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MATH MODEL STUDY, RUNWAY 16R INSTRUMENT LANDING SYSTEM LOCALIZER AT SEATTLE-TACOMA AIRPORT, WASHINGTON

Jesse D. Jones

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16. Abstract

Results of a math model study for the runway 16R instrument landing system (ILS) localizer at the Seattle-Tacoma Airport, Washington, are presented. This study was performed at the request of the Northwest Region of the Federal Aviation Administration (FAA) to determine the effects to the course structure of a proposed building and the replacement of the existing ILS localizer system. Resultant course structure plots are presented for both the existing Texas Instruments Basic Parabolic Category II Localizer and the proposed Wilcox 14/6 Catergory III Localizer, with and without the effects of the proposed Boeing building. The course structure plots are the output from the ILSLOC mathematical model computer program developed by the Transportation Systems Center and run on the Honeywell 66/60 computer at the FAA Technical Center.

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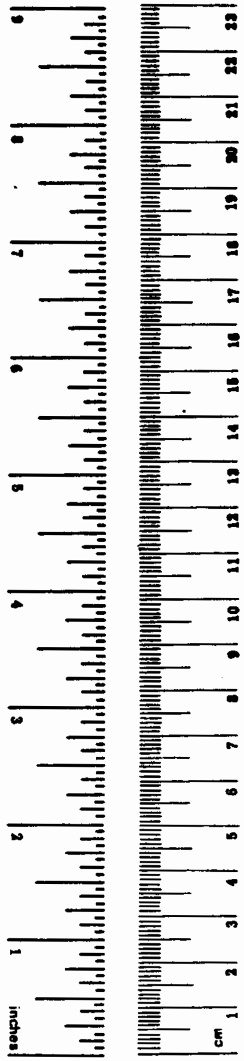
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

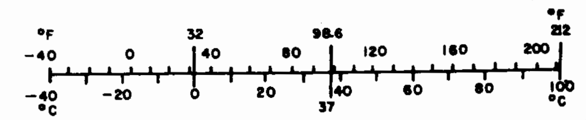
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

The purpose of this study was to provide computer modeled performance data showing the effects of a proposed building on the course structure of the existing Basic Parabolic Localizer System and the planned Wilcox Category III Localizer System on runway 16R at the Seattle-Tacoma Airport.

BACKGROUND.

The existing Instrument Landing System (ILS) Localizer on runway 16R at the Seattle-Tacoma Airport, Seattle, Washington, consists of a Texas Instruments Basic Parabolic System. This localizer system is commissioned for ILS performance category II service. To upgrade the ILS to performance category III, the Federal Aviation Administration (FAA) proposed to replace the existing localizer system with a Wilcox 14/6 Localizer.

In addition, the Boeing Company is proposing to build its corporate headquarters building 1,200 feet west of runway 16R. Reflections from this new building are expected to contribute to the degradation of the localizer course structure near the threshold of the runway.

To determine the magnitude of this effect, the Northwest Region of the FAA requested a computer model analysis of the above proposals. This request was referred to the FAA Technical Center by the Airway Facilities Service (AAF-420).

DISCUSSION.

The FAA Technical Center conducted mathematical computer model studies through application of a localizer model which was developed by the Transportation Systems Center (TSC) and converted to the Technical Center's Honeywell 66/60 computer. For a description of this modeling technique, see references. Reference 5 provides validation data for the localizer model.

Site data inputs to the model were as follows:

1. Runway length: 9,425 feet

2. Localizer frequency: 111.7 megahertz (MHz)

3. Localizer course width: 3.95°

4. Origin of coordinate system: runway 16R threshold

5. Localizer ground elevation: 353 feet mean sea level (MSL)

The coordinate system used has the origin at the threshold of runway 16R. The positive y-axis is directed toward the west. The positive x-axis is directed along the runway centerline toward the north. The positive z-axis is directed up. Alpha, the angle between the base of a wall and the x-axis, is measured in the counterclockwise direction. An alpha of 90° faces the wall of the building in the positive x-direction. Delta, the angle between the surface of a wall and the vertical direction, is equal to -90° for a horizontal wall facing down.

Surfaces entered into the model as sources of reflections and scattering are listed in table 1 and shown in figure 1. The surfaces are considered to be of infinite conductivity over the total surface and to have zero thickness. This assumption will result in a worst-case performance prediction. Only those surfaces of buildings which are parallel to the runway were entered into the model. Reflections from surfaces not parallel to the runway would be reflected such that they would not affect the course structure.

The parabolic array radiation pattern (figure 2) is based on actual measurements at Seattle-Boeing Field International. Wilcox 14/6 theoretical antenna data from various sources are provided in figure 3. Actual measurements of the 14/6 antenna radiation pattern were not available. A comparison of the model input data for the two antennas is given in table 2.

DATA PRESENTATION.

Distances shown on the horizontal axis of the course structure plots (figures 4 through 10) are referenced to the threshold of runway 16R. Negative values are between threshold and the localizer. Positive values of distances are between the threshold and the outer marker. Angles shown on the horizontal axis of the clearance orbit plots (figures 11 through 15) are negative on the 150-hertz (Hz) side of the extended runway centerline and positive on the 90-Hz side. The vertical axis of the course structure and clearance orbit plots shows the model output value of the course deviation indicator (CDI).

Model output course structure plots for the parabolic antenna are shown in figures 4, 5, and 6. Figure 4 shows that the parabolic antenna without scattering from the proposed Boeing building meets ILS category II performance standards. Figure 5 shows that the proposed Boeing building will cause increased course structure error within 1,000 feet of threshold and thus degrade the course to ILS performance category I. Rotating the Boeing building clockwise 8° or more would permit ILS performance category II operation as shown in figure 6. The category II operation is very marginal in figures 4 and 6.

Figures 7, 8, 9, and 10 are 14/6 antenna course structure plots. The plot shown in figure 7 indicates that the 14/6 antenna without the proposed Boeing building will meet ILS performance category II tolerances, and the plot in figure 8 indicates that the proposed Boeing building will result in the localizer course structure meeting only ILS performance category I tolerances. Rotating the proposed building 8° clockwise would result in the course structure meeting ILS performance category II tolerances (figure 9). Changing the clearance ratio from 12.5 to 20 decibels (dB) would improve the course structure with the Boeing building to marginal ILS performance category II tolerances as shown by figure 10.

Figures 11 through 15 show 6-nautical-mile clearance orbits at 1,000 foot altitude for the two antennas with and without the proposed building. These plots indicate that adequate clearance is provided for these conditions.

The course structure plots and the clearance orbits are based on the static values of CDI (the value existing at that location in space). The smoothing effect of the CDI output current time constant (0.4 second) of the flight check receiver will result in slightly smaller values of peak-to-peak CDI deviations.

REFERENCES

1. Instrument Landing System Scattering, DOT/FAA Report FAA-RD-72-137, 1972.

2. User's Manual for ILSLOC: Simulation for Derogation Effects on the Localizer Portion of the Instrument Landing System, DOT/FAA Report FAA-RD-73-76, 1973.

3. Performance Predictions for a Parabolic Localizer Antenna on Runway 28R - San Francisco Airport, DOT/FAA Report FAA-RD-73-81, 1973.

4. Instrument Landing System Performance Prediction, DOT/FAA Report 4AA-RD-73-200, 1974.

5. ILS Localizer Performance Study, Part 1, Dallas/Fort Worth Regional Airport and Model Validation, Syracuse Hancock Airport, DOT/FAA Report FAA-RD-72-96, 1972.

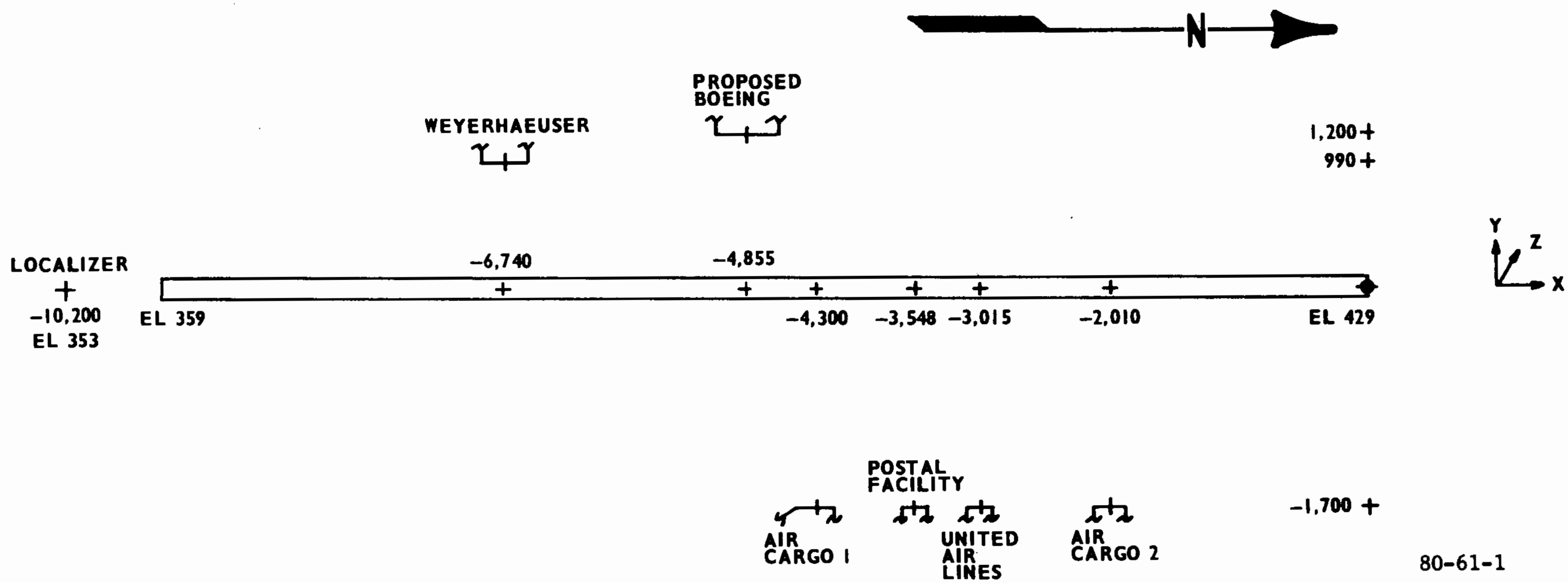

FIGURE 1. SEATTLE-TACOMA RUNWAY 16R, SCATTERING LAYOUT

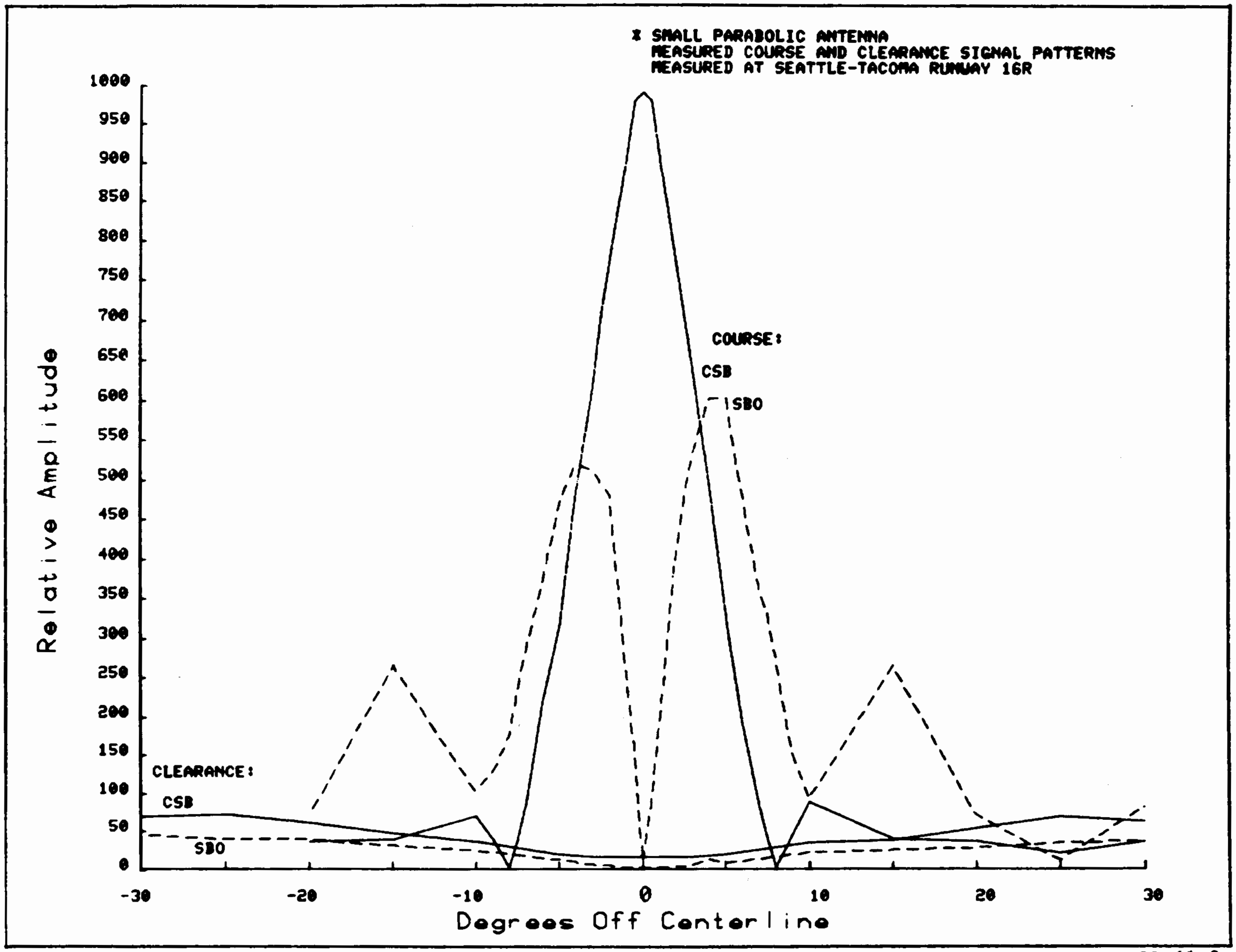

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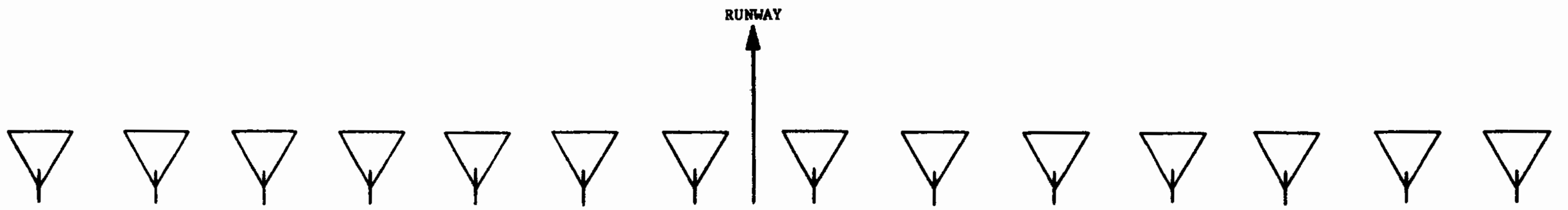
FIGURE 2. TEXAS INSTRUMENTS BASIC PARABOLIC LOCALIZER ANTENNA - MEASURED COURSE AND CLEARANCE ANTENNA PATTERNS



Antenna	7L	6L	5L	4L	3L	2L	1L	1R	2R	3R	4R	5R	6R	7R
ANTENNA SPACING FROM CENTER														
Inches	514.95	434.59	354.12	273.65	193.18	112.72	32.25	32.25	112.72	193.18	273.65	354.12	434.59	514.95
Degrees	1753.2	1479.6	1205.64	931.68	657.72	383.76	109.80	109.80	383.76	657.72	931.68	1205.64	1479.60	1753.20
Wave Lengths	4.870	4.110	3.349	2.588	1.827	1.066	0.305	0.305	1.066	1.827	2.588	3.349	4.110	4.870
Course CSB														
Amp	0.160	0.160	0.491	0.491	0.714	1.000	0.893	0.893	1.000	0.714	0.491	0.491	0.160	0.160
Phase	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Course SBO														
Amp	0.367	0.555	0.889	1.000	1.000	0.667	0.222	0.222	0.667	1.000	1.000	0.889	0.555	0.367
Phase	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-180.0	-180.0	-180.0	-180.0	-180.0	-180.0	-180.0
Clearance CSB														
Amp					0.200	0.0	1.000	1.000	0.0	0.200				
Phase					0.0	0.0	0.0	-180.0	-180.0	-180.0				
Clearance SBO														
Amp					0.139	0.333	1.000	1.000	0.333	0.139				
Phase					0.0	0.0	0.0	-180.0	-180.0	-180.0				
Antenna	7L	6L	5L	4L	3L	2L	1L	1R	2R	3R	4R	5R	6R	7R

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FIGURE 3. WILCOX TYPE IB LOCALIZER 14/6 ANTENNA - ANTENNA CURRENTS AND PHASES

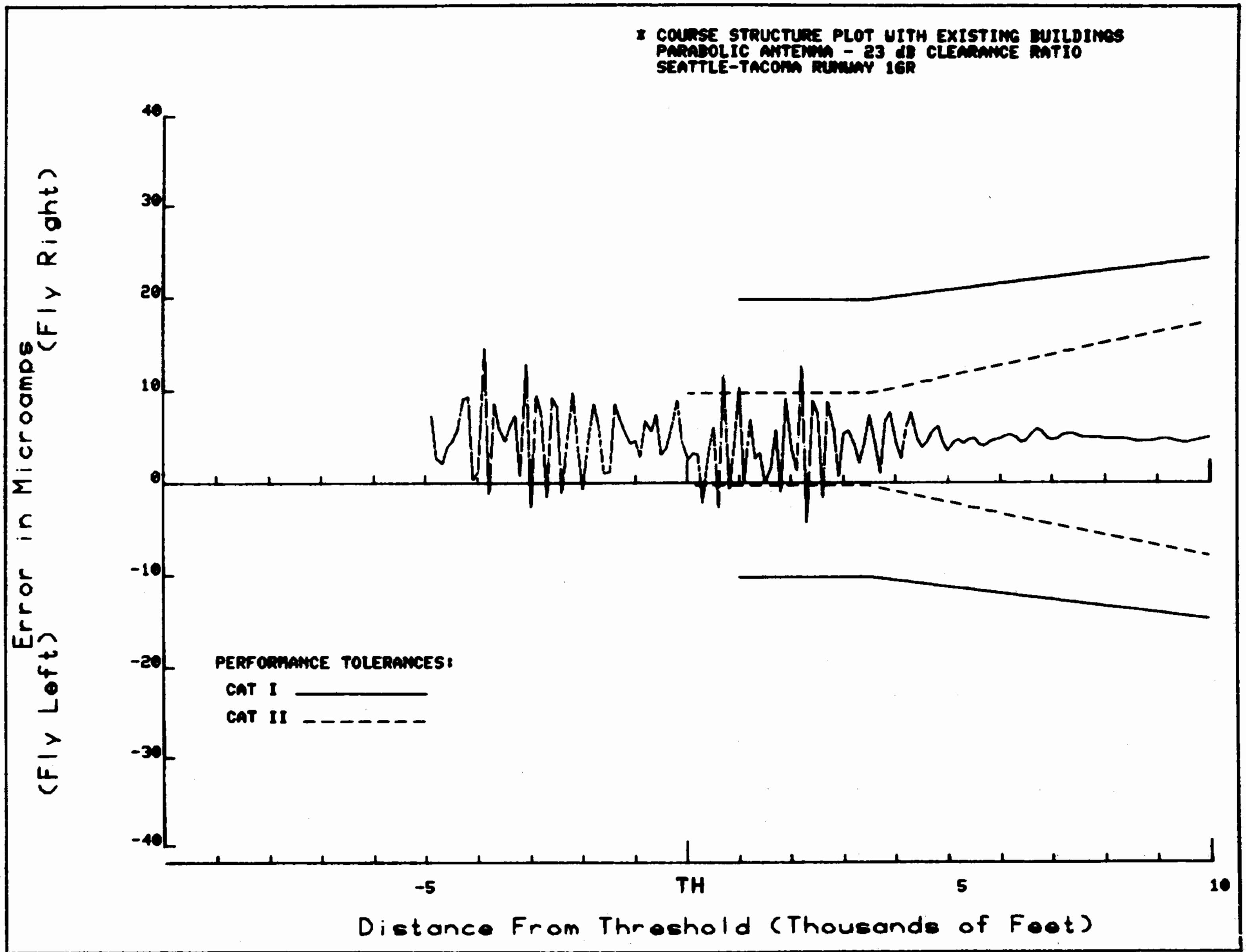

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FIGURE 4. PARABOLIC ANTENNA, COURSE STRUCTURE PLOT WITH EXISTING BUILDINGS

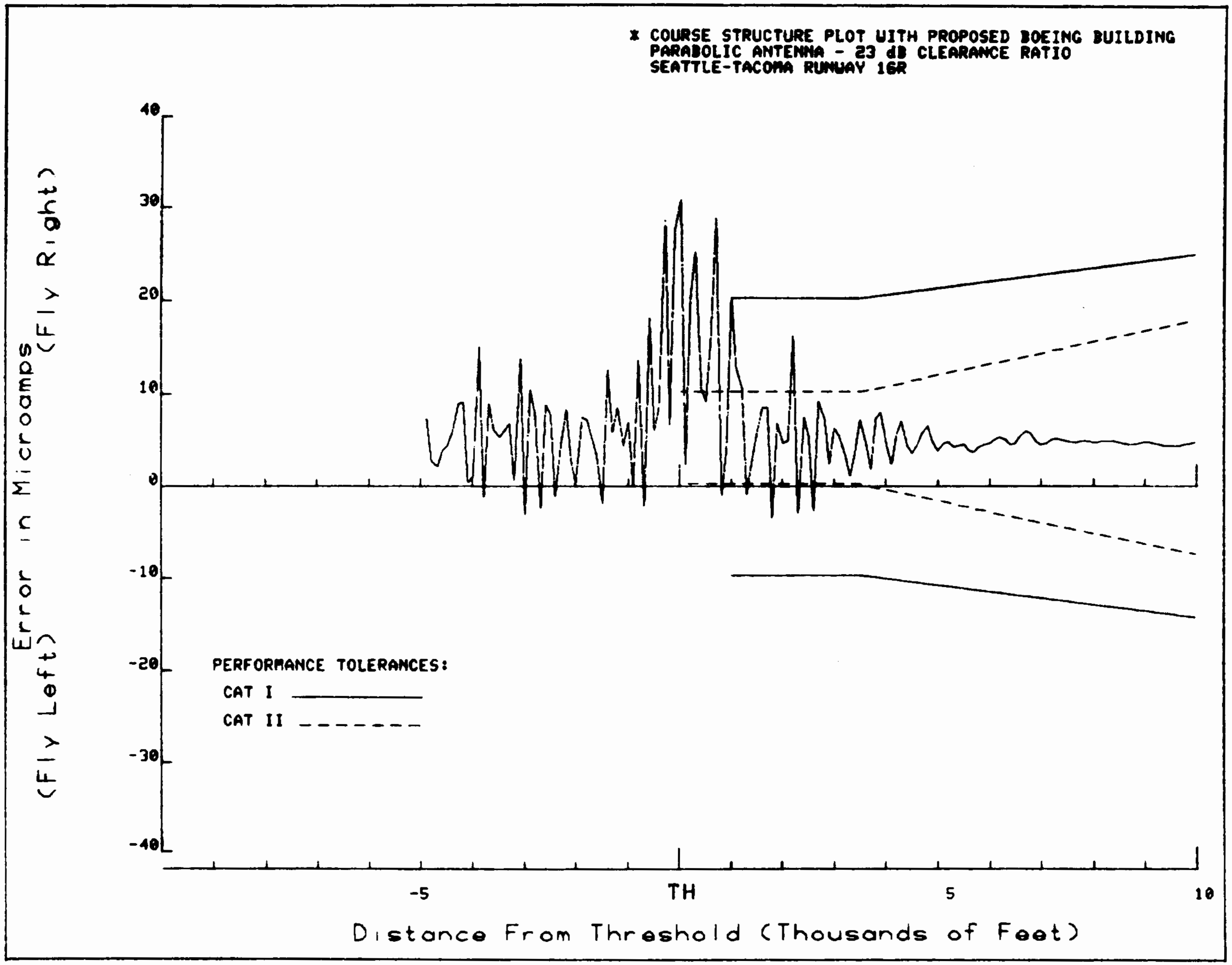

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FIGURE 5. PARABOLIC ANTENNA, COURSE STRUCTURE PLOT WITH PROPOSED BUILDING

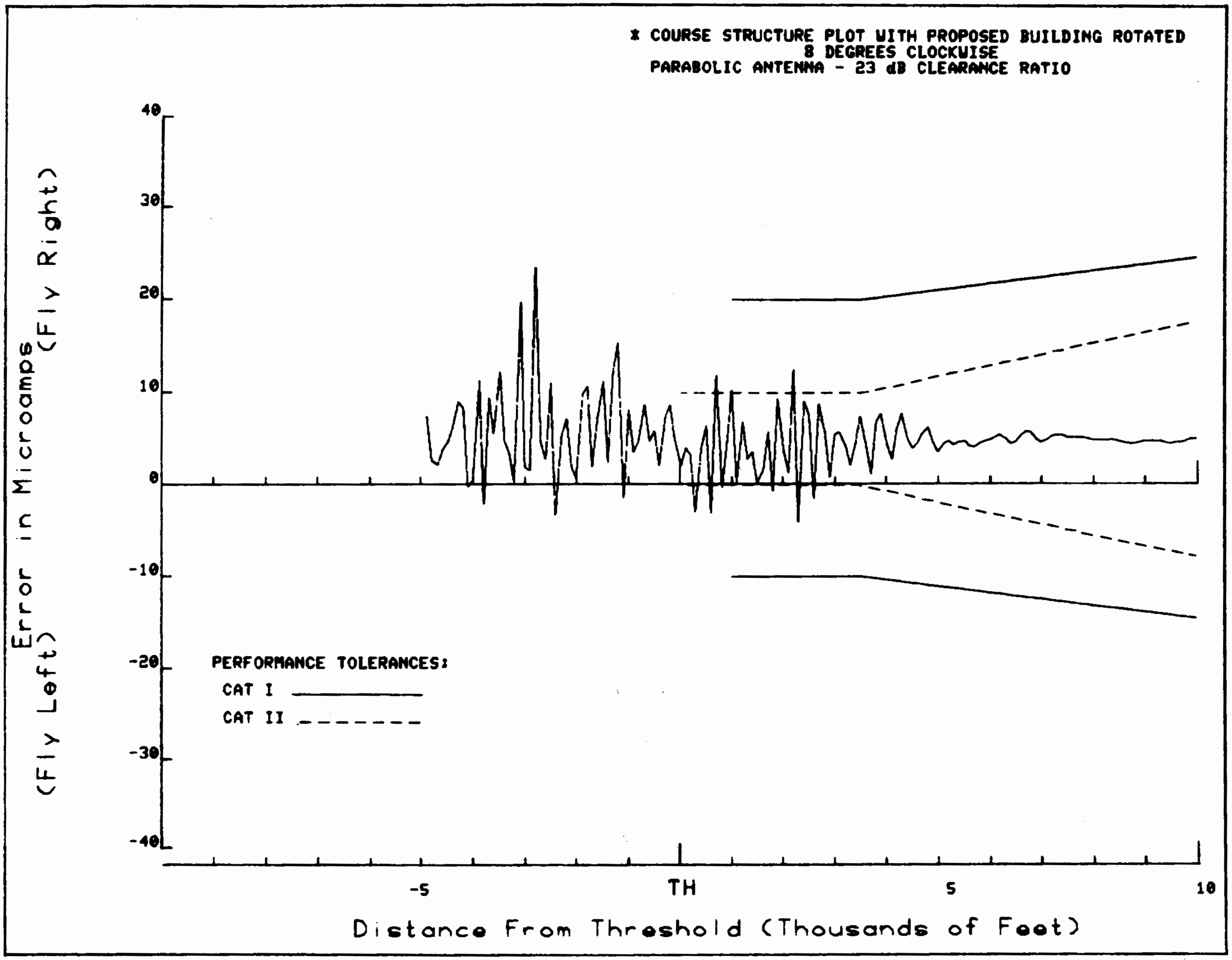

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FIGURE 6. PARABOLIC ANTENNA, COURSE STRUCTURE PLOT WITH PROPOSED BUILDING ROTATED 8°ClOCKWISE

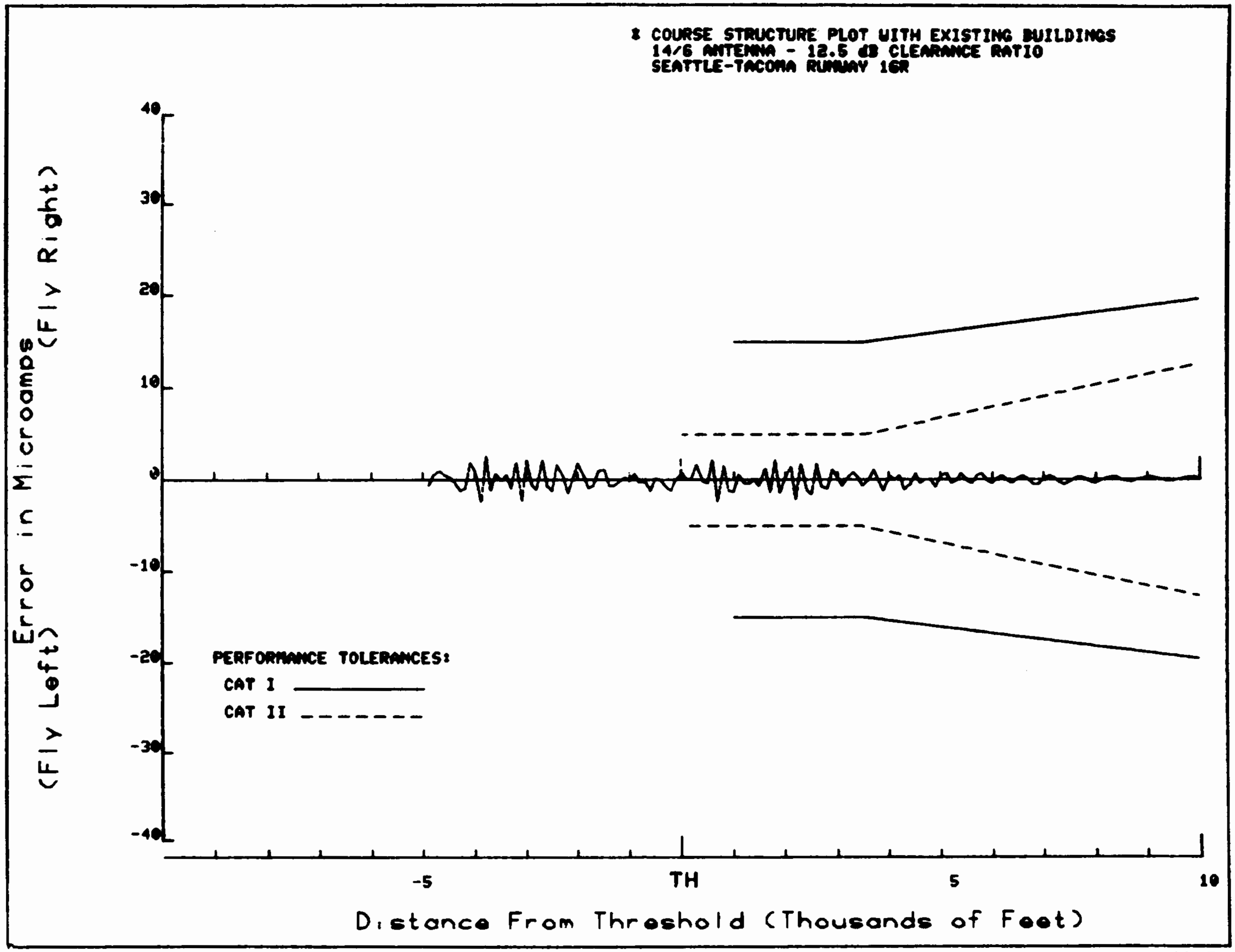

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FIGURE 7. 14/6 ANTENNA, COURSE STRUCTURE PLOT WITH EXISTING BUILDINGS

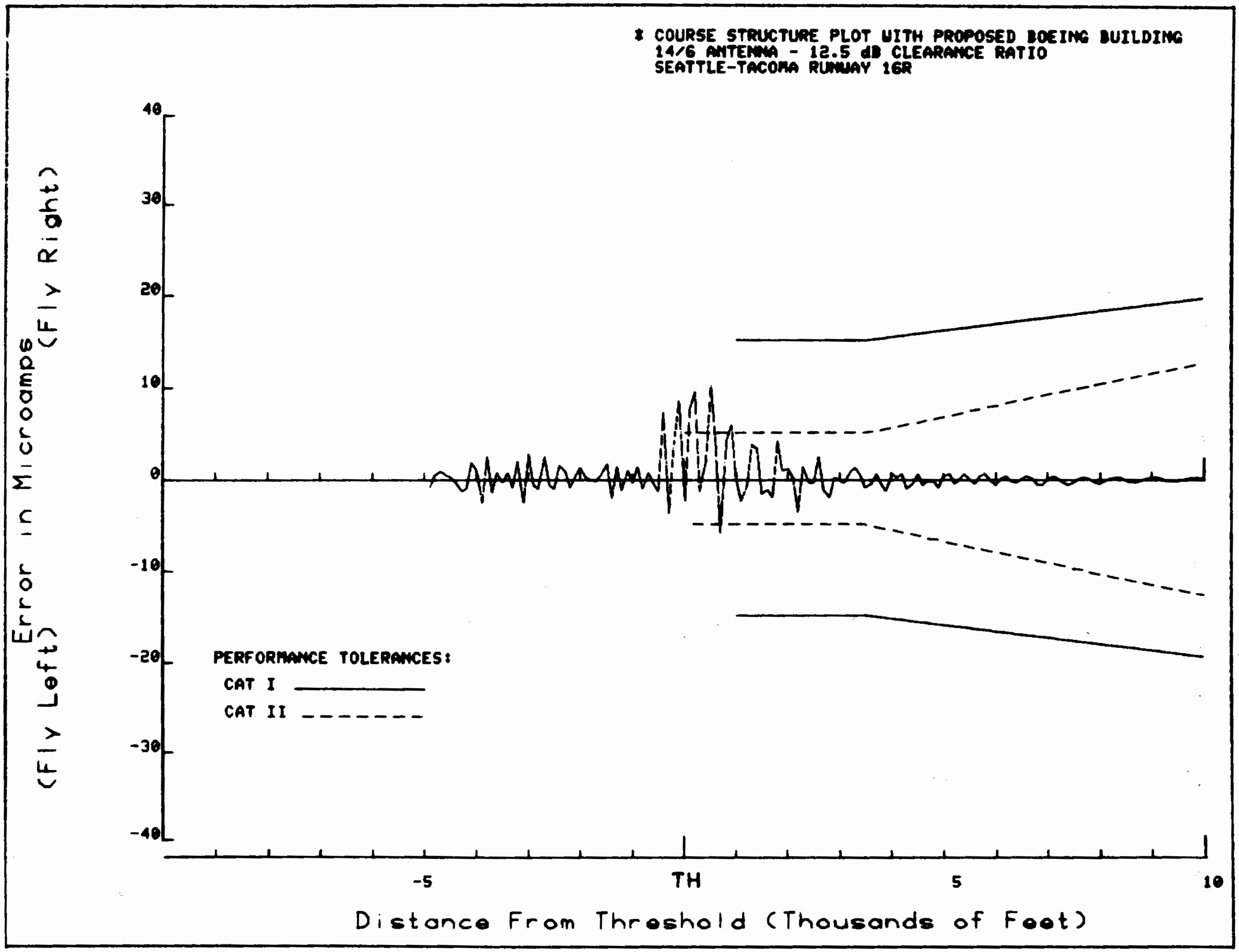

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FIGURE 8. 14/6 ANTENNA, COURSE STRUCTURE PLOT WITH PROPOSED BUILDING

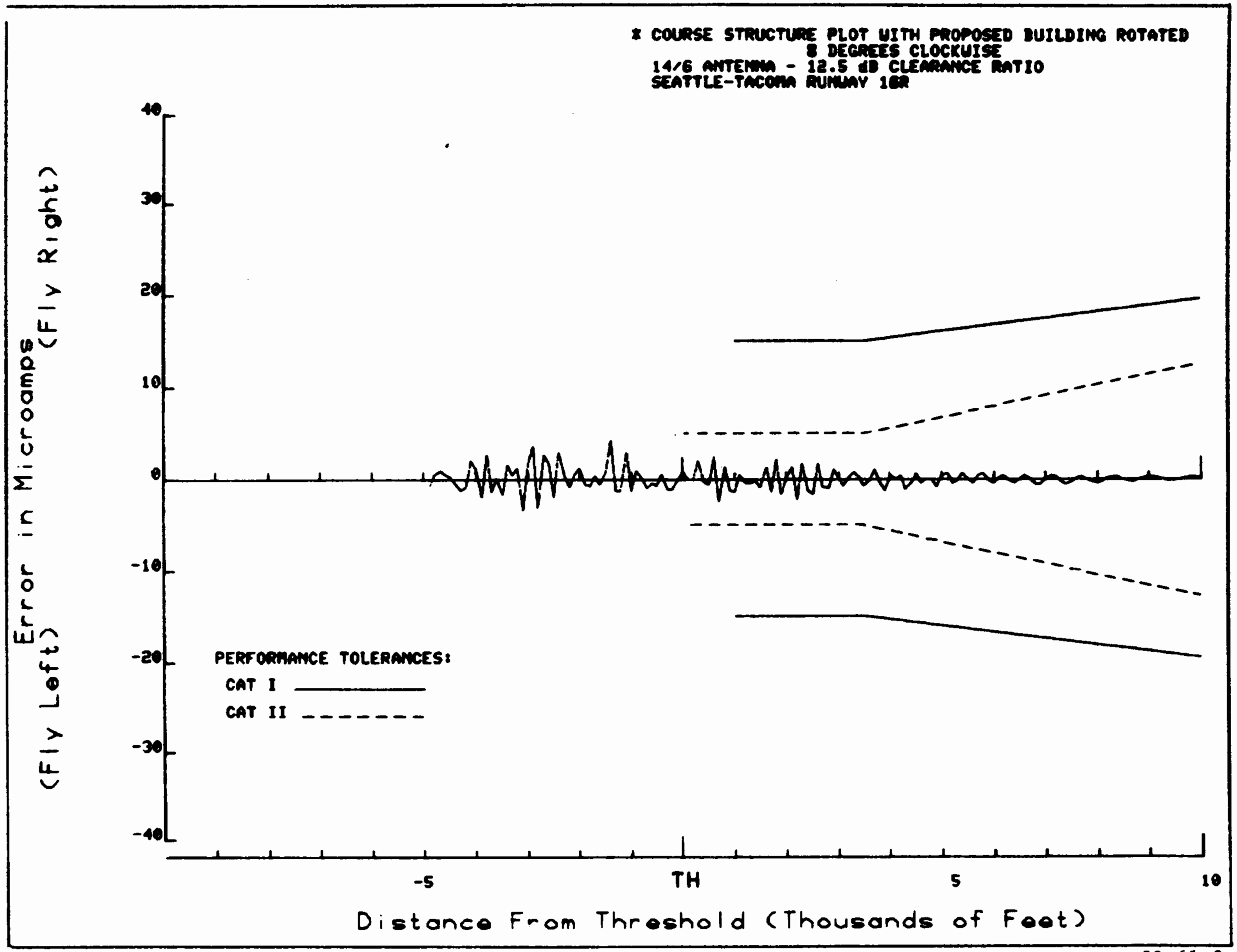

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FIGURE 9. 14/6 ANTENNA COURSE STRUCTURE PLOT WITH PROPOSED BUILDING ROTATED 8° CLOCKWISE

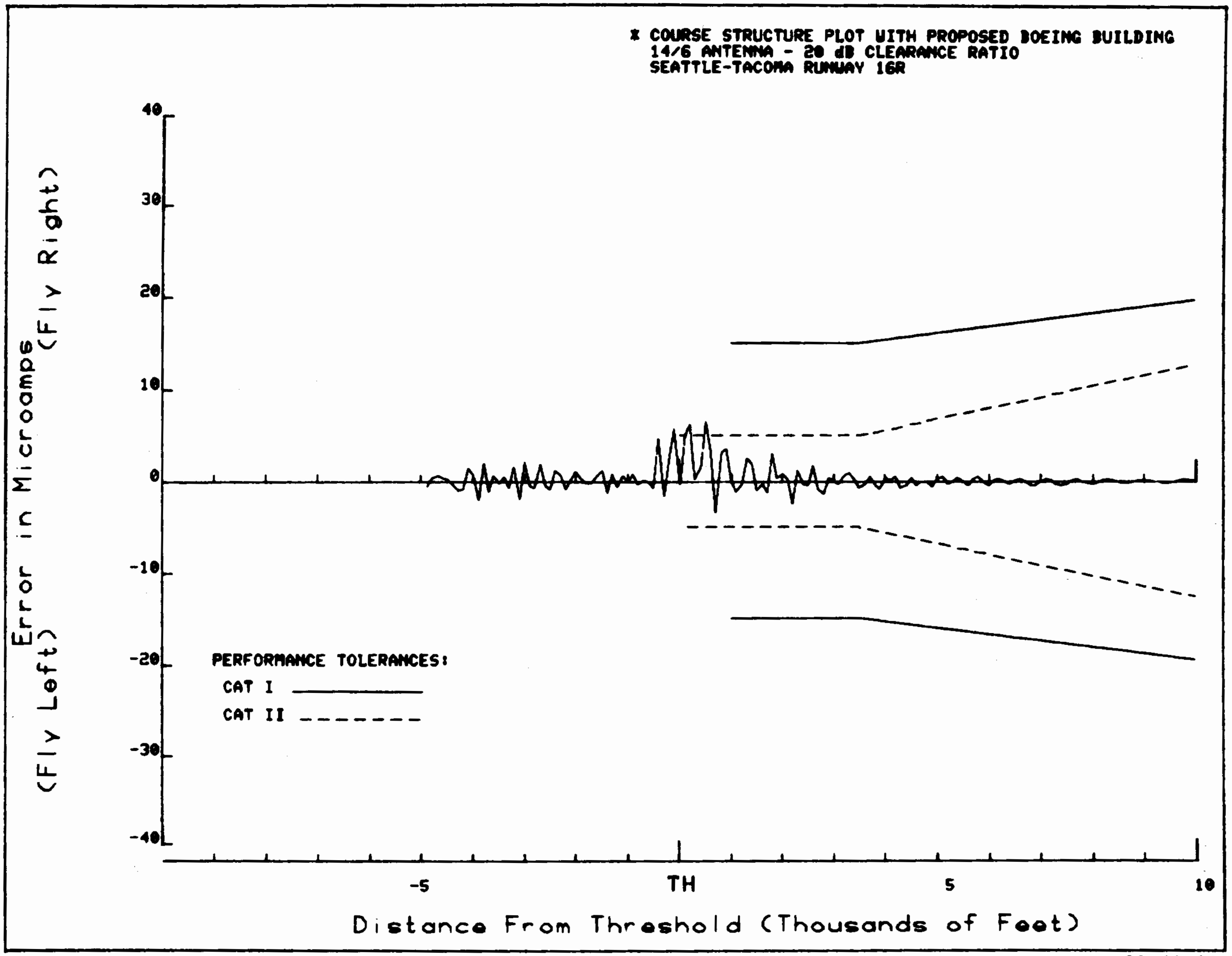

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FIGURE 10. 14/6 ANTENNA, COURSE STRUCTURE PLOT WITH PROPOSED BUILDING AND 20-dB CLEARANCE RATIO

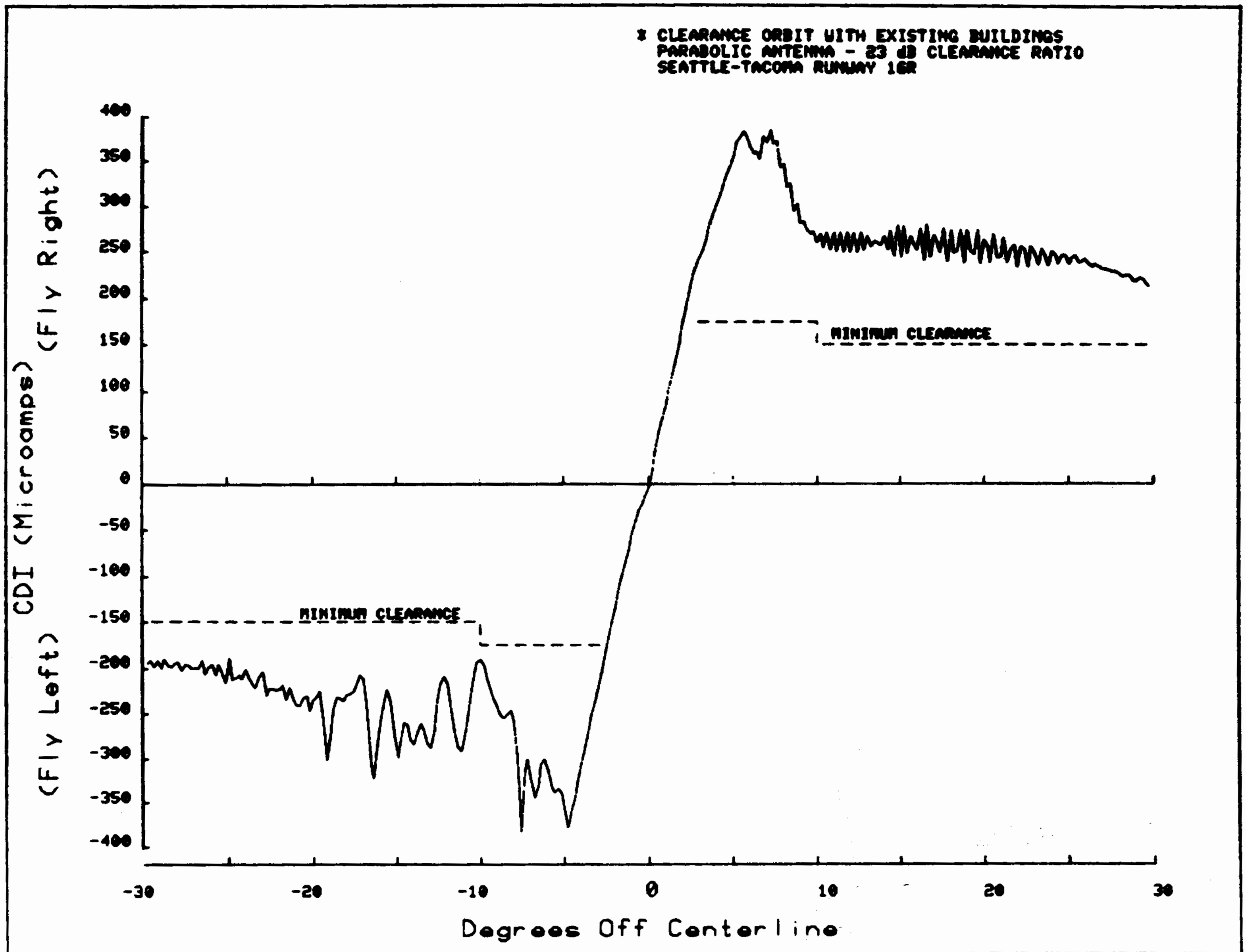

FIGURE 11. PARABOLIC ANTENNA, CLEARANCE ORBIT WITH EXISTING BUILDING

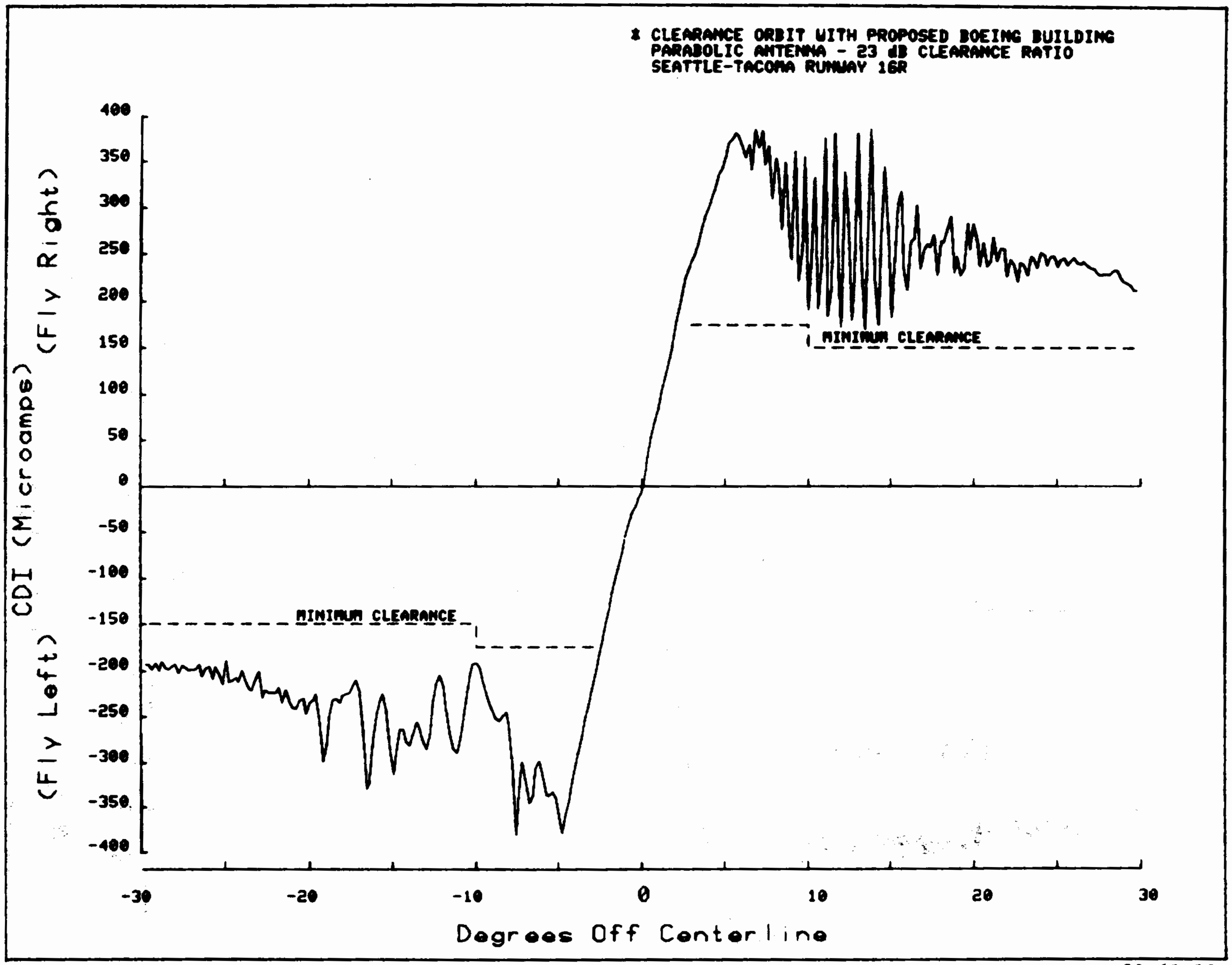

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FIGURE 12. PARABOLIC ANTENNA, CLEARANCE ORBIT WITH PROPOSED BUILDING

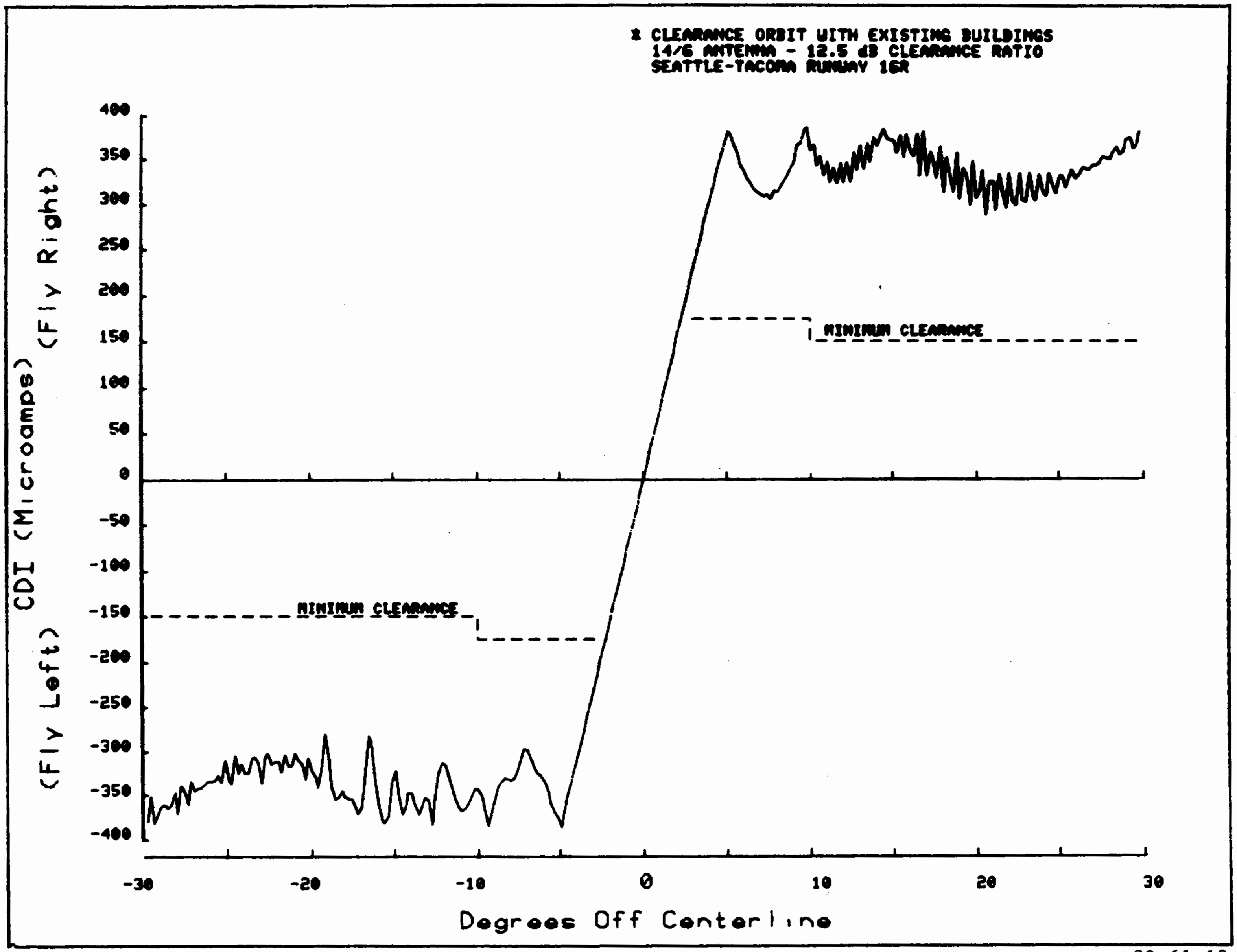

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FIGURE 13. 14/6 ANTENNA, CLEARANCE ORBIT WITH EXISTING BUILDINGS

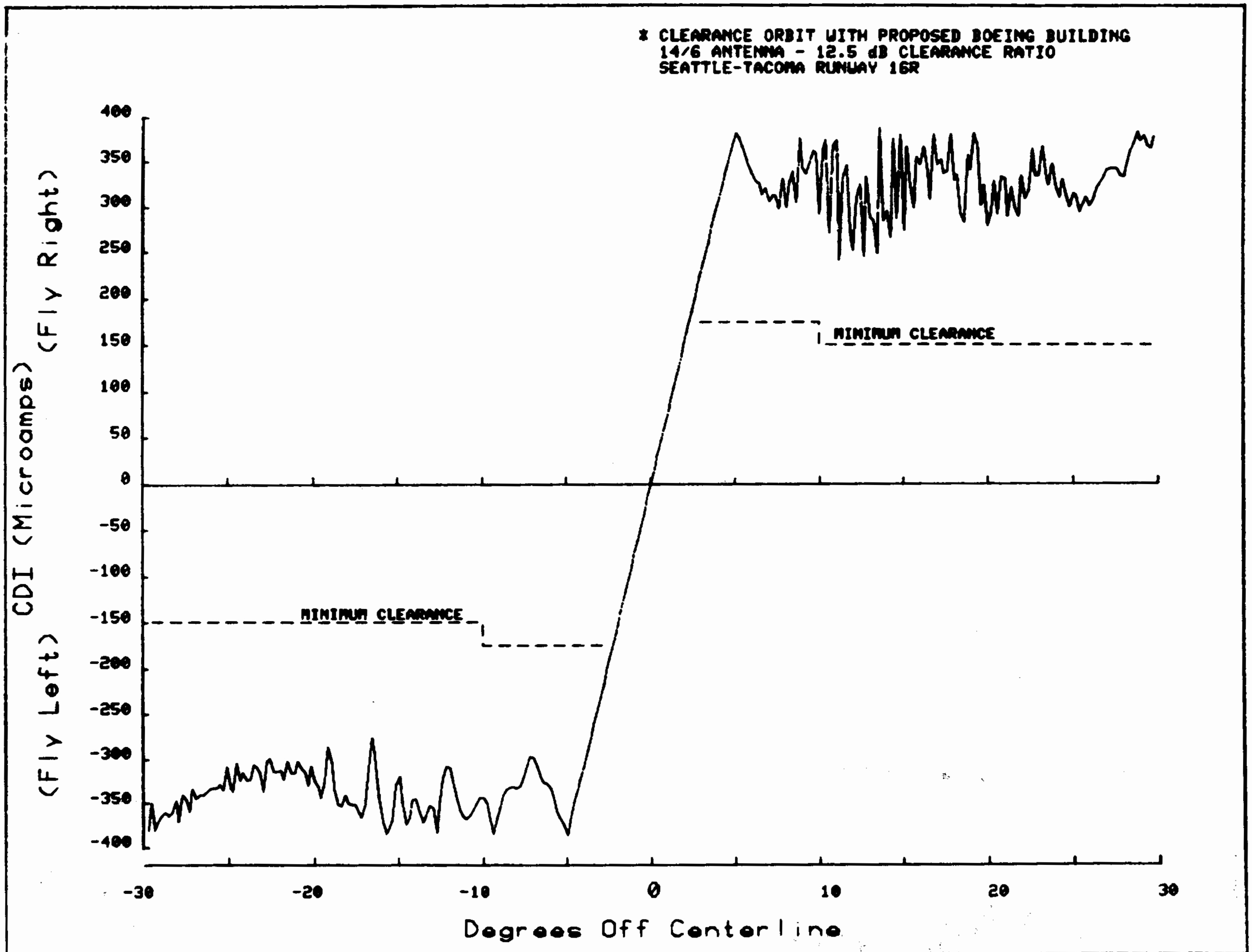

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FIGURE 14. 14/6 ANTENNA, CLEARANCE ORBIT WITH PROPOSED BUILDING

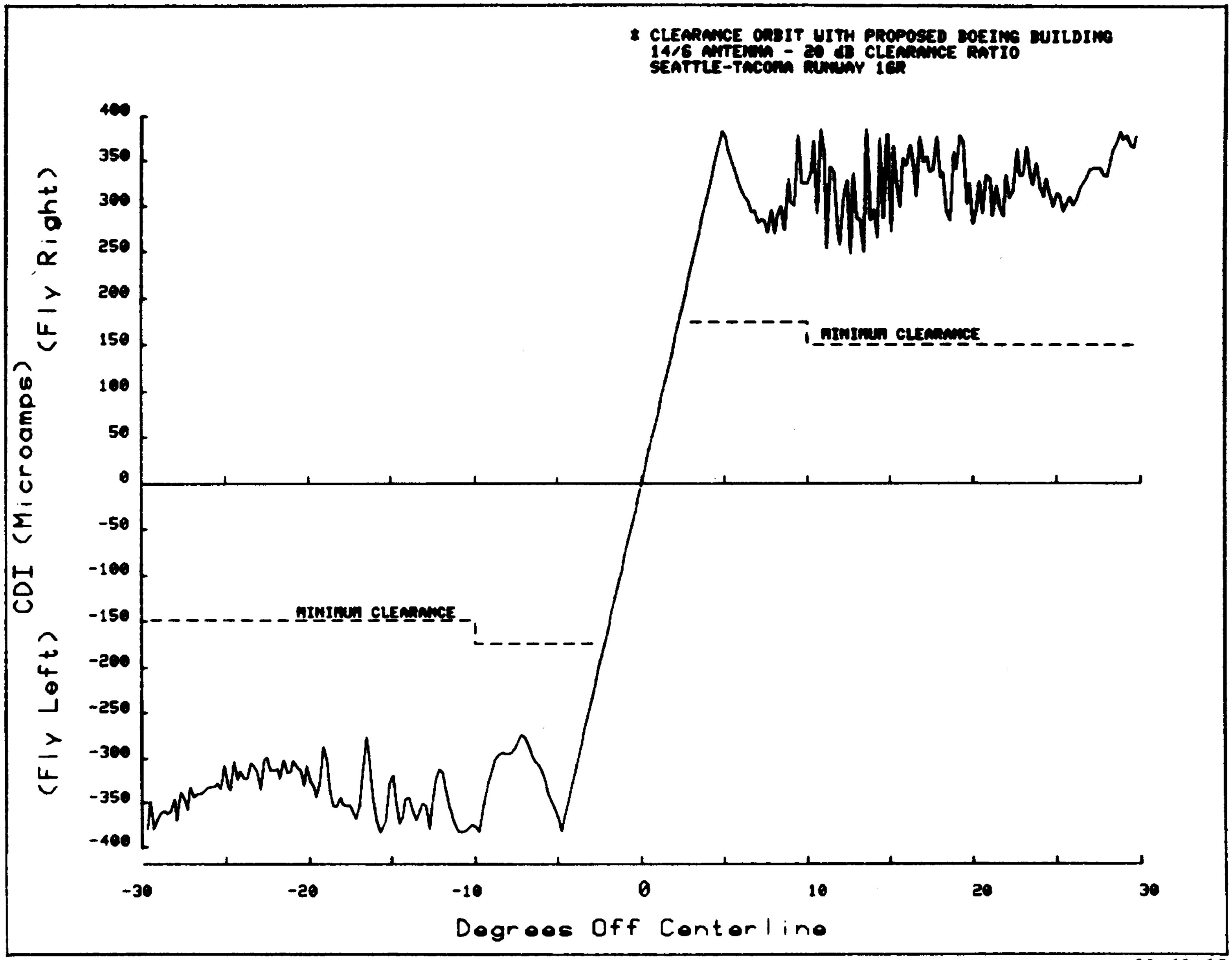

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FIGURE 15. 14/6 ANTENNA, CLEARANCE ORBIT WITH PROPOSED BUILDING AND 20-dB CLEARANCE RATIO

TABLE 1. BUILDING DATA

Building	Coordinates (ft)* X	Y	Z	Width (ft)	Height (ft)	Alpha (deg.)	Delta (deg.)
Air Cargo 1	-4300	-1700	408	300	30	180	0
Air Cargo 2	-2010	-1700	430	250	40	180	0
Postal Facility	-3548	-1700	422	200	45	180	0
United Airlines	-3015	-1700	425	210	40	180	0
Weyerhaueser	-6740	990	370	180	40	0	0
Proposed Boeing	-4855	1200	407	475	65	0	0

* Reference at midpoint of base of wall

TABLE 2. LOCALIZER ANTENNA DATA

Item	Basic Parabolic Array	14/6 Array
Antenna Pattern Source	Measured at Seattle-Tacoma	Theoretical amplitudes and phases
Antenna Height (Radiating Elements)	10.5 feet	6.5 feet
Distance to End of Runway Course/Clearance Antennas	775/725 feet	775/775 feet
Distance to Threshold Course/Clearance Antennas	10,200/10,150 feet	10,200/10,200 feet
Site Elevation	353 feet MSL	353 feet MSL
Centerline Course Carrier plus Sidebands (CSB) to Clearance CSB Ratio	23 dB	12.5 dB