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ILS Mathematical Modeling Study of the Effects of an Air Traffic Control Tower at the Los Angeles International Airport Runway 24R, Los Angeles, California

James D. Rambone

February 1991

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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 Western-Pacific Region. Computed localizer data are presented showing the effects of an Air Traffic Control (ATC) tower proposed for construction south of the stop-end of runway 6L on the performance of an ILS localizer serving runway 24R at the Los Angeles International Airport. The Western-Pacific Region is concerned that radio frequency (RF) signal reflections from the ATC tower may degrade the localizer course beyond Category III tolerances. Modeled course structure results indicate that Category III localizer performance should be maintained with the Wilcox 14-element, dual-frequency log periodic dipole antenna with the ATC tower constructed at the currently proposed location. 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 Western-Pacific Region to compute the effects of an air traffic control (ATC) tower proposed for construction south of the stop-end of runway 6L on the performance of an ILS localizer serving runway 24R at the Los Angeles International Airport. The localizer was modeled using a physical optics mathematical model developed by the Transportation Systems Center and extensively modified by Ohio University. As requested by AWP-454, a Wilcox 14-element, dual frequency log periodic antenna array was modeled. Derogative effects from a proposed ATC tower was the only structure considered in this modeling study. Modeled course structure results indicate that Category III localizer performance should be maintained for runway 24R with the ATC tower constructed at the currently proposed location. 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 serving runway 24R at the Los Angeles International Airport.

BACKGROUND.

The Western-Pacific Region, AWP-454, is concerned that signal reflections from an air traffic control (ATC) tower proposed for construction south of the stop-end of runway 6L at the Los Angeles International Airport may degrade the runway 24R ILS localizer performance. AWP-454 has requested a math modeling study through the Navigation and Landing Division, ANN-100, which, in turn, was forwarded to the Federal Aviation Administration (FAA) Technical Center for accomplishment. Localizer math modeling was requested for a proposed ATC tower to determine if this structure derogates the runway 24R localizer performance. Runway 24R is serviced by a Wilcox 14-element, dual-frequency log periodic dipole (LPD) antenna array providing Category III localizer performance. This modeling effort was performed under project T0605A. The Technical Program Manager is Mr. Edmund A. Zyzys. Additional information regarding this study may be obtained by contacting Mr. James D. Rambone at FTS 482-5373 or (609) 484-5373.

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 the runway 24R localizer was performed using the physical optics model which was developed by the Transportation Systems Center (TSC), modified extensively by Ohio University, and then converted to the Technical Center's mainframe computer. References 1 through 4 describe the modeling technique and implementation. Reference 4 also provides validation data for the model.

This model operates using the physical optics principles by considering the structure or aircraft as a target or reflector. The reflecting object is modeled by considering it to be a collection of flat plates, whose profile is that of the specific structure. The flat plate representing the structure is located with a specified orientation and location on the airport.

This flat plate may be divided up into arbitrarily small areas, each of which is receiving incident electromagnetic radiation from the transmitting antennas. The incident signals arrive at the respective incremental area with a specific amplitude and phase which are dependent on the phase and amplitude of the source currents in the transmitting antennas and the path length from the antennas to the incremental area on the plate. The fields are, in effect, terminated by currents in the conducting surface so that the boundary

conditions at the conducting surface are met. These currents flowing in the incremental plate, thus, become source currents for the scattering signal.

Figure 1 illustrates the right-handed coordinate system used in this computer model with the origin located at the antenna site for localizer modeling and the runway point intercept (RPI) for glide slope modeling. The positive x-axis is directed out beyond 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 degrees. A reflector with a delta of 0 degrees is perpendicular to the ground (figure 1A). Delta is equal to -90 degrees for a horizontal reflector facing down (figure 1B). An alpha of 90 degrees, as shown in figure 1C, faces the reflector out along the positive x-axis. The reflecting 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.

As previously indicated, the predicted radiation is calculated assuming an array of incremental, flat-plate antennas each with its own radiation pattern. Course deviation indicator (CDI) deflections are computed as follows. First, the magnitude and phase of the radio frequency (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.

Some limitations do exist with this particular model; however, the resultant errors due to these limitations or assumptions are considered small. One limitation in the model is that it does not compute multiple reflections or diffractions. Another limitation is the assumption that the terrain is level and perfectly smooth.

ILS MATH MODELING PERFORMED.

Figure 2 shows the general orientation of the runway and the location of the ATC tower. The modified TSC physical optics model was used to model the effects of the tower on the runway 24R localizer performance. As requested, the Wilcox 14-element, dual frequency LPD antenna was modeled at the ILS localizer site. Table 1 summarizes the localizer model input data, including antenna currents and phases.

Localizer course structure and clearance orbit computer runs were made with the proposed ATC tower as the only reflecting source. The tower was modeled with a single rectangular plate (44 feet wide and 289 feet high) placed parallel to the runway centerline. The proposed location for the tower is located 10,800 feet from the antenna site and 2,830 offset of runway centerline. The tower has a base elevation of 103 feet mean sea level (m.s.l.).

TABLE 1. LOCALIZER ANTENNA MODEL INPUT DATA SUMMARY

Localizer Antenna Type:	Wilcox 14-Element,LPD Dual Frequency
Runway 24R Length (ft):	8925.0
Distance to Runway 6L End (ft):	2925.0
Frequency (MHz):	108.5
Site Elevation (ft m.s.l.):	121.0
Antenna Height (ft):	7.0
Course Width (deg):	3.38

14-Element LPD Array

Ant. No.	Spacing (Wave Length)	Carrier+Sideband Amplitude	Carrier+Sideband Phase (deg)	Sideband Only Amplitude	Sideband Only Phase (deg)
7L	-4.73480	0.16000	0.00000	0.36700	180.00000
6L	-3.99503	0.16000	0.00000	0.55500	180.00000
5L	-3.25526	0.49100	0.00000	0.88900	180.00000
4L	-2.51550	0.49100	0.00000	1.00000	180.00000
3L	-1.77530	0.71400	0.00000	1.00000	180.00000
2L	-1.03596	1.00000	0.00000	0.66700	180.00000
1L	-0.29619	0.89300	0.00000	0.22200	180.00000
1R	0.29619	0.89300	0.00000	0.22200	0.00000
2R	1.03596	1.00000	0.00000	0.66700	0.00000
3R	1.77350	0.71400	0.00000	1.00000	0.00000
4R	2.51550	0.49100	0.00000	1.00000	0.00000
5R	3.25526	0.49100	0.00000	0.88900	0.00000
6R	3.99503	0.16000	0.00000	0.55500	0.00000
7R	4.73480	0.16000	0.00000	0.36700	0.00000

Clearance Signals

3L	-1.77350	0.20000	0.00000	0.13900	180.00000
2L	-1.03596	0.00000	0.00000	0.33300	180.00000
1L	-0.29619	1.00000	0.00000	1.00000	180.00000
1R	0.29619	1.00000	0.00000	1.00000	0.00000
2R	1.03596	0.00000	0.00000	0.33300	0.00000
3R	1.77350	0.20000	0.00000	0.13900	0.00000

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

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 approximately 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 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 (fly left) to -40 (fly right) 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.

Computed localizer performance results with the ATC tower as the only reflecting source modeled are provided in figures 3 through 5. Modeled course structure results are plotted in figure 3. Computed clearance orbit results are given in figure 4. Figure 5 shows computed CSB and SBO antenna pattern plots.

DATA ANALYSIS.

Localizer course structure results with the ATC tower as the only reflecting structure modeled (figure 3) show computed CDI deflections that are well within Category III course structure tolerances. The modeled course structure plot shows that the tower has virtually no effect on localizer performance. Computed clearance orbit plot (figure 4) indicates satisfactory linearity, course crossover, and clearance levels. Figure 5, CSB and SBO antenna patterns for the Wilcox dual frequency antenna array, show smooth computed course and clearance signals on both sides of the pattern.

CONCLUSIONS

Localizer modeled results indicate that Category III localizer performance should be maintained with the Wilcox 14-element, dual frequency log periodic dipole (LPD) antenna array with the air traffic control tower constructed as proposed. Computed clearance orbit results indicate satisfactory linearity, course crossover, and clearance levels.

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

4. Chin, G., et al., ILS Localizer Performance Study, Part I, Dallas-Fort Worth Regional Airport and Model Validation, Syracuse Hancock Airport, Report DOT/FAA-RD-72-96, 1972.

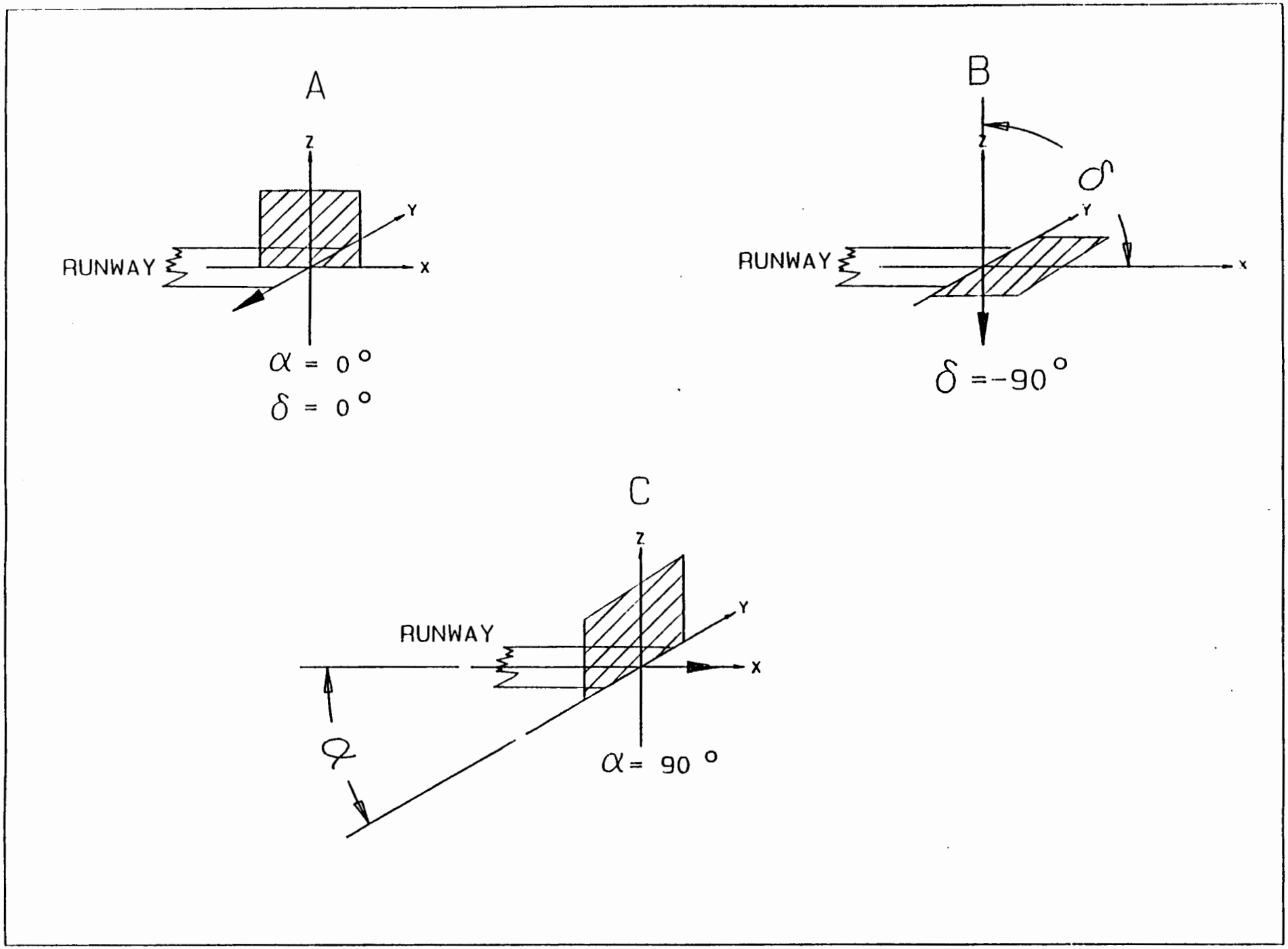

FIGURE 1. INSTRUMENT LANDING SYSTEM LOCALIZER MATH MODEL COORDINATE SYSTEM

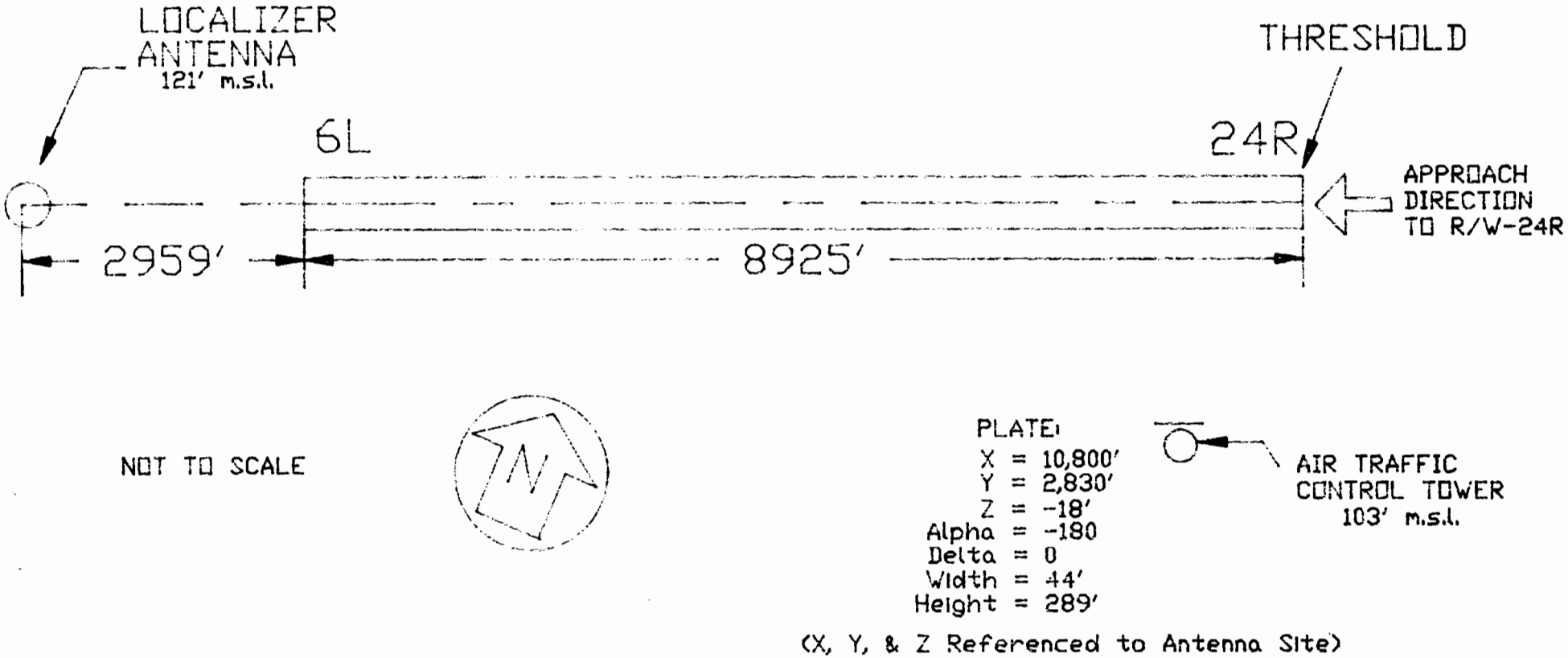

FIGURE 2. LOS ANGELES RUNWAY 24R, ILS MODELING LAYOUT

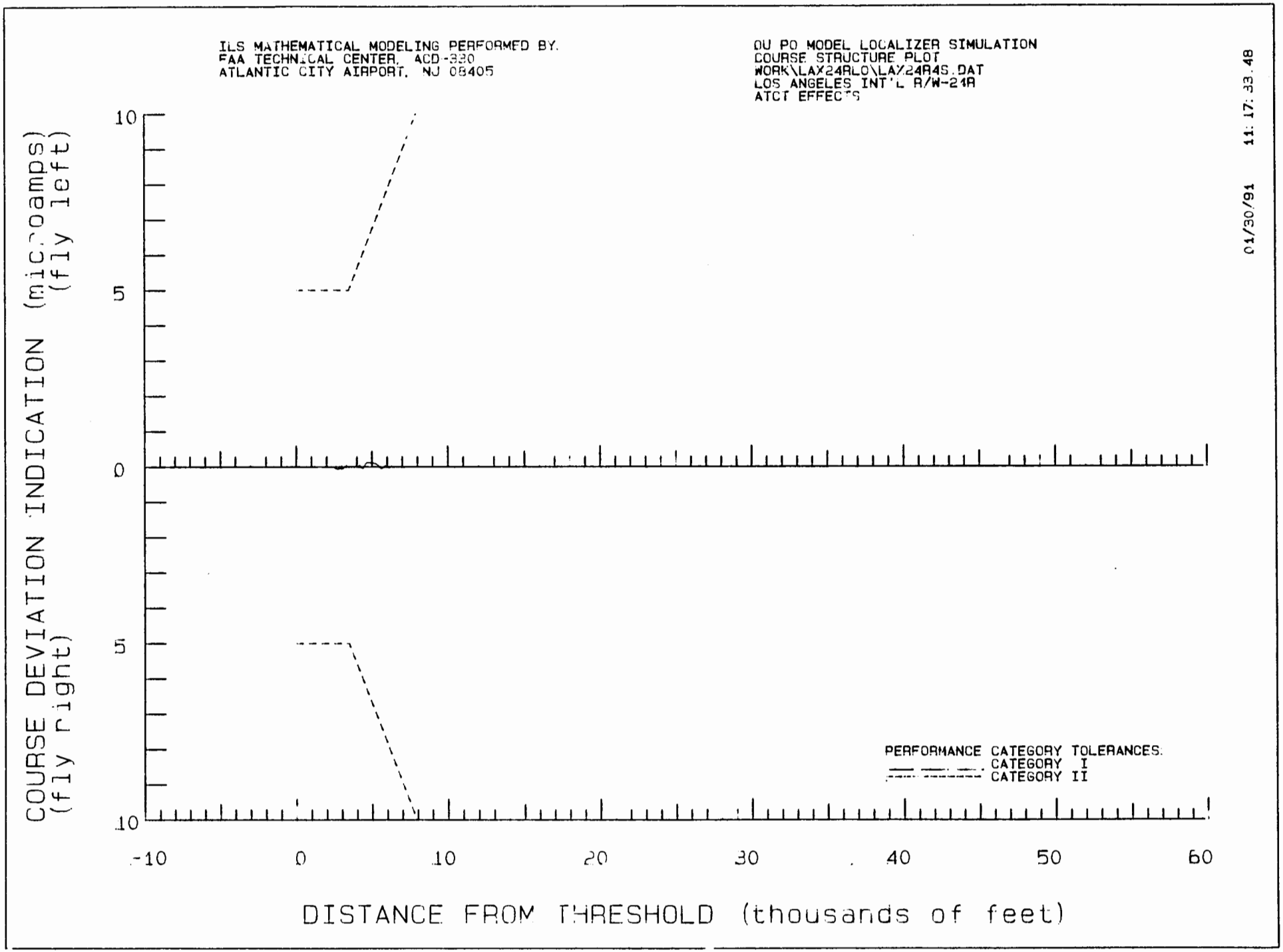

FIGURE 3. COURSE STRUCTURE, LOS ANGELES RUNWAY 24R, AIR TRAFFIC CONTROL TOWER EFFECTS ONLY

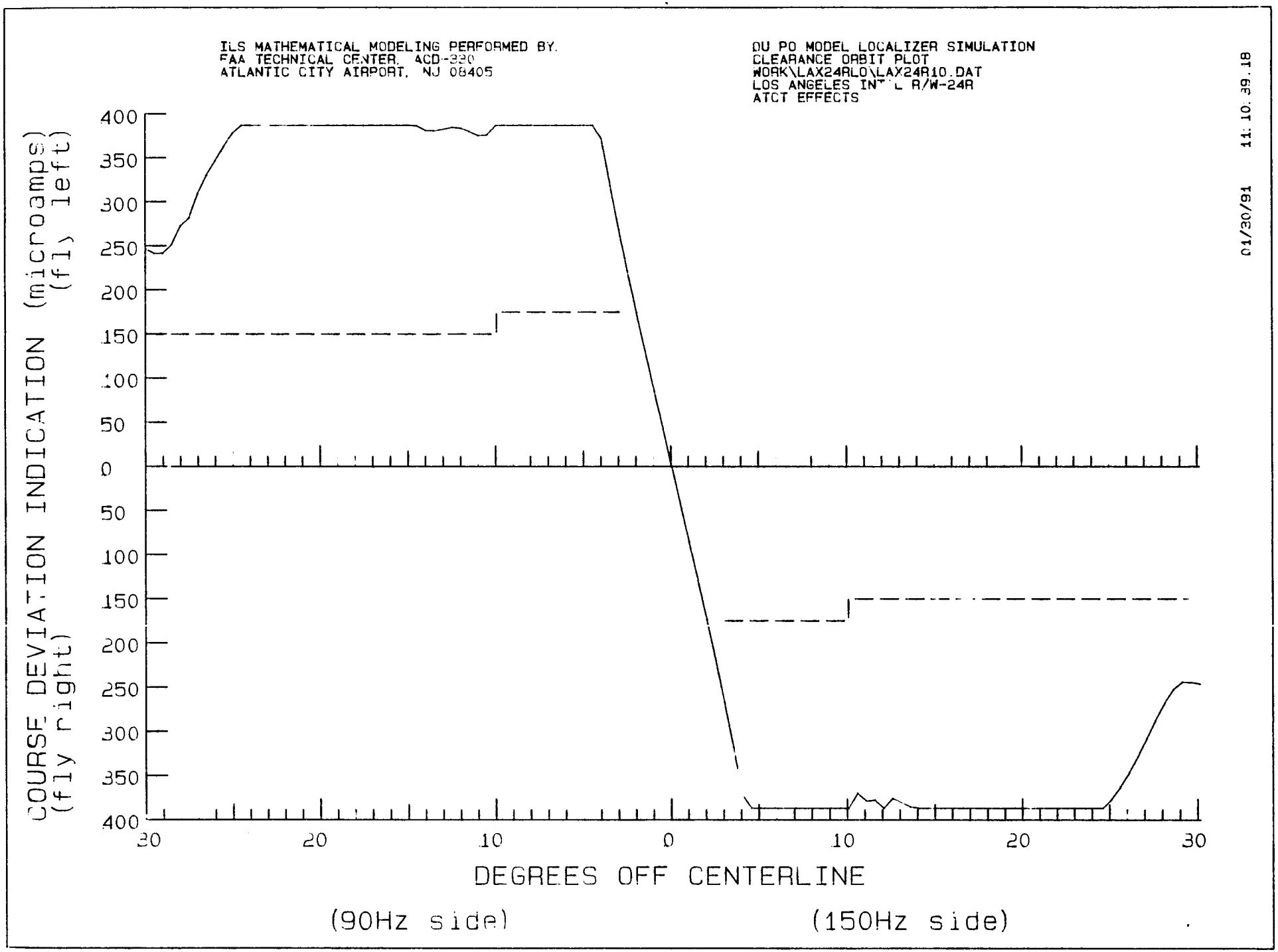

FIGURE 4. CLEARANCE ORBIT, LOS ANGELES RUNWAY 24R, AIR TRAFFIC CONTROL TOWER EFFECTS ONLY

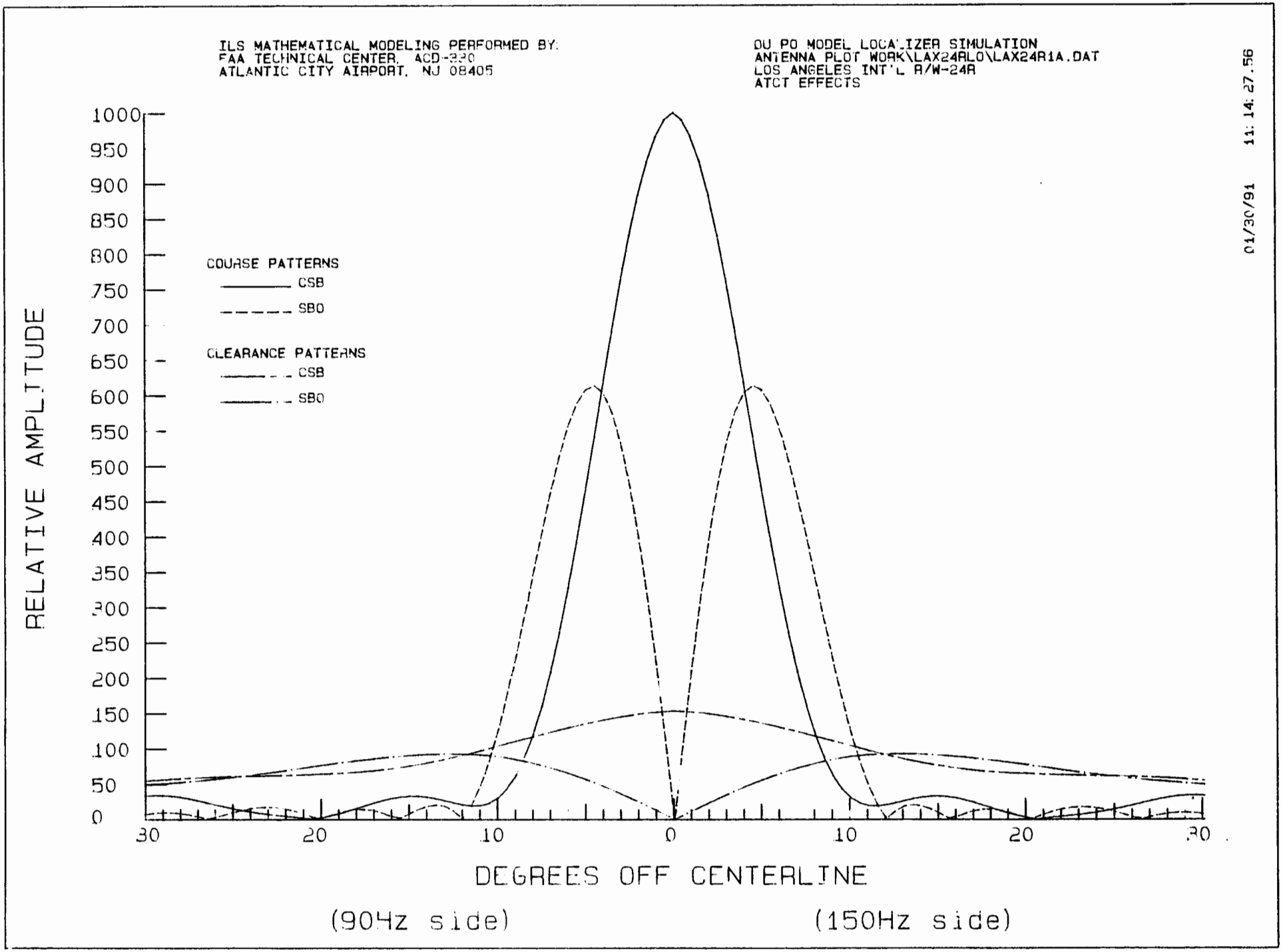

FIGURE 5. CSB AND SBO ANTENNA PATTERNS, LOS ANGELES RUNWAY 24R, AIR TRAFFIC CONTROL TOWER EFFECTS ONLY