ILS Mathematical Modeling Study on the Effects of Proposed Hangar Construction West of Runway 18R on Localizer Performance at Dallas-Fort Worth International Airport

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16. Abstract

This Technical Note describes the instrument landing system (ILS) math modeling performed by the Federal Aviation Administration (FAA) Technical Center at the request of the Southwest Region. Computed data are presented showing the effects of several proposed hangar configurations on the performance of the ILS localizer for runway 18R at the Dallas-Fort Worth International Airport. The Southwest Region is concerned that reflections from the proposed hangars may degrade the localizer course beyond category II tolerances. Modeled course structure results indicate that category II localizer performance should be obtained with the existing 14/6 Type IB antenna for the proposed hangar configurations. Computed clearance orbit results indicate satisfactory linearity, course crossover, and signal clearance levels.

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EXECUTIVE SUMMARY

This instrument landing system (ILS) math modeling study was performed at the request of the Southwest Region to compute the effects of several proposed hangar configurations on the performance of the runway 18R ILS localizer at the Dallas-Fort Worth International Airport. Reflections from other structures on the airport are not considered in this modeling study. The existing 14/6 Type IB localizer antenna was modeled using a physical optics mathematical model developed by the Transportation Systems Center. Derogative effects from hangar buildings in several reflecting source configurations were considered. Modeled course structure results indicate that category II localizer performance should be obtained for runway 18R with the proposed hangar configurations. Computed clearance orbit results indicate satisfactory linearity, course crossover, and signal clearance levels.

INTRODUCTION

PURPOSE.

The purpose of this math modeling study was to provide computer modeled performance data for an instrument landing system (ILS) localizer for runway 18R at the Dallas-Fort Worth International Airport.

BACKGROUND.

The Dallas-Fort Worth Airport has proposed constructing hangars in the area west of runway 18R. In support of this project, ASW-400 has requested a math modeling study through the Navigation and Landing Division, APS-400, which, in turn, was forwarded to the Federal Aviation Administration (FAA) Technical Center for accomplishment. Localizer math modeling was requested for three proposed hangar configurations to determine if the hangars derogate the runway 18R localizer category II performance. Figure 1 indicates the proposed construction area. Figure 2 details the proposed configurations provided by ASW-434 for study. Phase 1 proposes construction of a single 429 x 408 foot hangar 100 feet high. Phase 2 proposes two options for consideration: option 1 consists of the phase 1 hangar plus an additional 408 x 429 foot hangar with a height of 100 feet; option 2 proposes the phase 1 hangar plus a second 110 foot tall hangar 558 feet wide x 249 feet deep. This modeling effort was performed under project T0605A. The Program Manager is Mr. Edmund A. Zyzys. Additional information regarding this study may be obtained by contacting Messrs. James D. Rambone or John E. Walls at FTS 482-4572 or (609) 484-4572.

DISCUSSION

ILS MATH MODELS.

The FAA Technical Center conducts ILS mathematical computer model studies through application of physical optics or geometric theory of diffraction techniques to compute anticipated ILS performance. The modeling for runway 18R localizer was performed using the physical optics localizer model developed by the Transportation Systems Center (TSC) and converted to the Technical Center's mainframe computer. References 1 through 3 describe the modeling technique and implementation. Reference 4 provides validation data for the localizer model.

Figure 3 illustrates the right-handed coordinate system used in this computer model with the origin located at the threshold of the runway. The positive x-axis is directed out from the threshold along runway centerline extended, the positive y-axis is directed to the left, the positive z-axis is directed up. Alpha, the angle between the base of a reflector and the x-axis, is measured in the counterclockwise direction. Delta is the angle between the surface of the reflector and the vertical direction. The large solid arrows in the figure point in the direction that the reflecting surface faces. A reflector facing in the negative y-direction has an alpha of 0°. A reflector with a delta of 0° is perpendicular to the ground (figure 3A). Delta is equal to -90° for a horizontal reflector facing down (figure 3B). An alpha of 90°, as shown in figure 3C, faces the reflector out along the positive x-axis. A surface illuminated by radio frequency (RF) energy from the antenna is modeled by a rectangular flat or cylindrical surface. The surface is 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. The model does not compute multiple reflections or diffractions. Course deviation indicator (CDI) deflections are computed as follows. First, the magnitude and phase of the RF signals arriving at the aircraft location are determined for each surface independently. Next, a resultant RF signal is computed by vectorially combining the independent signals. CDI deflection is then computed from the resultant RF signal.

ILS MODELING PERFORMED.

Figure 1 shows the general orientation of the runway. The TSC localizer model was used to model the effects of the hangar wall surfaces on signals radiated by the existing 14/6 Type IB antenna. Table 1 summarizes the localizer model input data. Antenna currents and phases used for the antenna array are also given in table 1.

Localizer course structure and clearance orbit computer runs were made for the hangar configurations shown in figure 2. Rectangular plates were used to simulate all of the reflecting surfaces. The location and dimensions of all reflecting surfaces are detailed in table 2. The phase 1 hangar was modeled by two surfaces: surfaces A and B. Option 1 of phase 2 was not modeled because the major additional reflecting surface introduced by this option (surface E) will be completely blocked by the phase 1 structure (surface B) and directed to a location which will not effect localizer performance. For this reason the modeled results for this option will be essentially the same as those shown for phase 1. Phase 2, option 2 was modeled using plates representing surfaces A, B, C, and D. Note that the plate representing surface C is a single plate which is 10 feet high and 558 feet long. The base of this plate is 100 feet above ground level. This plate represents the upper section of the option 2 hangar which will not be blocked, as described for the phase 2, option 1 case. The wall sections perpendicular to the runway (surfaces B, D, and F) will have minimal derogative effect on localizer performance.

DATA PRESENTATION.

Modeled output results for the localizer are provided on three types of plots: (1) course structure plots, (2) clearance orbit plots, and (3) carrier plus sideband (CSB) and sideband only (SBO) antenna pattern plots. The simulated flightpaths for the course structure runs are centerline approaches starting 60,000 feet from runway threshold. The aircraft crosses the runway threshold at the threshold crossing height and continues at this altitude to a point just short of the stop end of the runway. Distances shown on the horizontal axis of the course structure plots are referenced to the approach threshold. Negative values are shown for distances between the threshold and the localizer. Positive values apply to distances on the approach path toward the outer marker. Angular values on the horizontal axes of the CSB and SBO antenna pattern plots and on the clearance orbit plots were run with flight arcs of 35,000 feet at altitudes of 1,000 feet with respect to the localizer site.

The vertical axes of the course structure and clearance orbit plots are the model output values of CDI deflection in microamps (0.4-second time constant applied for smoothing). The vertical axes of the antenna pattern plots use a

TABLE 1. LOCALIZER ANTENNA MODEL INPUT DATA SUMMARY

Localizer Antenna Type:	14/6 Type IB
Runway 18R Length (ft):	11388.0
Course Array to Runway 36L End (ft):	960.0
Clearance Array to Runway 36L End (ft):	1160.0
Frequency (MHz):	111.9
Site Elevation (ft m.s.l.):	581.0
Course Width (deg):	3.25

<u>14-Element Course Array</u>

Ant. No.	Spacing (wave length)	Carrier+Sideband Amplitude	Carrier+Sideband Phase (deg)	Sideband Only Amplitude	Sideband Only Phase (deg)
7L	-4.88	0.160	0	0.367	0
6L	-4.12	0.160	0	0.555	0
5L	-3.36	0.263	0	0.889	0
4L	-2.59	0.491	0	1.000	0
3L	-1.83	0.714	0	1.000	0
2L	-1.07	1.000	0	0.667	0
1L	-0.31	0.893	0	0.222	0
1R	0.31	0.893	0	0.222	180
2R	1.07	1.000	0	0.667	180
3R	1.83	0.714	0	1.000	180
4R	2.59	0.491	0	1.000	180
5R	3.36	0.263	0	0.889	180
6R	4.12	0.160	0	0.555	180
7R	4.88	0.160	0	0.367	180

<u>6-Element Clearance Array</u>

Ant. No.	Spacing (wave length)	Carrier+Sideband Amplitude	Carrier+Sideband Phase (deg)	Sideband Only Amplitude	Sideband Only Phase (deg)
3L	-1.83	0.200	0	0.013	0
2L	-1.07	0.000	0	0.300	0
1L	-0.31	1.000	0	0.900	0
1R	0.31	1.000	0	0.900	180
2R	1.07	0.000	0	0.300	180
3R	1.83	0.200	0	0.013	180

ft = feet
MHz = megahertz
m.s.l. = mean sea level
deg = degree

TABLE 2. LOCALIZER REFLECTING SURFACES DATA SUMMARY

Surface	Coordinates X	Y	(ft)* Z**	Alpha (deg)	Delta (deg)	Width (ft)	Height (ft)
A	-1963	1778	31	0.0	0.0	429	100
B	-2178	1982	31	270.0	0.0	408	100
C	-2400	2183	131	0.0	0.0	558	10
D	-2679	2308	31	270.0	0.0	249	110

* - Midpoint of base of surface referenced to threshold of runway 18R.

** - Referenced to base of antenna.

relative scale with the pattern normalized to its peak value. The usual range for the vertical scale of modeled course structure data plots is +40 to -40 microamps. This range has been reduced to +10 to -10 microamps for the course structure plots provided in this study in order to better display small values of CDI deflection. This choice of scale eliminates the display of category I limits from the plot and shows only the final segment of the category II tolerance limits. Category III tolerance limits (not shown) extend the 5-microamp tolerance shown for category II performance to a point on the runway 3,000 feet from threshold. The limits then increase linearly to 10 microamps at a point which is 2,000 feet from the stop end of the runway.

Modeled localizer output data are provided in figures 4 through 9. Figures 4 through 6 provide computed performance results with the phase 1 hangar as the only reflecting source. Modeled course structure is plotted in figure 4. Computed clearance orbit results are given in figure 5. Figure 6 shows the computed CSB and SBO antenna pattern plots. Figures 7 through 9 provide similar plots for the phase 2, option 2 reflecting surface configuration consisting of the phase 1 hangar plus the additional option 2 hangar.

DATA ANALYSIS.

Modeled course structure results for the phase 1 hangar alone, and the phase 1 hangar plus the additional option 2 hangar of phase 2 (figures 4 and 7, respectively) show computed CDI deflections that are well within category II course structure tolerance limits. The phase 2, option 1 hangar configuration was not modeled for reasons previously described. The modeled results for this configuration are essentially the same as provided for the phase 1 configuration. The computed clearance orbit plots (figures 5 and 8) indicate satisfactory linearity, course crossover, and clearance levels. Figures 6 and 9, CSB and SBO antenna patterns for the 14/6 Type IB antenna array, each show some roughness in the computed clearance signals of the pattern on the 150 hertz side of the signal.

CONCLUSIONS

Modeled results indicate that category II localizer performance should be obtained for runway 18R and the existing 14/6 Type IB antenna array with the proposed hangar configurations. Computed clearance orbit results indicate satisfactory linearity, course crossover, and clearance levels.

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2. Chin, G., et al., User's Manual for ILSLOC: Simulation for Derogation Effects on the Localizer Portion of the Instrument Landing System, Report DOT/FAA-RD-73-13, 1973.

3. Chin, G., et al., Instrument Landing System Performance Prediction, Report DOT/FAA-RD-73-200, 1974.

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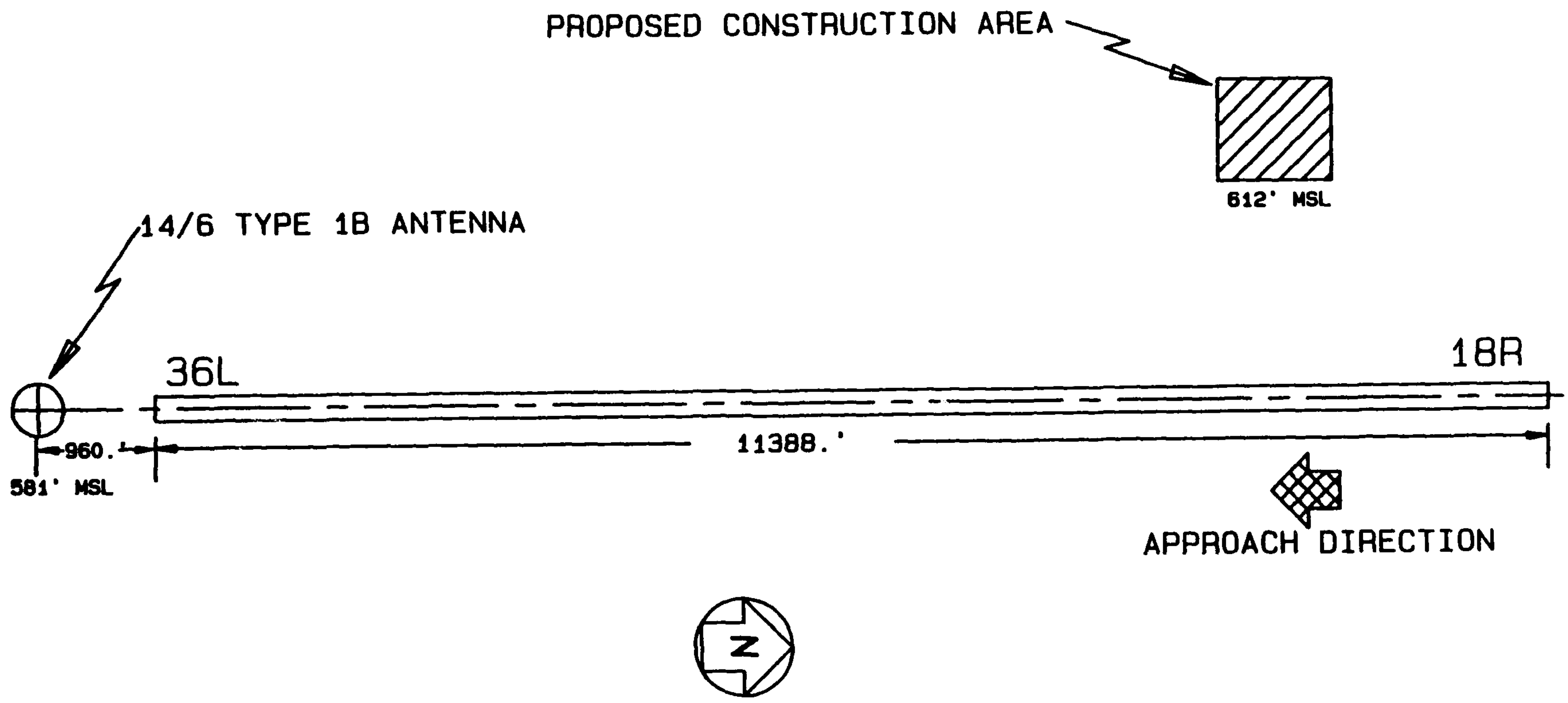
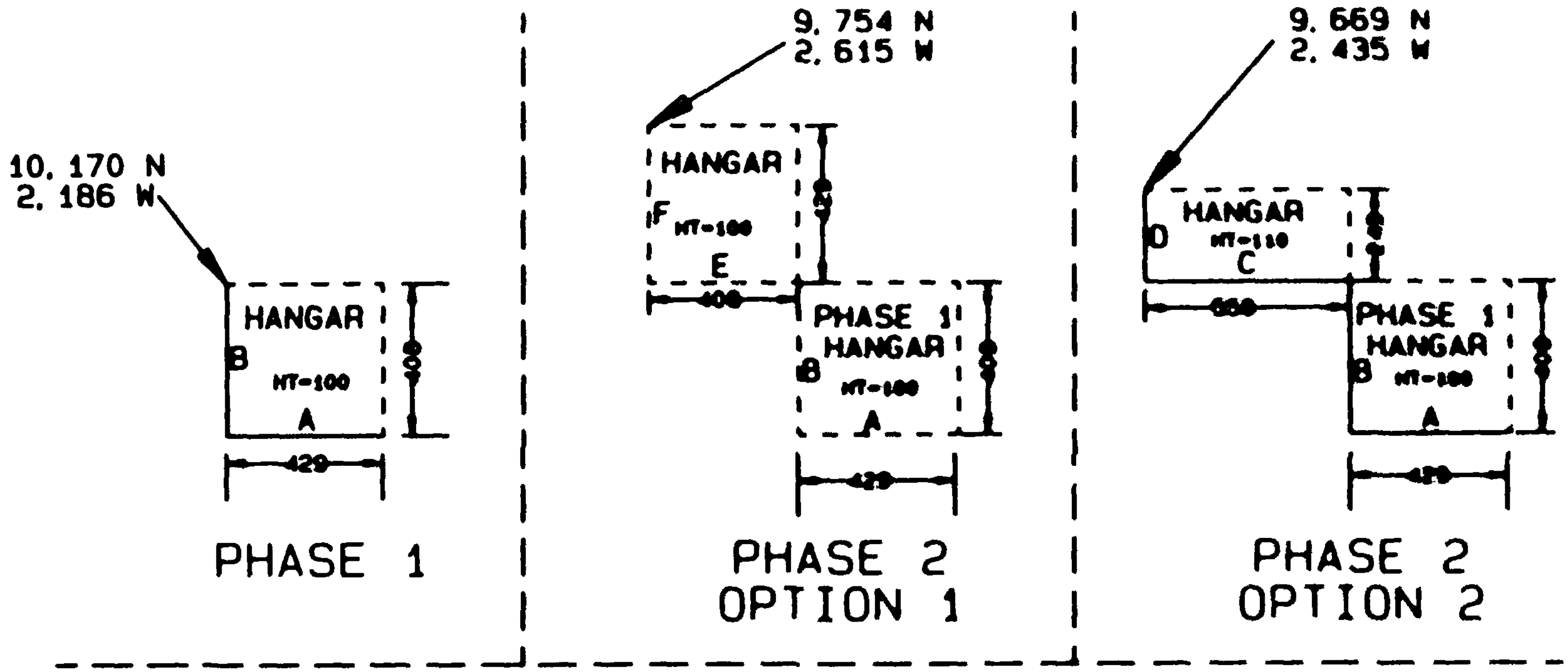


FIGURE 1. DALLAS-FORT WORTH RUNWAY 18R, ILS MATH MODELING LAYOUT



NOTES:

Coordinates referenced to localizer antenna
Construction area ground height 612' msl.
All distances in feet.
HT - Height of top of hanger
Wall surface modeled ———
Wall surface not modeled - - - - -

FIGURE 2. DALLAS-FORT WORTH RUNWAY 18R, PROPOSED HANGAR OPTIONS

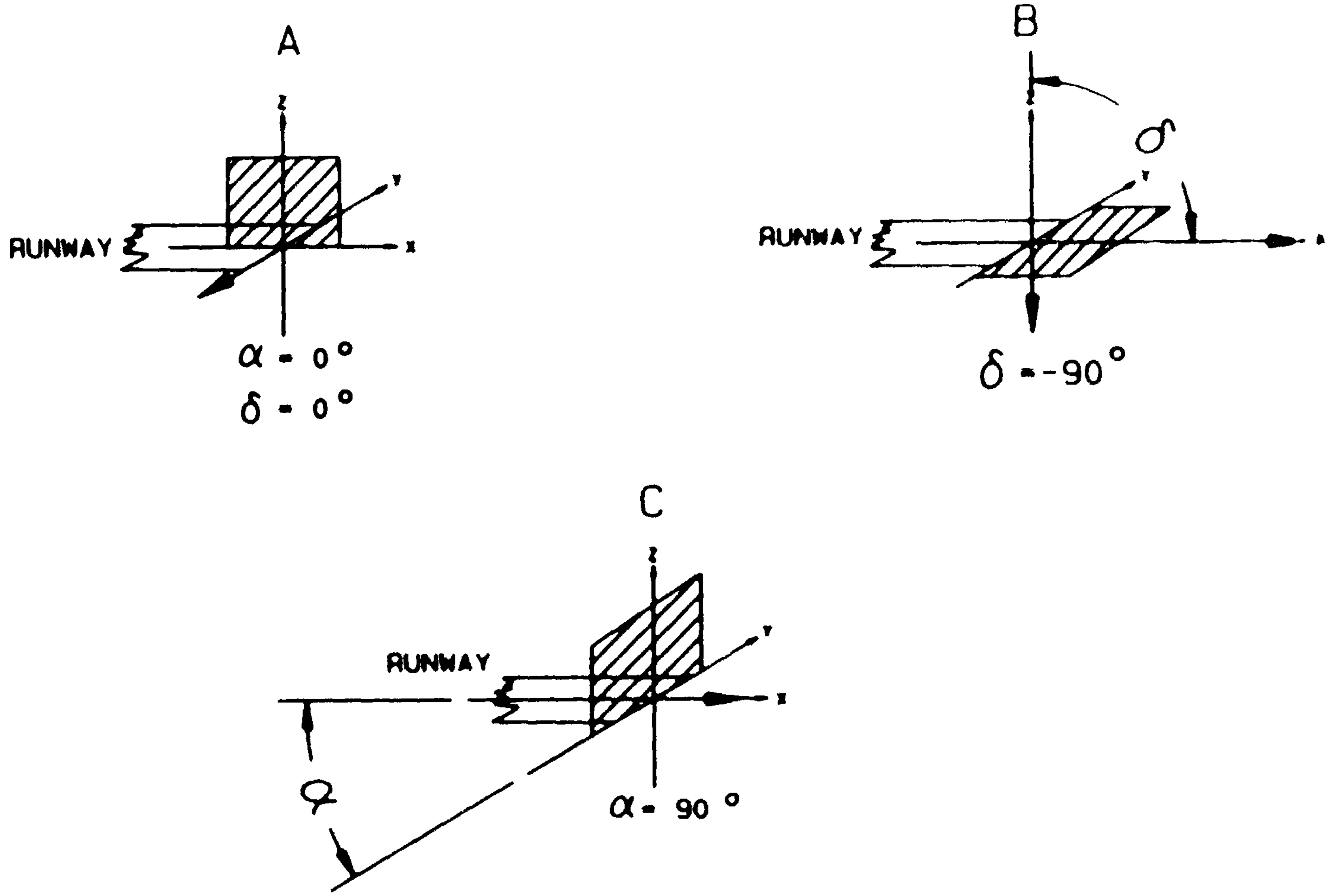


FIGURE 3. INSTRUMENT LANDING SYSTEM LOCALIZER MATH MODELING COORDINATE SYSTEM AND REFLECTOR SURFACE DETAILS

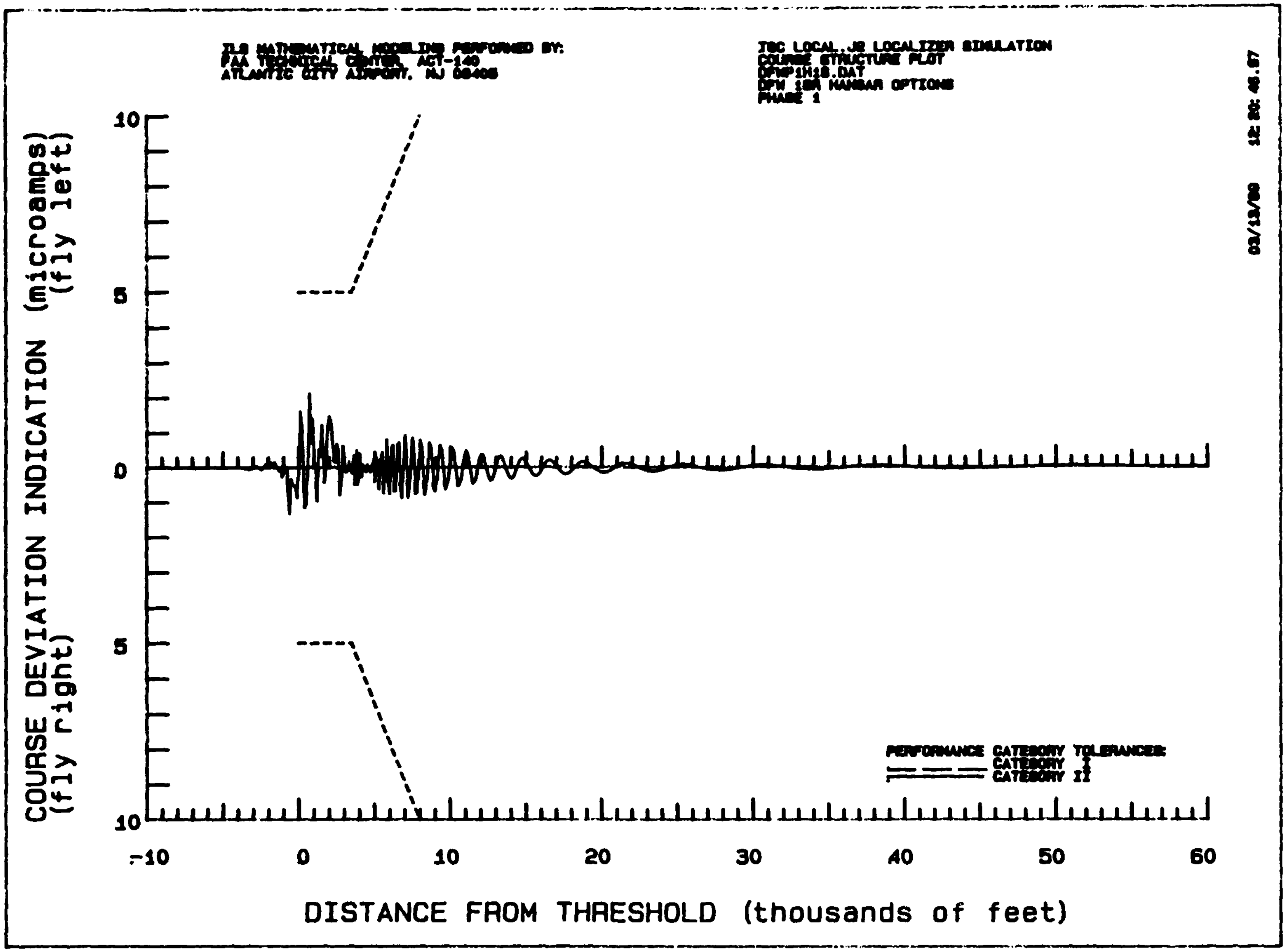


FIGURE 4. COURSE STRUCTURE, DALLAS-FORT WORTH RUNWAY 18R LOCALIZER, HANGAR CONFIGURATION PHASE I

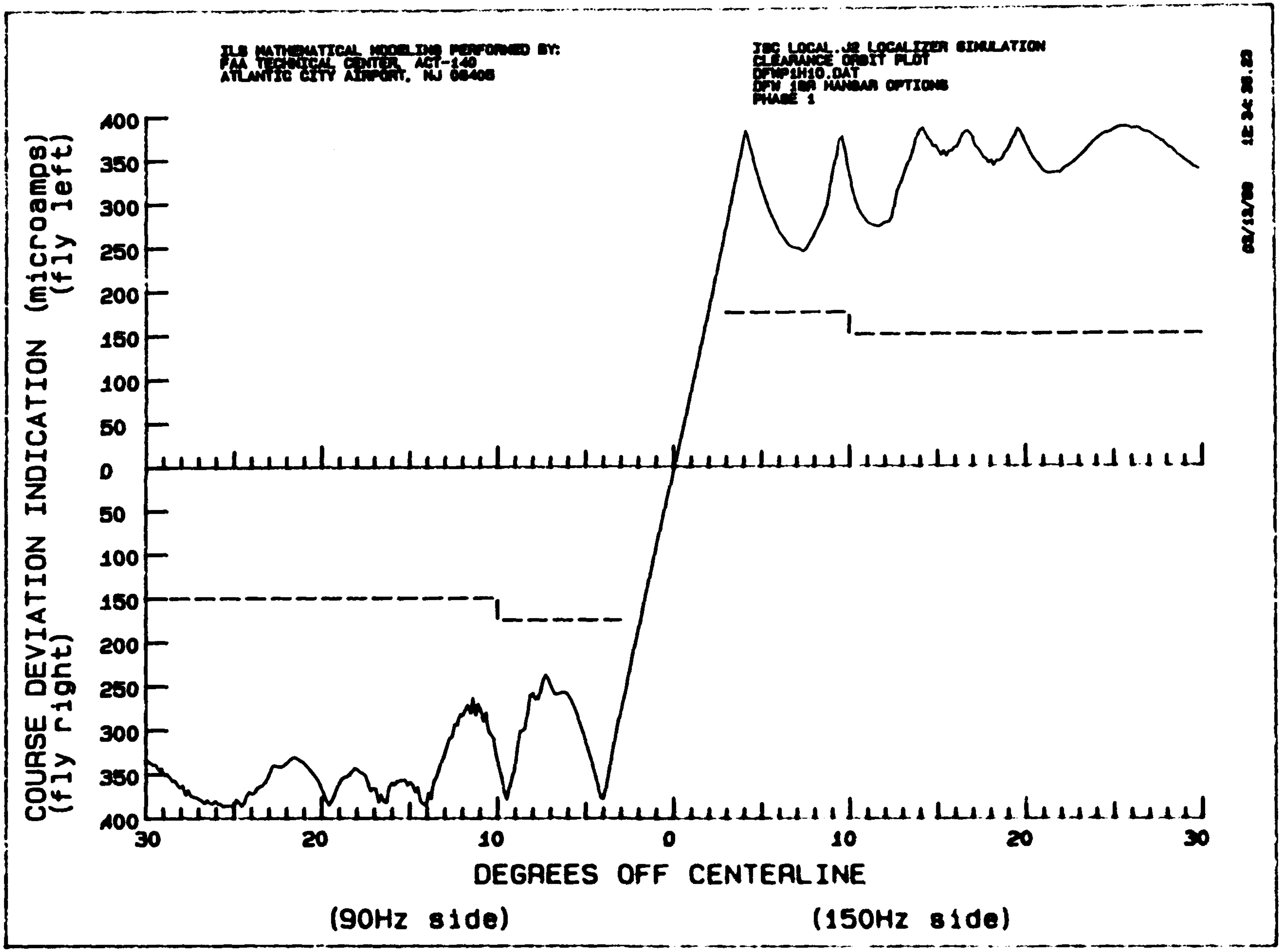


FIGURE 5. CLEARANCE ORBIT, DALLAS-FORT WORTH RUNWAY 18R LOCALIZER, HANGAR CONFIGURATION PHASE 1

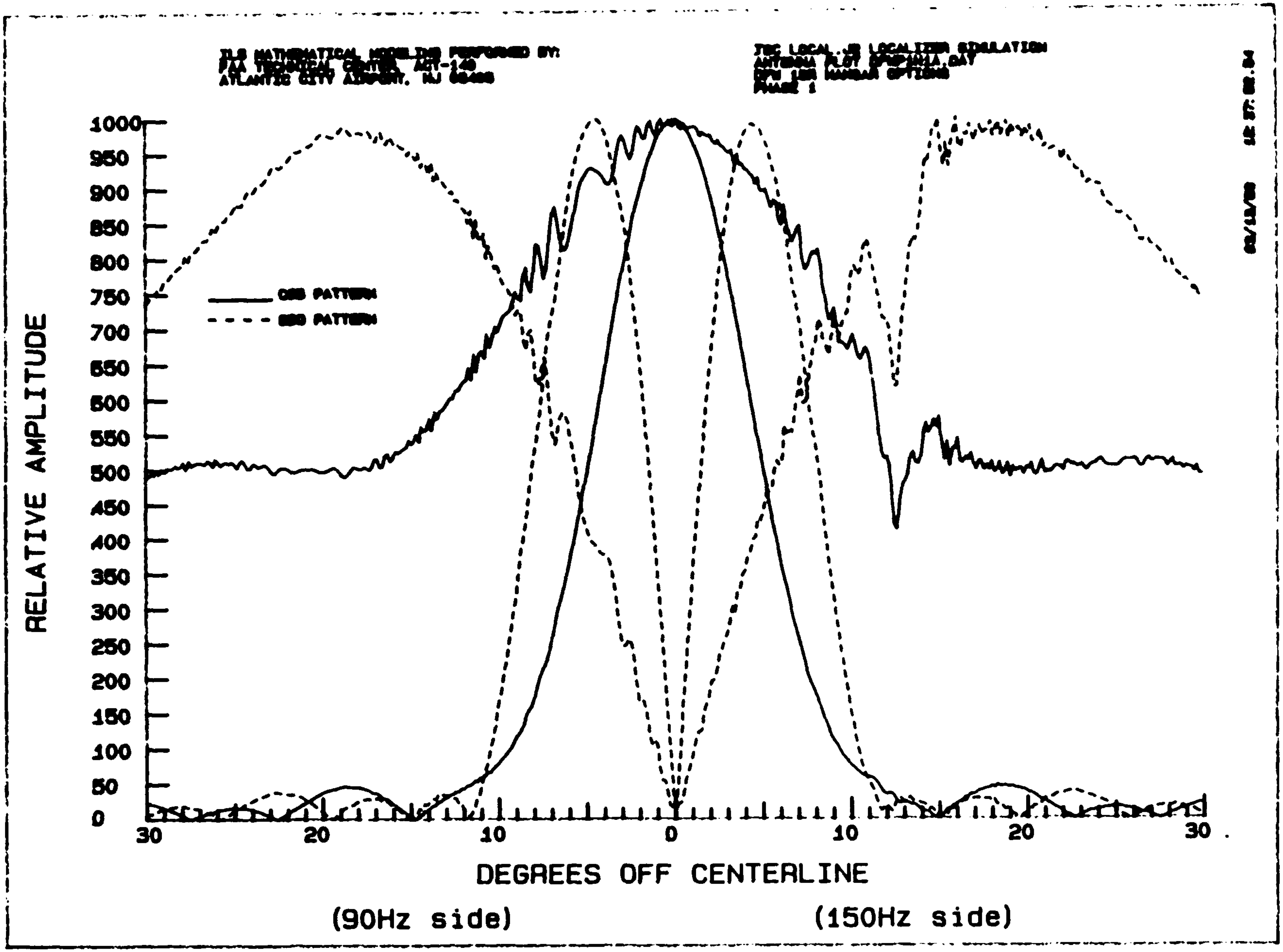


FIGURE 6. CSB AND SBO ANTENNA PATTERNS, DALLAS-FORT WORTH RUNWAY 18R LOCALIZER, HANGAR CONFIGURATION PHASE 1

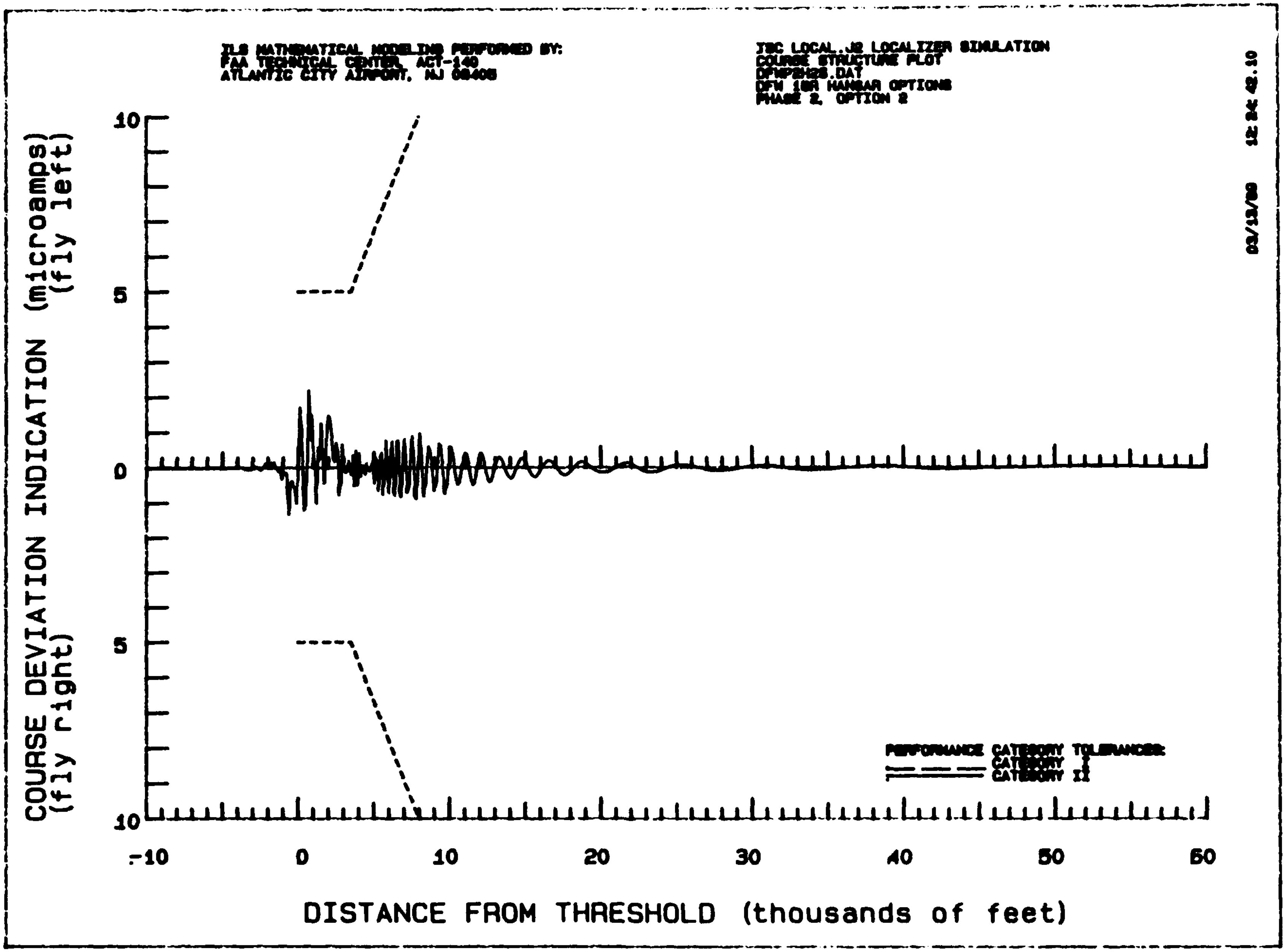


FIGURE 7. COURSE STRUCTURE, DALLAS-FORT WORTH RUNWAY 18R LOCALIZER, HANGAR CONFIGURATION PHASE 2, OPTION 2

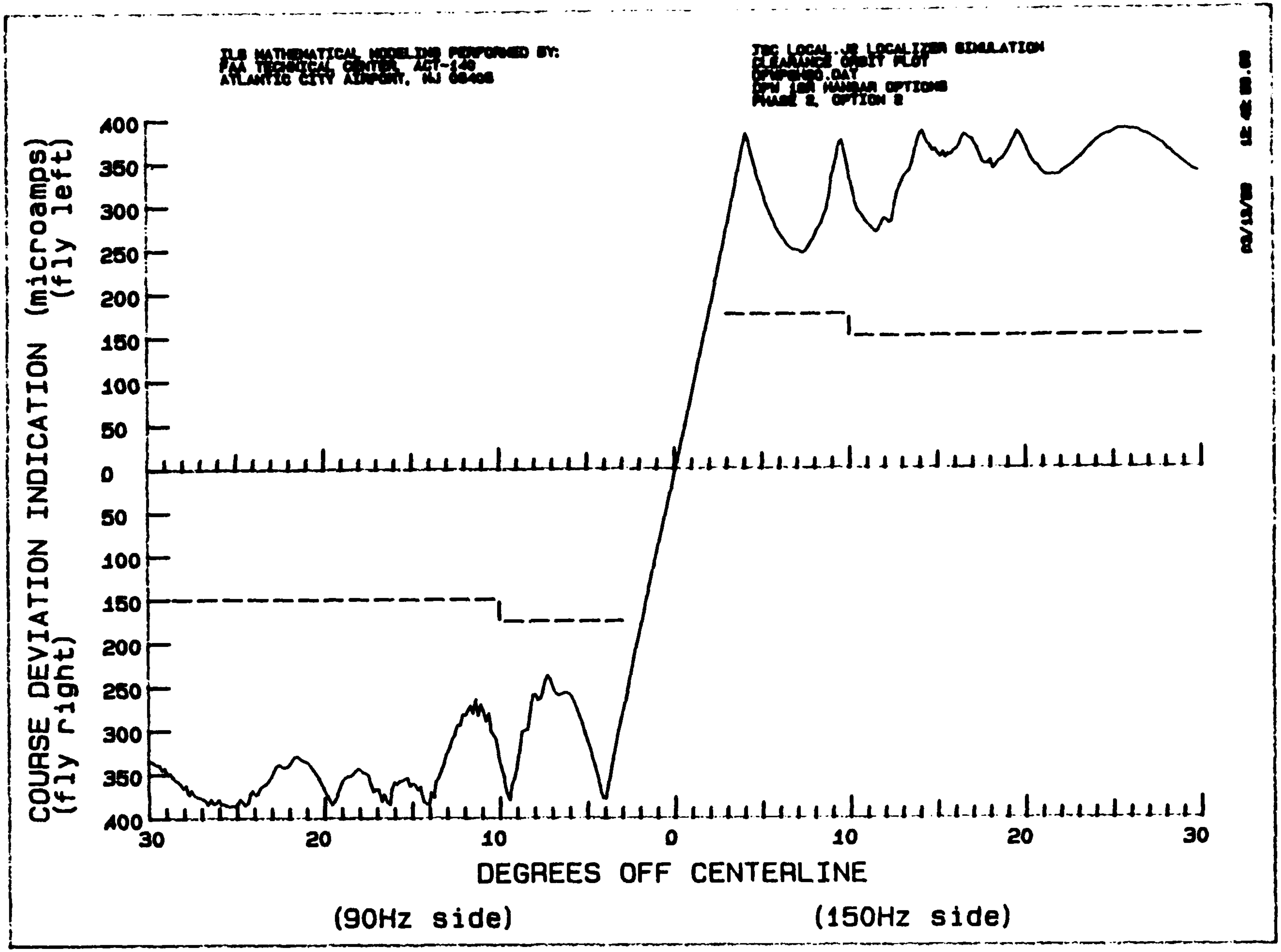


FIGURE 8. CLEARANCE ORBIT, DALLAS-FORT WORTH RUNWAY 18R LOCALIZER, HANGAR CONFIGURATION PHASE 2, OPTION 2

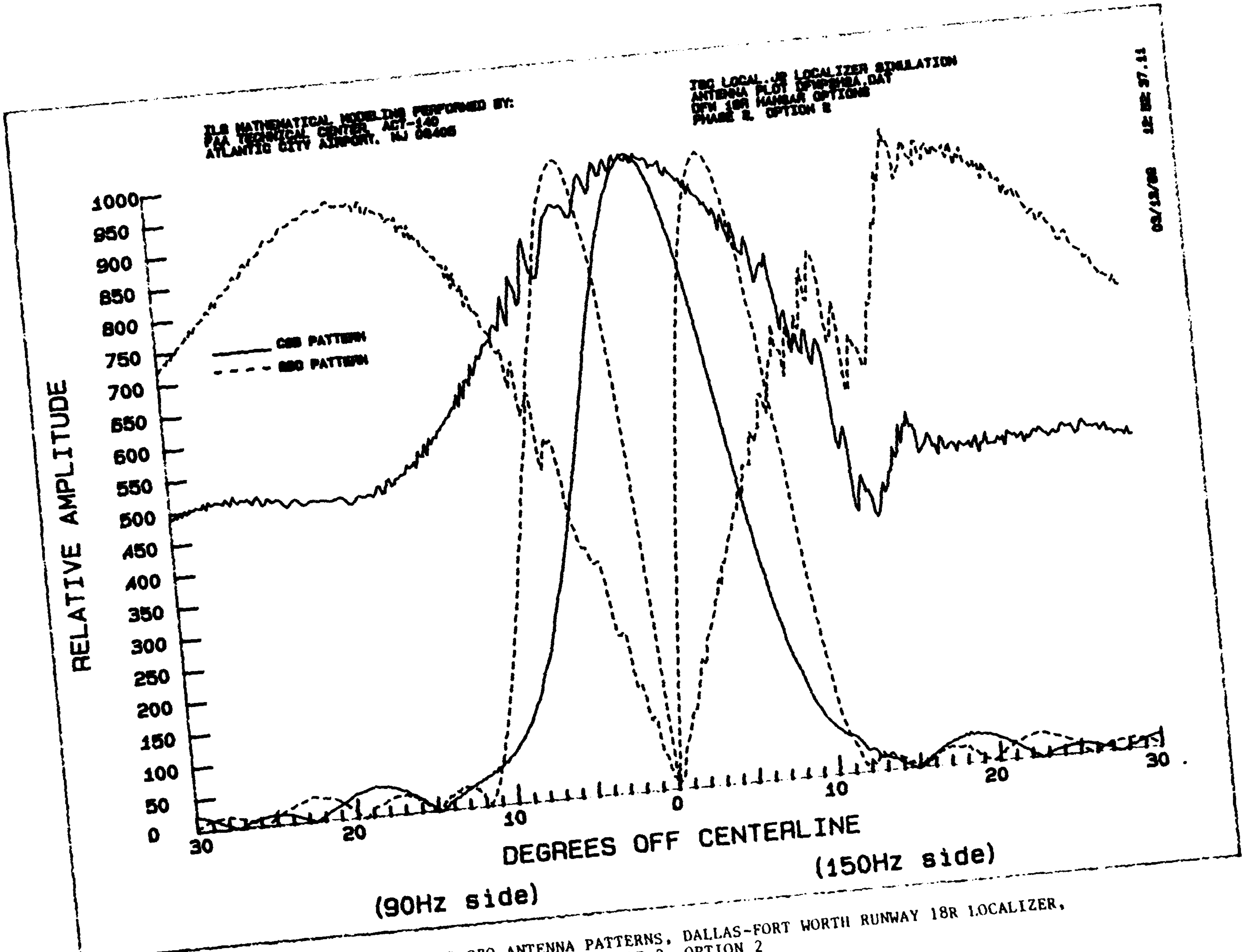


FIGURE 9. CSB AND SBO ANTENNA PATTERNS, DALLAS-FORT WORTH RUNWAY 18R LOCALIZER, HANGAR CONFIGURATION PHASE 2, OPTION 2