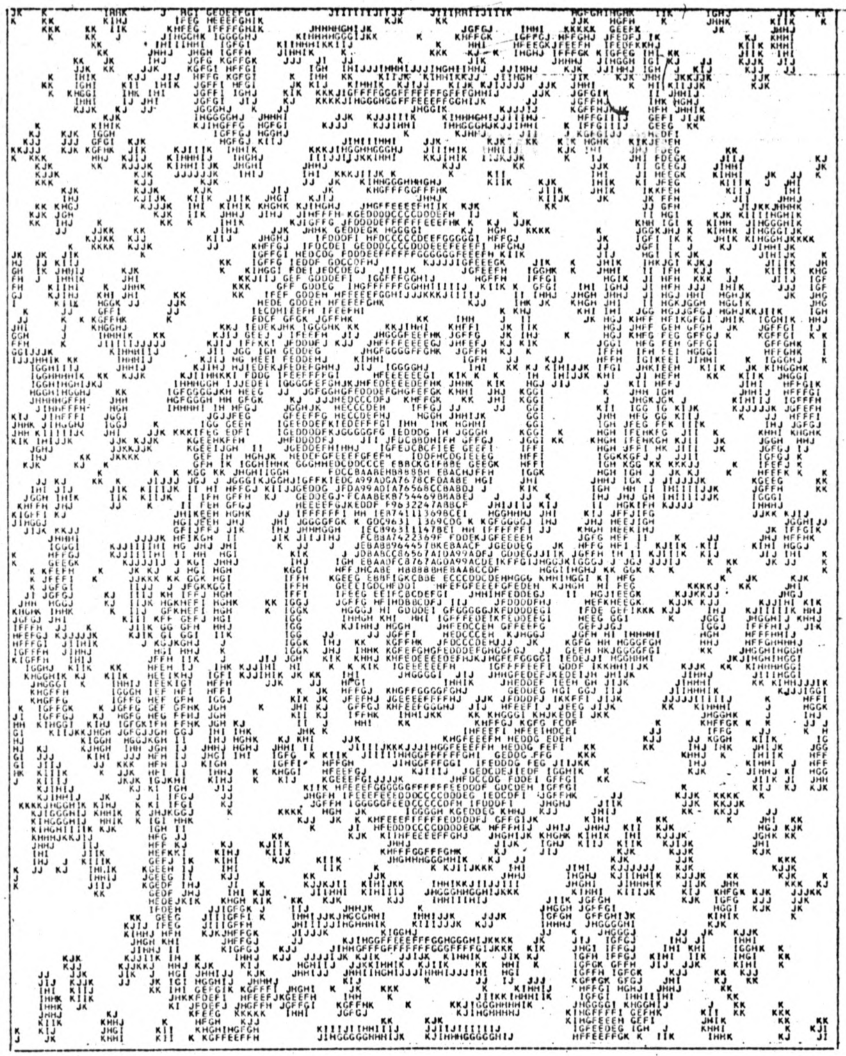
MAXIMUM SIDELOBE
WITHIN FIELD OF VIEW (DB)
- 2
- 4
- 6
- 8
-10
-12
-14
TRACKING TIME 12^h
FIELD
OF VIEW
17'
10'
5'
-10°
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
DECLINATION

Figure 4

~~MODEL NUMBER N0840N12 DECLINATION 40.00 DEGREES TRACKING TIME 12.00 HOURS~~

THE BEAM IS PLOTTED BELOW IN TERMS OF THE POWER LEVELS FOR THE ENTIRE FIELD OF VIEW. ALL BLANKS INDICATE POWER LEVELS LESS THAN -20DB. ALL INTEGERS INDICATE POWER LEVEL(DB BELOW THE MAIN BEAM PLUS OR MINUS 0.5DB).LETTER CODING IS GIVEN BELOW

CODE	A	B	C	D	E	F	G	H	I	J	K
POWER(DB)	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20

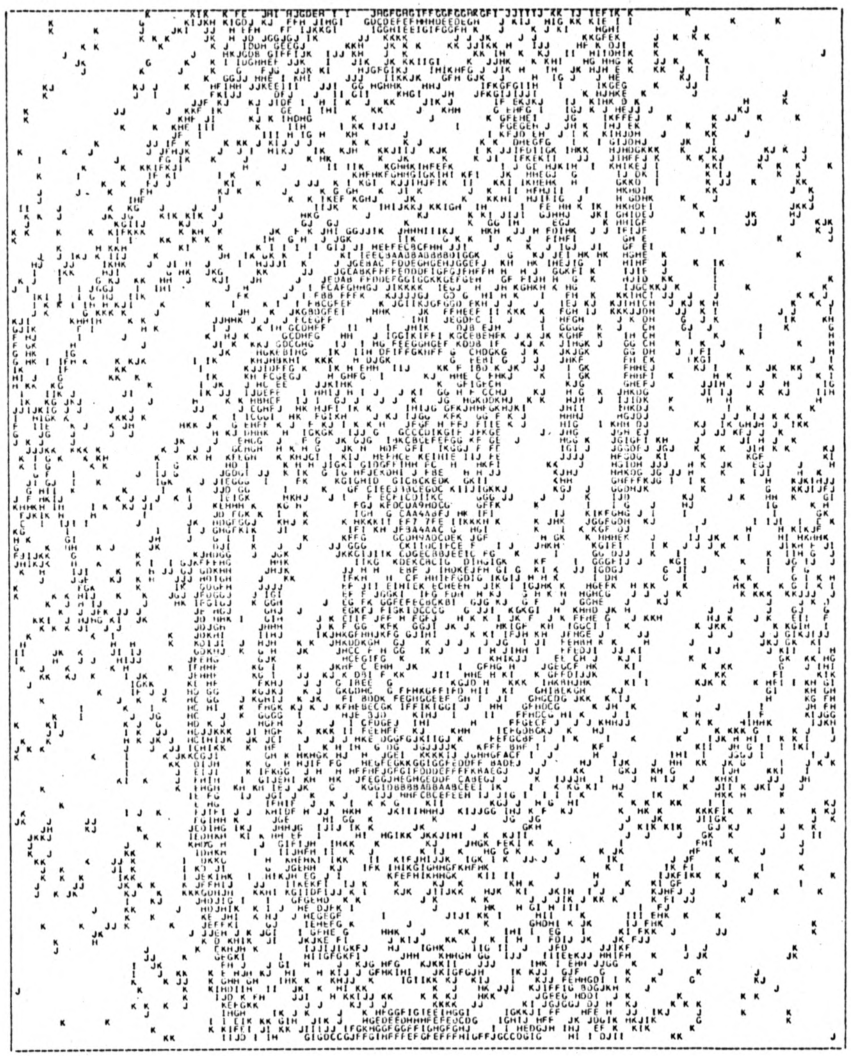


Field of view 5'

MODEL NUMBER S0840N17 DECLINATION 40.00 DEGREES TRACKING TIME 12.00 HOURS

THE BEAM IS PLOTTED BELOW IN TERMS OF THE POWER LEVELS FOR THE ENTIRE FIELD OF VIEW. ALL BLANKS INDICATE POWER LEVELS LESS THAN -20DB. ALL INTEGERS INDICATE POWER LEVEL(DB BELOW THE MAIN BEAM PLUS OR MINUS 0.5DB).LETTER CODING IS GIVEN BELOW

CODE	A	B	C	D	E	F	G	H	I	J	K
POWER(DB)	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20



Field of view 17'

Number of Stations = 8, Declination 40°, Tracking Time = 12 hours

Figure 5

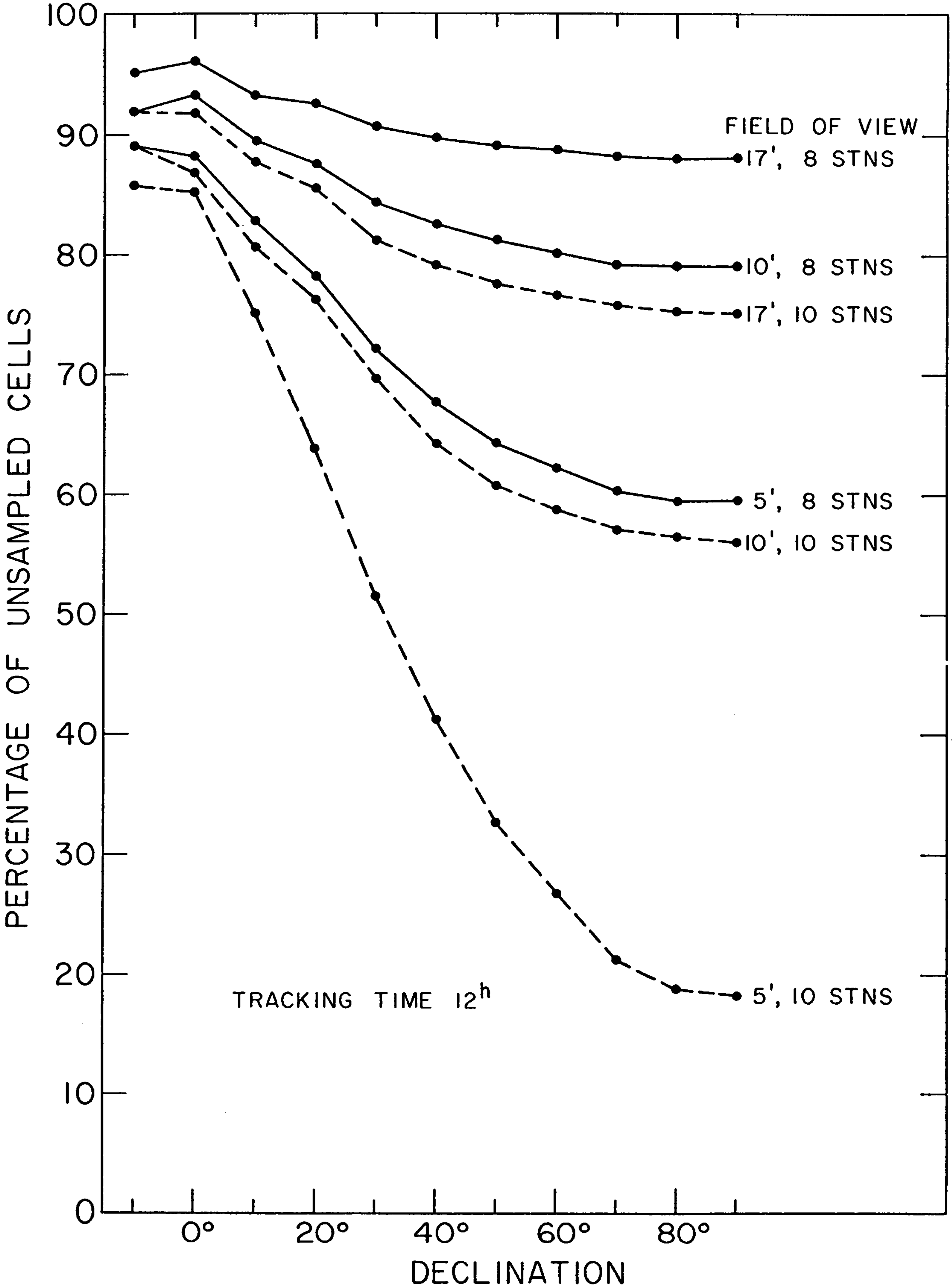

100
90
80
70
60
50
40
30
20
10
0
PERCENTAGE OF UNSAMPLED CELLS
FIELD OF VIEW
17', 8 STNS
10', 8 STNS
17', 10 STNS
5', 8 STNS
10', 10 STNS
5', 10 STNS
TRACKING TIME 12h
0°
20°
40°
60°
80°
DECLINATION

Figure 6

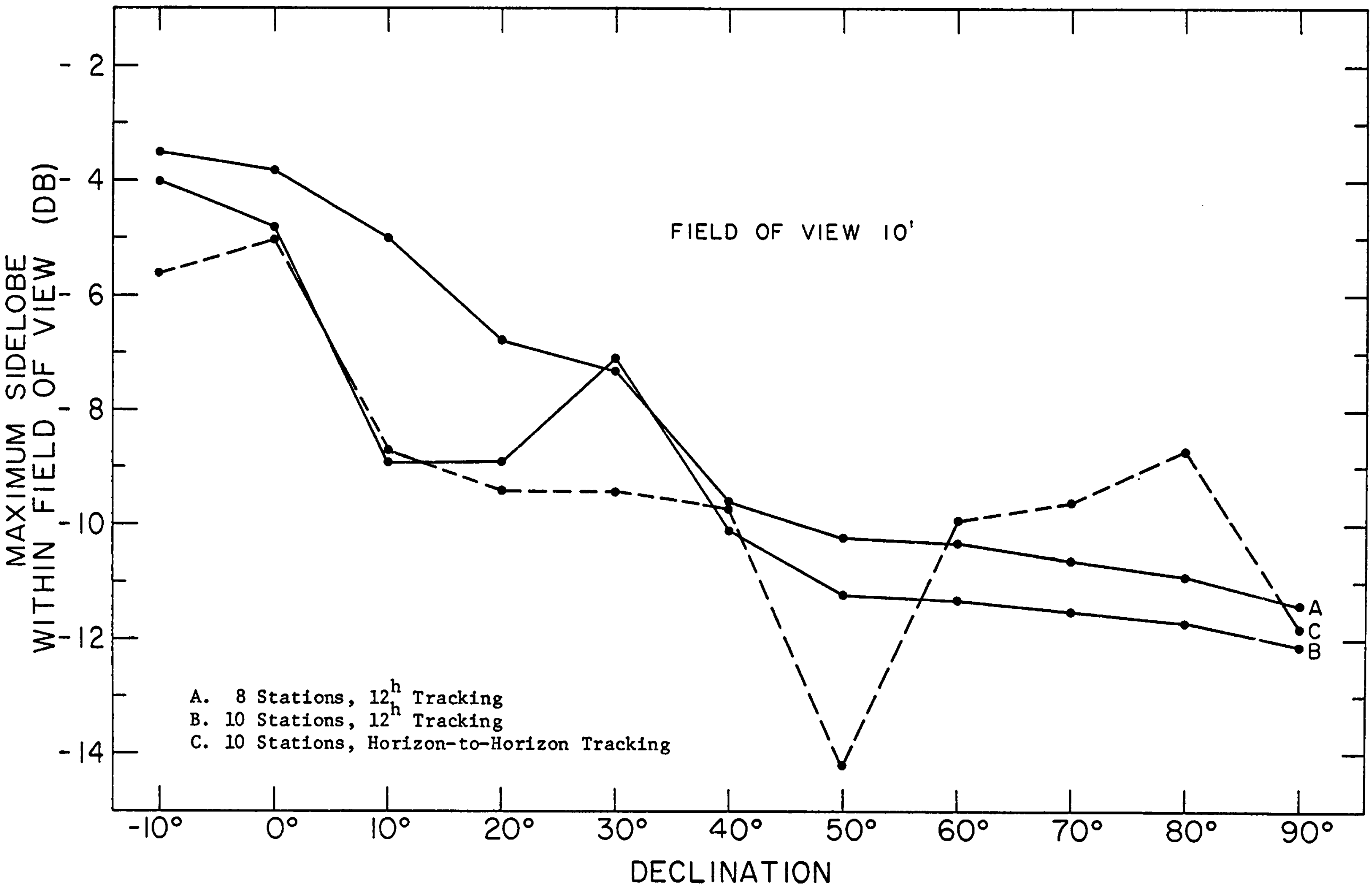

MAXIMUM SIDELOBE WITHIN FIELD OF VIEW (DB)
-2
4
6
8
-10
-12
-14
FIELD OF VIEW 10'
A
C
B
A. 8 Stations, 12h Tracking
B. 10 Stations, 12h Tracking
C. 10 Stations, Horizon-to-Horizon Tracking
-10°
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
DECLINATION

Figure 7

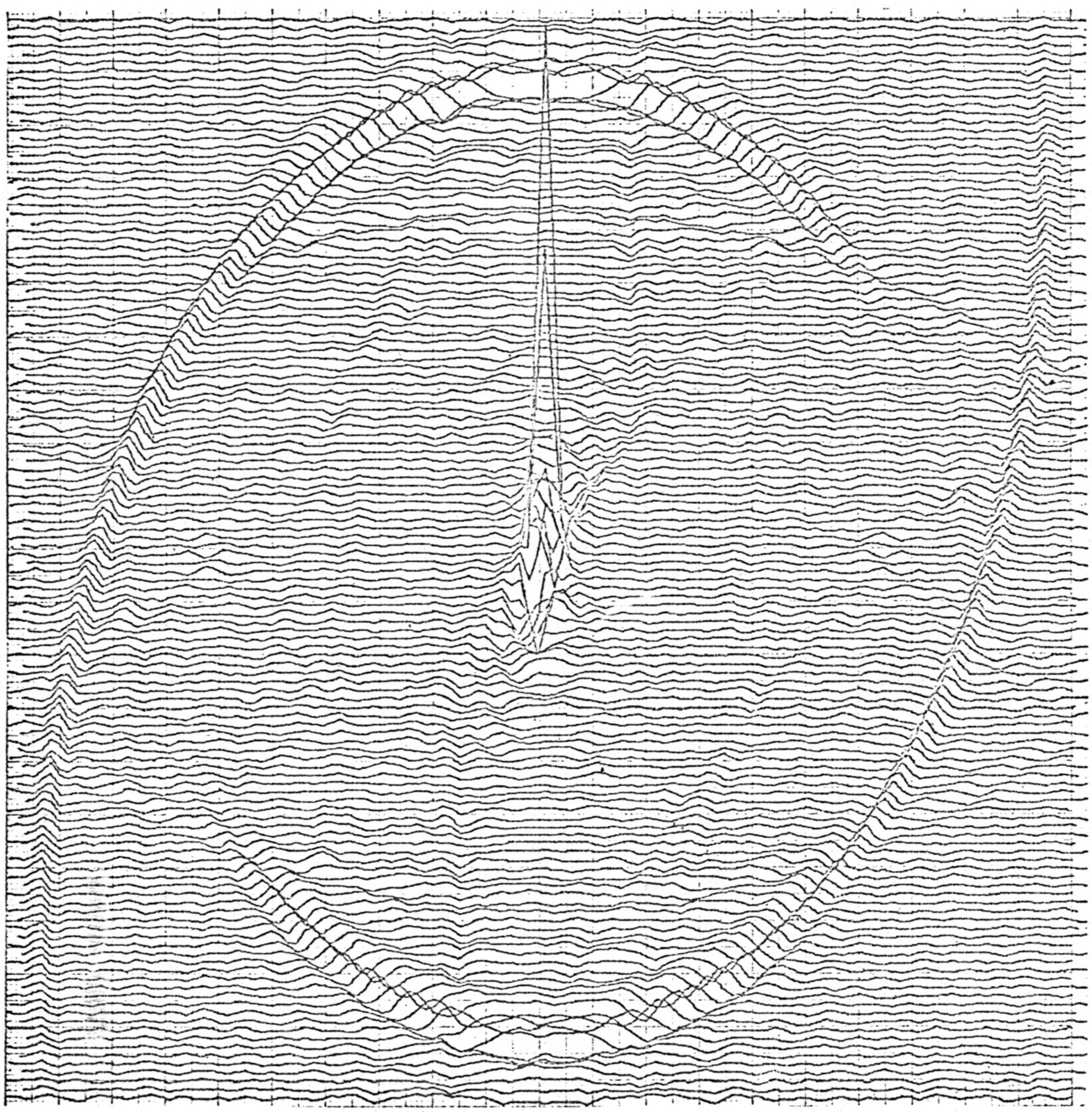


Figure 8. Beam Pattern with 10 Stations.
$\delta = 40°$, Field of View 10',
Tracking Horizon-to-Horizon

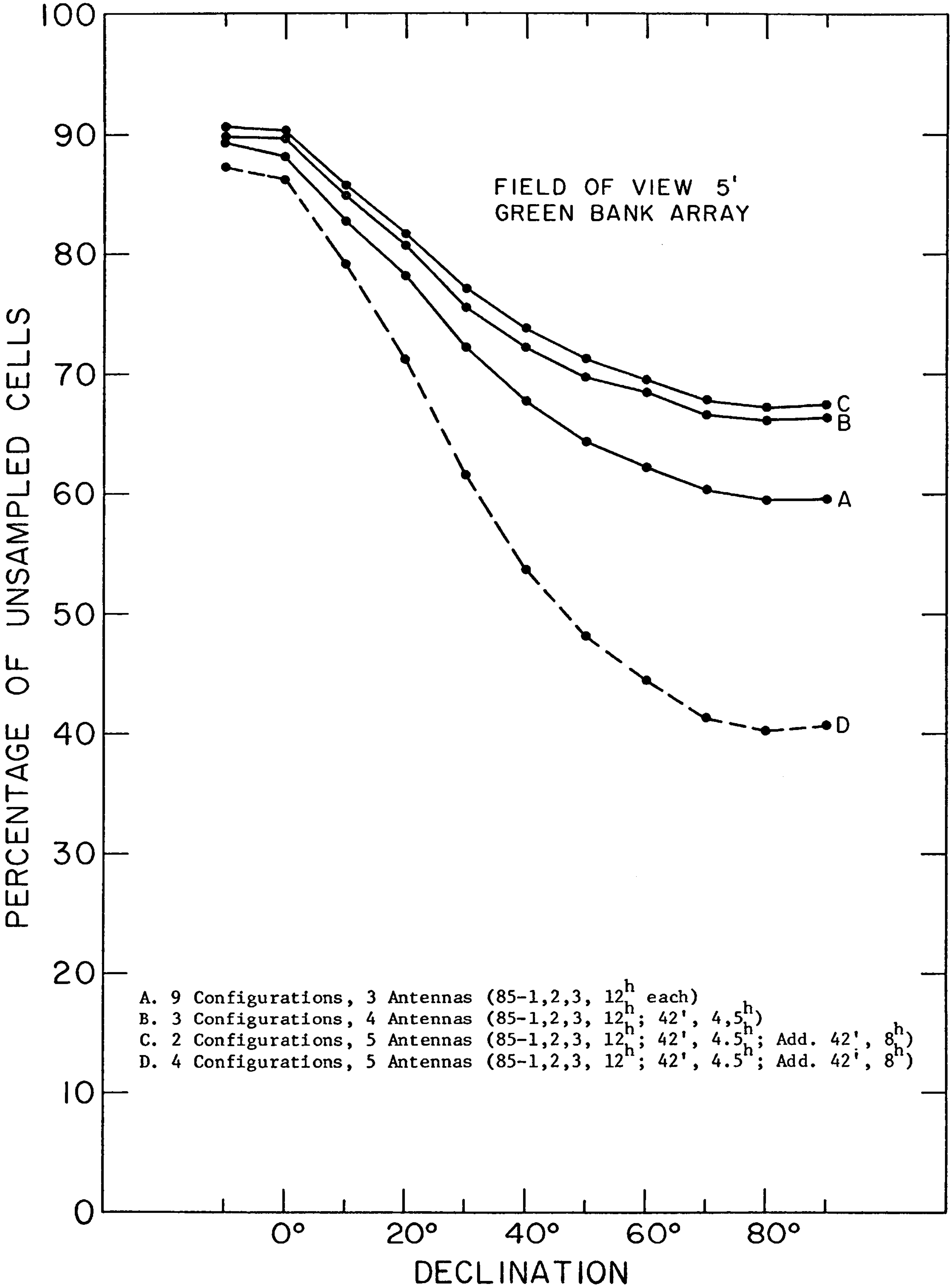

FIELD OF VIEW 5'
GREEN BANK ARRAY
PERCENTAGE OF UNSAMPLED CELLS
DECLINATION
0° 20° 40° 60° 80°
0 10 20 30 40 50 60 70 80 90 100
A
B
C
D
A. 9 Configurations, 3 Antennas (85-1,2,3, 12^h each)
B. 3 Configurations, 4 Antennas (85-1,2,3, 12^h; 42', $4,5^h$)
C. 2 Configurations, 5 Antennas (85-1,2,3, 12^h; 42', 4.5^h; Add. 42', 8^h)
D. 4 Configurations, 5 Antennas (85-1,2,3, 12^h; 42', 4.5^h; Add. 42', 8^h)

Figure 9

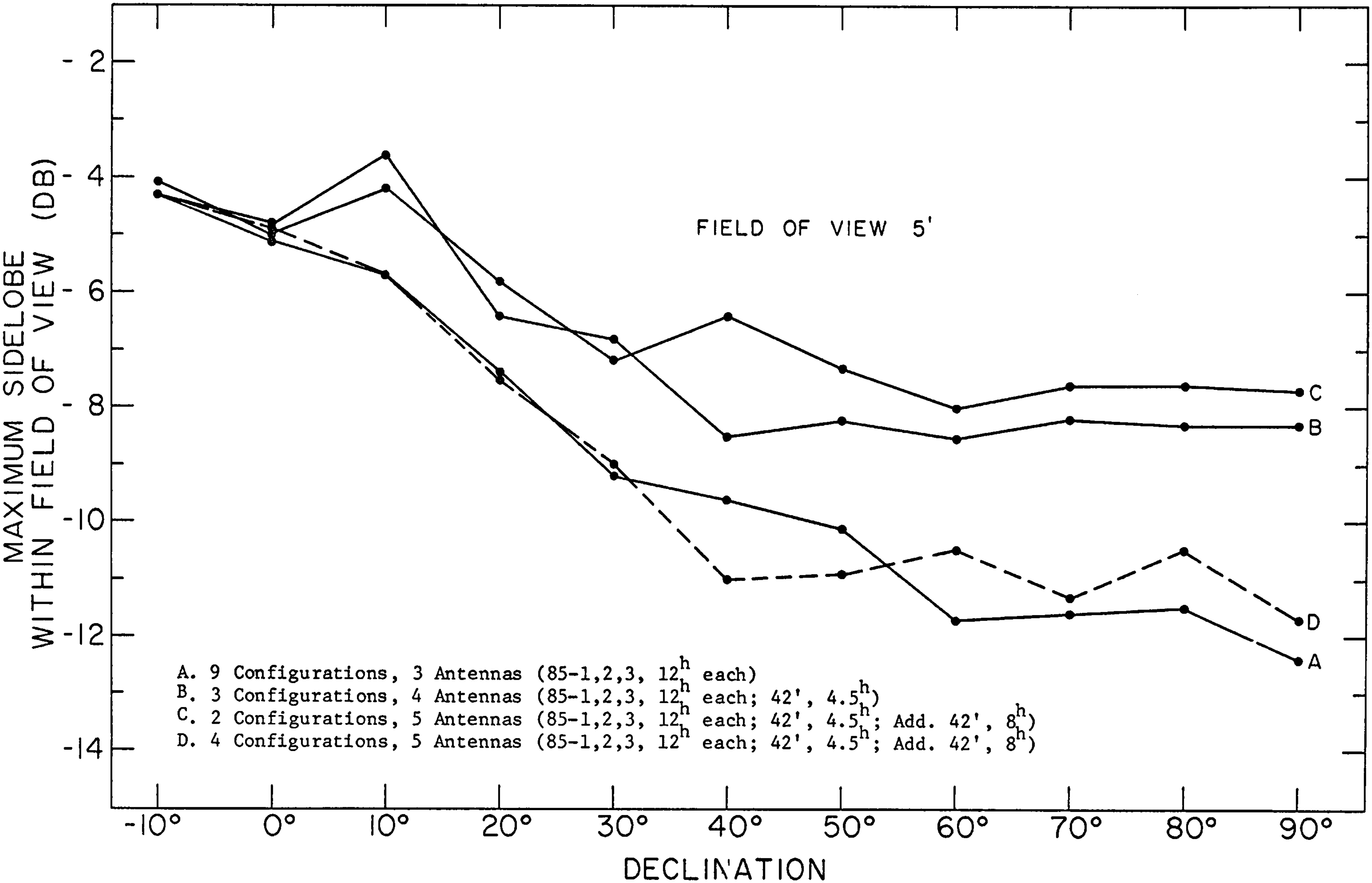
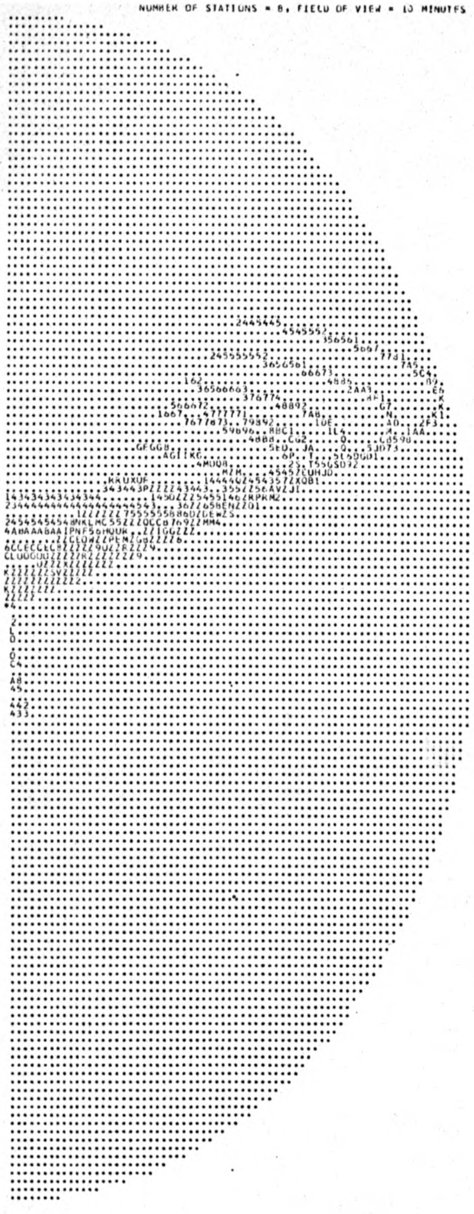

FIELD OF VIEW 5'
MAXIMUM SIDELOBE WITHIN FIELD OF VIEW (DB)
- 2
- 4
- 6
- 8
-10
-12
-14
-10°
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
DECLINATION
C
B
D
A
A. 9 Configurations, 3 Antennas (85-1,2,3, 12h each)
B. 3 Configurations, 4 Antennas (85-1,2,3, 12h each; 42', 4.5h)
C. 2 Configurations, 5 Antennas (85-1,2,3, 12h each; 42', 4.5h; Add. 42', 8h)
D. 4 Configurations, 5 Antennas (85-1,2,3, 12h each; 42', 4.5h; Add. 42', 8h)

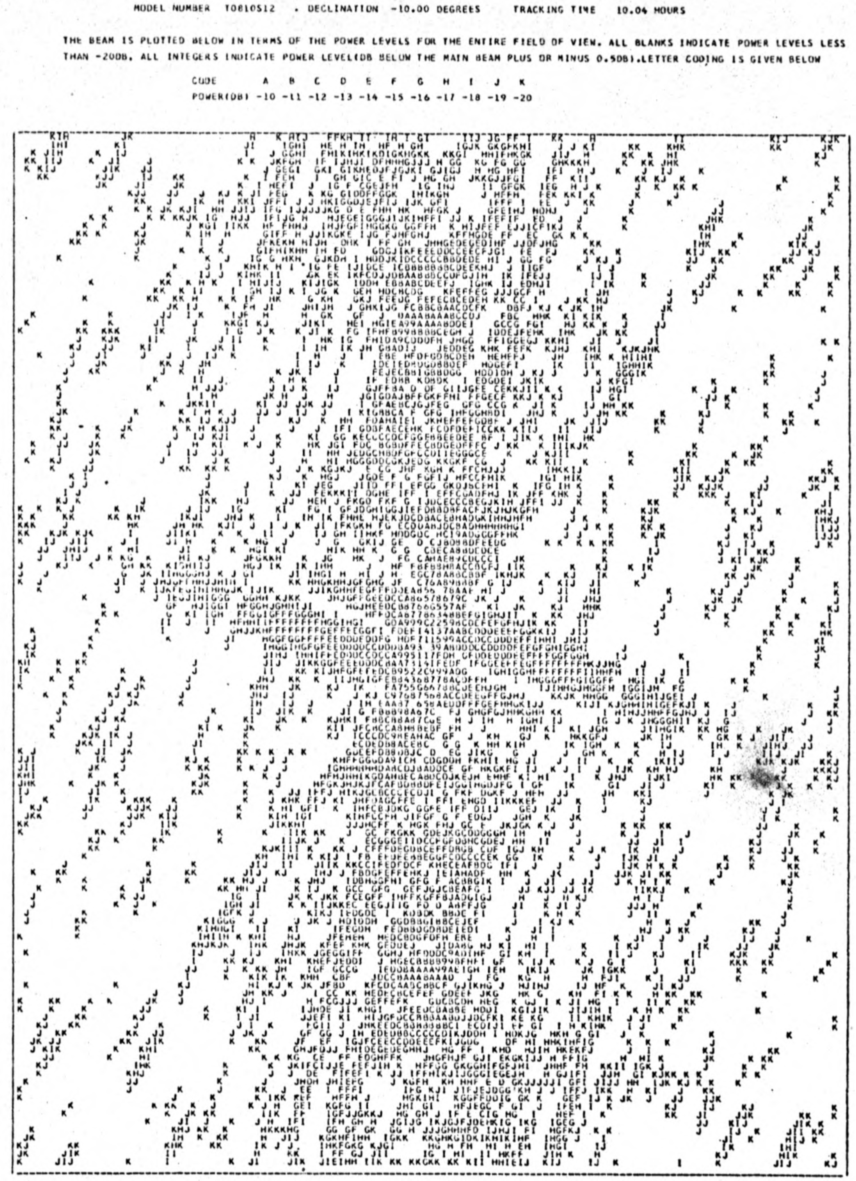
Figure 10

APPENDIX

The beam plots are obtained by sampling the beam by a 128 x 128 point grid. The power level at each point is computed in dbs to the nearest integer. Only sidelobe levels greater than -20dbs are printed out. The code used for power levels from -11 db to -20 db is shown on the plot. Each integer or letter represents the power level to within ±0.5 db. These diagrams can be used as coutour diagrams of the beam. Plots of the beam obtained on a Calcomp Plotter are also shown. These plots are particularly helpful at higher declinations where the sidelobes are low. Alongside these plots, there are computer printouts of the central part of the beam. The beam shape and orientation as well as the beamwidth can be roughly judged from these by considering the 3 db points.



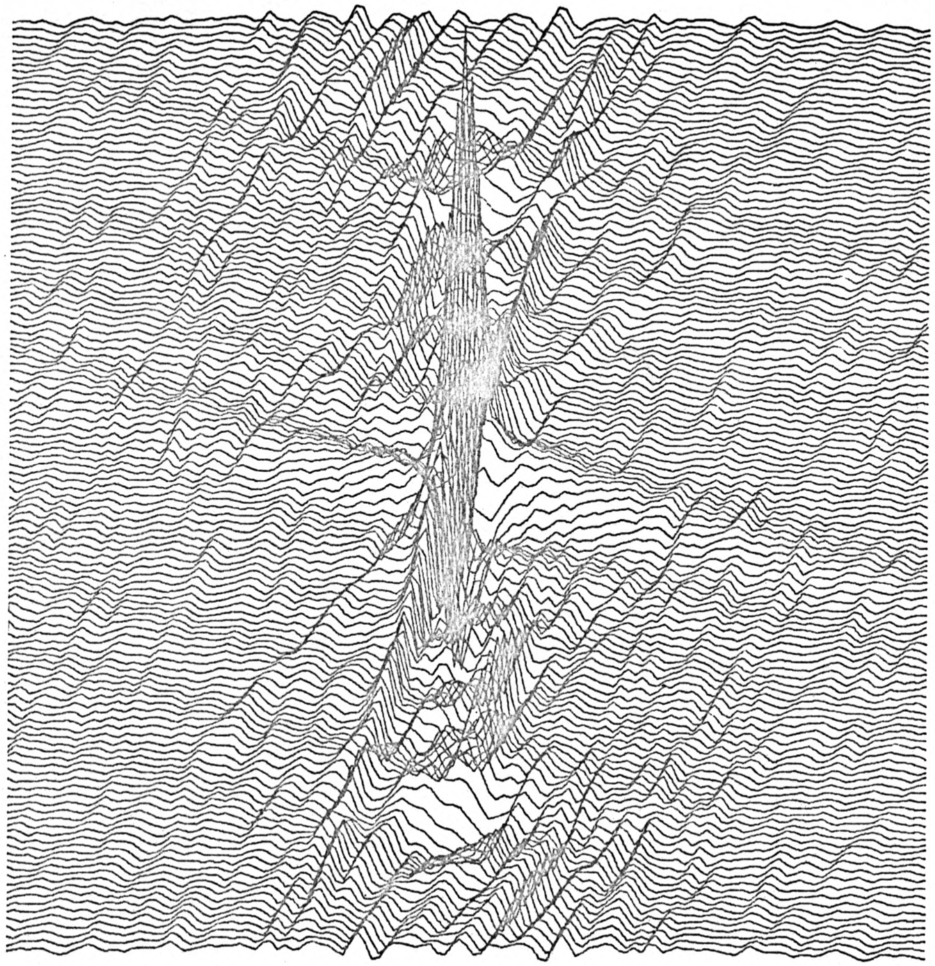
Transfer Function



Power Levels

Model Number T0810S12 $\delta = -10°$

Figure A1-(a)



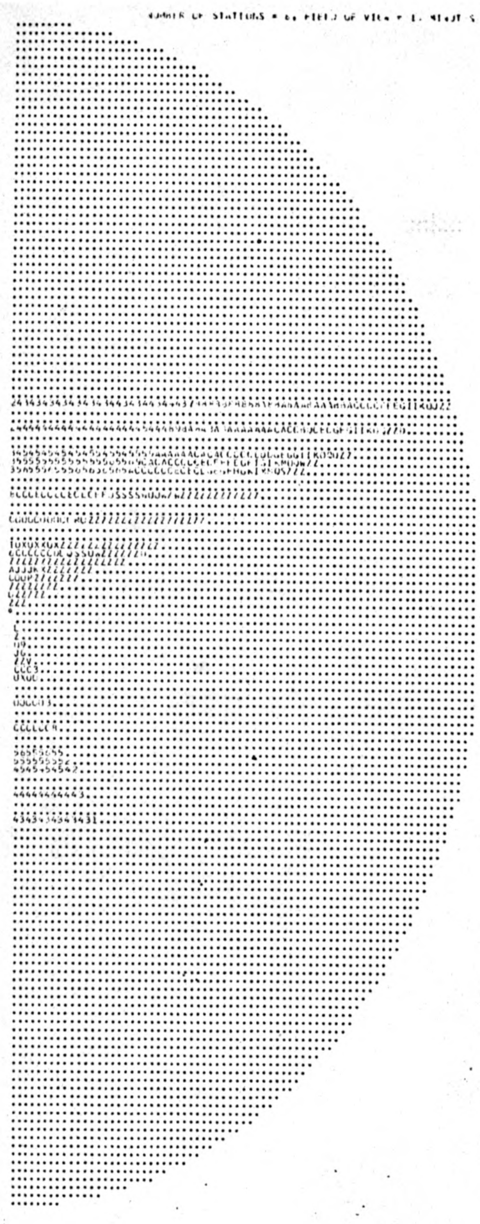
Beam Pattern (10' x 10')

9	8	8	8	8	8	8	*	8	4	2	2	3	5	6
9	9	9	9	9	9	*	*	5	2	2	2	3	5	7
*	*	*	*	*	*	*	7	3	1	1	2	4	6	8
*	*	*	*	*	*	9	4	1	1	1	3	5	7	9
*	*	*	*	*	*	5	2	1	0	2	4	6	8	9
*	*	*	*	*	7	3	1	0	1	2	5	8	9	9
*	*	*	*	8	4	2	0	0	1	4	7	9	*	*
*	*	*	9	6	3	1	0	1	3	6	9	*	*	*
*	*	9	7	4	1	0	0	2	4	8	*	*	*	*
9	9	8	5	2	1	0	1	3	7	*	*	*	*	*
9	8	6	4	2	0	1	2	5	*	*	*	*	*	*
9	7	5	3	1	1	1	4	9	*	*	*	*	*	*
8	6	4	2	1	1	3	7	*	*	*	*	*	*	*
7	5	3	2	2	2	5	*	*	9	9	9	9	9	9
6	5	3	2	2	4	8	*	8	8	8	8	8	8	9

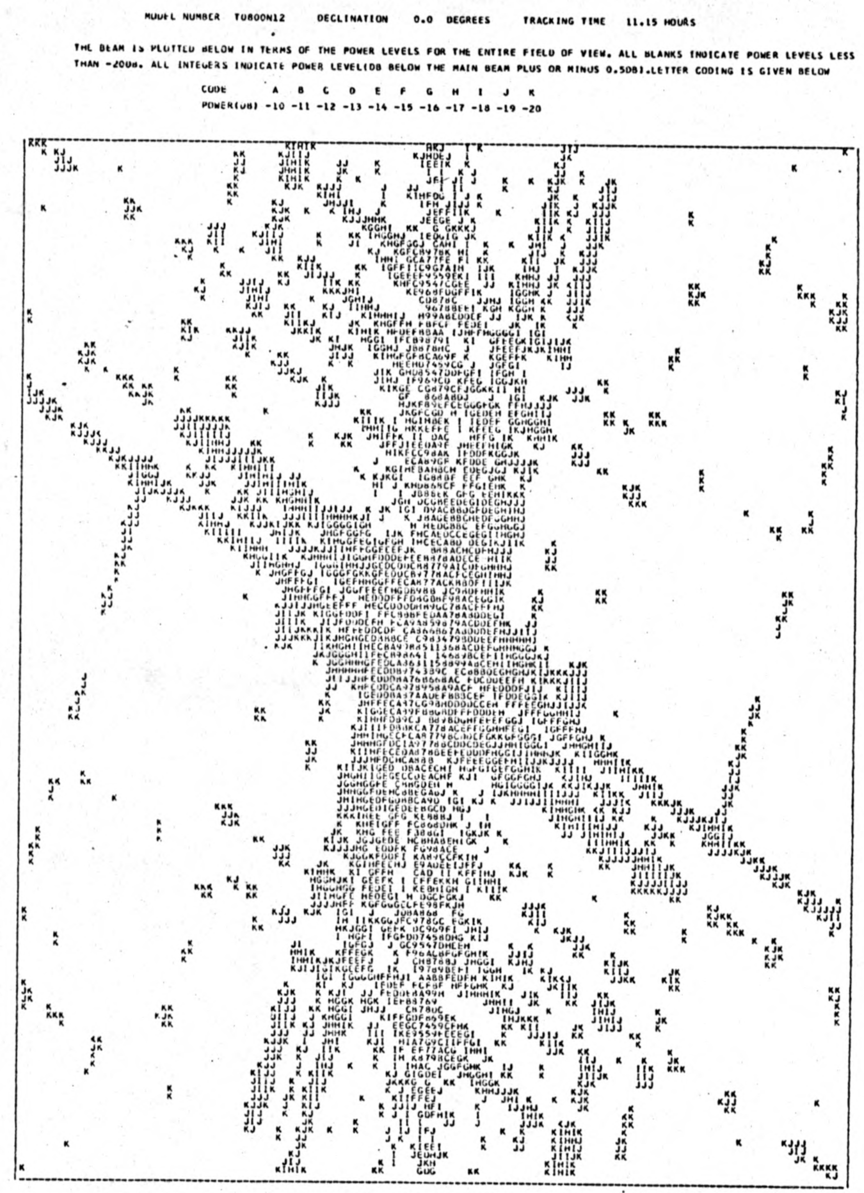
Central Portion of Beam (33" x 33")

Model Number T0810S12 $\delta = -10°$

Figure A1-(b)



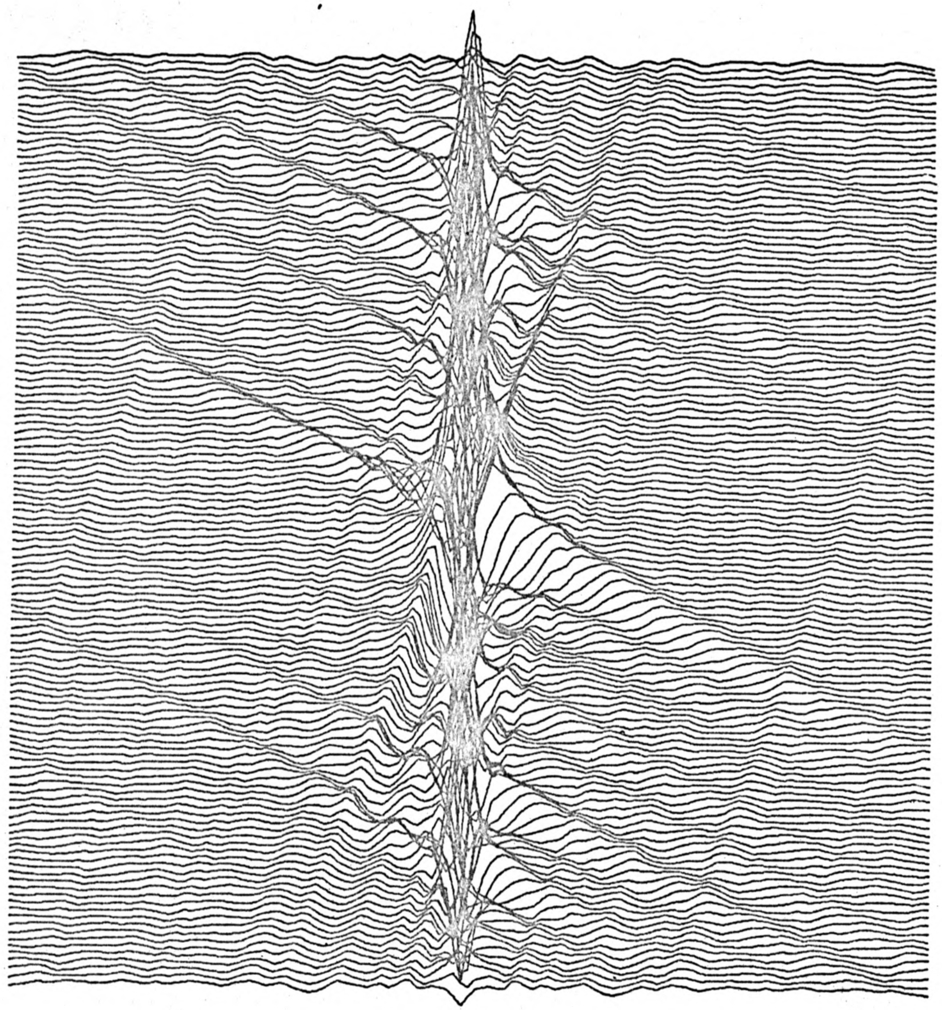
Transfer Function



Power Levels

Model Number T0800N12 $\delta = 0°$

Figure A2-(a)



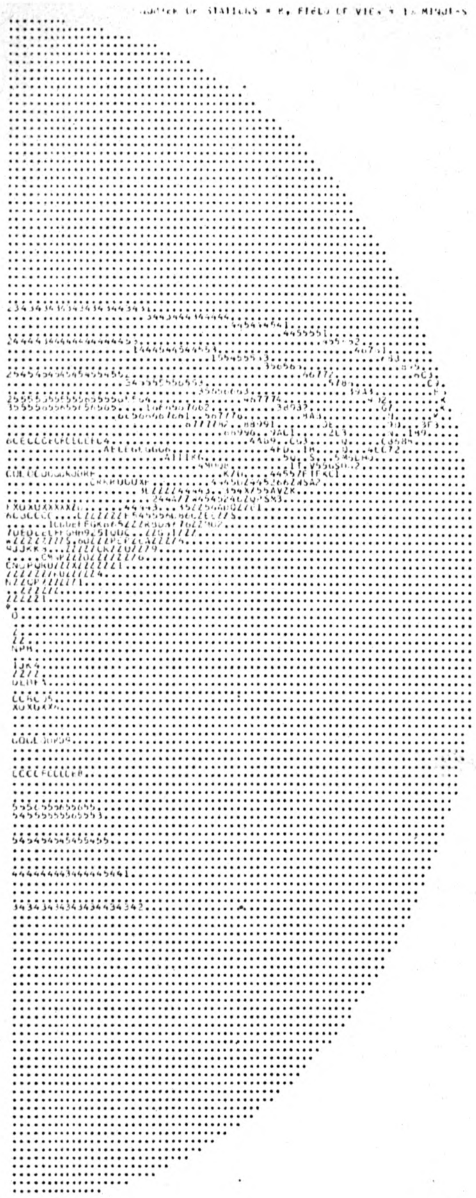
Beam Pattern (10' x 10')

*	9	9	9	8	6	5	5	6	*	9	7	7	8	9
*	*	9	8	7	6	5	6	*	*	6	6	6	7	9
*	*	*	9	7	6	7	*	*	5	4	5	6	7	8
*	*	*	*	*	9	*	8	4	3	3	4	5	7	8
*	*	*	*	*	*	6	3	2	2	2	3	5	6	7
9	8	8	8	7	5	3	1	1	1	2	3	5	6	7
7	7	6	6	4	3	1	0	0	1	2	3	5	6	7
7	6	5	4	3	1	0	0	0	1	3	4	5	6	7
7	6	5	3	2	1	0	0	1	3	4	6	6	7	7
7	6	5	3	2	1	1	1	3	5	7	8	8	8	9
7	6	5	3	2	2	2	3	6	*	*	*	*	*	*
8	7	5	4	3	3	4	8	*	9	*	*	*	*	*
8	7	6	5	4	5	*	*	7	6	7	9	*	*	*
9	7	6	6	6	*	*	6	5	6	7	8	9	*	*
9	8	7	7	9	*	6	5	5	6	8	9	9	9	*

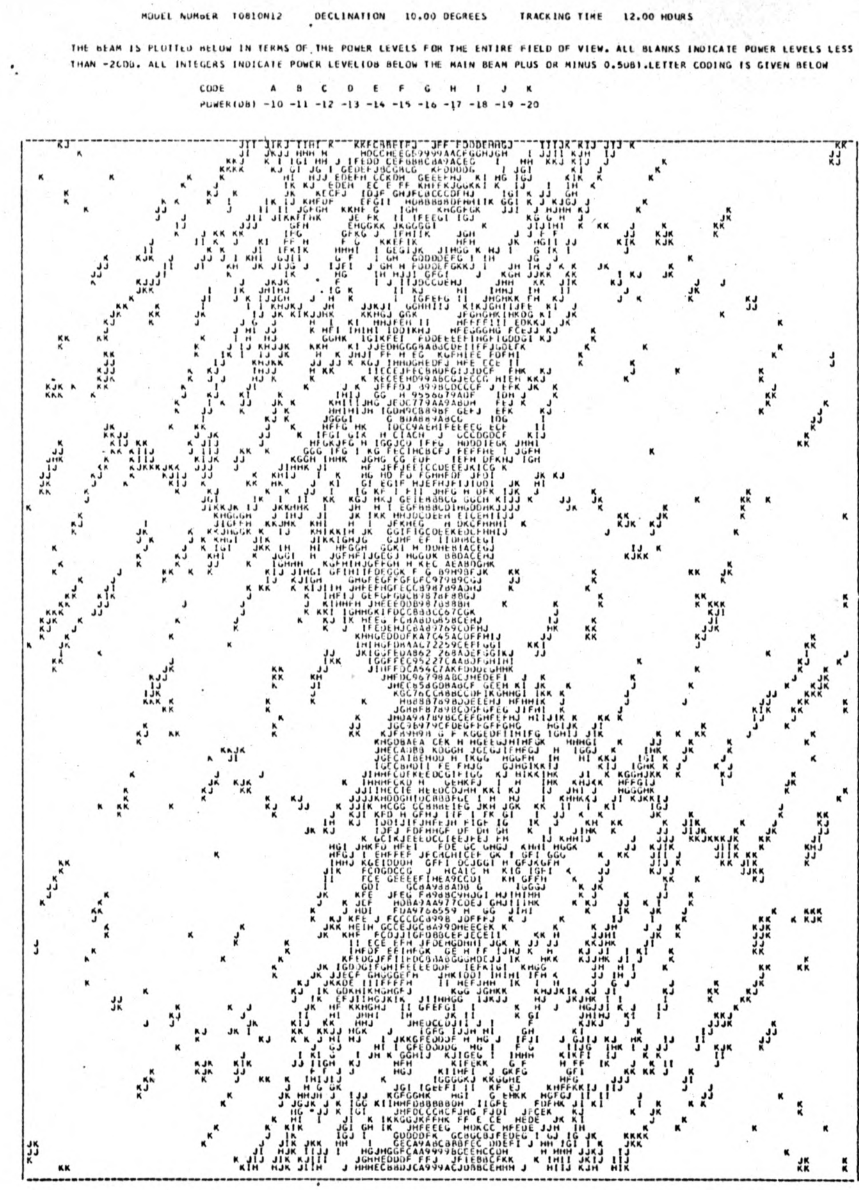
Central Portion of Beam (33" x 33")

Model Number T0800N12 $\delta = 0°$

Figure A2-(b)



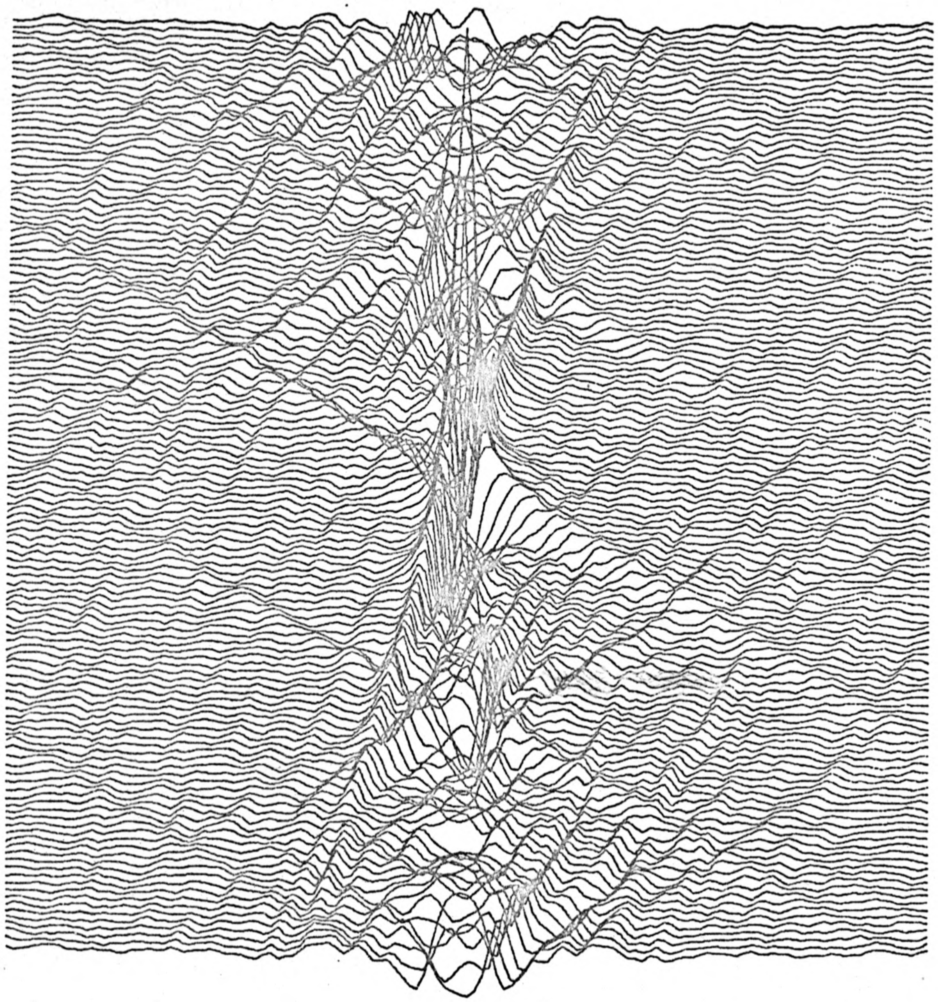
Transfer Function



Power Levels

Model Number T0810N12 $\delta = 10°$

Figure A3-(a)



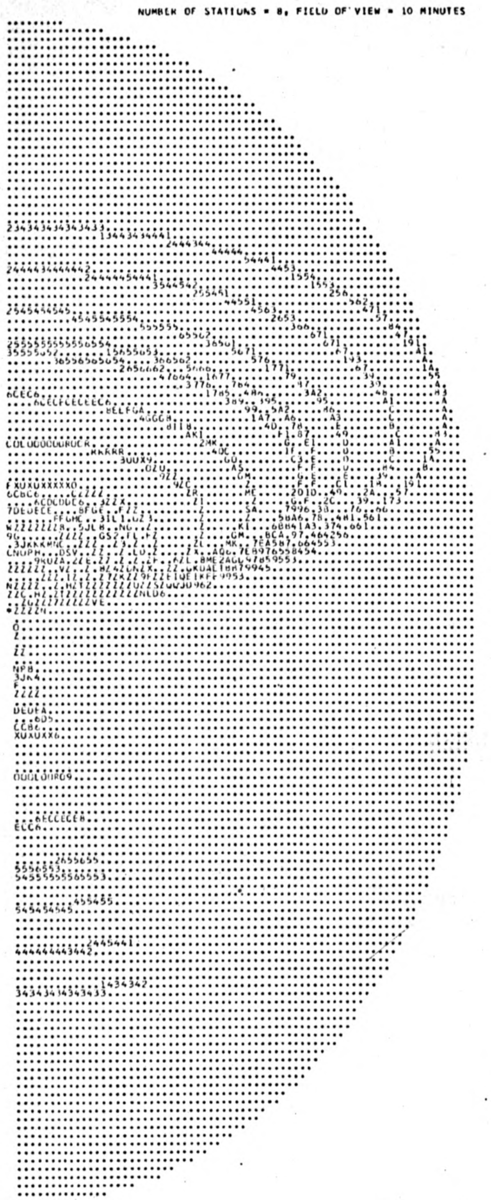
Beam Pattern (10' x 10')

*	*	*	*	*	*	*	*	*	8	6	5	6	8	*
*	*	*	*	9	8	7	9	*	7	5	6	7	9	*
*	*	*	9	8	7	7	*	*	6	5	6	7	9	*
*	*	*	*	8	7	9	*	6	4	4	5	7	*	*
*	*	*	*	*	*	*	5	3	2	3	5	7	*	*
*	*	*	*	*	7	4	2	1	2	3	5	7	9	*
9	9	9	8	6	3	1	0	0	1	3	5	7	9	*
9	8	7	6	4	2	0	0	0	2	4	6	7	8	9
*	9	7	5	3	1	0	0	1	3	6	8	9	9	9
*	9	7	5	3	2	1	2	4	7	*	*	*	*	*
*	*	7	5	3	2	3	5	*	*	*	*	*	*	*
*	*	7	5	4	4	6	*	9	7	8	*	*	*	*
*	9	7	6	5	6	*	*	7	7	8	9	*	*	*
*	9	7	6	5	7	*	9	7	8	9	*	*	*	*
*	8	6	5	6	8	*	*	*	*	*	*	*	*	*

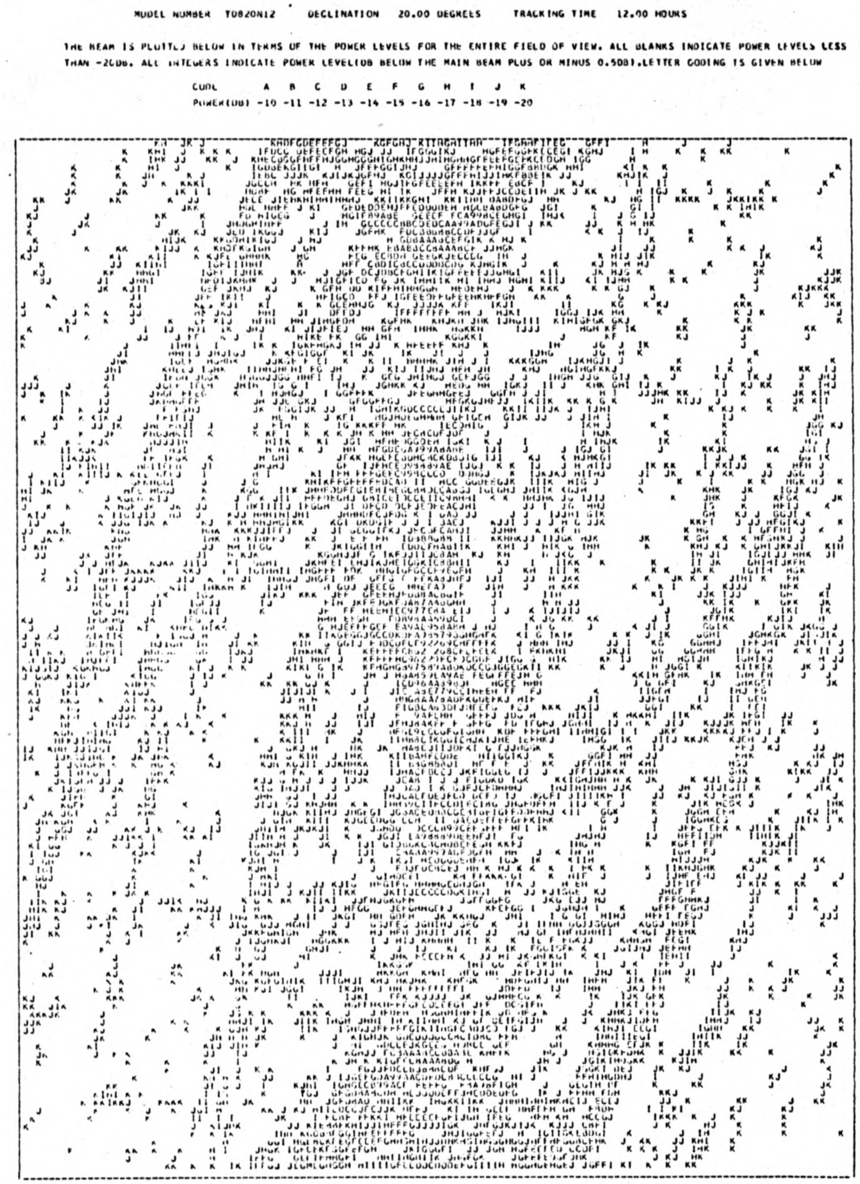
Central Portion of Beam (33" x 33")

Model Number T0810N12 $\delta = 10°$

Figure A3-(b)



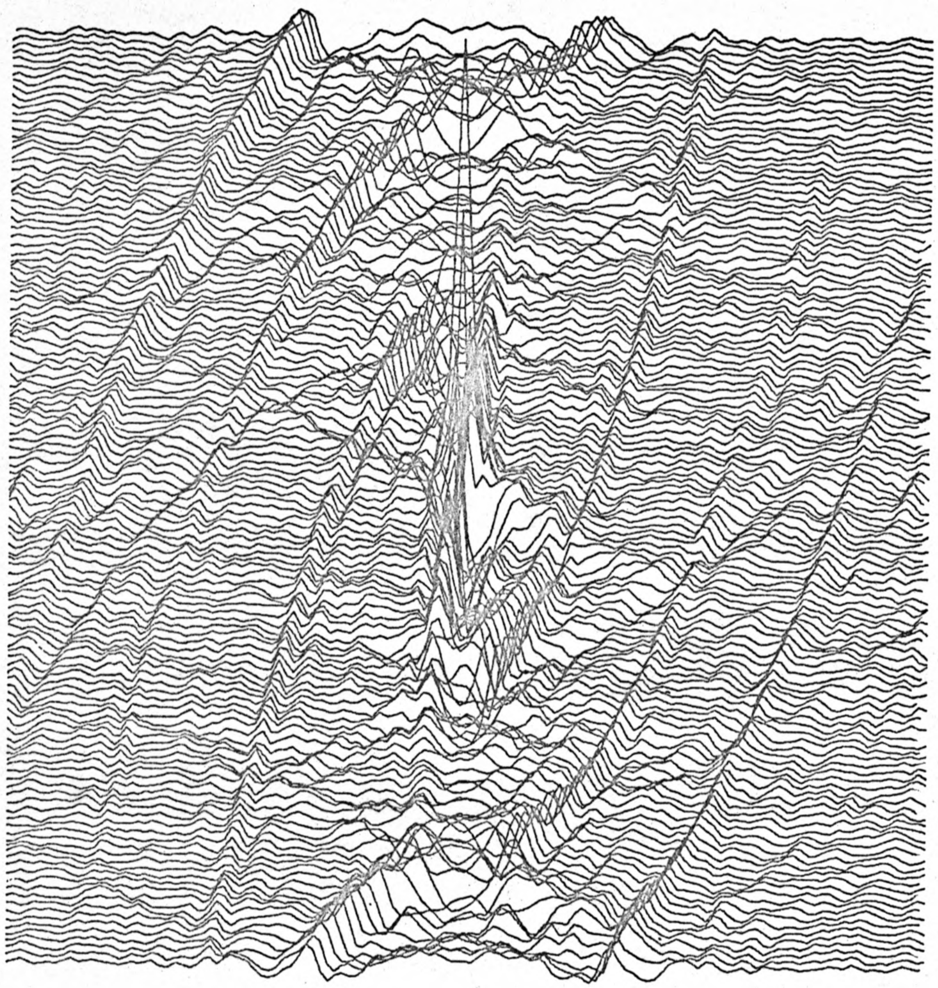
Transfer Function



Power Levels

Model Number T0820N12 $\delta = 20°$

Figure A4-(a)



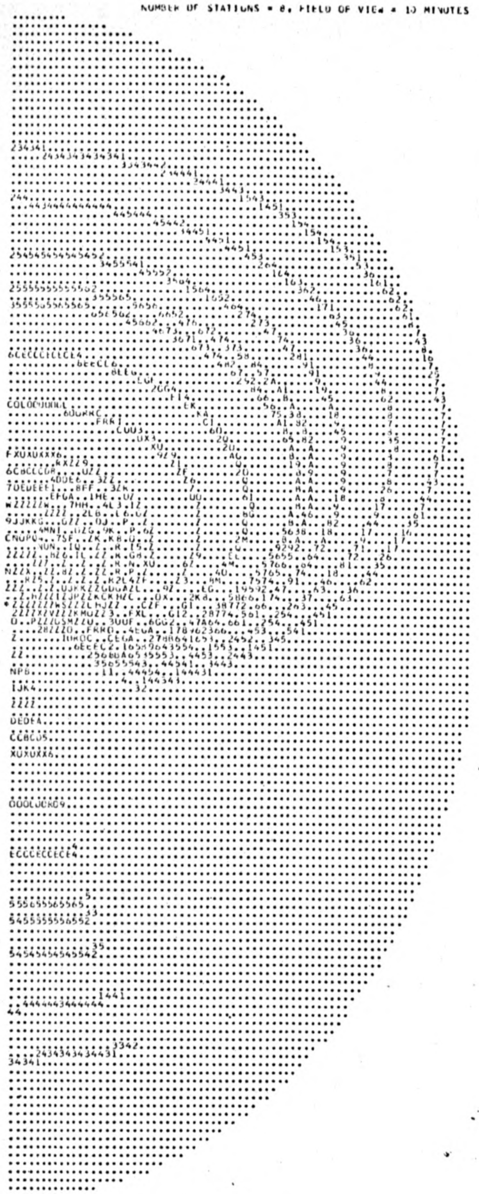
9	8	9	9	*	*	*	8	6	6	6	8	*	*	*
9	9	9	*	*	*	*	9	6	5	6	8	*	*	*
9	9	9	*	*	*	*	*	6	5	6	8	9	9	*
*	*	*	*	9	9	*	8	5	5	6	7	9	9	*
*	*	*	*	*	*	*	5	3	3	5	7	8	9	*
*	*	*	*	*	9	4	2	2	2	4	6	8	9	*
*	9	9	9	7	4	2	1	1	2	4	6	7	8	*
*	8	7	6	4	2	1	0	1	2	4	6	7	8	*
*	8	7	6	4	2	1	1	2	4	7	9	9	9	*
*	9	8	6	4	2	2	2	4	9	*	*	*	*	*
*	9	8	7	5	3	3	5	*	*	*	*	*	*	*
*	9	9	7	6	5	5	8	*	9	9	*	*	*	*
*	9	9	8	6	5	6	*	*	*	*	*	9	9	9
*	*	*	8	6	5	6	9	*	*	*	*	9	9	9
*	*	*	8	6	6	6	8	*	*	*	9	9	8	9

Beam Pattern (10' x 10')

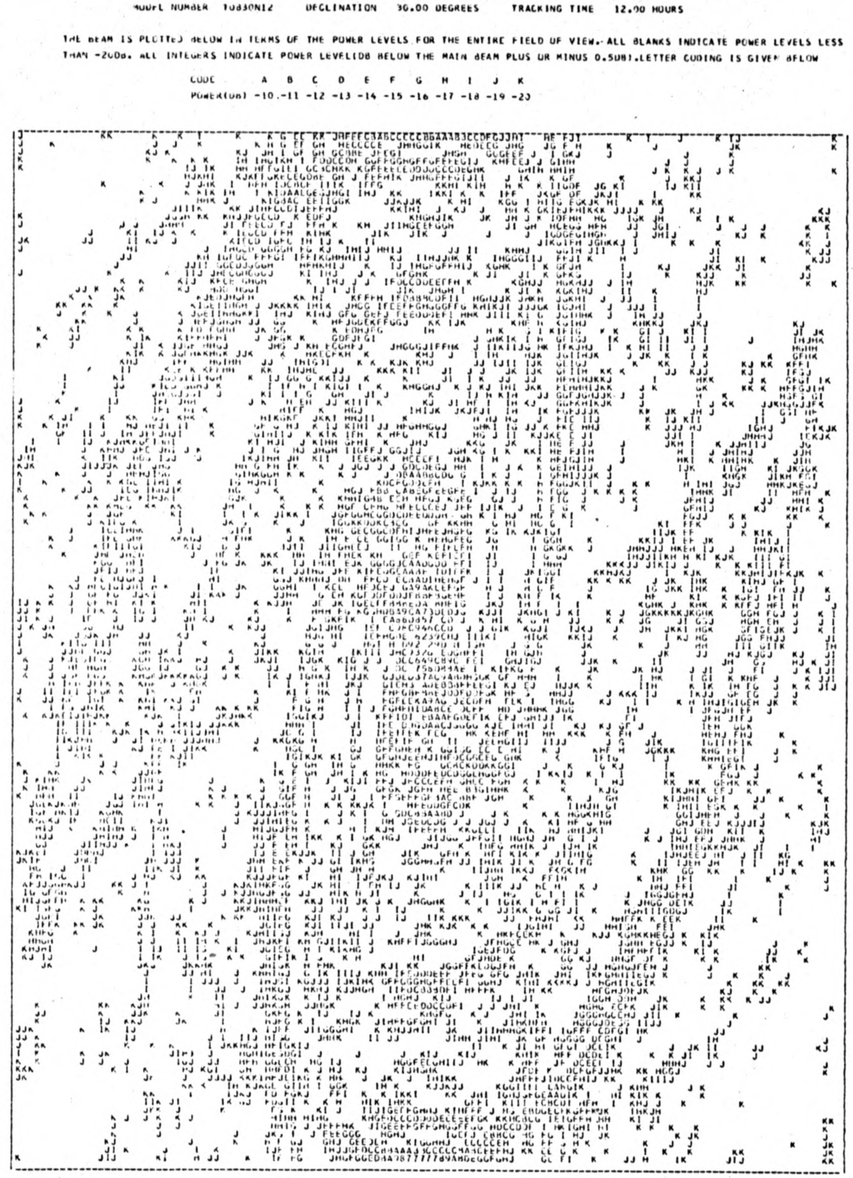
Central Portion of Beam (33" x 33")

Model Number TO820N12 $\delta = 20°$

Figure A4-(b)



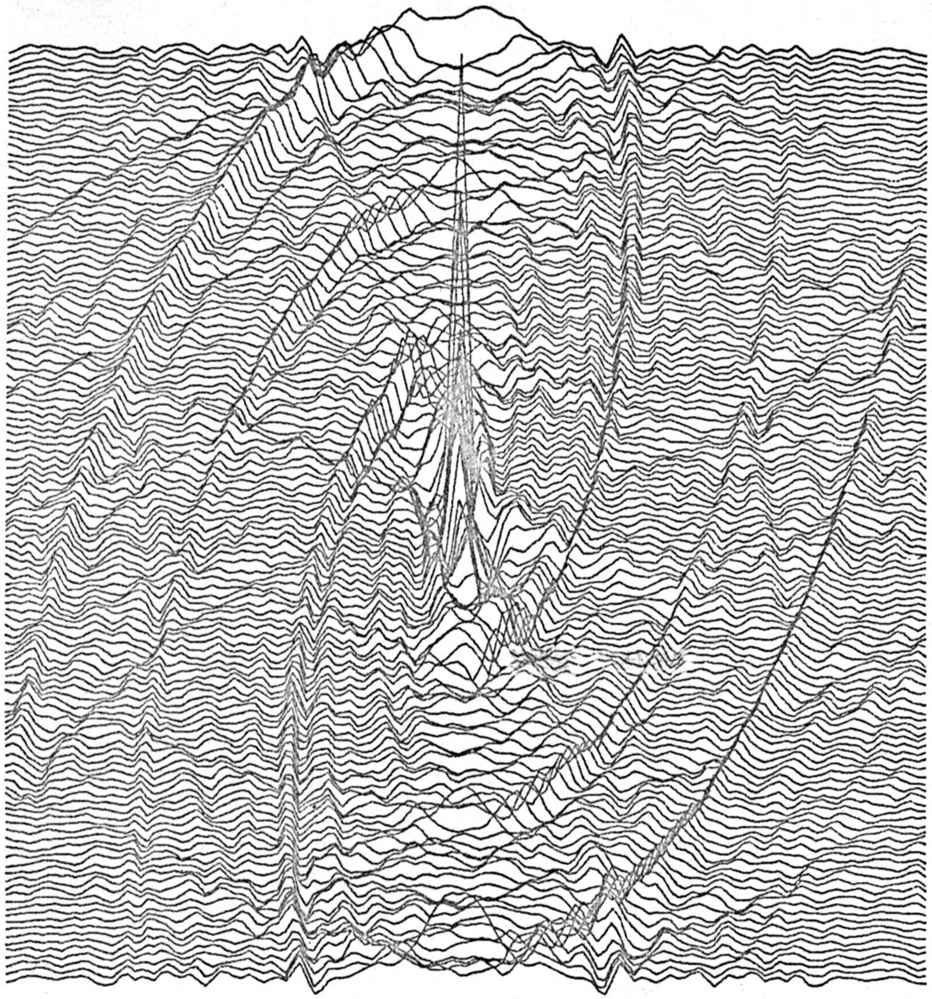
Transfer Function



Power Levels

Model Number T0830N12 δ = 30°

Figure A5-(a)



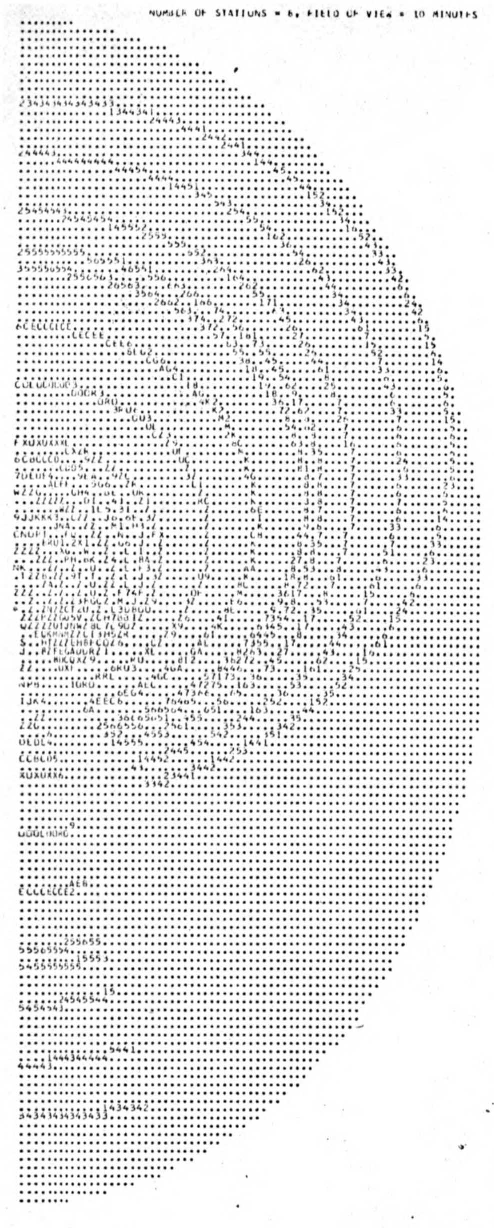
Beam Pattern (10' x 10')

8	8	9	*	*	9	6	6	6	9	*	*	*	*	*
8	8	9	*	*	8	6	5	5	7	*	*	*	*	*
6	8	9	*	*	8	6	5	5	7	*	*	*	*	*
8	8	*	*	*	9	6	4	4	6	8	*	*	*	*
*	*	*	*	*	9	5	3	3	4	7	*	*	*	*
*	*	*	*	*	6	3	2	2	3	6	9	*	*	*
*	*	*	*	7	4	1	0	1	2	5	8	*	*	*
*	*	*	9	6	2	1	0	1	2	6	9	*	*	*
*	*	*	8	5	2	1	0	1	4	7	*	*	*	*
*	*	*	9	6	3	2	2	3	6	*	*	*	*	*
*	*	*	*	7	4	3	3	5	9	*	*	*	*	*
*	*	*	*	8	6	4	4	6	9	*	*	*	8	8
*	*	*	*	*	7	5	5	6	8	*	*	9	8	8
*	*	*	*	*	7	5	5	6	8	*	*	9	8	8
*	*	*	*	*	9	6	6	6	9	*	*	9	8	8

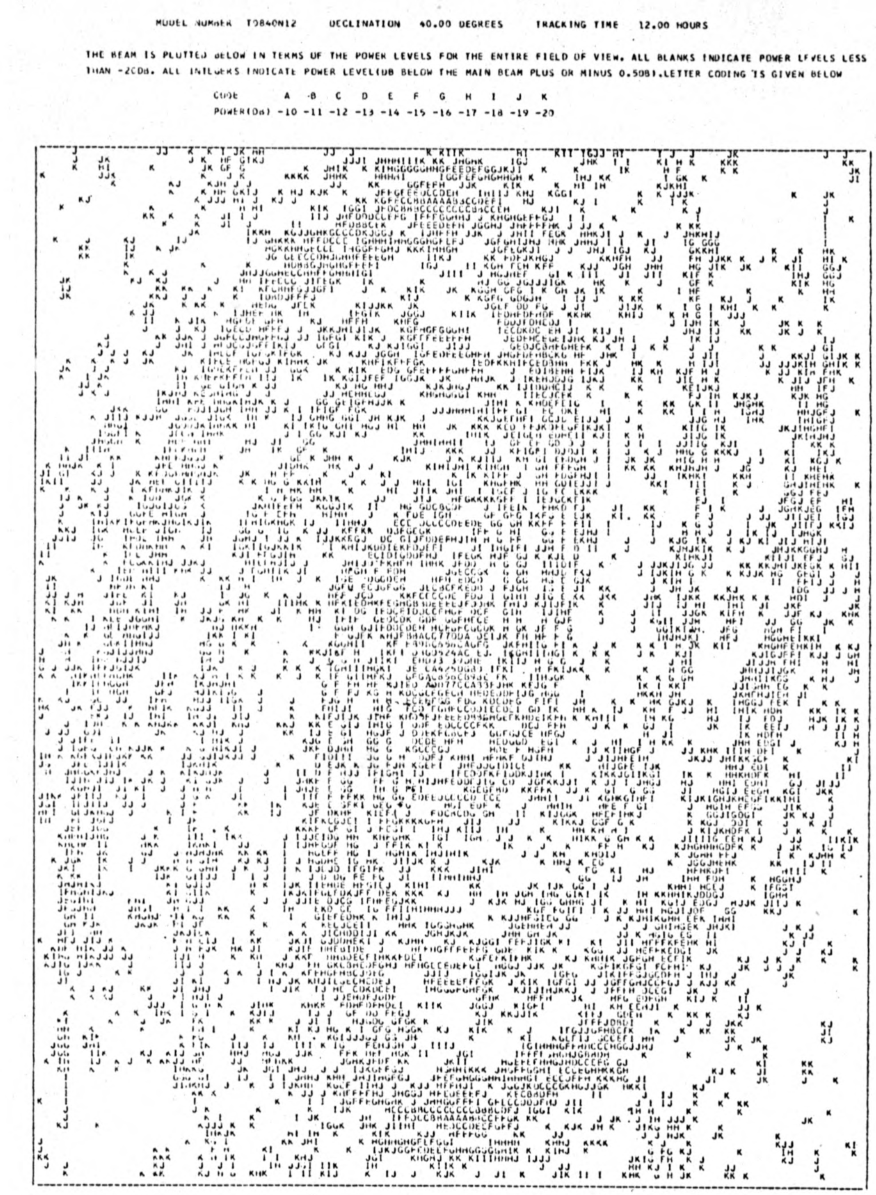
Central Portion of Beam (33" x 33")

Model Number T0830N12 $\delta = 30°$

Figure A5-(b)



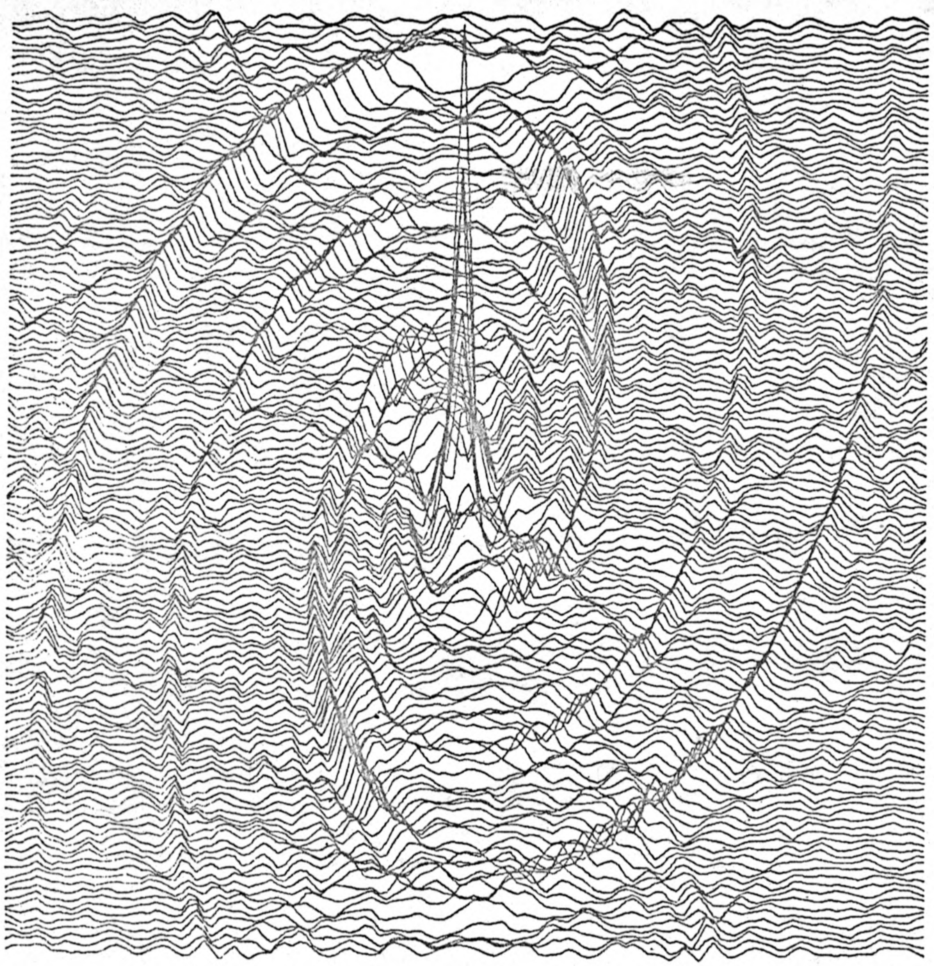
Transfer Function



Power Levels

Model Number T0840N12 $\delta = 40°$

Figure A6-(a)



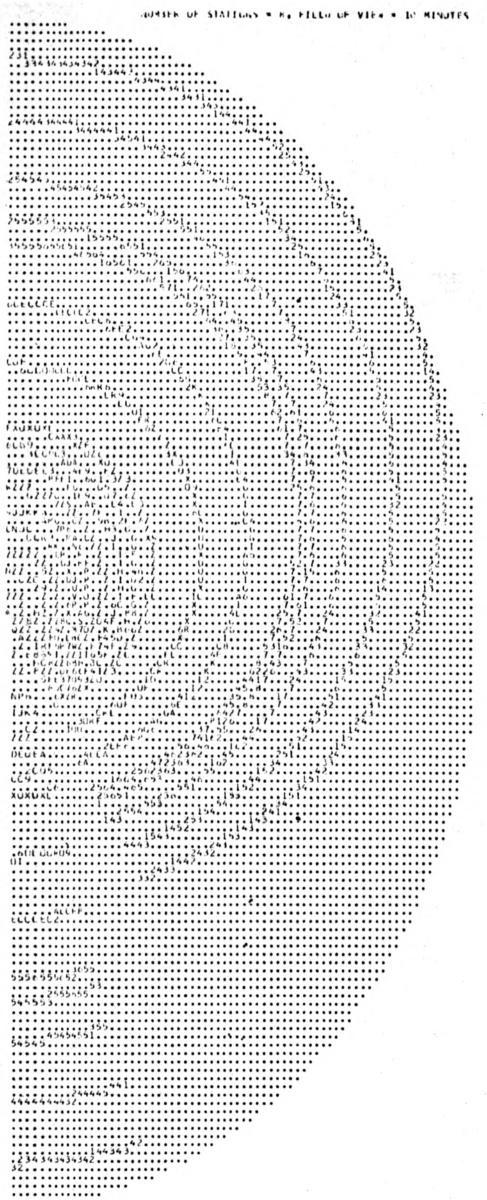
Beam Pattern (10' x 10')

*	*	*	*	*	9	9	*	*	*	*	*	*	*	*
*	*	*	*	9	7	6	7	9	*	*	*	*	*	*
*	*	*	*	8	6	5	6	7	*	*	*	*	*	*
9	*	*	*	8	6	5	5	5	8	*	*	*	*	*
*	*	*	*	9	6	4	3	4	5	8	*	*	*	*
*	*	*	*	8	5	3	2	2	4	6	*	*	*	*
*	*	*	*	7	3	1	0	1	3	5	9	*	*	*
*	*	*	9	6	3	1	0	1	3	6	9	*	*	*
*	*	*	9	5	3	1	0	1	3	7	*	*	*	*
*	*	*	*	6	4	2	2	3	5	8	*	*	*	*
*	*	*	*	8	5	4	3	4	6	9	*	*	*	*
*	*	*	*	*	8	5	5	5	6	8	*	*	*	9
*	*	*	*	*	*	7	6	5	6	8	*	*	*	*
*	*	*	*	*	*	9	7	6	7	9	*	*	*	*
*	*	*	*	*	*	*	*	9	9	*	*	*	*	*

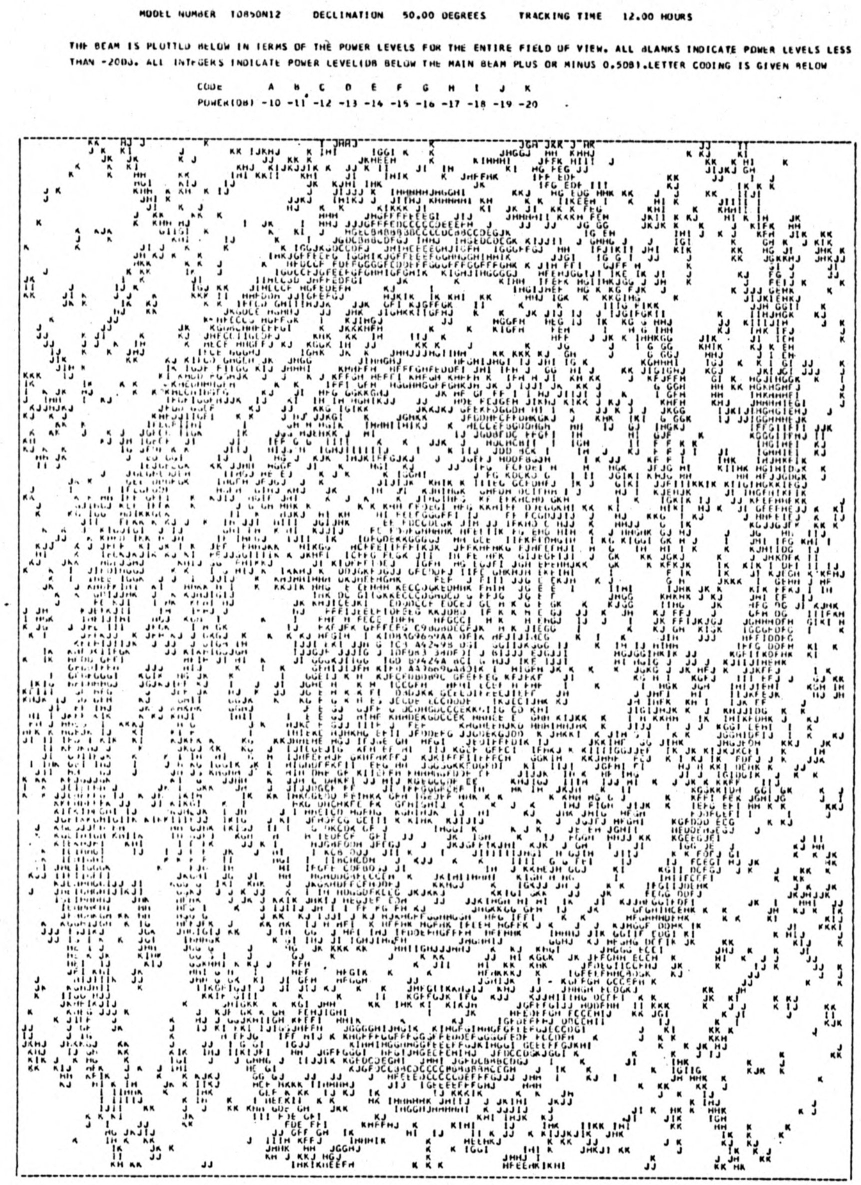
Central Portion of Beam (33" x 33")

Model Number T0840N12 $\delta = 40°$

Figure A6-(b)



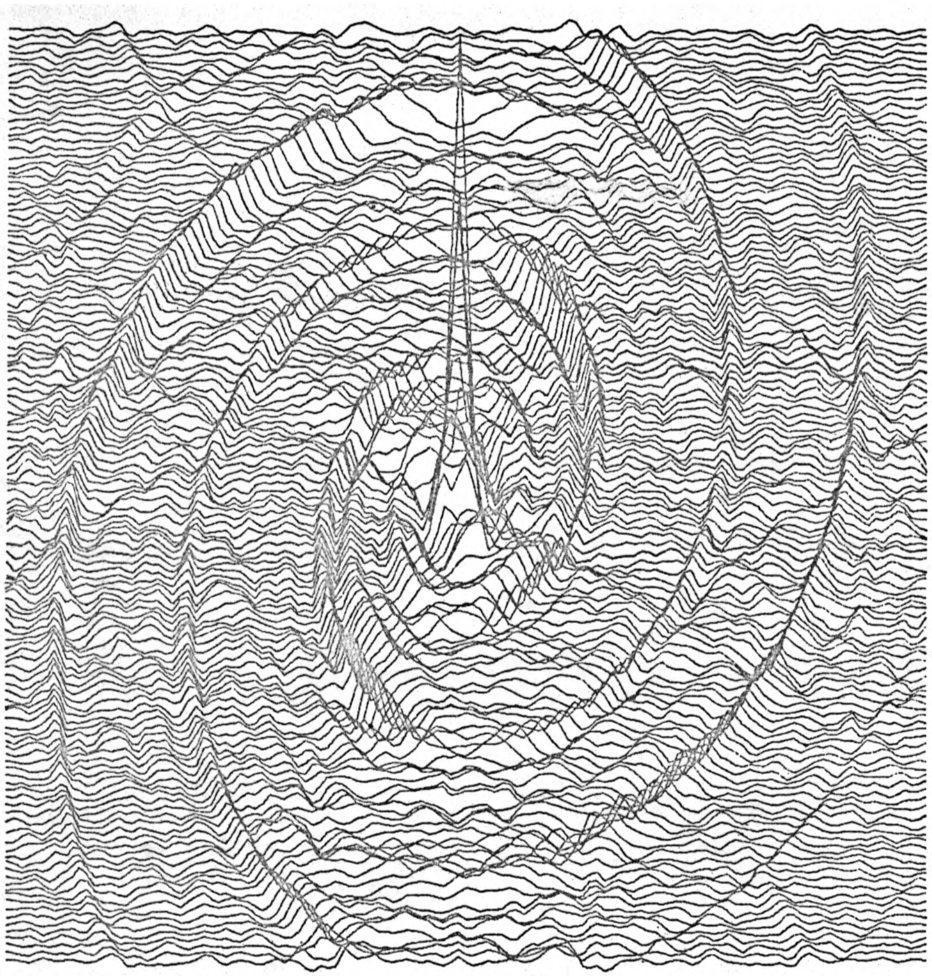
Transfer Function



Power Levels

Model Number T0850N12 $\delta = 50°$

Figure A7-(a)



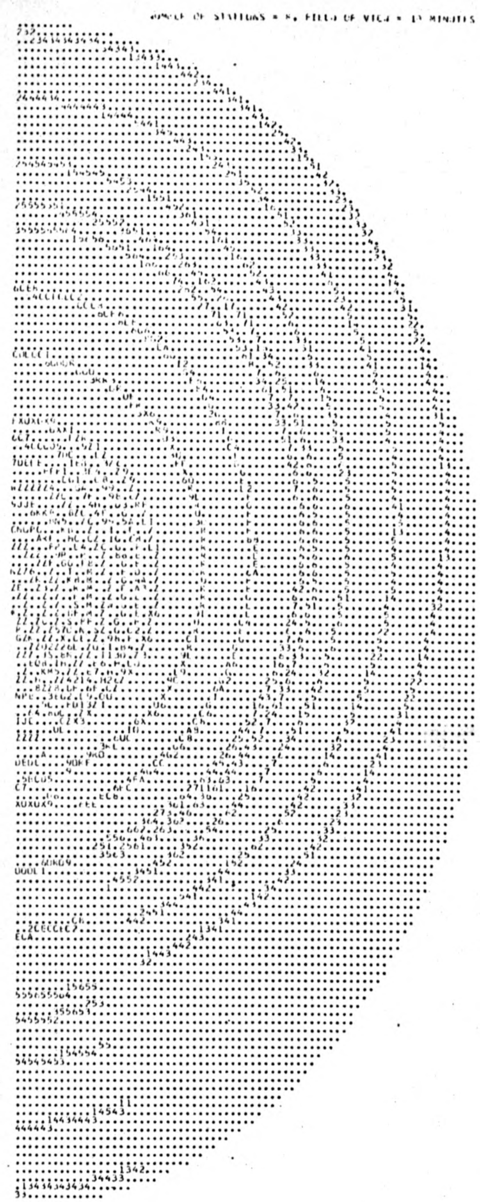
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	9	9	*	*	*	*	*	*	*	*
*	*	*	*	8	7	7	8	9	*	*	*	*	*	*
*	*	*	9	7	6	6	6	7	9	*	*	9	*	*
*	*	*	9	7	5	4	4	5	7	9	*	*	*	*
*	*	*	*	7	4	3	2	2	4	7	9	*	*	*
*	*	*	9	6	3	1	1	1	3	6	9	*	*	*
*	*	*	8	5	3	1	0	1	3	5	8	*	*	*
*	*	*	9	6	3	1	1	1	3	6	9	*	*	*
*	*	*	9	7	4	2	2	3	4	7	*	*	*	*
*	*	*	*	9	7	5	4	4	5	7	9	*	*	*
*	*	9	*	*	9	7	6	6	6	7	9	*	*	*
*	*	*	*	*	*	9	8	7	7	8	*	*	*	*
*	*	*	*	*	*	*	*	9	9	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Beam Pattern (10' x 10')

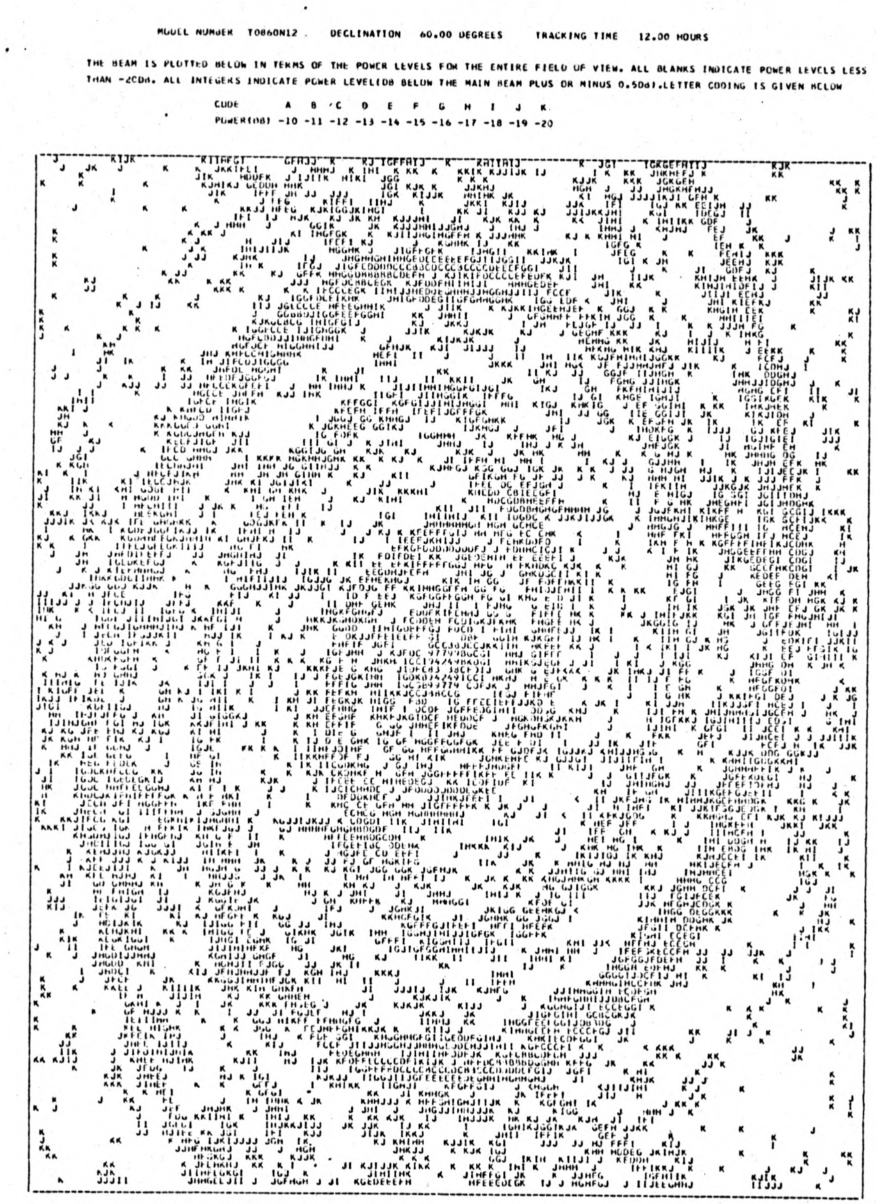
Central Portion of Beam (33" x 33")

Model Number T0850N12 $\delta = 50°$

Figure A7-(b)



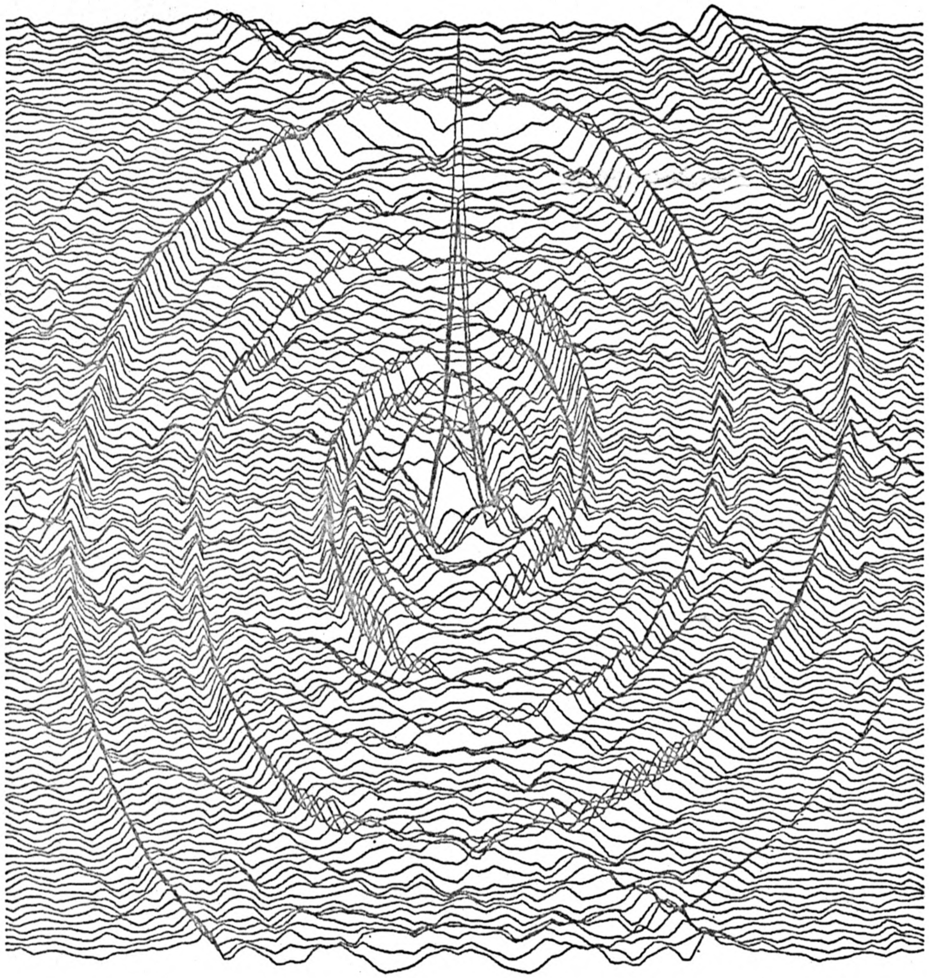
Transfer Function



Power Levels

Model Number T0860N12 $\delta = 60°$

Figure A8-(a)



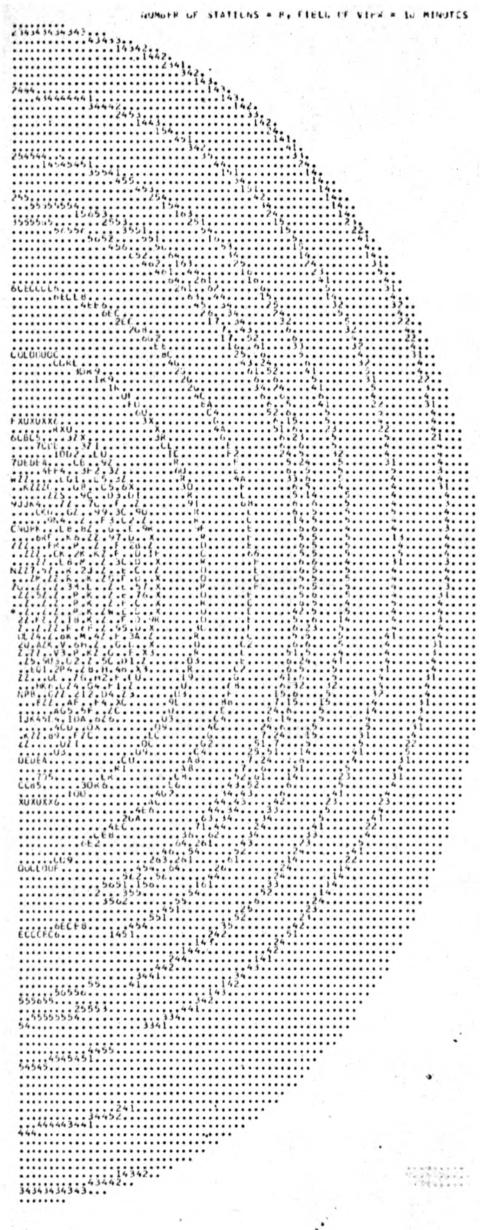
Beam Pattern (10' x 10')

*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	9	8	8	9	*	*	9	9	*	*	*
*	*	*	9	7	7	6	7	8	9	9	9	9	*	*
*	*	*	9	7	6	5	4	5	7	8	9	9	*	*
*	*	*	9	7	4	3	2	3	4	7	9	9	*	*
*	*	*	9	6	3	1	1	1	3	6	8	*	*	*
*	*	*	8	5	3	1	0	1	3	5	8	*	*	*
*	*	*	8	6	3	1	1	1	3	6	9	*	*	*
*	*	9	9	7	4	3	2	3	4	7	9	*	*	*
*	*	9	9	8	7	5	4	5	6	7	9	*	*	*
*	*	9	9	9	9	8	7	6	7	7	9	*	*	*
*	*	*	9	9	*	*	9	8	8	9	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

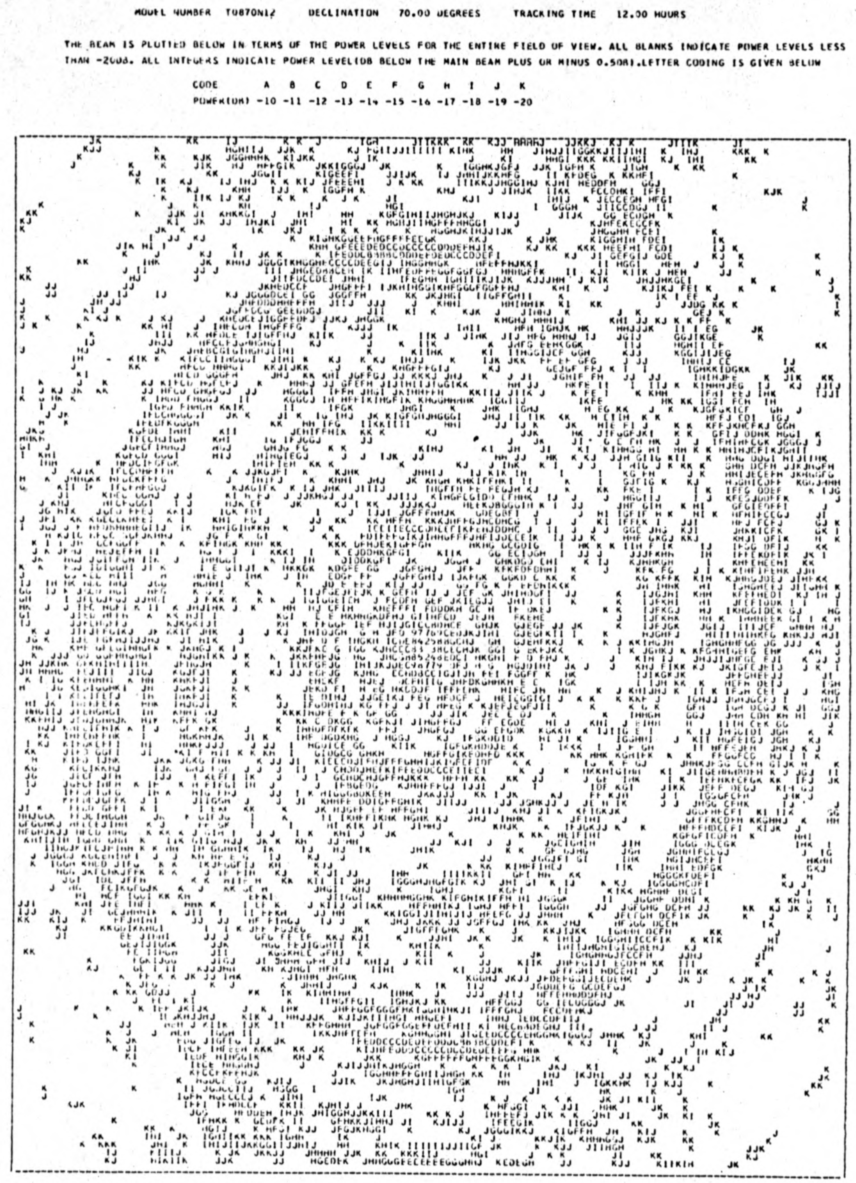
Central Portion of Beam (33" x 33")

Model Number T0860N12 $\delta = 60°$

Figure A8-(b)



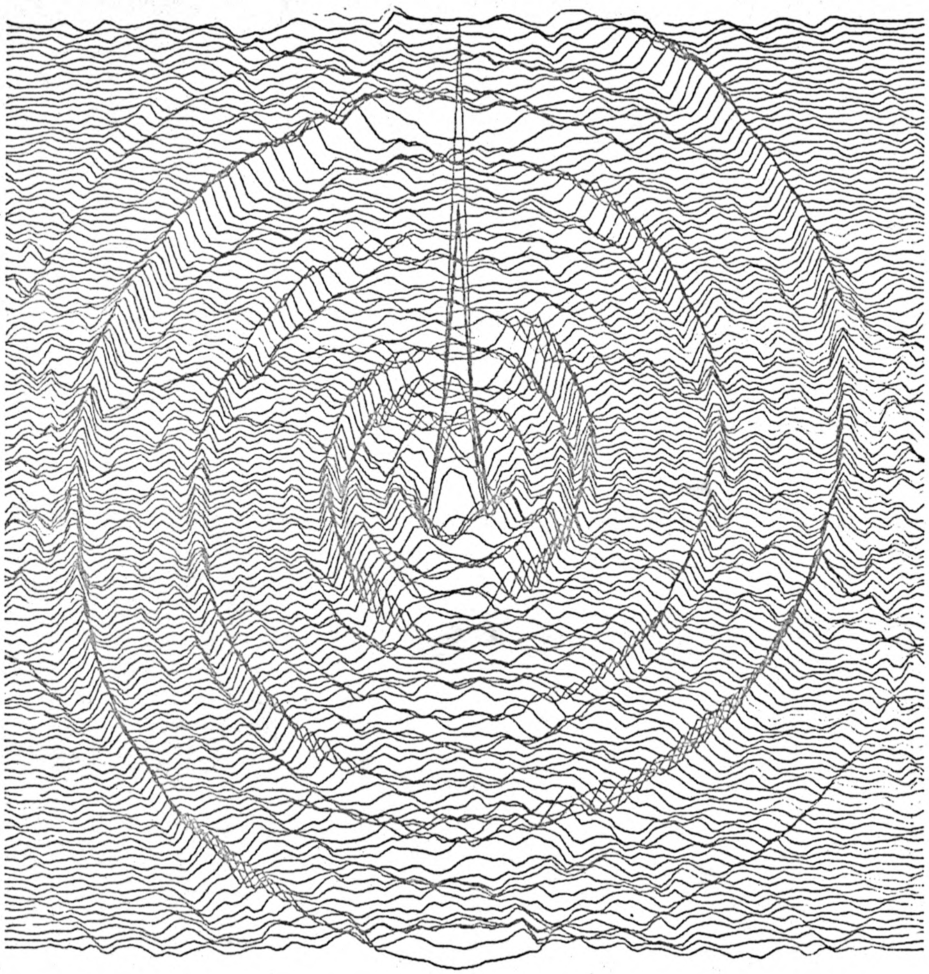
Transfer Function



Power Levels

Model Number T0870N12 $\delta = 70°$

Figure A9-(a)



Beam Pattern (10' x 10')

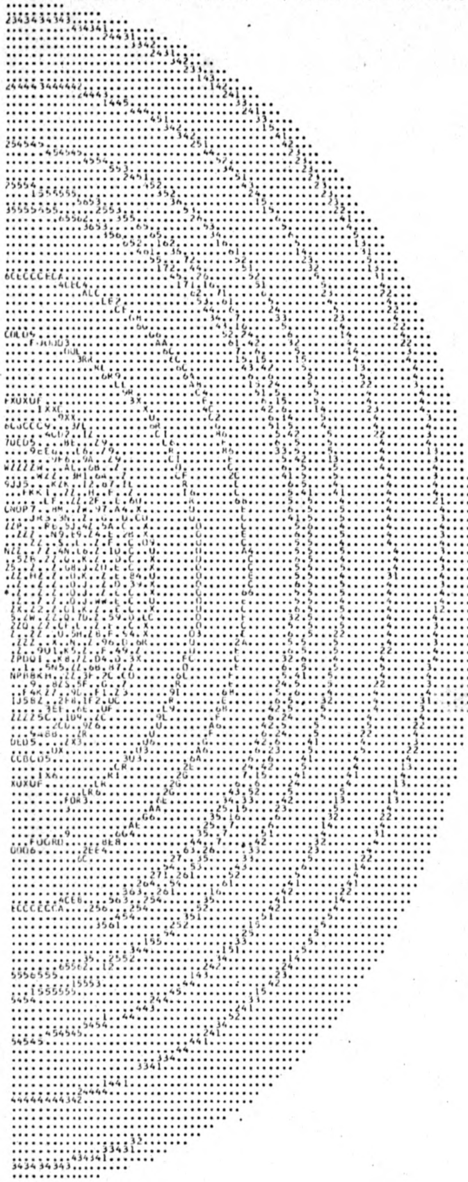
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	9	9	9	*	9	9	*	*	*	*
*	*	*	9	8	7	7	7	8	8	8	9	*	*	*
*	*	*	8	7	6	5	5	5	7	8	8	9	*	*
*	*	*	8	6	4	3	2	3	5	7	8	9	*	*
*	*	*	8	6	3	1	1	1	3	6	8	9	*	*
*	*	*	8	5	3	1	0	1	3	5	8	*	*	*
*	*	9	8	6	3	1	1	1	3	6	8	*	*	*
*	*	9	8	7	5	3	2	3	4	6	8	*	*	*
*	*	9	8	8	7	5	5	5	6	7	8	*	*	*
*	*	*	9	8	8	8	7	7	7	8	9	*	*	*
*	*	*	*	9	9	*	9	9	9	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Central Portion of Beam (33" x 33")

Model Number T0870N12 $\delta = 70°$

Figure A9-(b)

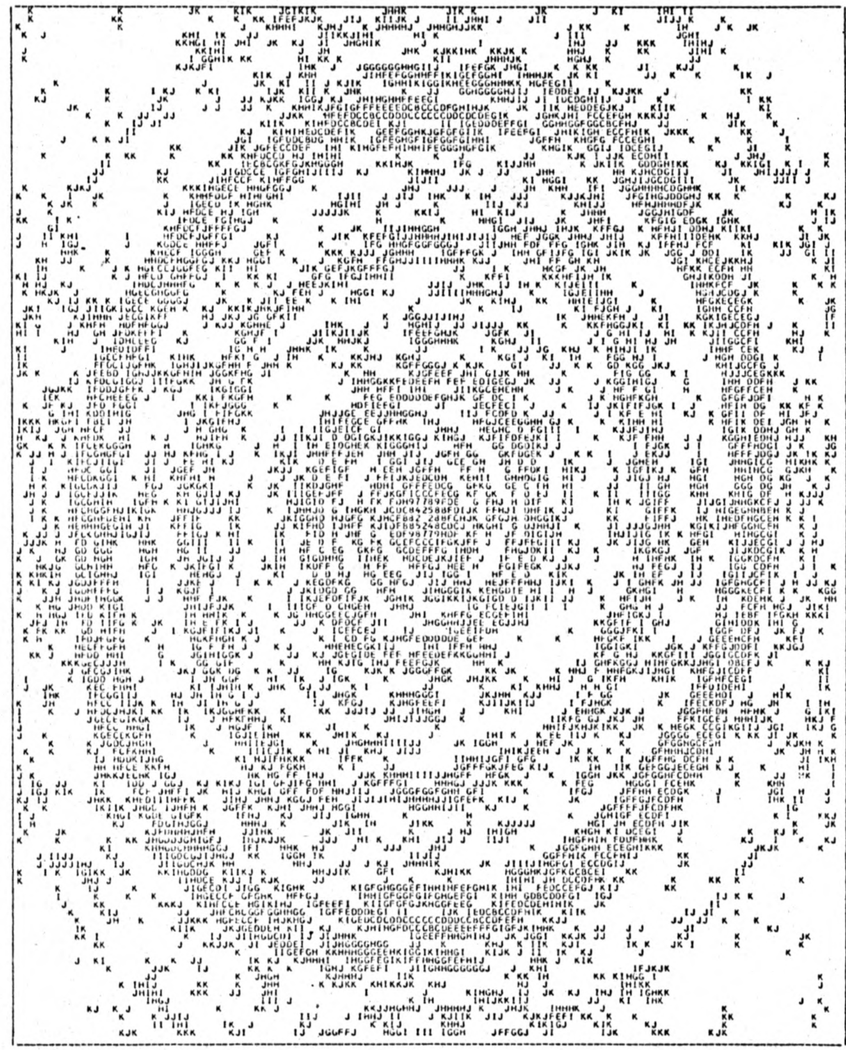
NUMBER OF STATIONS = 8, FIELD OF VIEW = 10 MINUTES



MODEL NUMBER T0880N12   DECLINATION 80.00 DEGREES   TRACKING TIME 12.00 HOURS

THE BEAM IS PLOTTED BELOW IN TERMS OF THE POWER LEVELS FOR THE ENTIRE FIELD OF VIEW. ALL BLANKS INDICATE POWER LEVELS LESS THAN -20DB. ALL INTEGERS INDICATE POWER LEVEL(DB BELOW THE MAIN BEAM PLUS OR MINUS 0.5DB).LETTER CODING IS GIVEN BELOW

CODE	A	B	C	D	E	F	G	H	I	J	K
POWER(DB)	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20

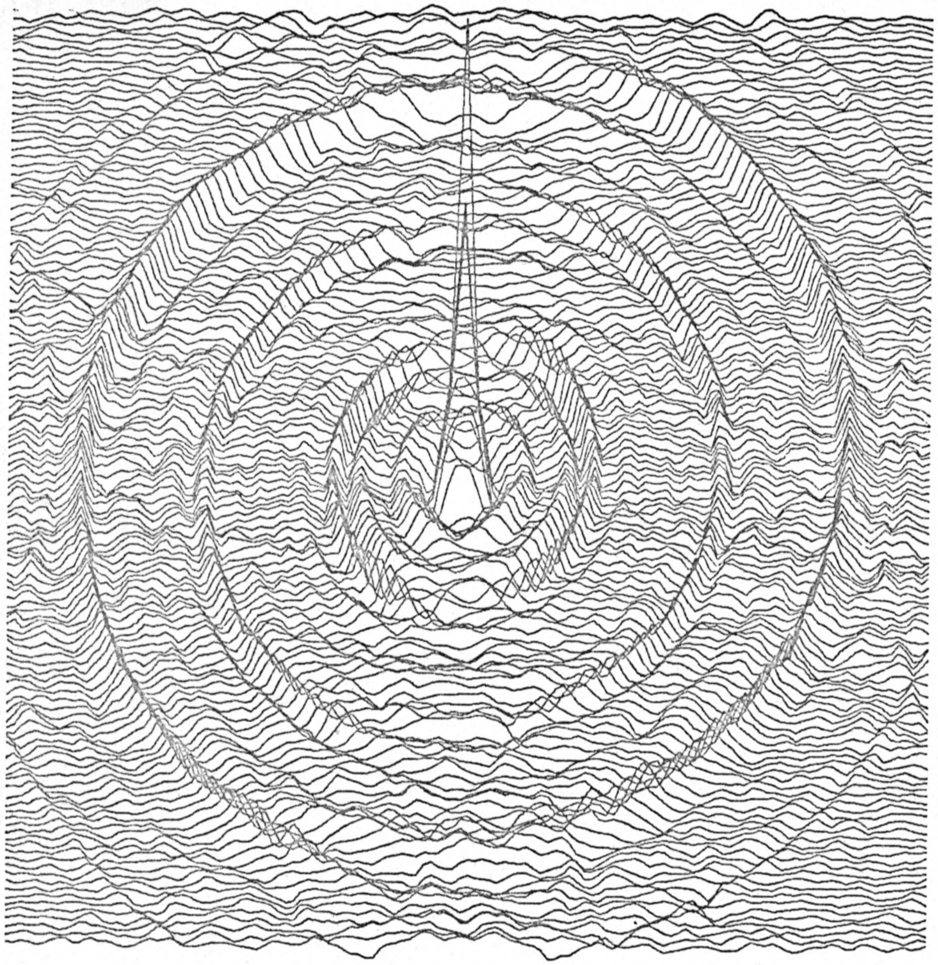


Transfer Function

Power Levels

Model Number T0880N12 $\delta = 80°$

Figure A10-(a)



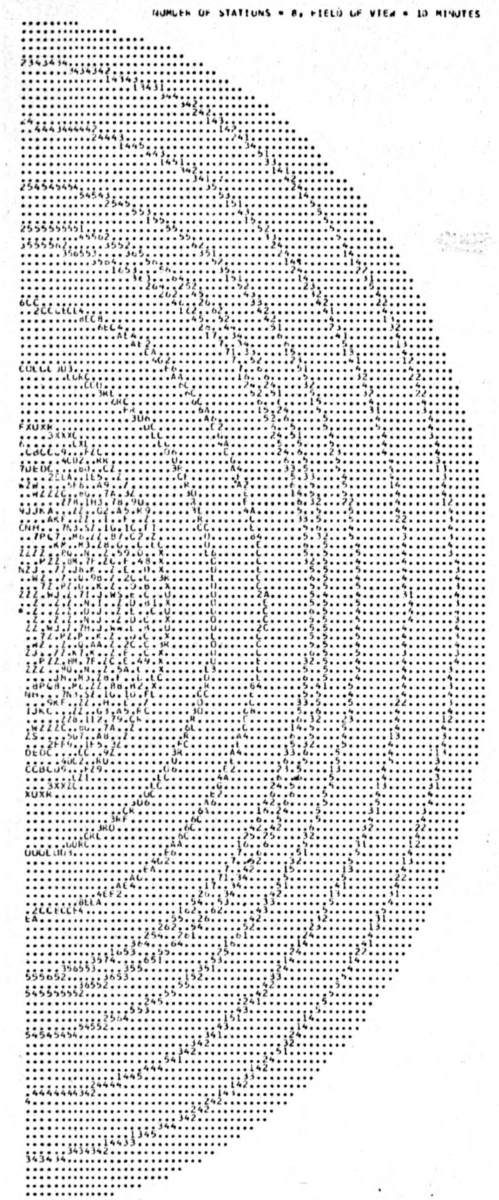
Beam Pattern (10' x 10')

*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	9	9	9	9	9	9	*	*	*	*
*	*	*	9	8	7	7	7	8	8	8	9	*	*	*
*	*	*	8	7	6	5	5	5	6	7	8	9	*	*
*	*	9	8	6	4	3	2	3	5	7	8	9	*	*
*	*	9	8	5	3	1	1	1	3	6	8	9	*	*
*	*	9	8	5	2	1	0	1	2	5	8	9	*	*
*	*	9	8	6	3	1	1	1	3	5	8	9	*	*
*	*	9	8	7	5	3	2	3	4	6	8	9	*	*
*	*	9	8	7	6	5	5	5	6	7	8	*	*	*
*	*	*	9	8	8	8	7	7	7	8	9	*	*	*
*	*	*	*	9	9	9	9	9	9	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

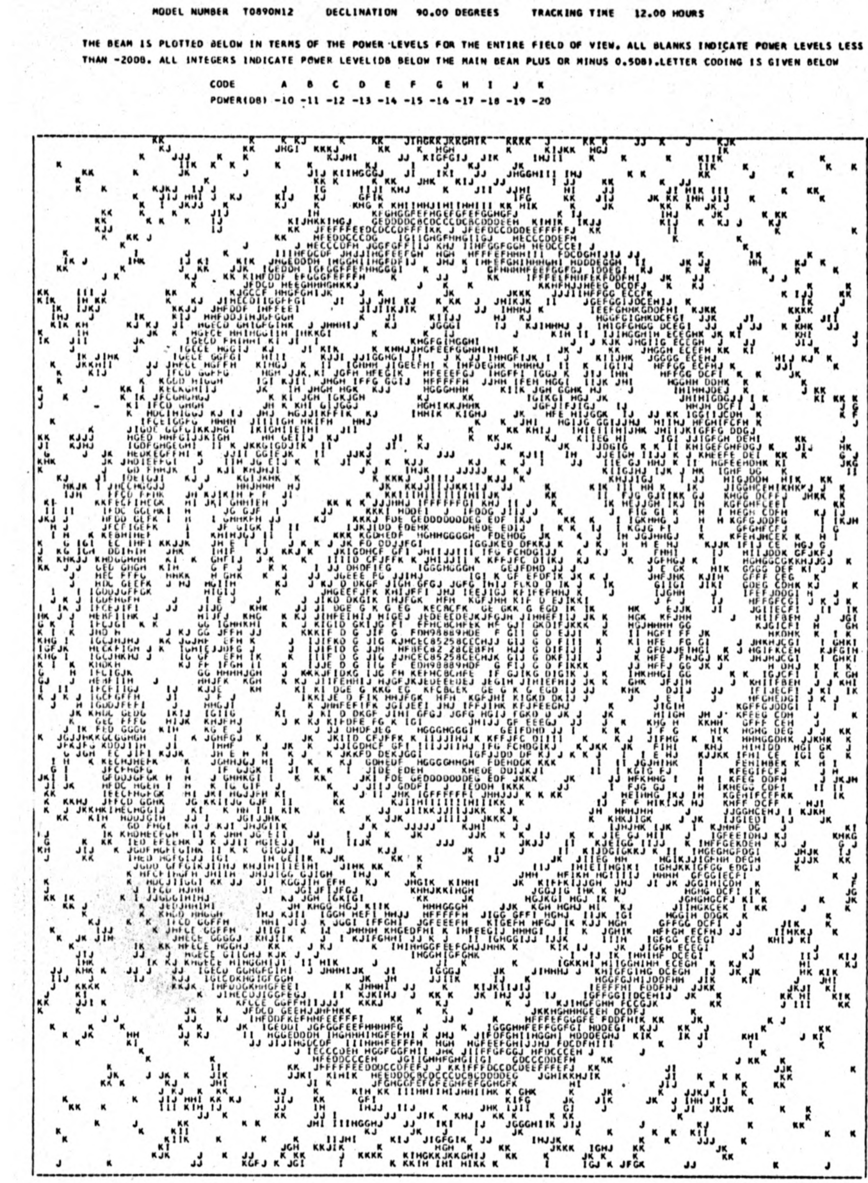
Central Portion of Beam (33" x 33")

Model Number T0880N12 $\delta = 80°$

Figure A10-(b)



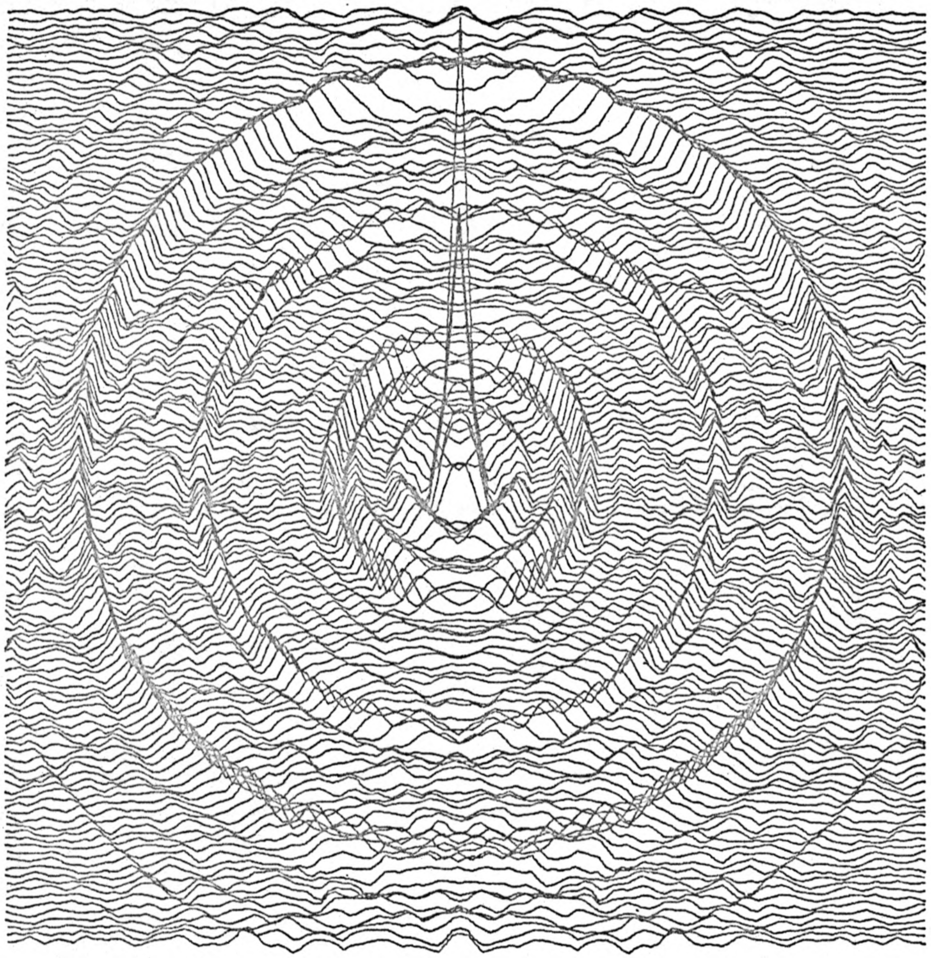
Transfer Function



Power Levels

Model Number T0890N12 $\delta = 90°$

Figure A11-(a)



Beam Pattern (10' x 10')

*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	9	9	9	9	9	*	*	*	*	*
*	*	*	9	8	8	8	8	8	8	8	9	*	*	*
*	*	*	8	7	6	6	5	6	6	7	8	*	*	*
*	*	9	8	6	5	3	2	3	5	6	8	9	*	*
*	*	9	8	6	3	1	1	1	3	6	8	9	*	*
*	*	9	8	5	2	1	0	1	2	5	8	9	*	*
*	*	9	8	6	3	1	1	1	3	6	8	9	*	*
*	*	9	8	6	5	3	2	3	5	6	8	9	*	*
*	*	*	8	7	6	6	5	6	6	7	8	*	*	*
*	*	*	9	8	8	8	8	8	8	8	9	*	*	*
*	*	*	*	*	9	9	9	9	9	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Central Portion of Beam (33" x 33")

Model Number T0890N12 $\delta = 90°$

Figure A11-(b)