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technical note technical note

AD-A164 907

Math Model Study of A Proposed Glide Slope for Runway 13R, Dallas-Fort Worth Airport, Texas

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January 1986

DOT/FAA/CT-TN85/80

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/CT-TN85/80	AD-A164 967	

4. Title and Subtitle
MATH MODEL STUDY OF A PROPOSED GLIDE SLOPE FOR RUNWAY 13R, DALLAS-FORT WORTH AIRPORT, TEXAS

5. Report Date
January 1986

6. Performing Organization Code
ACT-140

7. Author(s)
John Walls

8. Performing Organization Report No.
DOT/FAA/CT-TN85/80

9. Performing Organization Name and Address
U.S. Department of Transportation
Federal Aviation Administration
Technical Center
Atlantic City Airport, New Jersey 08405

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
T0603C

12. Sponsoring Agency Name and Address
U.S. Department of Transportation
Federal Aviation Administration
Program Engineering and Maintenance Service
Washington, DC 20590

13. Type of Report and Period Covered
Technical Note
January 1986

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This Technical Note describes instrument landing system (ILS) math modeling performed at the request of the Southwest Region. Data are presented showing the computed performance of a proposed glide slope for runway 13R at the Dallas-Fort Worth Airport, Texas. Modeled path structure and level run plots are provided for capture effect, null reference, and sideband reference systems installed at a location selected by region engineers. Results indicate that all three systems should meet category II path structure, linearity, and symmetry tolerances. The capture effect system provides the smoothest glidepath structure of the three systems modeled.

17. Key Words
Instrument Landing System
Math Modeling
Glide Slope

18. Distribution Statement
This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	19	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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EXECUTIVE SUMMARY

This instrument landing system (ILS) math modeling study, performed at the request of the Southwest Region, provides data showing the computed performance of a proposed glide slope for runway 13R at the Dallas-Fort Worth Airport, Texas. Modeled path structure and level run plots are provided for capture effect, null reference, and sideband reference systems installed at a location selected by region engineers. Results indicate that all three systems should meet category II path structure, linearity, and symmetry tolerances. The capture effect system provides the smoothest glidepath structure of the three systems modeled.

INTRODUCTION

PURPOSE.

This study was performed to provide computer modeled instrument landing system (ILS) glide slope performance data for the proposed glide slope for runway 13R at the Dallas-Fort Worth Airport, Texas.

BACKGROUND.

Runway 13R is presently under construction at the Dal' -Fort Worth Airport. The Southwest Region is concerned that upsloping terrain in the vicinity of the proposed glide slope location may adversely affect the performance of the proposed category II system. Region engineers have selected a site which is 1,080 feet back from runway threshold and offset 400 feet from runway centerline (figure 1). The original ASW-400 request was for math modeling of a null reference system. This request was later expanded to include math modeling of capture effect and sideband reference systems at the same location.

DISCUSSION

MODEL DESCRIPTION.

The mathematical model used for this simulation was the Ohio University Geometrical Theory of Diffraction (OUGTD) model which was obtained from Ohio University under an Federal Aviation Administration (FAA) Technical Center contract. This program was written for Ohio University by Mr. Vichate Ungvichian to account for the interactions of electromagnetic waves when reflected and/or diffracted from the terrain between an ILS antenna and an aircraft (reference 1). The OUGTD program utilizes the Geometrical Theory of Diffraction (GTD) and the Uniform Theory of Diffraction (UTD) as the basic theories when computing the diffraction of the electromagnetic waves. The GTD and UTD theories both treat electromagnetic waves as rays. This is acceptable due to the localized nature of wave interactions at very high frequencies (above 100 megahertz (MHz)). This treatment allows one to include the multiple interaction (i.e., doubly diffracted, etc.) between neighboring ground plates with little computational effort; whereas, this is a very difficult task when using the Physical Optics theory. The UTD theory is used to calculate the fields in the transition areas; the GTD theory is used in all other areas.

The model considers the direct ray plus 13 additional rays. Each ray is determined by the various terrain irregularities encountered in front of the ILS antenna system. These rays are:

1. Direct
2. Reflected
3. Diffracted
4. Reflected-reflected
5. Reflected-diffracted
6. Diffracted-reflected
7. Diffracted-diffracted
8. Reflected-reflected-diffracted
9. Reflected-reflected-reflected
10. Reflected-diffracted-reflected
11. Diffracted-diffracted-reflected
12. Reflected-diffracted-diffracted
13. Diffracted-reflected-reflected
14. Diffracted-reflected-diffracted

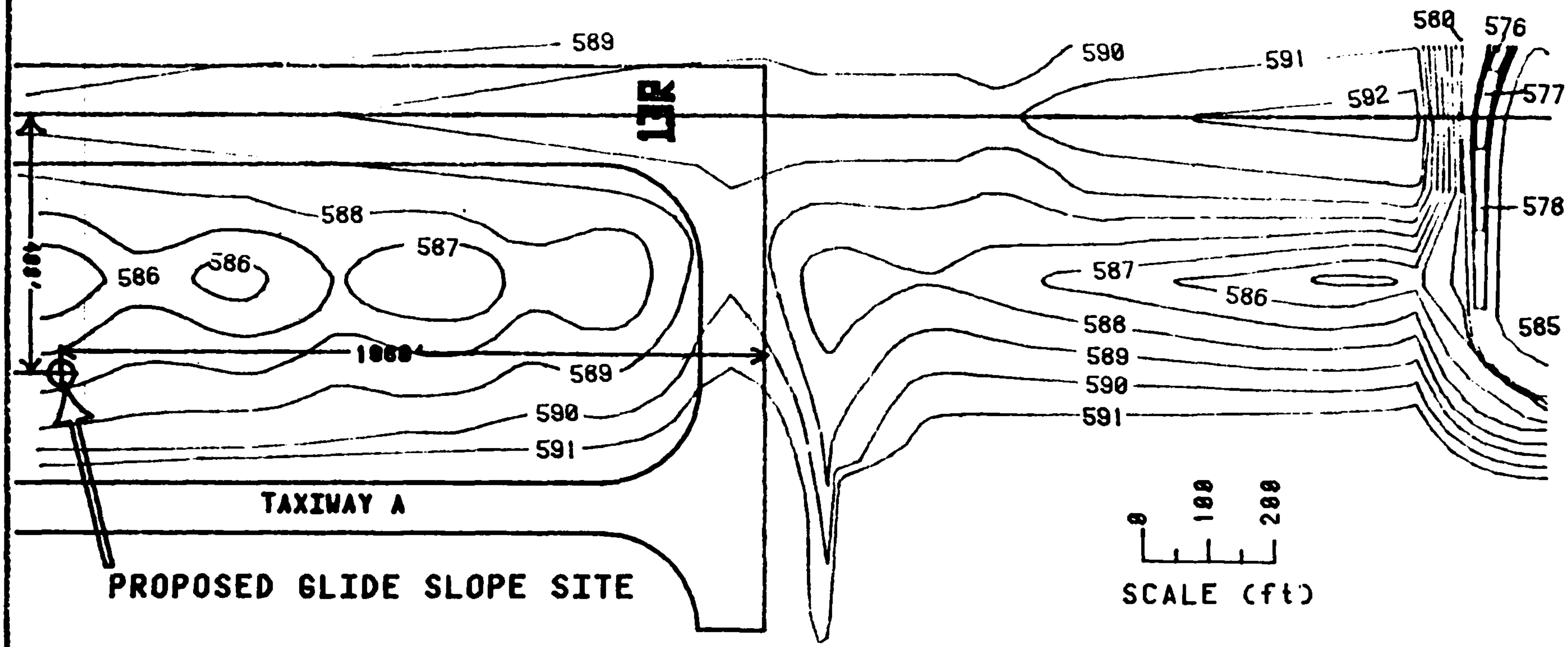

FIGURE 1. PROPOSED GLIDE SLOPE, RUNWAY 13R, DALLAS-FORT WORTH AIRPORT

The psuedo-3D version of the model was used for this modeling effort. This version uses a matrix of X, Y, and Z coordinates for the terrain to compute a new terrain profile for each observation point (simulated aircraft position). The term "psuedo-3D" is used to emphasize the fact that the model is not truly 3-dimensional, but rather an enhancement of the 2D version which uses a single terrain profile for all observation points. The subroutine that determines the profile was modified by FAA Technical Center engineers to eliminate some restrictions on establishing the origin and selection of coordinates. For each observation point and its associated terrain profile, the simulated Course Deviation Indicator (CDI) deflection is computed from the various combinations of rays.

MODEL INPUT DATA.

Input data required by the model consists of two data files: the terrain matrix file and the input/control file. The terrain matrix file consists of X (distance perpendicular to the runway), Y (distance along the runway centerline extended), and Z (elevation values referenced to the base of the antenna mast). The input/control file consists of data describing the antenna system (location, amplitude, and phase of each antenna element), along with other pertinent site and flightpath data. Antenna heights were computed to produce actual path angles of approximately 3°. Antenna current phasing for all simulations were computed using a simulation of the airborne phasing techniques detailed in the Flight Inspection Manual OAP 8200.1 (reference 2). In the simulation, samples of antenna current phase are recorded while flying the simulated aircraft along an approach angle of 1.5° from 8 to 4 nautical miles (nmi) with respect to the site. Ten samples of antenna current phase are recorded for each antenna. Using average phase values, the phase of the upper antenna is adjusted for zero phase difference with respect to the lower antenna for sideband reference or null reference systems. For the capture effect system, the phases of the lower and upper antennas are adjusted to result in zero phase difference with respect to the middle antenna. This technique is similar to the method originated by the Ohio University Avionics Center for their modeling applications.

A summary of the model input data describing the antenna systems is provided in table 1. Figure 1 shows the location of the proposed glide slope system with respect to runway 13R.

The computer model applies an interpolation process to the terrain matrix file to determine a new terrain profile for each observation point (simulated aircraft position) along the flightpath. The new profile is that of the terrain directly below a line drawn from the ILS antenna to the observation point. This profile is the surface used in the computation of the glide slope radio frequency (RF) energy at the observation point. Figure 2 shows a composite of terrain profiles for simulated aircraft positions in the distance interval from 35,000 to 1,000 feet from runway point of intercept (RPI) in increments of 1,000 feet. The glide slope path structure for all data presented was modeled with shorter distance intervals (150 feet between samples). The RPI is located on runway centerline opposite the glide slope mast.

DATA PRESENTATION.

The modeling results are presented in the form of course structure and level run plots for each system configuration. The reference flightpath for structure

TABLE 1. SUMMARY - ANTENNA INPUT DATA

Configuraation	Antenna Heights (feet)		A-Ratio (1)	Antenna Current Amplitude & Phase			
				ISS(2)	ICS(3)	ICC(4)	(degrees)
Capture Effect	Lower	14.417	0.292	-0.500	1.000	0.484	3.966
	Middle	28.945		1.000	-0.500	0.000	0.000
	Upper	43.417		-0.500	0.000	0.484	-1.835
Null Reference	Lower	14.432	0.305	0.000	1.000	0.000	0.000
	Upper	28.847		1.000	0.000	0.000	-3.925
Sideband Reference	Lower	7.183	0.305	-1.000	1.000	0.000	0.000
	Upper	21.550		1.000	0.000	0.000	-4.775

(1) A-Ratio - Ratio of separate sideband amplitude to carrier sideband signal amplitude.
(2) ISS - Separate sideband current.
(3) ICS - Carrier sideband current.
(4) ICC - Clearance carrier current.

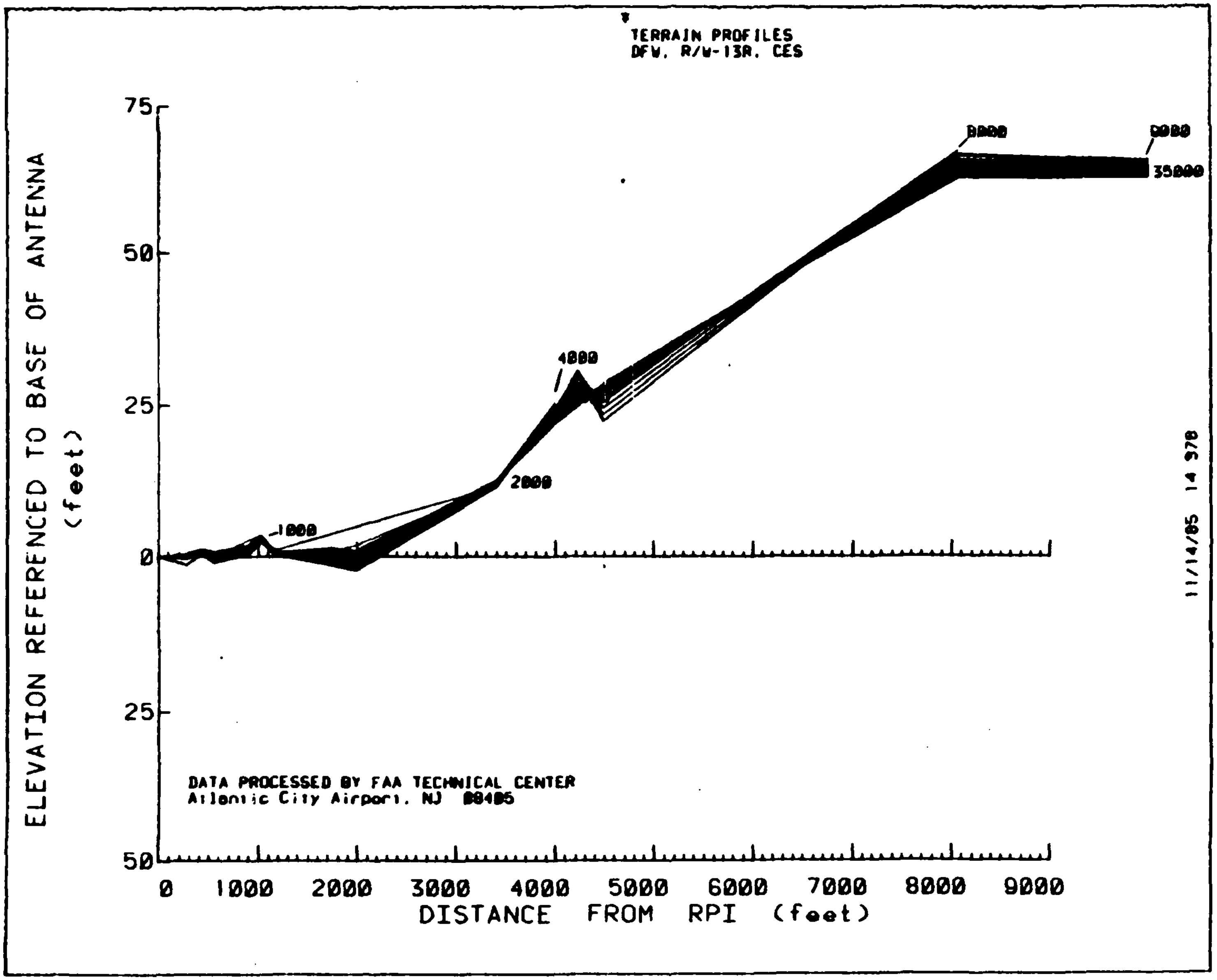

FIGURE 2. COMPUTED TERRAIN PROFILES, RUNWAY 13R, DALLAS-FORT WORTH, TEXAS

plots is the hyperbolic path formed by the intersection of a cone originating at the base of the antenna and a vertical plane located along runway centerline. In the model, this path is determined by the location of the eyepiece of the theodolite. For the data presented, the theodolite eyepiece is located at the base of the glide slope antenna mast (587.5 feet above mean sea level). Figures 3 and 4 are the modeled path structure and level run results for a capture effect system installed at the proposed site. Figures 5 and 6 are the respective modeled plots for a null reference system installed at the same location. The sideband reference system modeling results are given in figures 7 and 8.

DATA ANALYSIS.

Course structure results (figures 3, 5, and 7) indicate that all three systems should provide path structures well within the category II tolerance limits. The path structure for the capture effect system (figure 3) shows an almost perfect glidepath. Minor perturbations of the CDI are apparent in the distance intervals from 15,000 to 3,000 feet from runway threshold for the null reference and sideband reference systems. Level run results (figures 4, 6, and 8) show linear crossovers and symmetrical paths for all three systems which meet category II tolerances.

CONCLUSIONS

Modeled results indicate that satisfactory category II path structure performance should be obtained with either the capture effect, null reference, or sideband reference system installed at the proposed location. Of the three systems, the capture effect system should provide the smoothest path structure. Level run results indicate that all three systems meet category II tolerances for glidepath linearity and symmetry.

REFERENCES

1. User's Manual for the Ohio University Geometric Theory of Diffraction Glide Slope Model, Ohio University, Technical Report Number OU/AEC/ERR 47-7, February 1982.

2. United States Flight Inspection Manual, FAA Handbook OAP 8200.1, Change 32, Section 217.

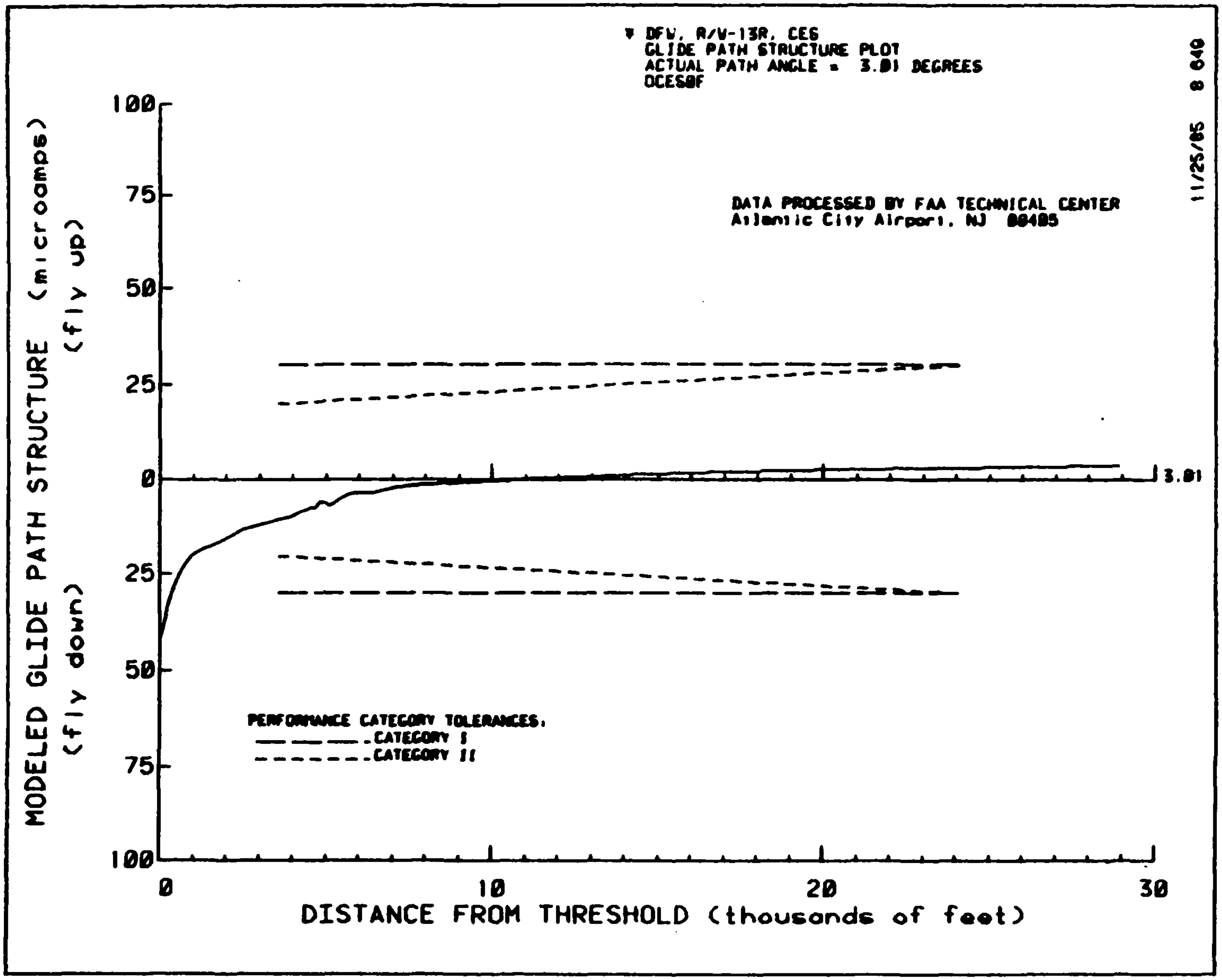

FIGURE 3. MODELED PATH STRUCTURE, CAPTURE EFFECT SYSTEM, RUNWAY 13R, DALLAS-FORT WORTH, TEXAS

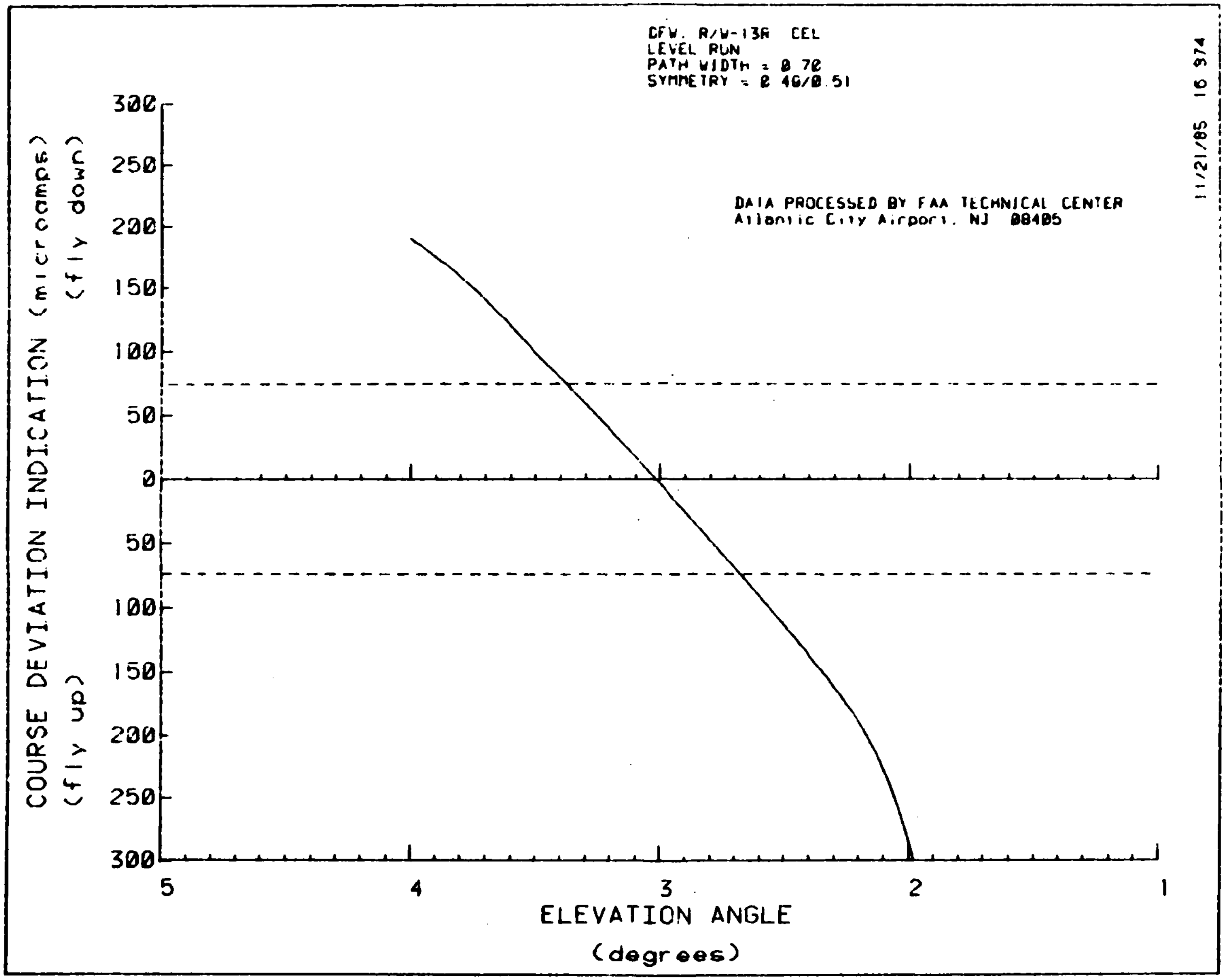

FIGURE 4. MODELED LEVEL RUN, CAPTURE EFFECT SYSTEM, RUNWAY 13R, DALLAS-FORT WORTH, TEXAS

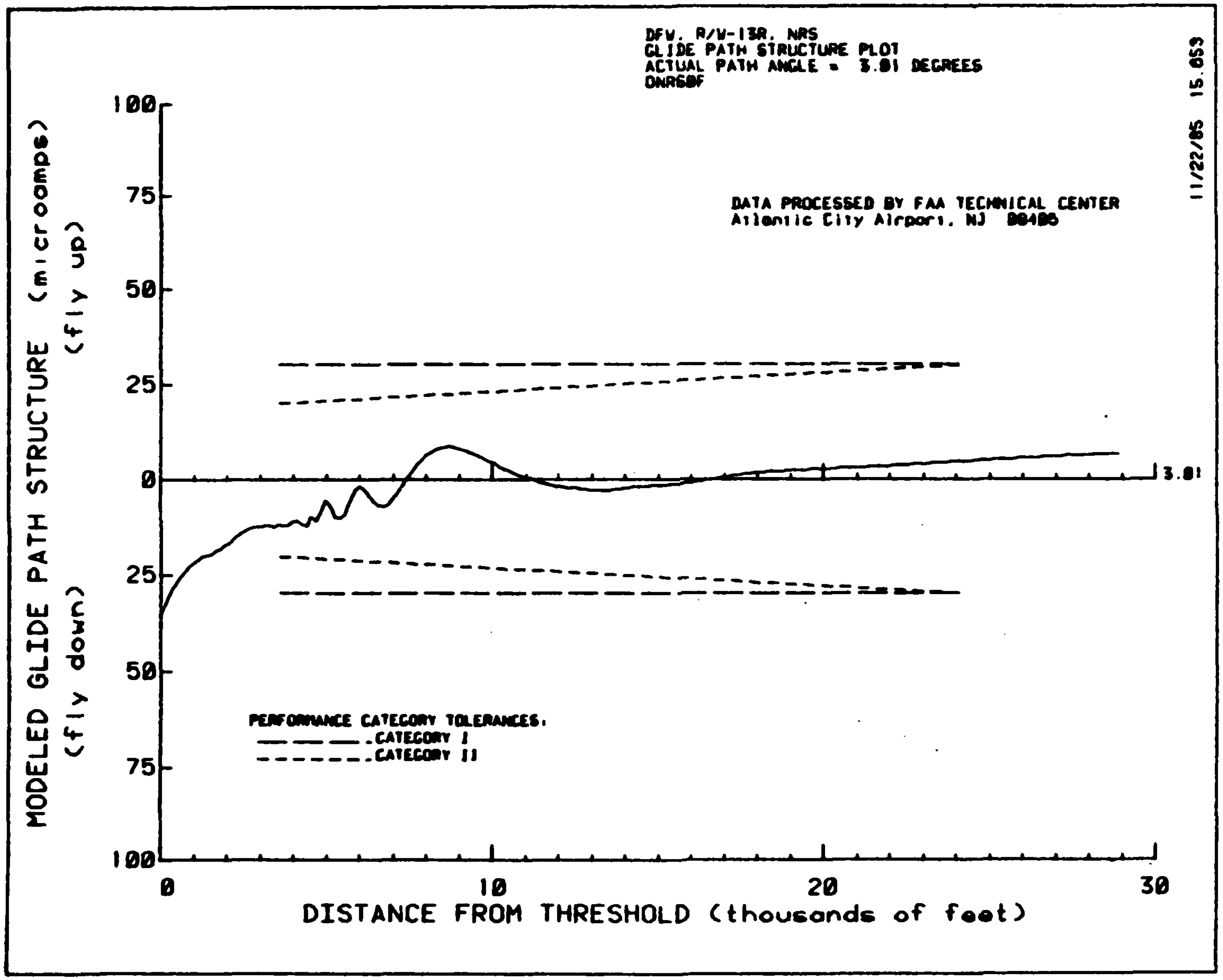

FIGURE 5. MODELED PATH STRUCTURE, NULL REFERENCE SYSTEM, RUNWAY 13R, DALLAS-FORT WORTH, TEXAS

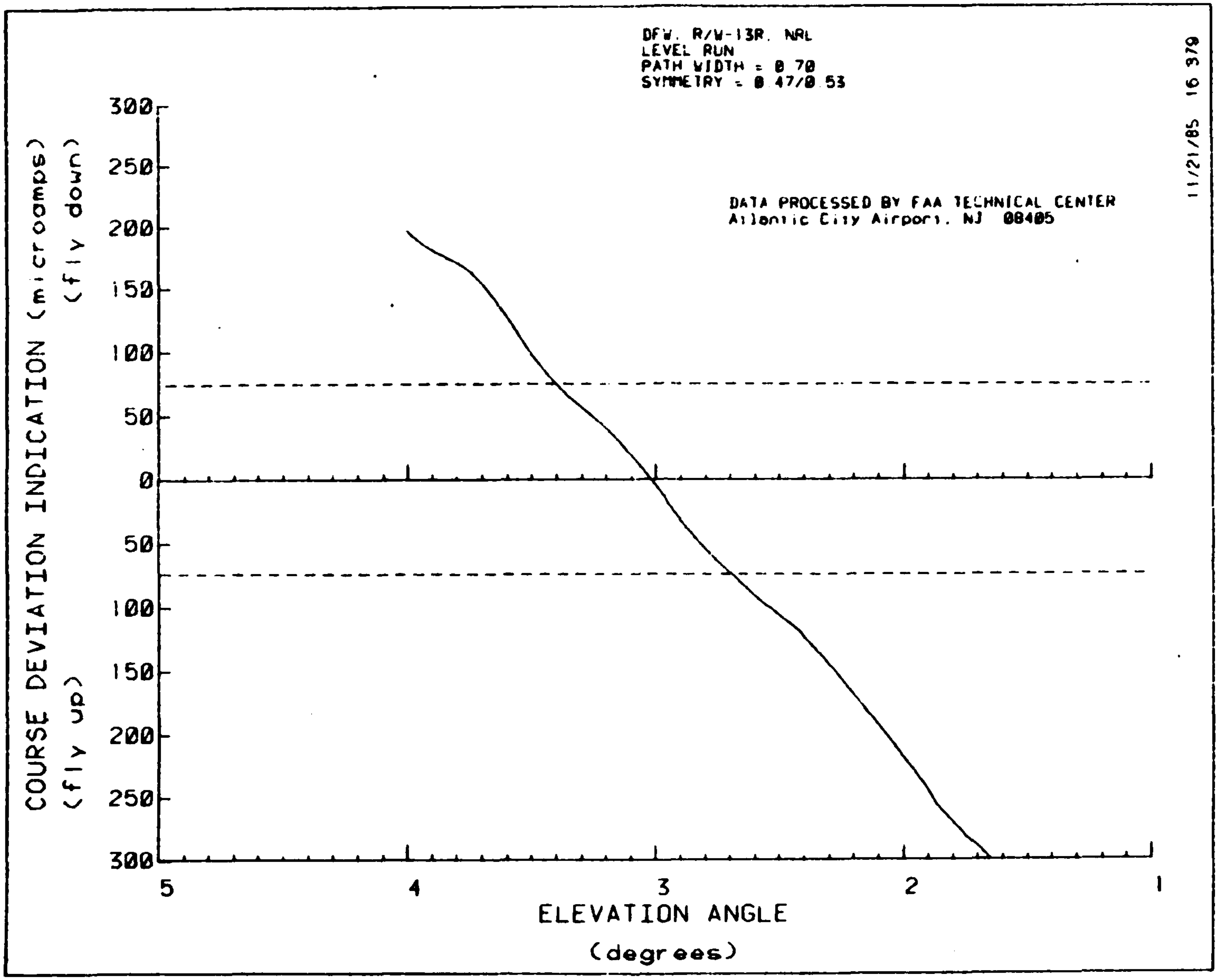

FIGURE 6. MODELED LEVEL RUN, NULL REFERENCE SYSTEM, RUNWAY 13R, DALLAS-FORT WORTH, TEXAS

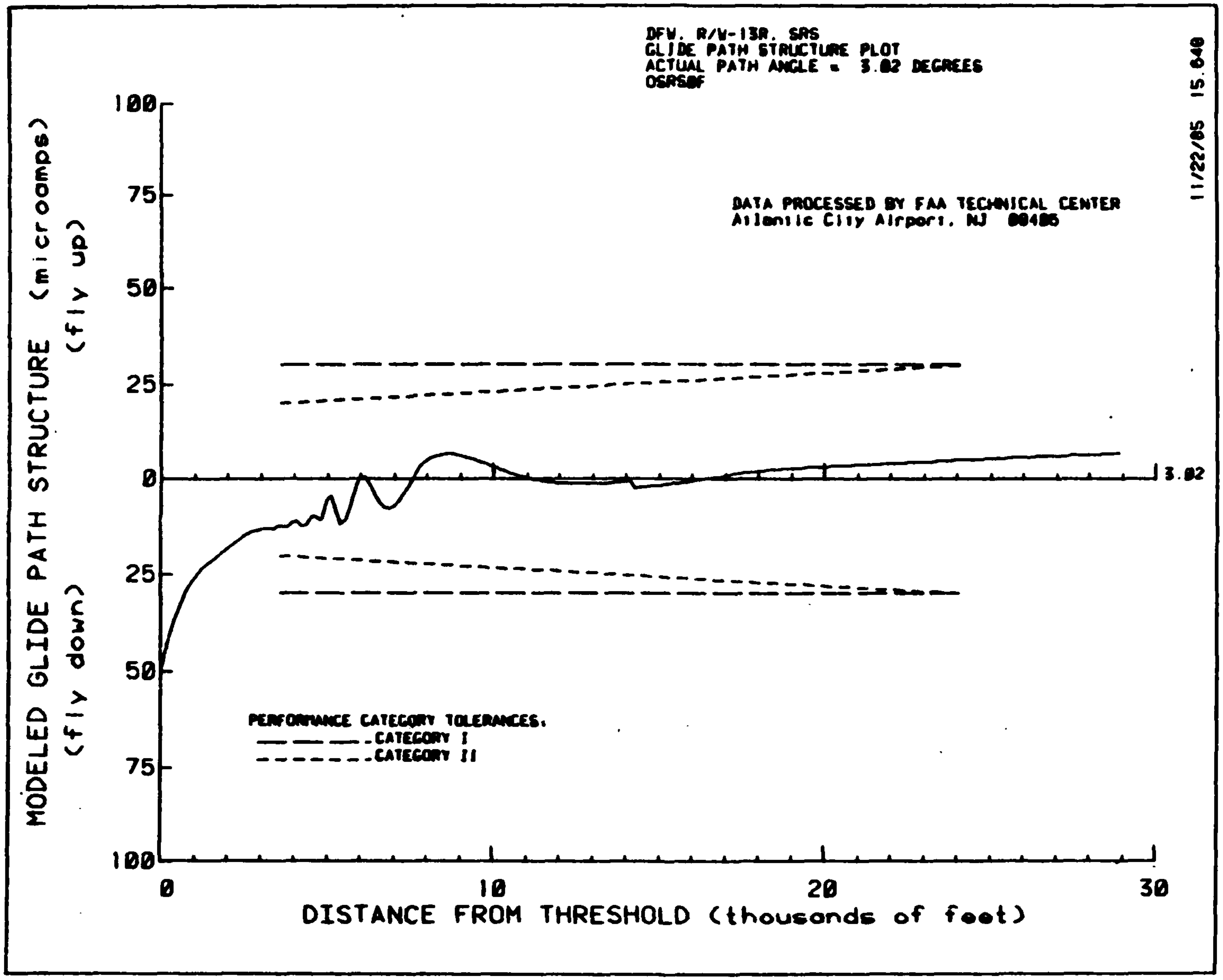

FIGURE 7. MODELED PATH STRUCTURE, SIDEBAND REFERENCE SYSTEM, RUNWAY 13R, DALLAS-FORT WORTH, TEXAS

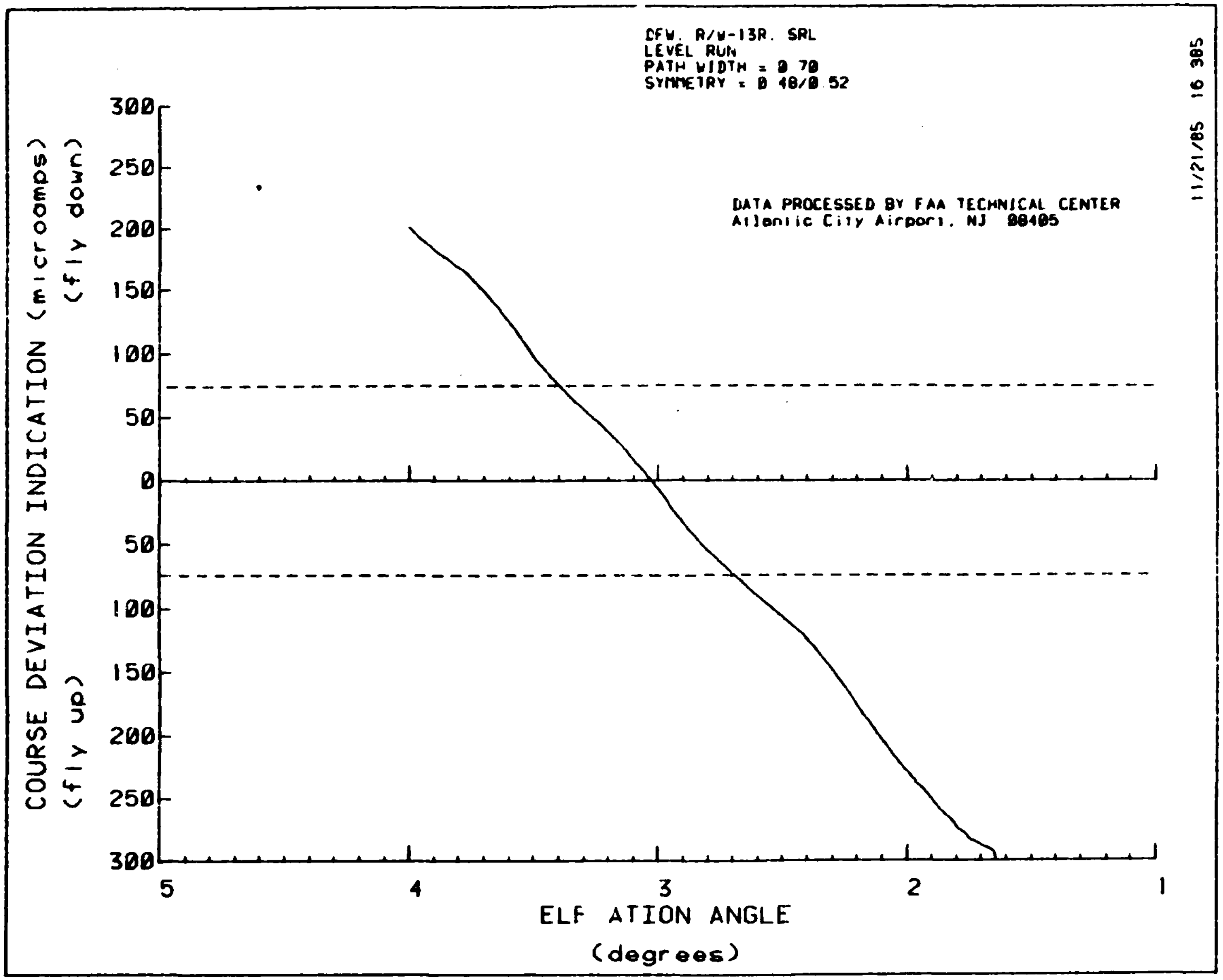

FIGURE 8. MODELED LEVEL RUN, SIDEBAND REFERENCE SYSTEM, RUNWAY 13R, DALLAS-FORT WORTH, TEXAS