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NAFEC TECHNICAL LETTER REPORT

NA- 80-7-LR

ARSR-3 BEACON ANTENNA TESTS AT NASHWAUK, MINNESOTA, AND ARLINGTON, IOWA

by

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Approved by _____

JOSEPH M. DEL BALZO
Director, National Aviation Facilities
Experimental Center
Federal Aviation Administration
Department of Transportation

ABSTRACT

Flight tests were made on June 12, 1979, at Nashwauk, Minnesota, and on June 14, 1979, at Arlington, Iowa, to obtain vertical lobing patterns on the ARSR-3 beacon antenna. Filmed measurements show that the antenna patterns were generally acceptable compared to tests made at other en route antenna sites. As expected, the width of the ARSR-3 beams was about 50 percent wider than NAFEC Dipole Feed (NADIF) antennas, producing long run lengths.

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INTRODUCTION

PURPOSE.

The purpose of this study is to obtain baseline data on the vertical lobing patterns of ARSR-3 beacon antennas which were installed at two en route sites.

BACKGROUND.

In response to a request by Airways Facilities (AAF-310), a flight test was made on June 12, 1979, at the air route surveillance radar (ARSR-3) site at Nashwauk, Minnesota, and data were collected at the Minneapolis Air Route Traffic Control Center (ARTCC). A similar flight test was made on June 14, 1979, at the Arlington, Iowa, ARSR-3 site. The Arlington site was commissioned on June 25, 1979, becoming part of the National Airspace System (NAS). Plots of the patterns are presented in the appendix.

TEST PROCEDURE

During the flight test of June 12, 1979, high-speed film data were obtained in the National Aviation Facilities Experimental Center (NAFEC) B-727 aircraft N-40, and common digitizer (CD) digital tapes were made at the Minneapolis and Chicago centers. Six radial runs were made in the morning flight over the Nashwauk site at an altitude of 20,000 feet, with the ARSR-3 antenna at a -1° tilt. The radials flown were 130°, 315°, and 220°. Six more radial runs were made in the afternoon flight over Nashwauk at the 20,000-foot altitude on radials of 40°, 130°, and 315°, with the ARSR-3 antenna at a zero-degree tilt. The tilt used and radials chosen were as requested by the regional office. The directional power of the air traffic control beacon interrogator (ATCBI-5) transmitter was 160 watts, and the omni power was 500 watts. The sensitivity time control (STC) was -46 decibels (dB) at 1 nautical mile (nmi) and increased 6 dB per octave. Figure 1 is a diagram of the flight test system.

On June 14, 1979, a similar flight test was made over the Arlington, Iowa, ARSR-3 site at an altitude of 20,000 feet. Seven radial runs were made with the normal -1° tilt of the ARSR-3. The radials flown were 320°, 140°, 80°, and 245°. The directional power at the Arlington transmitter (ATCBI-5) was 175 watts, and the omni power was 700 watts. The STC curve was also -46 dB. Table 1 shows the test plan summary.

DISCUSSION OF RESULTS

The continuous film in the aircraft was used to record complete scans of the uplink signals from the directional and omni antennas. A typical vertical pattern (figure 2) was obtained by plotting the peak value of the P3 and P2 pulses of each scan versus range. Plots of the patterns for all flights are presented in the appendix.

Some sections have been taken from the recorded film to show the typical appearance of the uplink signals as the ARSR-3 antenna scans past the aircraft. Figure 3 is an enlargement showing the envelope of the P3 pulses in the directional beam and includes some nearby sidelobes. The aircraft was 10 nmi from Nashwauk on the 220° radial. The continuous P2 pulses from the omni can also be seen as pairs of pulses having a relatively constant amplitude. In figure 3, the P2 pulses appear in pairs because the interlace sequence is 3, 3, and C, but the P2 from mode C, because of its timing, does not appear in front of the camera on our oscilloscope.

In figure 4, the aircraft was 30 nmi from Nashwauk on the same 220° radial. In figure 5, the aircraft was 80 nmi from Nashwauk on the 220° radial, and it can be seen that the P2 pulses dropped into the noise level.

Figure 6 is a section showing 131° of azimuth of scan 54 where the aircraft was 6 nmi from the Nashwauk site on the 315° radial in run 4. This shows how the sidelobes extend on both sides of the main beam when the aircraft is at relatively short range.

Similar enlargements were used to produce the plots shown in figures 7, 8, and 9. By a careful tracing procedure, the relative shape of the main beam has been plotted for ranges of 6, 60, and 100 nmi on run 5 at Arlington. The receiver calibration is accurate to $\pm 1/2$ dB.

In each figure, the peak of the main beam was translated upward to the zero-dB reference point, and then an accurate plot of antenna gain versus degrees of azimuth was made. In figures 7, 8, and 9 the azimuth pattern is lopsided, due to the beacon antenna being mounted on the leading edge side of the ARSR-3 radar horn. This characteristic lopsidedness occurred in the data for all runs at both ARSR-3 sites. It is more pronounced at short ranges and higher elevation angles and decreases at longer ranges and lower elevation angles.

In figure 7, the width of the beam is 6.2° at the 20-dB point down from the peak of the beam. This was the pattern received in the aircraft when the range was 6 nmi. In figure 8, at a range of 60 nmi, the beam width was 5.2° at the 20-dB point down from the peak. In figure 9, at a range of 100 nmi,

TABLE 1. SUMMARY OF TEST PLAN

NASHWAUK

TILT = -1°

Run No.	RADIAL (Degrees)	Direction
1	130	Outbound
2	130	Inbound
3	315	Outbound
4	315	Inbound
5	220	Outbound
6	220	Inbound

TILT = 0°

7	40	Outbound
8	40	Inbound
9	130	Outbound
10	130	Inbound
11	315	Outbound
12	315	Inbound

ARLINGTON

TILT = -1°

Run No.	RADIAL (Degrees)	Direction
1	320	Outbound
2	320	Inbound
3	140	Outbound
4	140	Inbound
5	80	Outbound
6	80	Inbound
7	260	Outbound

the beam width was also 5.2° at the 20-dB point. These figures indicate that the beam width is essentially independent of range. These results show that the azimuth beam width of the ARSR-3 beacon antenna is about the same as an FA 7202 "hog trough" antenna, and about 50 percent wider than the typical NAFEC Dipole Feed (NADIF) beacon antenna.

Figures 10 and 11 are comparisons of ARSR-3 antennas and the ARSR-2 NADIF. There are no antenna pattern standards for the ARSR-3 when it is installed at an operational site. Airways Facilities considers coverage acceptable when a site is made operational at the time of commissioning.

Figures 12 through 16 are photographs of the plan position indicator (PPI) display of beacon replies at Arlington. In figure 12, all targets are shown in the full 200-nmi range, and many targets appear as long arcs because of the wide antenna beam; i.e., long run length. Actually two complete scans were photographed to provide intensity, causing the high-speed aircraft to appear as double slashes. In figure 13, the maximum range was changed to 60 nmi. Near the bottom of the photograph at 170° azimuth, an example of beacon reply garbling can be seen. Garbling of codes between two aircraft occurs more frequenty when the run length is long than it does when the run length is short.

Figure 14, is a multiple exposure to show the path of the flight test aircraft on discrete code 5063 as the aircraft flies inbound on the 140° radial during run 4. The aircraft turned around between 120 and 130 nmi range. Figure 15, shows the track of the NAFEC aircraft flying outbound on the 80° radial during run 5. Full scale in figure 15 is 60 nmi.

Figure 16, shows the track of the aircraft inbound on the 80° radial during run 6. After passing over the site, the aircraft circled to the right to prepare for the next outbound run. Notice that many replies were missed in two scans between 75 and 70 nmi range. The reasons are unknown at the present time. This caused the aircraft to be reported south of its true 80° radial position. Also, between 120 and 95 nmi, the run length went through three nulls in the antenna pattern. This can be checked by examining the plot of signal versus range for run 6 in the appendix (page A-6). This is <u>not</u> a significant deficiency, but shows how short run lengths correlate with nulls in the vertical antenna pattern. Measurements of targets of opportunity during the test flight determined that the beacon run lengths for many targets between 100 and 200 nmi range were often as long as 55 to 65 hits.

CONCLUSIONS

1. The antenna patterns obtained were considered acceptable in areas tested at 20,000 feet altitude and ranges between zero and 120 nmi for both sites when compared to other en route antennas.

2. The directional beam was about 50 percent wider than NADIF antennas at some sites previously tested, producing long run lengths.

3. No significant lobing effects were found in the first 100 nmi of range, but vertical lobing nulls do appear beyond 100 nmi at 20,000 feet altitude.

This effort was conducted under NPD 03-173, ATCRBS Engineering Applications, Subprogram 031-241, ATCRBS Transmitter Site Improvements, Project 820, ATCRBS Antenna Field Problems. The NAFEC Program Manager was Carl Hazelwood. Data for all the flight test runs are available at ANA-130. Information may be obtained by contacting the Project Manager, William Sullivan, ANA-130.

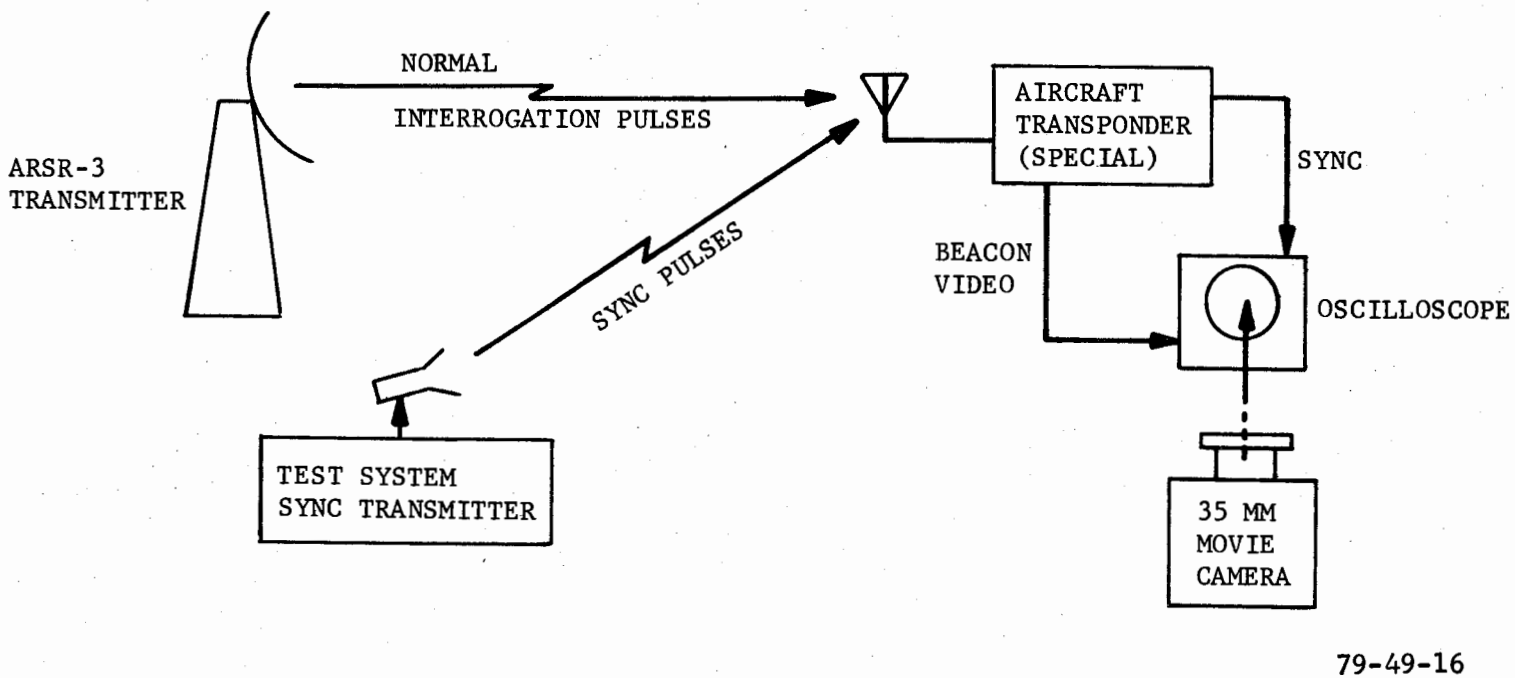


FIGURE 1. FLIGHT TEST SYSTEM

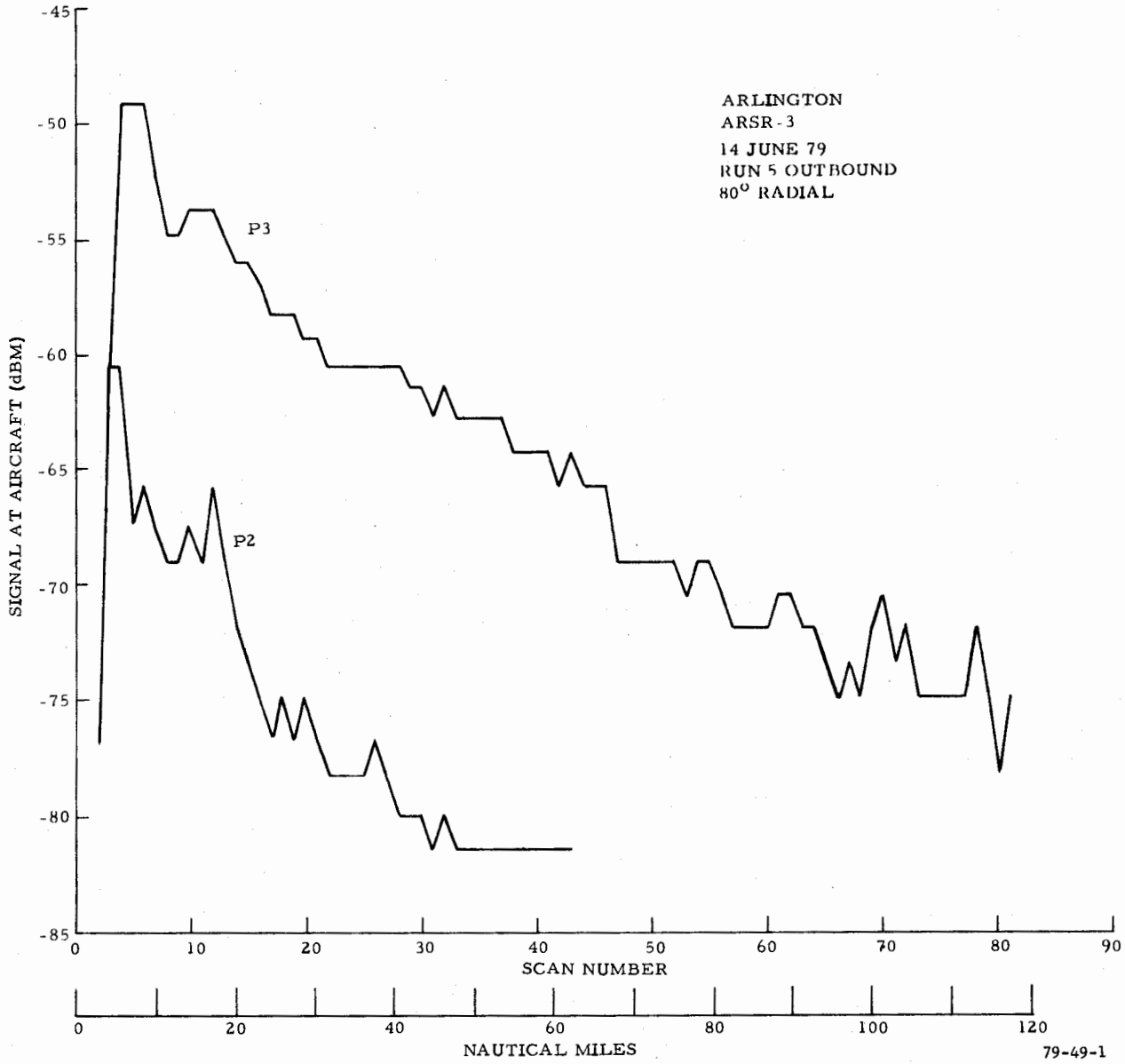


FIGURE 2. ARLINGTON VERTICAL LOBING PATTERN

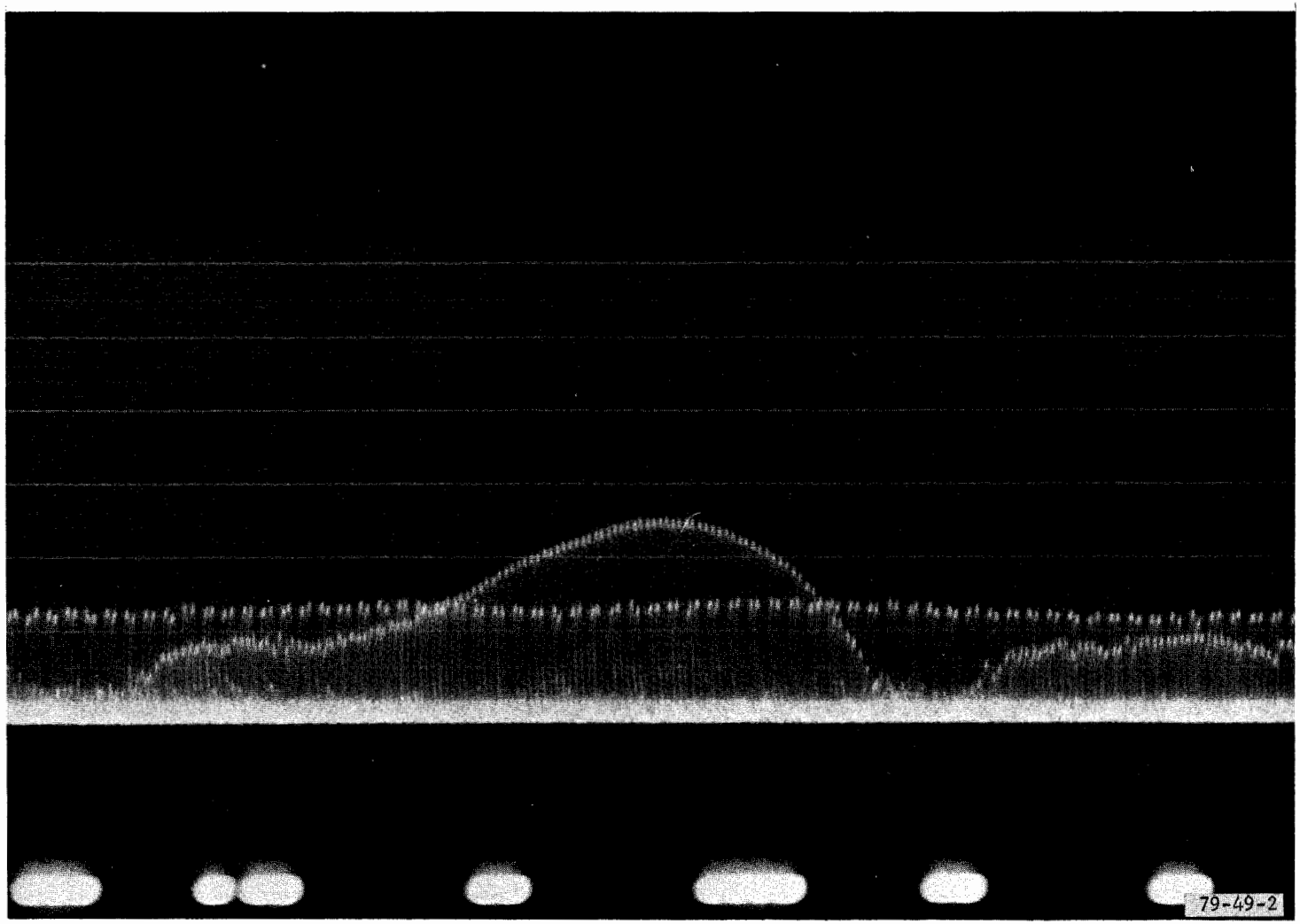


FIGURE 3. NASHWAUK RUN 5, 220° RADIAL AT 10 NMI RANGE

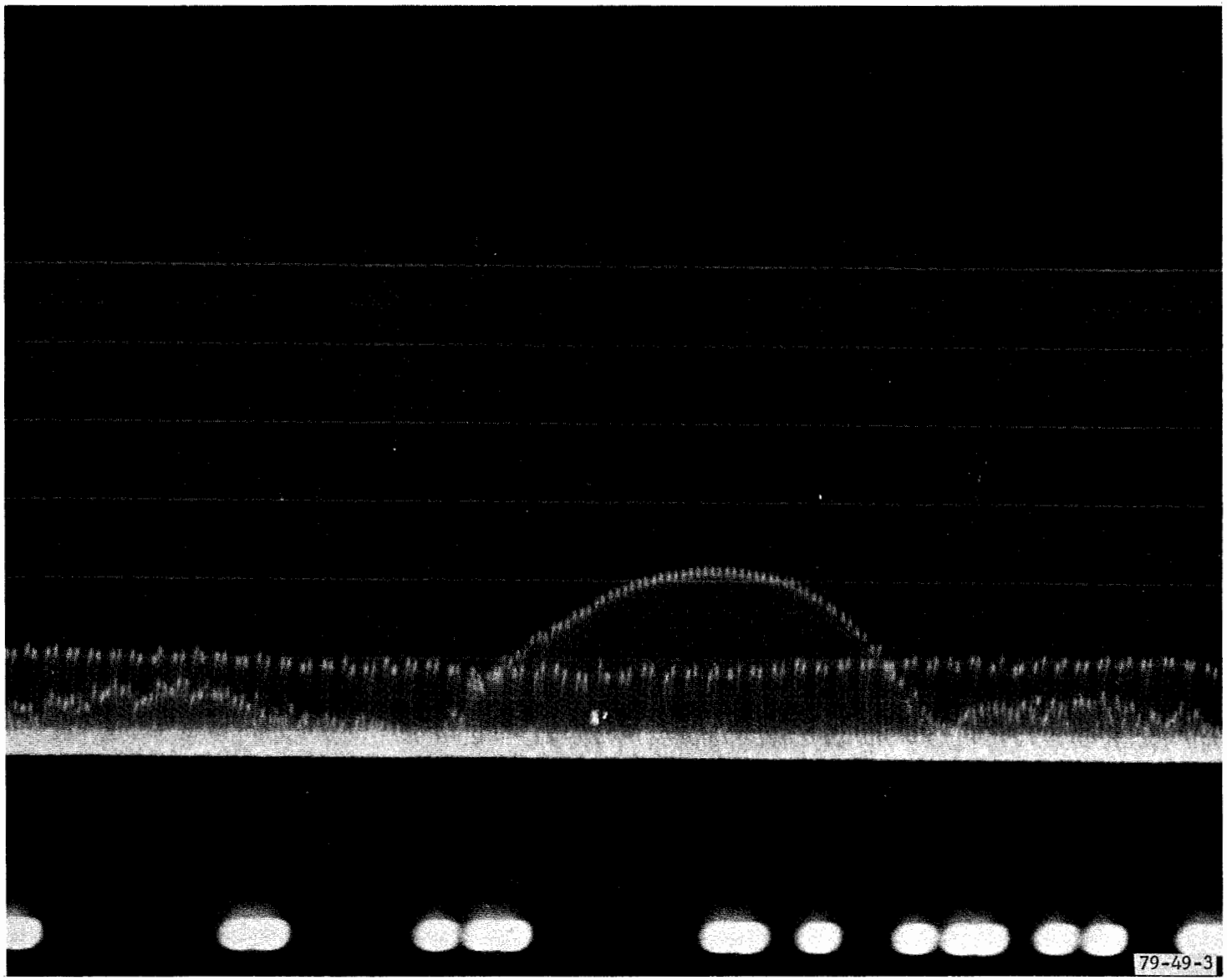


FIGURE 4. NASHWAUK RUN 5, 220° RADIAL AT 30 NMI RANGE

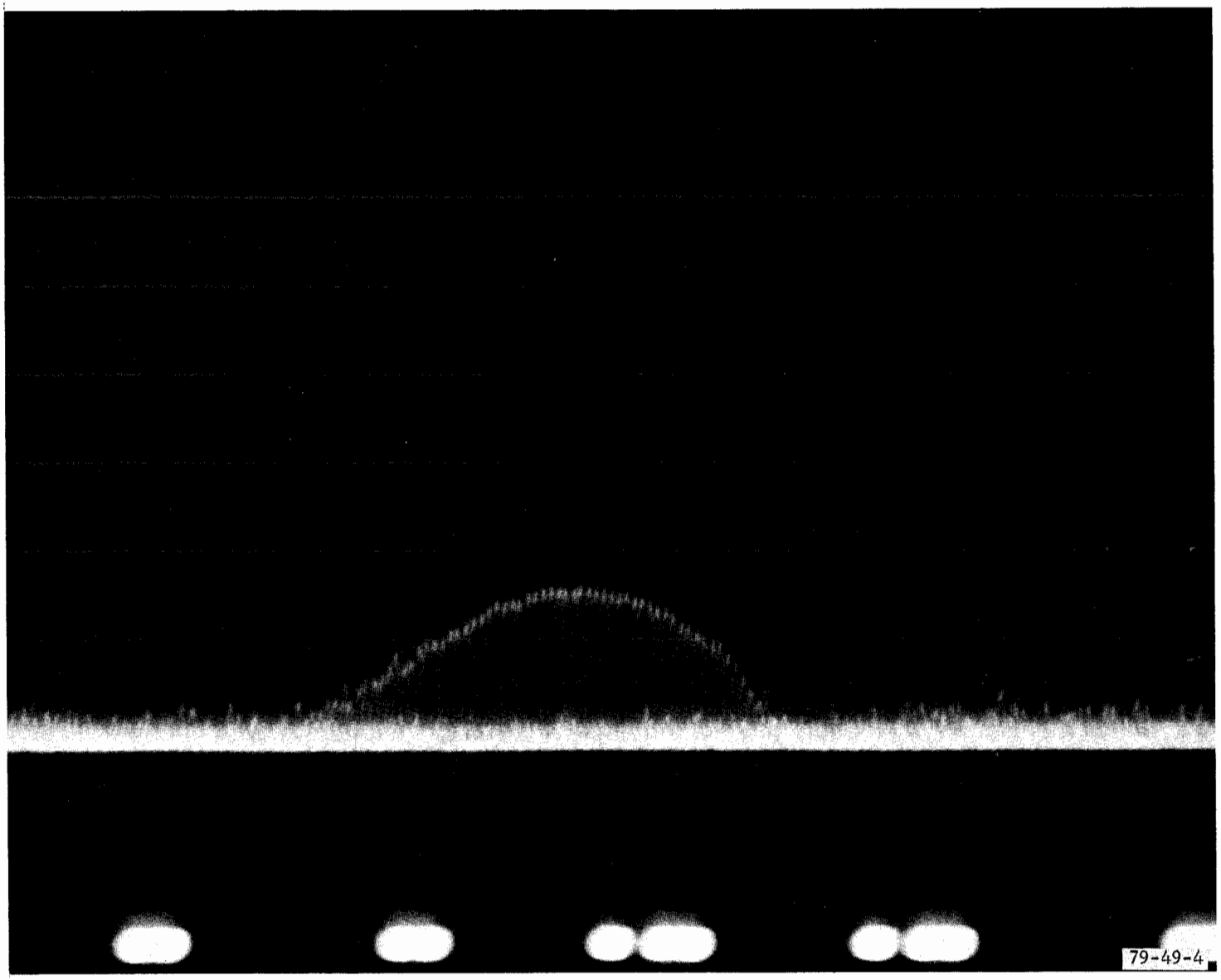


FIGURE 5. NASHWAUK RUN 5, 220° RADIAL AT 80 NMI RANGE

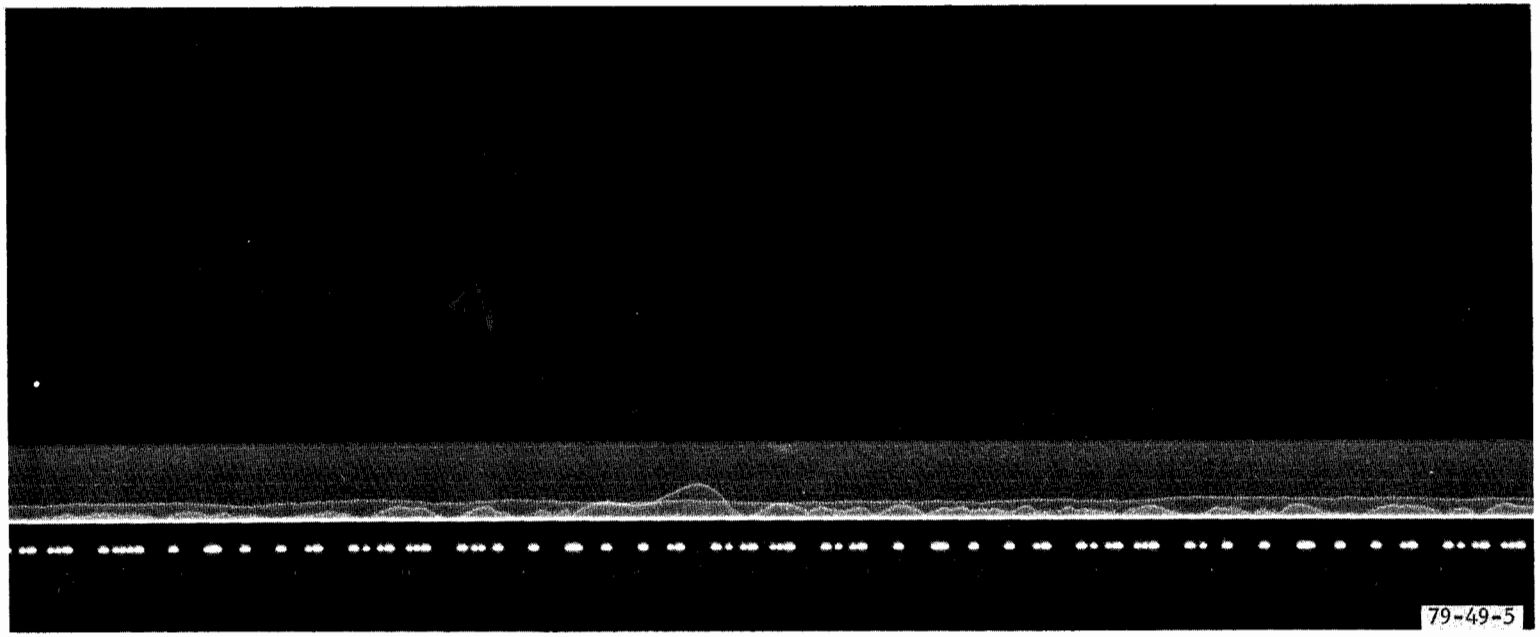


FIGURE 6. NASHWAUK RUN 4, 315° RADIAL AT 6 NMI RANGE

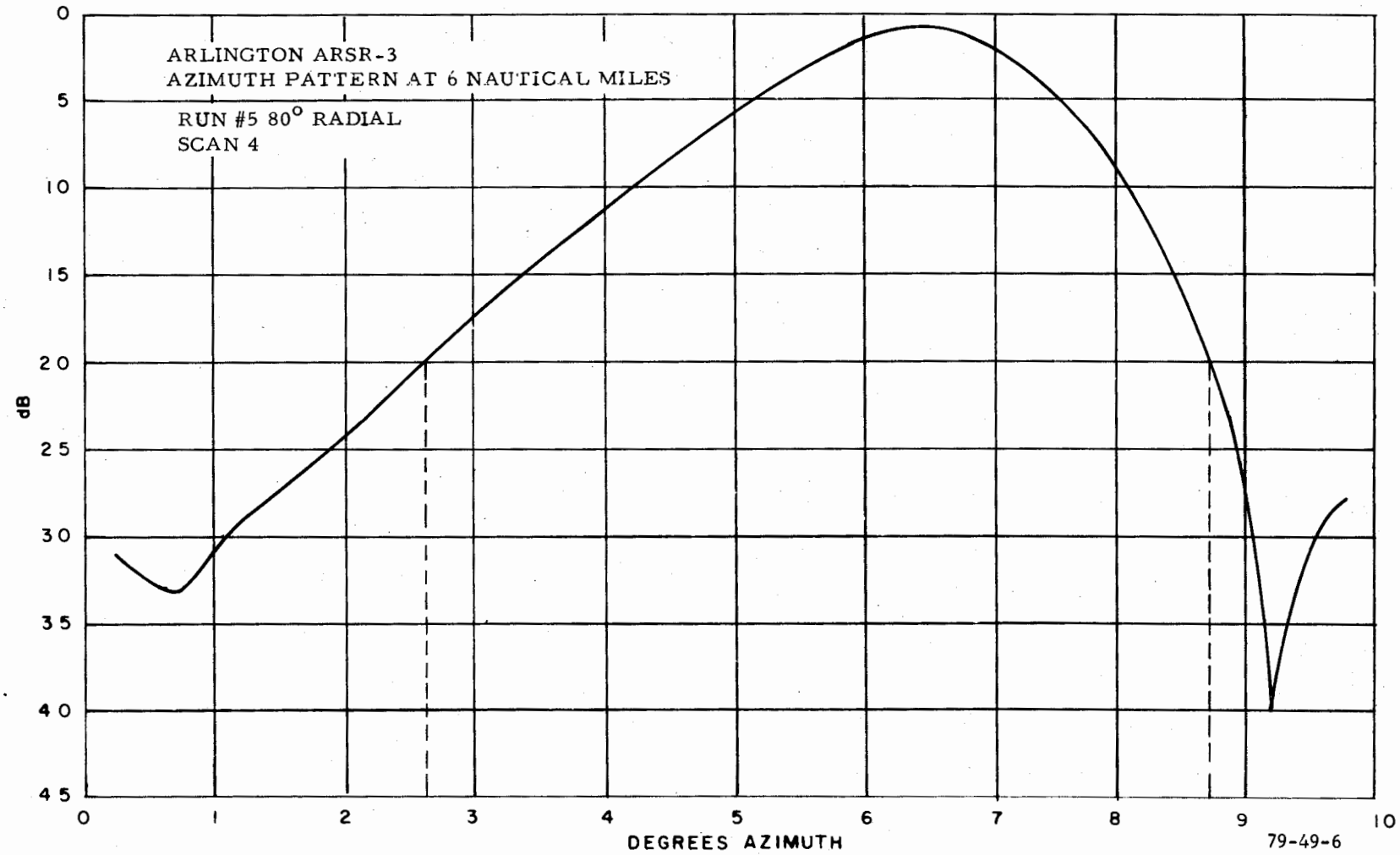


FIGURE 7. ARLINGTON, BEAM WIDTH AT 6 NMI RANGE

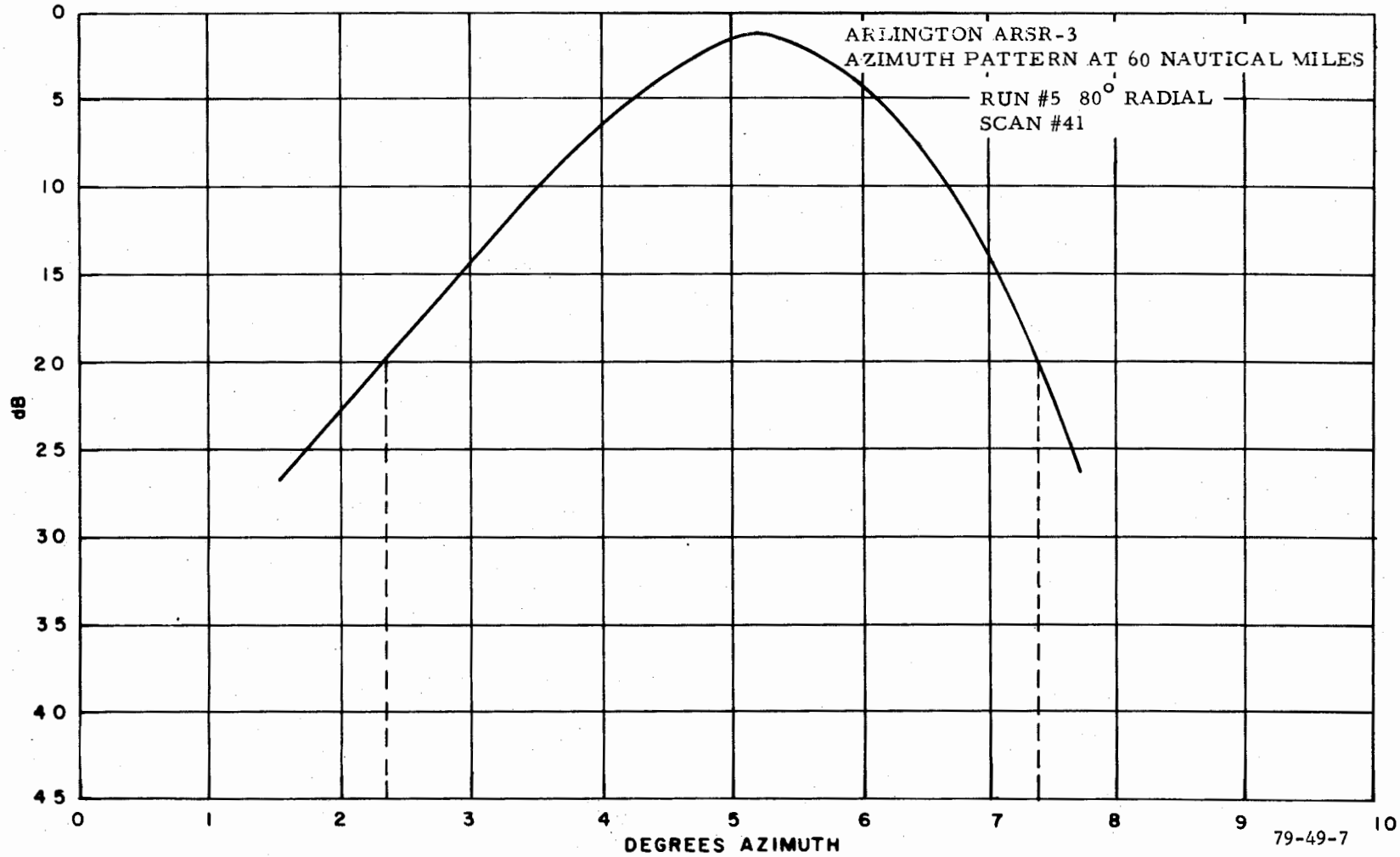


FIGURE 8. ARLINGTON, BEAM WIDTH AT 60 NMI RANGE

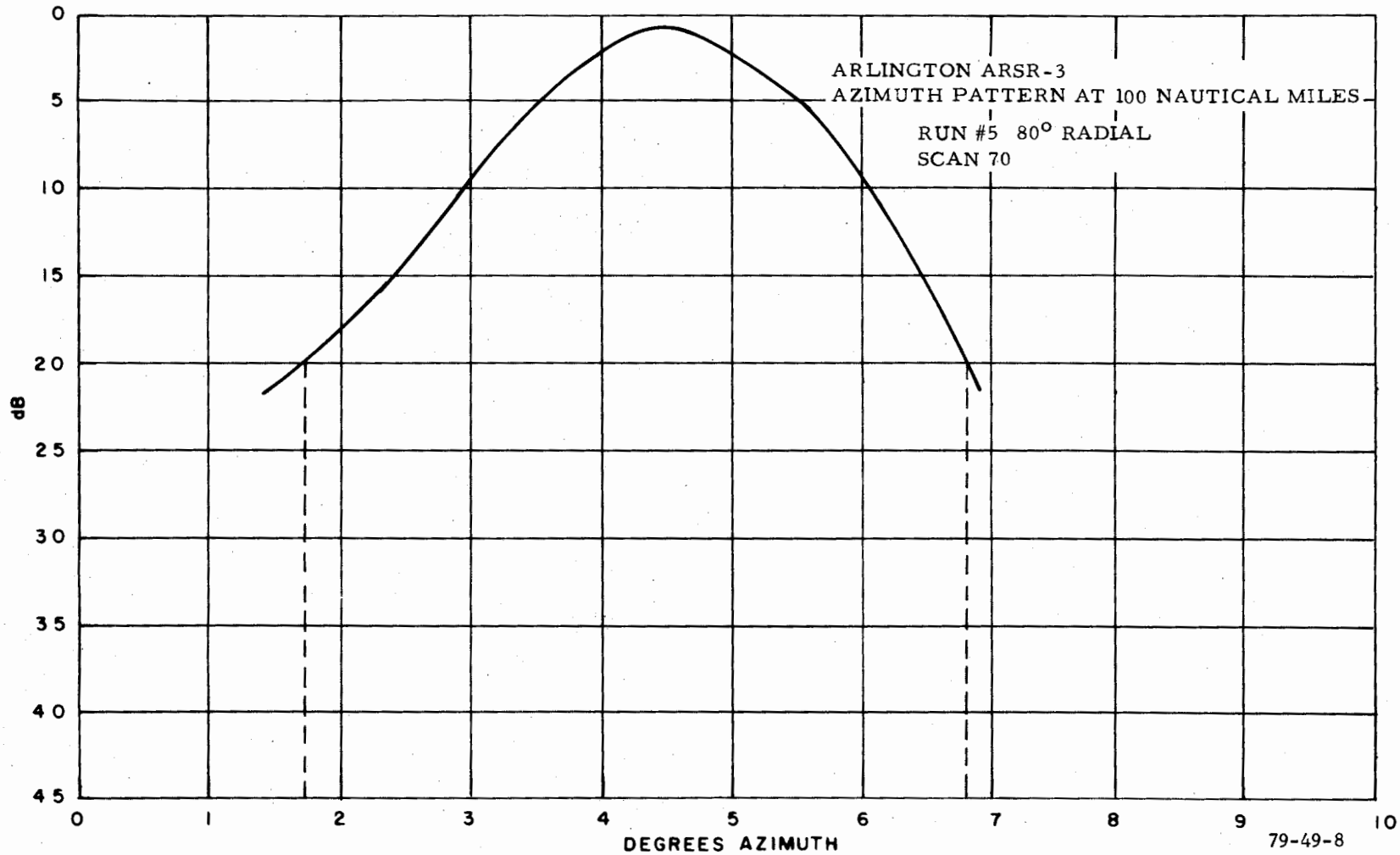


FIGURE 9. ARLINGTON, BEAM WIDTH AT 100 NMI RANGE

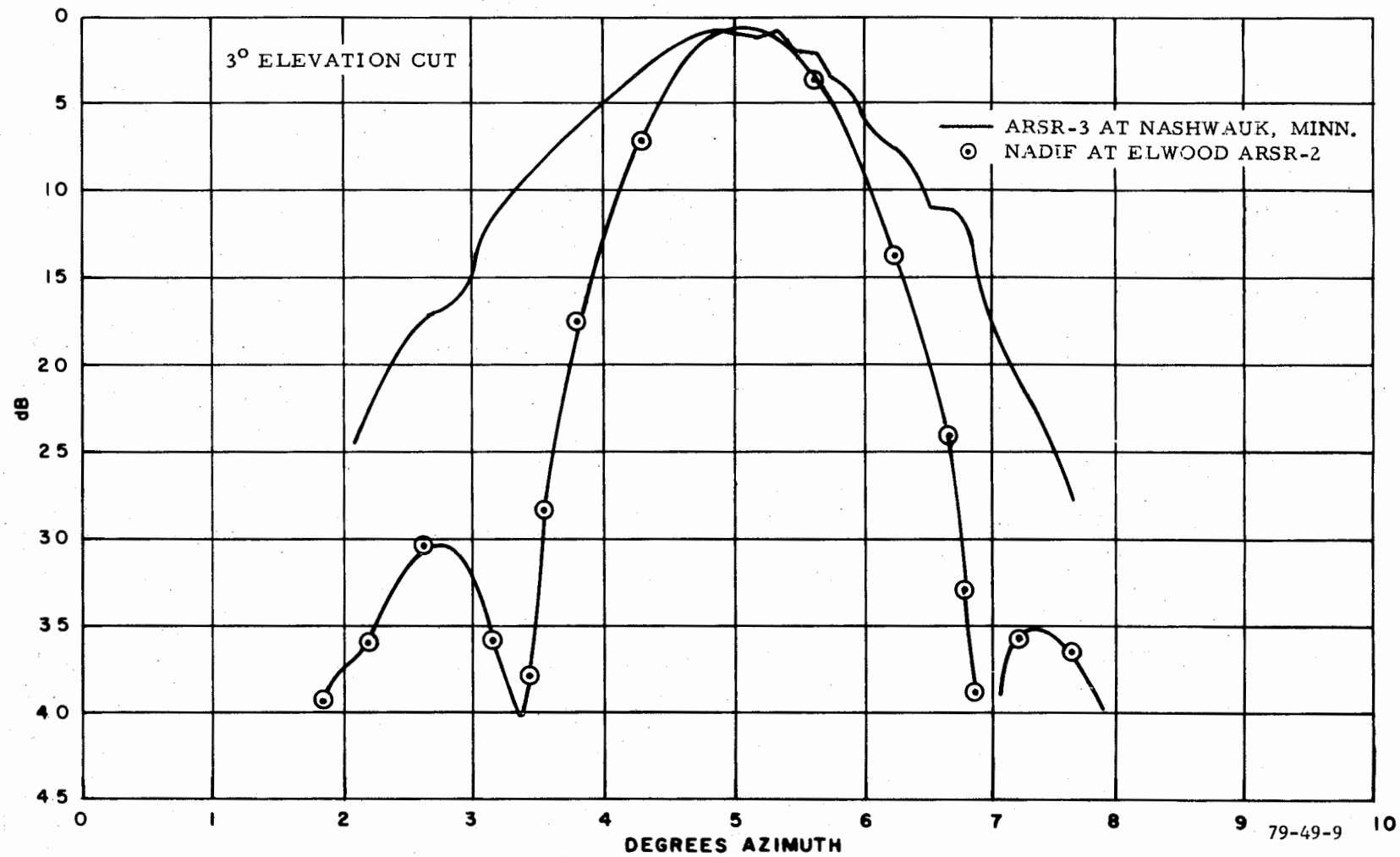


FIGURE 10. NASHWAUK ARSR-3 COMPARED WITH ARSR-2 NADIF

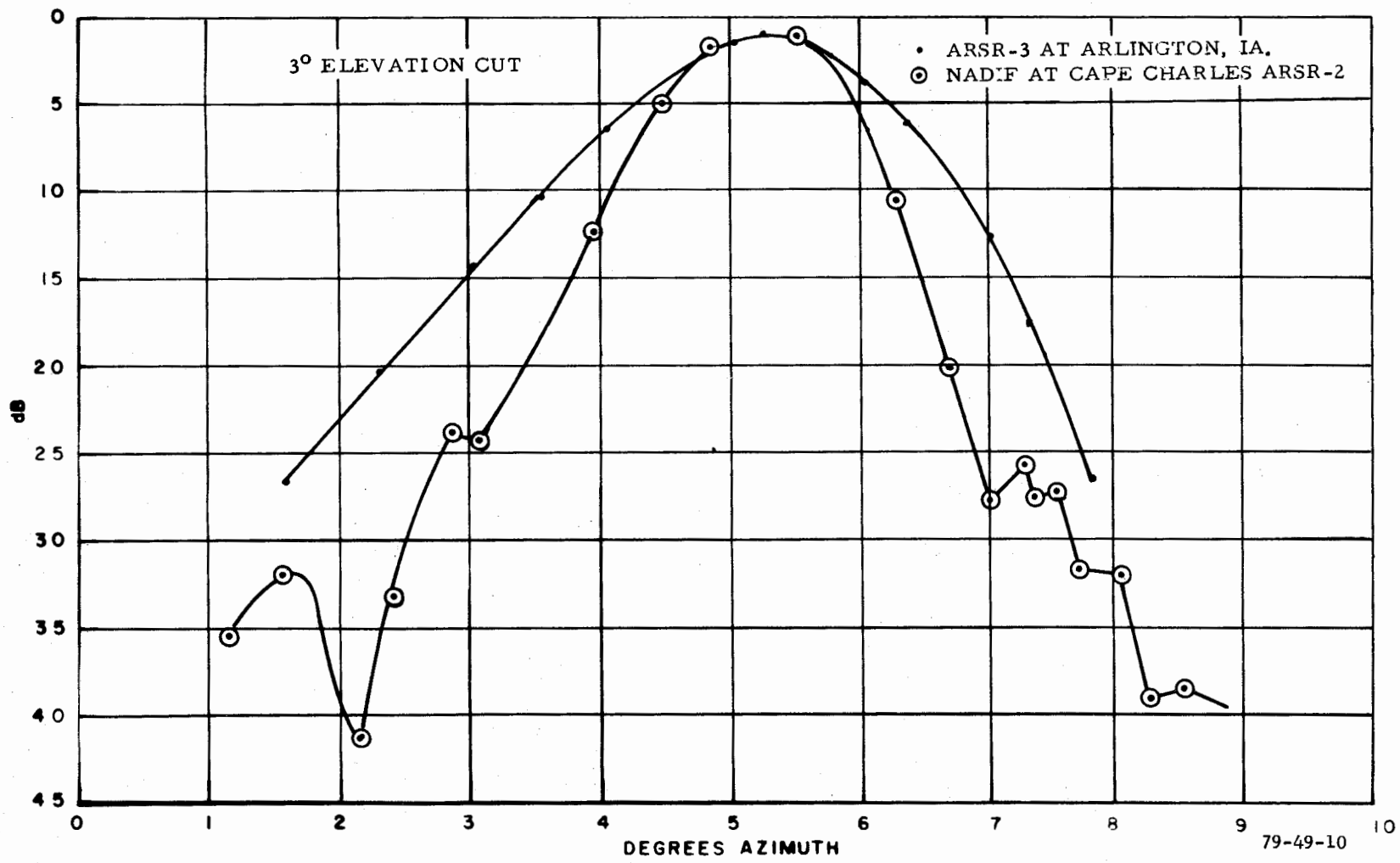


FIGURE 11. ARLINGTON ARSR-3 COMPARED WITH ARSR-2 NADIF

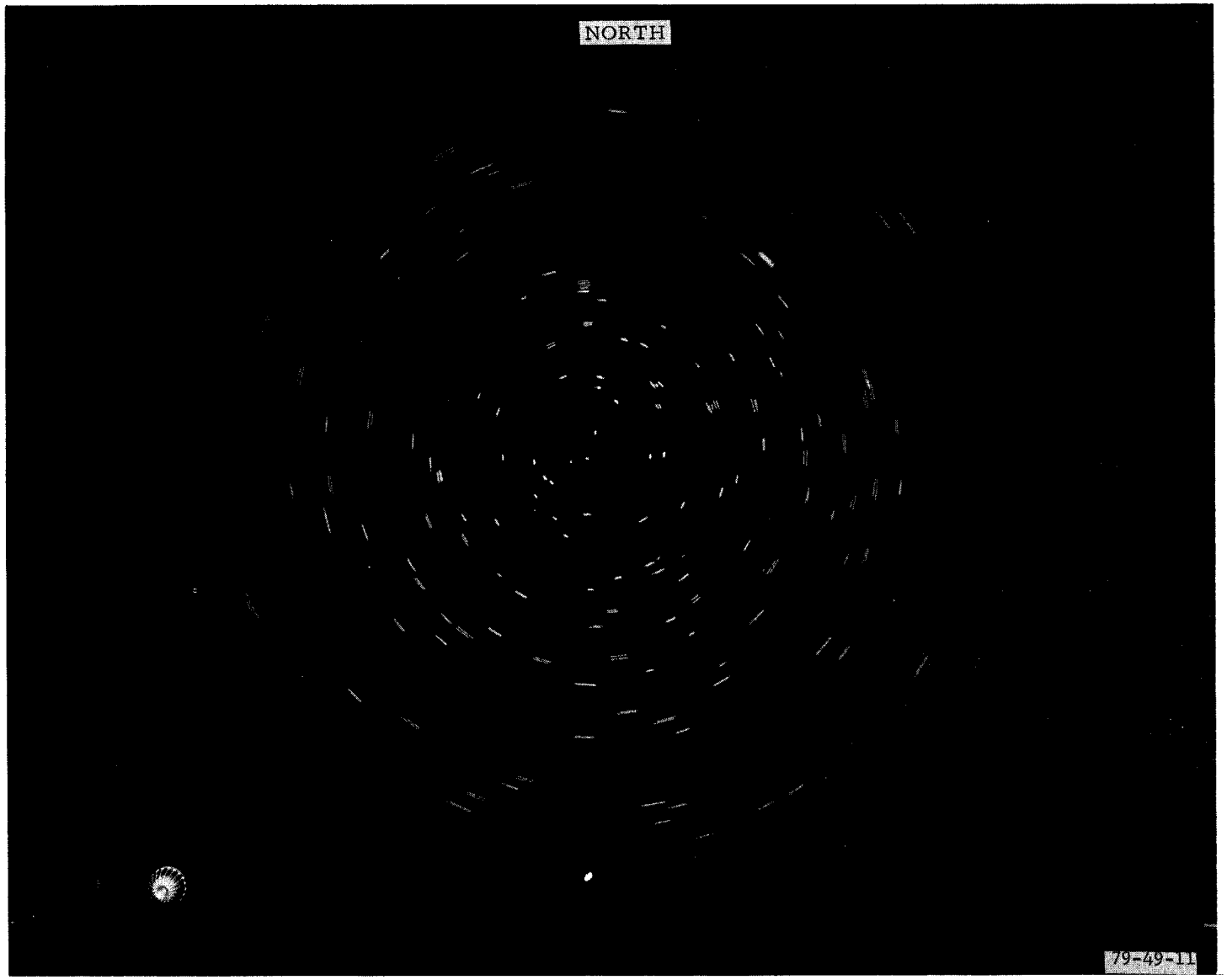


FIGURE 12. ARLINGTON PPI DISPLAY, 200 NMI FULL SCALE

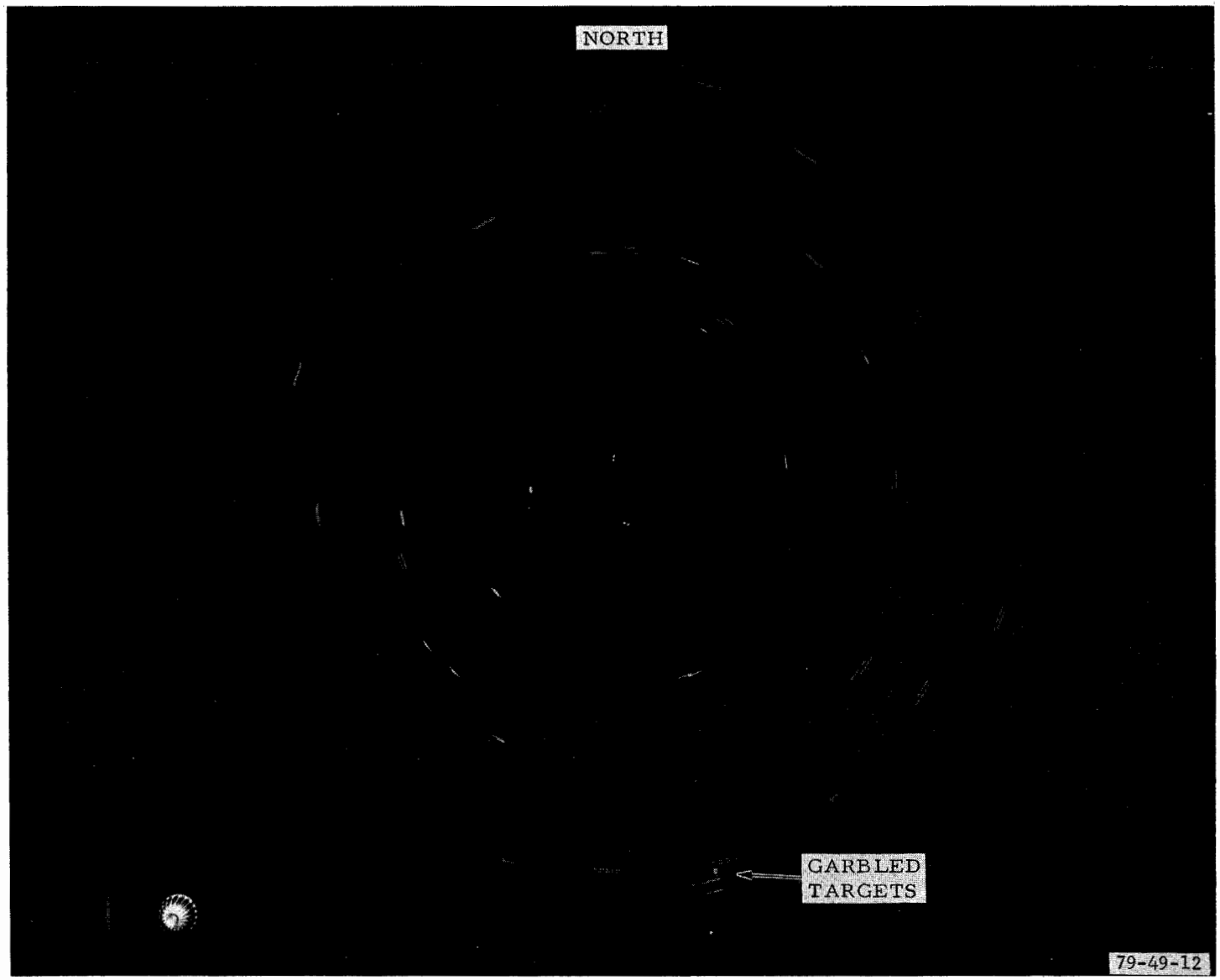


FIGURE 13. ARLINGTON PPI DISPLAY, 60 NMI FULL SCALE

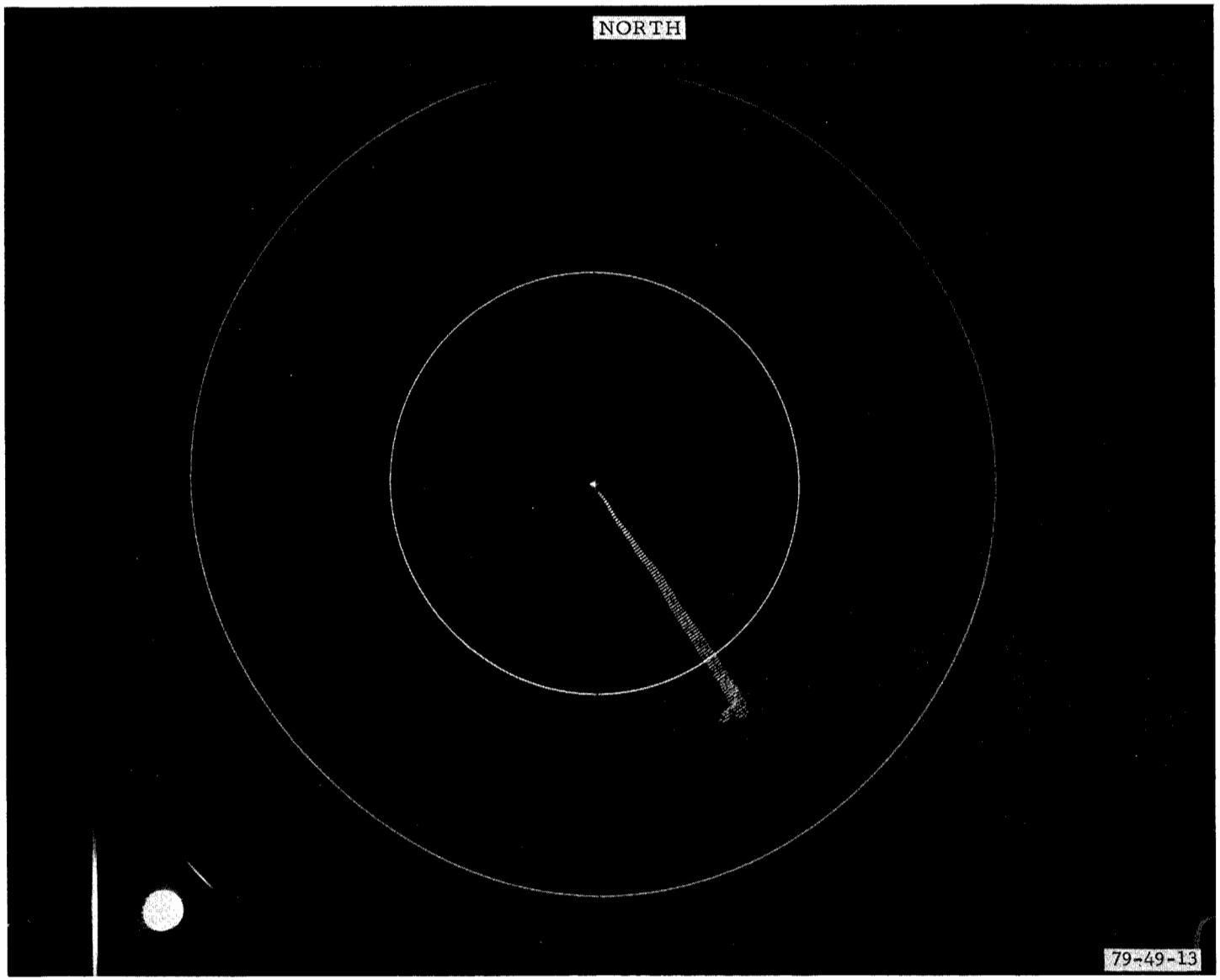


FIGURE 14. ARLINGTON DISPLAY, NAFEC AIRCRAFT TRACK, RUN 4, 200 NMI FULL SCALE

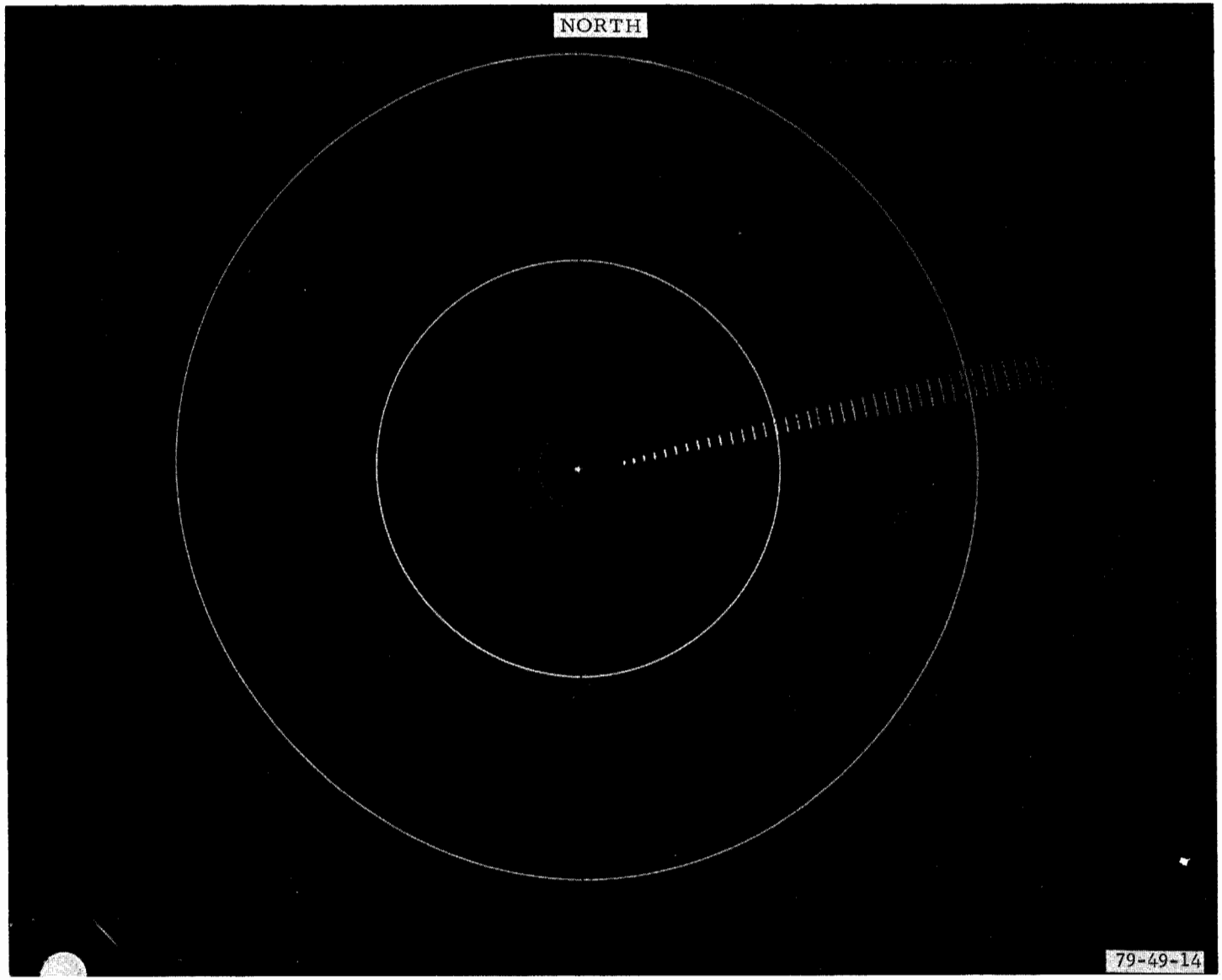


FIGURE 15. ARLINGTON DISPLAY, NAFEC AIRCRAFT TRACK, RUN 5, 60 NMI FULL SCALE

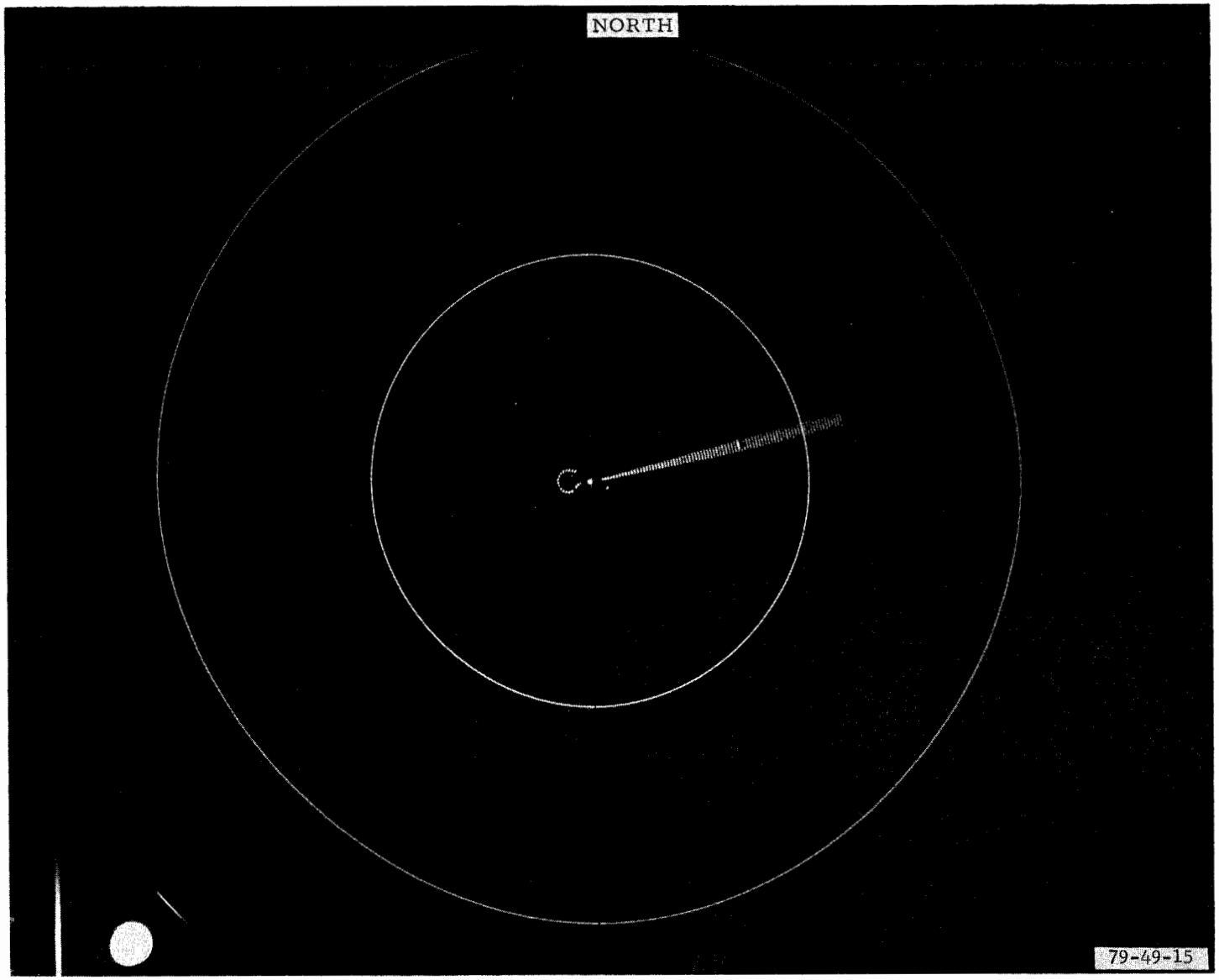
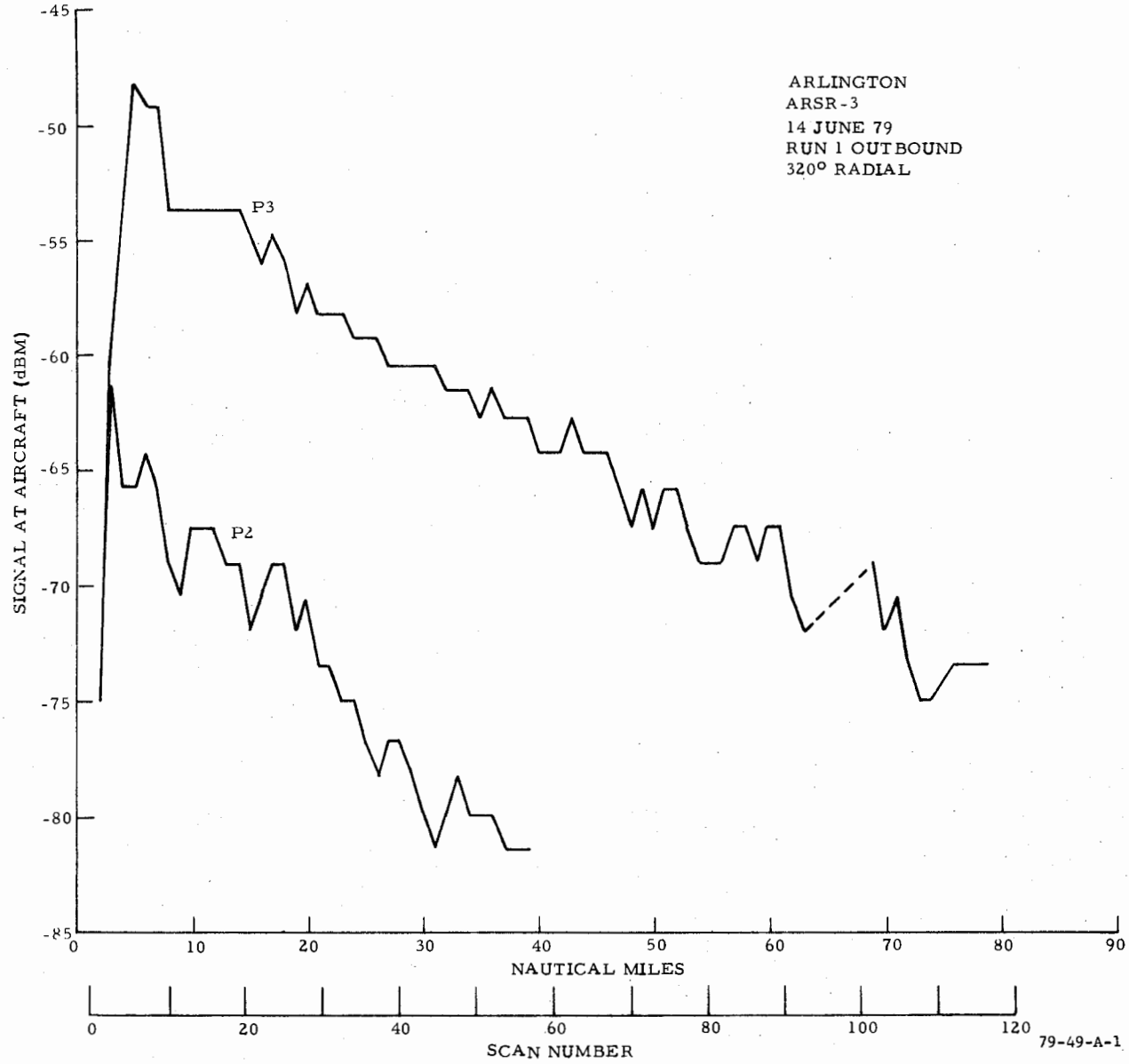
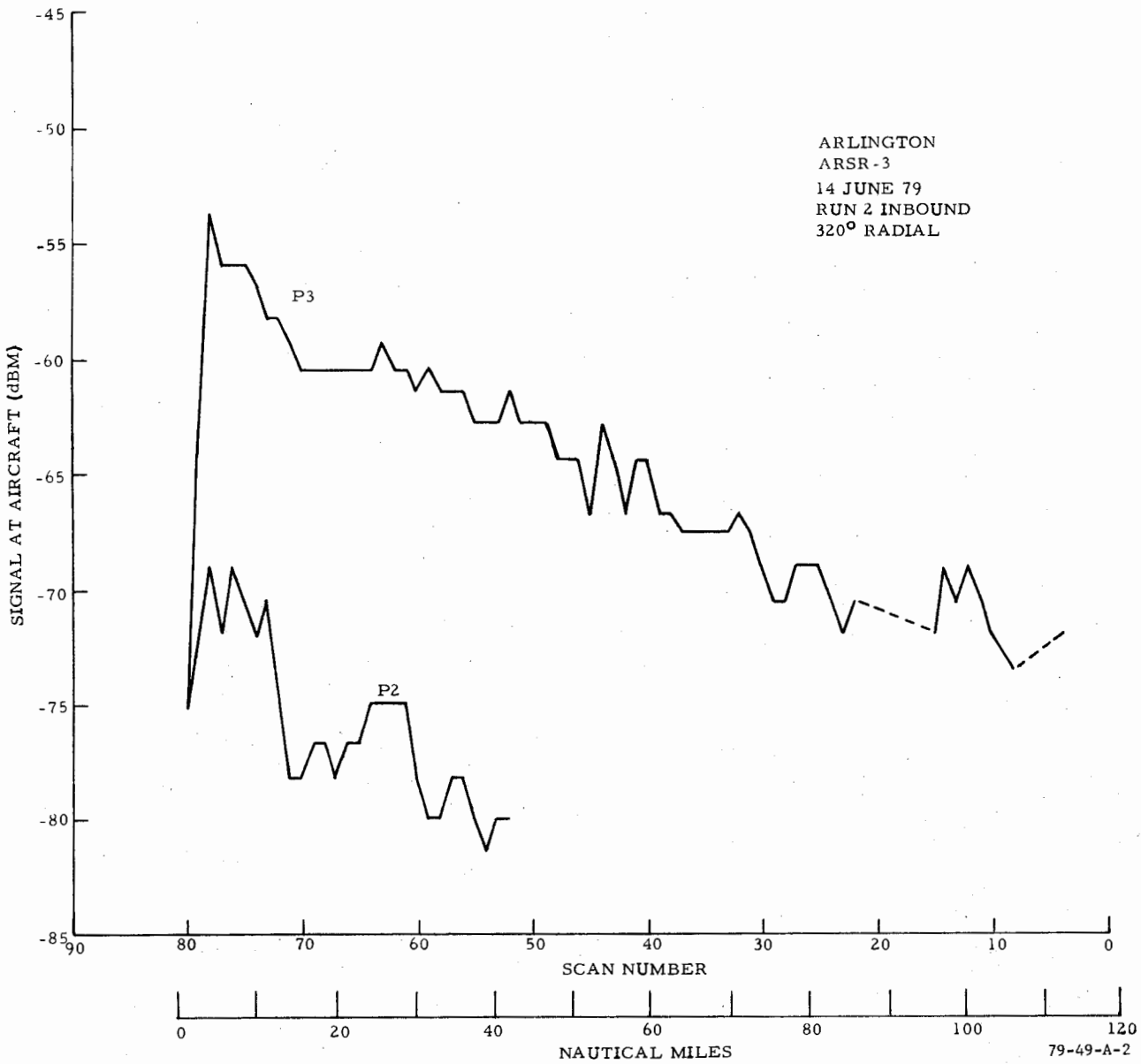


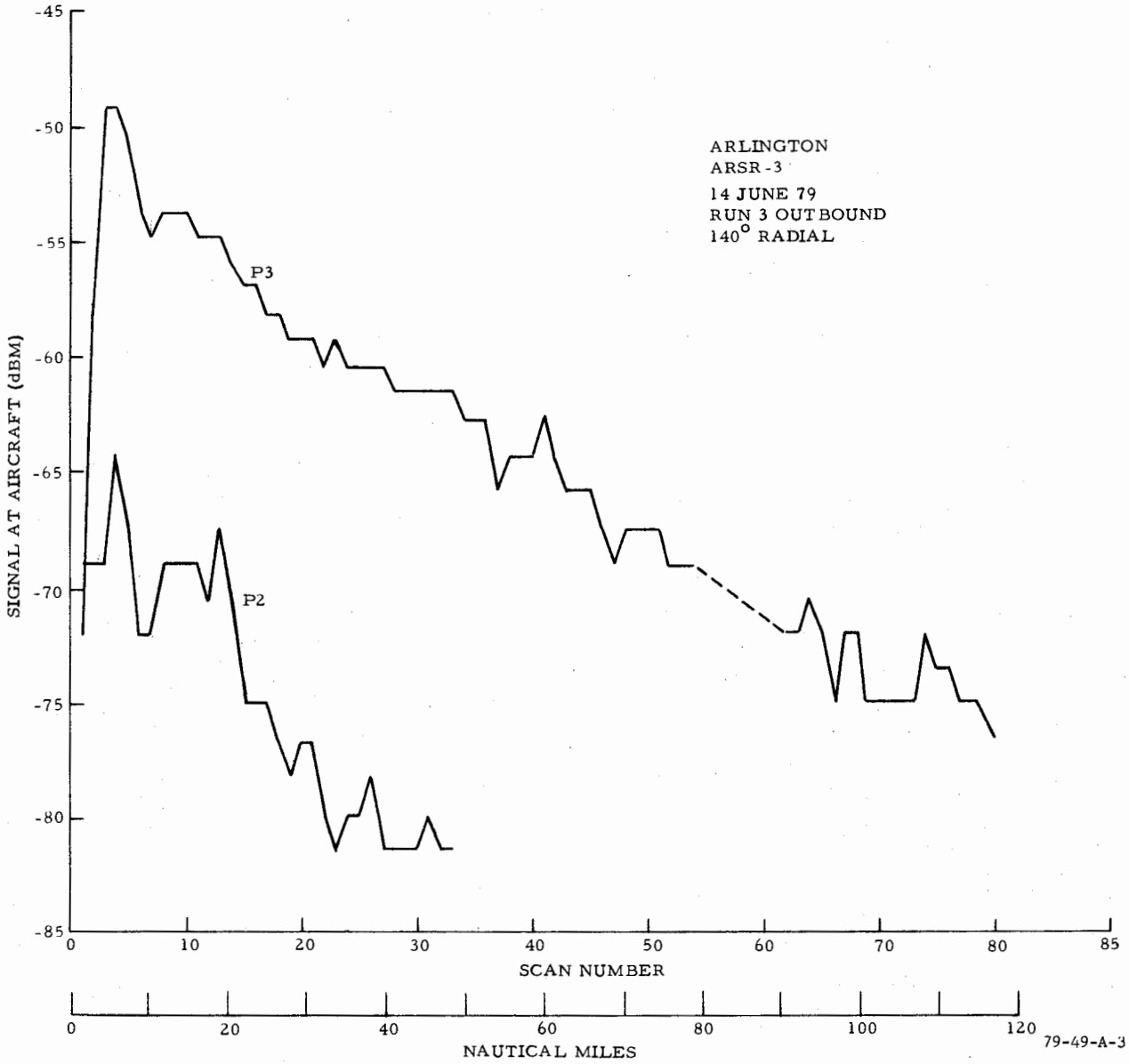
FIGURE 16. ARLINGTON DISPLAY, NAFEC AIRCRAFT TRACK, RUN 6, 200 NMI FULL SCALE

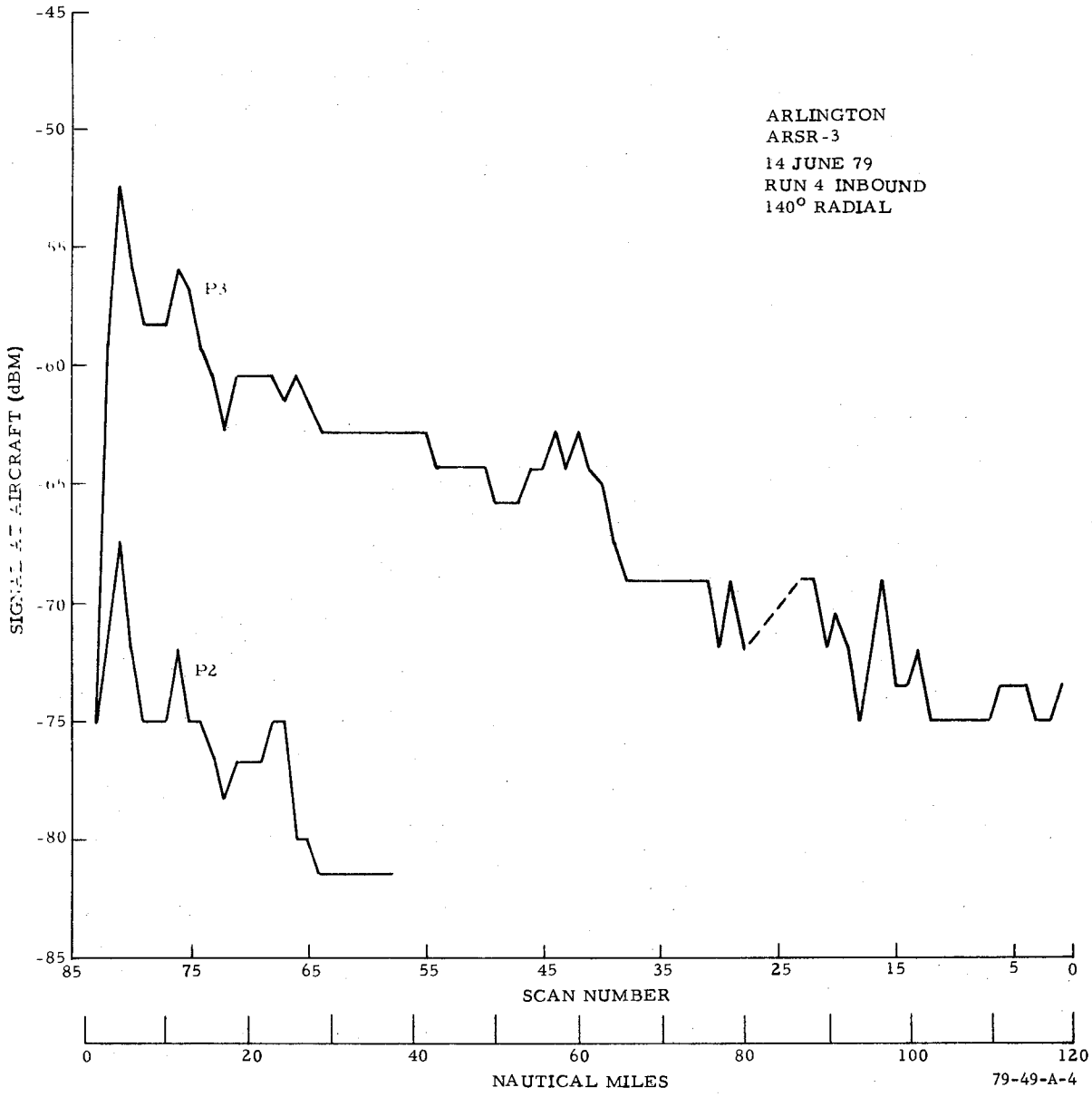
APPENDIX

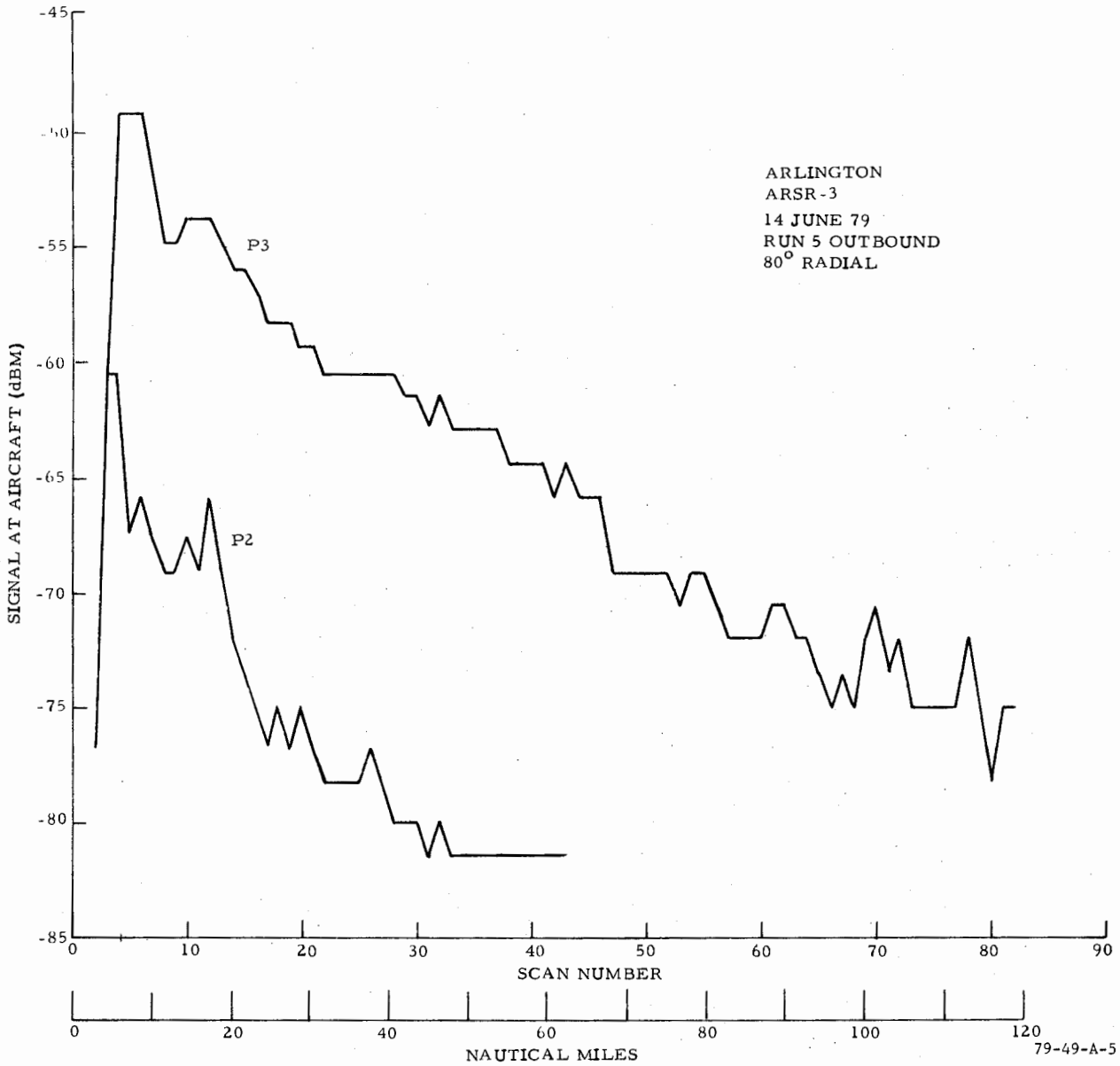
Vertical Antenna Patterns for Arlington and Nashwauk

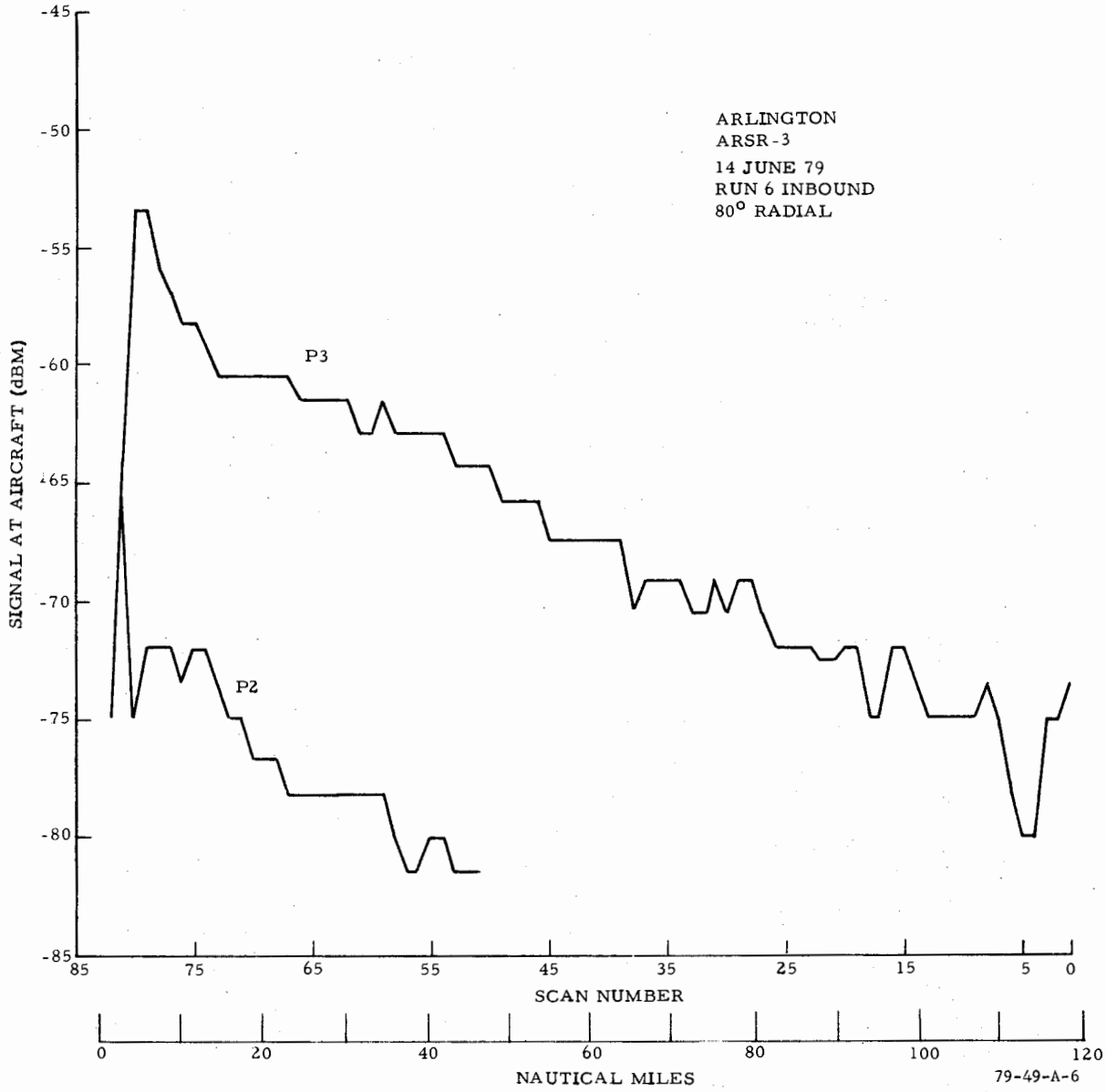

ARLINGTON
ARSR-3
14 JUNE 79
RUN 1 OUTBOUND
320° RADIAL
P3
P2
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
0
10
20
30
40
50
60
70
80
90
NAUTICAL MILES
0
20
40
60
80
100
120
SCAN NUMBER
79-49-A-1

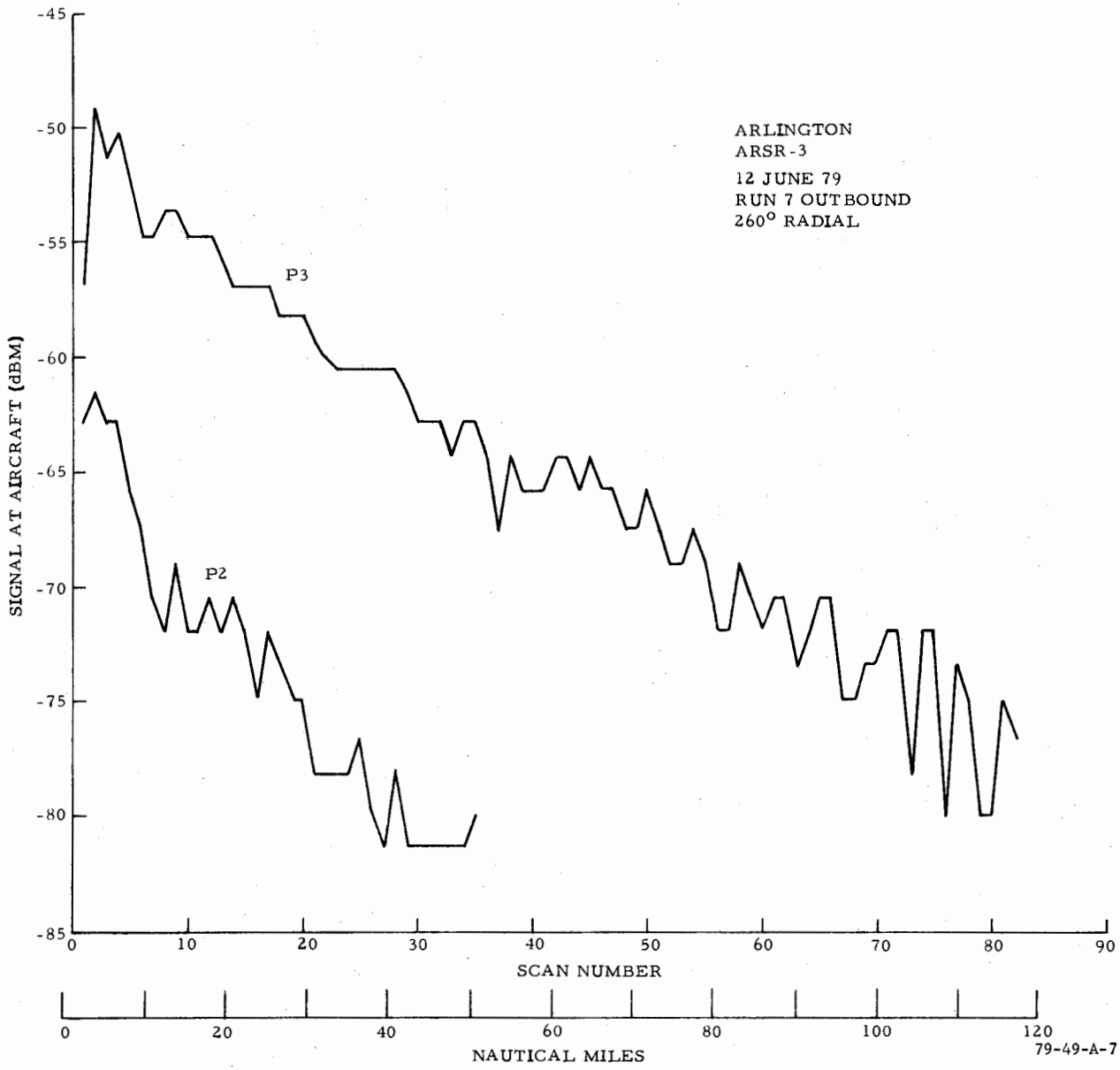

ARLINGTON
ARSR-3
14 JUNE 79
RUN 2 INBOUND
320° RADIAL
P3
P2
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
90
80
70
60
50
40
30
20
10
0
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-2

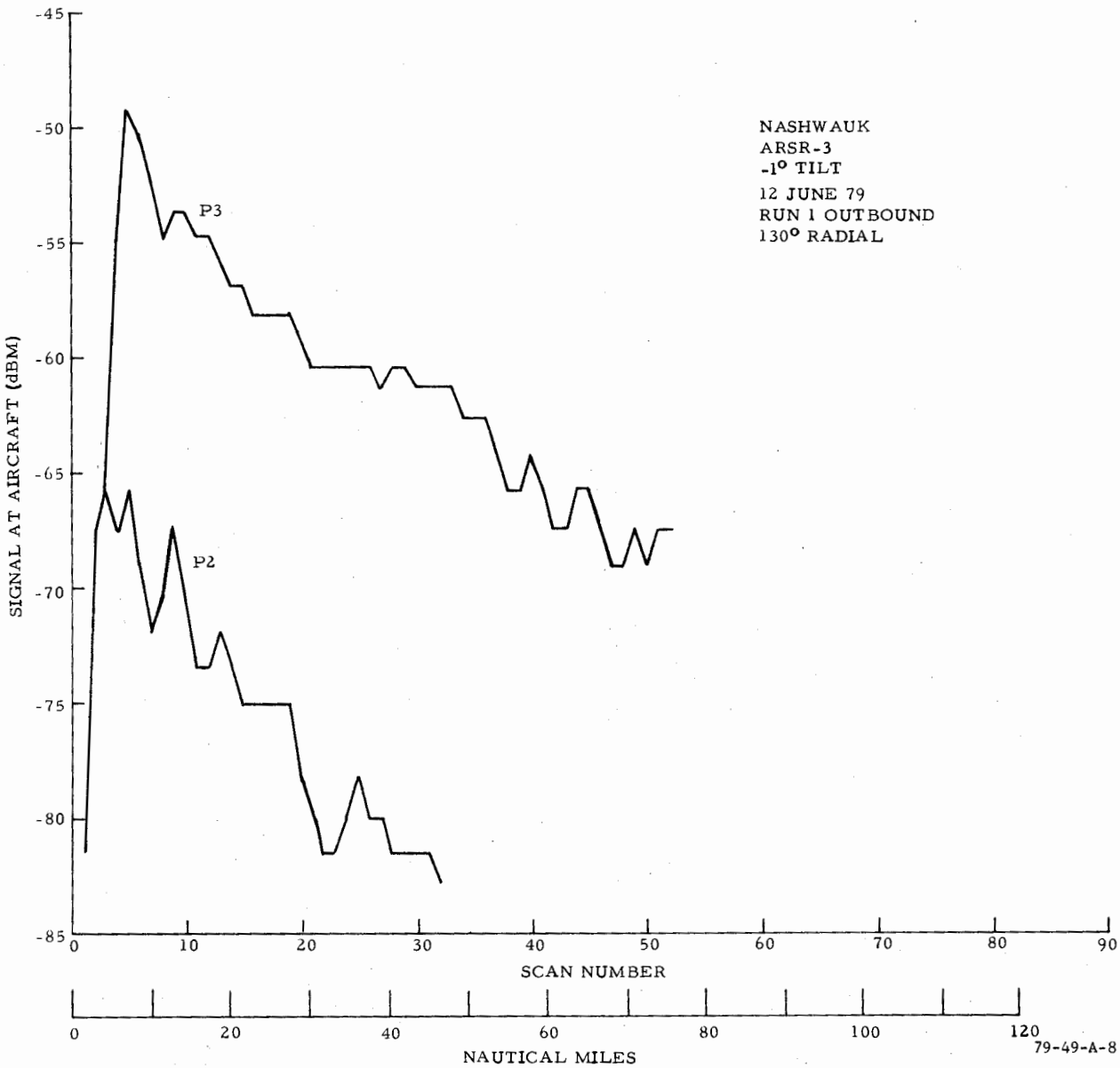

ARLINGTON
ARSR-3
14 JUNE 79
RUN 3 OUTBOUND
140° RADIAL
P3
P2
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
0
10
20
30
40
50
60
70
80
85
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-3

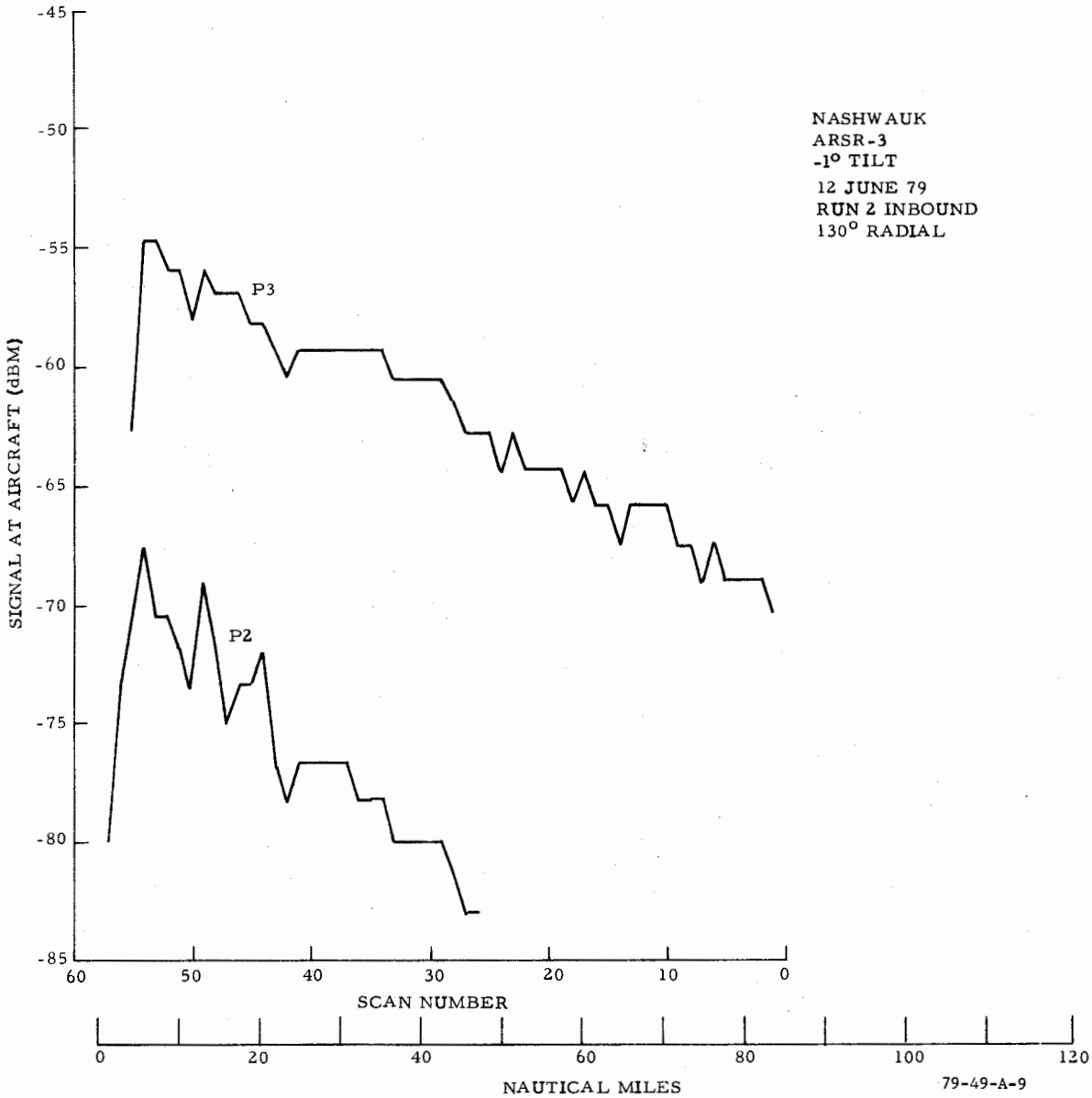

ARLINGTON
ARSR-3
14 JUNE 79
RUN 4 INBOUND
140° RADIAL
P3
P2
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
85
75
65
55
45
35
25
15
5
0
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-4

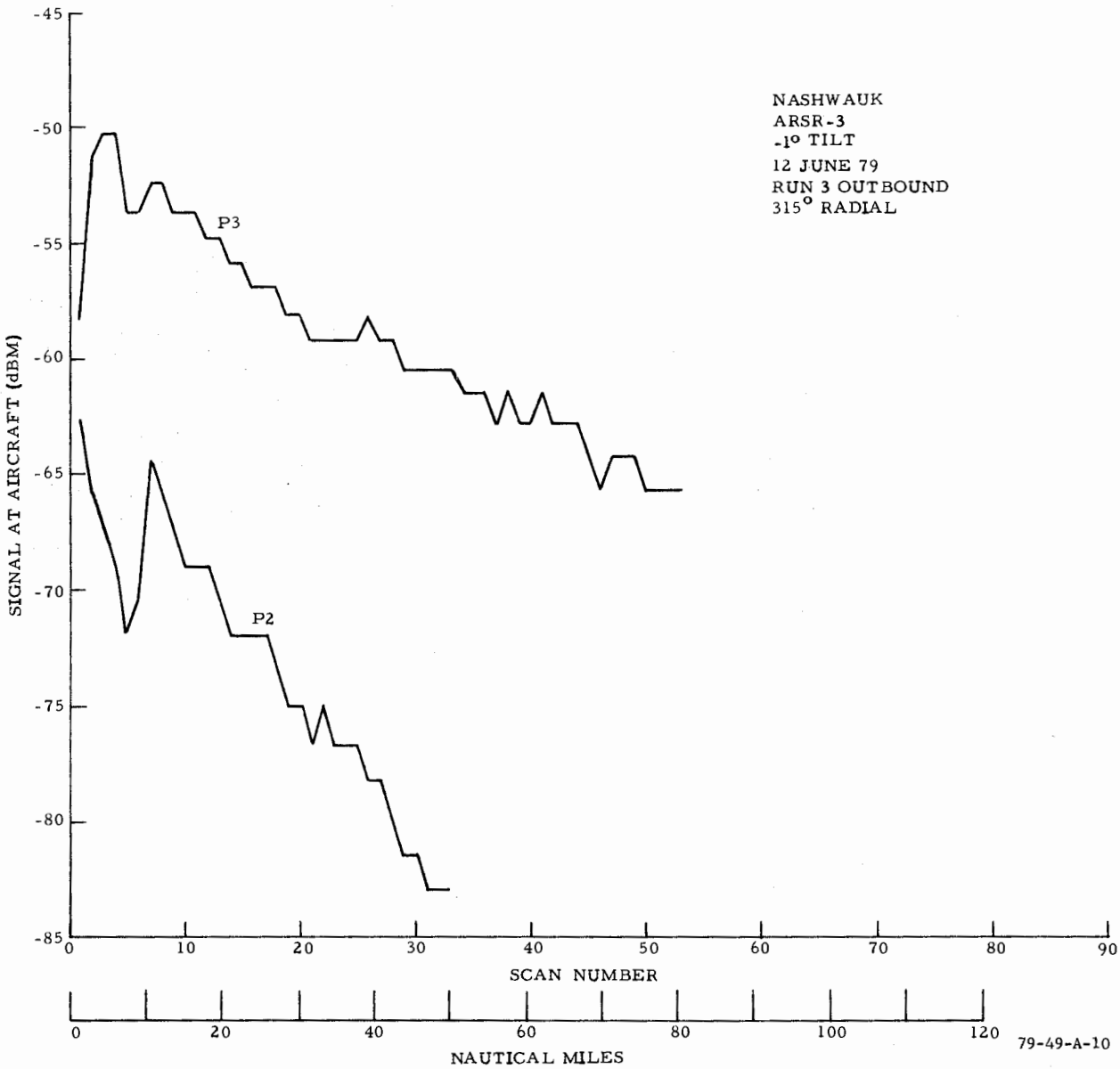

ARLINGTON
ARSR-3
14 JUNE 79
RUN 5 OUTBOUND
80° RADIAL
P3
P2
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
0
10
20
30
40
50
60
70
80
90
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-5

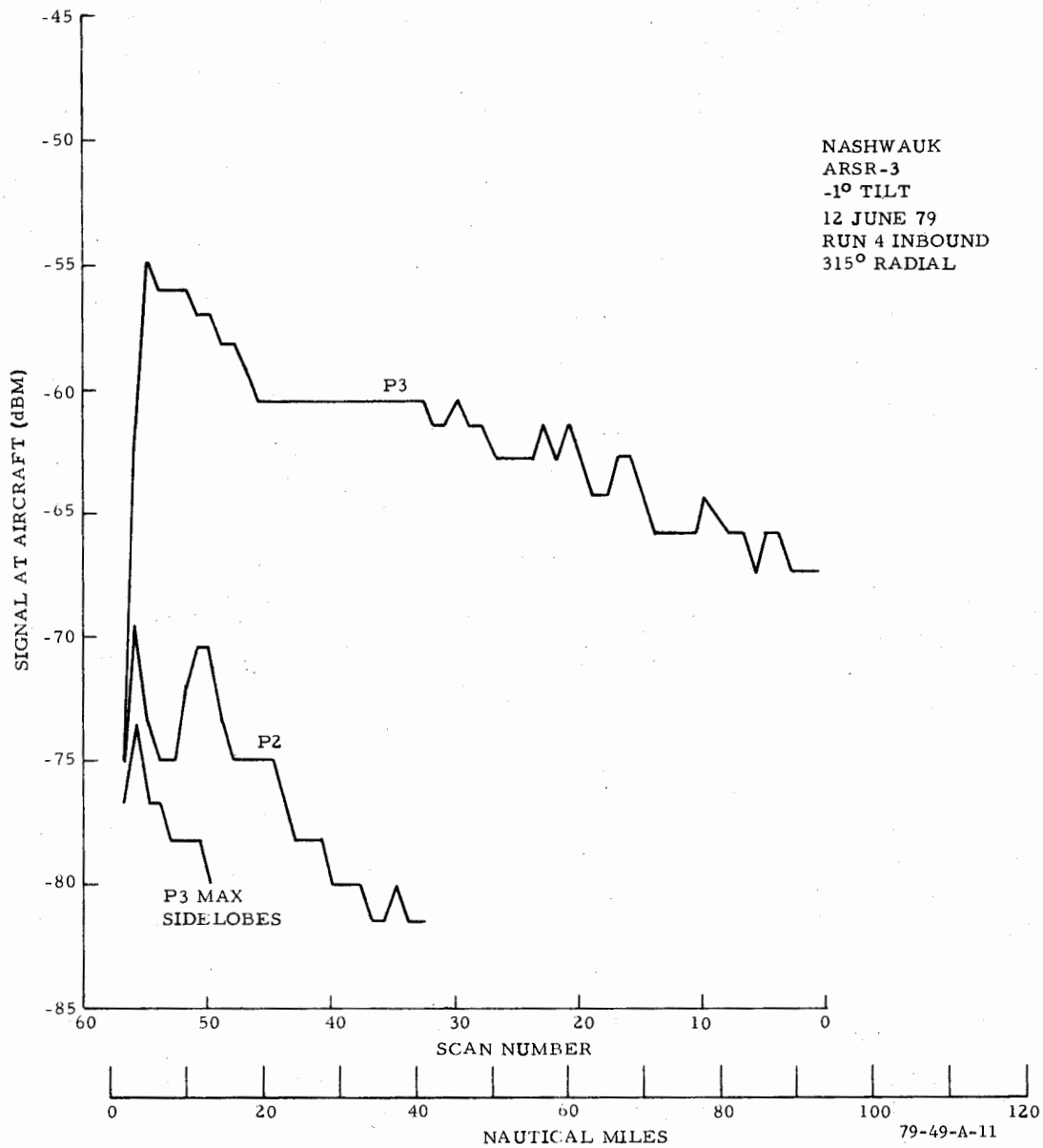

ARLINGTON
ARSR-3
14 JUNE 79
RUN 6 INBOUND
80° RADIAL
P3
P2
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
85
75
65
55
45
35
25
15
5
0
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-6

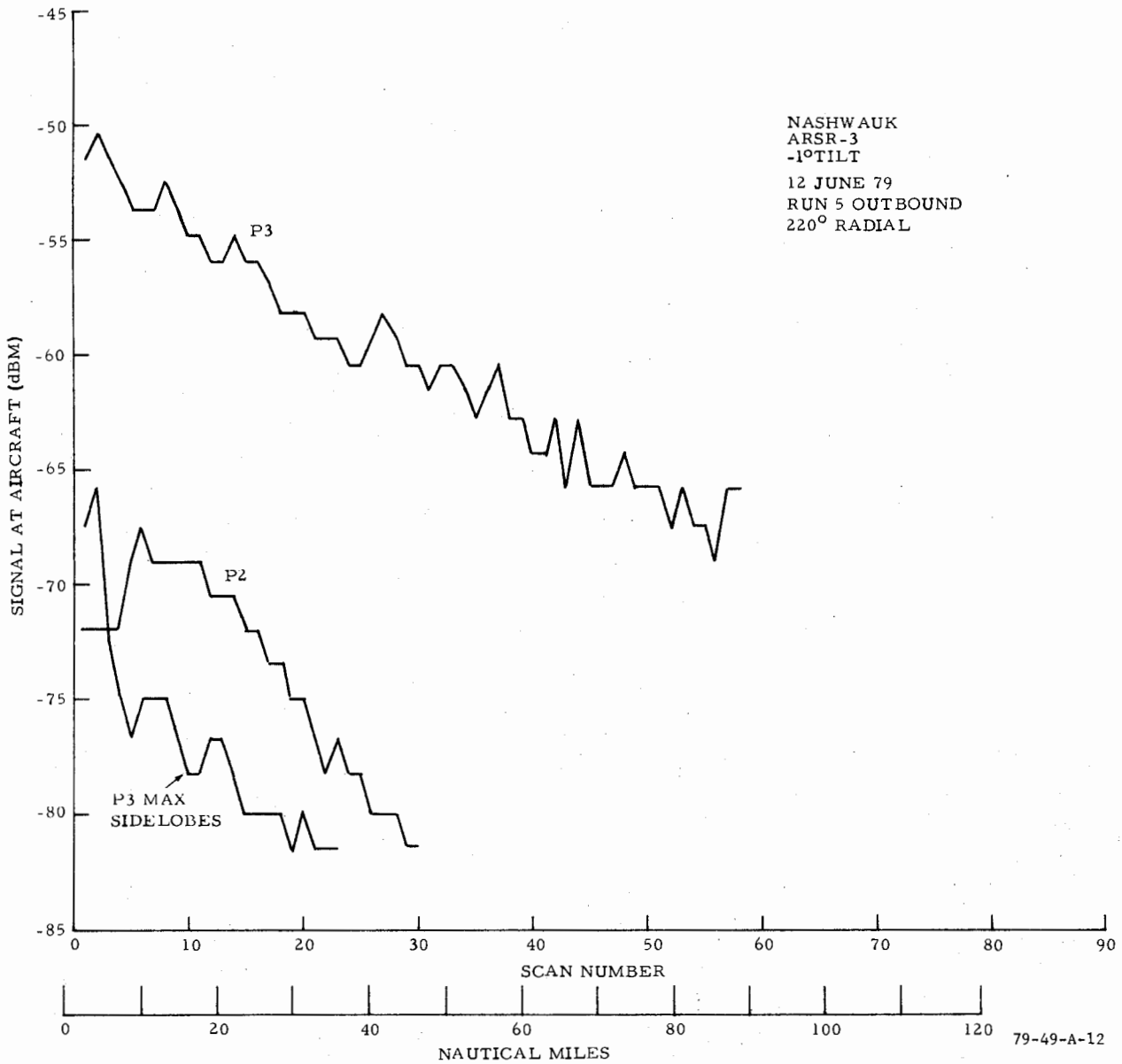

ARLINGTON
ARSR-3
12 JUNE 79
RUN 7 OUTBOUND
260° RADIAL
P3
P2
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
0
10
20
30
40
50
60
70
80
90
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-7

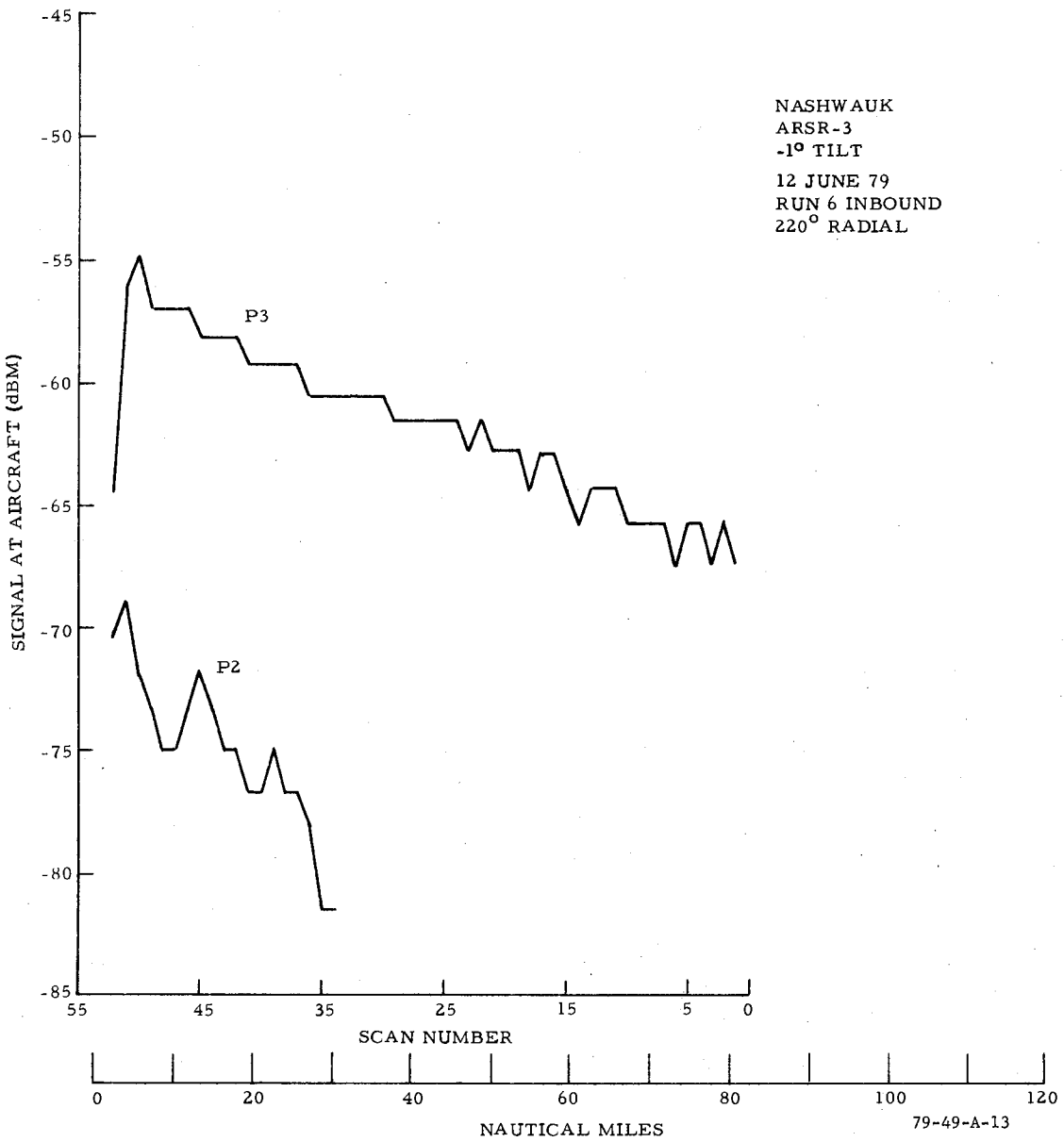

NASHWAUK
ARSR-3
-1° TILT
12 JUNE 79
RUN 1 OUTBOUND
130° RADIAL
P3
P2
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
0
10
20
30
40
50
60
70
80
90
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-8

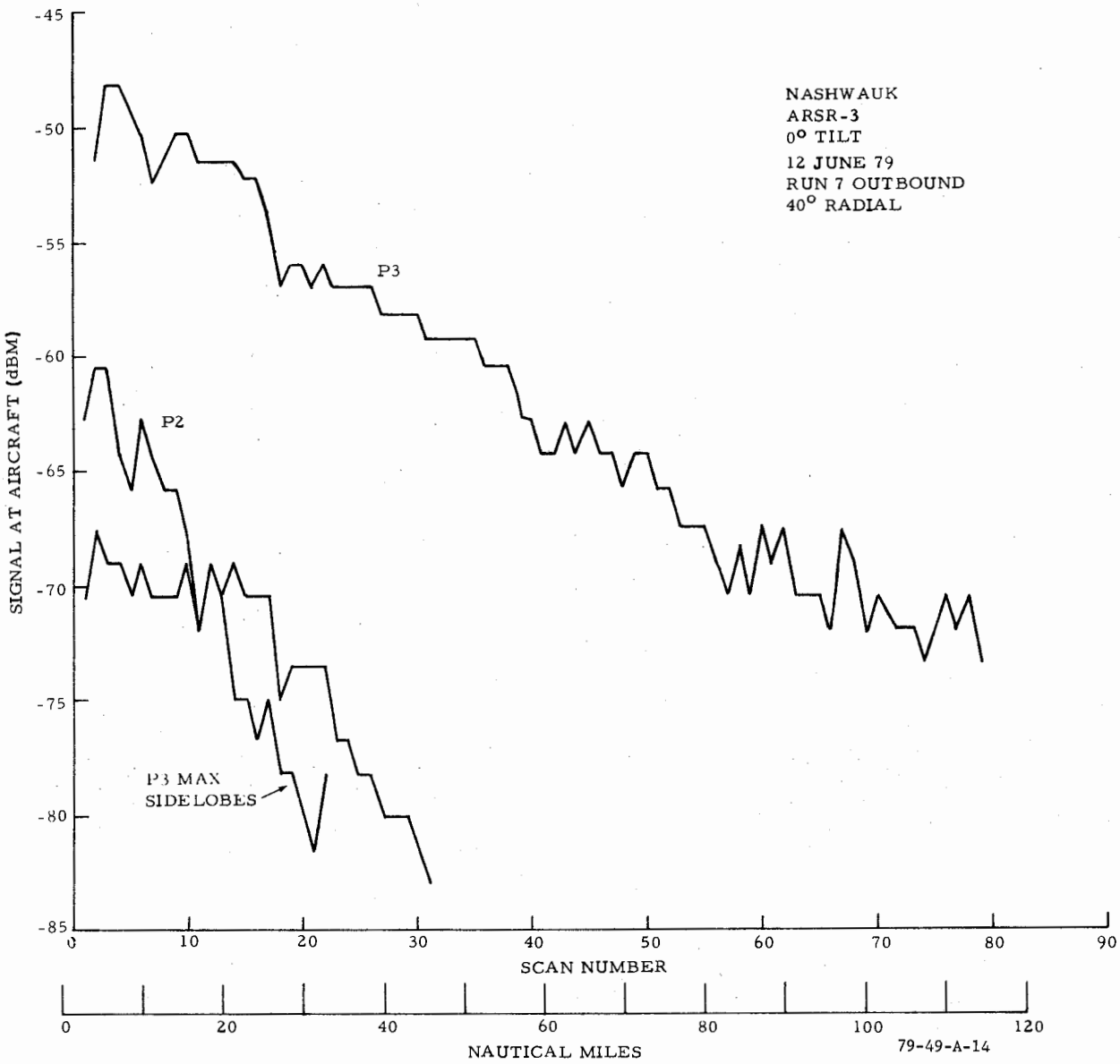

NASHWAUK
ARSR-3
-1° TILT
12 JUNE 79
RUN 2 INBOUND
130° RADIAL
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
P3
P2
60
50
40
30
20
10
0
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-9

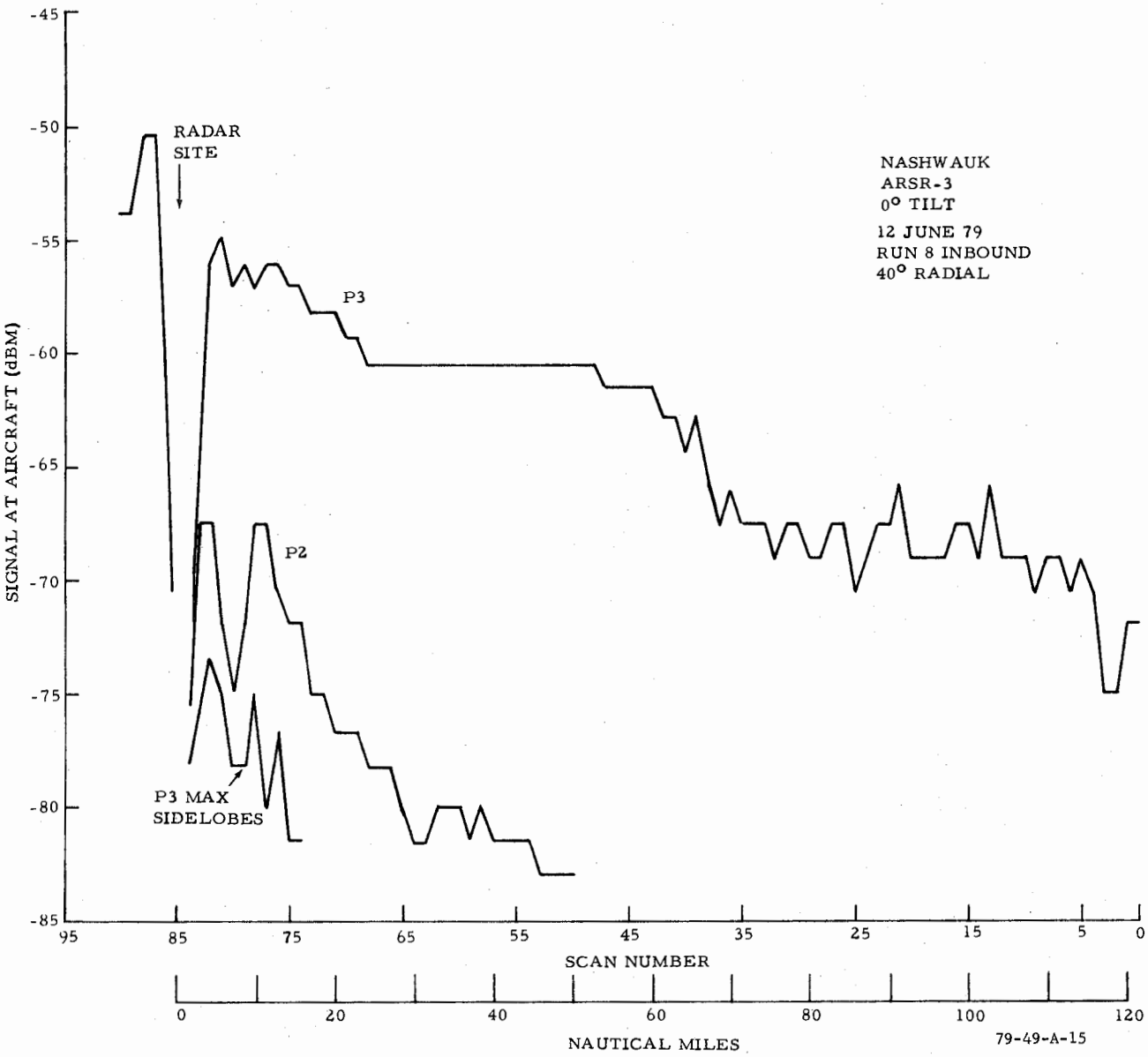

NASHWAUK
ARSR-3
-1° TILT
12 JUNE 79
RUN 3 OUTBOUND
315° RADIAL
P3
P2
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
0
10
20
30
40
50
60
70
80
90
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-10

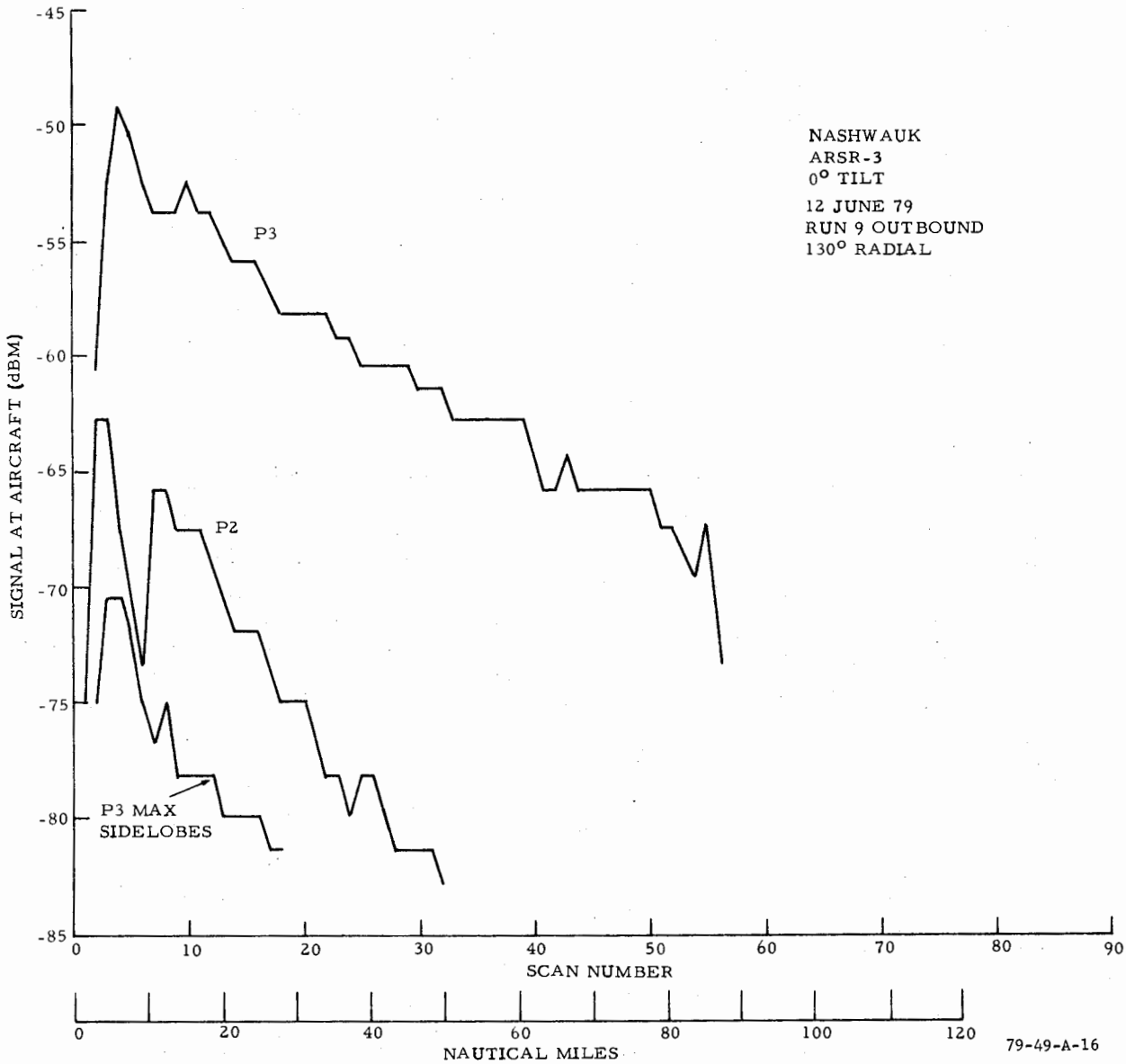

NASHWAUK
ARSR-3
-1° TILT
12 JUNE 79
RUN 4 INBOUND
315° RADIAL
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
P3
P2
P3 MAX
SIDELOBES
60
50
40
30
20
10
0
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-11

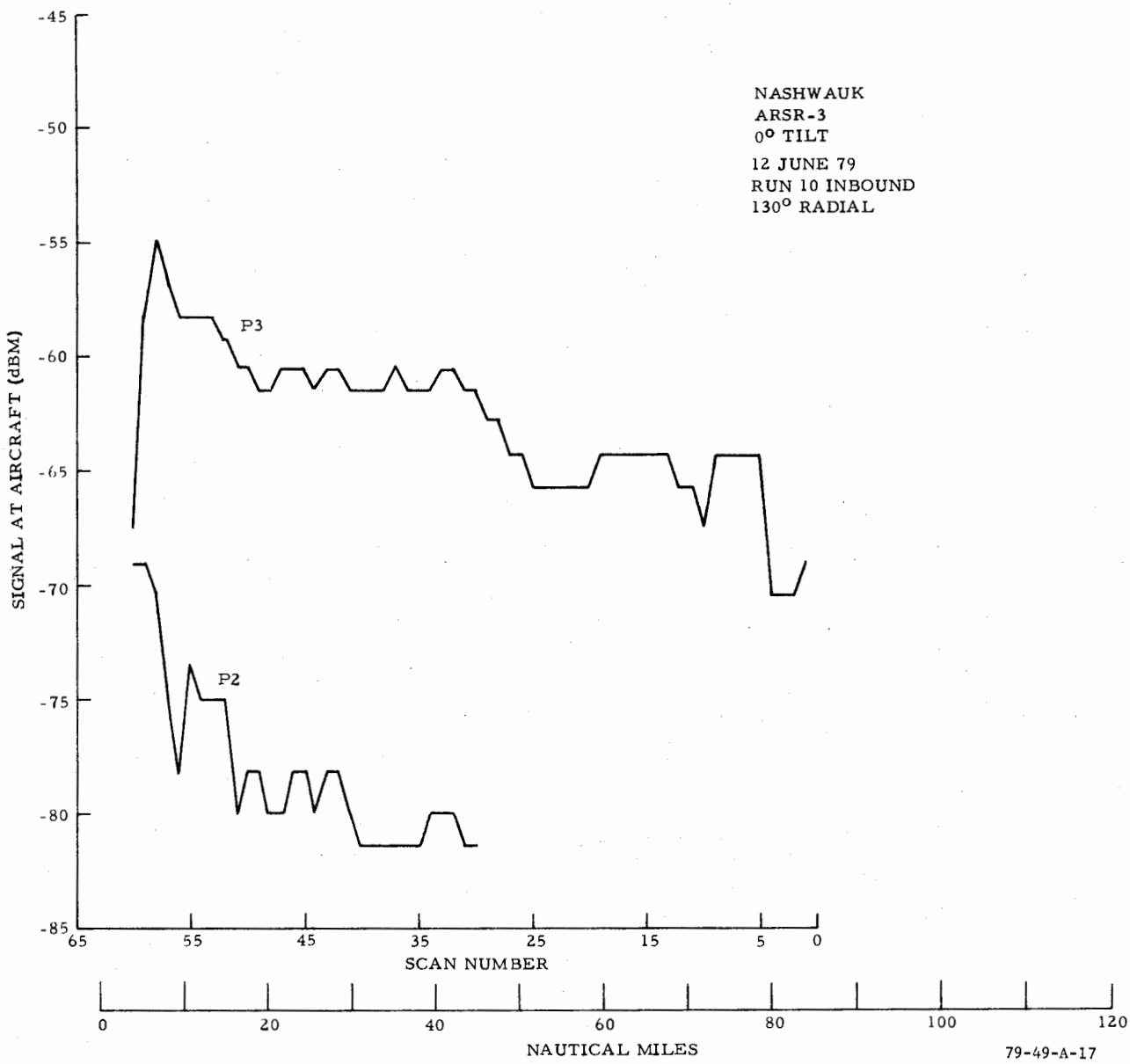

NASHWAUK
ARSR-3
-1°TILT
12 JUNE 79
RUN 5 OUTBOUND
220° RADIAL
P3
P2
P3 MAX
SIDELOBES
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
0
10
20
30
40
50
60
70
80
90
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-12

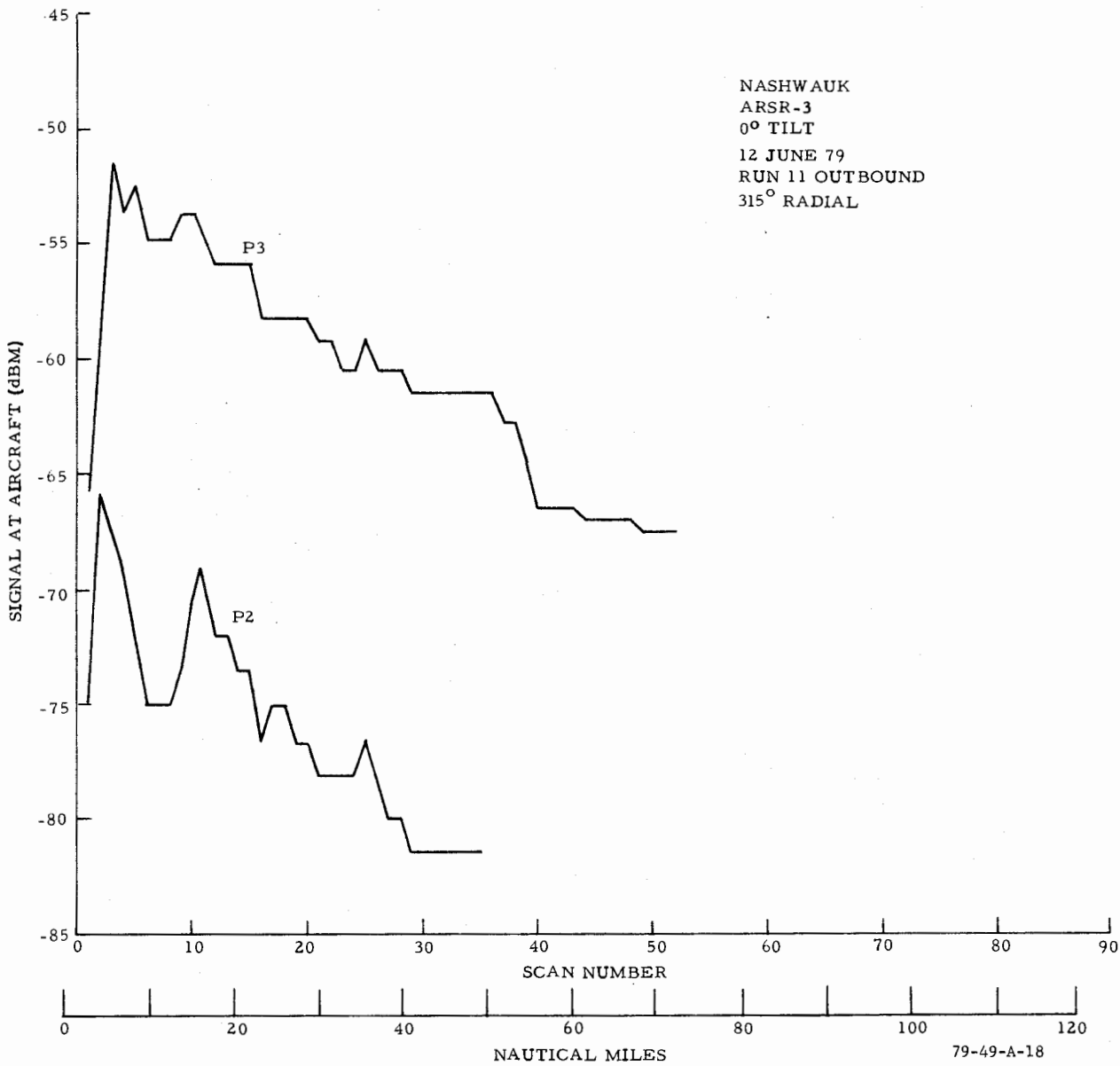

NASHWAUK
ARSR-3
-1° TILT
12 JUNE 79
RUN 6 INBOUND
220° RADIAL
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
P3
P2
55
45
35
25
15
5
0
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-13

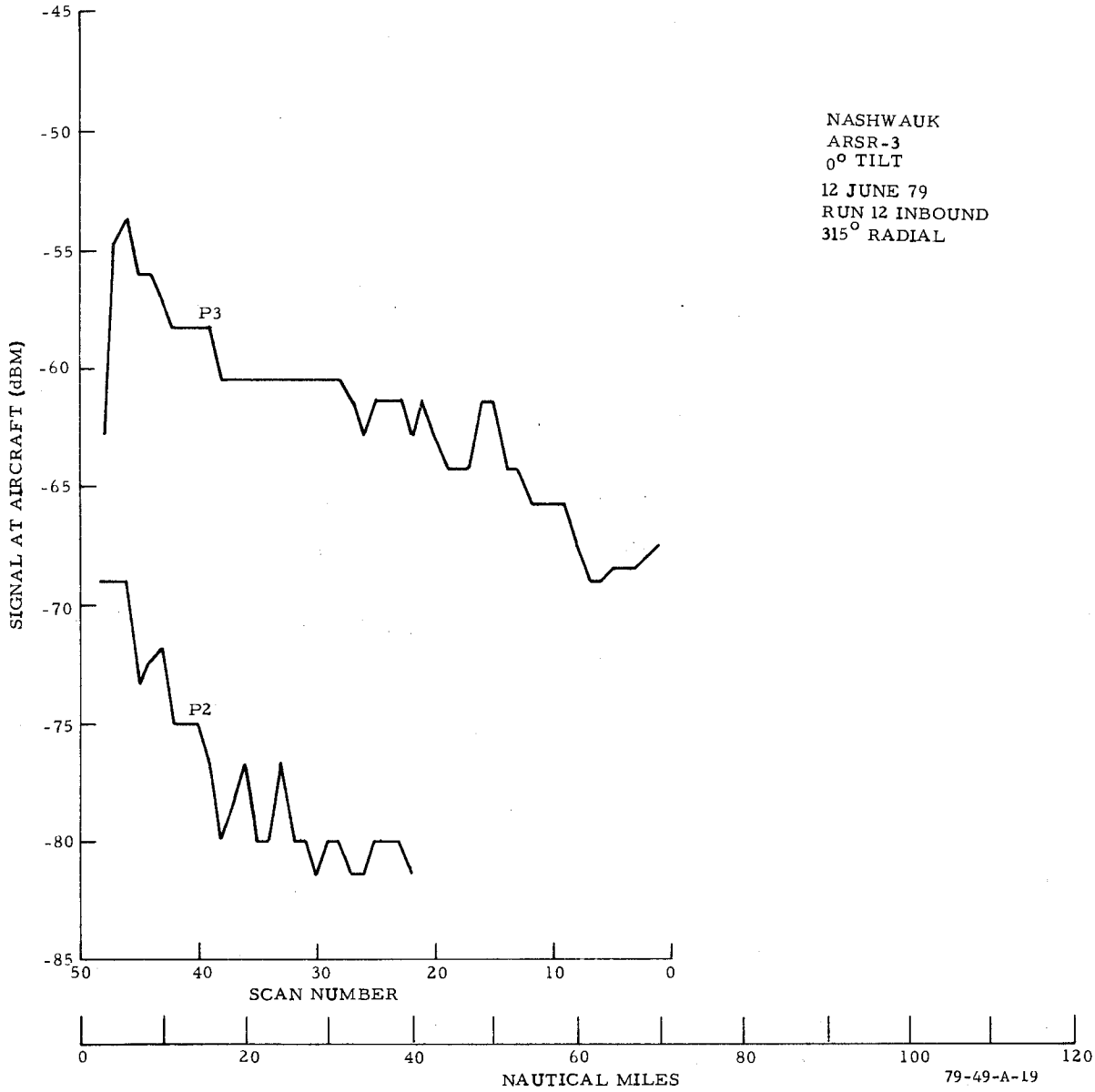

NASHWAUK
ARSR-3
0° TILT
12 JUNE 79
RUN 7 OUTBOUND
40° RADIAL
P3
P2
P3 MAX
SIDELOBES
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
0
10
20
30
40
50
60
70
80
90
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-14


-45
-50
-55
-60
-65
-70
-75
-80
-85
SIGNAL AT AIRCRAFT (dBM)
RADAR SITE
P3
P2
P3 MAX SIDELOBES
NASHWAUK
ARSR-3
0° TILT
12 JUNE 79
RUN 8 INBOUND
40° RADIAL
95
85
75
65
55
45
35
25
15
5
0
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-15


NASHWAUK
ARSR-3
0° TILT
12 JUNE 79
RUN 9 OUTBOUND
130° RADIAL
P3
P2
P3 MAX
SIDELOBES
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
0
10
20
30
40
50
60
70
80
90
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-16


NASHWAUK
ARSR-3
0° TILT
12 JUNE 79
RUN 10 INBOUND
130° RADIAL
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
P3
P2
65
55
45
35
25
15
5
0
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-17


NASHWAUK
ARSR-3
0° TILT
12 JUNE 79
RUN 11 OUTBOUND
315° RADIAL
P3
P2
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
0
10
20
30
40
50
60
70
80
90
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-18


NASHWAUK
ARSR-3
0° TILT
12 JUNE 79
RUN 12 INBOUND
315° RADIAL
SIGNAL AT AIRCRAFT (dBM)
-45
-50
-55
-60
-65
-70
-75
-80
-85
P3
P2
50
40
30
20
10
0
SCAN NUMBER
0
20
40
60
80
100
120
NAUTICAL MILES
79-49-A-19

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