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NASA General Working Paper No. 10,019

A RAPID GRAPHICAL TECHNIQUE FOR OBTAINING RADAR DATA TIME HISTORY FOR CLOSE EARTH ORBITS

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
Houston, Texas
November 25, 1963

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A RAPID GRAPHICAL TECHNIQUE FOR OBTAINING RADAR DATA TIME HISTORY FOR CLOSE EARTH ORBITS

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INTRODUCTION

In the near future, manned orbital flights will be of several days duration. The need for quick estimates of radar tracking coverage for given radar locations will be greater than for previous six and twenty-two orbit Mercury flights. A graphical method which yields this data quickly and accurately would be advantageous. The purpose of this report is to present such a method.

METHOD AND RESULTS

The main assumption made in the report is that when in view of a radar, the great circle arc formed by the ground track is a straight line when viewed from above. That is, when looking at a polar plot centered at the radar the projection of the orbit path onto this plot is a straight line. It was found that this assumption coupled with the use of a stationary earth, caused a nearly constant bias in the time over the station. This bias is reflected in the scales in this report. On the polar graphs in this paper, the radial lines indicate azimuth angle, and the concentric circles are taken to indicate both range and elevation angle with respect to the radar. The azimuth angle is measured positive clockwise from North, and positive elevation angles are measured vertically from the horizontal plane to the vehicle position.

The proper orientation of this straight line ground track for a given orbit and radar location is found by means of two numbers. The first number is the maximum elevation angle of the vehicle as seen by the radar. For a given circular orbit altitude this angle will define the distance between the vehicle and the radar at the time of closest approach. The second number is the azimuth angle corresponding to the maximum elevation angle. Knowledge of these two parameters and the orbit altitude enables one to construct a straight line representing the ground track. Thus, one finds the radial line corresponding to the given azimuth, follows it out to the given elevation circle, and at that point draws the perpendicular to the radial line. After drawing the ground track on a polar map, radar data time histories are found as explained in the following examples.

Figure 1(a) represents the situation near a California TLM-18 radar, in the first orbit of a multi-orbit mission. The graph and the scales below correspond to a 90 nautical mile circular orbit. The azimuth angle corresponding to the point of closest approach is specified as 153 degrees. A maximum elevation angle of 4.0 deg. is given. Therefore, in order to construct the ground track, go out from the center on the radial line corresponding to 153 deg. lay off a length equal to the distance on the elevation angle scale from 90 to 4.0 degrees. If a perpendicular is now drawn, it will coincide with the line representing the ground track. Also note the coverage circle for a 5 deg. elevation angle shown there.

It now remains to briefly describe how the data of figure 1(b) was obtained from this graph. First, a convention is established that zero time will correspond to zero elevation angle. Marking the ground track at the distance from the center corresponding to zero degrees elevation, lay off along the ground track a length equal to the distance from zero to one of the time scale at the bottom. Now measure the distance from the center to this point. Lay off this distance from the center of the elevation angle scale, and read 2.5 degrees. This is the reading corresponding to the elevation angle at 1 minute on figure 1(b). By a straightforward use of the scales, and figure 5, the other two parameters are plotted easily.

Figure 2(a) presents another example where the azimuth angle was 350 deg. at a maximum elevation angle at 72.5°. The data of figure 2(b) were obtained from this polar graph and its associated scales. The orbital altitude in this case was 140 nautical miles.

Figure 1(c) and 2(c) show the results computed on a digital computer. The comparison of these results with the corresponding graphical results is very favorable.

Circular orbit examples are shown in figures 3(a) and 4(a) where the azimuth angles were 182° and 147° for corresponding maximum elevation angles of 65° and 10° respectively. The scales and plots were prepared for 100 nautical mile altitudes. Figures 3(b) and 4(b) are the graphic results obtained from figures 3(a) and 4(a), while 3(c) and 4(c) depict the computer results. From a comparison of 3(b) and 3(c), 4(b) and 4(c) results show that the graphic method is very accurate for determining circular orbit pointing data.

Figures 6 and 7 provide additional information relative to construction of the scales at the bottom of the polar graphs in this paper. It is anticipated, however, that enough charts are included in figures 8(a) - 1 for making practical use of this method without further construction of scales, as scales and plots were prepared for orbits from

90 to 200 nautical miles altitude in increments of 10 nautical miles.

In order that the time scale for a given orbital altitude be the same no matter what orientation the ground track has, it was necessary to use ground range as the range scale, since ground range is a linear function of time. Conversion to slant range is facilitated by figure 5, which shows slant range as a function of ground range for different orbital altitudes.

Earth rotation again, is not considered in the construction of the ground tracks, and the effect of this is borne out in table I, where it is seen that the total contact time for an actual case will be greater than that given by the graphical technique. It was therefore necessary to build the bias into the time scales. This was done; therefore, earth rotation effects are essentially included in the time scales at the bottom of figures 8(a) - 1(e). Based on the data in table I, a mean bias of .26 min was used.

CONCLUSION

In conclusion, comparison of the graphical results with the computed results for elliptical and circular orbits reveal that the graphical technique provides a rapid, practical way of determining radar data time histories for near earth orbits.

TABLE I.- RADAR TRACKING PARAMETERS AND CONTACT TIME ERRORS DUE TO GRAPHIC ESTIMATION OF RADAR TRACKING COVERAGE

Case Number	Radar Station & orbit No.	Minimum Slant Range (nm)	Maximum Elevation Angle (deg)	Altitude (nm)	Minimum Ground Range (nm)	Azimuth Angle (deg)	Actual Contact Time (min)	Graphic Contact Time (min)	Contact Time Error (min)
1	BDA F2	90	80.	88.7	15.2	350	6.66	6.29	.37
2	BDA F3	245	20.8	94.4	223.	195	6.56	6.03	.53
3	BDA F4	695	2.65	100.8	679.	206	4.00	3.74	.26
4	CYI 1	100	74.	96.2	26.8	210	6.80	6.51	.29
5	CYI 2	548	6.40	103.1	531.	207	5.44	5.07	.37
6	KNO 1	270	21.4	107.4	244.	30	7.05	6.71	.34
7	MUC 1	155	65.0	141.1	62.9	180	8.33	8.00	.33
8	MUC 2	140	72.5	133.8	40.5	350	8.26	7.65	.51
9	MUC 3	422	14.4	128.4	395.	335	7.25	6.98	.32
10	WOM 1	150	66.0	137.6	58.7	167	8.23	8.01	.22
11	WOM 2	315	21.5	127.5	283.	335	7.63	7.30	.33
12	WOM 3	855	1.0	119.1	834.	325	2.70	2.51	.19
13	HAW 2	460	7.55	90.0	446.	150	5.43	5.15	.28
14	HAW 3	168	29.60	86.0	143.	335	6.38	6.25	.13
15	HAW 4	537	4.80	85.8	524.	347	4.73	4.48	.25
16	HAW 5	640	2.60	87.4	627.	8	3.86	3.70	.16
17	CAL 1	585	3.60	85.4	572.	153	4.30	4.19	.11
18	CAL 2	204	23.3	85.7	183.	165	6.25	6.10	.15
19	CAL 3	94	67.4	87.0	35.2	160	6.58	6.29	.29
20	CAL 4	525	6.40	97.2	509.	202	5.38	5.26	.12

21	CAL 5	177	30.0	91.8	149.	192	6.58	6.18	.40
22	CAL 1	682	1.6	85.6	669.	153	3.07	3.11	.04
23	CAL 2	289	14.80	84.9	273.	165	6.00	5.52	.48
24	GYM 1	135	38.5	85.6	103.	158	6.42	6.23	.19
25	GYM 2	235	19.6	85.7	216.	352	6.25	6.02	.23
26	GYM 3	297	16.0	93.4	278.	346	6.25	5.88	.37
27	GYM 4	105	76.7	102.3	23.5	20	6.83	6.51	.32
28	WHS 1	285	15.0	84.5	269.	160	6.00	5.51	.49
29	WHS 2	87	78.2	85.2	17.4	200	6.36	6.30	.06
30	WHS 3	90	79.5	88.5	16.0	163	6.28	6.30	.02
31	WHS 4	302	15.8	94.2	283.	199	6.36	5.85	.51
32	TEX 1	160	31.3	85.8	133.	346	6.38	6.20	.18
33	TEX 2	315	13.6	87.4	299.	356	6.00	5.79	.21
34	TEX 3	210	24.8	93.2	186.	12	6.56	6.11	.45
35	TEX 4	220	24.9	98.3	194.	204	6.71	6.50	.21
36	TEX 5	795	1.15	106.2	778.	212	2.85	2.95	.10
37	EGL 1	120	46.	87.3	81.3	345	6.25	6.28	.03
38	EGL 2	145	36.	87.2	114.	5.5	6.41	6.22	.19
39	EGL	156	36.7	95.4	122.	197	6.75	6.66	.09
40	EGL	605	4.65	100.8	589.	207	4.95	4.66	.29

TABLE I.- RADAR TRACKING PARAMETERS AND CONTACT TIME ERRORS DUE TO GRAPHIC ESTIMATION OF RADAR TRACKING COVERAGE - Concluded

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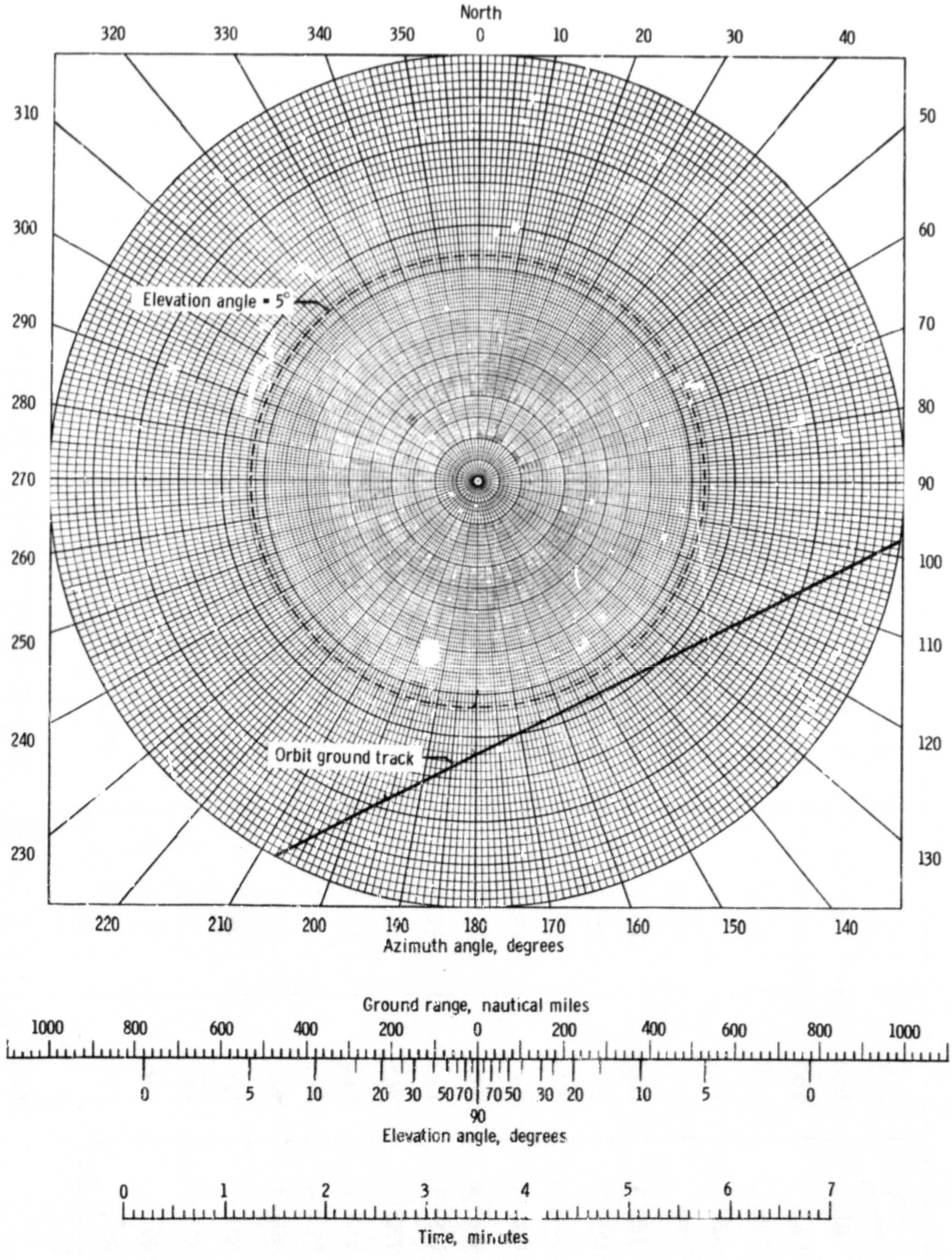
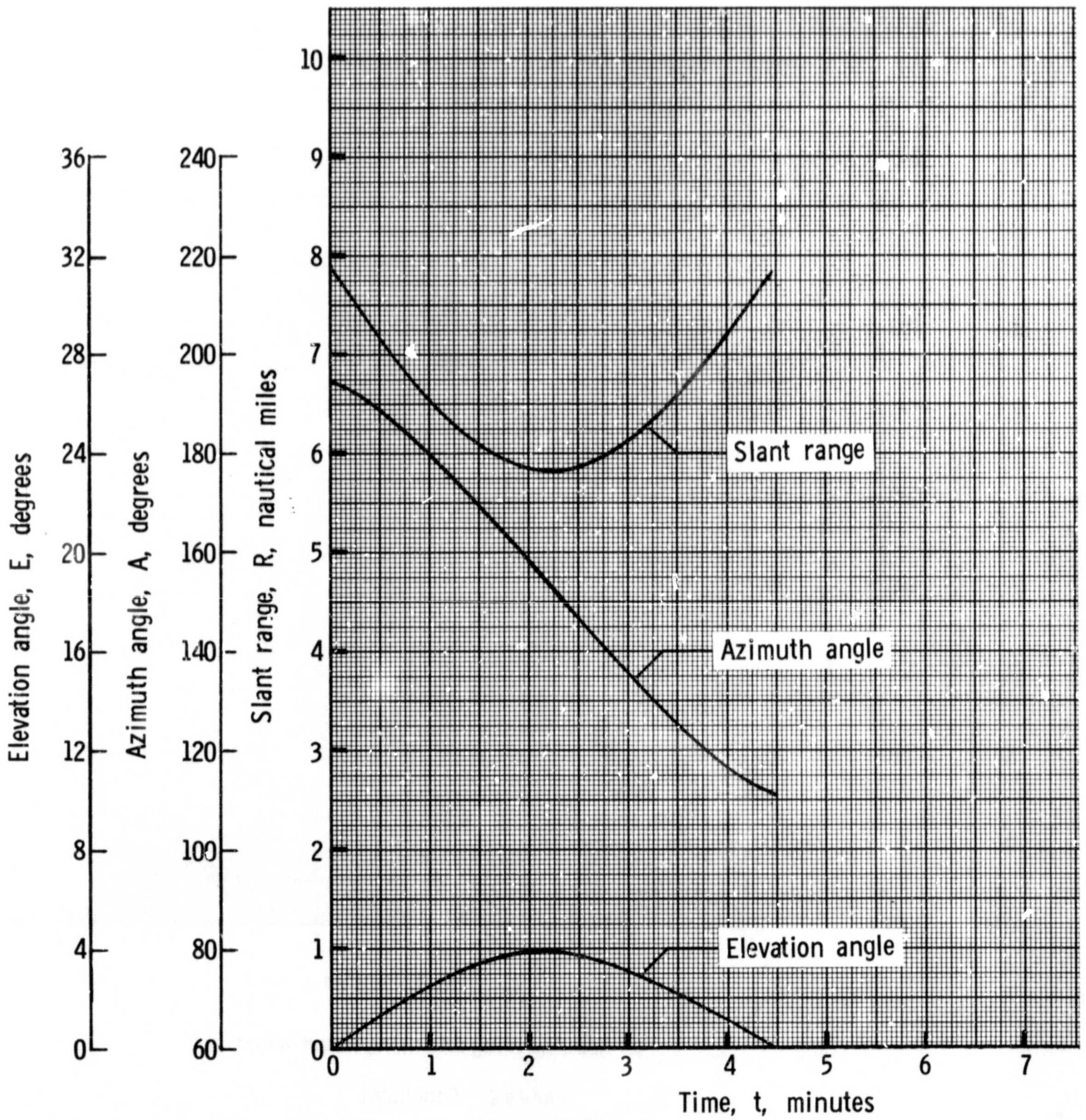


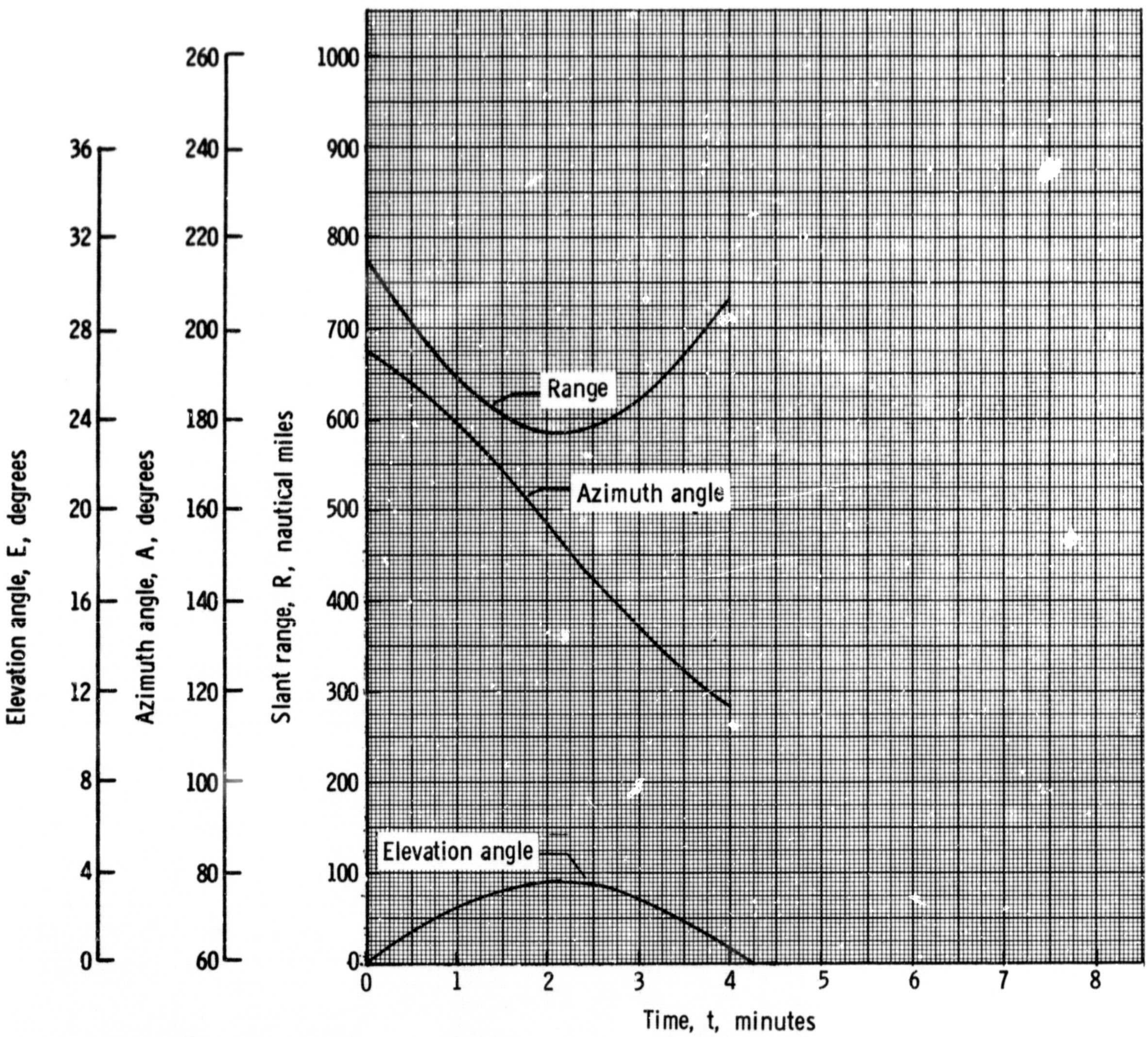
(a) Pointing data scales for 90 nautical mile orbital altitude with polar graph showing the orbit ground track of the vehicle.

Figure 1. - Radar tracking data of elliptical orbit (h_a=144 nm, h_p=87 nm, i = 32.5°) for California TLM-18 radar, first orbit, first pass.



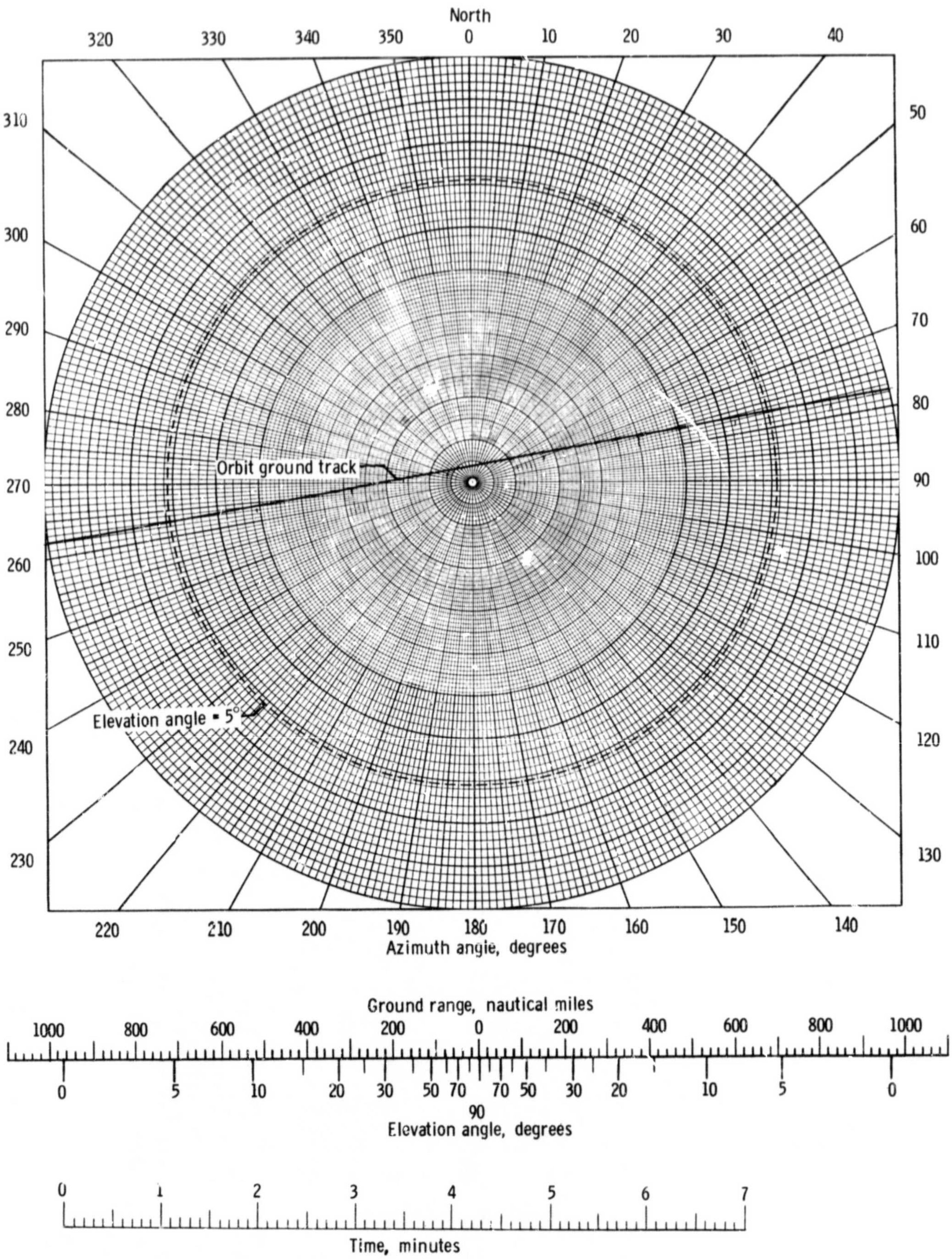
(b) Radar pointing data using values from polar graph (Figure 1 (a)).

Figure 1. - Continued.



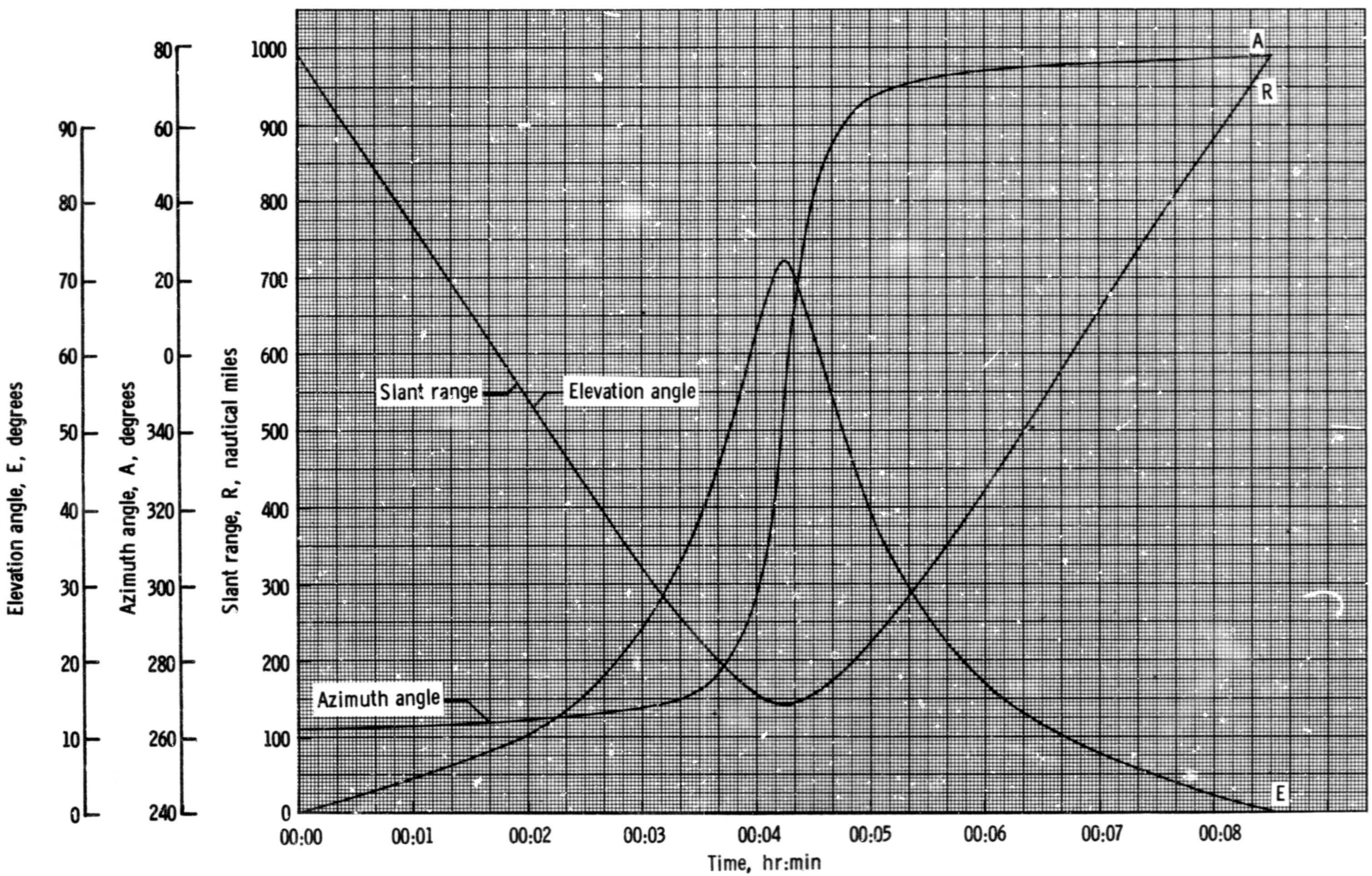
(c) Radar pointing data using actual values.

Figure 1. - Concluded.



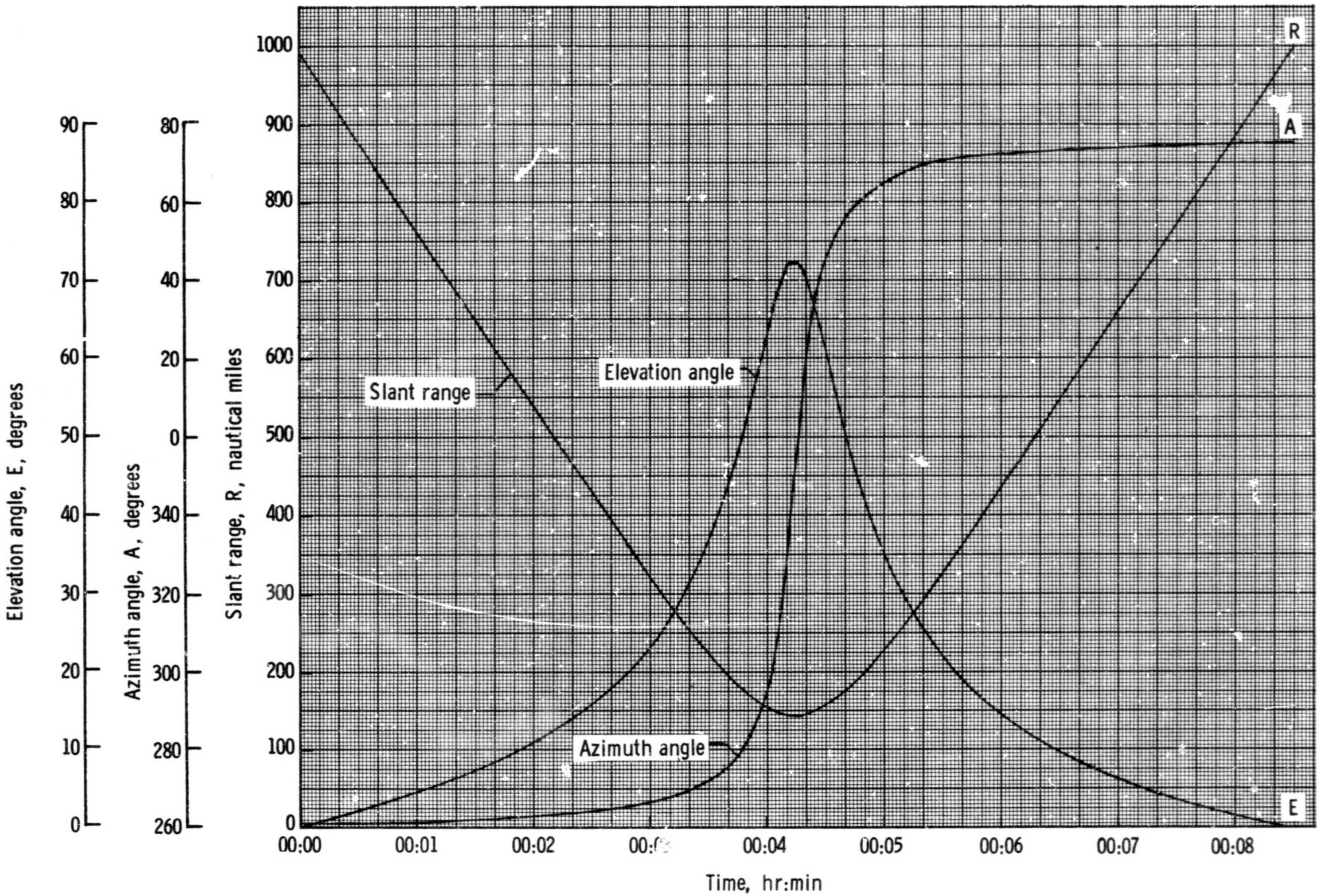
(a) Pointing data scales for 140 nautical mile orbital altitude with polar graph showing the orbit ground track of the vehicle.

Figure 2. - Radar tracking data of elliptical orbit (h_a=144 nm, h_p=87 nm, i=32.5°) for Muchea VERLORT radar, second orbit, second pass.



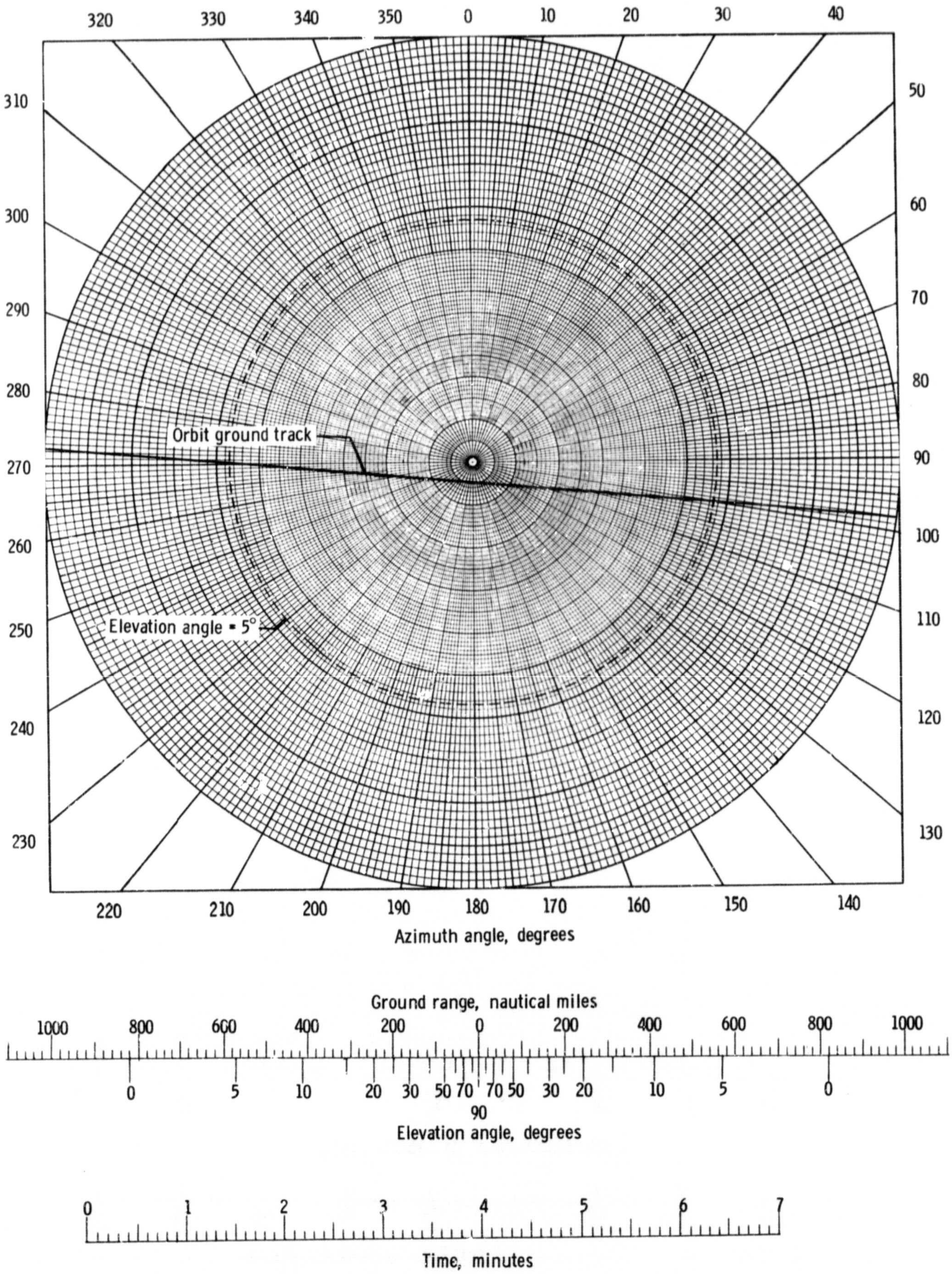
(b) Radar pointing data using values from polar graph (Figure 2 (a)).

Figure 2. - Continued.



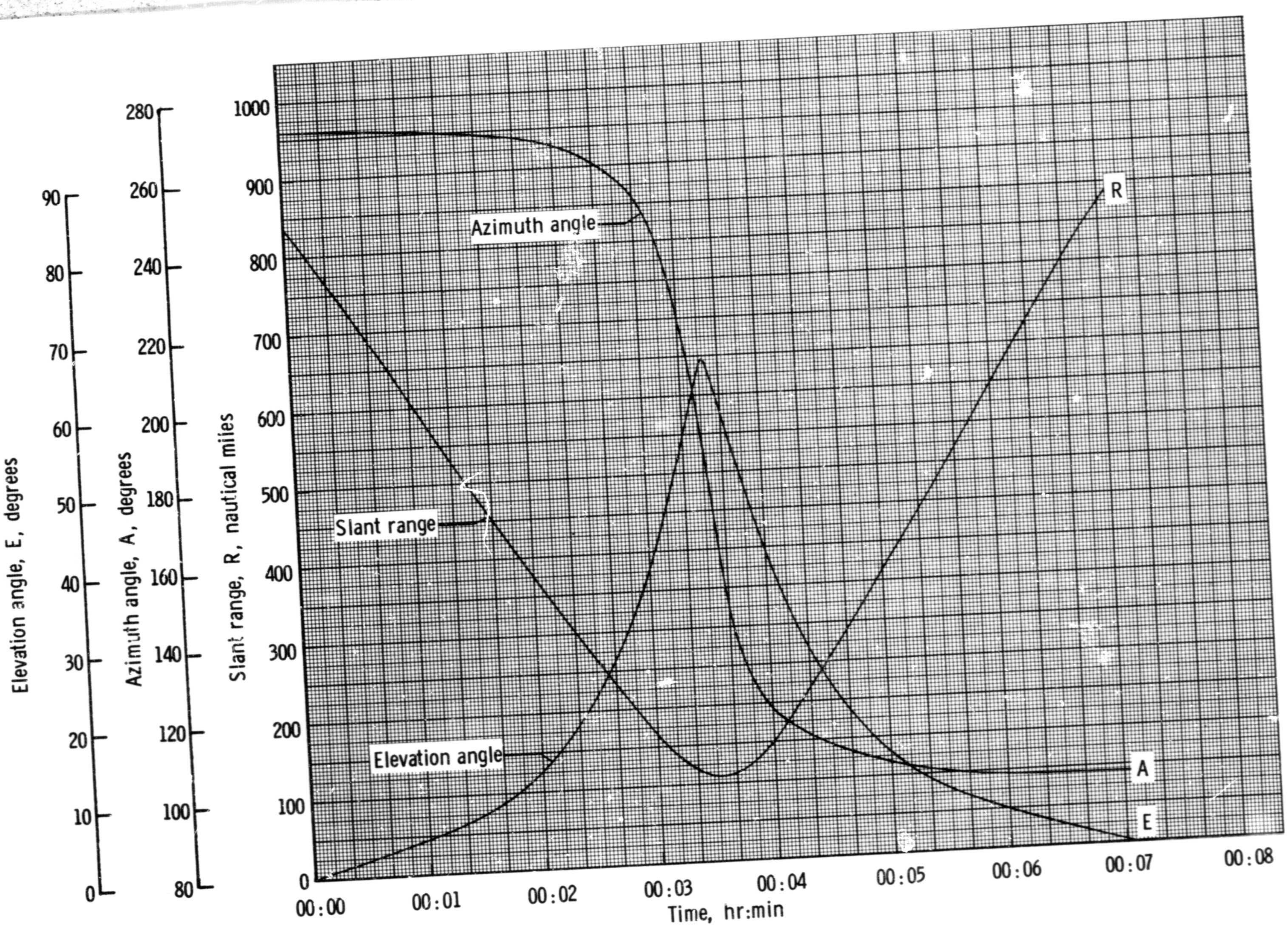
(c) Radar pointing data using actual values.

Figure 2. - Concluded.



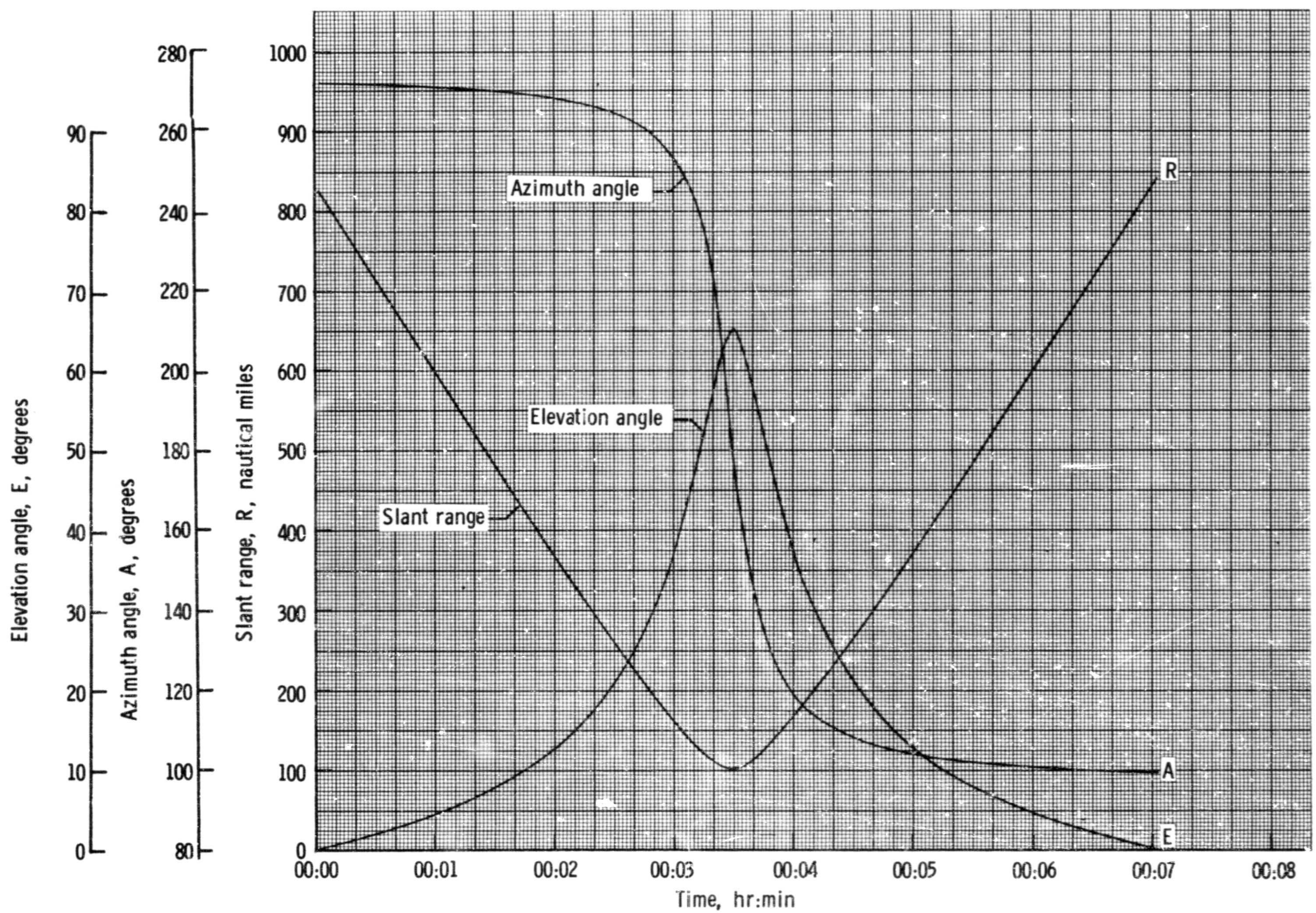
(a) Pointing data scales for 100 nautical mile orbital altitude with polar graph showing the orbit ground track of the vehicle.

Figure 3. - Radar tracking data of circular orbit (h=100 nm, i = 32°) for Bermuda, second orbit, second pass.



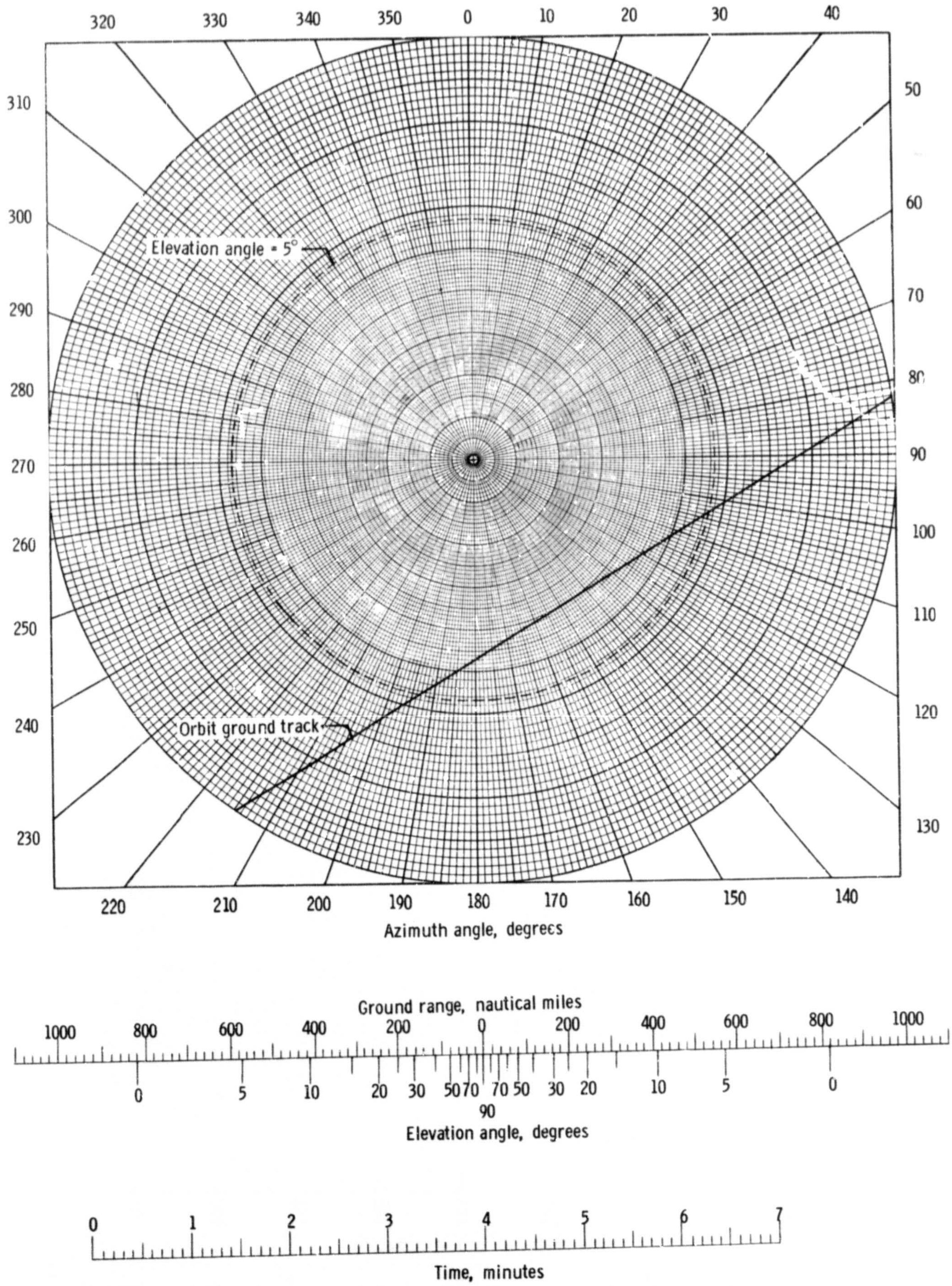
(b) Radar pointing data using values from polar graph (Figure 3 (a)).

Figure 3. - Continued.



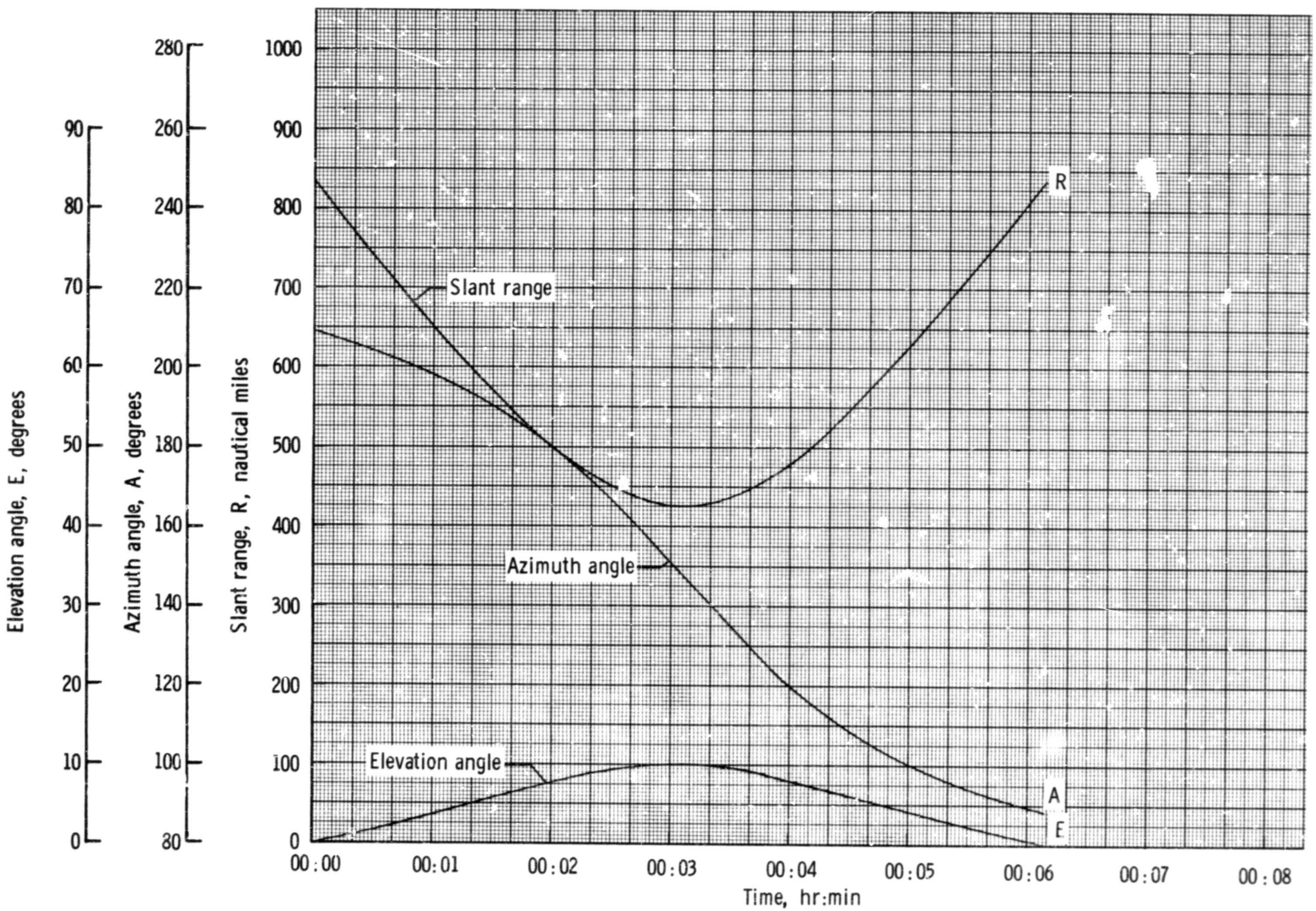
(c) Radar pointing data using actual values.

Figure 3. - Concluded.



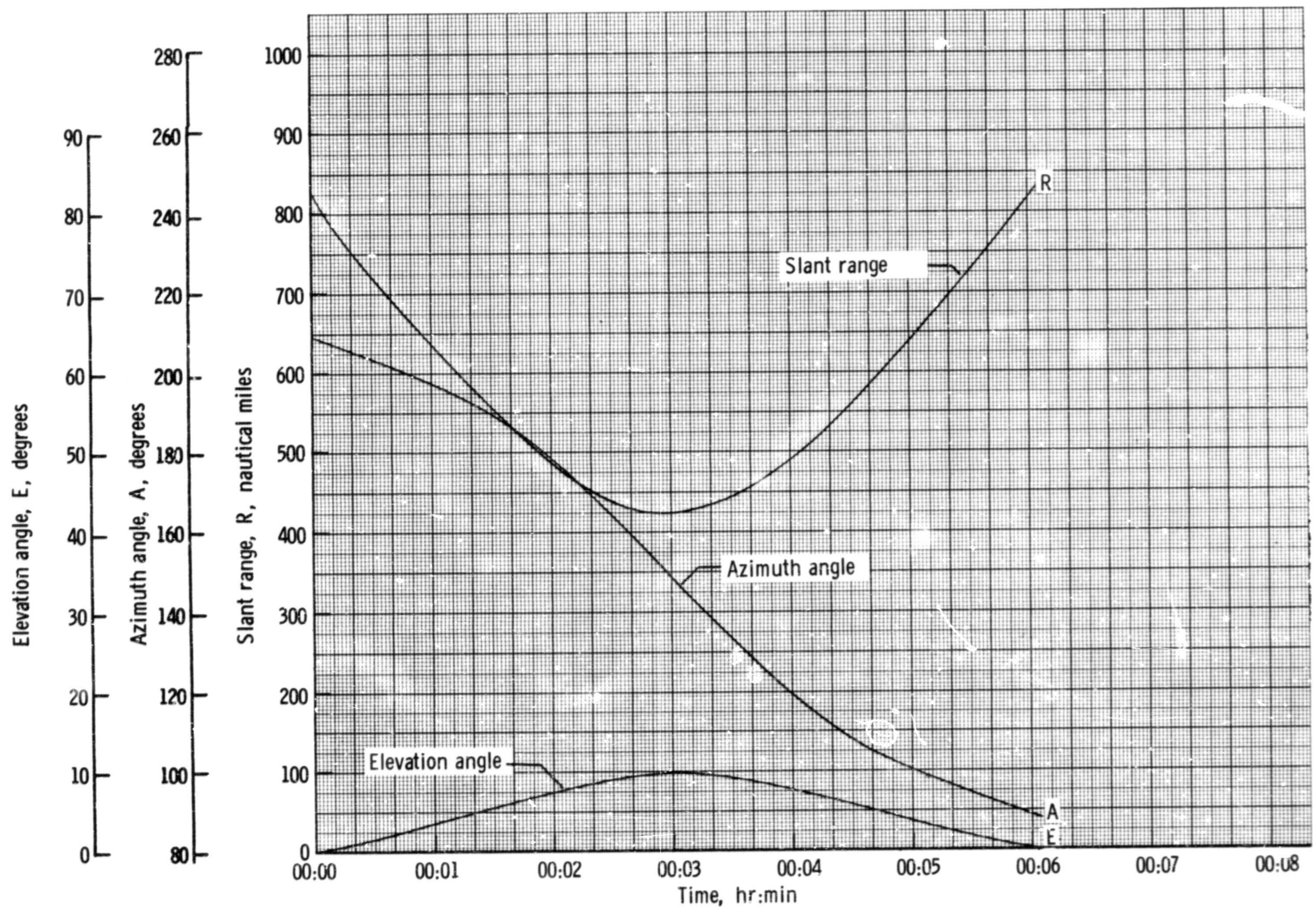
(a) Pointing data scales for 100 nautical mile orbital altitude with polar graph showing the orbit ground track of the vehicle.

Figure 4. - Radar tracking data of circular orbit (h=100 nm, I = 32°) for Hawaii, second orbit, second pass.



(b) Radar pointing data using values from polar graph (Figure 4 (a)).

Figure 4. - Continued.



(c) Radar pointing data using actual values.

Figure 4. - Concluded.

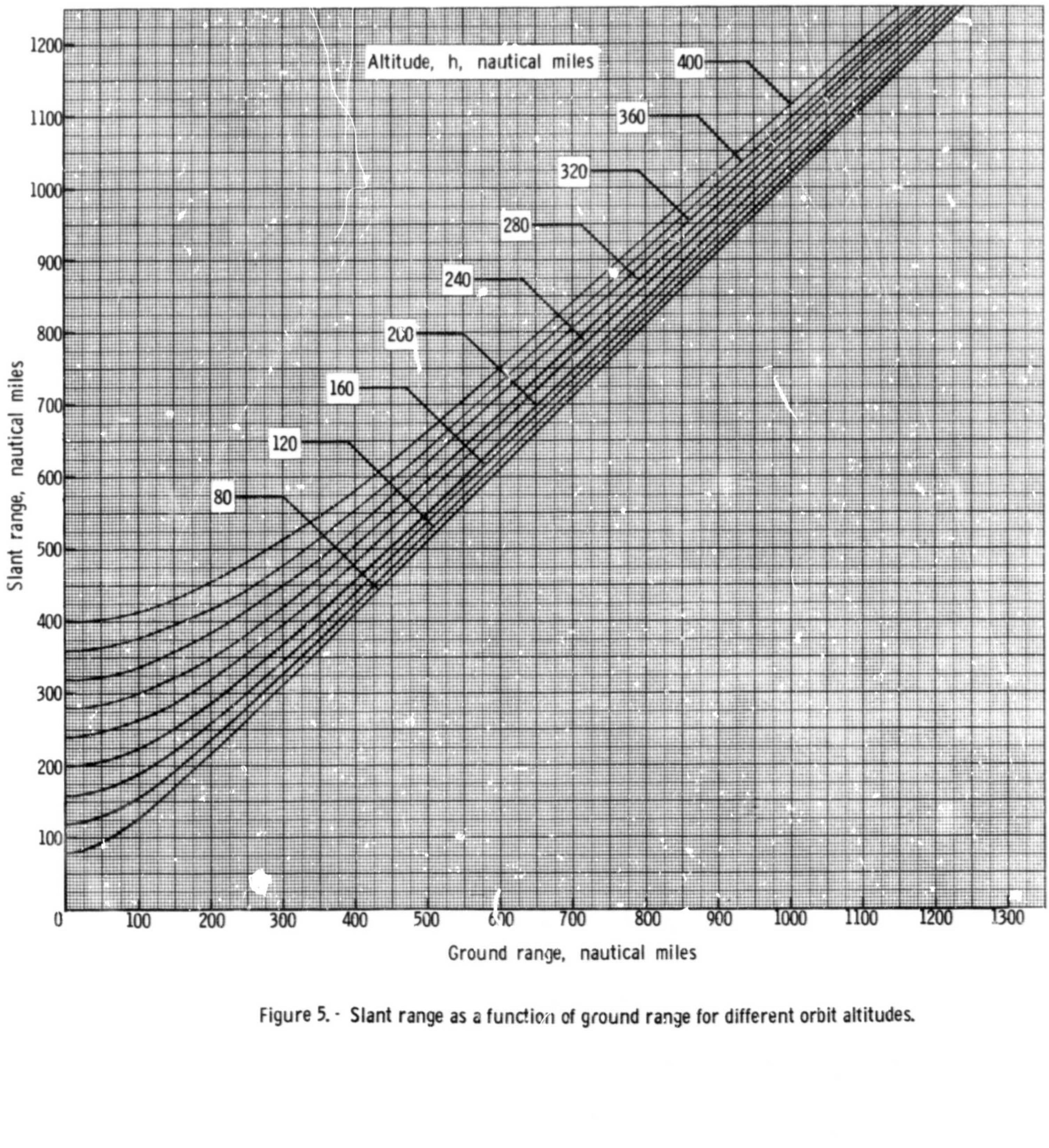


Figure 5. - Slant range as a function of ground range for different orbit altitudes.

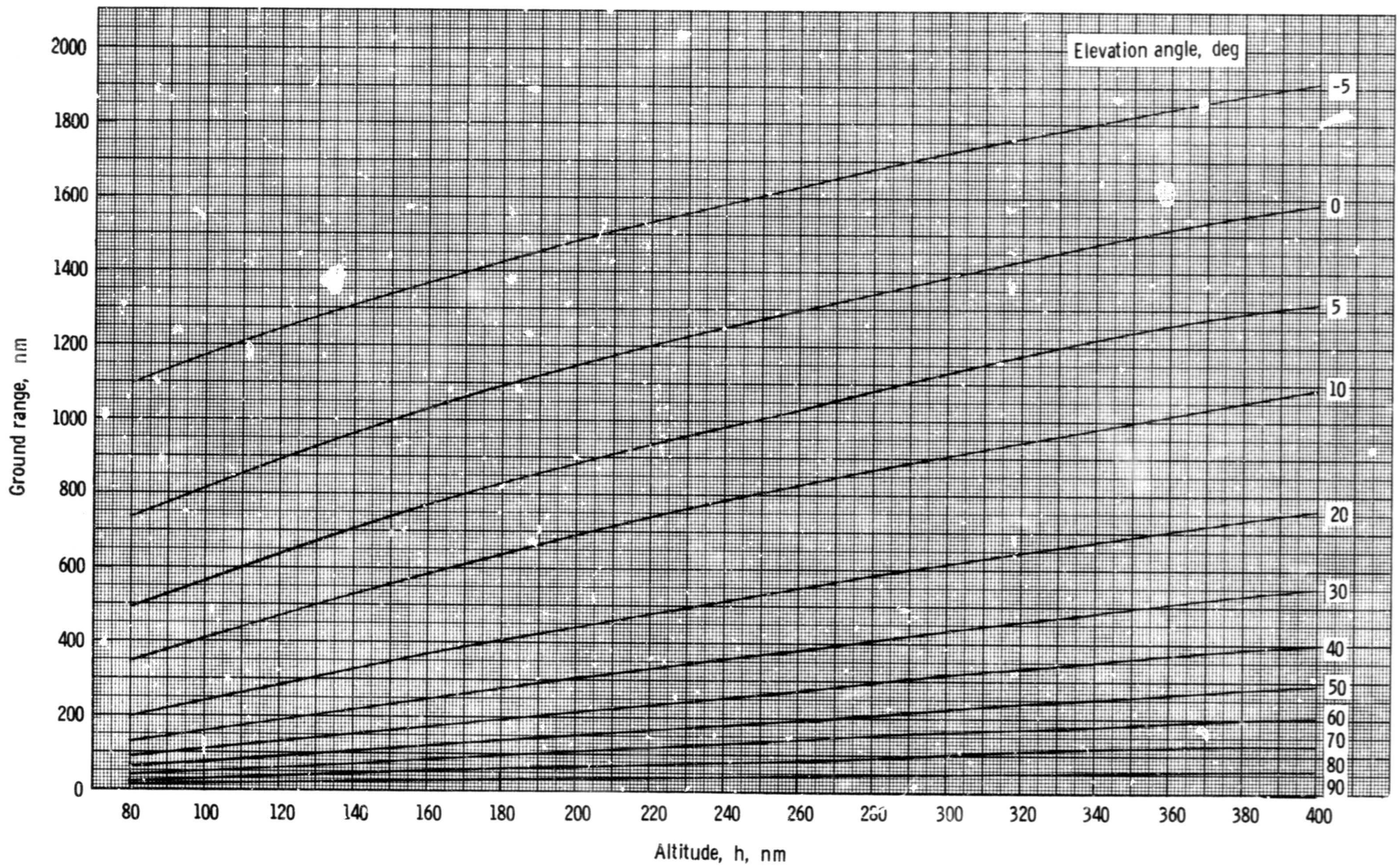


Figure 6. - Ground range as a function of altitude for different elevation angles.

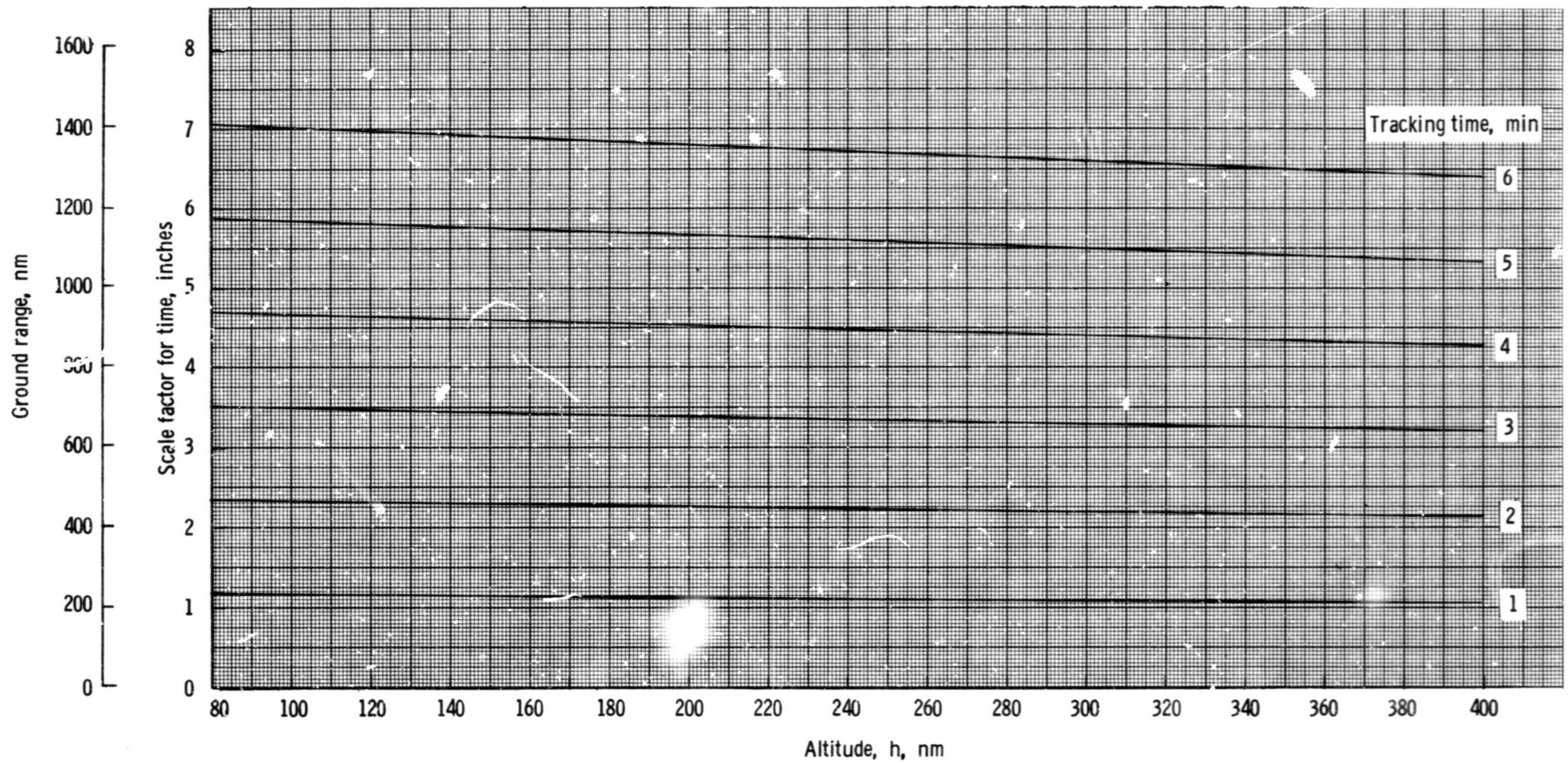
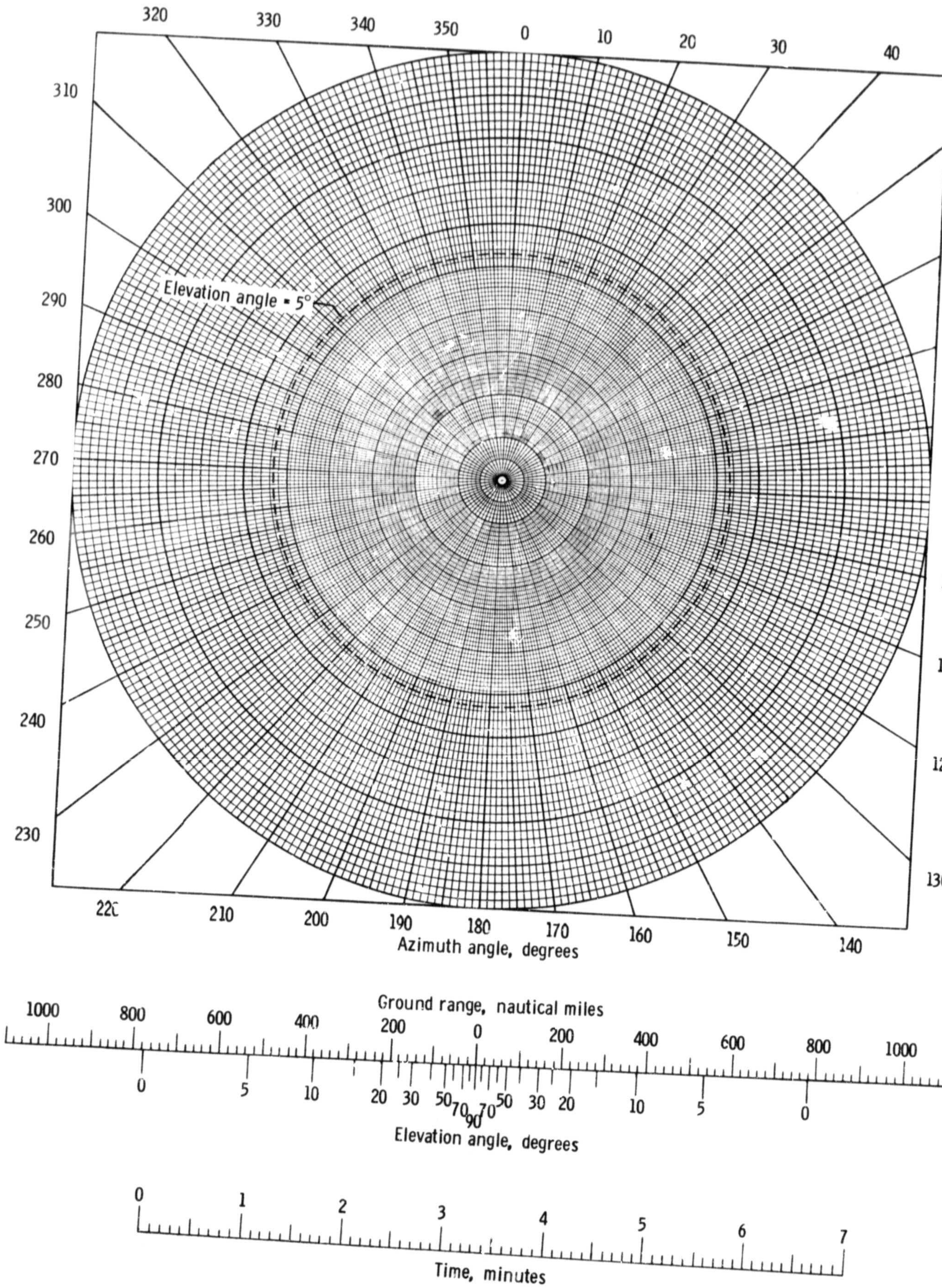
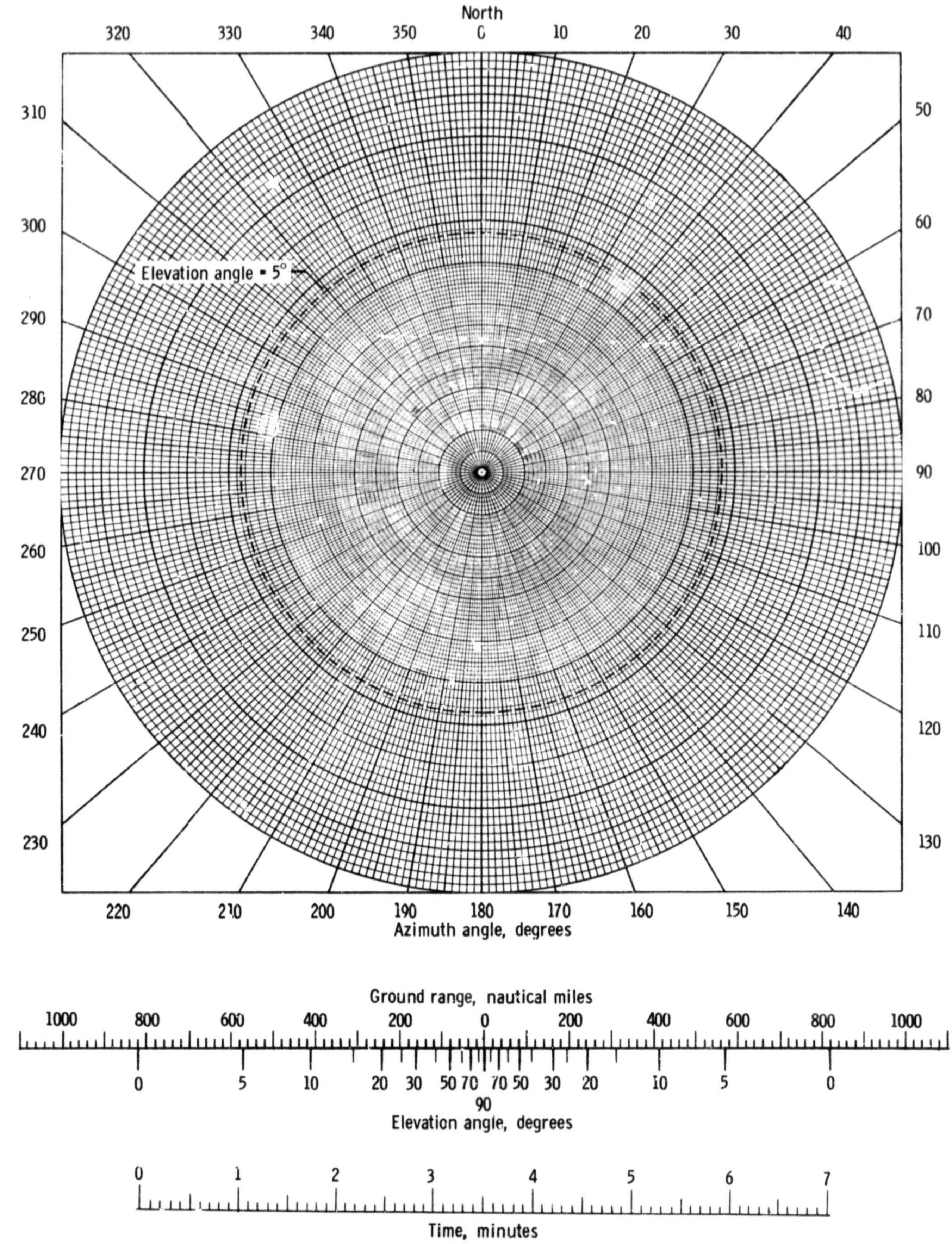


Figure 7. - Ground range as a function of altitude for determining radar tracking time.



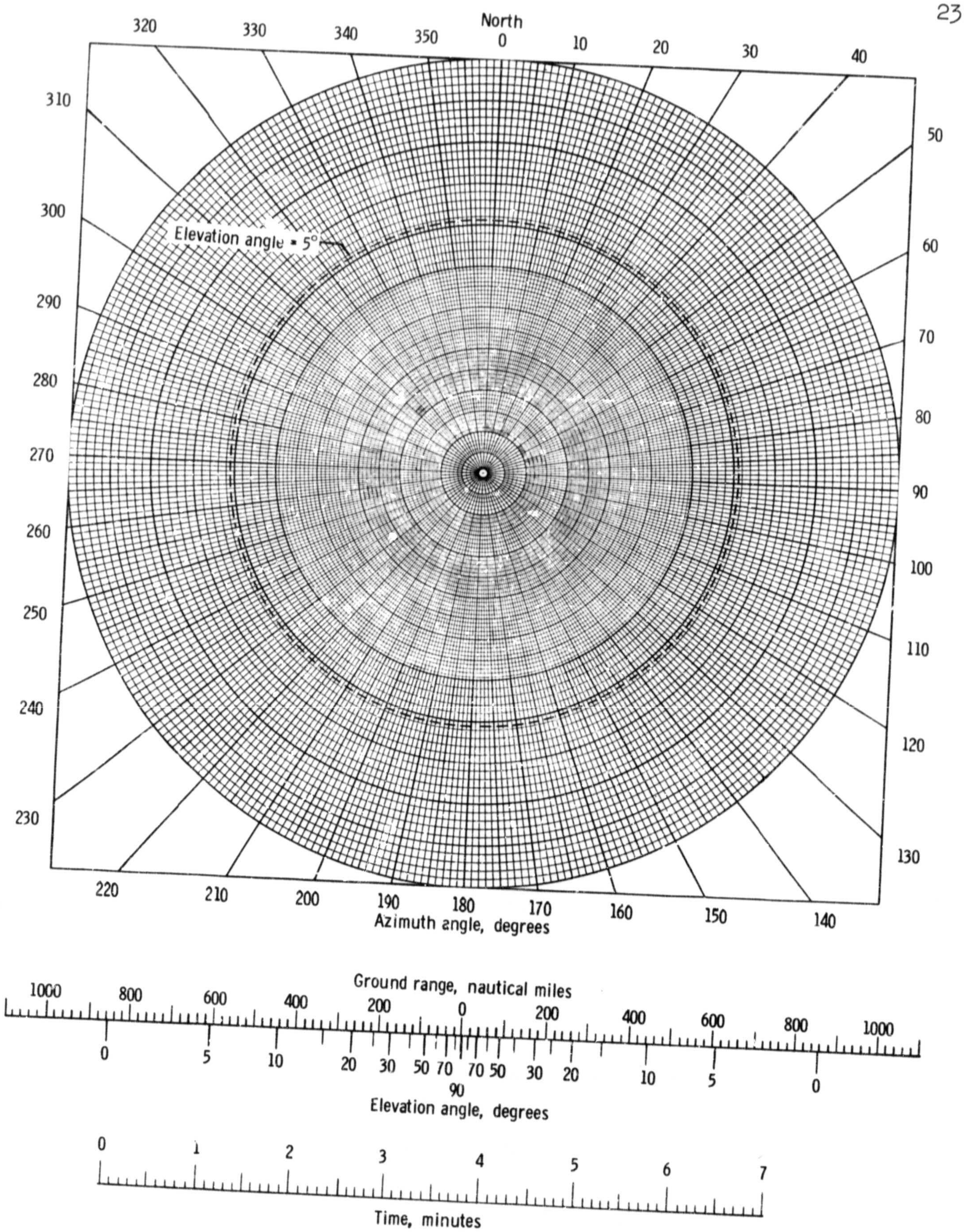
(a) 90 nautical mile orbital altitude.

Figure 8. - Polar maps for various orbital altitudes.



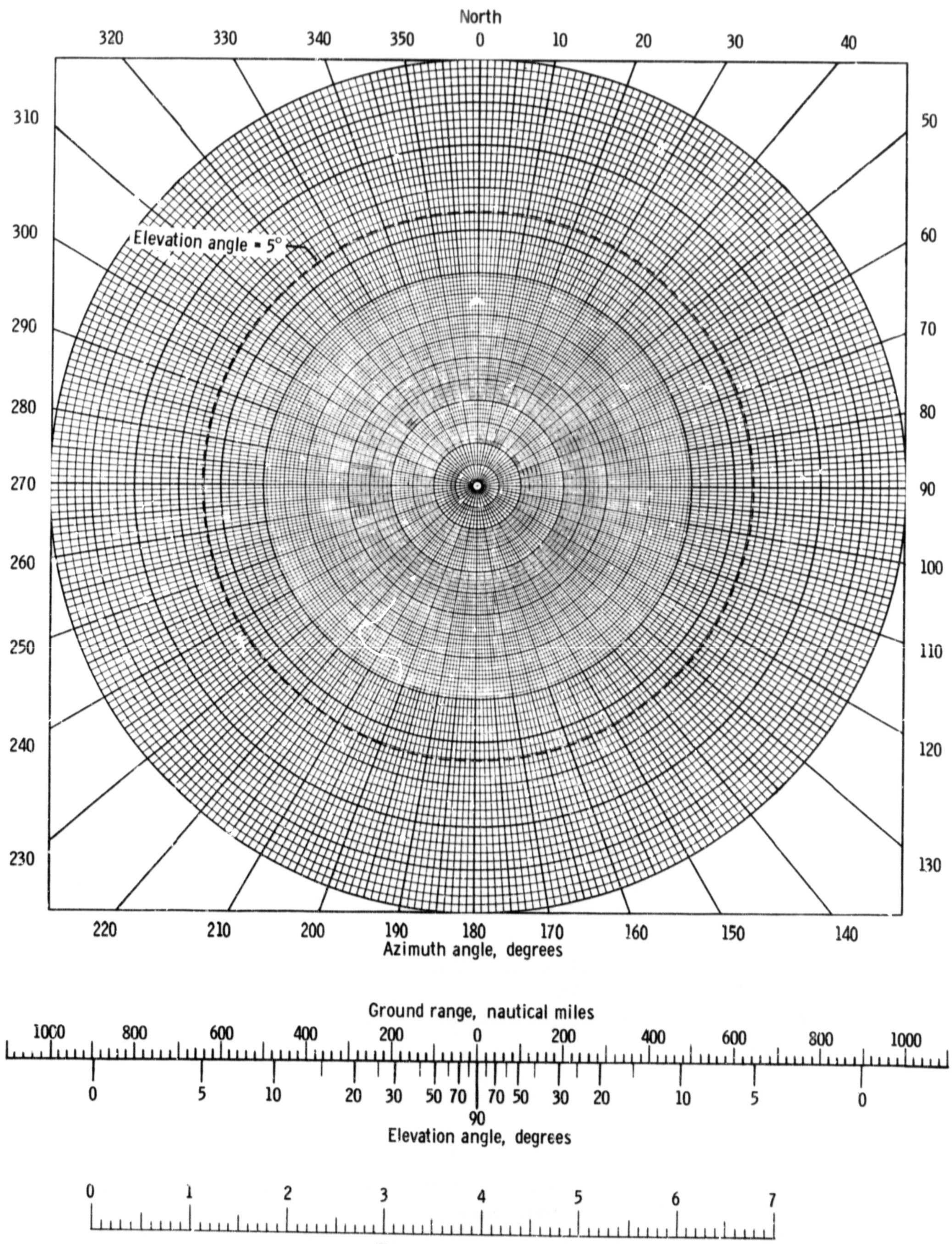
(b) 100 nautical mile orbital altitude.

Figure 8. - Continued.



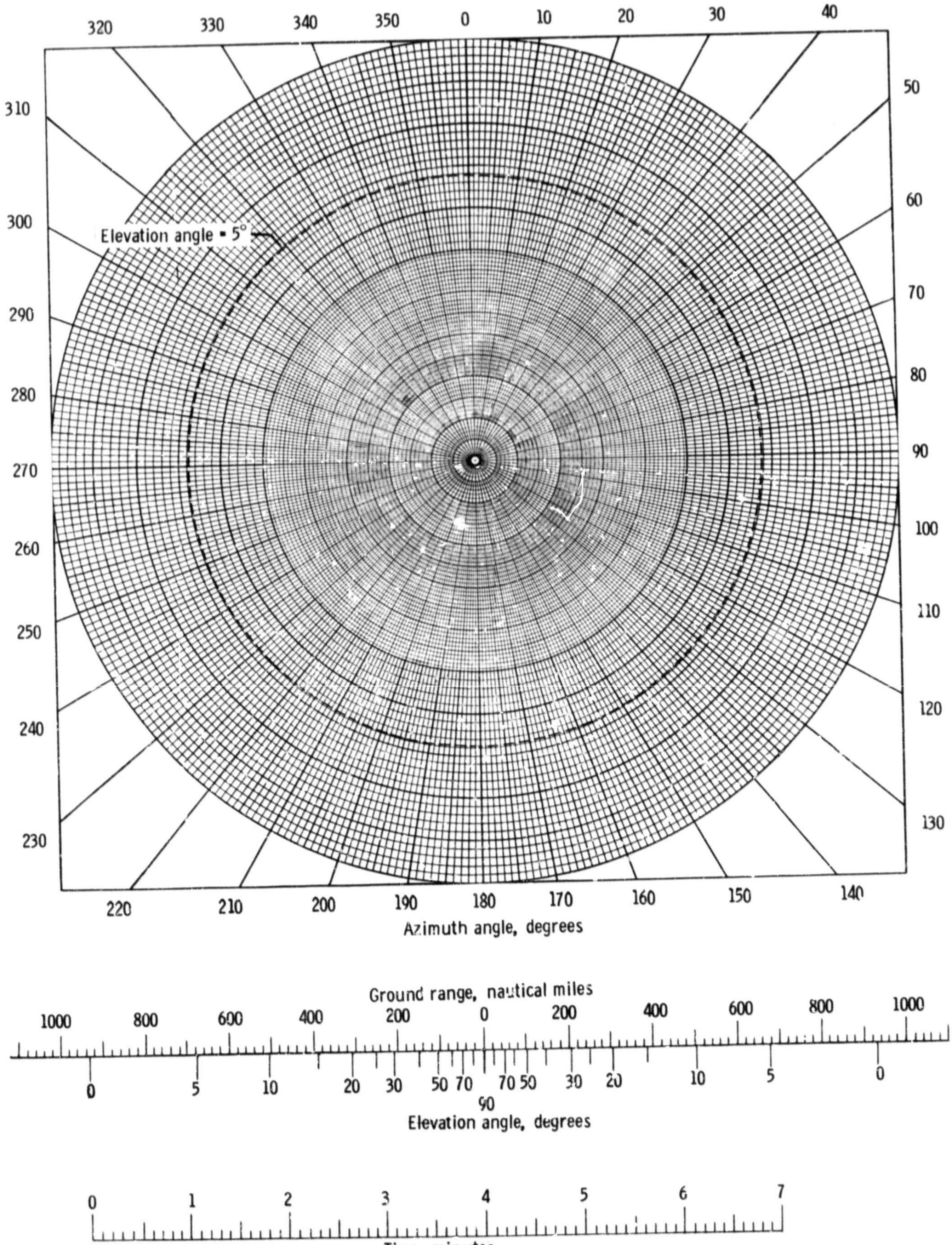
(c) 110 nautical mile orbital altitude.

Figure 8. - Continued.



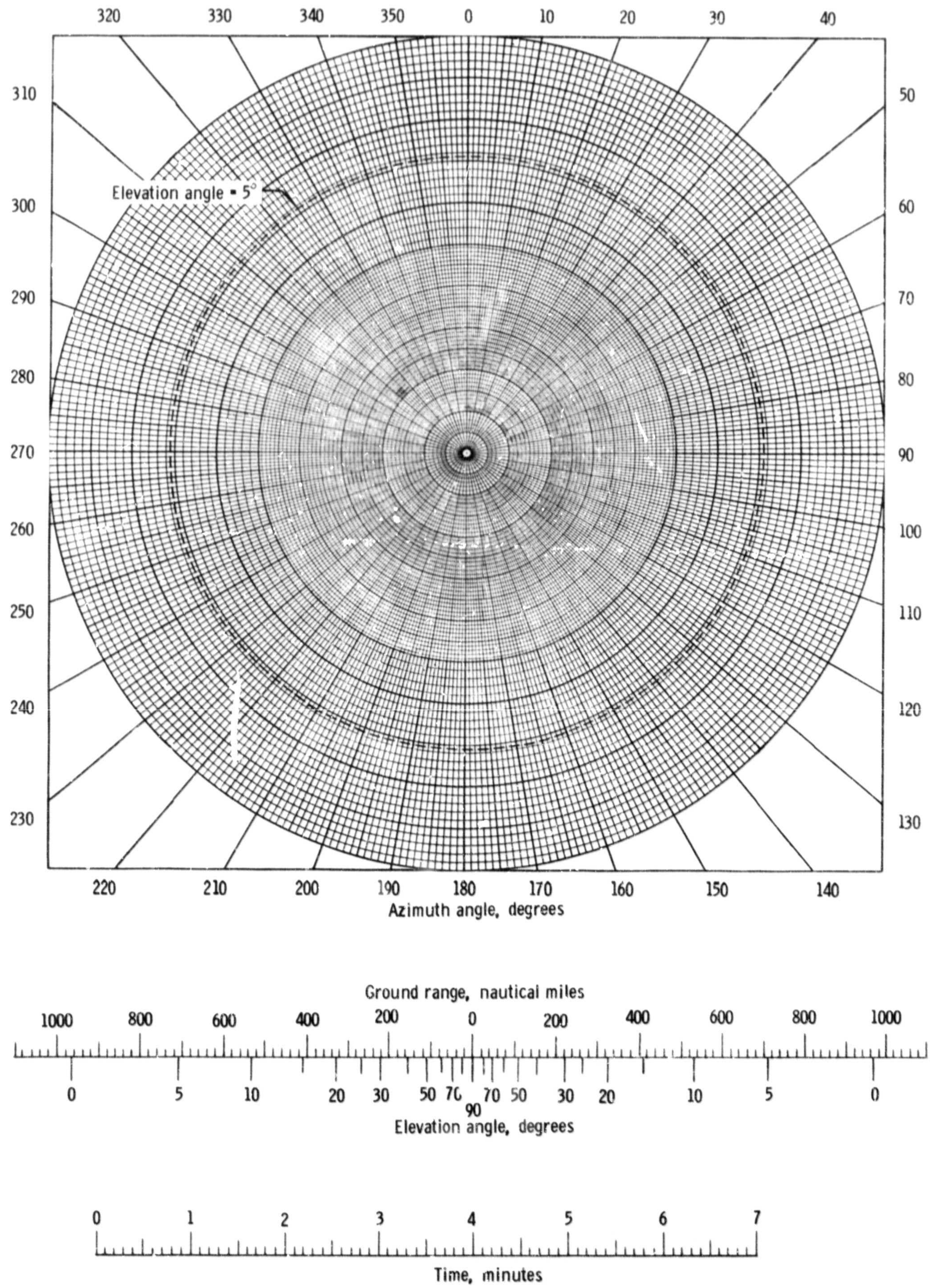
(d) 120 nautical mile orbital altitude.

Figure 8. - Continued.



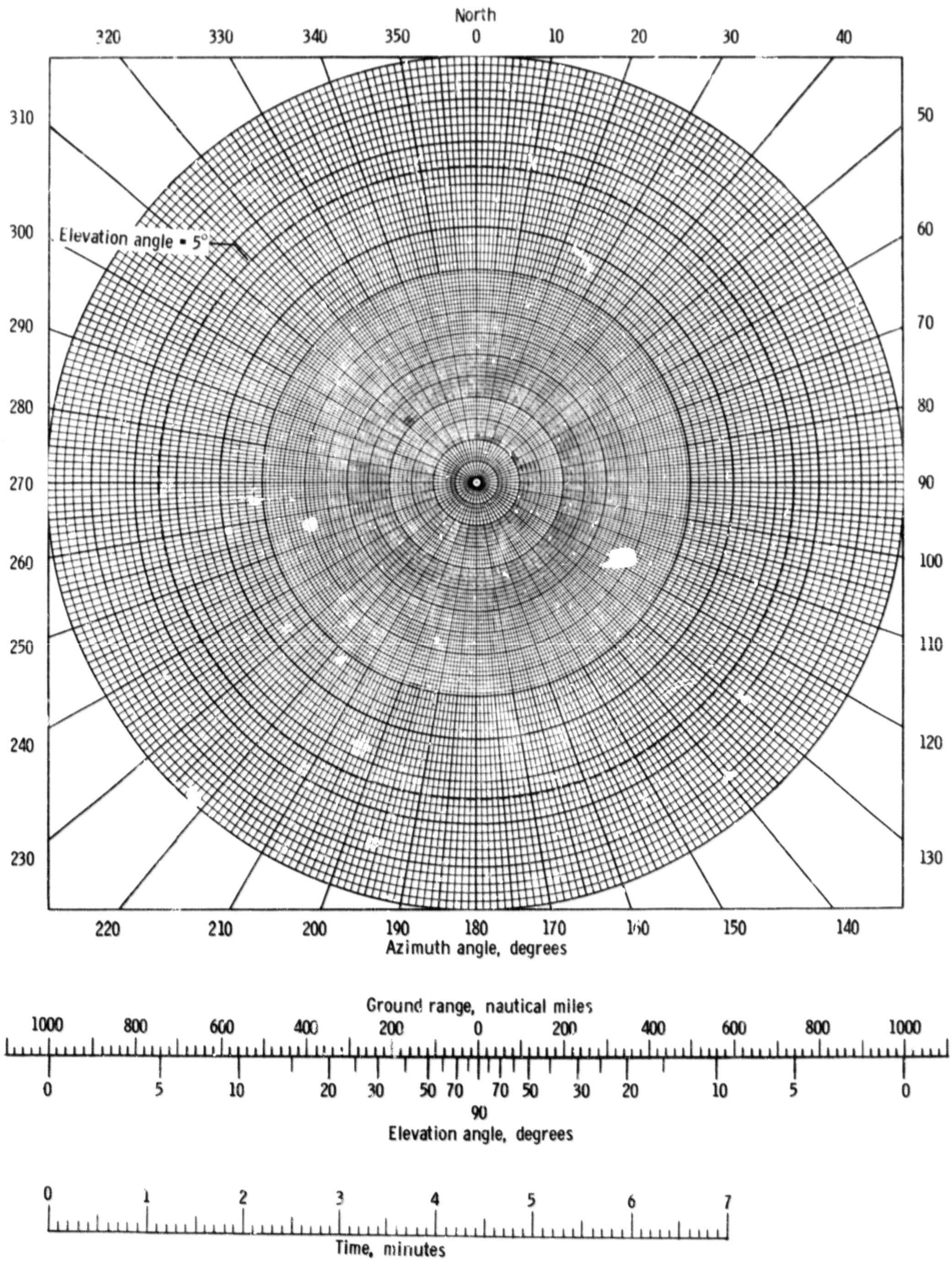
(e) 130 nautical mile orbital altitude.

Figure 8. - Continued.



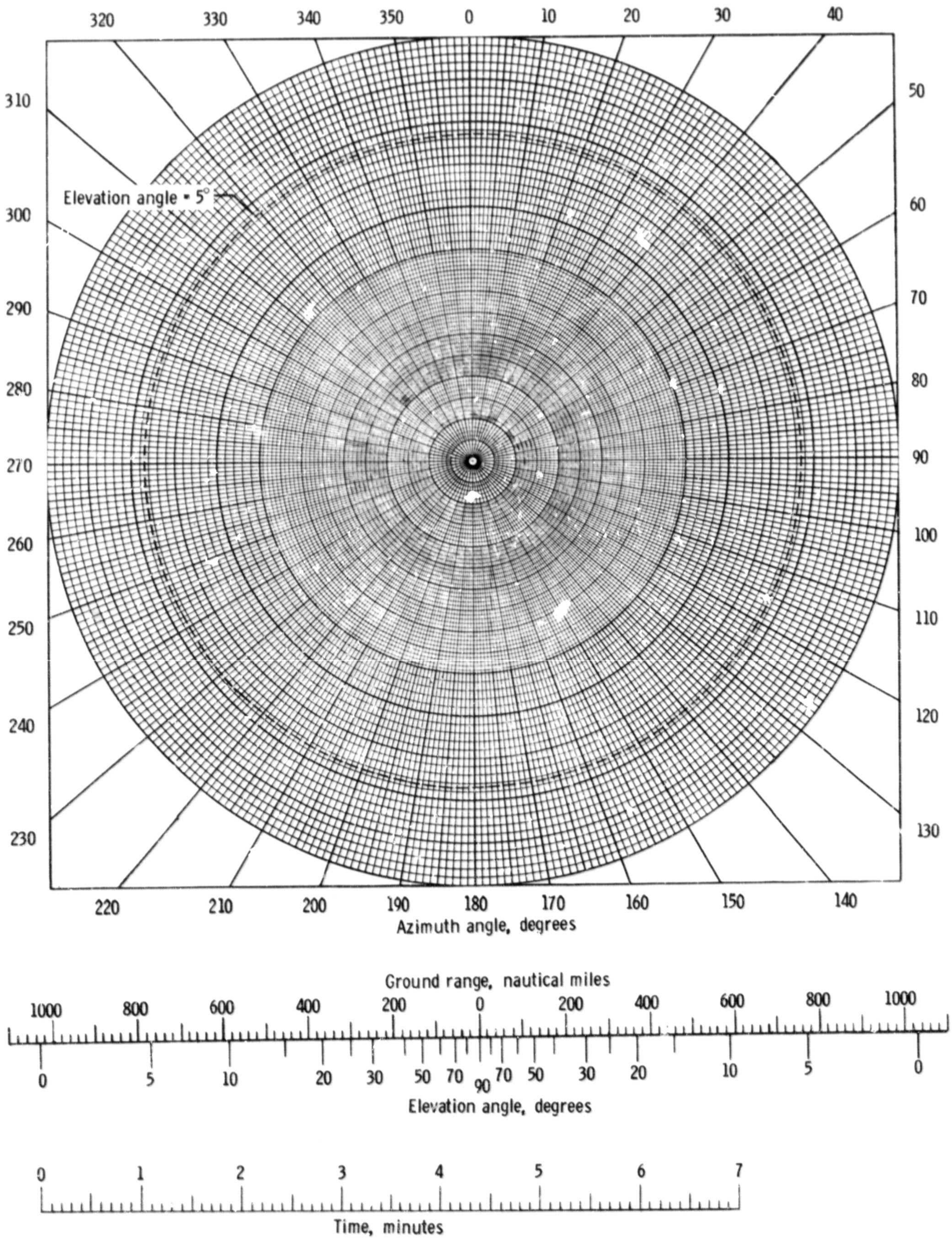
(f) 140 nautical mile orbital altitude.

Figure 8. - Continued.



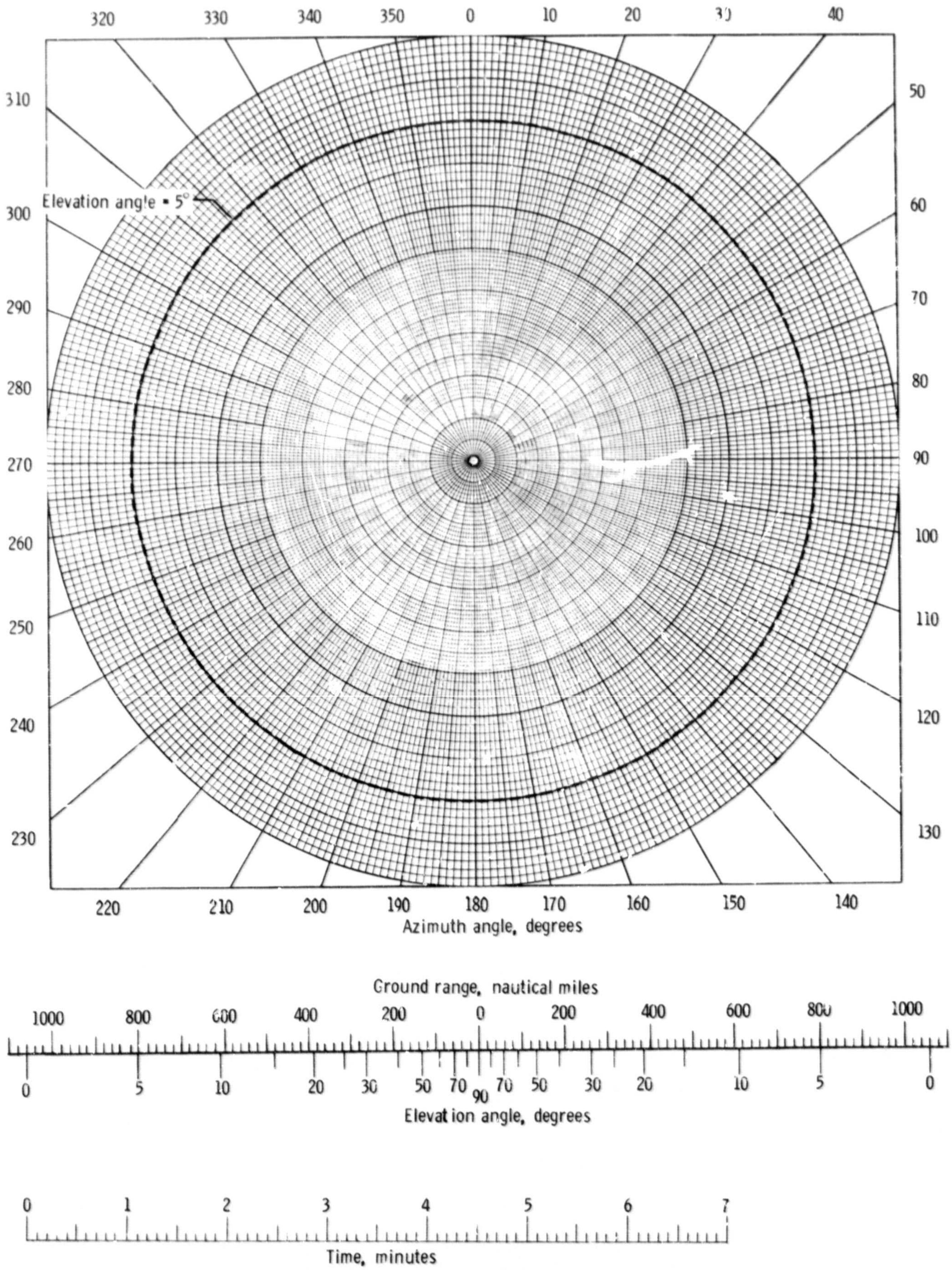
(g) 150 nautical mile orbital altitude.

Figure 8. - Continued.



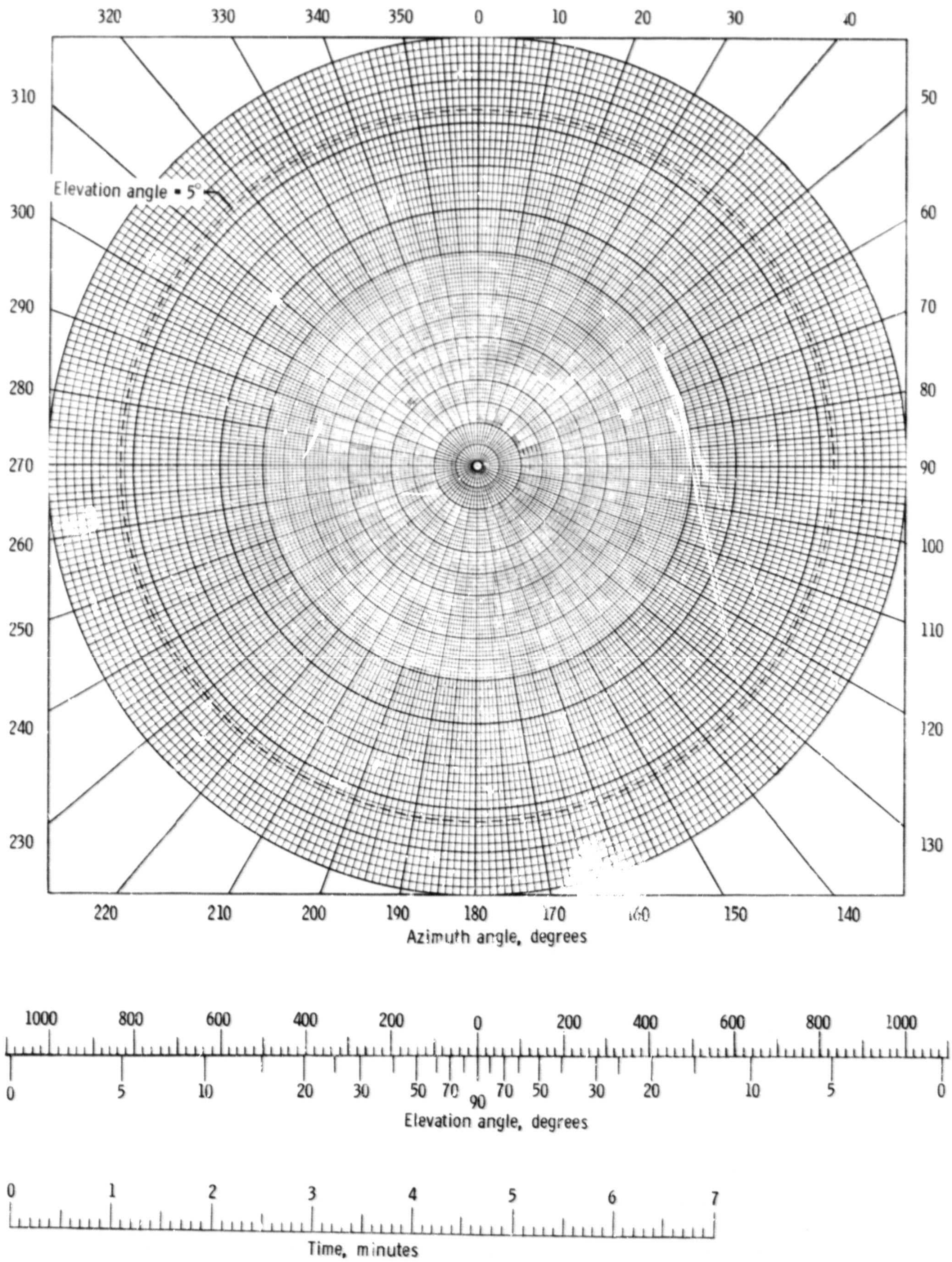
(h) 160 nautical mile orbital altitude.

Figure 8. - Continued.



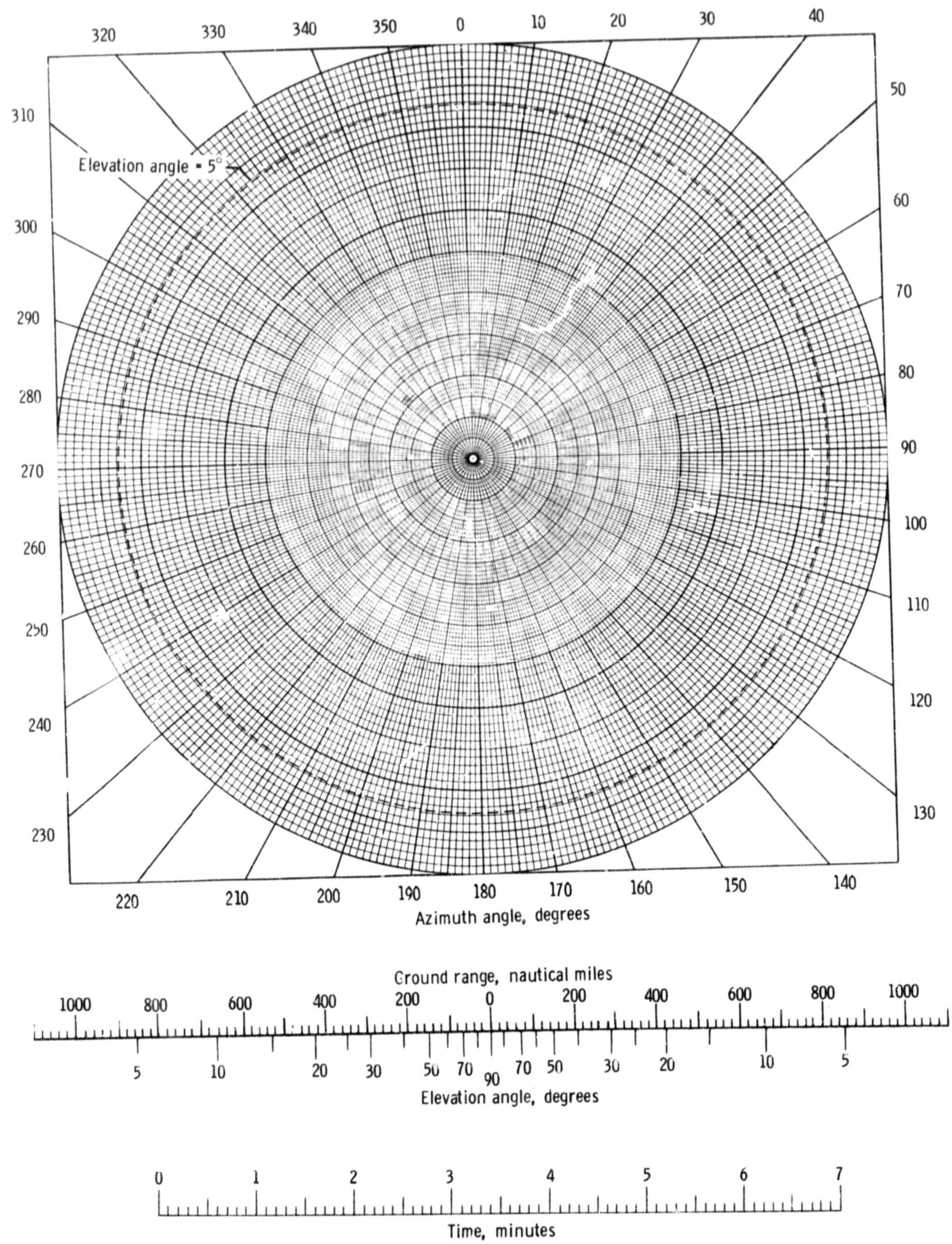
(i) 170 nautical mile orbital altitude

Figure 8. - Continued.



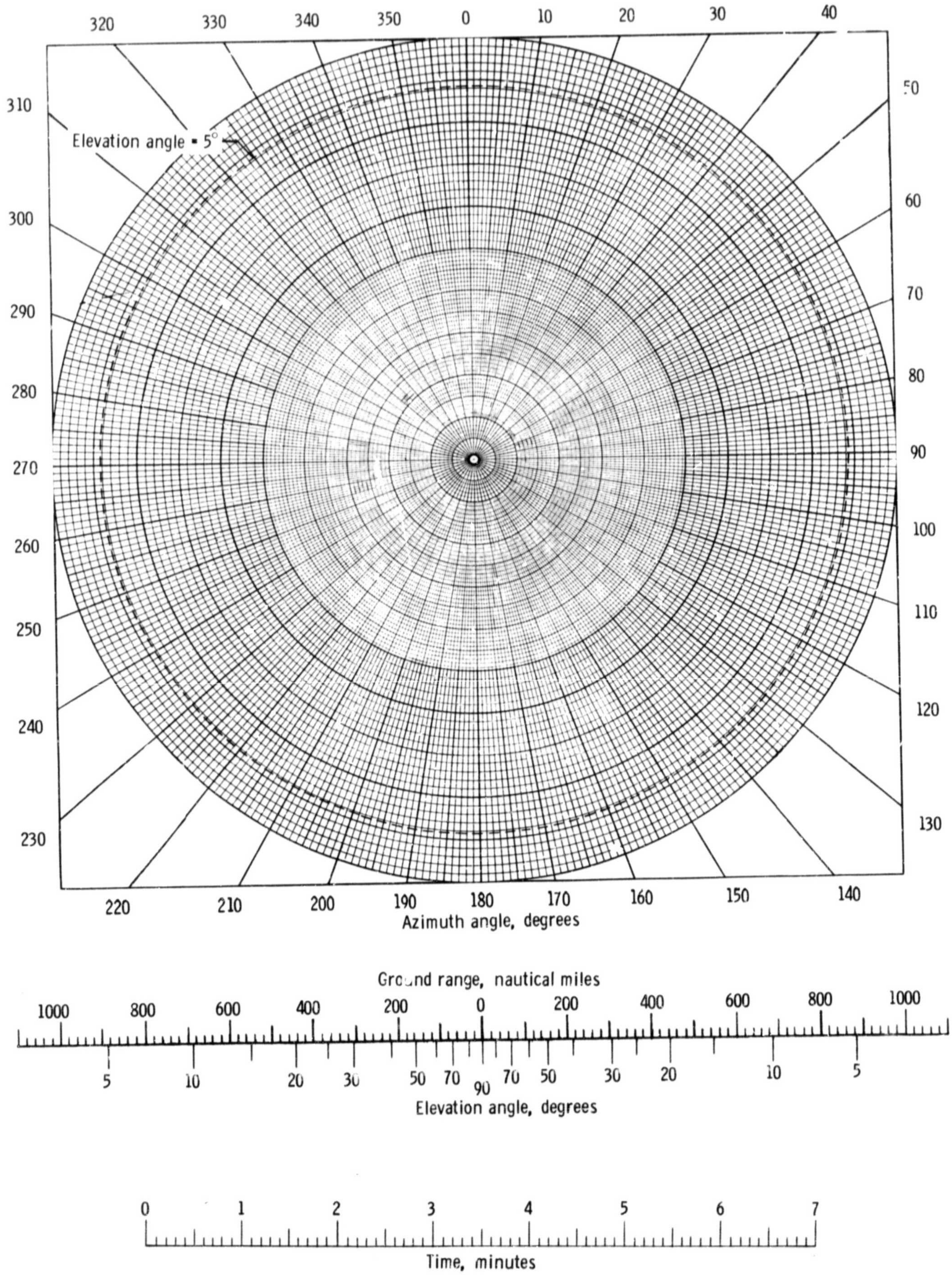
(j) 180 nautical mile orbital altitude.

Figure 8. - Continued.



(k) 190 nautical mile orbital altitude.

Figure 8. - Continued.



(l) 200 nautical mile orbital altitude.

Figure 8. - Concluded.

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