TECHNICAL MEMORANDUM
OU/AEC 91-50TM-TRANSCAL

INVESTIGATION OF ALL POTENTIAL NEGATIVE IMPACTS ON LANDING CAPABILITY AT THE LOS ANGELES INTERNATIONAL AIRPORT DUE TO INSTALLATION OF THE METRO GREEN LINE AT ITS EAST BOUNDARY

by

Richard H. McFarland, Ph.D., P.E.
Robert W. Lilley, Ph.D.

January 1992

Prepared for:

TRANSCAL
403 West 8th Street
Los Angeles, California 90014

Avionics Engineering Center
Ohio University
Athens, Ohio

TECHNICAL MEMORANDUM
OU/AEC 91-50TM-TRANSCAL

INVESTIGATION OF ALL POTENTIAL NEGATIVE IMPACTS ON LANDING CAPABILITY AT THE LOS ANGELES INTERNATIONAL AIRPORT DUE TO INSTALLATION OF THE METRO GREEN LINE AT ITS EAST BOUNDARY

Presented are the results of an investigation to identify potential negative factors that could be produced by the Metro Green Line running along the east boundary of the Los Angeles International Airport. Where effects adverse to flight operations appear, solutions are proposed and documentation given to support the viability of these solutions. The solutions, albeit in some cases expensive, are such that they do not violate the initial constraints, viz., no degradation of safety will be allowed, runway length or operational capability will not be decreased, nor will any navigation or radio aid be allowed to be degraded significantly in terms of tolerance limits.

by

Richard H. McFarland, Ph.D., P.E.
Robert W. Lilley, Ph.D.

Avionics Engineering Center
Department of Electrical and Computer Engineering
Ohio University
Athens, Ohio 45701

January 1992

Prepared for:

TRANSCAL
403 West 8th Street
Los Angeles, California 90014

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

TABLE OF CONTENTS (cont'd)

TABLE OF CONTENTS (cont'd)

LIST OF FIGURES

LIST OF FIGURES (cont'd)

LIST OF FIGURES (cont'd)

LIST OF FIGURES (cont'd)

disturbed by vehicles passing in front of the antennas; accordingly, the FAA has published standards that prohibit placement of conducting objects in what are called critical areas. The Metro Green Line, as planned, would penetrate the critical areas of both of the present localizer transmitting antenna systems each of which is located approximately 700 feet east of the airport boundary.

The recommendation is made to relocate both of these antenna systems onto the airport nearer the runways. The complication is that with the 07L localizer, in particular, the separation distance between jet engines spooling up for takeoff on Runway 25R and the antennas would be less than 250 feet. Two solutions are proposed. One is to locate specially ruggedized, directive antennas in front of the existing blast fence. This places the Metro Green Line behind the antennas where there is very little radiation which could reflect and corrupt course guidance information. Another is to move the antennas east of the blast fence and elevate them over a counterpoise. The proposed position allows the antennas and counterpoise to remain west of the airport boundary and importantly, also west of the Metro Green Line. This solution requires a counterpoise to protect signals from being incident on and reflecting from traffic that operates on the airport perimeter road. This road presently exists immediately to the west of the airport boundary fence.

The solution for the other parallel runway is easier. Because the threshold of this runway, (25L/07R), is relocated over 1000 feet west of the airport boundary, there is room for installing a localizer array for Runway 07R in this overrun area. This again places the Metro Green Line to the east and behind the localizer array, thus preventing radiation from becoming incident on the railcars, scattering and causing course derogation. The issue of collocating the localizer for Runway 07R and the inner marker for Runway 25L, which now becomes necessary with the localizer antennas being moved onto the airport, is dealt with in a straightforward manner and an engineering solution is presented.

The glide slope serving Runway 24L is a null-reference glide slope and is impacted significantly. The combination of the present environment with railcars and a station added is predicted to produce an out-of-tolerance condition. A design for converting to a capture-effect system is presented which will correct this problem. None of the other runways was affected significantly by the presence of the railcars, principally because all others are of the capture-effect type.

The effects of the overhead catenary system running in front of the glide slopes for Runways 24L, 24R, 25L and 25R were also investigated. This investigation which involved both theoretical and experimental portions indicates that the OCS is not a problem.

The other significant issues are those of accommodating the Metro Green Line alignment through Parking Lot C in an area where the middle markers for Runways 24R and 24L are located, and the far-field course monitors for Runway 24R are existing. The problems are created because the Metro Green Line cars will prevent the FAA required line-of-sight between the three probe antennas for far-field monitors and the localizer transmitting antennas. The relatively simple and obvious solution to each of these three discrete but identical problems is to elevate each of the three monitor probe antennas so they will have line-of-sight to the transmitter and receive more direct localizer signals. This minimizes the effects of the reflected signals coming from the rail line components, e.g., the overhead catenary system. Fortunately these far-field monitor antennas can be elevated and still remain below the 50:1 surface.

An investigation of potential negative impacts on performance of ASDE radars, airport surveillance radars, communications facilities, radio data links, the VHF Omni Range, TACAN, non-directional beacons, and distance measuring equipment (DME) reveals that no significant derogative effects will result from the Metro Green Line.

The results of this study show that, of the more than 50 facilities present at LAX, in only 6 of these cases (3 of these being components of the same monitor system) will performance be affected significantly by the Metro Green Line. The findings are that in each of these 6 cases at least one engineering solution exists.

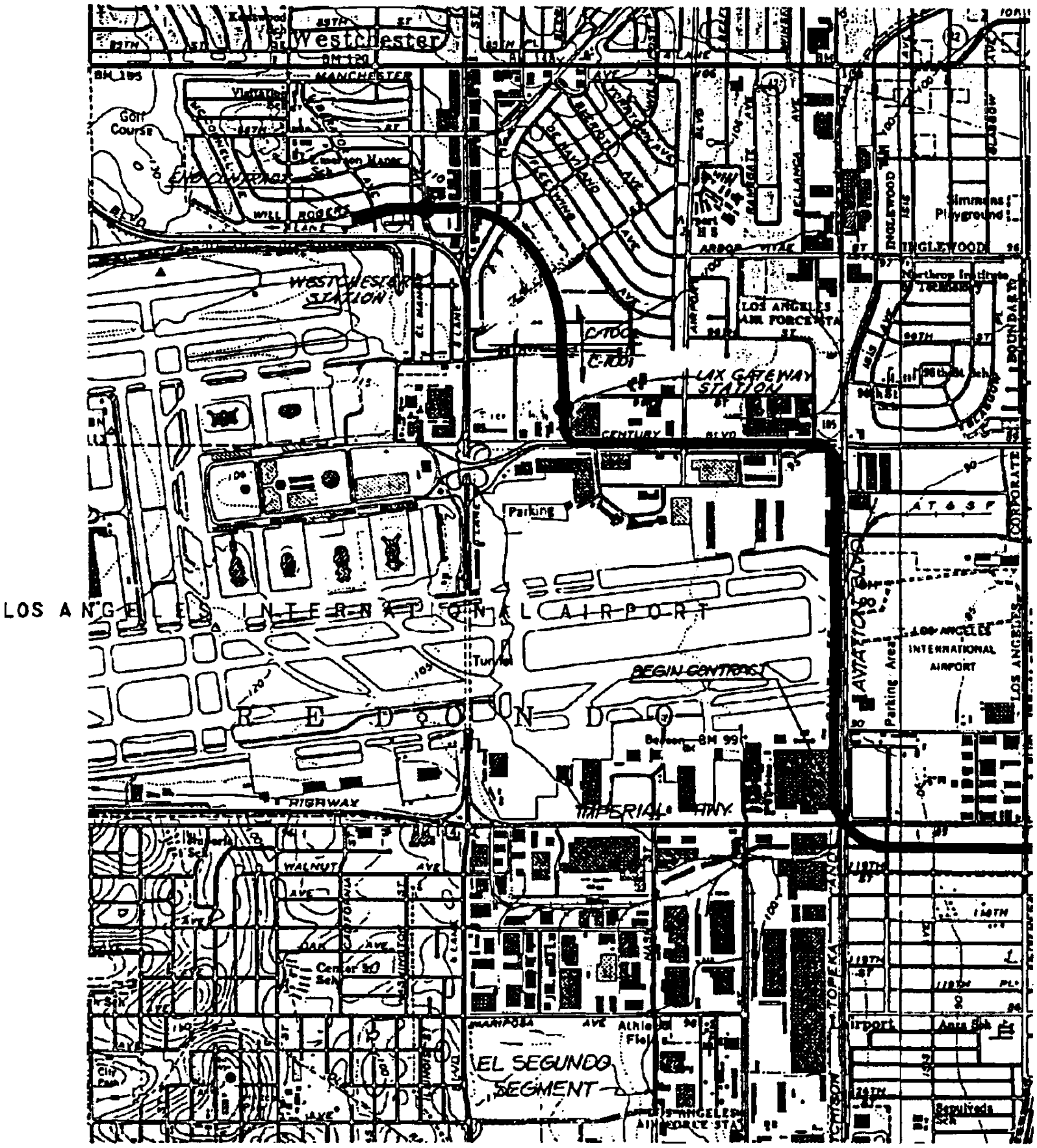
I. INTRODUCTION AND BACKGROUND

By May 1991, The Los Angeles County Transportation Commission had completed many of the preliminary steps necessary for running the North Coast Extension of the Metro Green Line along the east boundary of the Los Angeles International Airport (LAX). The plan calls for the rail alignment to be along the east boundary of the south complex of the airfield, and from there proceeding northward eventually passing through Parking Lot C which is east of the north complex. A possible extension from there northwestward is being considered. This layout, which is foundational to this study, is shown in Figure 1-1. An alternate plan shown in Section IV defines an alignment which consists of a station in the Lot 'C' area (relocated Gateway Station) with the line continuing northerly through Lot 'C' as either a continuation to the next station or as a tail track. This alignment was considered in modeling of the effects that could be expected concerning the performance of the glide slopes that serve Runways 24L and 24R.

In late spring of 1991 the Federal Aviation Administration expressed in writing a concern that all factors which relate to the potential impacts of the Metro Green Line running along the east boundary of the Los Angeles Airport had not been identified. They were especially concerned that electronic aids for aircraft operations would be impacted adversely. They expressed interest that a report accompany a formal new Notice of Proposed Construction or Alteration Form 7460-1, to replace the one submitted earlier in July 1990. In response to that interest TransCal commissioned this study to be conducted by Ohio University that would investigate all possible negative impacts on LAX flight operations. The purpose of this technical report is to document the findings of the investigation. The findings hopefully will meet the need of providing detailed technical information to the Federal Aviation Administration as they perform their work of evaluating the request for rail construction.

There are well over 50 radio aids involved in handling the operation of aircraft in and out of LAX. There are navigation aids, communications stations, radar surveillance facilities, radar beacon sites and wind shear alerting devices all using the radio spectrum in one way or another. The very dependence of LAX operations on radio waves in space offers the potential for creating problems with airport operations. For example, an unwanted separate source of radio frequency energy might appear effectively to jam the desired radio operation; surfaces such as provided by railcars might cause reflection of the desired signals to produce signal distortion, or the relatively large surfaces of the combined railcars might simply block microwave radio signals that propagate essentially line-of-sight. Further, there are concerns that visual cues provided for the pilot might be rendered less effective and confusion created by the sources of direct or reflected illumination from the railcars.

The intent of this study is to address all radio aid issues and to identify possible derogative effects that can be expected from the Metro Rail Green Line running



P252054

Figure 1-1. Planned Layout and Alignment of Metro Green Line as the Reference used in this Report.

in the planned location. Special study is given to identify solutions to the problems in the cases where these effects are significant. Typically the steps takenin approaching the problems and obtaining solutions are examining results of previous work and research of data produced elsewhere for similar type problems, performing special theoretical developments, executing computer-based modeling of the physical situation, analyzing of data derived from specially conducted field tests and applying experience obtained from over 30 years of work in the field and in flight, particularly as pilots.

The period of this investigation has not been long but it has been intense. Considerable time has been spent at the Los Angeles International Airport, with the FAA, with airport personnel, and in interviews and discussions with knowledgeable people involved in managing, operating, and maintaining the radio facilities.

Interviews revealed a spirit of cooperation in trying to help solve any problems that the Metro Green Line might create. The general agreement is that the Los Angeles population and visitors to Los Angeles need and deserve efficient means of ground transportation, and everyone needs to cooperate to bring this about. The positive attitude from all concerned has certainly been helpful in refining ideas and approaches that have been generated during this study.

The study has been broad. The intent has been to address every possible radio facility existing to support LAX operations. The basic rule that was adopted for this study is that any circumstance of interference is considered totally unacceptable if it causes aircraft and airport operations to be less effective. In other words, runways cannot be shortened, navigation aid service cannot be derogated noticeably, communications cannot be degraded, radar range and resolution capability cannot be reduced, and published safety factors cannot be diminished.

Fortunately the majority of the aids have assigned frequencies for their radio operation or are located in such places that there is no conceivable way they would be adversely affected by the Metro Green Line, as it is planned. There are, however, several radio aids that will be affected by the Metro Green Line and these are discussed in Sections II, III, and IV. In these sections the problems are delineated, solutions proposed, and data given supporting the proposed solution or solutions.

From the perspective of providing transportation service to society, it is good to report that with appropriate, careful engineering, and sufficient financial resources, all problems that will be created by the Metro Green Line can be solved with existing technology. Only in one case will an alternative solution require the development of a new product, viz., a ruggedized localizer antenna.

II. LOCALIZER CONCERNS

There are two localizers that will be impacted by the Metro Green Line in its planned location. The localizers serve approaches to Runways 07L and 07R. These two cases are treated individually in the two major portions of this section of the report. Because the inner marker for Runway 25L is involved with placement of the localizer for Runway 07R, it will be discussed along with this localizer.

A. Design for Localizer Array to Serve Runway 07R and Inner Marker to Serve Runway 25L.

1. Statement of the Problem.

The localizer is an aircraft navigational aid which provides the pilot with an electronic signal that is, in effect, an extension of the runway centerline. By using this signal the pilot, or auto pilot, can align the aircraft within a few feet of the runway centerline as it approaches the runway threshold. It is important that this signal not be corrupted or noisy if the aircraft is to be aligned precisely.

The inner marker is also a radio air navigation facility which provides the aircraft with a signal when it passes directly over the transmitter site. This allows the pilot to know that he is at a precise point on the approach to landing. The inner marker is similar to the outer and middle markers in that it transmits on a 75 MHz carrier frequency but is distinct by having a 3000-Hz tone modulation producing short, morse-code-type dots. Its location must be at a point over which the aircraft passes on the approach 100 feet above touchdown.

It turns out that the inner marker for one runway may be essentially collocated with the localizer which serves the opposite runway. If this collocation is required, then precautions must be taken to insure they operate on a non-interfering basis.

The present localizer antenna array which radiates the signal the aircraft uses for approaching Runway 07 is to the east, well beyond the stop end of the runway. Unfortunately, at Los Angeles International Airport, this means that Aviation Boulevard and the Santa Fe Railroad which pass north-south along the east boundary of the airfield also pass in front of the two localizer antenna arrays for Runways 07R and 07L. The problems associated with the localizer for Runway 07L are discussed in the subsequent section. Corruption of the localizer signals typically takes place when conducting objects, i.e., objects made of a conducting material such as steel or aluminum, pass between the antennas and the approaching aircraft. In general, the closer the conducting object is to the transmitting antennas, the greater the corruption.

Knowing the possibility of such signal disturbances, the FAA has designated (in two dimensions), an area near the antennas as a "critical area" and restricts objects from being placed therein. In 1974, serious study began to identify boundaries of critical areas. For nearly two decades, Ohio University has performed the calculations to define the boundaries of the critical areas and the experimental work for validating the mathematical models. These areas, if occupied by large objects such as aircraft or other vehicles, can be expected to produce unacceptable magnitudes of course disturbance. The FAA order which contains the specifications for critical areas is 6750.16B [2A-1]* and its amendments, the latest being in 1989.

Aviation Boulevard and the Santa Fe Railroad, while violating the specification, are considered by some to have grandfather rights. This is now being reviewed by the FAA. Both localizer arrays serving Runways 07R and 07L are mounted on 18-foot high platforms which some believed would eliminate corruption caused by vehicular traffic. In the case of the Metro Green Line there is no grandfather possibility to allow for mitigation. Clearly the Metro Green Line's planned alignment will pass through the presently specified critical areas for the localizers serving Runways 07R and 07L.

Experience shows that objects which are:

a) less than 15 feet tall,
b) fixed in place,
c) more than 100 feet from the antennas,
d) symmetrical in shape, and
e) located symmetrically with respect to the runway centerline

can be accommodated by reasonably simple adjustments to the localizer system. Unfortunately, vehicular traffic on Aviation Boulevard, rail traffic on the Santa Fe Line and the Metro Green Line cannot meet all of these requirements [2A-2]. Note should be made that modest-size vehicles use the airport perimeter (patrol) road, and these vehicles should not move in front of the localizer either.

In summary, this task addresses finding acceptable solutions to the problems of having rather large, moving, conducting objects such as the railcars passing between the localizer transmitting array and the receiving antennas on the aircraft and having to collocate an ILS inner marker with a localizer transmitting array.

2. Proposed Solution to the Problem.

To eliminate the problem of signal corruption due to railcars in front of the antenna, the relative positions of the cars and the antennas need to be changed.

---

*See references at end of each section.

Given that, there are not only proposed Green Line cars penetrating the critical areas, but Santa Fe railcars and traffic on Aviation Boulevard as well. The proposed solution to the problem is that of relocating the localizer antenna array so the moving traffic passes behind the localizer array of directional, log-periodic, dipole antennas.

The only practical acceptable location for this localizer antenna system is in the Runway 07 overrun area which has a concrete surface. At one time this was probably part of the runway. Fortunately, for the purposes of locating a localizer array, the approach threshold for Runway 25L which is the runway for the opposite flow of traffic, is displaced. This means there is 965 feet of concrete between the operating threshold and the east boundary of the concrete. The recommended solution to this critical area issue is to locate the 07R localizer 922 feet from the displaced threshold on this concrete surface that appears as abandoned runway area. This old runway surface is unused, undoubtedly, because of the need to meet required obstruction clearances for Runway 25L approaches through the use of a displaced threshold.

An inner marker site, which serves the Category II flight operations on Runway 25L, presently exists on this concrete overrun area. Figures 2-1 and 2-2 show the existing inner marker facility. The components are two dipole antennas mounted above a screen counterpoise (artificial ground plane) and a small shelter containing the electronic transmitting and monitoring components. There is a small blast shield located immediately adjacent to the facility in the direction toward the runway (west). This facility is 972 feet (0.16 nmi) from the displaced threshold. The recommendation is that this inner marker not be moved laterally nor longitudinally. This will place it approximately 50 feet to the rear of the planned localizer array. This will meet the critical area requirements, and allow for minimum equipment modification and relocation. The only recommended action is that the counterpoise and antennas be refurbished and elevated approximately 3 feet from its present location to increase its independence from the light lane and localizer antenna structures.

A sketch is provided that illustrates the recommended placement of the localizer and inner marker antenna arrays that will provide a solution to the critical area problem for Runway 07R. See Figure 2-3.

3. Discussion and Data Supporting Recommendation.

The issue of critical area penetration is not peculiar to Los Angeles. In 1988, St. Louis Lambert Airport was found to have a critical area penetration with a two-lane road passing in front of a log-periodic dipole array radiating localizer signal to serve Runway 12L [2A-3 & 4]. This array was also on a platform, this one being approximately 10 feet high. While some thought there would be no problem because the localizer antennas were on a platform "overlooking" the

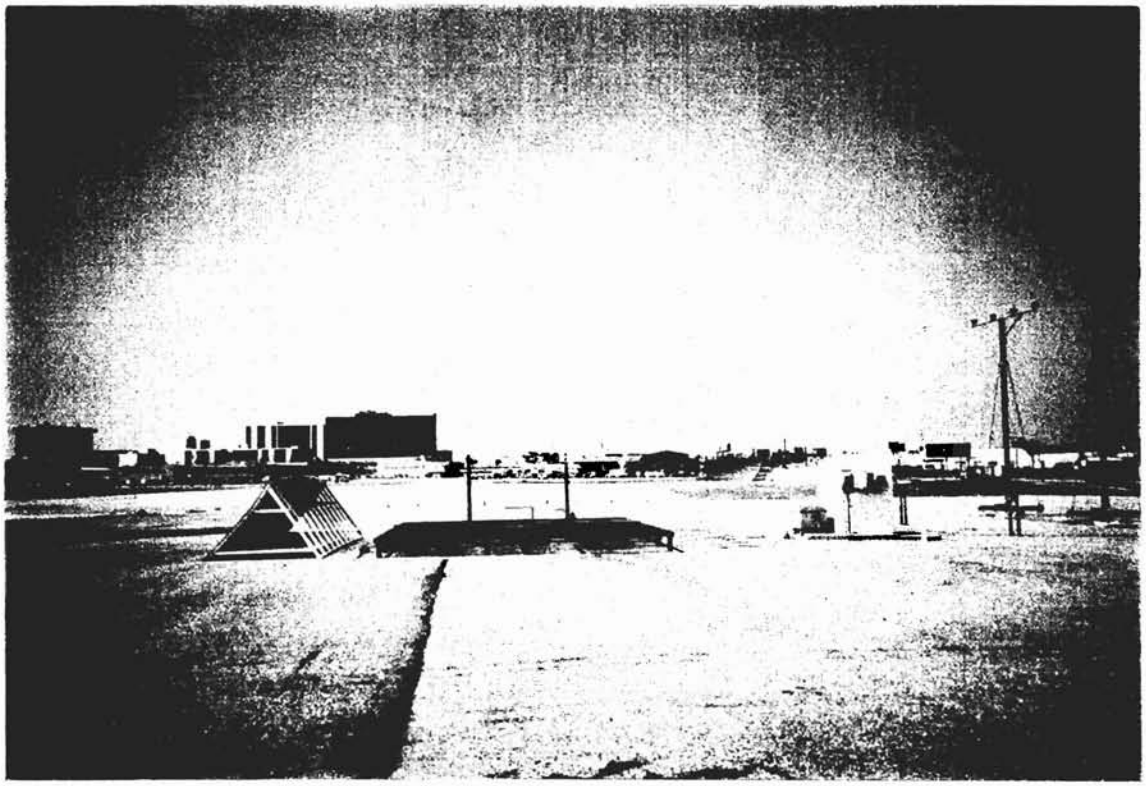


Figure 2-1. Inner Marker Installation for Runway 25L Looking North.

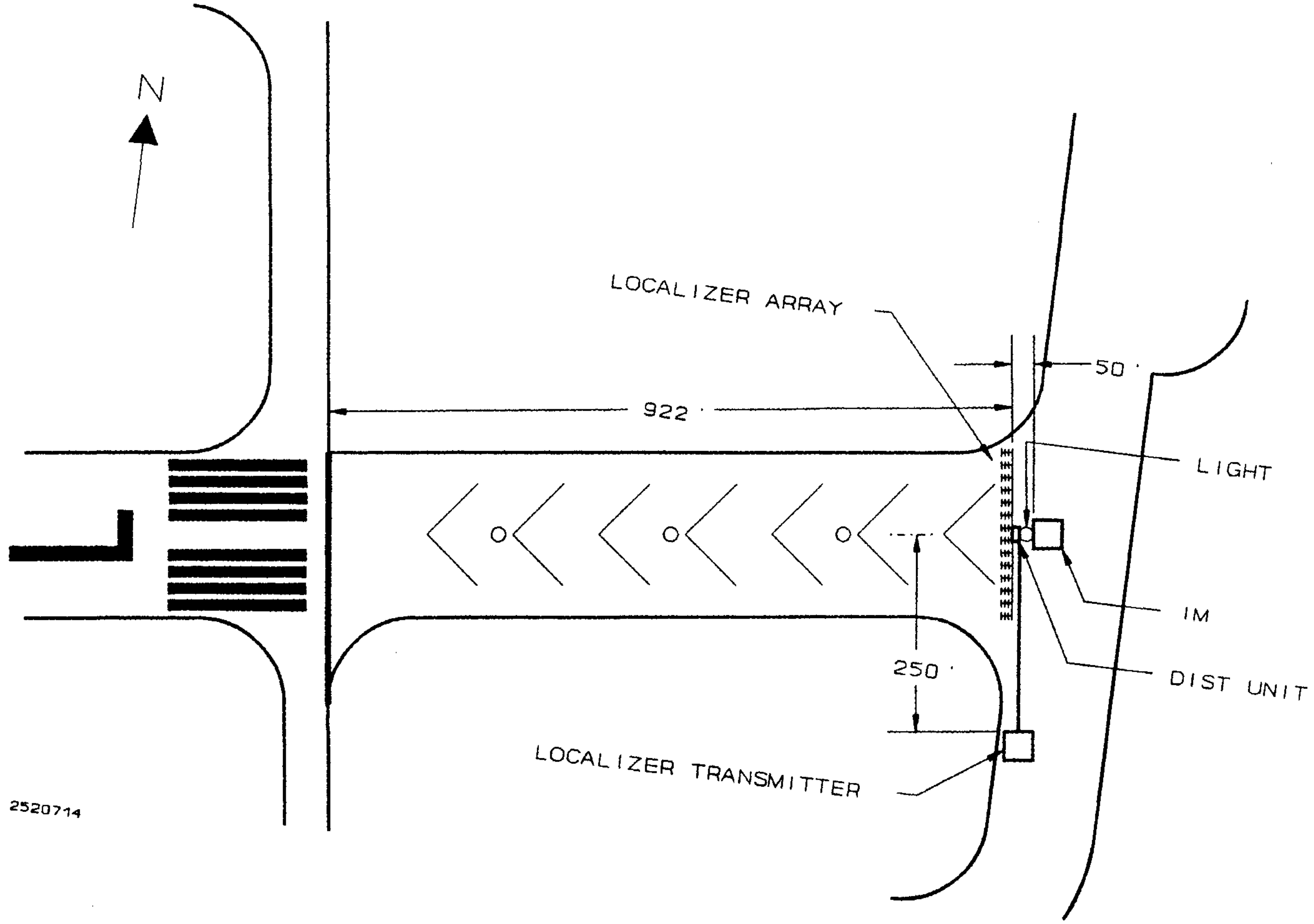


Figure 2-3. Proposed Layout of Collocated Inner Marker and Localizer for Runway 07R.

traffic, FAA flight measurements showed that the elevated platform did not make the signal immune to the traffic. This problem was solved by relocating the array closer to the runway, specifically 480 feet from the threshold and inside the airport boundary fence. This is a very similar, but somewhat milder circumstance than at Los Angeles. Fortunately the FAA has collected the necessary flight inspection data to show that the move at St. Louis did indeed provide a solution to the critical area problem.

Another case is the relocation of a localizer at Cheyenne, Wyoming. A four-lane road crosses in front of the localizer serving Runway 26 [2A-5]. The FAA is presently in the process of relocating this localizer so it will be within the airfield boundaries.

Because of these and other cases, there is sufficient background and experience to state that there is little technical risk in obtaining good localizer performance with an antenna array location on the airdrome proper and embedded in an approach-light lane.

There are more than 6 collocated marker-localizer facilities throughout the United States and there have been no special problems reported because of the collocation aspect. Marker beacon energy is radiated nearly vertical which gives a high tolerance level to conducting structures that are adjacent to the facility. Because of the good experience and the theoretical considerations which support compatible collocation, the conclusion is that there is very low technical risk to planning collocation of facilities.

4. Recommended Further Action.

There is no testing needed prior to a relocation. Sufficient evidence exists that collocated localizer and marker beacon facilities that are installed as depicted in Figure 2-3 will perform satisfactorily. Present localizer performance recorded by the FAA indicates that about 55% of allowable Category I tolerance limits exist; this is comfortable. If minimum down time is a major issue, the recommendation is for acquisition of a second localizer array system which can be installed approximately 800 feet from the displaced threshold while the present array remains operational. The changeover from one system to another would then amount to a cut-over of wiring with a minimum of down time, conceivably a matter of hours.

At the recommended new location for the localizer there will be a 5-foot separation between the standard-mounted antennas and the desired 50:1 protected slope. The separation distance from the displaced threshold is 800 feet which is great enough that no special treatment of the antennas is warranted.

5. References.

[2A-1] "Siting Criteria for Instrument Landing Systems", Department of Transportation, Federal Aviation Administration, Order #6750.16B, June 17, 1985.

[2A-2] Edwards, Jamie S. and Michael F. DiBenedetto, "Effects of a Simulated MLS Azimuth Station Constructed of Sheet Metal on the 8-element V-ring and 8-element LPD Localizer Arrays at the Tamiami Airport, Miami, Florida", Technical Memorandum OU/AEC 64-87TM-00006/2-6/ICAO, Avionics Engineering Center, Department of Electrical and Computer Engineering, Ohio University, Athens, Ohio, December 1987.

[2A-3] McFarland, R.H., "Recommendations for Alleviating Critical Area Problems for Localizer 12L at St. Louis Lambert Airport", Precis 77, Avionics Engineering Center, Department of Electrical and Computer Engineering, Ohio University, Athens, Ohio, April 18, 1988.

[2A-4] McFarland, R.H., "Demonstration of Category II ILS Performance for Runway 12L, St. Louis, Mo.", Precis 78, Avionics Engineering Center, Department of Electrical and Computer Engineering, Ohio University, Athens, Ohio, June 1988.

[2A-5] McFarland, Richard H., "Report of Investigation of Localizer Siting at Cheyenne, Wyoming", Precis 112, Avionics Engineering Center, Department of Electrical and Computer Engineering, Ohio University, Athens, Ohio, March 9, 1990.

B. Investigation of Techniques to Solve the Runway 07 Left Localizer Siting Problem

1. Statement of the Problem.

The localizer serving Runway 07L at the Los Angeles International Airport has many similar issues as listed in the preceding Section IIA of this report which discusses the Runway 07R localizer. However, the Runway 07L localizer transmitting array presently consists of 15 V-Ring antennas which provide a more-omnidirectional signal pattern than the LPD antennas located to serve Runway 07R. These antennas are mounted on a 19-foot high platform approximately 1100 feet beyond the stop end of the runway. Figure 2-4 shows a photograph of the array presently in place. The Metro Green Line guideway, as it is planned, proceeds north-south along the east boundary of the airport, cutting through the critical areas 810 feet in front of the localizer antennas. This violates FAA order 6750.16B, Change 2, dated May 1989, as does the current condition which was described in Section IIA. The addition of the Metro Green Line at grade level between the antennas and the runway would serve only to provide further degradation of signals. The Metro Green Line would have to be 2000 feet from the array not to be in the critical area.

The most important distinction between the Runway 07R and Runway 07L cases is that the runway threshold for Runway 25L (the stop end of Runway 07R) is relocated, thus making a concrete area available that is never used by aircraft. On the other hand, the threshold of Runway 25R is displaced for landings; however, there is 1100 feet of concrete on the east end for use with takeoffs on Runway 25R and for rollouts on Runway 07L. This means that the nearest guideway is only 290 feet from the end of the concrete which is tantamount to saying the tails of the aircraft and jet engines spooled up for takeoff may only be that far away from the cars. The 16-foot high blast fence presently in place would substantially minimize the effects of the jet blast on the cars, however.

As mentioned in an earlier section of this report, the principal means for eliminating the effects of multipath from the Metro Green Line is to prevent the radiated localizer signal from becoming incident on the cars and OCS. This may be accomplished in either one of two ways. First, the Metro Green Line location could be located behind the antennas if they are of the directional type (e.g., log periodic dipoles versus the V-Ring type), or second, the railcars and the OCS could be shielded from the direct radiation of the antennas. Both means are practical for this application; both will be discussed in this section of the report.

In summary, the problem is that of the Metro Green Line passing in front of the present localizer antenna system with the FAA-defined critical area violated. This is an unacceptable condition. Critical area definitions were developed based on

Figure 2-4. The 15-element V-ring Localizer Array that Presently Serves Runway 07L.

theoretical and experimental evidence that ILS signals are disturbed when large objects are in these areas. A solution is needed.

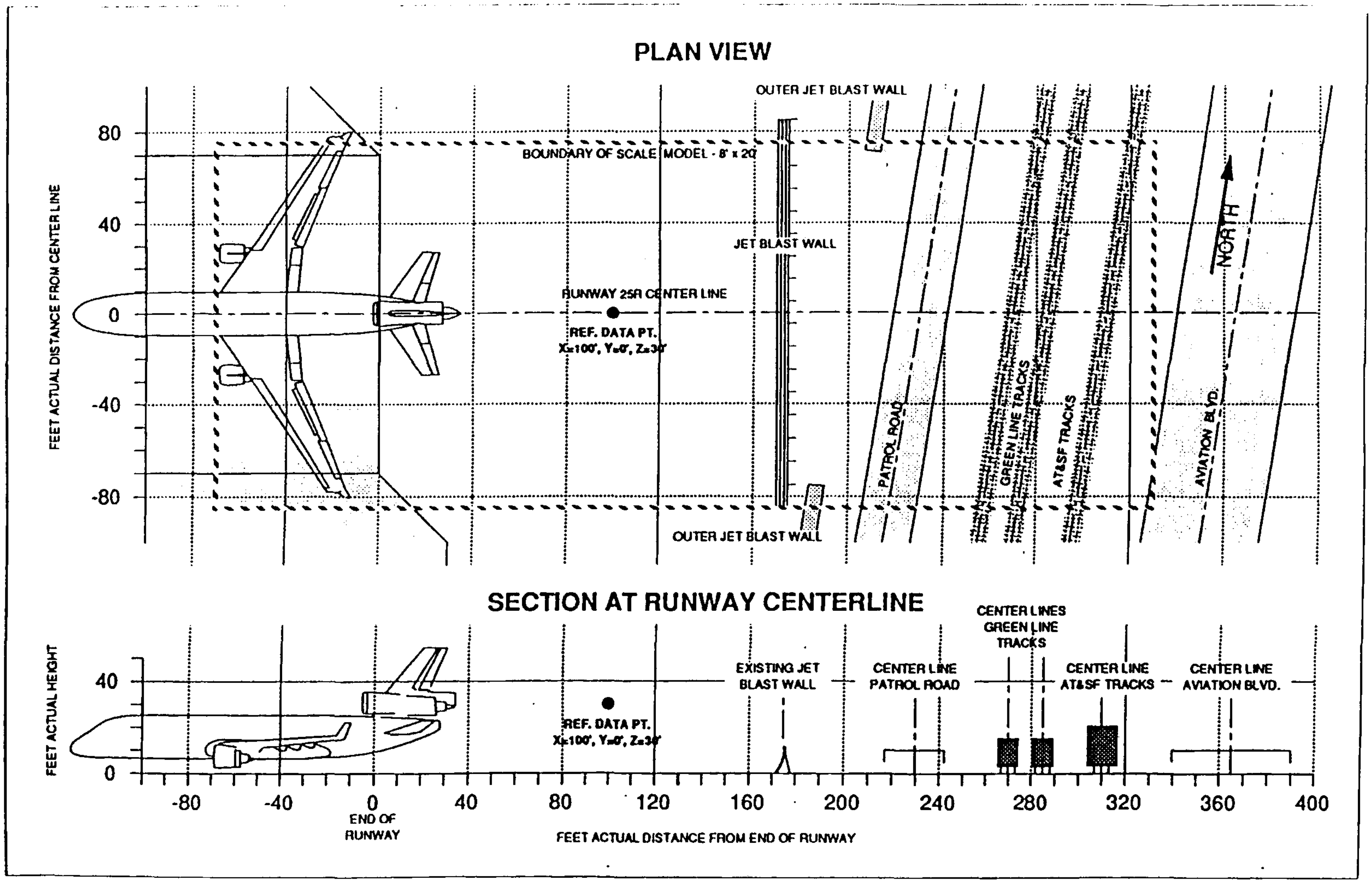
2. Proposed Solutions to the Problem.

There are at least two possible solutions to the problem of the Metro Green Line violating the Runway 07L critical area. The first is the elevated counterpoise which has minimal technical risk. This solution presents some requirements for antenna protection from jet blast and is an additional, undesirable physical structure near the runway. This is mitigated by the already existing jet blast fence. Another solution is that of mounting the localizer antennas low to the ground and immediately in front of the blast fence. Special modifications to the antennas will almost certainly be required so that they will survive the adverse environment of the jet blasts. Both of these proposed solutions place the Metro Green Line behind the antennas where the cars and OCS will have no effect on the localizer performance.

a. The Elevated Counterpoise.

Figure 2-5 shows the planned profile along the Runway 25R centerline extended. Proceeding from the displaced threshold eastward, one encounters the physical (takeoff) threshold, the blast fence, the airport perimeter road, the proposed Metro Green Line, the Santa Fe Rail, Aviation Boulevard (6 lanes), a grass field, and the localizer, in that order. The proposed solution is essentially to construct an elevated counterpoise screen and mount the localizer antenna array on top of this screen. This places the patrol road and the Metro Green Line behind the antennas. This screen, commonly called a counterpoise when it is used in this fashion, forms the imaging ground for the antenna array, and of course, insures that it is a nearly ideal ground, viz, it is smooth, flat, and highly conducting. In this location not only is the Metro Green Line protected from incident radiation, but the similar problem involving the Santa Fe and the Aviation Boulevard traffic is also resolved. Figures 2-6 and 2-7 show sketches of a proposed counterpoise. The screen and antennas could be physically extended to join the blast fence if necessary to add capability for the counterpoise to withstand the environment. The blast fence provides for a turbulent volume of space to exist and should remove physical stress on the antennas. The AeroVironment data shown in Figure 2-8 support the statement. Finally, there should not be a problem electromagnetically either because the blast fence is fixed and symmetrical.

While the counterpoise is a large structure rising 16 feet vertically, it can be made of aluminum to provide low mass and frangibility. Aluminum also provides good electrical characteristics and resistance to corrosion. It can also be made to have some space-frame features to allow it to be more aesthetically pleasing. If the structure is not regarded as a physical problem, these elevated antennas will provide a good solution to this localizer critical area problem.



General site layout showing scale model boundary and the reference velocity data point location.

Figure 2-5. Profile Along Runway 25L Centerline Extended (Approach Region). Taken from AeroVironment, Inc., Report, Title, "Scale Model", Dated July 26, 1991.

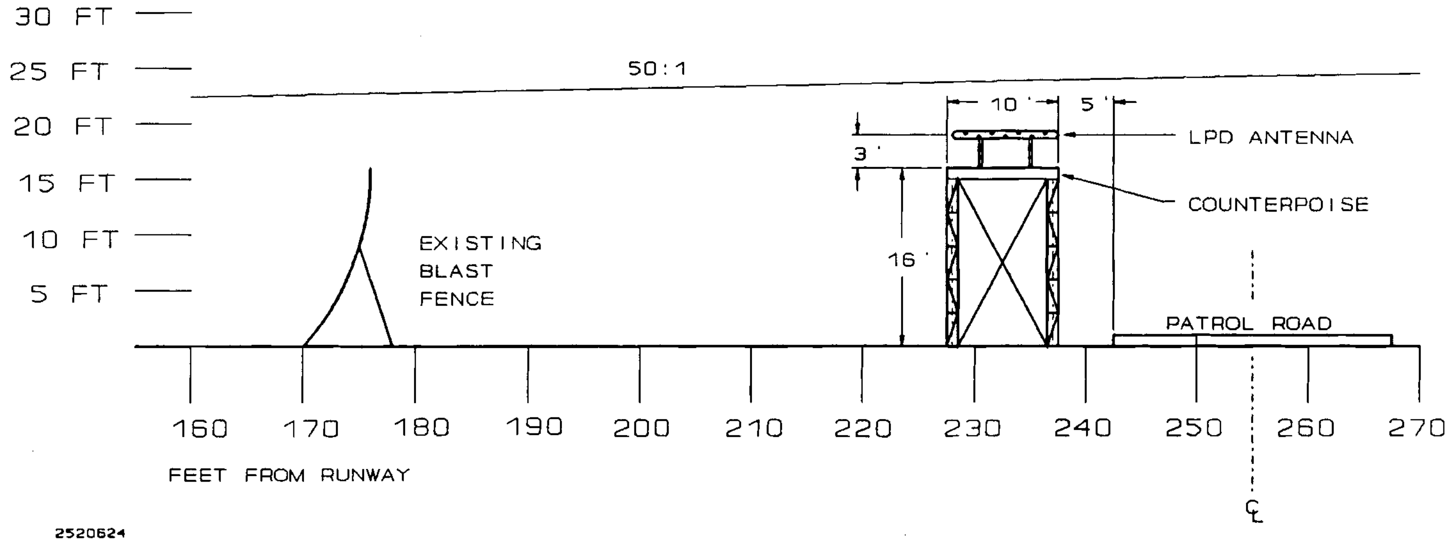


Figure 2-6. Optimum Placement of Runway 07L Localizer with Minimum Size Counterpoise Dimension Perpendicular to Face is 150 Feet.

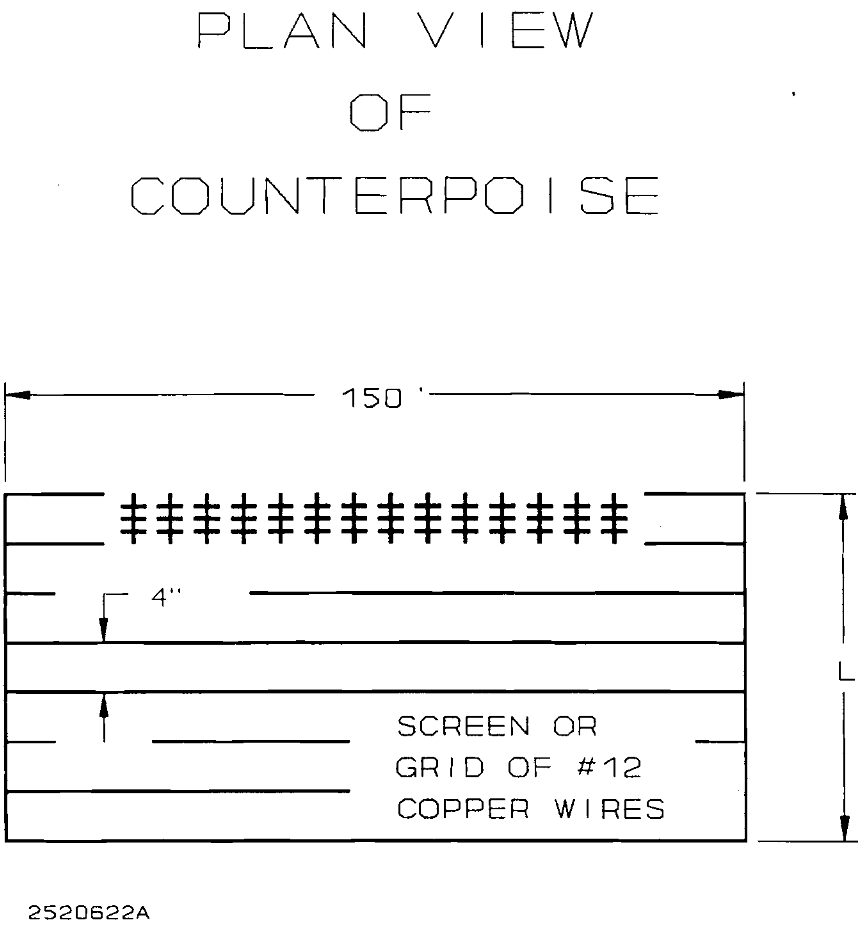


Figure 2-7. Proposed Counterpoise for the Runway 07L Localizer. The Acceptable Range for the Parameter L is Found to be from 10 to 40 Feet.

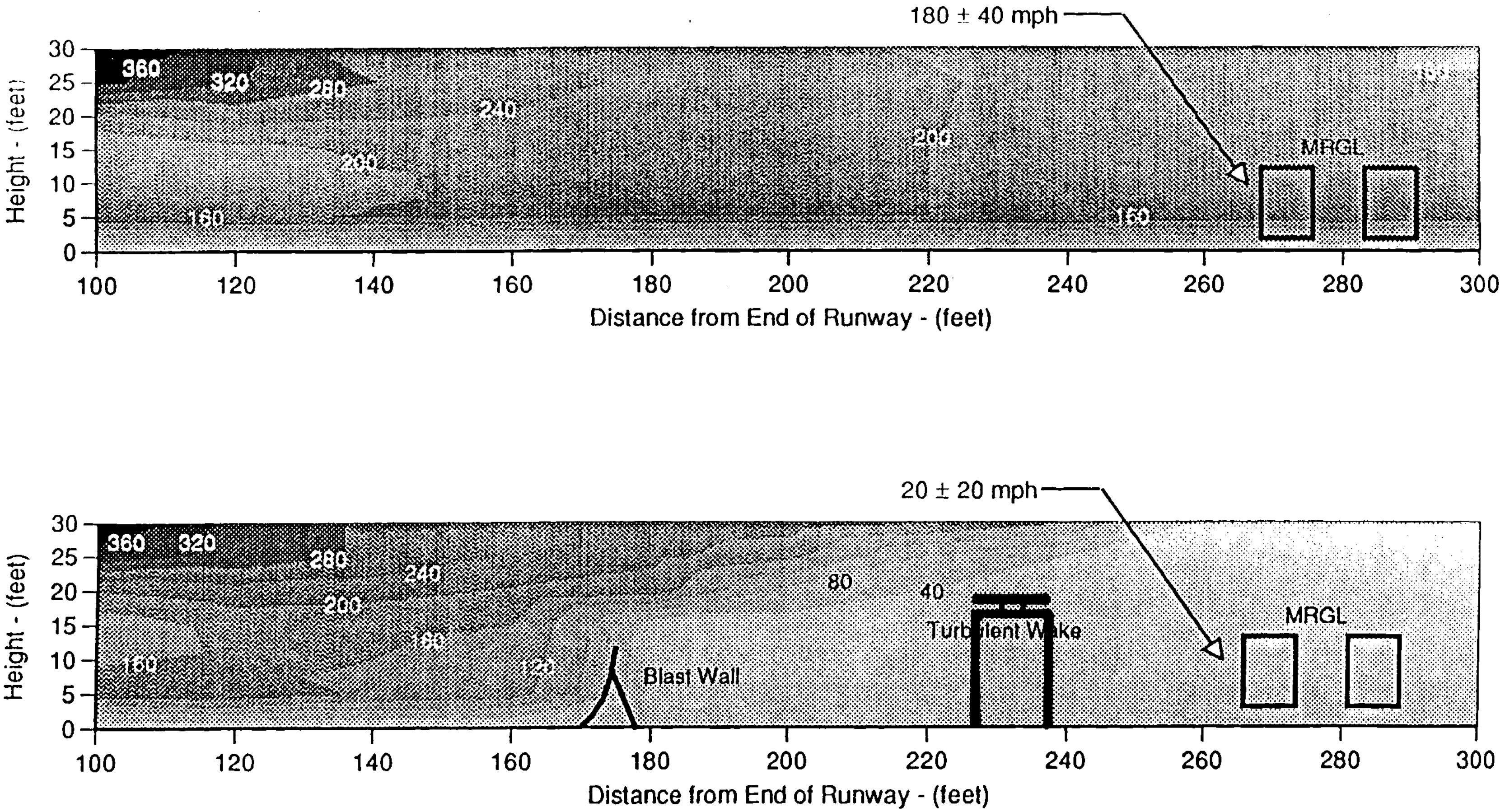


Figure 2-8. Velocity Contour (in mph) along Centerline with and without Blast Wall, no Ambient Wind.

b. Localizer Array Located in Front of Blast Fence.

With all things considered, location of the antenna array in front of the blast fence serving Runway 25R is also a solution to this problem. Several different locations of the localizer antenna array have been considered. Among these were; on top of the blast fence, behind an electromagnetically transparent blast fence which would replace the present steel fence, below a diffraction edge on the blast fence, and simply in front of the present blast fence. While all of these locations present significant problems, the one with the least impact on increasing the significance of physical obstructions in the approach zones is to mounting the antennas low and immediately in front of the present blast fence. This fence would clearly be the controlling obstruction.

The proposal is to mount the localizer antenna array approximately 3 feet from, and directly in front of, the blast fence; ruggedize the antennas and mount them 27 inches above the earth's surface. This surface should have a conducting screen over it to stabilize the effective electrical ground level especially when varying amounts of moisture are present. The antennas should be mounted on frangible supports even though the large, massive, blast fence nearby is not frangible. No modifications or changes to the blast fence are needed. The significance of the antennas as a physical obstruction is overshadowed by the fence which is a massive steel structure that extends to a height of nearly 16 feet. Mounting the antenna elements low to the ground with a paved area in front provides greater frictional surface effects that reduce the velocity of jet blast compared to that experienced at a 6-foot standard height. This location of the transmitting system provides for an unobstructed clear area in front of the antennas, except for aircraft as they move through the critical area on roll-out.

c. Additional Approaches.

The plan to diffract localizer signal over the fence which would act as a knife edge, was ruled out because the localizer signal levels would be significantly reduced in space, possibly requiring that the localizer transmitter signals be amplified. Such amplifiers are not readily available. Further, there is no available data and experience to indicate how well this scheme would work in practice. This, in effect, would make the blast fence an integral part of the localizer transmitting system.

The plan to place the array behind an electromagnetically transparent blast shield raises the issues again of the fence becoming an integral part of the localizer transmitting system. Because the surfaces are large and the forces great, a careful design for the structural support system would have to be prepared. This is important since some of this support framework would probably be metallic, therefore conducting. Nevertheless, this is believed feasible, but the details on how to do this precisely are not known. Considerable engineering and some research and development would have to be accomplished that would involve maintaining stability both in terms of electrical and physical characteristics. This is believed to be a good approach but undoubtedly one which is more expensive to develop than the ones recommended in this section. Finally, maintenance of the surface would have to be considered because deposits from the jet blast would adhere, possibly providing some hygroscopic properties to offer the potential for disturbing the transmission of the localizer radio frequency energy. These are not believed to be high risks, but because of the lack of experience, answers must be obtained prior to any recommendations for use in commissioned service, especially at a major airport where outage time is of great concern. One must note also, that localizer signal performance in space resulting from such a scheme is effectively unmonitored by ground-based equipment. Aircraft would be the first to observe problems with signals. All things considered, this scheme should be regarded as a fall-back possibility.

3. Discussion and Data Supporting Recommendation.

When locating electrical hardware in a zone where there are strong forces encountered, the question of both electrical and mechanical stability arises. The strong forces in this case of the Runway 07L localizer, clearly come from the engines of heavy jet aircraft. Examples of aircraft which have engines of great concern are the Boeing 747, the Douglas DC-10, and the McDonnell Douglas MD-11. Because the separation between the Metro Green Line and the tails of the aircraft using the full length of the available runway for departing Runway 25R, is only 230 feet, any antenna placement must take into account the jet blast effects.

In August 1991, TransCal commissioned a study with AeroVironment, Inc. of Monrovia, California, to use scale models to determine the magnitudes of winds due to jet engines in typical locations. Their data indicate that the existing blast fence is a powerful influence on the wind flow from the engines and that directly in front of the fence and low to the ground there exists a minimum in wind speed. The indication is that antennas in such a location would have a good chance of enduring the jet-blast environment and providing good service, albeit probably with increased maintenance. Certainly field tests are needed before a final conclusion can be reached. Transverse flow to the fence could also be a problem which would be identified in testing.

In 1987, Ohio University performed an investigation for the Federal Aviation Administration for the purpose of determining how significant the height of the localizer antenna above the immediate ground was, when operating the ILS localizer [2B-6]. The results of that study showed that the height of the LPD antenna above ground was not critical. Heights as low as the elevation of the ground in front of the antennas could be tolerated, albeit at the sacrifice of signal strength. A localizer was operated successfully with antennas 27 inches above ground with no measurable effects on input impedances or monitoring capability. The signal strength is calculated at the required usable distance of 18 nmi to be reduced by 10 dB when the antenna is lowered from its normal 72-inch position to that of 27 inches.

Studies done by Ohio University for the FAA, also in 1987, indicated that large conducting structures could be placed symmetrically behind the localizer antennas without seriously disturbing the localizer [2B-7]. The front-to-back ratio of the LPD antenna is typically 28 dB so there is little coupling of energy into conductors to the rear of the antennas. The findings of relative immunity from height above ground and from any conducting members immediately to the rear of the antennas allows for mounting antennas immediately in front of the blast fence. See ICAO Standards [2B-8] for additional support for mounting within 10 feet (3 meters).

The technical risk in using the counterpoise approach is minimal. This is in part due to the experience at Fort Worth Alliance where a large counterpoise was built to cover 4 lanes of traffic that would have otherwise affected the localizer array performance. [2B-9] Because it is important to minimize the longitudinal extent (in the direction of the runway centerline) of a counterpoise, calculations were performed to ascertain what could be expected when the counterpoise is shortened [2B-9].

The two functions of the counterpoise are to provide shielding of the vehicular traffic from the localizer signals and to provide a fixed, stable ground plane. If the counterpoise is extended and the antennas moved east to reduce jet blast, it eventually would cover the Metro Green Line, then the Santa Fe and ultimately Aviation Boulevard. There are many undesirable aspects to doing this, not the least of which is expense. Consequently, there is considerable motive to find an optimum considering three tradeoff factors. These are: 1) staying west sufficiently to avoid covering the rail lines, 2) remaining far enough east to minimize structural requirements to resist jet blast, and 3) providing enough horizontal, longitudinal conducting surface so that the antennas will perform properly.

Mathematical modeling was performed to determine what would be the length (L) of the counterpoise that would allow the antennas to perform properly, and what would the effect be of lowering the antennas to a 3-foot height above the counterpoise. The references taken were antennas mounted 25 feet above the ground, such as the case presently with Runway 07L localizer, and antennas that were located at a standard height of 6 feet above the ground used commonly by the FAA. The first modeling was performed with an L equal to 50 feet to give indications of the respective distributions of radio frequency energy in the vertical plane, at the upper and lower edges of the mandated service volume, and finally on the 3-degree glide slope where the user is expected to fly. The height of the counterpoise was made to be 16 feet to allow the antenna on top to be below the 50:1 clear zone.

The baseline for comparison used an infinite ground with a conductivity of 0.008 Mho/meter and a relative dielectric constant of 8. These are believed to be reasonably representative of the ground at Los Angeles; however, it is not critical for the localizer.

The finding is that the performance of the antenna with the counterpoise is no less than 3 dB below the signal from the reference antenna (6 feet above ground), which the FAA consistently finds, at numerous sites in the United States, to have considerable margin of signal strength. The conclusion reached is that the antennas 3 feet above a counterpoise which is 16 feet above the ground will operate satisfactorily in all respects. Figures 2-9 through 2-12 show the results of these calculations.

Calculations, with antennas 3 feet above a counterpoise of lengths ranging from 50 to 15 feet in the direction parallel to the runway centerline, were made and compared with a baseline antenna height of 6 feet above the specified earth, to show that the performance of the antenna with the counterpoise falls no less than 2.5 dB below the baseline configuration for the top of the service volume. The calculations for the on-glide slope location and the bottom of the service volume show superior performance for all of the counterpoise lengths. In general, at any elevation angle below 5 degrees counterpoise with lengths less than 50 feet give better performance than the antennas over the earth. Calculations show that the shorter the counterpoise the better the performance obtained. In some respects this seems counter-intuitive; however, proper consideration must be given to the concept that with the vanishingly short counterpoise, an elevated VHF antenna is produced. These typically radiate greater amounts of energy at low elevation angles as their height is increased. From all indications, the performance of the localizer even with a short (10-foot) counterpoise would be satisfactory.

Given these data and the data generated by AeroVironment (see again Figure 2-6), the localizer antennas could be mounted on a counterpoise east of the blast fence and extend approximately 10 feet to the east with the antennas mounted 3 feet above the counterpoise. This places the antennas approximately 200 feet from the MD-11 type tail mounted engine and in a turbulent wake region where the velocities appear to be reasonable.

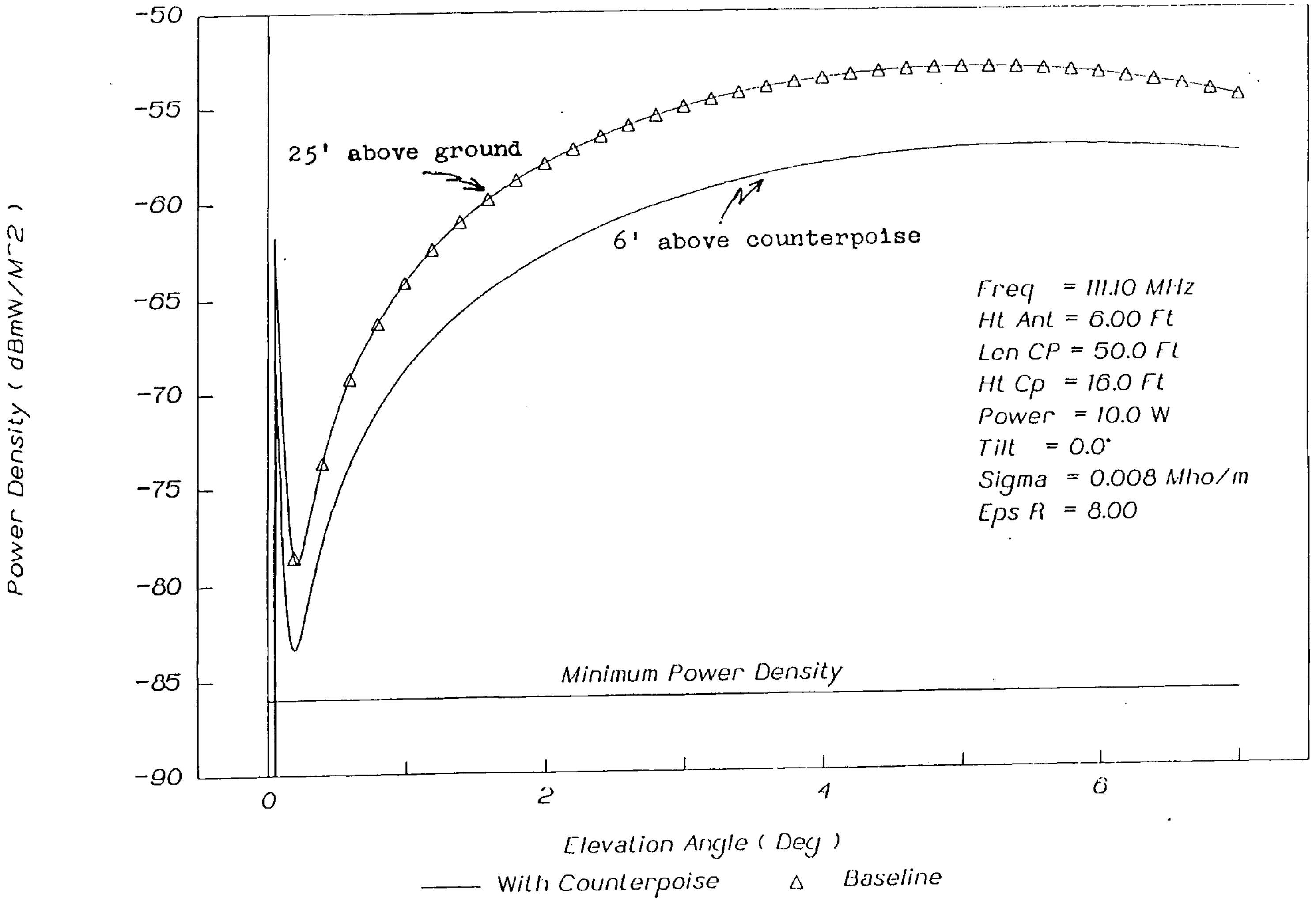


Figure 2-9A. Comparison of Calculated Signal Levels for the Antennas 6 Feet Above the Counterpoise and for those 25 Feet Above Ground as at Los Angeles. LAX - Vertical Pattern.

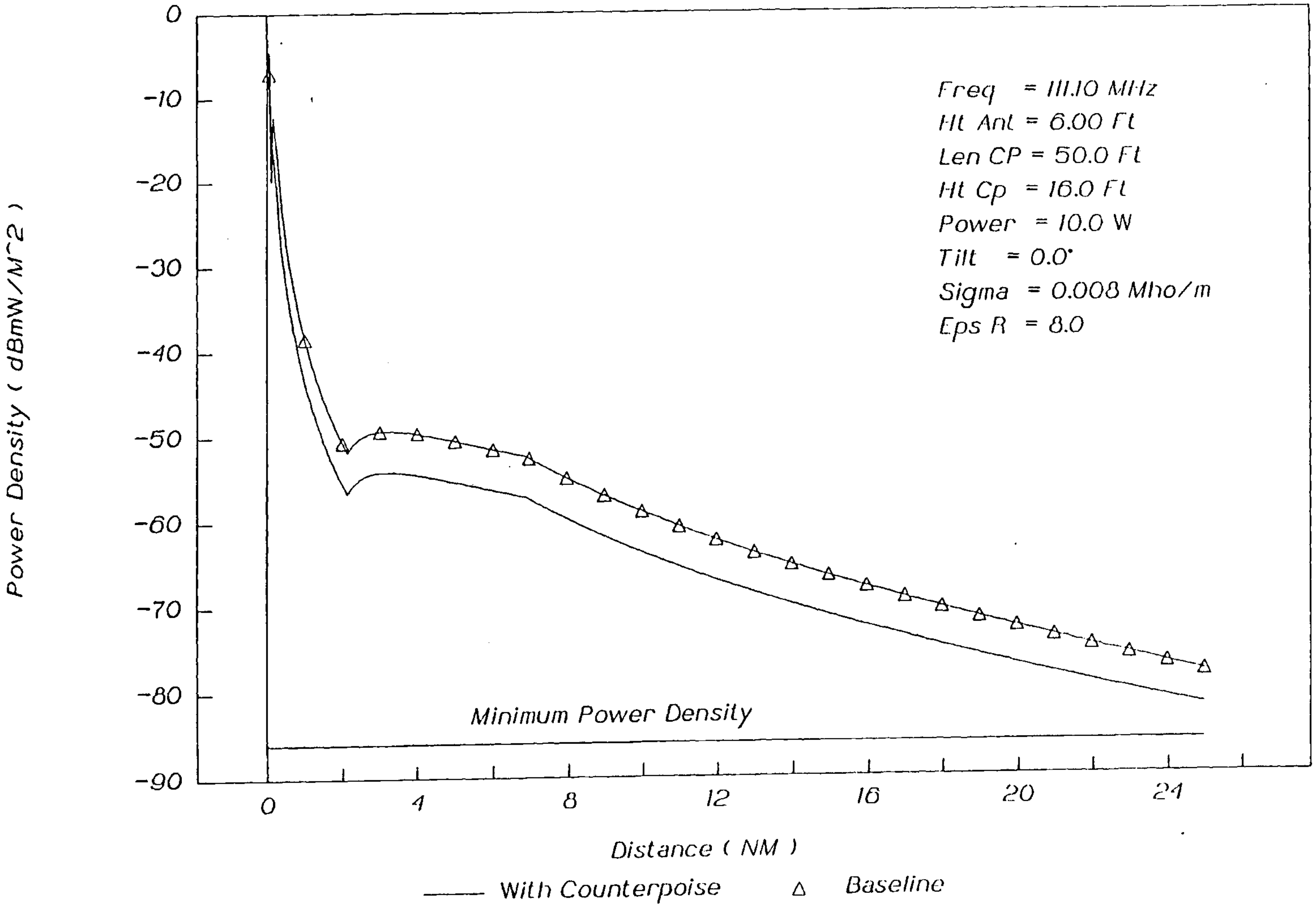


Figure 2-9B. Comparison of Calculated Signal Levels for the Antennas 6 Feet Above the Counterpoise and for those 25 Feet Above Ground as at Los Angeles. LAX - Bottom of Service Volume.

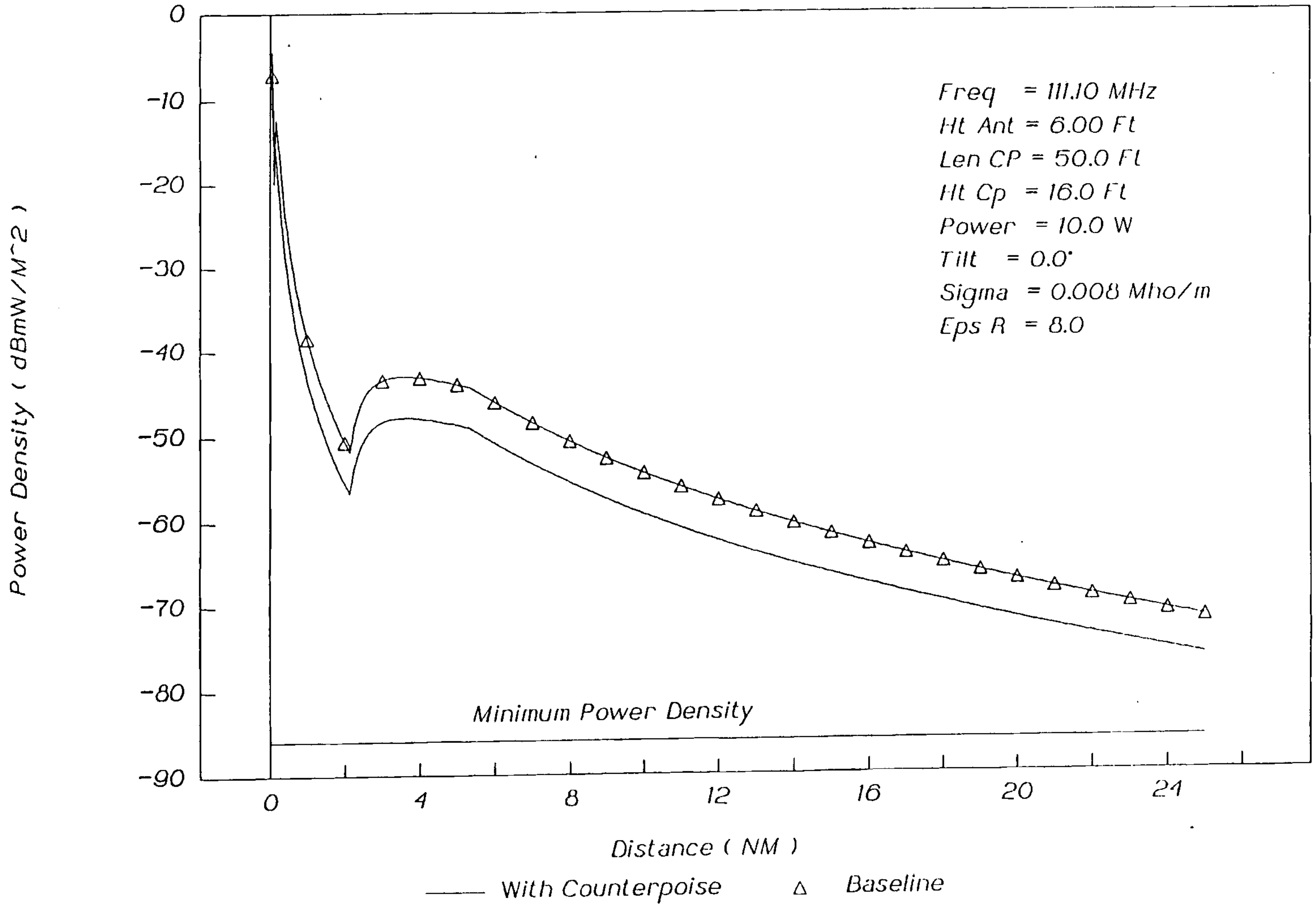


Figure 2-9C. Comparison of Calculated Signal Levels for the Antennas 6 Feet Above the Counterpoise and for those 25 Feet Above Ground as at Los Angeles. LAX - On Glide Path.

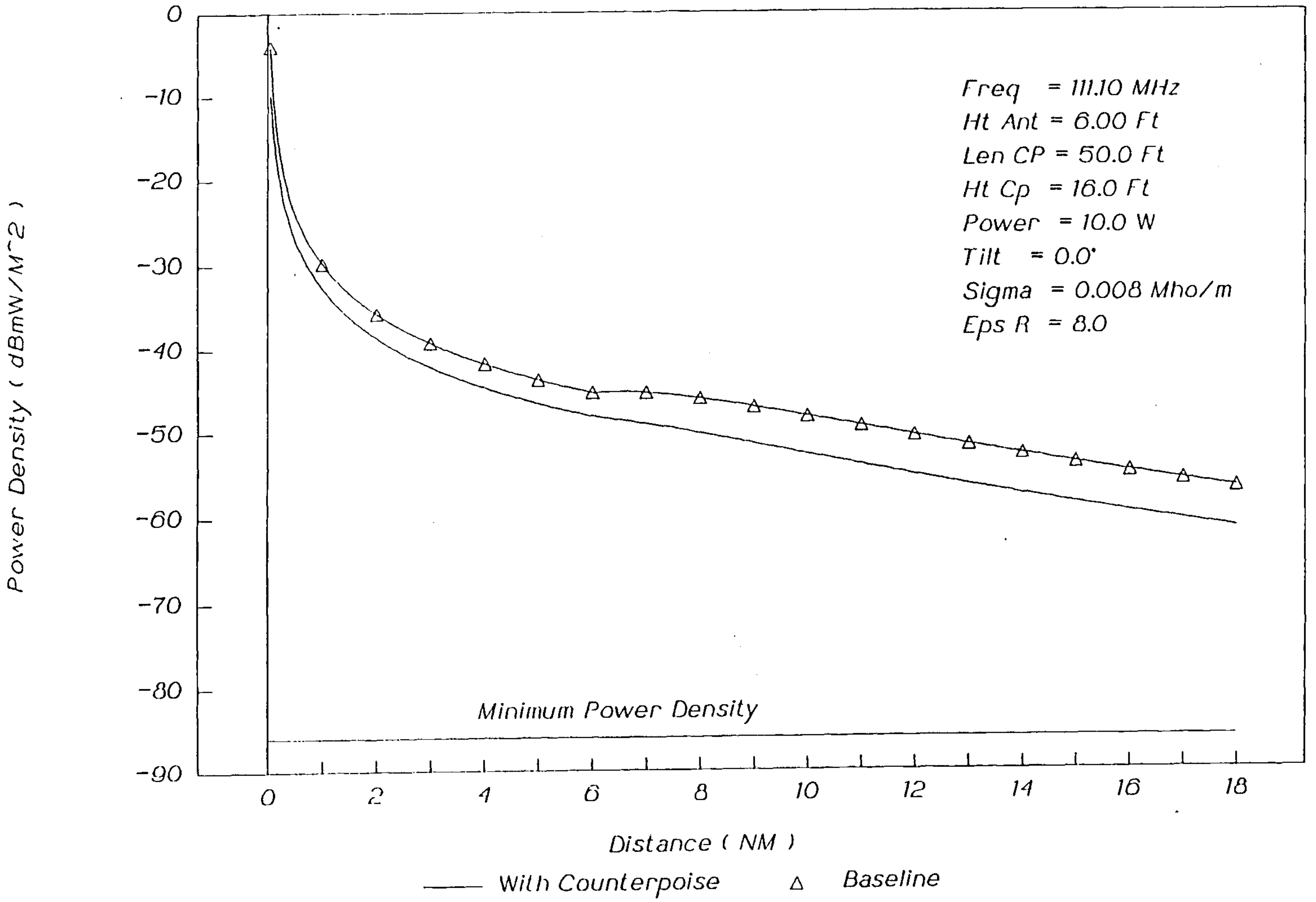


Figure 2-9D. Comparison of Calculated Signal Levels for the Antennas 6 Feet Above the Counterpoise and for those 25 Feet Above Ground as at Los Angeles. LAX - Top Normal Service Volume.

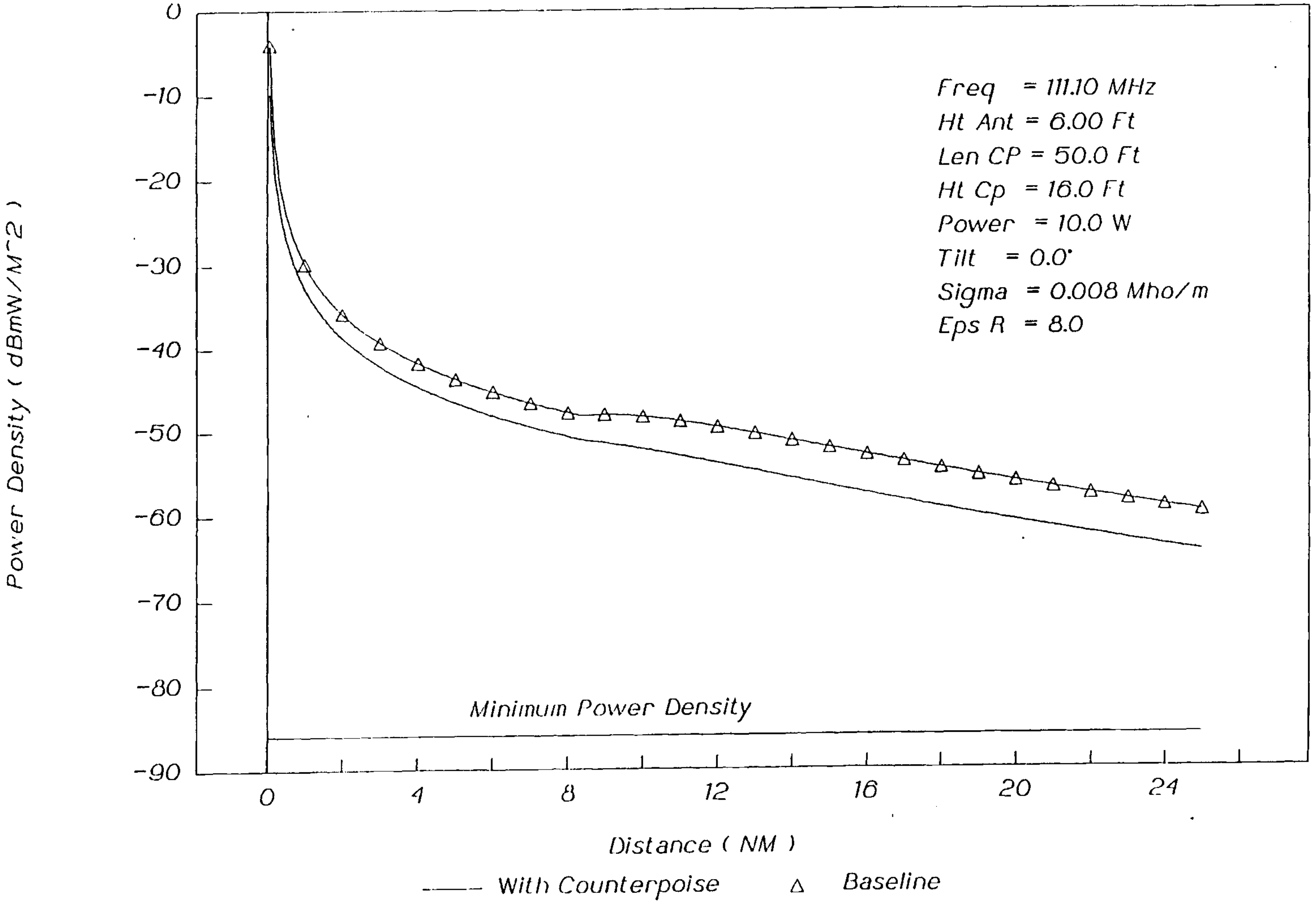


Figure 2-9E. Comparison of Calculated Signal Levels for the Antennas 6 Feet Above the Counterpoise and for those 25 Feet Above Ground as at Los Angeles. LAX - Top Extended Service Volume.

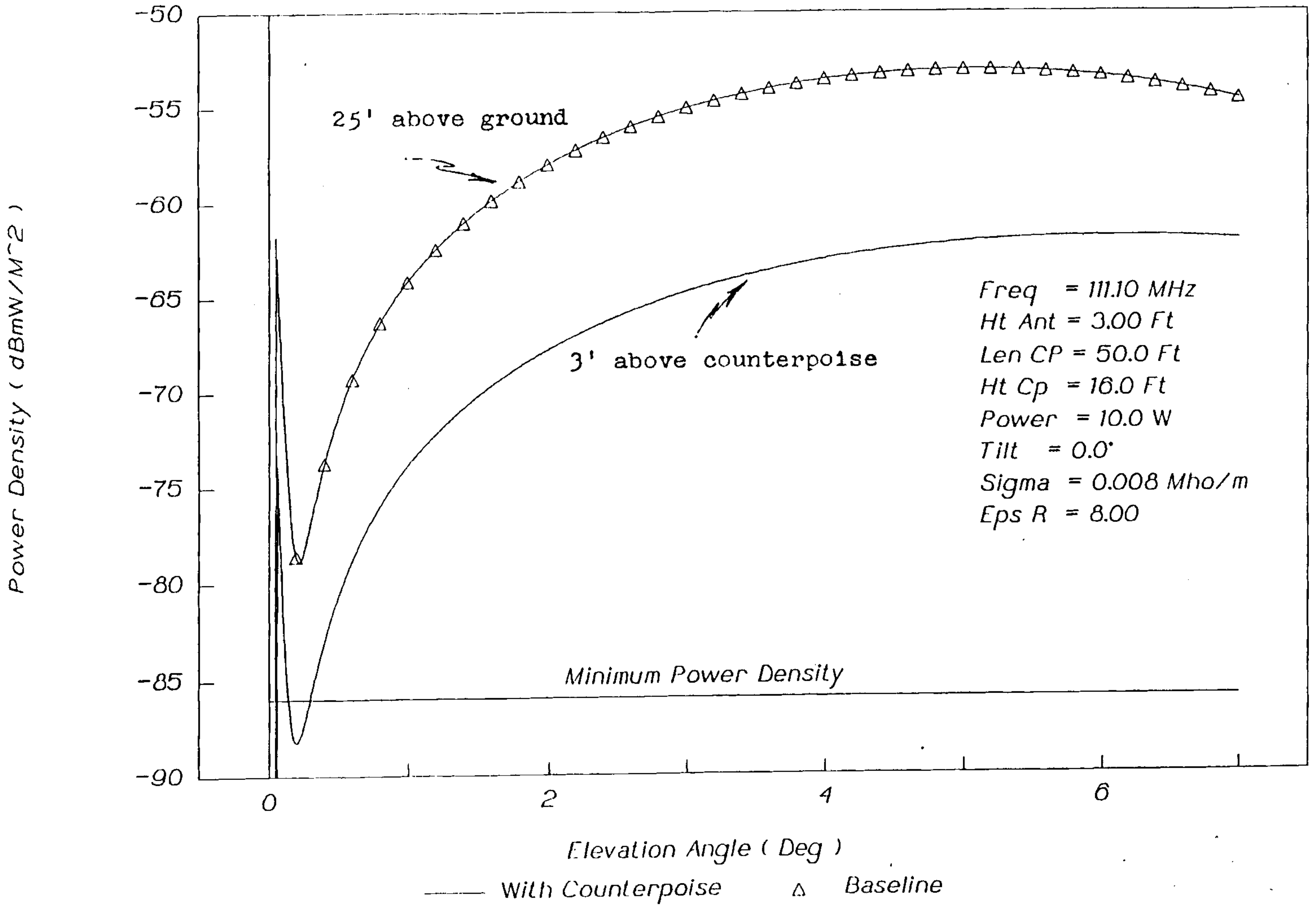


Figure 2-10A. Comparison of Calculated Signal Levels for the Antennas 3 Feet Above the Counterpoise and for those 25 Feet Above Ground as at Los Angeles. LAX - Vertical Pattern.

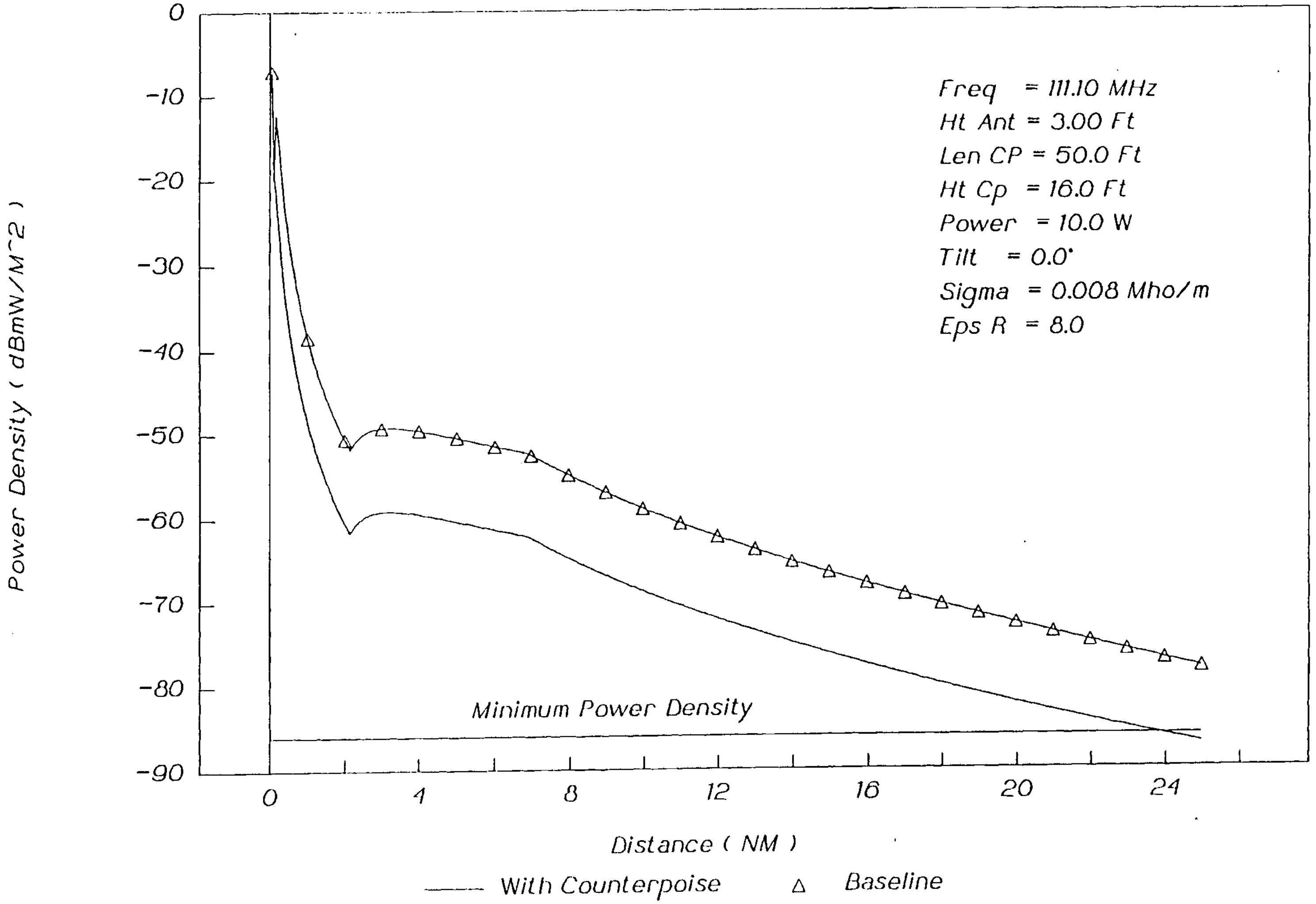


Figure 2-10B. Comparison of Calculated Signal Levels for the Antennas 3 Feet Above the Counterpoise and for those 25 Feet Above Ground as at Los Angeles. LAX - Bottom Service Volume.

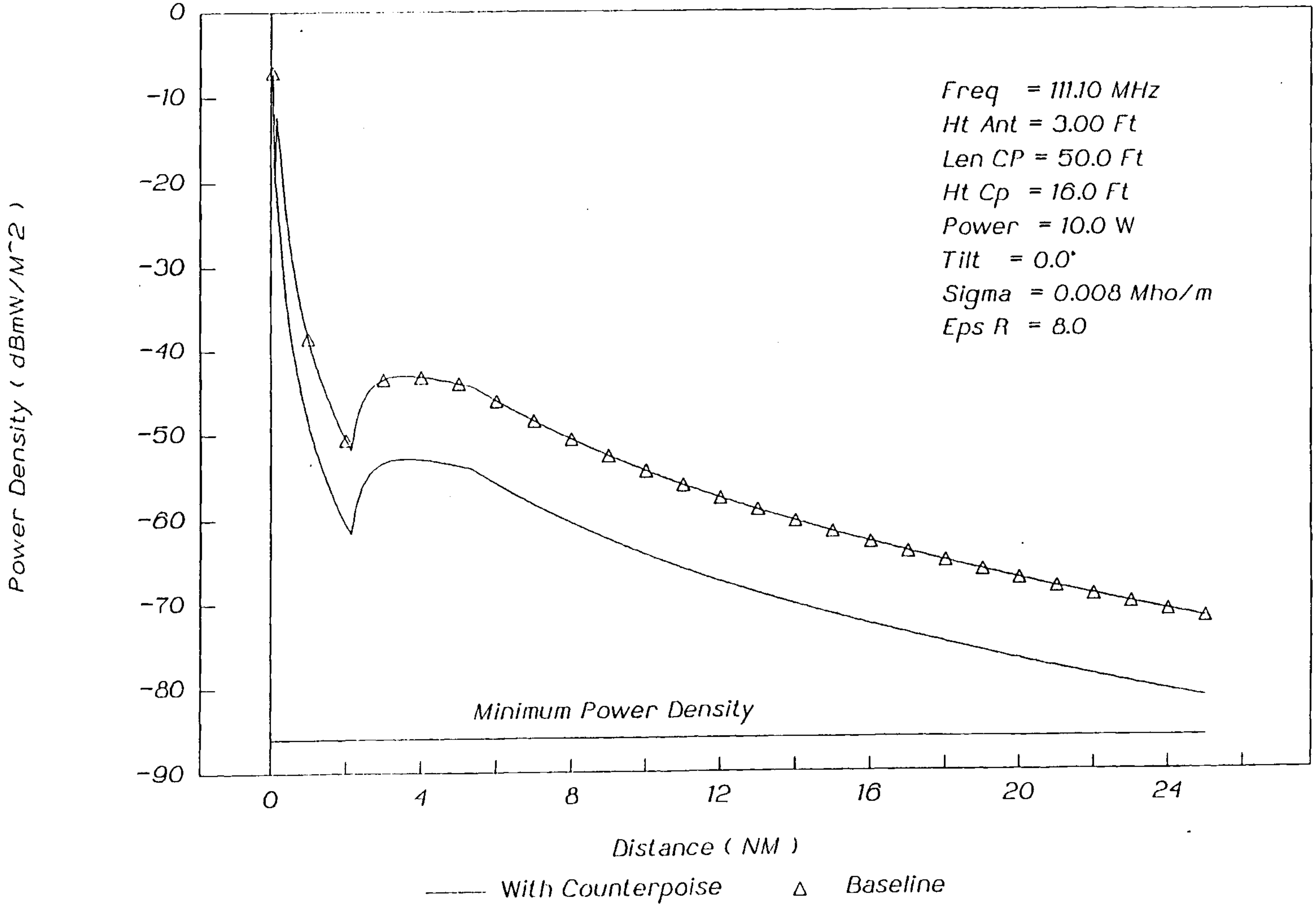


Figure 2-10C. Comparison of Calculated Signal Levels for the Antennas 3 Feet Above the Counterpoise and for those 25 Feet Above Ground as at Los Angeles. LAX - On Glide Path.

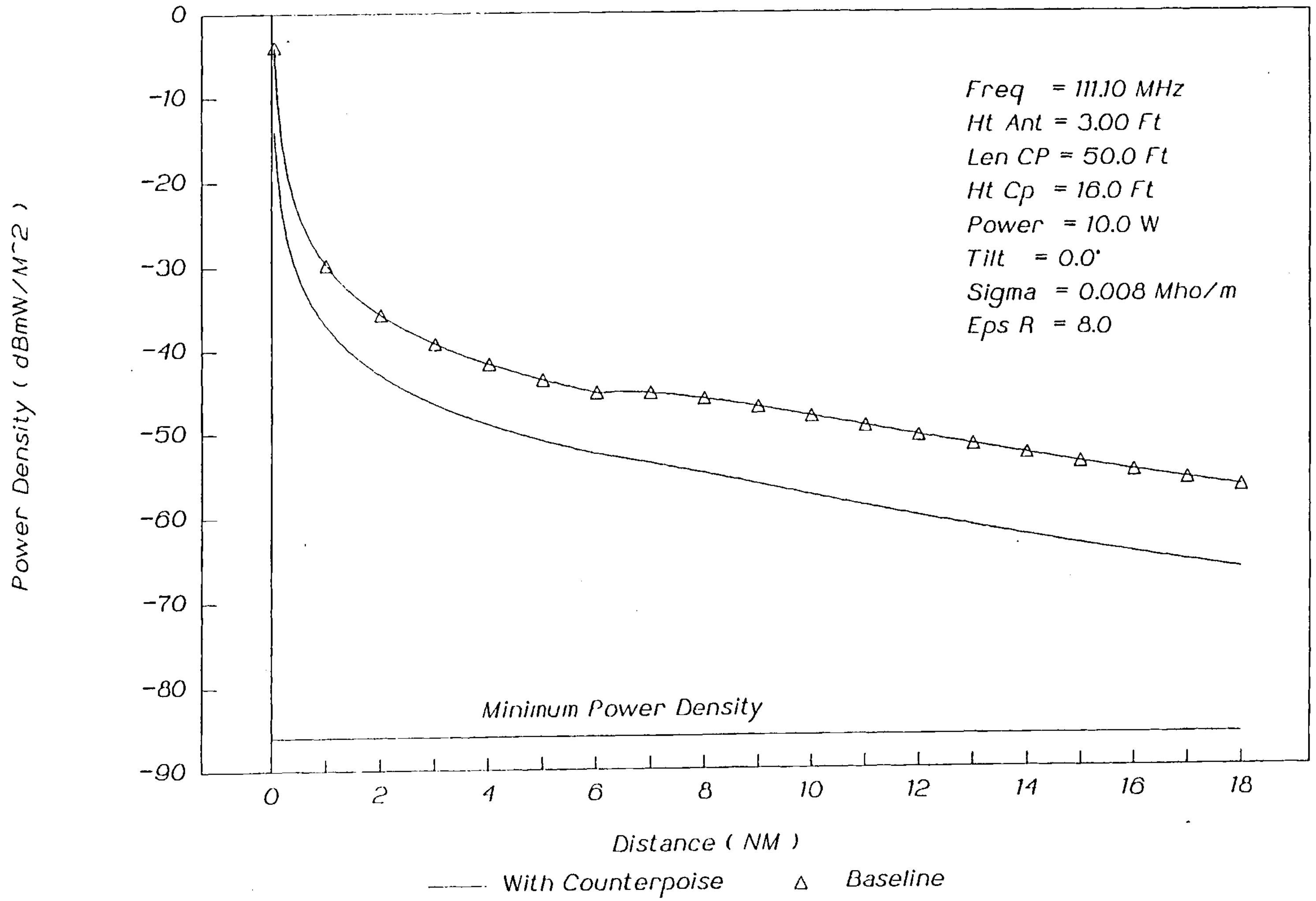


Figure 2-10D. Comparison of Calculated Signal Levels for the Antennas 3 Feet Above the Counterpoise and for those 25 Feet Above Ground as at Los Angeles. LAX - Top Normal Service Volume.

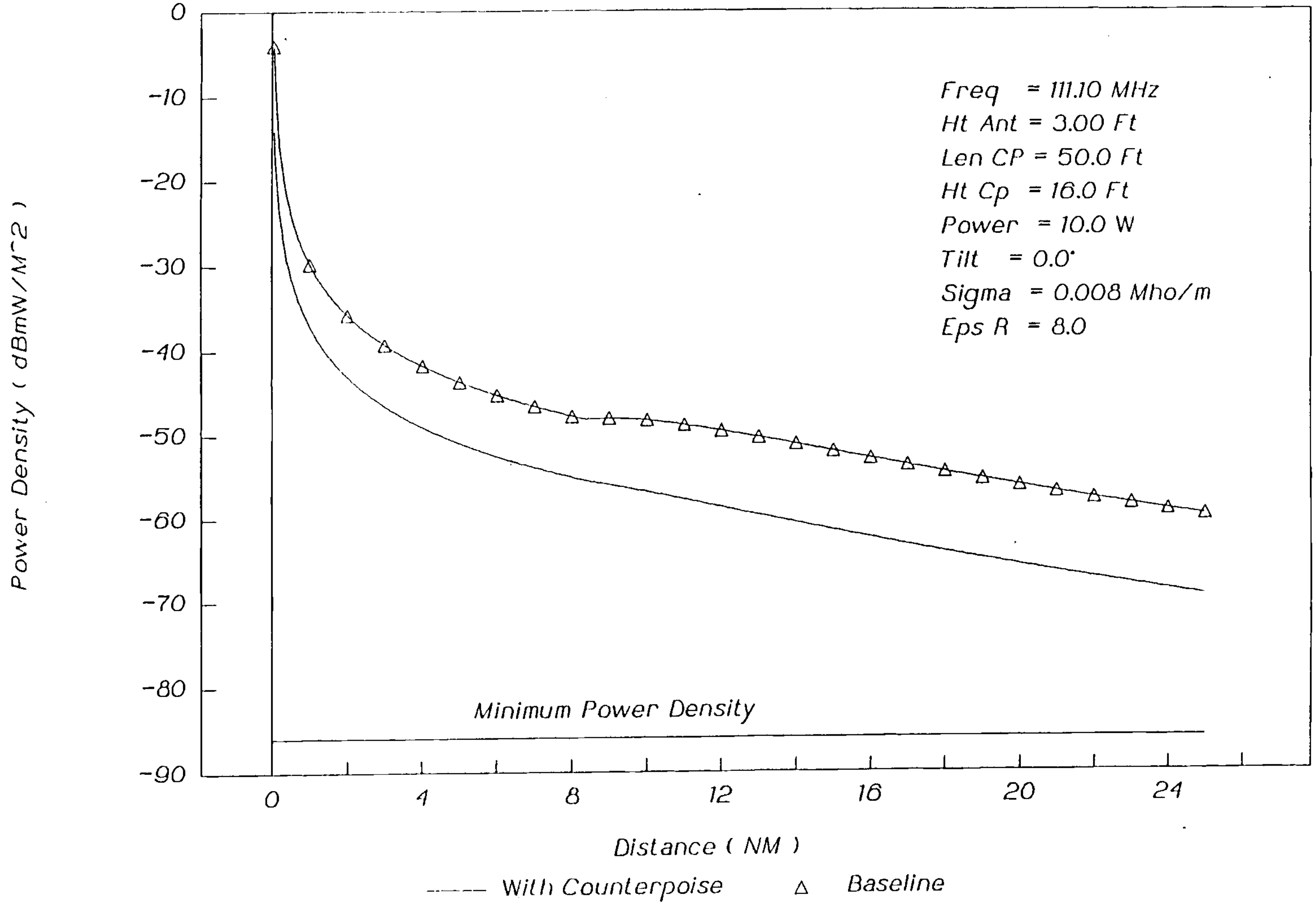


Figure 2-10E. Comparison of Calculated Signal Levels for the Antennas 3 Feet Above the Counterpoise and for those 25 Feet Above Ground as at Los Angeles. LAX - Top Extended Service Volume.

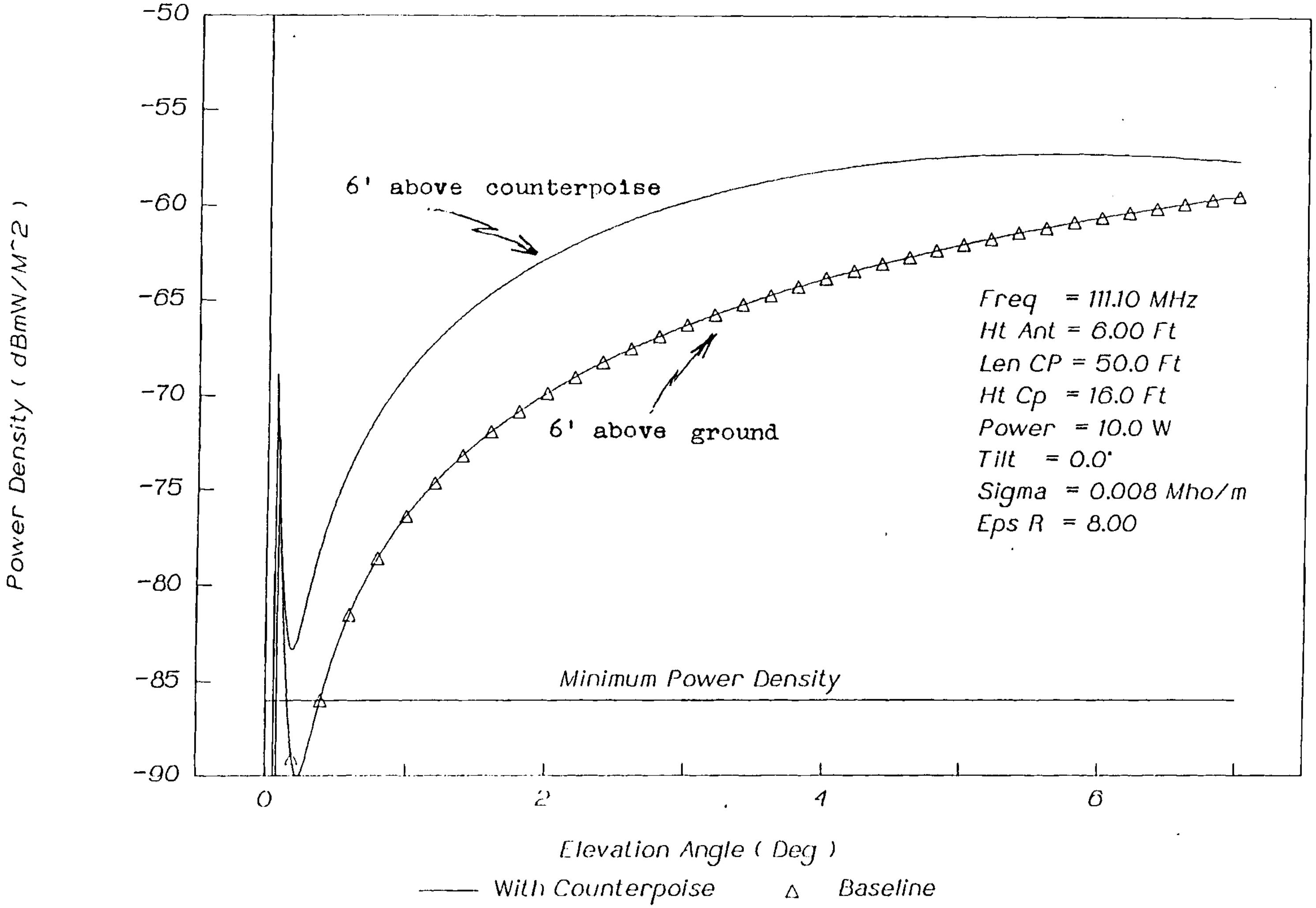


Figure 2-11A. Comparison of Calculated Signal Levels for the Antennas 6 Feet Above the Counterpoise and for those 6 Feet Above the Ground as is Typical for Localizers. LAX - Vertical Pattern.

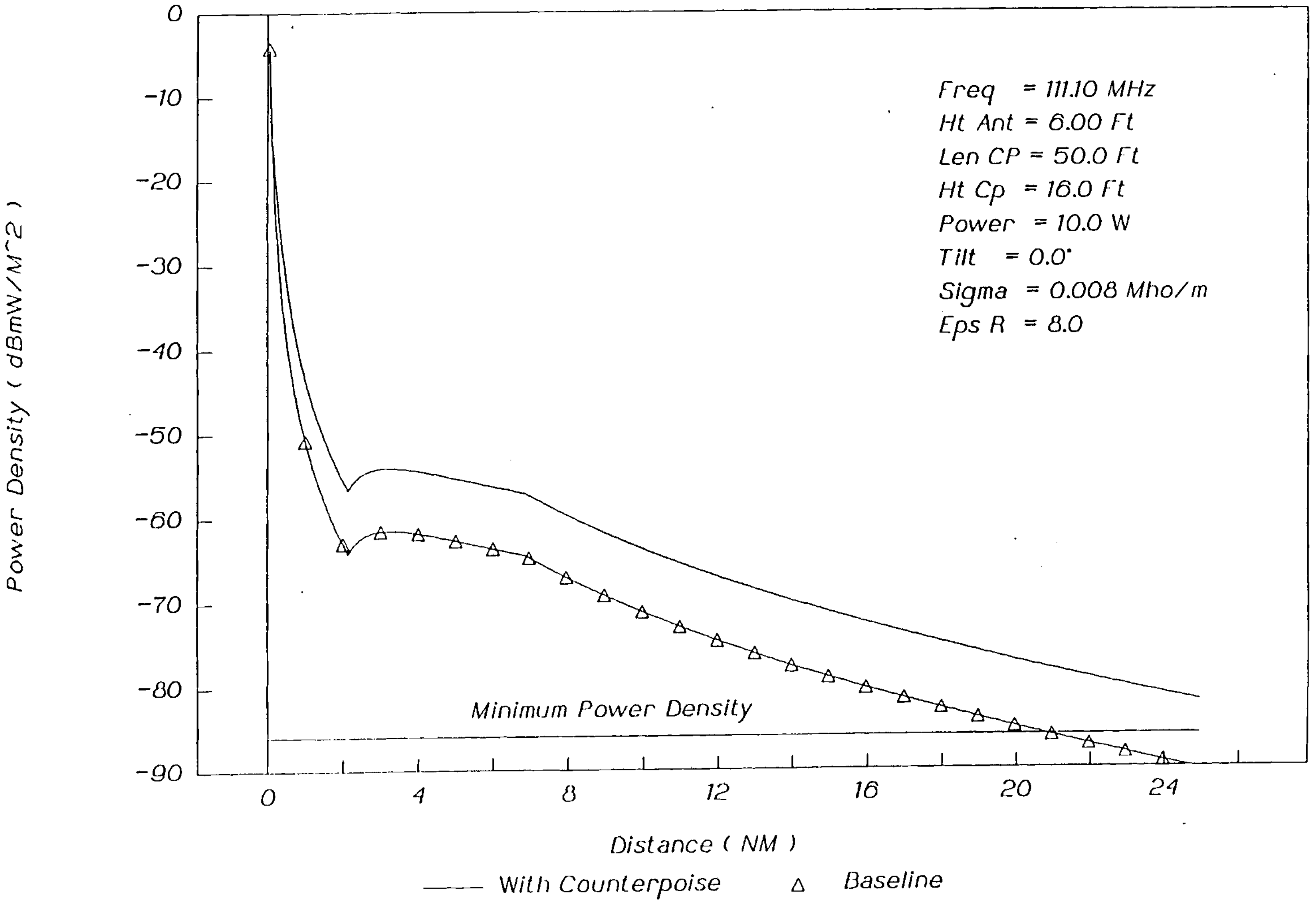


Figure 2-11B. Comparison of Calculated Signal Levels for the Antennas 6 Feet Above the Counterpoise and for those 6 Feet Above the Ground as is Typical for Localizers. LAX - Bottom Service Volume.

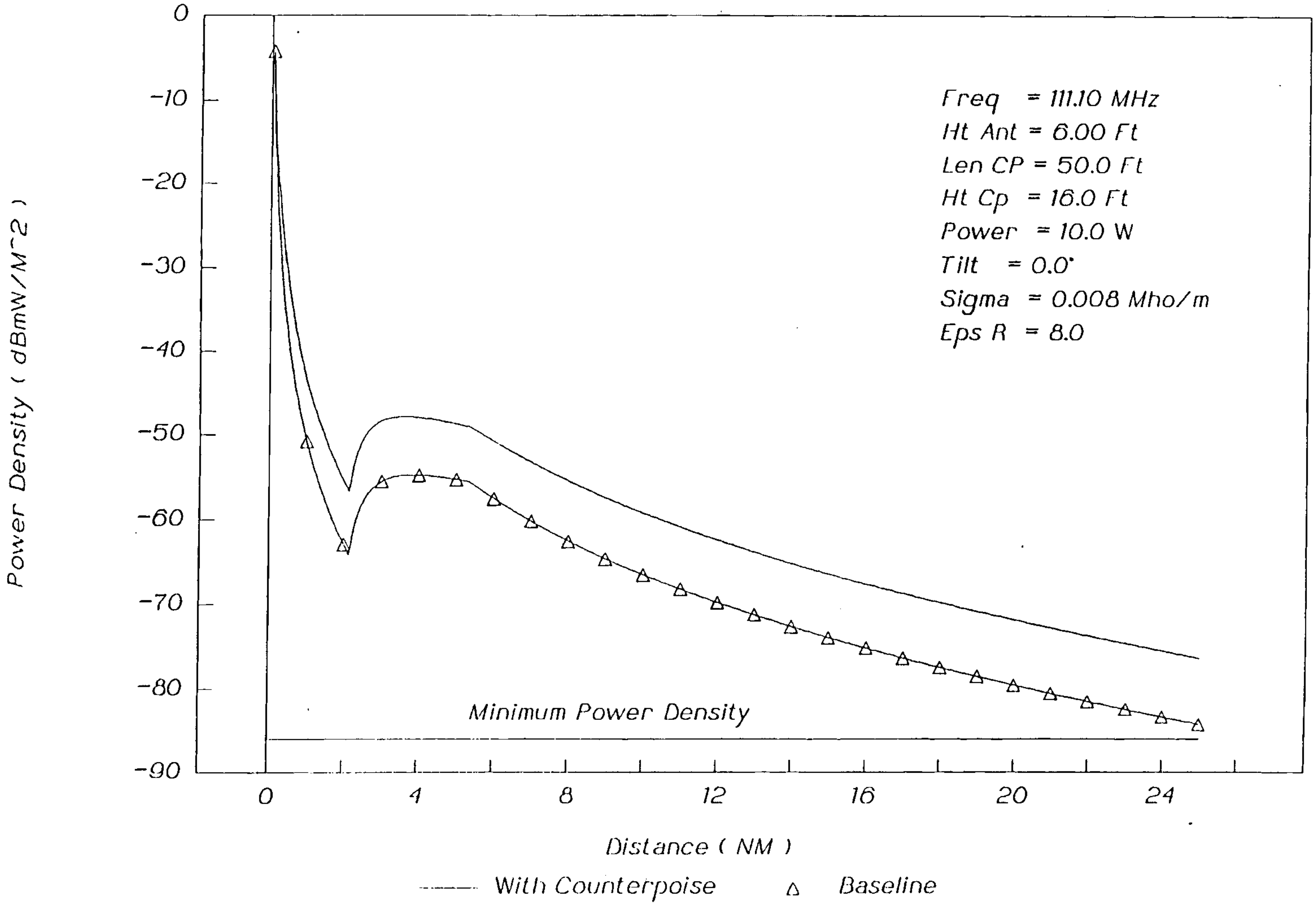


Figure 2-11C. Comparison of Calculated Signal Levels for the Antennas 6 Feet Above the Counterpoise and for those 6 Feet Above the Ground as is Typical for Localizers. LAX - On Glide Path.

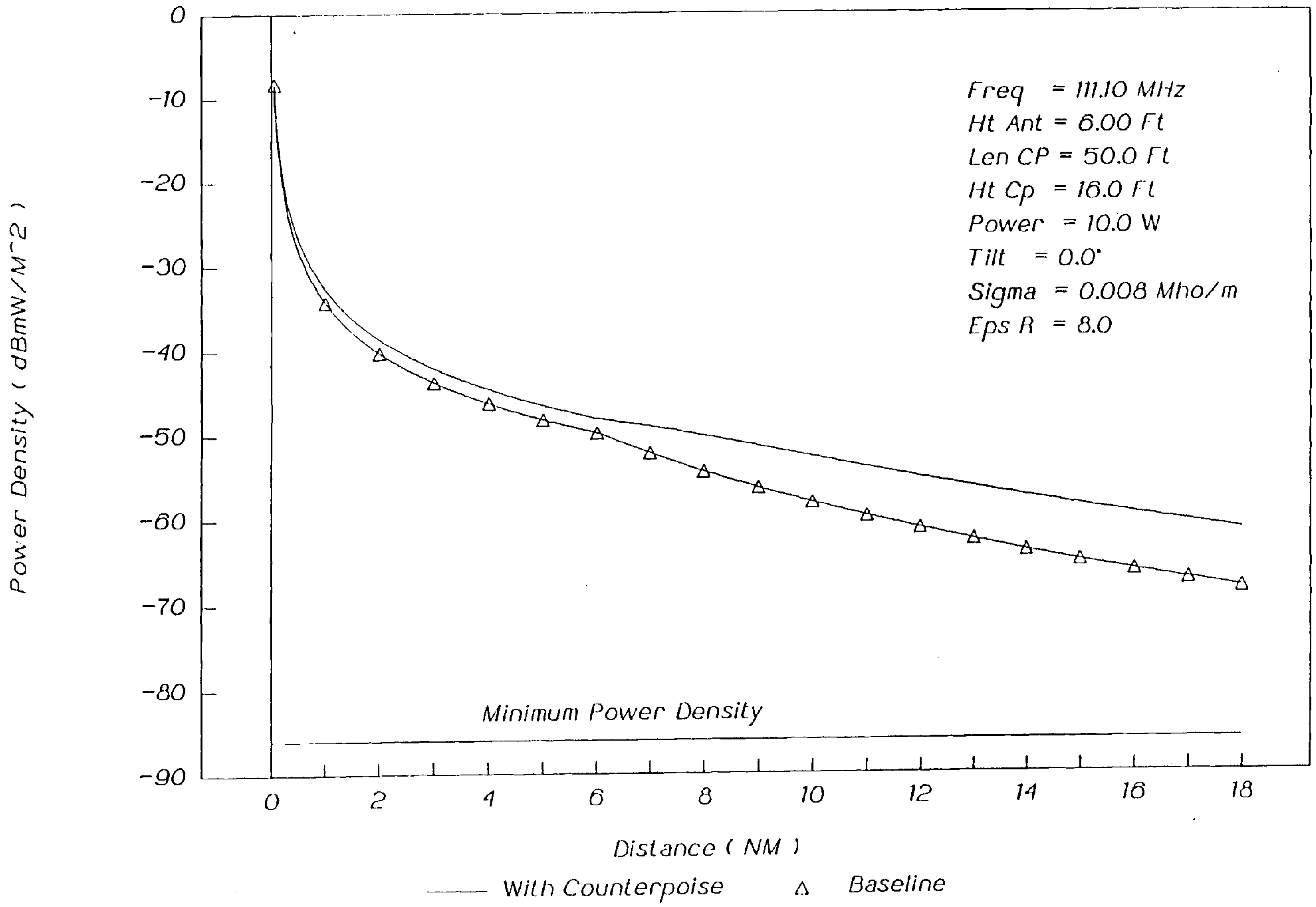


Figure 2-11D. Comparison of Calculated Signal Levels for the Antennas 6 Feet Above the Counterpoise and for those 6 Feet Above the Ground as is Typical for Localizers. LAX - Top Normal Service Volume.

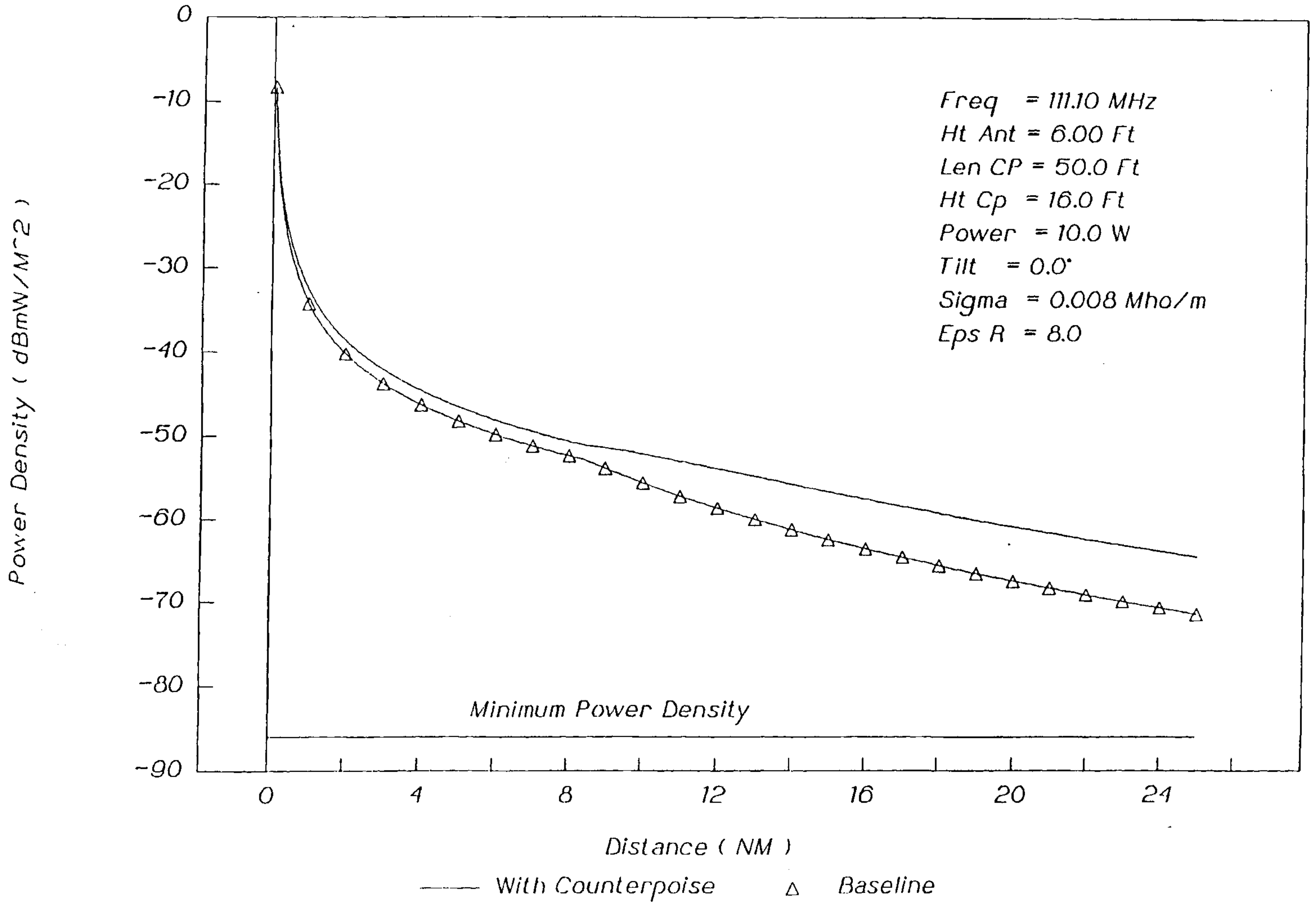


Figure 2-11E. Comparison of Calculated Signal Levels for the Antennas 6 Feet Above the Counterpoise and for those 6 Feet Above the Ground as is Typical for Localizers. LAX - Top Extended Service Volume.

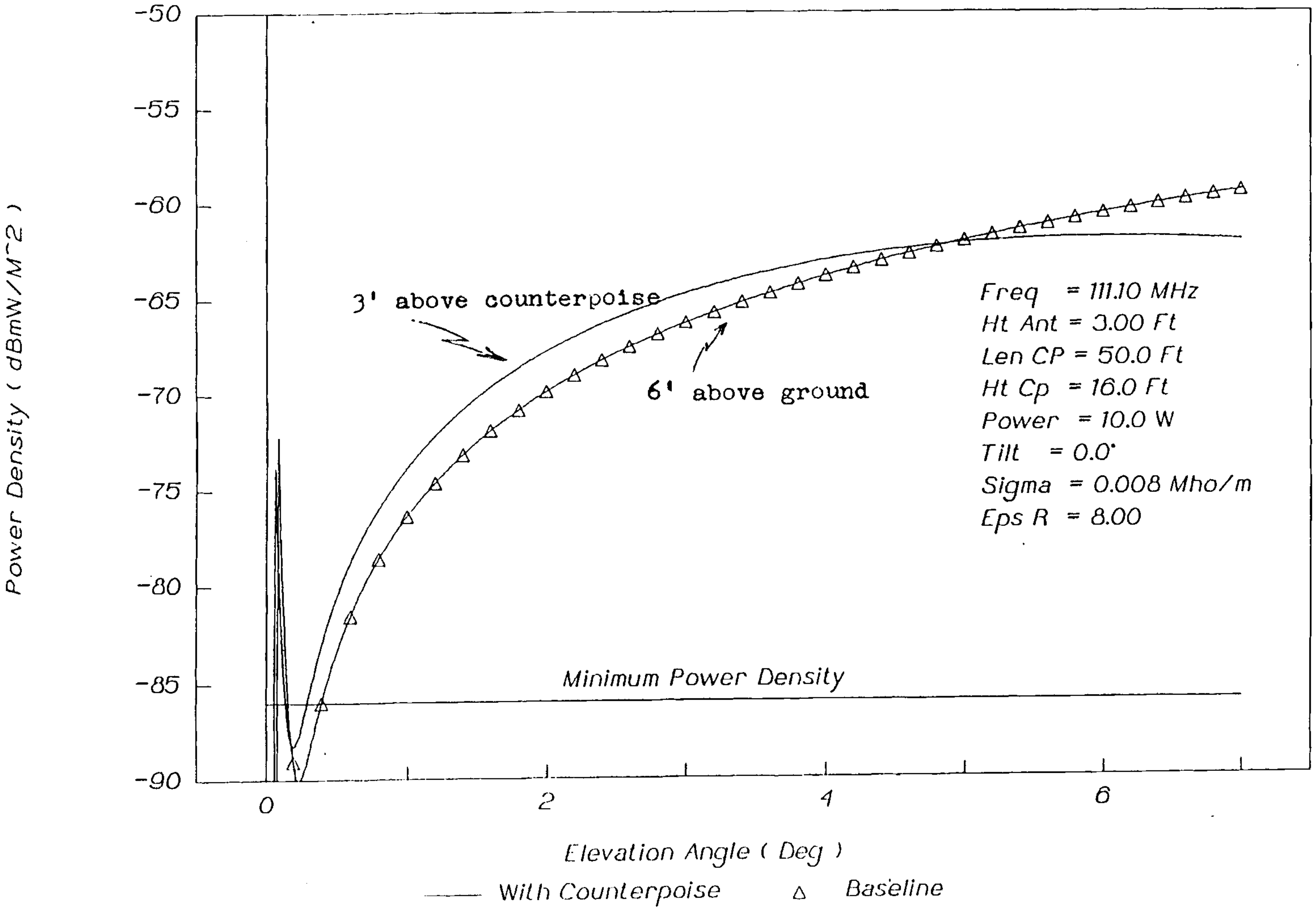


Figure 2-12A. Comparison of Calculated Signal Levels for the Antennas 3 Feet Above the Counterpoise and for those 6 Feet Above the Ground as is Typical for Localizers. LAX - Vertical Pattern.

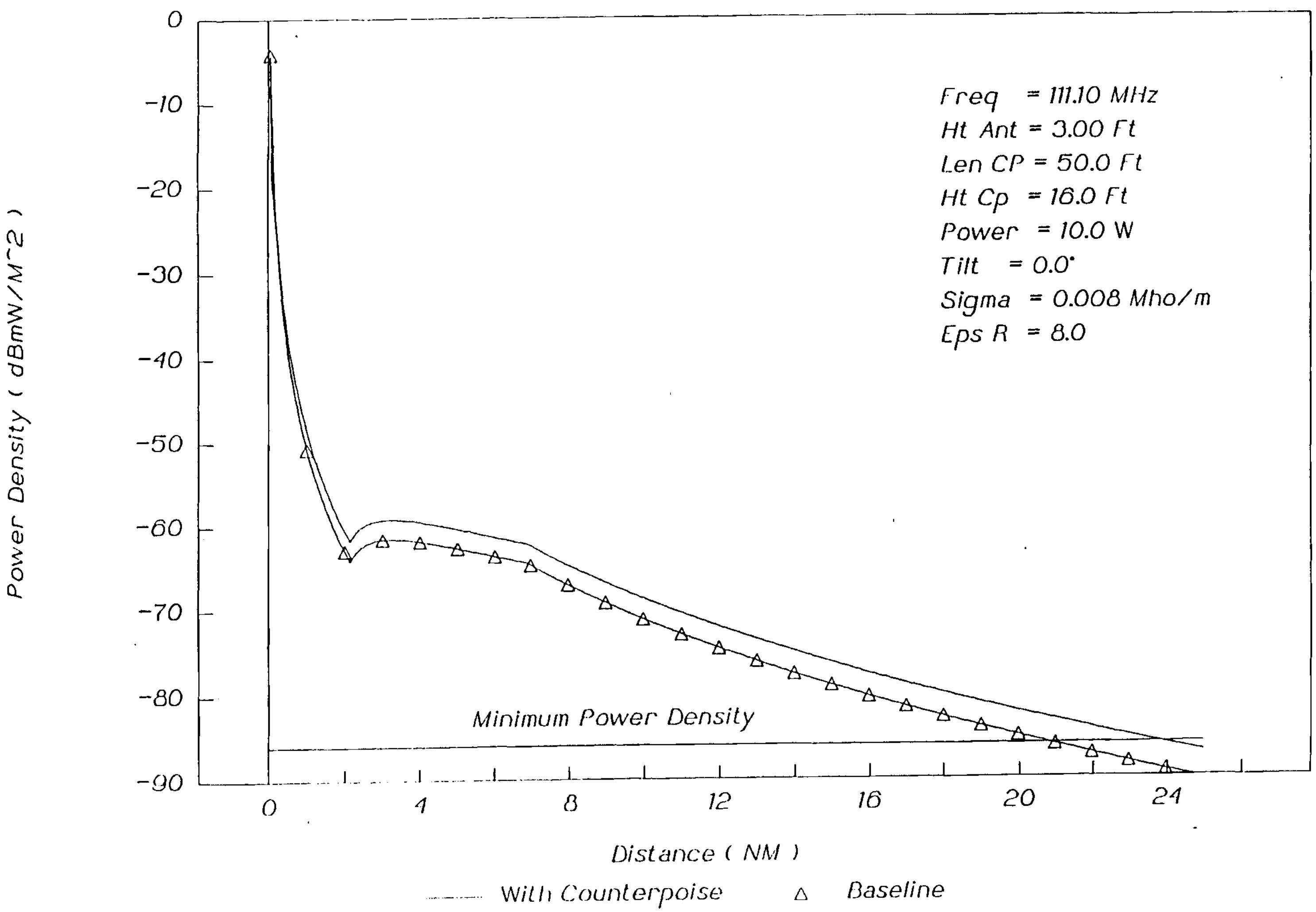


Figure 2-12B. Comparison of Calculated Signal Levels for the Antennas 3 Feet Above the Counterpoise and for those 6 Feet Above the Ground as is Typical for Localizers. LAX - Bottom Service Volume.

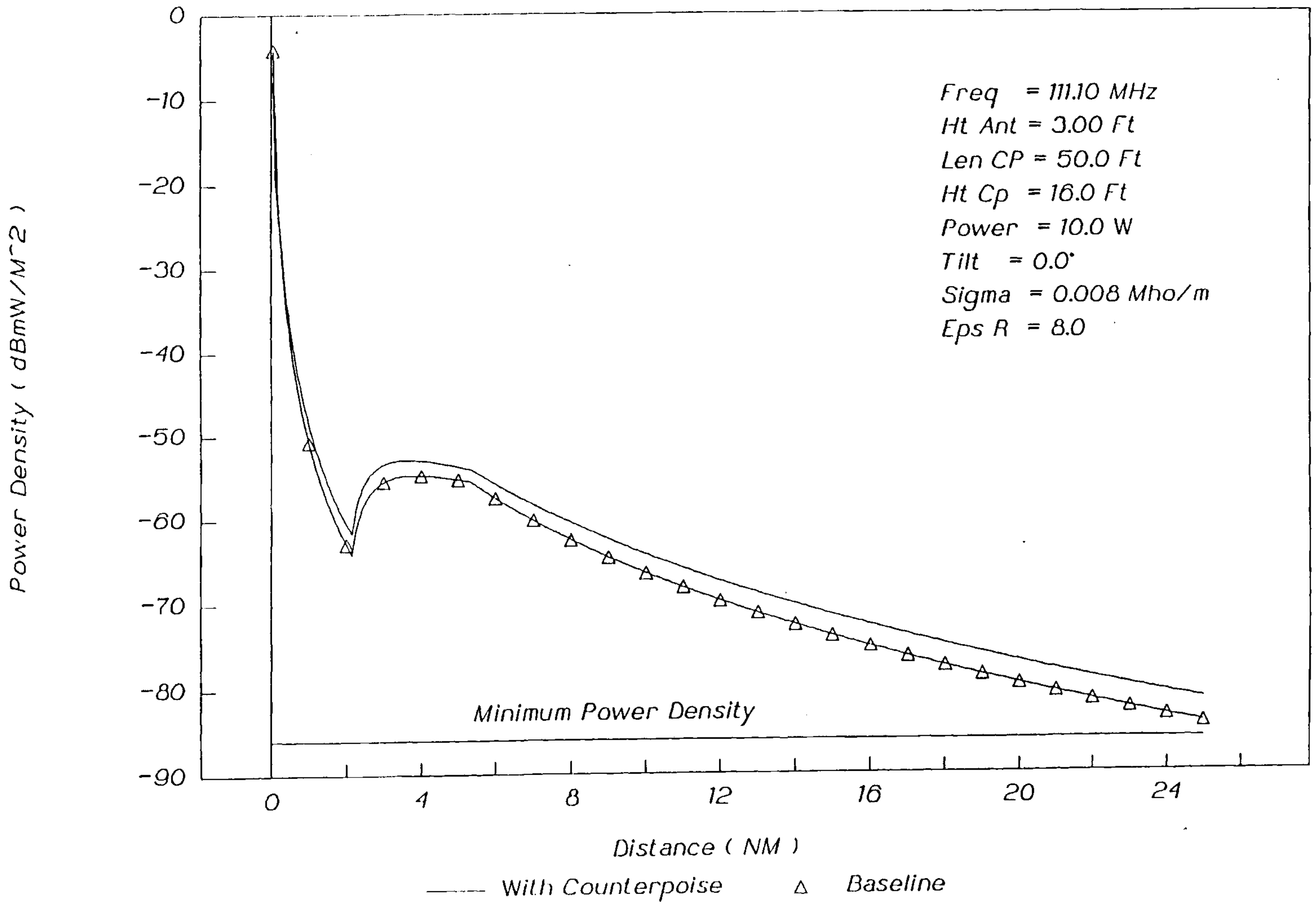


Figure 2-12C. Comparison of Calculated Signal Levels for the Antennas 3 Feet Above the Counterpoise and for those 6 Feet Above the Ground as is Typical for Localizers. LAX - On Glide Path.

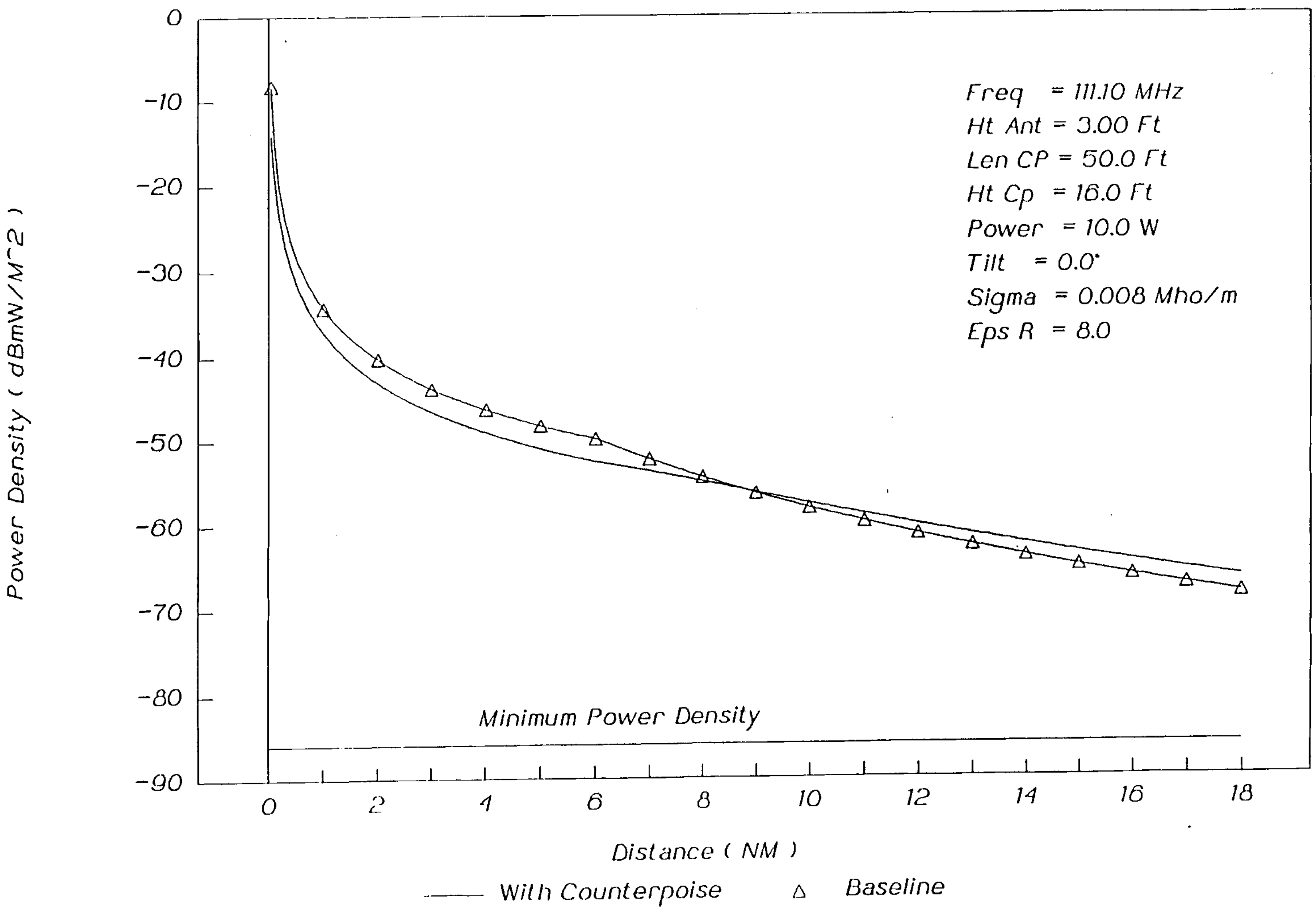


Figure 2-12D. Comparison of Calculated Signal Levels for the Antennas 3 Feet Above the Counterpoise and for those 6 Feet Above the Ground as is Typical for Localizers. LAX - Top Normal Service Volume.

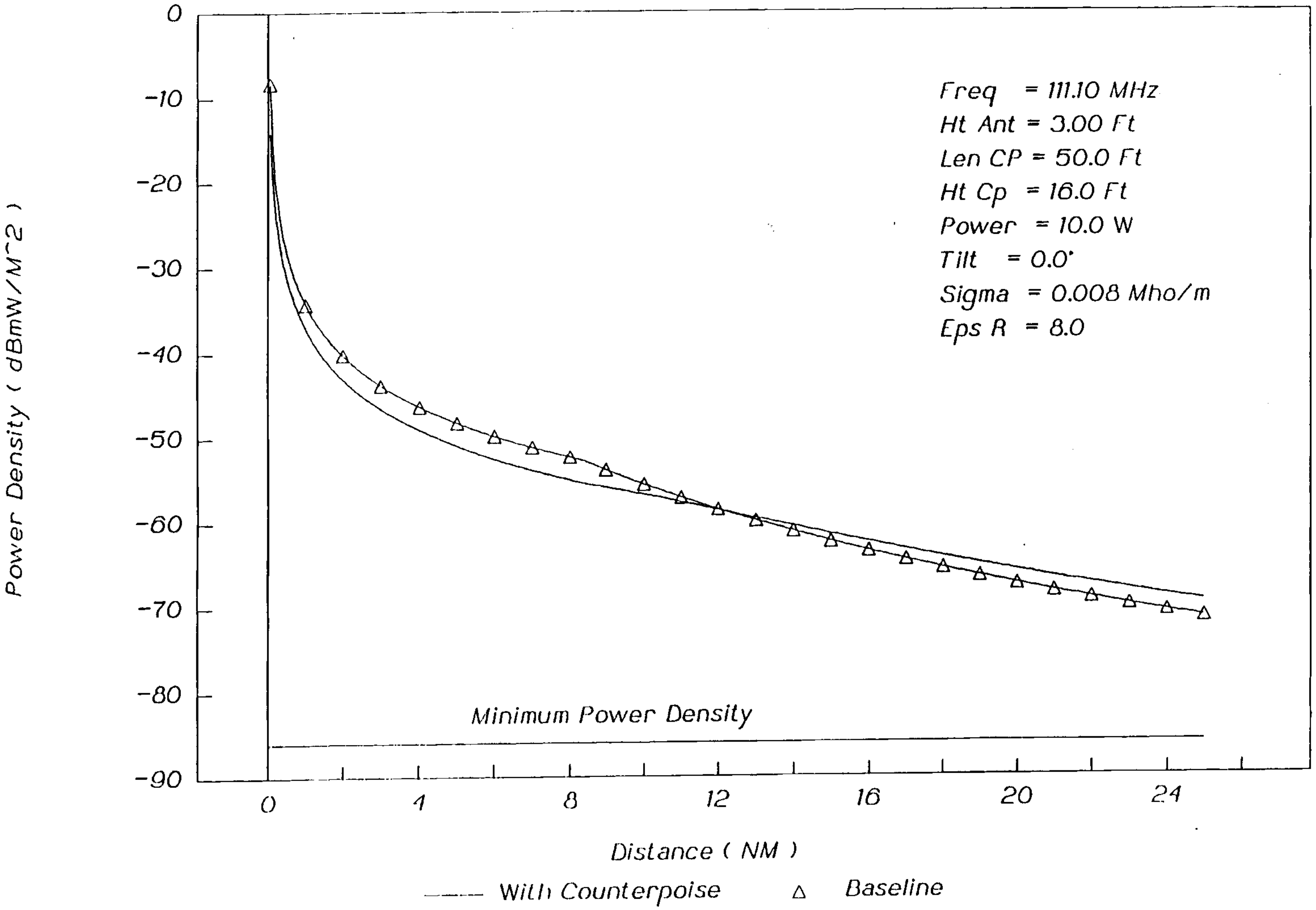


Figure 2-12E. Comparison of Calculated Signal Levels for the Antennas 3 Feet Above the Counterpoise and for those 6 Feet Above the Ground as is Typical for Localizers. LAX - Top Extended Service Volume.

Some experiential data have been obtained from observing effects of LPD arrays that are located close to the end of runways that accommodate jet traffic. Two particular examples are cited. In July 1991, a Boeing 727 ran up to its full takeoff power and held in position on Runway 12 at the Long Beach Airport. The result was that the system went into alarm and there was difficulty restoring the system.

The antennas were sprung out of their ordinary vertical position and the runway-facing surfaces of all portions of the antenna and distribution system were effectively sandblasted clean of paint due to the loose gravel area between the array and the threshold 300 feet away. The problem that was eventually identified was that of a latent defect in one of the cables that emerged when the strong winds were incident on the distribution unit housing.

The case of Runway 30L at San Jose, California, is further evidence that the LPD antenna is capable of withstanding considerable jet blast, perhaps as much as 150 knots according to AeroVironment data. Here, also, a gravel area exists in the 315 feet of real estate separating the runway threshold from the LPD antennas. The antenna surfaces after several years of operation are well scoured of paint. There appears to be no significant or substantial damage. This is quite remarkable because the speed contours presented by AeroVironment indicates that 160 knots exists at the antenna height of 6 feet.

Calculations have been made that indicate there is a factor of 15 separating the velocity value that will cause the LPD antenna to break, due to its design for frangibility, and a goal to withstand 200 knots of wind. This conclusion is based on a specimen cross-section shown in Figure 2-13 that an antenna can be designed to meet the requirements. The following gives the basis of this conclusion.

The T-section radar unit in Figure 2-14 is to withstand an air-blast of 200 knots yet break-away or fail in the event of a plane collision - approximately 6750 pounds. The force components exerted on the unit by the moving fluid (air @ 200 knots) are calculated, given the general equation:

$$F = C_d A \rho \frac{V^2}{2}$$

where F is the drag force in pounds, C_d is the coefficient of drag, A is the projection of the cross-sectional area in square feet normal to the direction of the fluid velocity, ρ is the density of the fluid in slugs per cubic foot, while V is the velocity of the fluid relative to the body in feet per second.

The coefficients of drag for the pipes comprising the T-section (cylinders) can be determined upon the calculations of their separate Reynolds numbers [2B-10].

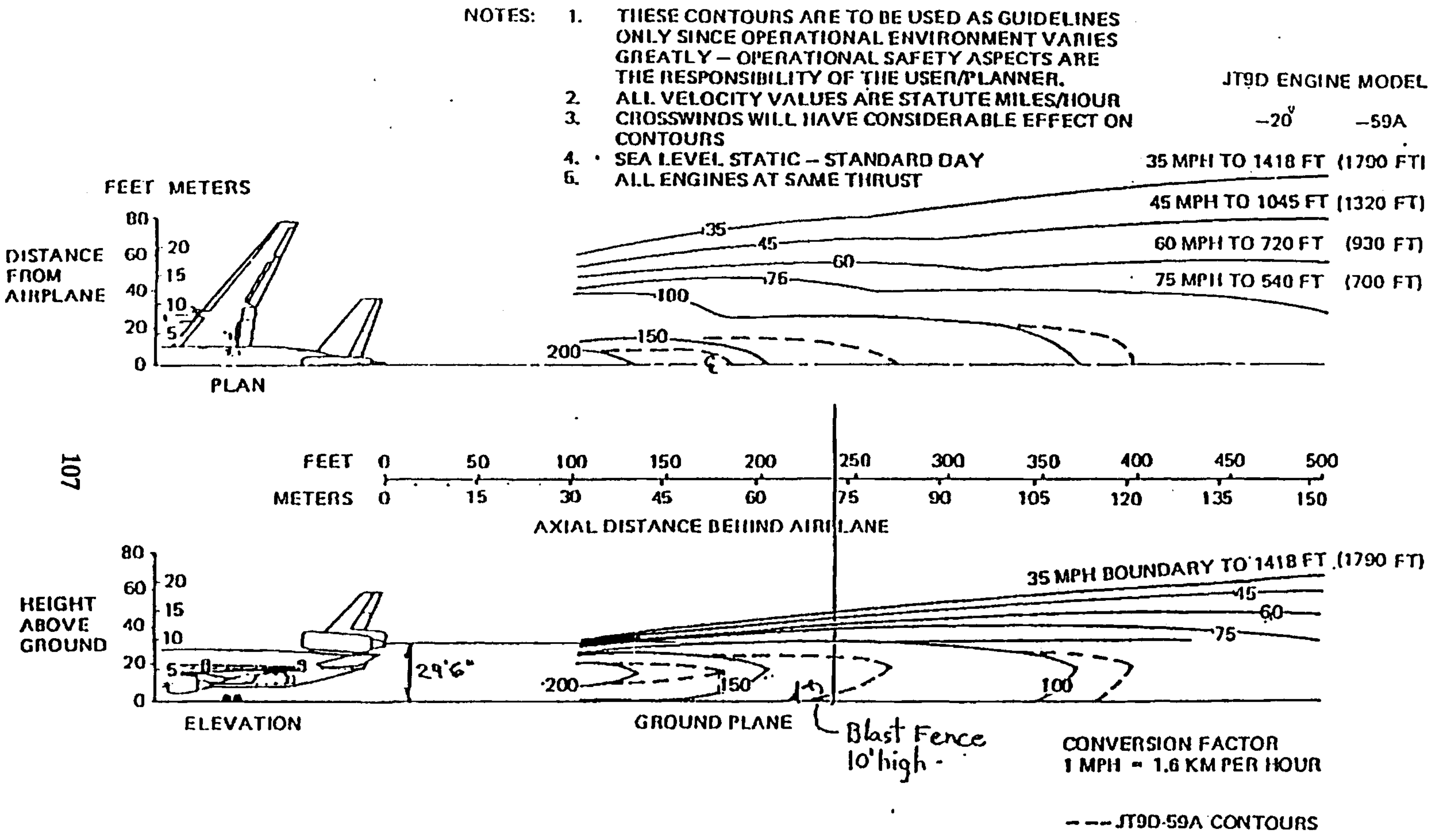


Figure 2-13. Jet Engine Exhaust Velocity Contours, Takeoff Power Model DC-10 Series 40 and 40CF (Estimated). (From McDonnell Douglas)

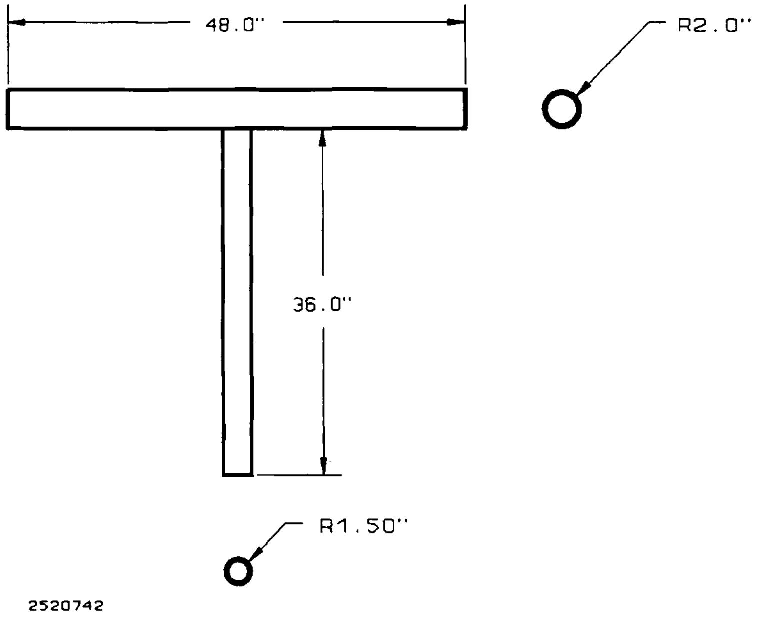


Figure 2-14. Specimen Cross-section.

The Reynolds number for the circular cylinders is defined as:

$$R = \frac{VD}{v}$$

where V is the velocity of the fluid relative to the body in feet per second, D is the outside diameter of the pipe in feet, and v is the kinematic viscosity of the fluid in square feet per second. The magnitude of the critical Reynolds number, which occurs at about 200,000 and 500,000 and at which the value of C_d drops, is dependant upon the turbulence in the fluid stream which approaches the radar unit.

Since the Reynolds number is used to define the turbulence of the stream and is highly dependent upon the temperature and velocity of the approaching stream, it may be noted that the values of C_d as well as ρ in the equation will fluctuate. For our purposes, the largest value of an expected, or assumed, variable's working range (worst possible scenario) will be incorporated within all calculations. For example, a C_d value of 1.2 will be used - the chosen value changes little for a large range of possible Reynolds numbers, see Figure 2-15. In addition, for the representation shown below [2B-11], the length-diameter ratio is infinity ($L/D = \infty$). According to Glen Cox and F. Germano, the drag is reduced about 50 percent for a length-diameter ratio of unity, about 30 percent for a ratio of 10 and about 17 percent for a ratio of 40 [2B-11]. Both T-section pipes have length-diameter ratios of 12; actual drag used for calculations will be 0.84. For an example see sample calculations in the appendix.

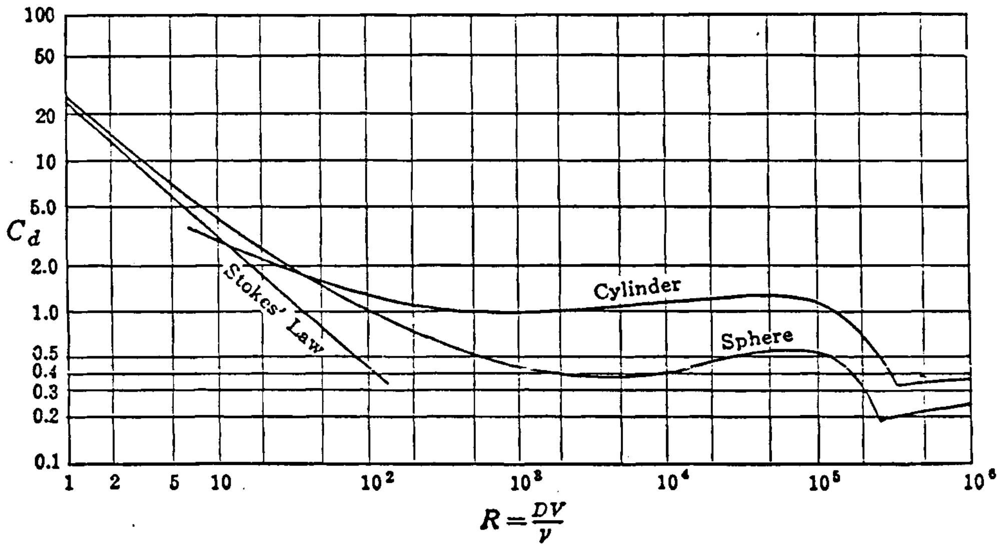


Figure 2-15. The Drag Coefficient for Cylinders and Spheres.

The projection of the cross-sectional area of the unit normal to the direction of the velocity, Figure 2-16, yields areas of 1.33 and 0.75 square feet for Sections 1 and 2, respectively.

Next, interpolation for the density of air @ -20°F yields 2.82E-3 slugs/ft^3 - as the temperature of the air blast decreases, ρ increases.

Finally, the velocity of the approaching fluid reaches a maximum of 200 knots or 230 mi/hr (337.56 ft/s).

Calculations of the antenna drag forces for each of the T-section members yield values of 179.5 and 101.1 lbf for pipes one and two respectively. Thus, the total drag force will be 280.7 lbf. However, to account for any uncertainties regarding the actual strength of the unit, a design factor of 1.6 (typical value for steel structures) will be used for basic design criteria. So, the lower limit of the design criteria will be based upon 449.12 lbf.

The basic design criteria are as follows:

Upper Limit	6750 lbf	
	•	
	.	- Leeway
Projected	449 lbf	- Designed to break-away
	•	
Lower Limit	281 lbf	- Drag force of 200 knots.

4. Recommended Further Action.

Both of the good possibilities, for solving the problem to relocate the Runway 07L localizer so that the Metro Green Line will not adversely affect its operation, require consideration be given to enhancing the present LPD antenna design to allow it to better withstand the hostile environment of nearby jet engines and their blast effects. There is no experience presently available that allows one to predict with confidence what problems will be presented with locations of LPD antennas as close as 150 feet to the runway threshold. Accordingly, the recommendation is made that two stock, specimen LPD antennas be located 160 feet from the threshold of Runway 25R at Los Angeles Airport. See Figures 2-17 and 2-18. This places the rear of antennas approximately 3 feet in front of the steel blast wall. This is an ideal test environment because this runway handles the most heavy commercial aircraft takeoffs in the world. The blast fence protection and the steep speed gradient immediately above the earth will offer protection. These tests will, in part, answer the question of how much protection is available. Recommended, also, is that the antennas be inspected weekly, and electrical measurements be made biweekly or at the very least, once per month. Included

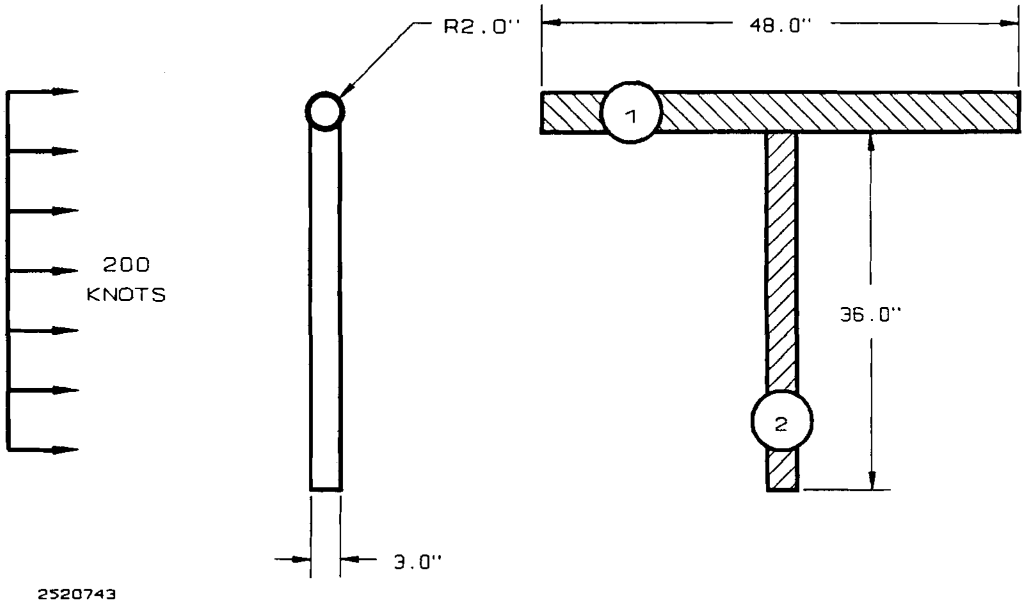


Figure 2-16. Cross-sectional Area of Antenna Unit.

Figure 2-17. The Proposed Test Location of a Log-Periodic Dipole Localizer Antenna.

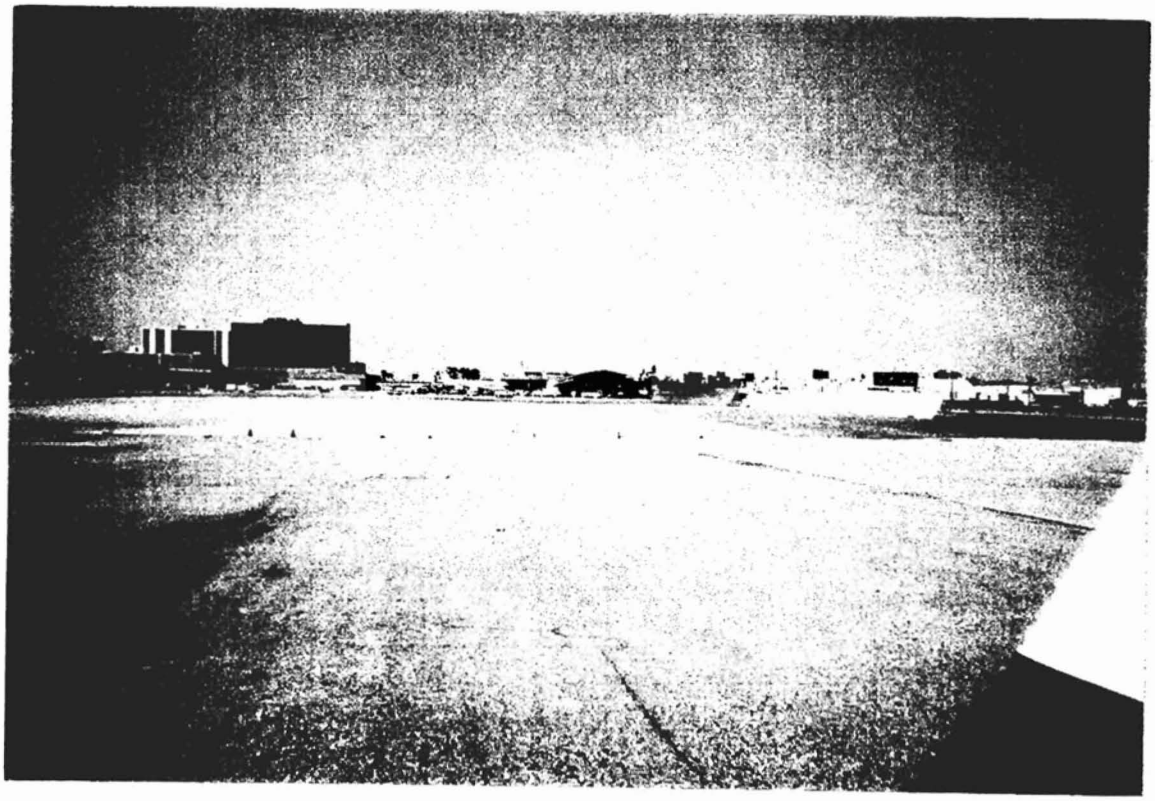


Figure 2-18. A Second, Closer View Looking North at the Area Proposed for Installing Test Localizer Antenna.

should be vector voltmeter measurements of SWR, complex impedance, reflection coefficient, and complex throughput to the monitor port.

The recommendation is made that obvious safeguards be taken for the tests of the antennas that will be provided by the manufacturer, Wilcox Electric. Specifically, the spline bolts should be replaced with metallic elements and the end caps of the tubular elements be spot welded in place.

FAA and Airport approval is needed. To begin the process of obtaining approval, an FAA Form 7460-1 Notice of Proposed Construction or Alteration should be submitted to the FAA. A sample FAA Form 7460-1 is shown in the appendix. The following are recommended for consideration for future designs that would make LPD antennas better able to withstand hostile environments near runway thresholds:

a) reduce the diameter of the tubular LPD elements by a factor of 2 to reduce wind resistance,
b) double the present wall thickness,
c) shape the tube with add-ons to reduce aerodynamic loading,
d) make the plastic nose section more rugged by use of Kevlar plastic,
e) insert gussets at the base of each dipole arm,
f) make tubular end plates flush and seal, and
g) eliminate the use of nylon bolts.

The V-Ring antennas presently in place for Runway 07L should not be considered for these tests because of their rather omnidirectional radiation patterns and general unsuitability for future applications with localizer systems.

5. References

[2B-6] Edwards, Jamie S., "A Solution to the Runway 4 Localizer Anomaly at the La Guardia Airport, New York", Technical Memorandum OU/AEC 37-87-TM0006/6-4, Avionics Engineering Center, Department of Electrical and Computer Engineering, Ohio University, Athens, Ohio, August 1987.

[2B-7] Edwards, Jamie S. and Michael F. DiBenedetto, "Comparison of the Effects of Two Simulated MLS Azimuth and Elevation Station Configurations on the Side-band Reference Glide Slope and 8-element V-ring Localizer at the Tamiami Airport, Tamiami, Florida", Technical Memorandum OU/AEC 38-87TM86:1088.001/6-FR, Avionics Engineering Center, Department of Electrical and Computer Engineering, Ohio University, Athens, Ohio, September 1987.

[2B-8] ICAO Standards, AWOP/13-wp/619, Appendix A to the Report on Agenda Item 1.2

[2B-9] Johnson, John H. and Jamie S. Edwards, "Precommissioning Flight Check of the Category I ILS Serving Runway 34 at the Alliance Airport in Fort Worth, Texas", Precis 114, Avionics Engineering Center, Department of Electrical and Computer Engineering, Ohio University, Athens, Ohio, March 8, 1990.

[2B-10] Streeter, Victor and E. Wyle, <u>Fluid Mechanics</u>, 8th edition, New York: McGraw-Hill, 1985, page 260.

[2B-11] Cox, Glen and F. Germano, <u>Fluid Mechanics</u>, New York: D. Van Nostrand Co., 1941, p. 242.

III. DESIGN FOR LOCATING MIDDLE MARKERS FOR RUNWAYS 24R & L AND FAR-FIELD MONITORS FOR 24R

A. Statement of the Problem.

1. Metro Green Line Alignment Near the 24L and 24R Middle Markers.

The proposed alignment for the Metro Green Line (Figure 1-1) passes near the ILS middle marker installations serving LAX Runways 24R and 24L. It is necessary to verify that FAA siting criteria for these markers are not violated.

2. Metro Green Line Effects on Localizer Far-field Monitors, Runways 24R and 25L.

Localizer far-field monitors are installed near the middle markers serving Runways 24R and 25L, to insure correct approach guidance during Category II and III instrument approaches. Concern for Metro Green Line effects on Category III operations was expressed by the Air Transport Association [3-1, Item 3].

The Metro Green Line structures must not interrupt the optical line-of-sight between the far-field monitor antennas and their associated localizer antenna array.

B. Proposed Solution to the Problem.

1. Middle Markers Serving Runways 24L and 24R.

This investigation verified that FAA siting criteria for the middle markers are not violated, and that correct operation of the existing middle marker facilities may be expected with the Metro Green Line structures in place.

2. Localizer Far-field Monitors Serving Runways 25L and 24R.

a. Runway 25L

Metro Green Line structures do not intersect the optical line-of-sight for the Runway 25L far-field monitor antenna. Future installation of a Category III far-field monitor to serve this runway will similarly not be affected by the rail system.

b. Runway 24R

The Metro Green Line operates on an elevated guideway with an overhead catenary line as it passes the Runway 24R centerline extended, between the approach lighting system and the middle marker installation. The line-of-sight for all three far-field monitor antennas is intersected by rail system structures or vehicles. To maintain correct operation of the monitor system, it is recommended that the three antennas be raised. The minimum height changes for the monitor antennas are given below, based on the survey documents cited in the following section.

i. Forward antenna (nearest to Runway 24R threshold) must be raised at least 8.52 feet.

ii. Center antenna (near the middle marker installation) must be raised at least 8.85 feet.

iii. Rear antenna (furthest from Runway 24R threshold) must be raised at least 8.88 feet.

C. Discussion and Data Supporting Recommendations.

1. Middle Markers.

Marker beacon transmitters, operating at a frequency of 75 MHz and providing an essentially elliptical pattern radiated vertically, are provided for distance references during an ILS instrument approach. The middle marker is located at a point over which the aircraft on a Category I approach arrives at the "decision height," from which either a visual completion of the landing or a missed-approach procedure must be initiated.

A middle marker is installed to serve each of the four west-facing runways at LAX. Figures 3-1a through 3-5 provide documentation of these installations. These figures will be referenced in later paragraphs of this section.

FAA siting criteria for marker beacon transmitters are published in the ILS Siting Criteria Order [3-2]. Figure 3-6 illustrates the siting geometry and clear-zone sectors appropriate for the middle markers serving Runway pairs 24 and 25 at LAX. The Order states:

> "Sectors I and III are critical pattern-forming areas for major axis [marker beacon] coverage. Interference sources in these sectors within 100 feet of the [marker] antenna and protruding above a 20-degree angle with respect to the counterpoise level should be removed. With no counterpoise, the 20 degrees is measured with respect to the lower antenna element."

At the outset, the determination is that the middle markers serving Runways 25L and 25R are not impacted by the Metro Green Line. The rail system is located at

Figure 3-1a. Runway 24R Localizer Far-field Monitor Antennas and Middle Marker.

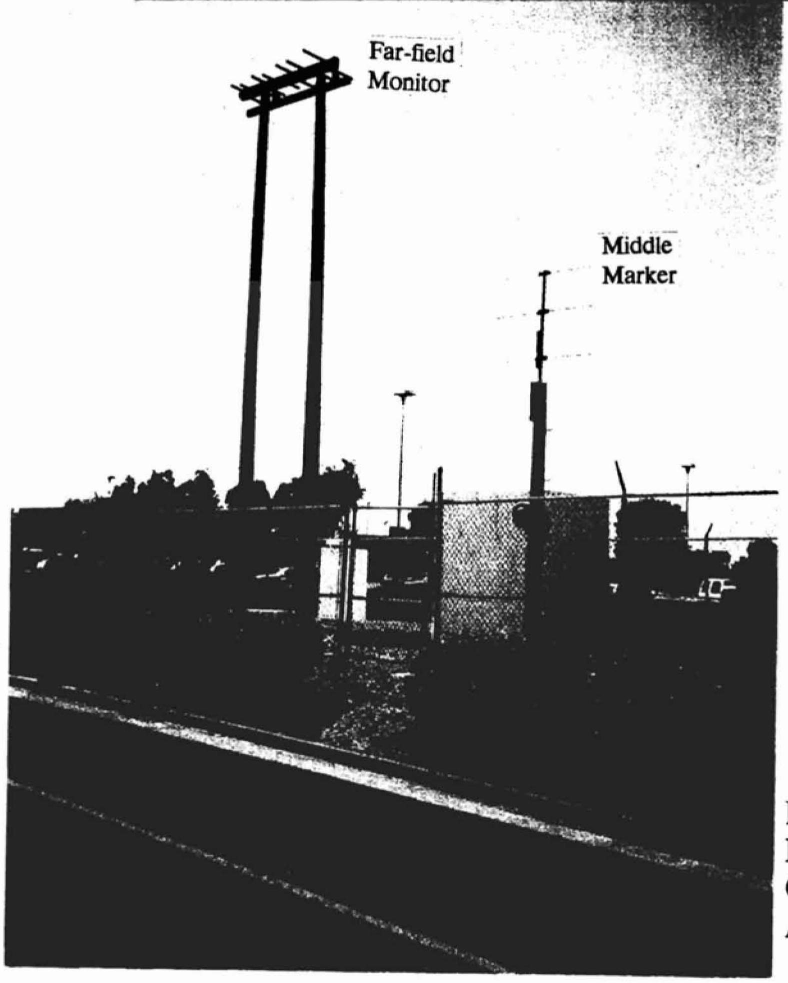


Figure 3-1b. Runway 24R Middle Marker Installation with Center Far-field Monitor Antenna.

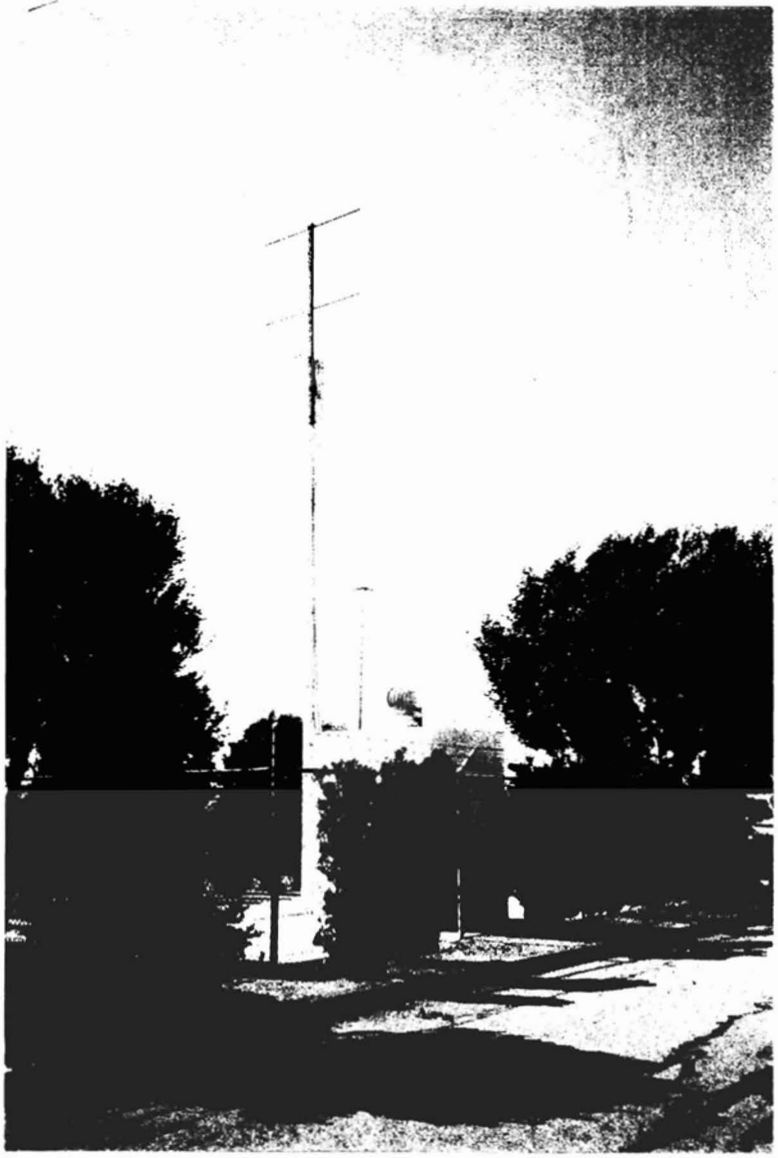


Figure 3-2. Runway 24L Middle Marker Installation.

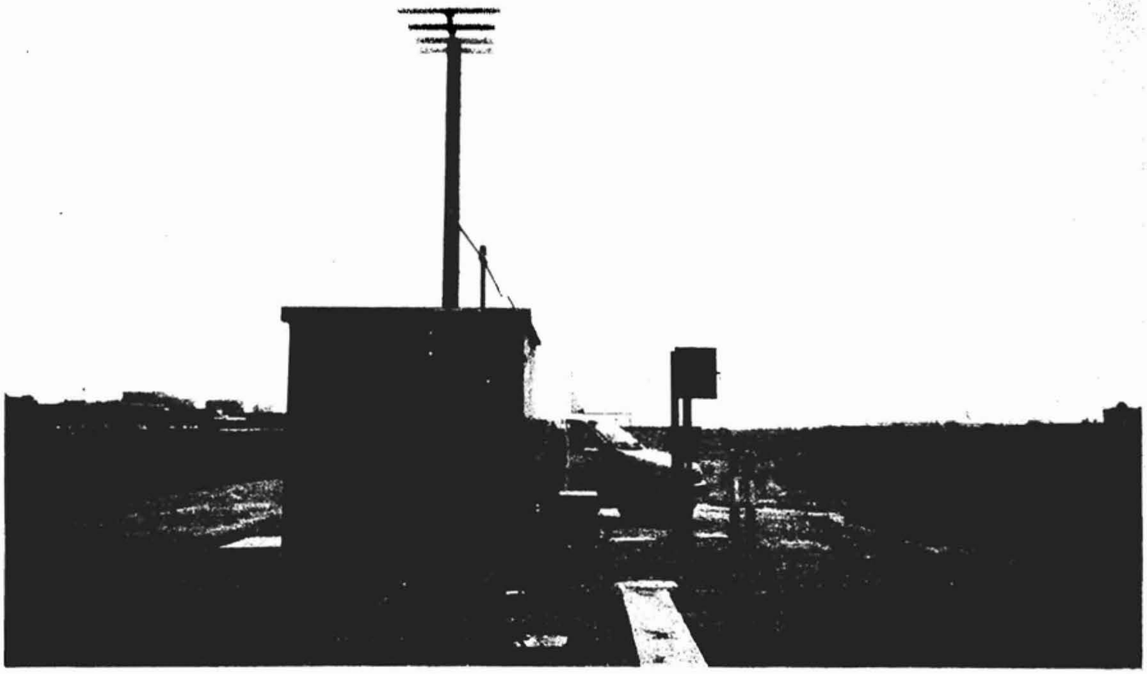


Figure 3-3. Runway 25L Middle Marker Installation with Localizer Far-field Monitor Antenna.

Figure 3-4. Runway 25R Middle Marker Installation.

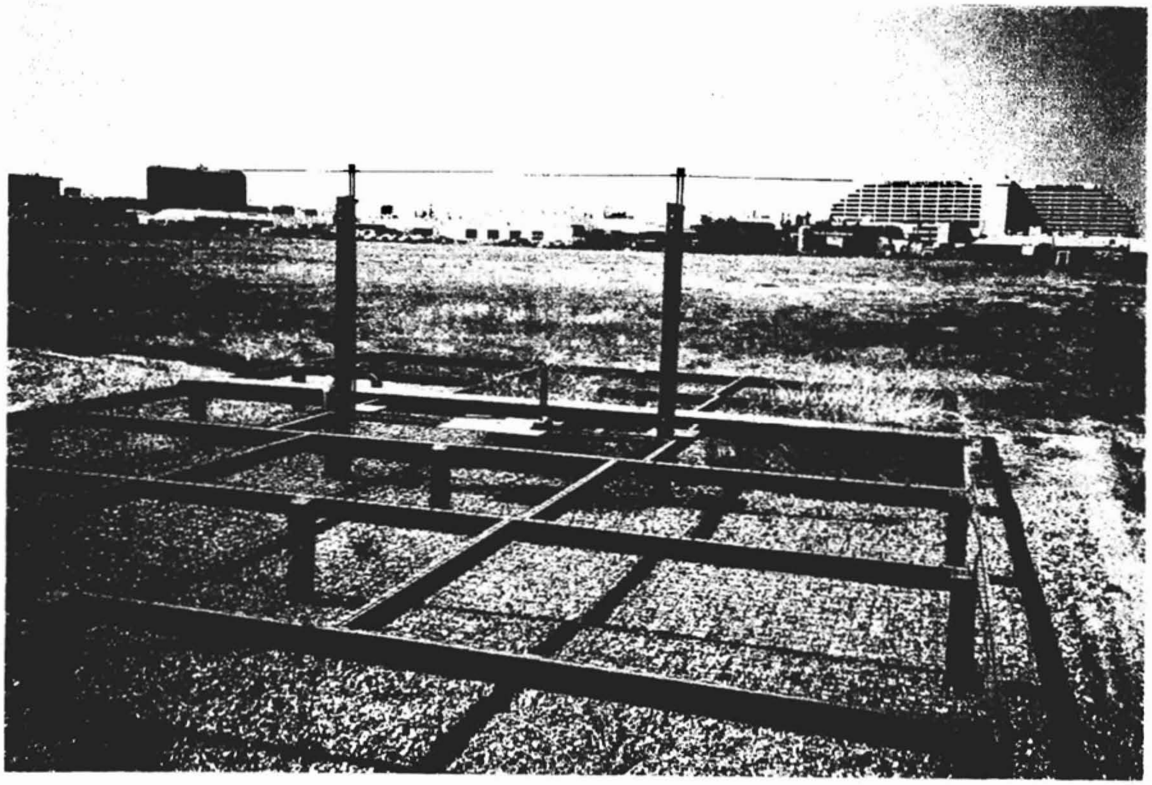
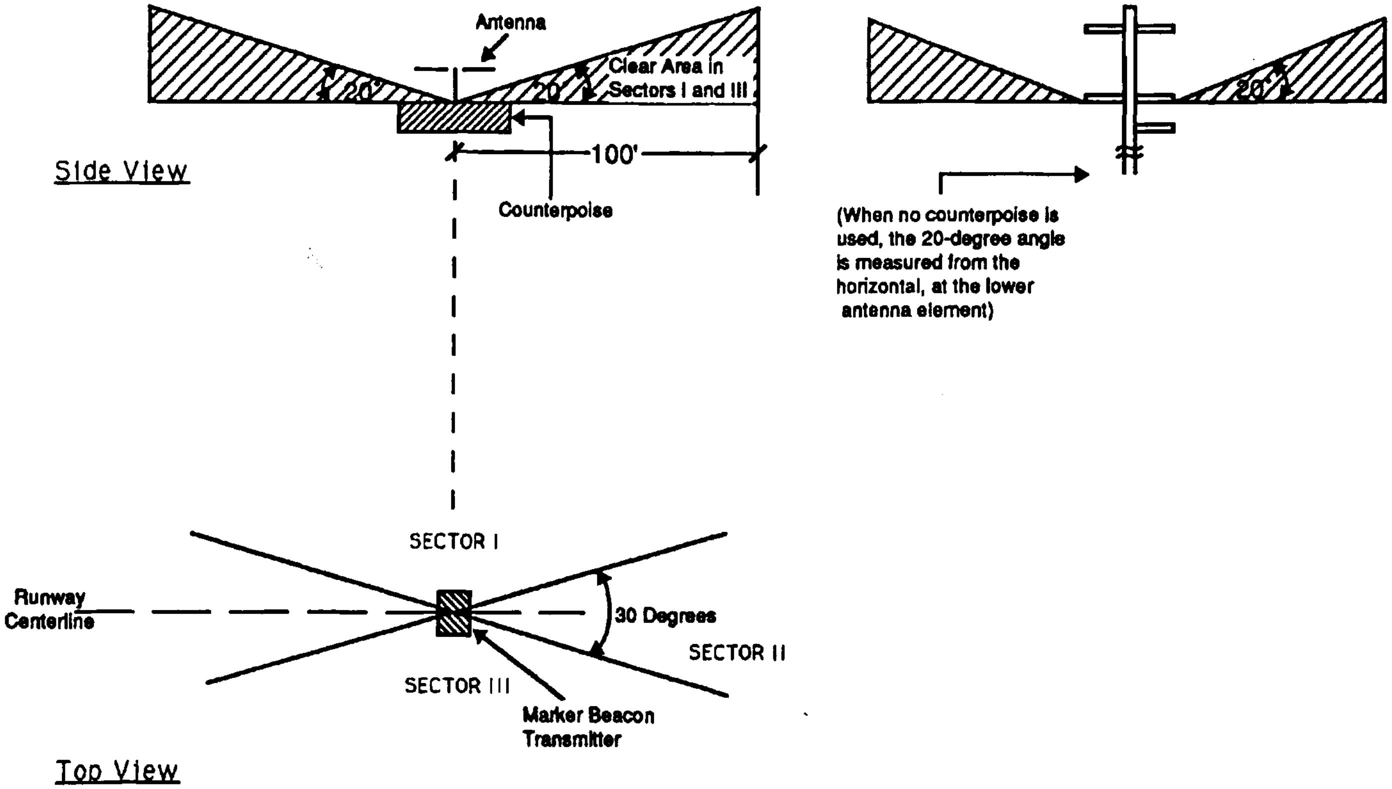


Figure 3-5. Runway 25L Middle Marker Antenna Showing Counterpoise.



scmac/9-trans.2
P252066

Figure 3-6. Siting Geometry for Marker Beacon Installation after [3-2].

grade level, over 1/2 mile to the west of the marker installations, and clearly does not violate the 20-degree cone in Sectors I and III for either middle marker.

The rail system is considerably closer to the middle markers serving Runways 24L and 24R, and examination of the survey cross-section drawings is necessary to determine whether problems exist for marker operation with the Metro Green Line in place. [It should be noted that the survey cross-section drawings show the 20-degree marker protection cone as measured from the vertical. This is the result of a mis-communication earlier in this study. Analyses for this study applied the 20-degree criterion from the horizontal, as specified by the ILS Siting Manual 6750.16B.]

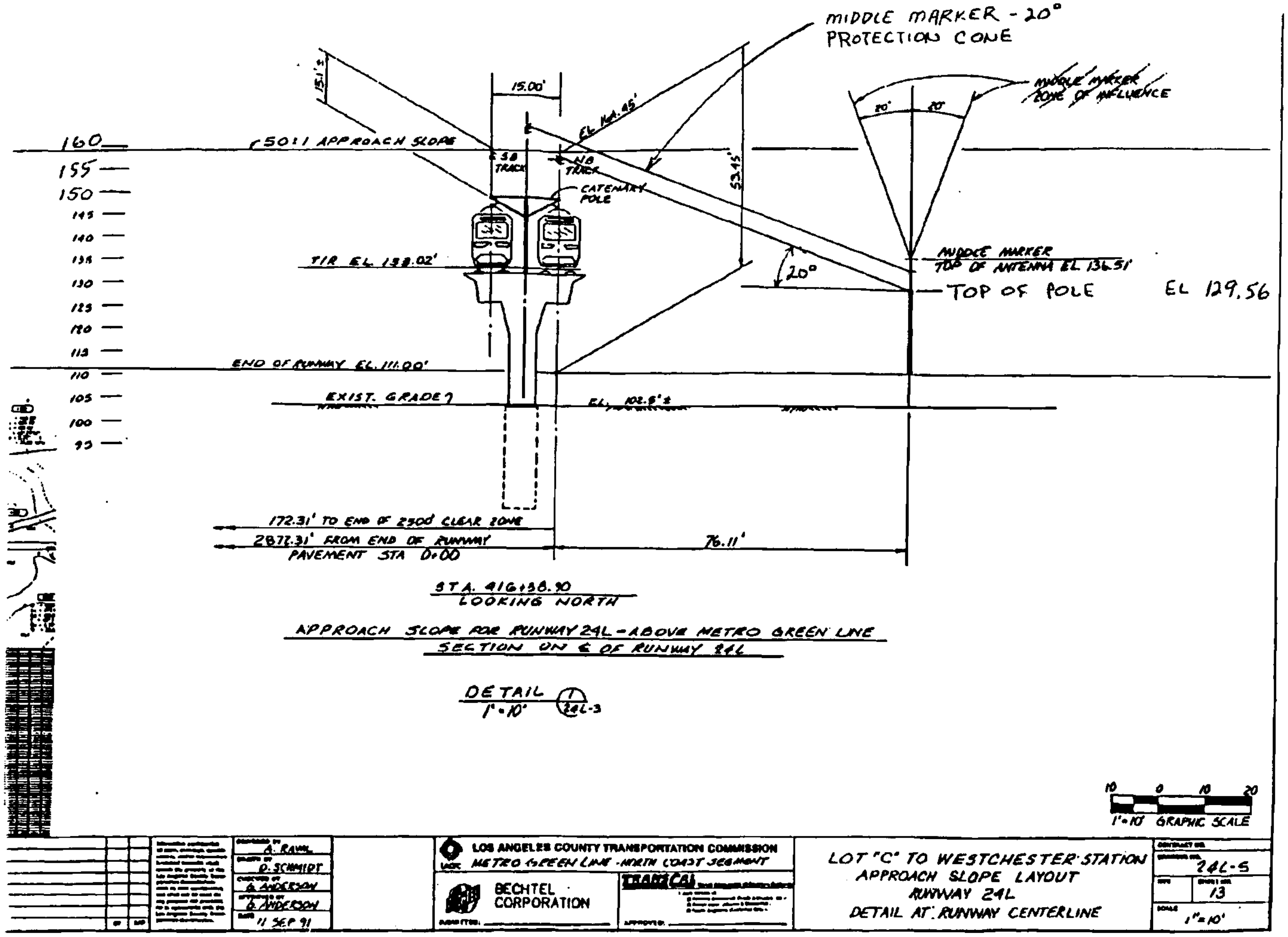
Figure 3-7 is a portion of the cross-section drawing on runway centerline extended, showing the relative positions of the rail structure and the Runway 24L middle marker. The 20-degree marker protection line has been added, as have elevations for the marker antenna and its supporting pole, using survey elevations [3-3]. This figure illustrates that the proposed Metro Green Line alignment easily meets the marker protection requirement for Runway 24L, even without application of the 30-degree Zone 1 criterion from Figure 3-6.

Figure 3-8 shows the rail structure relative to the middle marker installation for Runway 24R. The pole height for this marker is 121.00 feet (MSL) and the top of the marker antenna is 126.99. Using the pole height as the origin for convenience, the lower edge of the cone of protection reaches a height of 211.32 feet at the position of the nearest highest point on the rail structure. This represents a worst-case application of the marker siting criteria, since the Zone 1 exclusion shown in Figure 3-6 was not used. Since the rail structure does not penetrate the cone of protection and is further than 100 feet from the marker installation, normal marker operation may be expected.

2. Localizer Far-field Monitors.

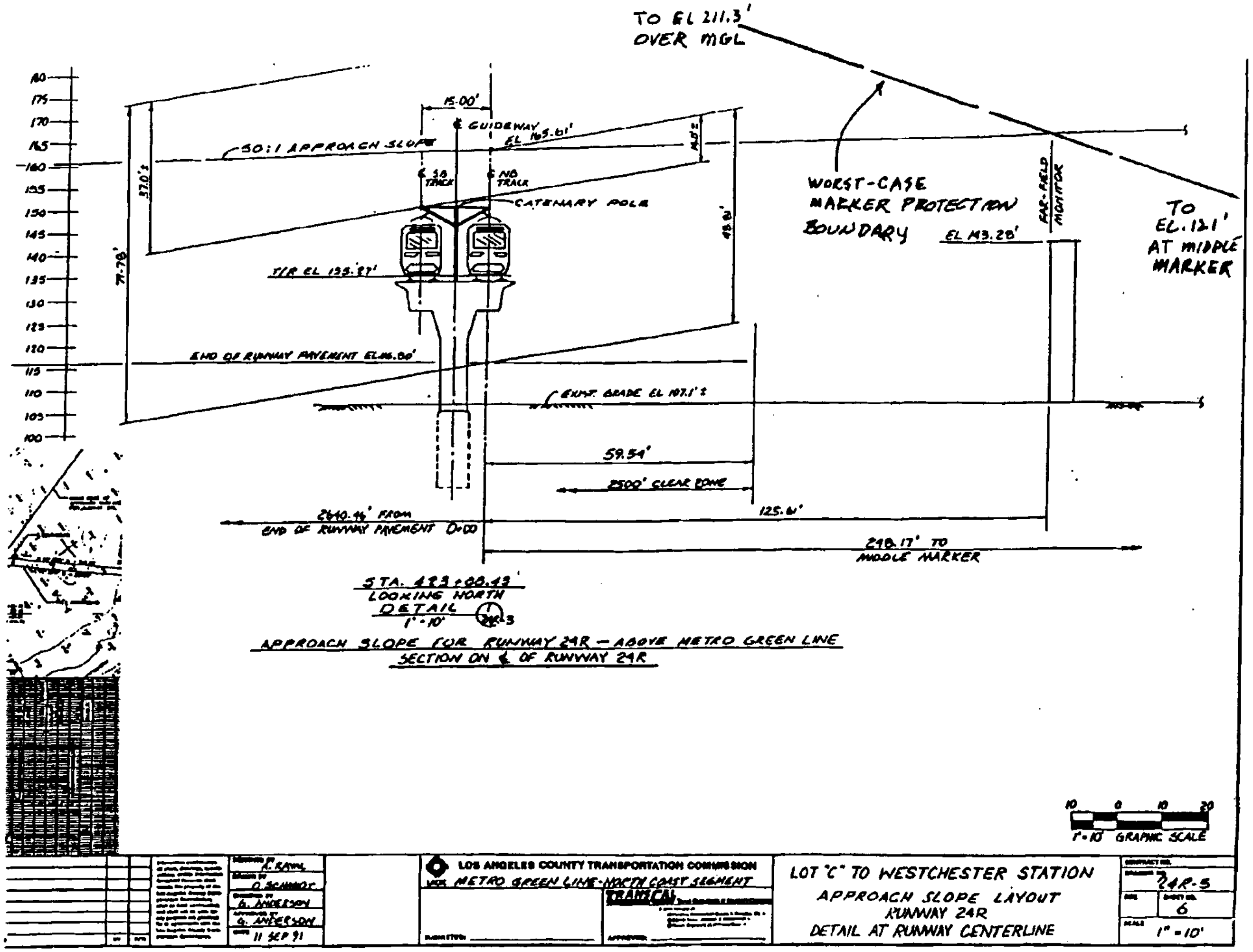
Categories I, II, and III instrument approach services are offered on LAX Runway 24R and Categories I and II approaches using 25L. Since Categories II and III approach procedures permit aircrews to descend to very low altitudes (100 feet or less) using only radio guidance from the ILS, additional monitoring equipment is provided to insure safety. These monitors sample the localizer signal at points near the middle marker, and alert air traffic controllers to any significant derogation of the lateral guidance transmitted to the aircraft.

The basic criterion for proper siting of these monitoring systems is that an optical line-of-sight exists between the monitor antennas and the localizer being monitored [3-4]. There are additional criteria for antenna placement relative to localizer centerline, and for minimum spacing between the monitor antenna and



P2520781

Figure 3-7. Proposed Metro Green Line Position Relative to Runway 24L Middle Marker.



P2520782

Figure 3-8. Proposed Metro Green Line Position Relative to Siting Criteria for Runway 24R Middle Marker.

the surrounding fence, but neither of these requirements is significant for the existing LAX installations.

a. Runway 25L

The localizer far-field monitor for Runway 25L serves only Category I and II instrument approaches, and is a simpler installation compared to the Runway 24R monitor. One monitor antenna is located at the middle marker site, on runway centerline extended. See Figure 3-3. This figure shows the middle marker installation and the single far-field monitor antenna, looking toward Runway 25L. It should be noted that while the proposed Metro Green Line rails are at grade level as they pass the Runway 25L centerline, this monitor antenna is also low, compared to the Runway 24R installation.

Investigation is therefore required, to insure that Metro Green Line structures do not penetrate the line-of-sight for the Runway 25L monitor.

Figure 3-9 shows a profile view from the localizer serving Runway 25L to the middle marker, where the localizer far-field monitor is installed. This profile is a composite of runway profile data [3-5] and survey data [3-3, 3-6]. The present monitor installation results in a "line-of-sight" from the localizer antenna at elevation 123 feet to the monitor antenna at 108.9 feet which grazes the top of the localizer installation for Runway 07L at elevation 111 feet and grazes (at best) the runway hump at 125 feet.

The center of the Metro Green Line passes the centerline of Runway 25L at a point 300.72 feet to the east of the pavement end. The middle marker is further to the east a distance of 1632.86 feet. The localizer antenna array is located 1,000 feet to the west of the 11,096-foot-long runway pavement. The resulting line-of-sight from monitor to localizer passes over the Metro Green Line at an elevation of 110.5 feet. The top of the rail system catenary passes the runway centerline at 106 feet, and therefore does not interfere with the far-field monitor.

b. Runway 24R

The Category III far-field monitor consists of three identical monitoring systems [3-7], which sense the localizer course signal in the far field and convey the detected signal to the monitoring system at the localizer transmitter site. Figure 3-10 shows a typical installation, with the three separate antennas located at approximately 100-foot intervals along runway centerline extended. Antenna elements used for the monitor system are the same log-periodic dipole (LPD) antennas used for the localizer transmitting array at the stop end of the runway. The center monitor antenna and the monitor electronics are located at the middle marker site.

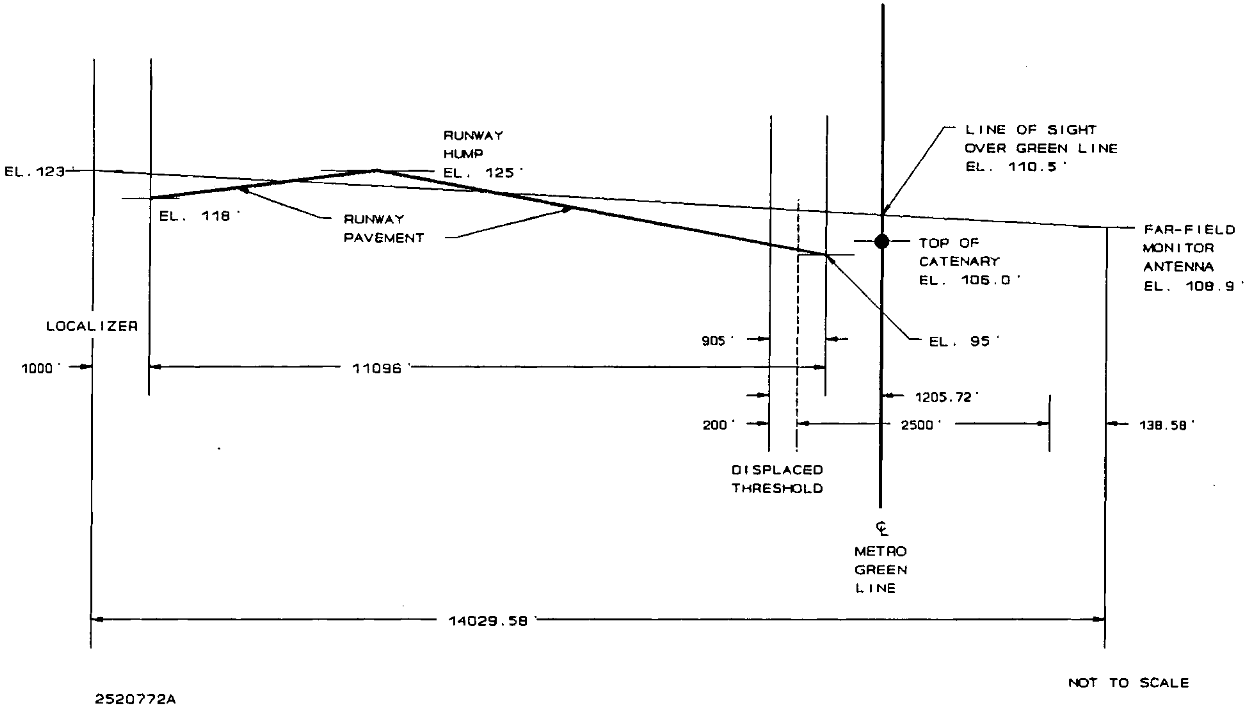


Figure 3-9. Profile Through Runway 25L Centerline Showing Far-Field Monitor Line-of-sight to Localizer.

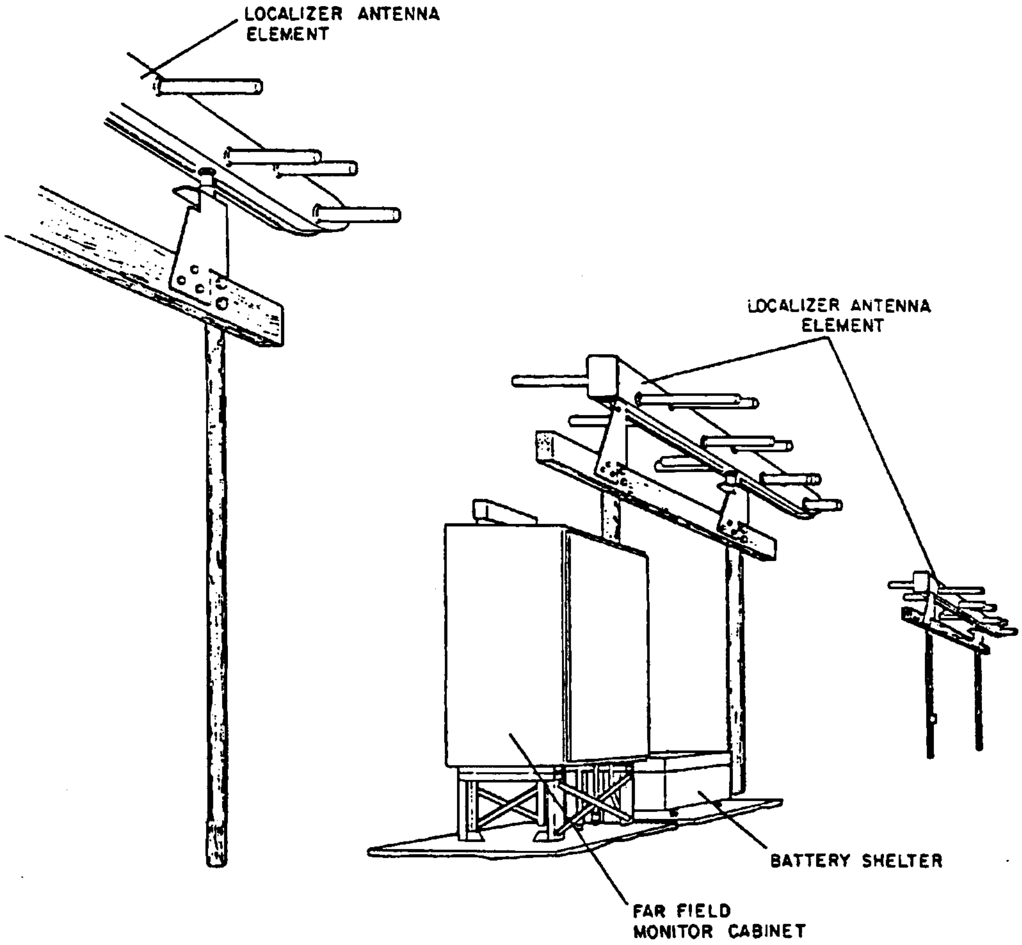


Figure 3-10. Typical Far-field Monitor Subsystem Outline Drawing after Wilcox [3-7].

A photograph of the three Runway 24R monitor antennas on tall poles is included as Figure 3-1a. This photograph looks towards the west. The middle marker installation may be seen near the center pole, and the end of the ALSF-2 approach lighting system is apparent at the left side of the photograph. The proposed Metro Green Line will pass between the end of the ALSF-2 and the leftmost monitor antenna poles. Further detail for the middle marker installation may be seen in Figure 3-1b, looking to the north, approximately perpendicular to the Runway 24R centerline extended. The Runway 24R threshold is approximately 3,000 feet to the left.

Figure 3-11 gives a profile view through the runway centerline, with elevations taken from FAA [3-8] and survey [3-3, 3-9] drawings. The proposed position of the Metro Green Line relative to the localizer for Runway 24R results in a line-of-sight which exceeds the height of the three existing far-field monitor antennas by 8.52 feet at the front antenna, 8.85 feet for the center, and 8.88 for the rear monitor antenna. It is therefore recommended that these monitor antennas be raised by at least the previously stated amounts, to re-establish the required optical line-of-sight.

D. Recommended Further Action.

Since the proposed Metro Green Line alignment will impact the far-field monitor for Runway 24R, requiring the movement of the three antennas serving this monitor, this fact should be included in the Form 7460-1 to be submitted to FAA.

The fact that all Metro Green Line structures fall outside the 20-degree cone of protection for the Runways 24L and 24R middle markers should be noted on the Form 7460-1.

At such time as FAA and LAX move toward Category III instrument approach capability for Runway 25L, the localizer far-field monitor will likely be upgraded. Since the Category III far-field monitor antennas will, in all probability, be higher than the present antenna, the line-of-sight to the localizer will be even higher above the Metro Green Line structures, and no future effects of Metro Green Line structures are expected.

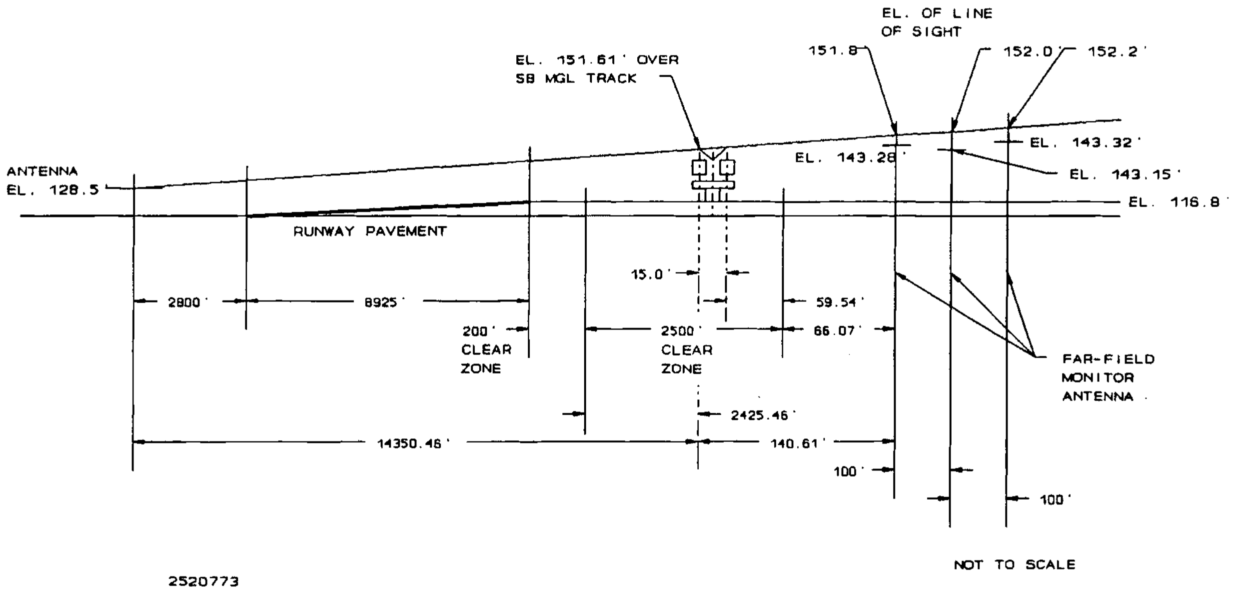


Figure 3-11. Profile Through Centerline of Runway 24R Showing Line-of-sight Far-field Monitor Antennas to the Localizer.

E. References.

[3-1] Letter from Mr. George H. Carver, ATA, to Mr. Carl B. Schellenberg, AWP-1, FAA Western Pacific Region, April 22, 1991, and a telephone conversation with Mr. Carver on October 9, 1991.

[3-2] Federal Aviation Administration, APM-440, "Siting Criteria for Instrument Landing Systems", Order No. 6750.16B, Washington, DC, June 17, 1985.

[3-3] Detail Survey Drawing, Navigational Device Survey, Los Angeles International Airport, Runways 24 Right and 24 Left, Project 602002, Sheets 1 and 2, KAWES and Associates, Inc., Rosemead, CA, September 11, 1991.

[3-4] Telephone conversation with Mr. Anthony Bommarito, ILS Product Manager, Wilcox Electric, Inc., Kansas City, MO, July 17, 1991.

[3-5] Runway Profile, LAX Runway 25L, provided by FAA Western Pacific Region, August 18, 1991.

[3-6] Survey Cross-Section Drawings, "Lot C to Westchester Station", 25L-1 through 25L-4, dated 11 September 1991, produced by the Bechtel Corporation and provided by TransCal.

[3-7] Wilcox Electric, Inc., "Instruction Book; Far Field Monitor Subsystem, Type FA-9759, Serial Nos. 1-10", Document Number T16750.132, Kansas City, MO, December 17, 1980.

[3-8] Profile view of LAX Runway 24R, provided by FAA Western Pacific Region, August 1991.

[3-9] Survey Cross-Section Drawings, "Lot C to Westchester Station", 24R-1 through 24R-7, dated 11 September 1991, produced by the Bechtel Corporation and provided by TransCal.

IV. GLIDE SLOPE CONCERNS

The four glide slopes that provide guidance at the Los Angeles International Airport, for landings to the west, present possibilities for having course derogation produced by the presence of railcars, the overhead catenary system (OCS), and a station located in front of the transmitter sites. Accordingly, these type of effects have been investigated both theoretically and experimentally. The subsections which immediately follow address these issues and provide the results of the investigation.

A. Investigation of Effects of Glide Slope Derogation Due to Overhead Catenary System and the Railcars.

The effects of the OCS and the railcars are investigated using different modeling techniques. These will be described individually in the following pages. Because of the lack of validation data for the OCS mathematical model, special experiments were conducted to obtain these kinds of data and the results are presented.

1. Discussion of Overhead Catenary System (OCS) Effects.

a. Statement of the OCS Problem.

The electric field of the glide slope is horizontally polarized. Because of this fact, it is particularly important to minimize the number, horizontal extent, and height of horizontal conducting elements be they surfaces, or wire elements. These are potential scatterers of the localizer energy. Some of the scattered energy will reach the aircraft in flight on the approach. As mentioned earlier in this report, localizer radio frequency energy that arrives at the aircraft via any other route than direct, is a contaminant that causes path roughness. This is also quite true with the glide slope. Tolerances are placed on the magnitude of this roughness. When roughness becomes large enough, it can mislead or disturb the pilot, can cause the autopilot to produce erratic motion in the control system of the aircraft or, in certain cases, can cause the auto pilot to disengage (uncouple).

The overhead catenary system, frequently called the OCS, which is planned for the Green Line has the potential for being troublesome. The OCS typically consists of a large copper conductor and a supporting steel cable, called a messenger. The problem arises because these are good conductors of electrical energy. They are relatively high above the ground, and extend horizontally for a considerable distance. Further, they are present at all times. These factors motivated a study to investigate the effects of an OCS both theoretically and experimentally. The second concern, that of the effects of the railcars, per se, were examined by using physical optics mathematical models.

The greater the quantity of glide slope radio frequency energy incident on the OCS, the greater potential for problems. While there are techniques that theoretically will reduce the effectiveness of the OCS to re-radiate, i.e. scatter (reflect or diffract) the signals, to date they have not been applied practically. For example, one could place radio frequency chokes along the OCS to prevent the radio frequency energy from propagating; however, these would present a problem to having a simple, effective trolley operation. Techniques that are practical for small circuit domains, such as found in radios, are not practical to reproduce 20 feet in the air with 1/2-inch diameter conductors.

b. Proposed Solution to the OCS Problem.

There are three different approaches that can be considered to minimize effects of horizontal conductors. One is to attenuate the radio frequency energy as it would flow in the OCS; one is to set up canceling fields; and the last is to prevent the signal from becoming incident on the OCS that will serve as a scatterer. As stated earlier, because of the practical considerations associated with use of chokes and cancellation wires, it is usually best to attempt to minimize the amount of incident energy on the scatterer, in this case the OCS. This is done usually by providing directivity, i.e., using an antenna system that confines the radio frequency energy precisely to those regions where it is to be used by the aircraft. This means, in the case of the glide slope, the energy should be confined to be near the three-degree path angle. Unfortunately, life is not that simple. If this is done precisely, there is no energy below the path to inform the pilot to fly up when the aircraft is below the desired safe angle for the landing approach. This is overcome with the capture-effect glide slope system that makes use of a special auxiliary signal and an observed phenomenon, called the capture principle. This principle relates to the operation of an AM-type (amplitude modulation) radio receiver.

With the proper arrangement of antennas, it is possible to produce carefully designed vertical radiation patterns to confine the principal guidance signal to the region near the path angle. While doing this, a second auxiliary signal with a slightly different radio frequency, containing only fly-up command information, is radiated into the region below path. The capture principle, in simplest terms, says that the information presented at the output of the receiver will be that associated with the radio frequency signal that has the greater magnitude. Scattered signal from the OCS will be from the auxiliary transmitter. Because it is a scattered signal, it is weaker than the signal coming directly from the main transmitter directed to the 3-degree region. Consequently, the path roughness is minimal because the reflected signal from the OCS on another frequency (still coming through the pass band of the receiver) is essentially ignored on path at 3 degrees, due to the capture principle. Importantly, the auxiliary signal captures the receiver operating below path and the main signal captures the receiver near 3 degrees. This is the reason that the two-frequency capture-effect glide slope system performs so commendably when there is a reflecting surface or objects such as an OCS or railcar below path. In all cases it will give a superior signal to that produced by the single-frequency null-reference system.

The proposed action for providing the highest possible quality glide slope signals for aircraft approaching LAX is to use a capture-effect system on every runway in both the north and south complexes at the Airport. Accomplishing this is also the objective of the work described in the following section on railcars. One remaining question is, will the capture-effect system be adequate to provide a quality path in the presence of the Metro Green Line hardware? Obtaining the answer to that question involves two steps. The first step is to assess the amount of the derogation that can be expected with both the null-reference and the capture-effect glide slope systems. A part of this is to determine the optimum performance from the capture-effect system.

The second step, if it is needed, is that should insufficient path quality be available from use of the capture-effect system, then recommendations for canceling signals with special cancellation wire schemes will have to be developed.

c. Discussion and Data Supporting the Recommendation Concerning the OCS.

While the environment is replete with reflecting objects including wires, no specific glide-slope model has been developed for predicting the effects of wires on glide-path performance. With the extensive modeling resource and experience available at Ohio University, a mathematical model was developed specifically for application to this Metro Green Line problem.

Several methods can be used to model the field scattered by a long thin wire when it is illuminated with plane or cylindrical radio frequency waves. Some of the most commonly known techniques include Physical Optics, Modal Techniques, Integral Equations and Geometrical Optics. The Electric Field Integral Equation using the Method of Moments is known to provide accurate results for thin wire scatterers [4A-1]. Because this method requires the solution of very large matrices, the length of the wire must be electrically short. In the case of the Metro Green Line, this method would not be practical but could be used to check the accuracy of other models using an appropriate length of wire.

The modal technique was used to solve for the induced current in the wire caused by the glide slope signals. Once the induced current is known, this current can be used to compute the field re-radiated by the wire. This involves solving the boundary value problem for the particular mode of propagation. It is easier to obtain the scattered field caused by an infinite length wire and use appropriate transformations to determine the field from a finite length wire. The induced current density in an infinite thin wire of radius a is given by Balanis [4A-1] as:

$$\vec{J}_s \approx \hat{a}_z \frac{2E_0}{\pi a \omega \mu} \frac{1}{H_0^{(2)}(\beta a)}$$

The total current on the surface of the wire is then given by:

$$\vec{I} = 2\pi a \vec{J}_s$$

By using the appropriate modification which takes into account the boundary conditions at the end of the wire, the current induced by a finite wire can be computed by [4A-2]:

$$\begin{aligned} I(y) = {} & \frac{4}{\beta_0 \eta_0 H_0^{(2)}(\beta_0 a)} \quad \times \\ & \{\, E(y) + \frac{j}{2\sin\beta_0 L}[(E(-L/2)e^{j\beta_0 L/2} - E(L/2)e^{-j\beta_0 L/2})e^{-j\beta_0 y} + \\ & (E(L/2)e^{j\beta_0 L/2} - E(-L/2)e^{-j\beta_0 L/2})e^{j\beta_0 y}] \,\} \end{aligned}$$

Once the current induced in the wire is known, the scattered field can be found by integrating over the length of the wire. This is similar to dividing the wire into segments or infinitesimal elements and calculating the field by summing the fields caused by each infinitesimal element. Then the field as seen in the far-field is given by [4A-3]:

$$E_\theta \approx \frac{j\eta\beta_0 I_e l \sin(\theta) e^{-jkr}}{4\pi r}$$

Figure 4-1 shows a comparison of the scattered fields caused by a 23-foot wire using the Modal technique and the Method of Moments. As seen by this figure, both models show comparable results.

The scattered field caused by the wire is then added to unperturbed glide slope signals. These signals are then processed through a receiver algorithm which calculates the amount of glide path roughness caused by the wire. This algorithm

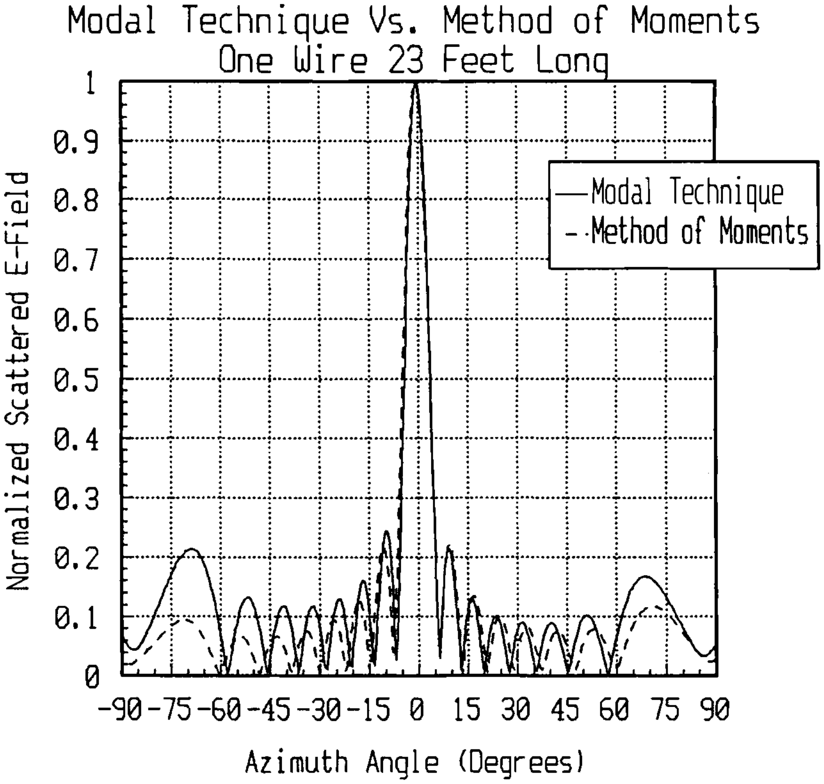


Figure 4-1. Comparison of Results of Two Modeling Techniques, viz., Modal Techniques and the Method of Moments.

has been used by Ohio University in other ILS mathematical models [4A-4 & 4A-5]. The ILS thin wire model was written in Fortran 77 and compiled using Microsoft Fortran Version 5.0. The model runs on any IBM PC compatible computers with at least 640K of memory. The model takes approximately 10 minutes on a 33 MHz 486 PC to perform the calculations for a 2000-foot wire.

Because this model had not been validated, an experimental task was performed to determine the accuracy of the model, in terms of how well it predicted glide slope performance. Both null-reference and capture-effect systems were set up sequentially during the period from September 5 through 17, 1991, at the Ohio University ILS test site in Miami, Florida. The electronic transmitting equipment was made available through the courtesy of the Federal Aviation Administration. Base line data were obtained. These data were extremely important because a high stand of grass, produced during a very wet growing season, was cut and remained on the ground plane. The grass beyond the 1100 foot range was not cut.

A set of 1/2 inch copper pipes was suspended above ground at a height of 16 and 20 feet for each of the two systems. Each of these was 100 feet long, the amount used in the mathematical model. The supports were 5 wooden tripods. .

Figure 4-2 shows the tripods but the copper pipe is not evident because of its size. The flight measurements were made for all of the combinations, i.e., baselines, tripods alone, and two conductors at 20 and 16 foot elevations. As mentioned earlier, this was first done with the null-reference and then followed by the capture effect. Plans were to begin at the 1000-foot range and move further away but with the magnitude of the perturbation found at the 1000-foot range the decision was made that it would be futile to attempt to identify perturbations in the path because of their low magnitude.

The flight data were collected using two different aircraft. One was a Beechcraft Model 35 and the other a Model 36. Each carried the Ohio University Mark IV Minilab. Tracking for reference purposes was accomplished through the use of a Warren-Knight WK-83 Radio Telemetering Theodolite and a Communitronics telemetry transmitter operating on 329.0 MHz. The glide slope station operated on 333.2 MHz.

The reader should clearly note that this was a model validation exercise and not a proofing for placement of specific elements of the Green Line. Experience has shown that when the model is validated satisfactorily, then predictions for various configurations can be accurately made. It is important to work with perturbations that are large enough to allow one to discriminate multipath effects of the wires from ambient noise in the real world and measure the magnitudes of the specific perturbations.

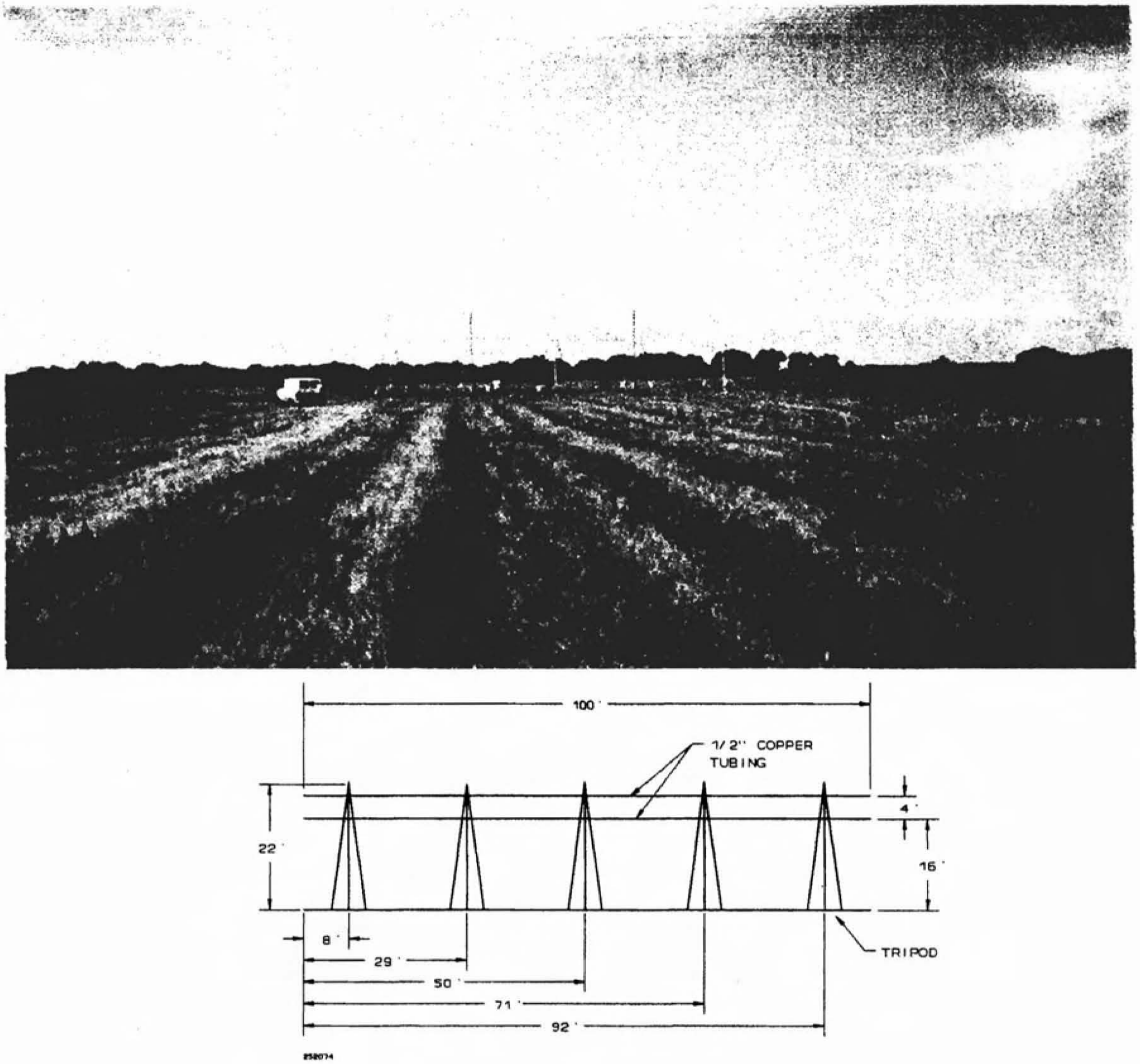


Figure 4-2. Photograph and Sketch of Supporting Structures Holding the Copper Pipe that is Simulating the Overhead Catenary System While a Flight Measurement is in Progress.

The results of the modeling and the experimental validation are presented in the following figures. The units used are microamperes which are related to the amount of course needle displacement observed by the pilot. The zero-centered instrument is calibrated such that it reaches the edge of the scale when 150 microamperes of displacement are present. Systems are adjusted and calibrated such that 75 microamperes is equal to 0.35-degree elevation or 1 microampere (μa) is equal to 0.0047-degree elevation angle.

The strategy used in making a determination as to how much effect the Metro Green Line will have on the performance of the glide slopes is to model a 100-foot length of a one and then two-wire catenary at a distance in front of a glide slope that would allow a path perturbation to be produced that was at least 5 to 10 microamperes in magnitude. Such a magnitude is needed to get values that would be measurable with confidence. This turned out to require a location of the OCS only 1000 feet in front of the glide slope. The height was taken as 16 and 20 feet which are representative of the expected situation with the two-cable (wire) OCS of the Metro Green Line. The 1000-foot distance is, however, hardly representative of an operational airport since this would have the cars penetrating obstruction zones and is certainly not planned. A 100-foot length of OCS was used because this was an amount that would be physically manageable when it came time to perform the validation measurements. Figures 4-3 and 4-4 show the predicted values for the null-reference system and the capture-effect system, respectively. In Figures 4-5 and 4-6 the results of the field measurements made with these systems at the Ohio University ILS test site in Miami, Florida, are shown.

The validation of the model which predicts the effects of the 100-foot length of OCS having been completed, the next step is to use the model to predict the effects of a 2000-foot length of OCS separated from the respective runway thresholds at the specific distances given in the Green Line planning documents. These results are shown in Figures 4-7 through 4-11.

2. Discussion of Railcar Effects.

a. Statement of the Railcar Problem.

The railcars are similar to the OCS in the sense that they present conducting material that exists in front of the glide slope antennas. The important distinction is that they present a large surface whereas the OCS are essentially thin linear conductors. As a consequence, a different mathematical modeling technique is necessary. The objective is identical to the work with the OCS, viz, determine the magnitude of the path perturbations caused by the railcars at worst case locations along the proposed guideways in front of the four glide slope transmitting facilities serving Runways 25L, 25R, 24L and 24R. Finally, the comparison must be made with allowable tolerance limits.

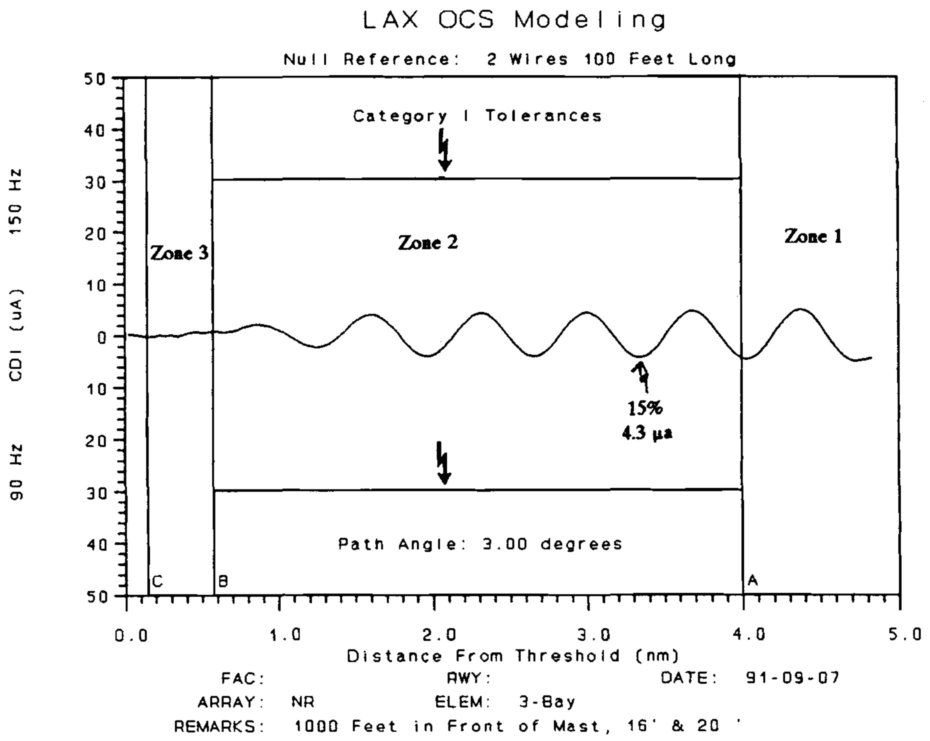


Figure 4-3. Prediction of Course Roughness Produced with 2-wire OCS 100 Feet Long, 1000 Feet in Front of Null-reference Glide Slope Mast.

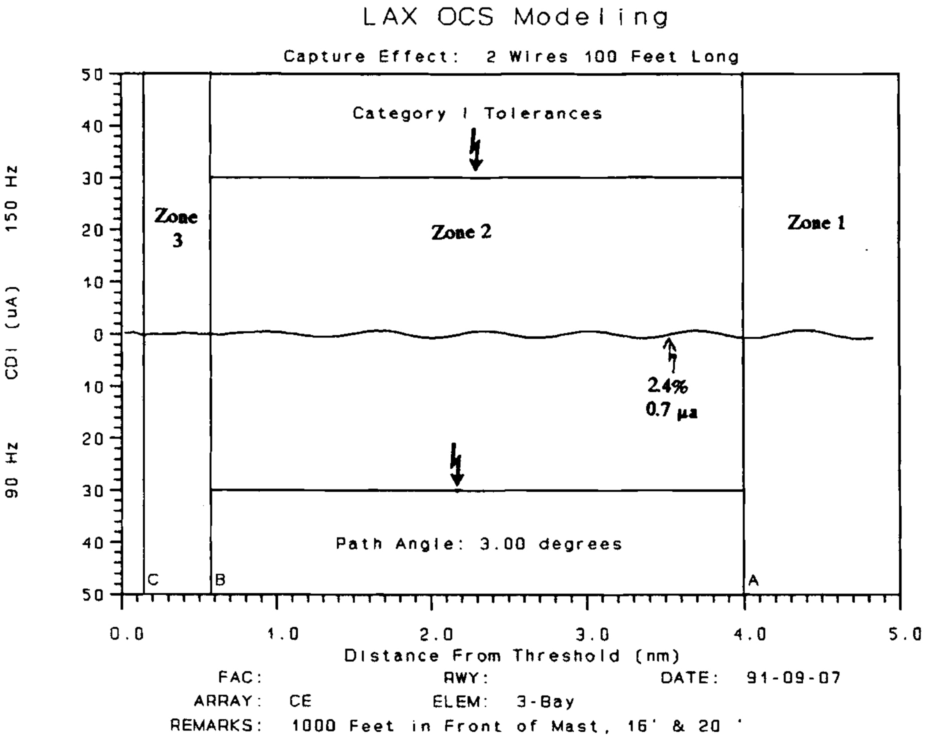


Figure 4-4. Prediction of Course Roughness Produced with 2-wire OCS 100 Feet Long, 1000 Feet in Front of the Capture-effect Glide Slope Mast.

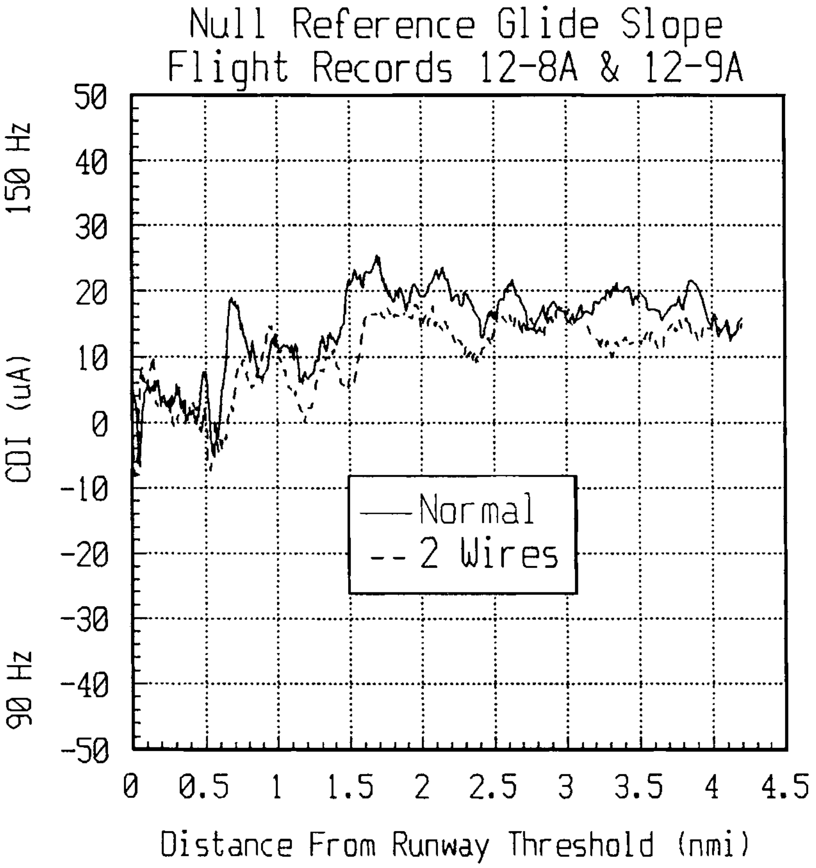


Figure 4-5. Measured Comparison of Null-reference Glide Slope Performance with and without OCS in Place.

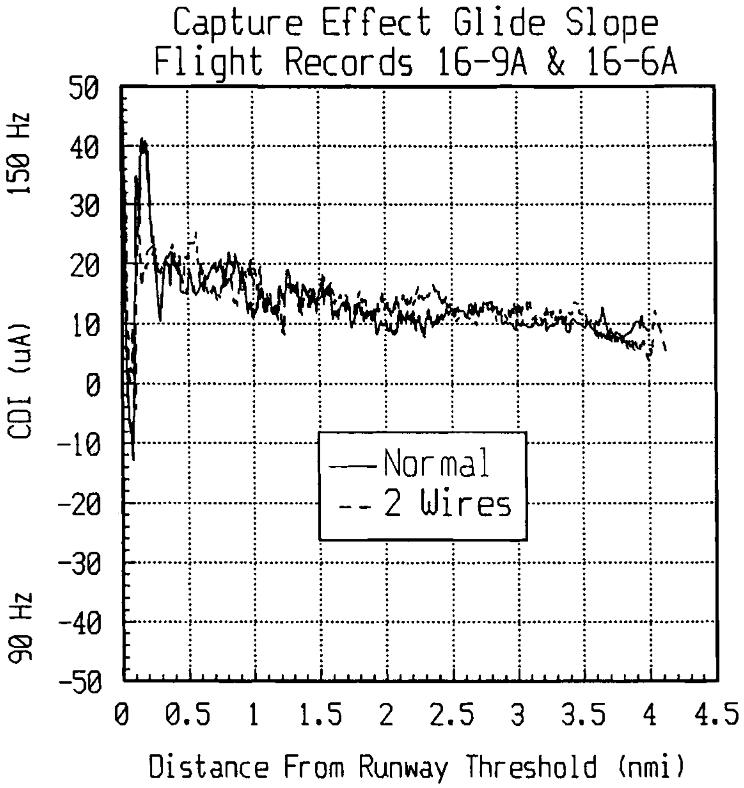


Figure 4-6. Measured Comparison of Capture-effect Glide Slope Performance with and without OCS in Place.

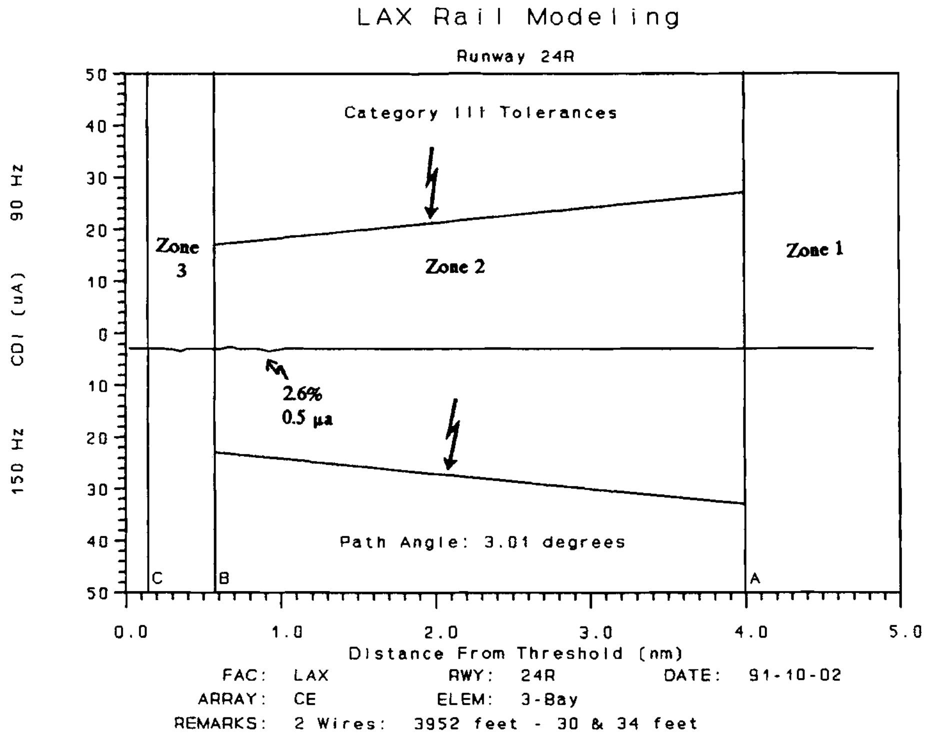


Figure 4-7. Prediction of Course Roughness Produced with 2-wire OCS, 2000 Feet Long, Set in Planned Location in Front of the Runway 24R Capture-effect Glide Slope.

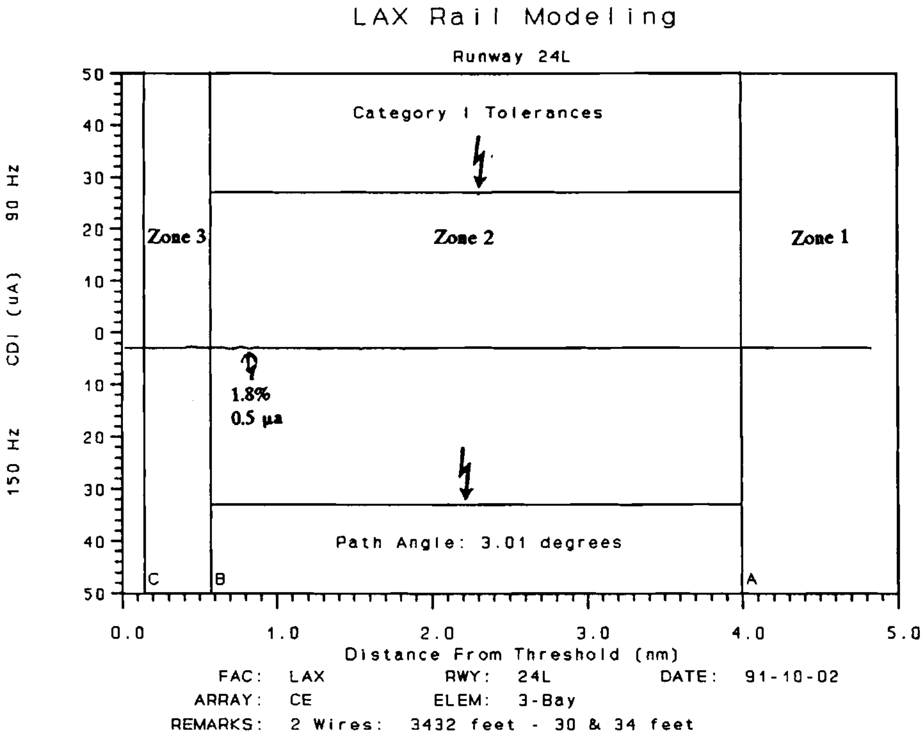


Figure 4-8. Prediction of Course Roughness Produced with 2-wire OCS, 2000 Feet Long Set in Planned Location in Front of the Runway 24L Capture-effect Glide Slope.

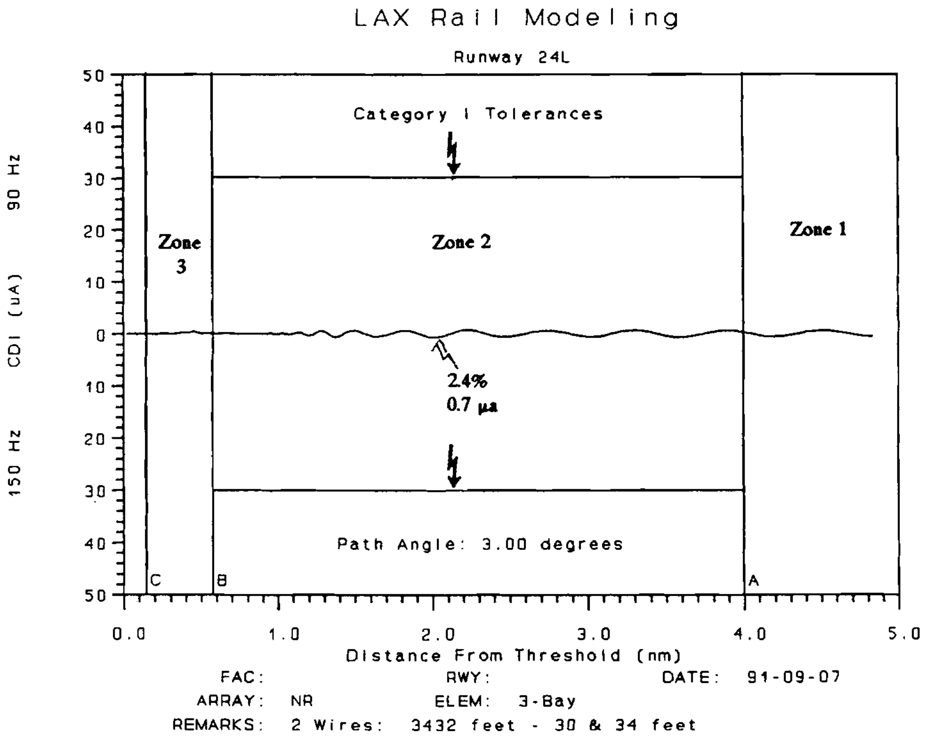


Figure 4-9. Prediction of Course Roughness Produced with 2-wire OCS, 2000 Feet Long, Set in Planned Location in Front of the Runway 24L Null-reference Glide Slope.

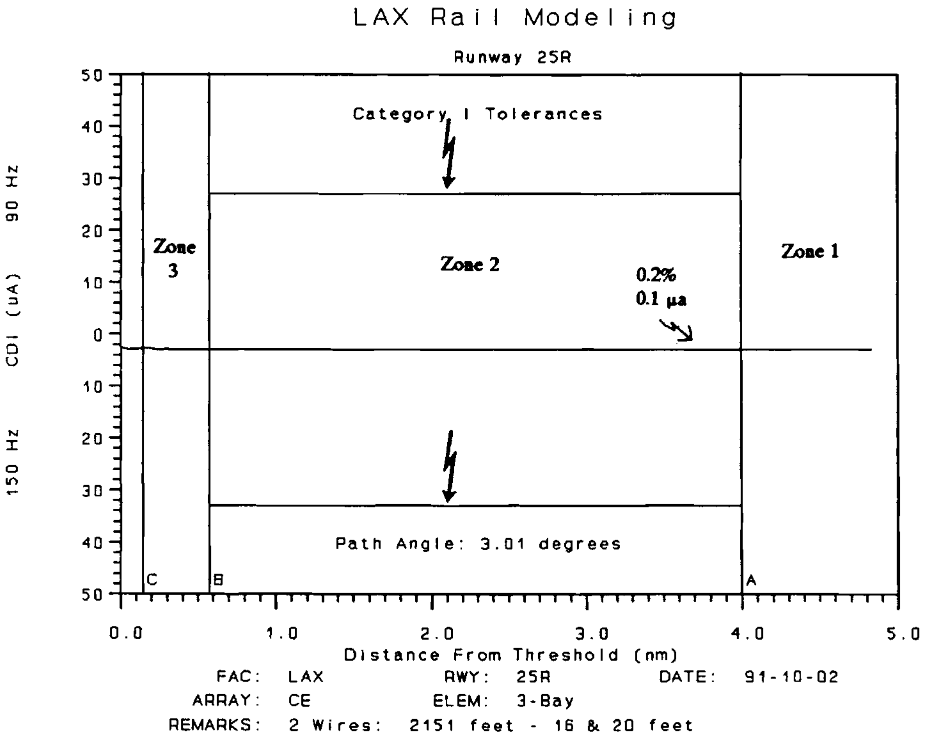


Figure 4-10. Prediction of Course Roughness Produced with 2-wire OCS, 2000 Feet Long, Set in Planned Location in Front of the Runway 25R Capture-effect Glide Slope.

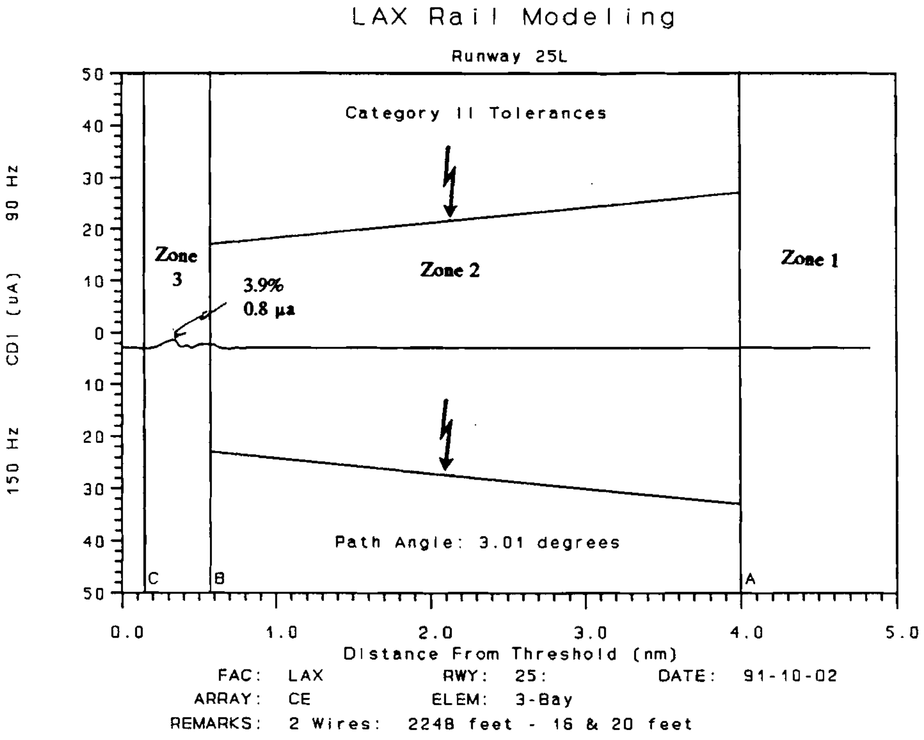


Figure 4-11. Prediction of Course Roughness Produced with 2-wire OCS, 2000 Feet Long, Set in Planned Location in Front of the Runway 25L Capture-effect Glide Slope.

b. Proposed Solution to the Railcar Problem.

The Metro Green Line railcars are large conducting objects which can disturb the guidance signals produced by the glide slope. The disturbance is caused by scattering of the radio frequency energy from the railcar surfaces which are reasonably good electrical conductors. The OCS is also a scatterer but with a different geometry, obviously.

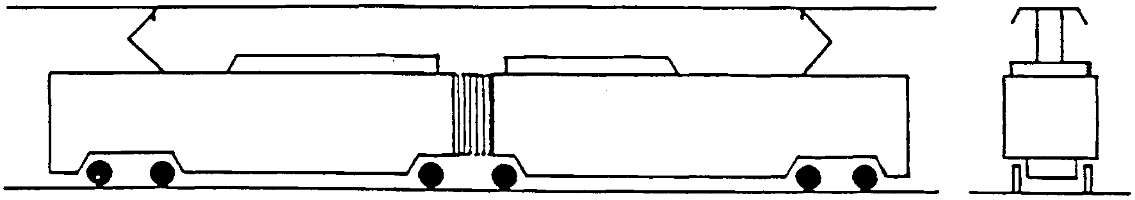
The solution to minimizing the effects of the railcars on the performance of the glide slopes is to have all of the glide slopes of the capture-effect configuration. As mentioned previously, this proposed solution needs effect a change only to the Runway 24L null-reference system. All other glide slopes at LAX are already of the capture-effect type.

c. Discussion and Data Supporting the Recommendations Concerning the Railcars.

The Metro Green Line railcars are modeled using the dimensional data given in Table 4-1 and their effects on the performance of each glide slope are determined using calculational methods. The results of the modeling and location of the railcars modeled are shown in Figures 4-12 through 4-25. The model used for this work is the Physical Optics model, the first version of which was developed at Ohio University in 1965 by David Hill. Good confidence has been gained through testing over the past two decades; therefore, it has not been necessary to perform validation measurements as a part of this project as was done in the OCS use. This physical optics model is the one used by Ohio University for performing the calculations that are the foundation for the critical areas standards published by the FAA that are currently in use.

Initial considerations were first given to a three-car train on the alignment shown in Section I. Subsequently, a different scenario was developed because of the evolution in the thinking of those responsible for the final layout of the guideway and the placement of the station. The attempt for this modeling study with the railcars is to include effects due to the maximum possible number of cars and the inclusion of a station. The latest information, obtained in November 1991, motivated the scene of having 6 railcars (2 trains of three cars each) which would be positioned, as with a snapshot, end to end. The practical case would be that one train would be sitting on a tail track which was hypothesized and the other moving towards it. The effective length of the train therefore becomes 540 feet. In addition, a station is assumed to exist as shown in Figure 4-12 which is based on the drawing RA-C-109 produced by Bechtel. The aforementioned station necessarily relates only to the course structures with the glide slopes serving the north complex. Modeling was also performed to predict performance for the systems on the south complex, viz., those serving Runways 25L and 25R. The results of these predictions are shown specifically in Figures 4-16 and 4-17.

Table 4-1. Characteristics of Vehicle used for the Mathematical Modeling. (Provided by Los Angeles County Transportation Commission)



BLUE LINE/GREEN LINE

Length (ft)	90 Articulated Car Length
Width (ft)	8.8
Height (ft)	11.5
Passengers/Car	~160 people
Cars/Train (Max)	3
Passengers/Train	~480 people (max)
Control	Manual / Automatic
Speed	55 / 65 mph

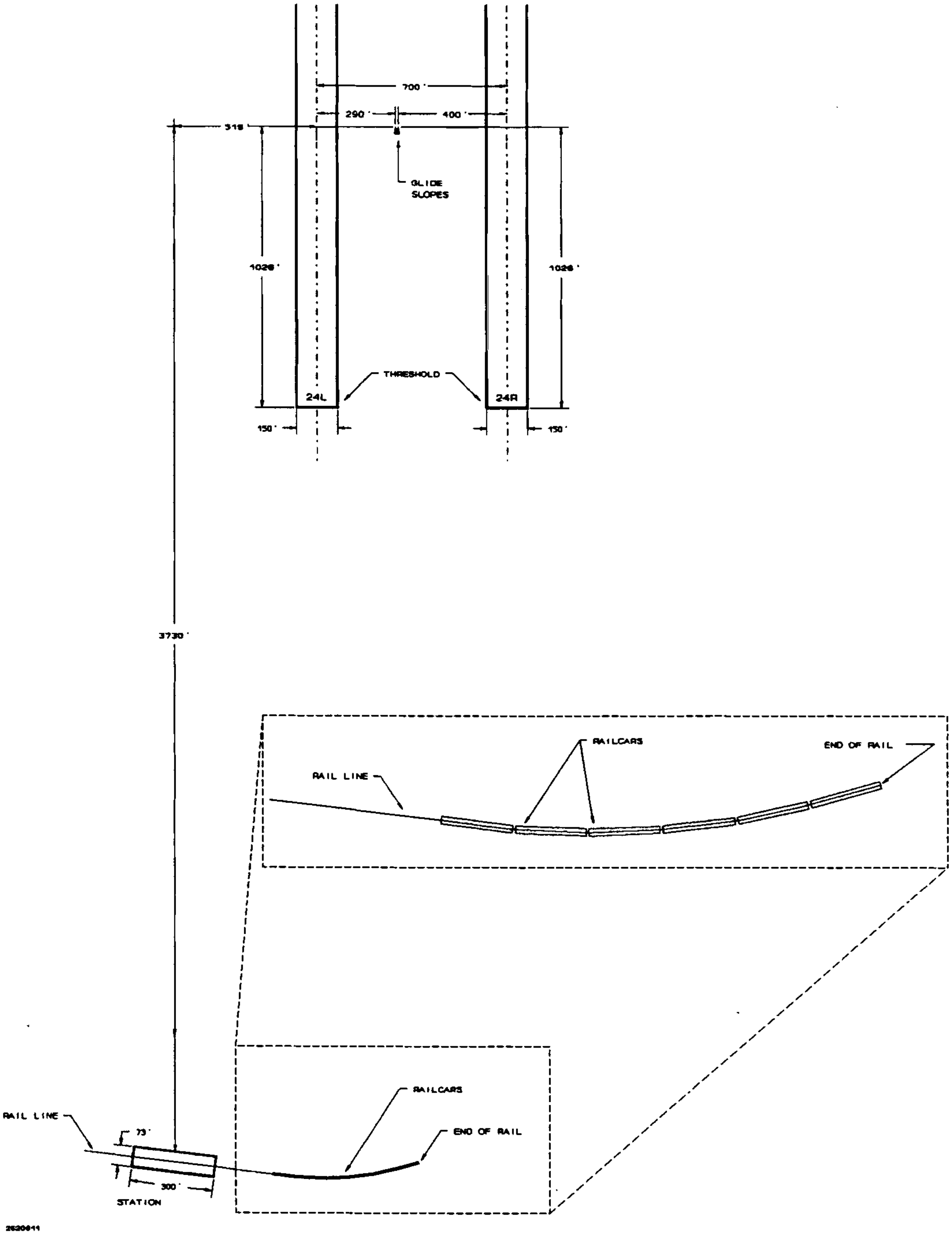


Figure 4-12. General Layout of Six Railcars and Station in Front of the Glide Slopes Serving Runways 24L and 24R (North Complex).

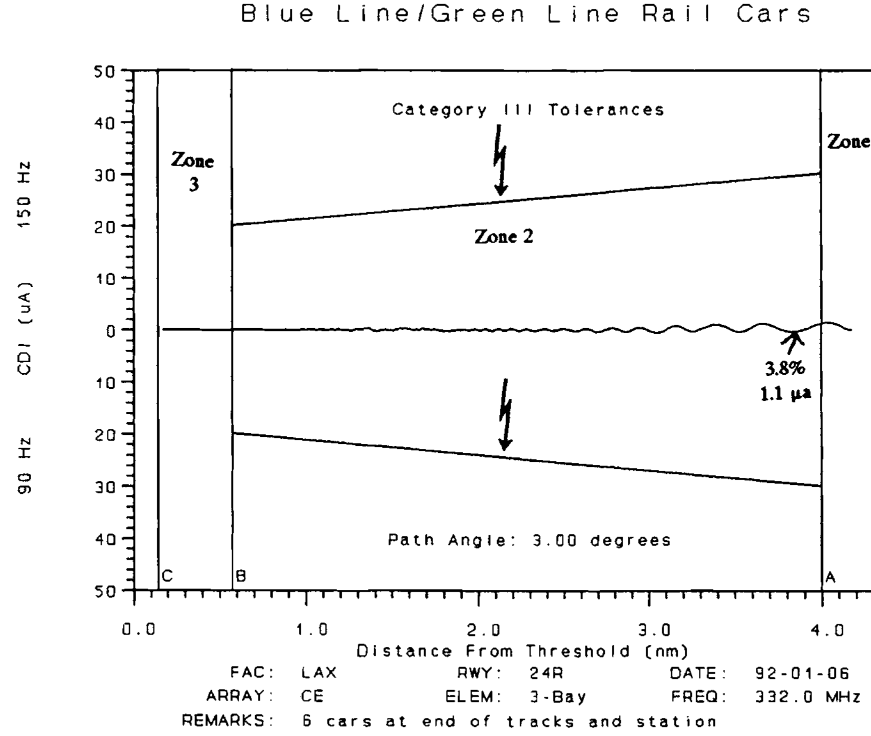


Figure 4-13. Prediction of Course Roughness Produced with 6 Metro Green Line Railcars and the Station in Front of Runway 24R Capture-effect Glide Slope.

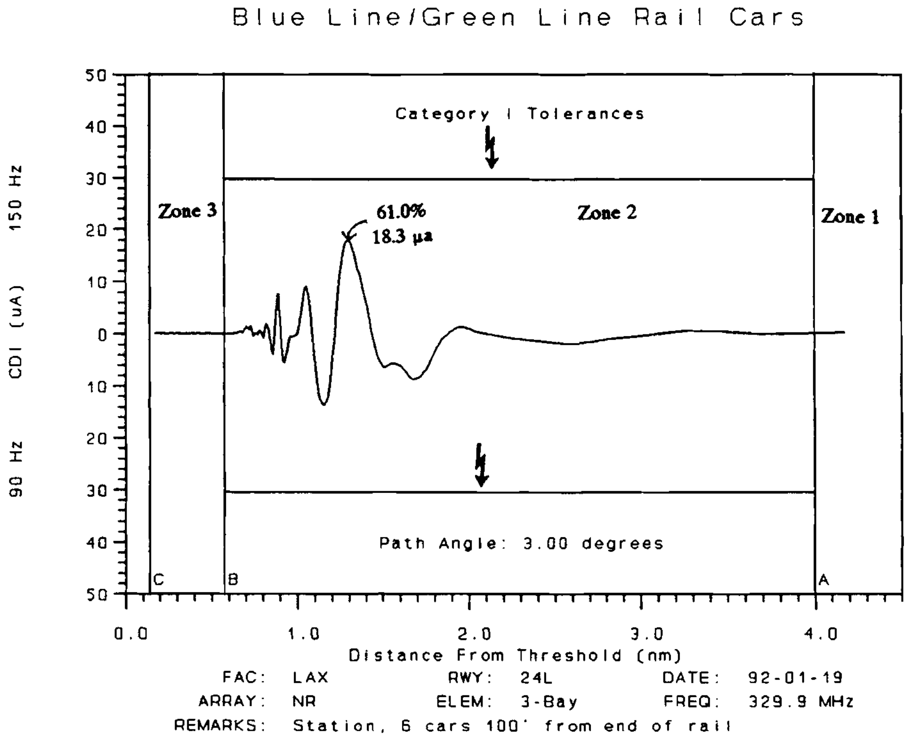


Figure 4-14A. Prediction of Course Roughness Produced with 6 Metro Green Line Railcars and the Station in Front of Runway 24L Null-reference Glide Slope.

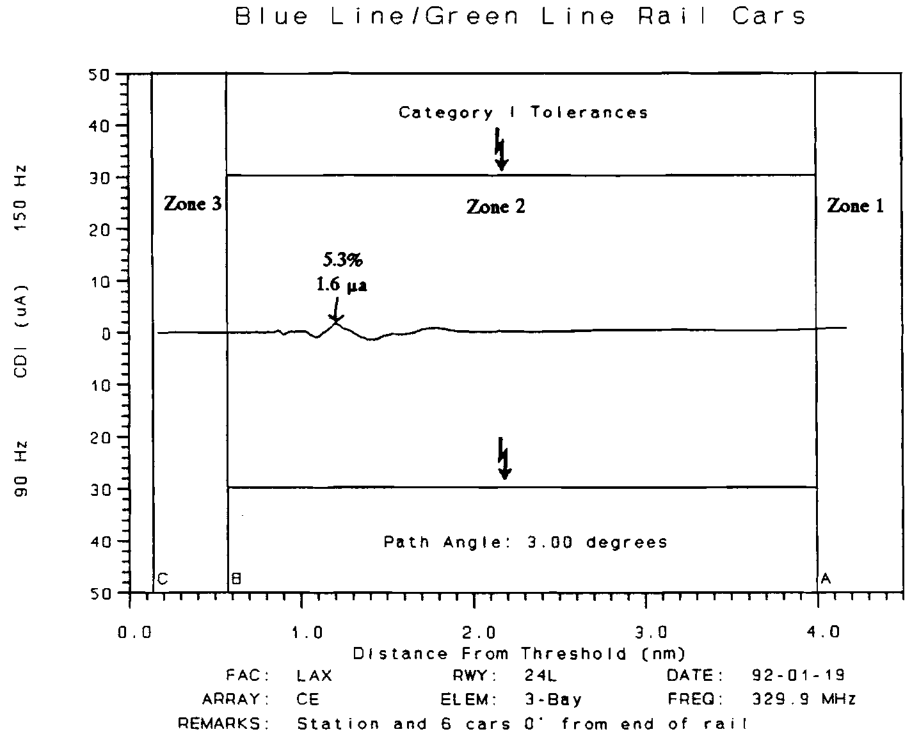


Figure 4-14B. Prediction of Course Roughness Produced with 6 Metro Green Line Railcars and the Station in Front of Runway 24L Capture-effect Glide Slope.

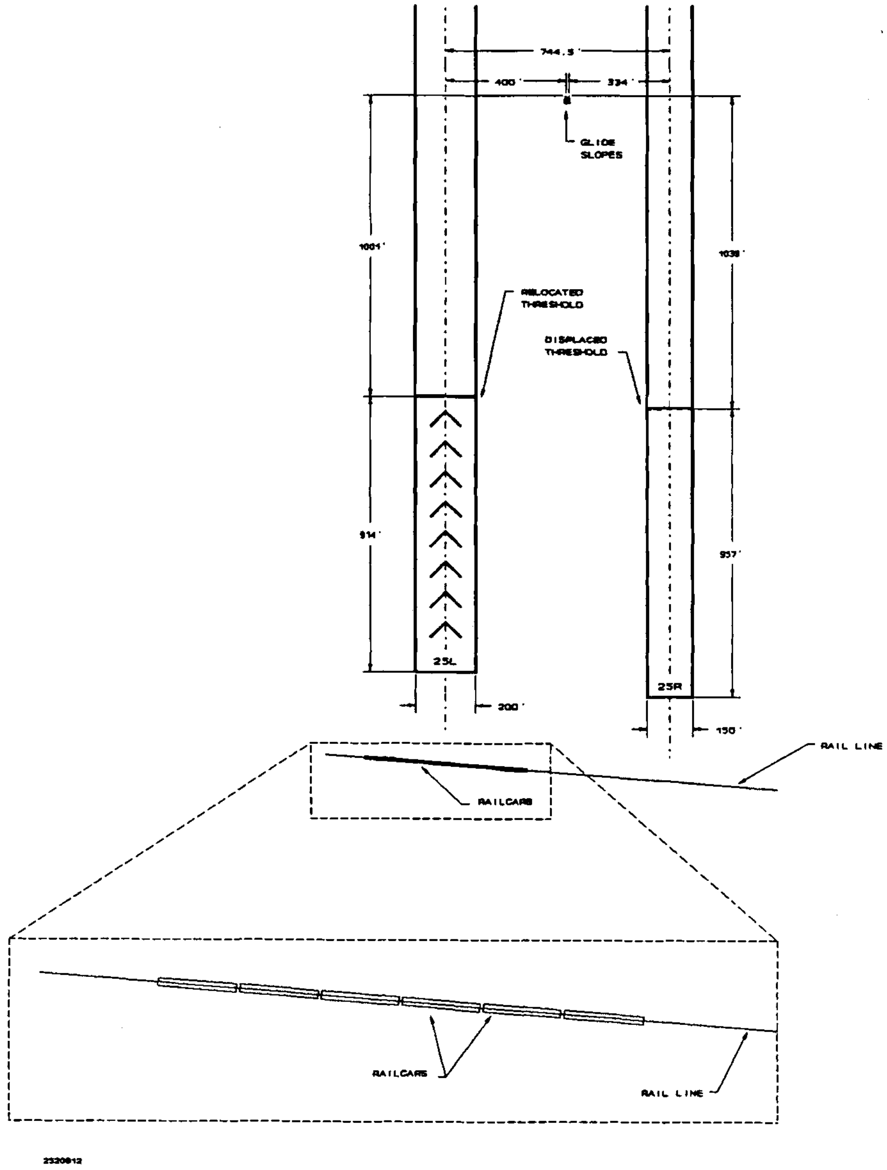


Figure 4-15. General Layout of Six Railcars in Front of the Glide Slopes Serving Runways 25L and 25R (South Complex).

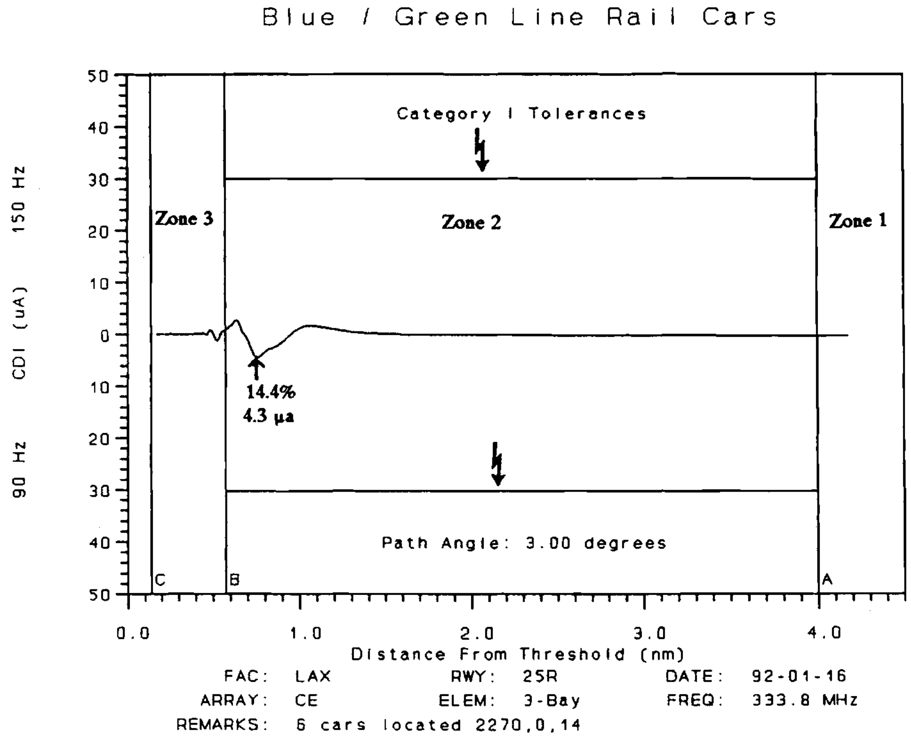


Figure 4-16. Prediction of Course Roughness Produced with 6 Metro Green Line Railcars and the Station in Front of Runway 25R Capture-effect Glide Slope.

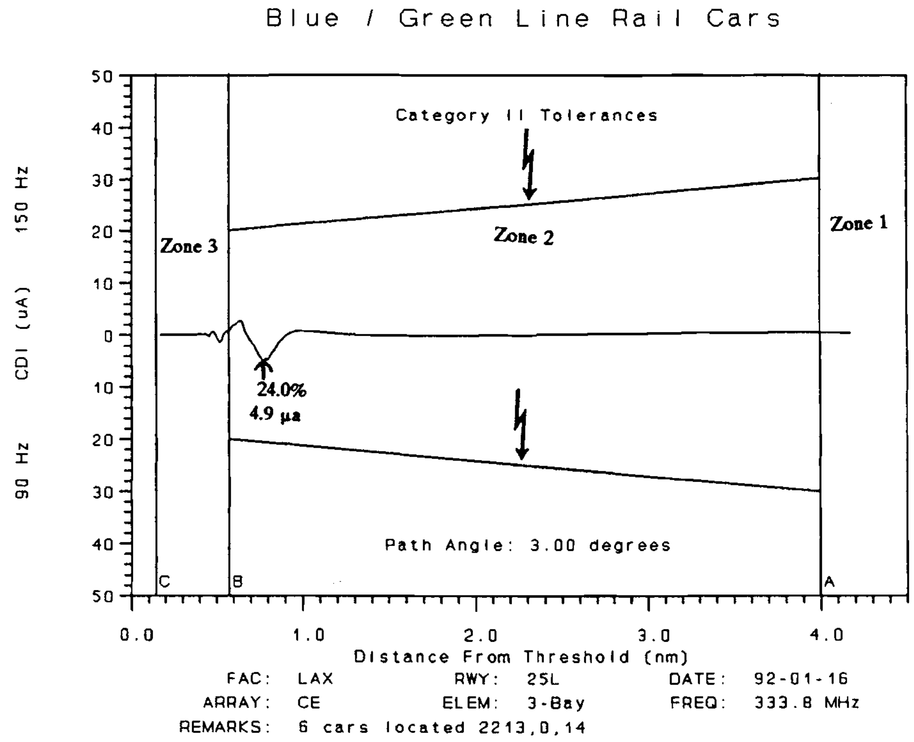


Figure 4-17. Prediction of Course Roughness Produced with 6 Metro Green Line Railcars and the Station in Front of Runway 25L Capture-effect Glide Slope.

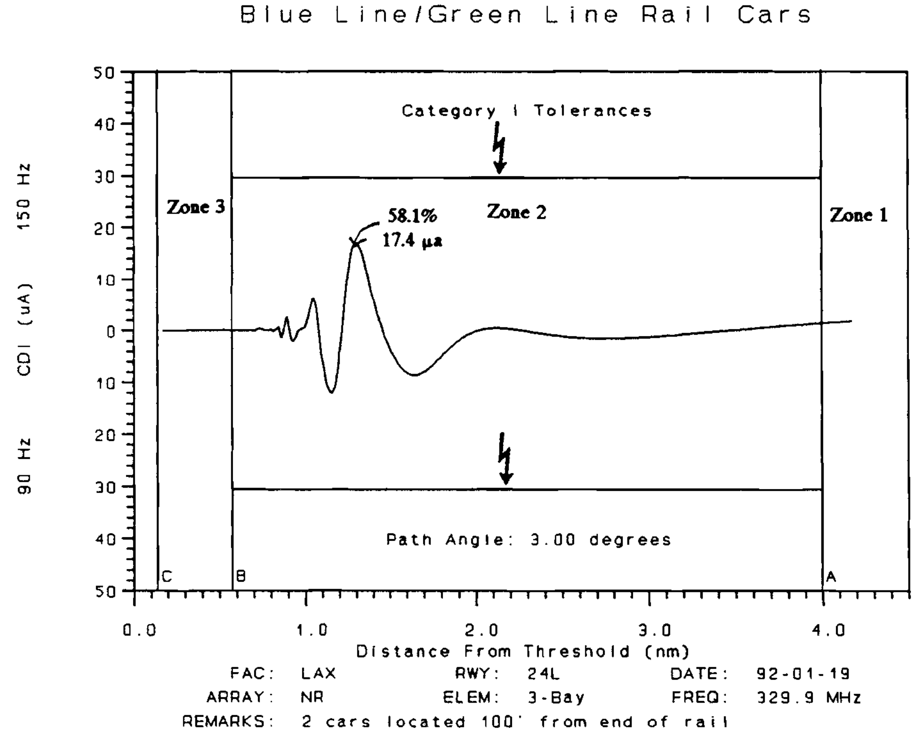


Figure 4-18. Predicted Course Roughness Produced by a Section of 2 Metro Green Line Railcars in Front of the Runway 24L Null-reference Glide Slope.

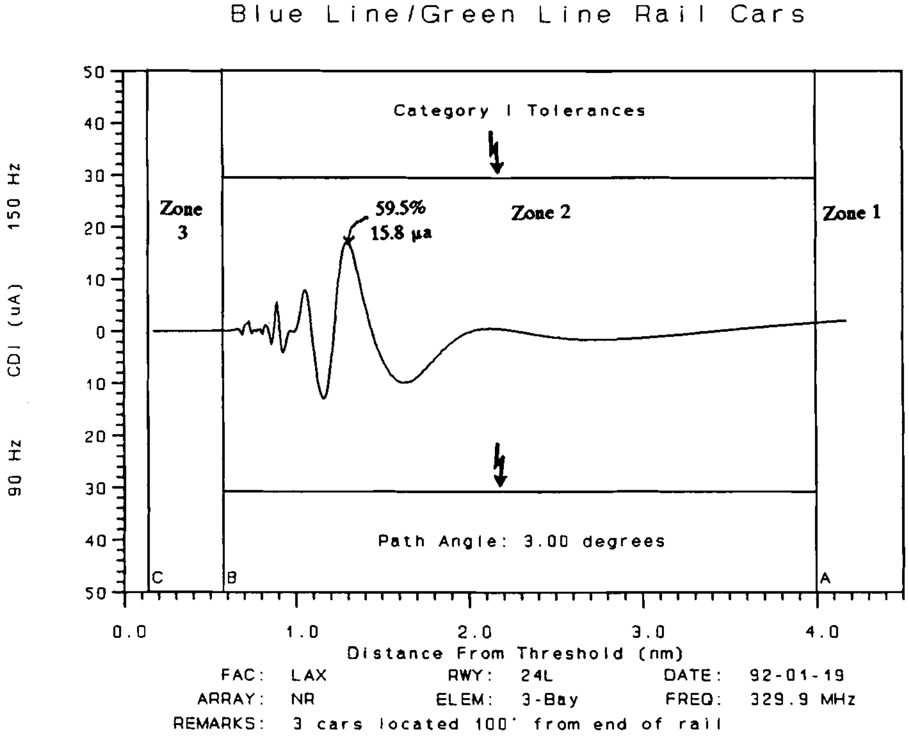


Figure 4-19. Predicted Course Roughness Produced by a Section of 3 Metro Green Line Railcars in Front of the Runway 24L Null-reference Glide Slope.

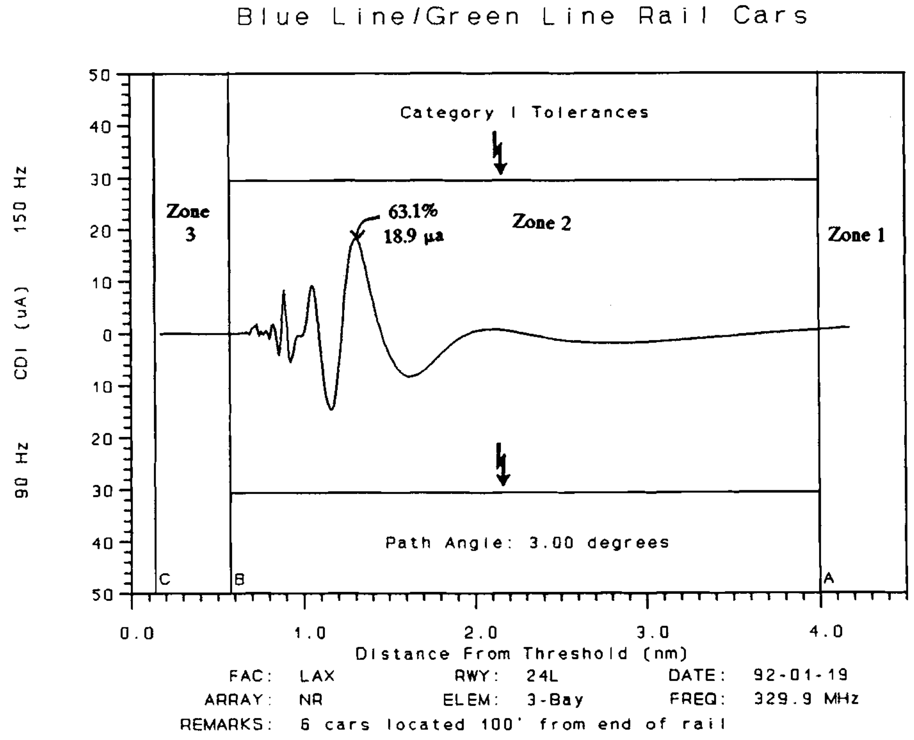


Figure 4-20. Predicted Course Roughness Produced by a Section of 6 Metro Green Line Railcars in Front of the Runway 24L Null-reference Glide Slope.

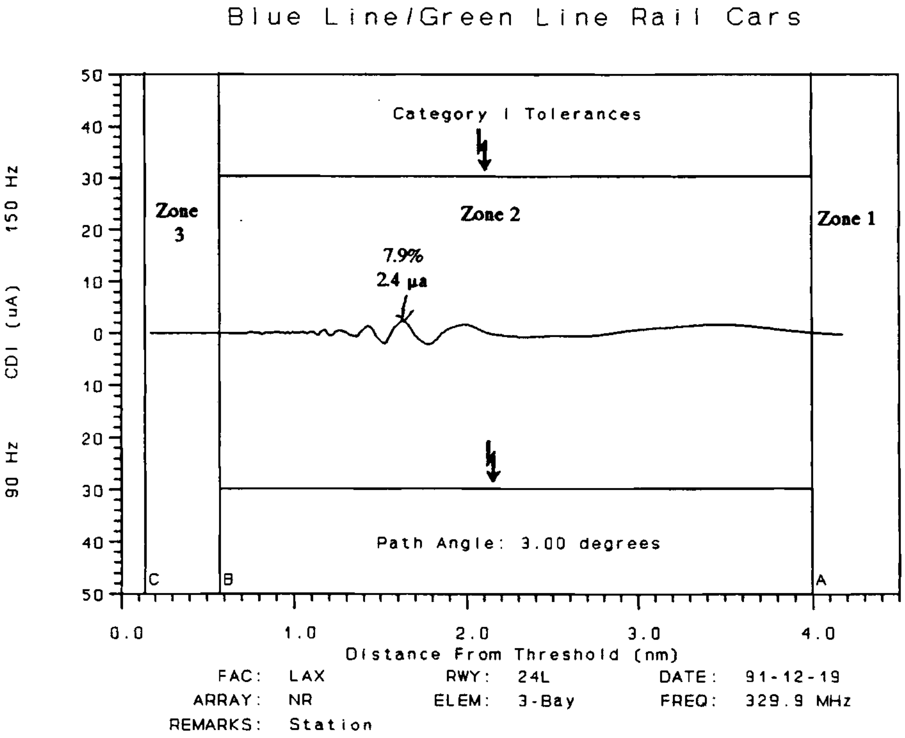


Figure 4-21. Predicted Course Roughness on the Runway 24L Null-reference Glide Slope Produced by the Metro Green Line Station in Parking Lot C.

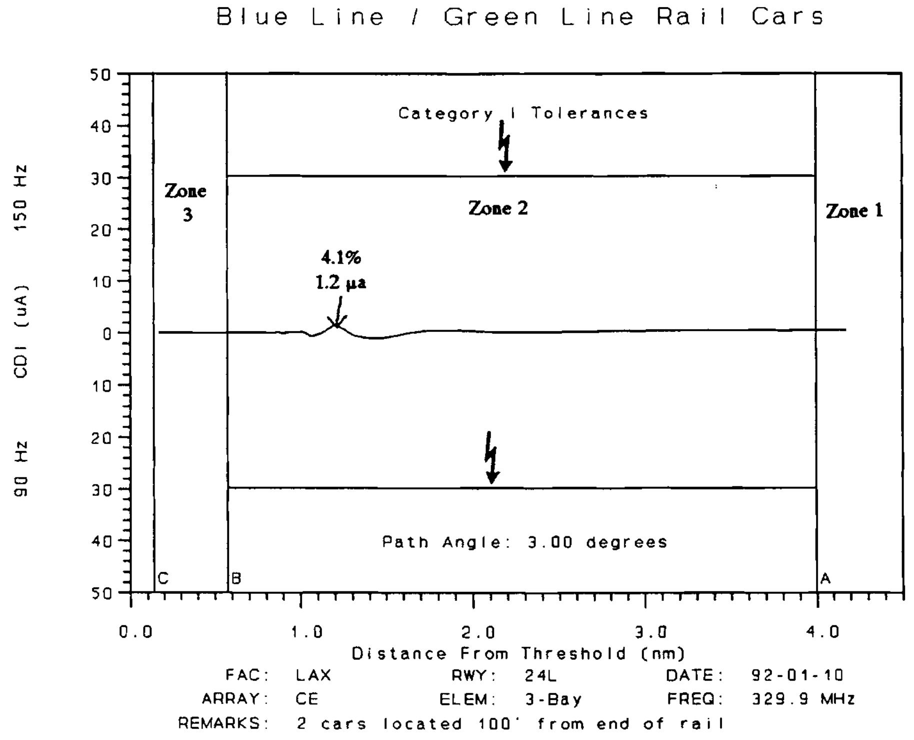


Figure 4-22. Predicted Course Roughness Produced by a Section of 2 Metro Green Line Railcars in Front of a Capture-effect Glide Slope that Would Serve Runway 24L.

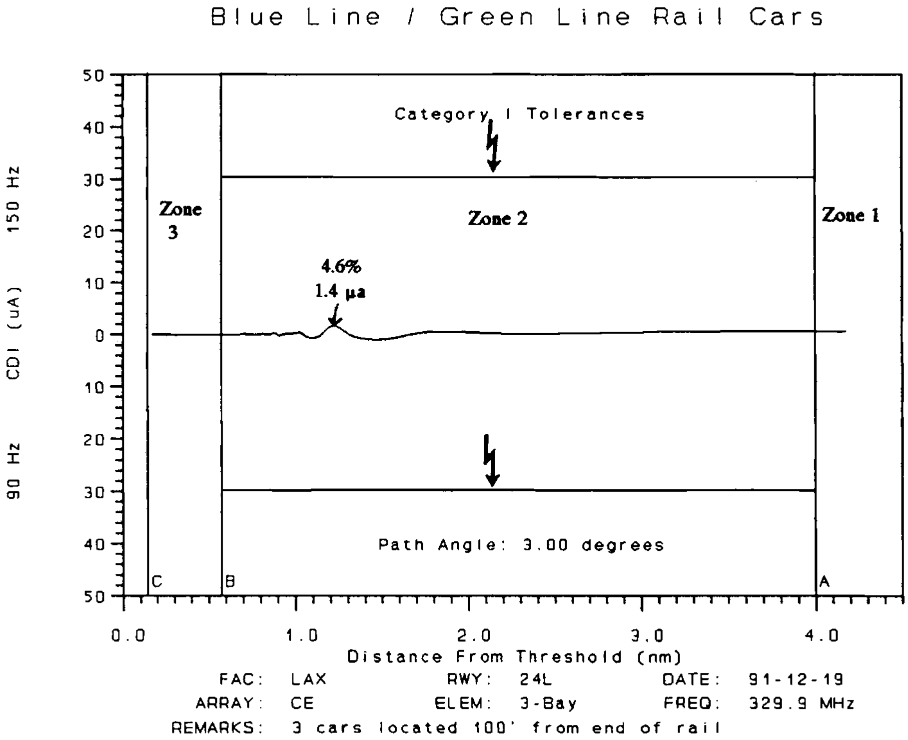


Figure 4-23. Predicted Course Roughness Produced by a Section of 3 Metro Green Line Railcars in Front of a Capture-effect Glide Slope that Would Serve Runway 24L.

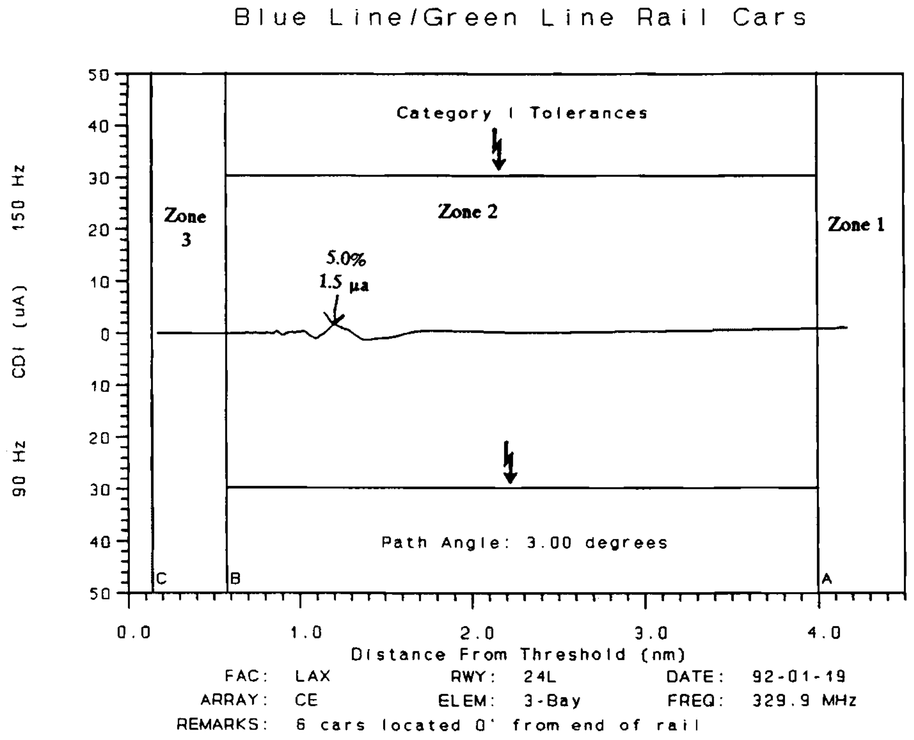


Figure 4-24. Predicted Course Roughness Produced by a Section of 6 Metro Green Line Railcars in Front of a Capture-effect Glide Slope that Would Serve Runway 24L.

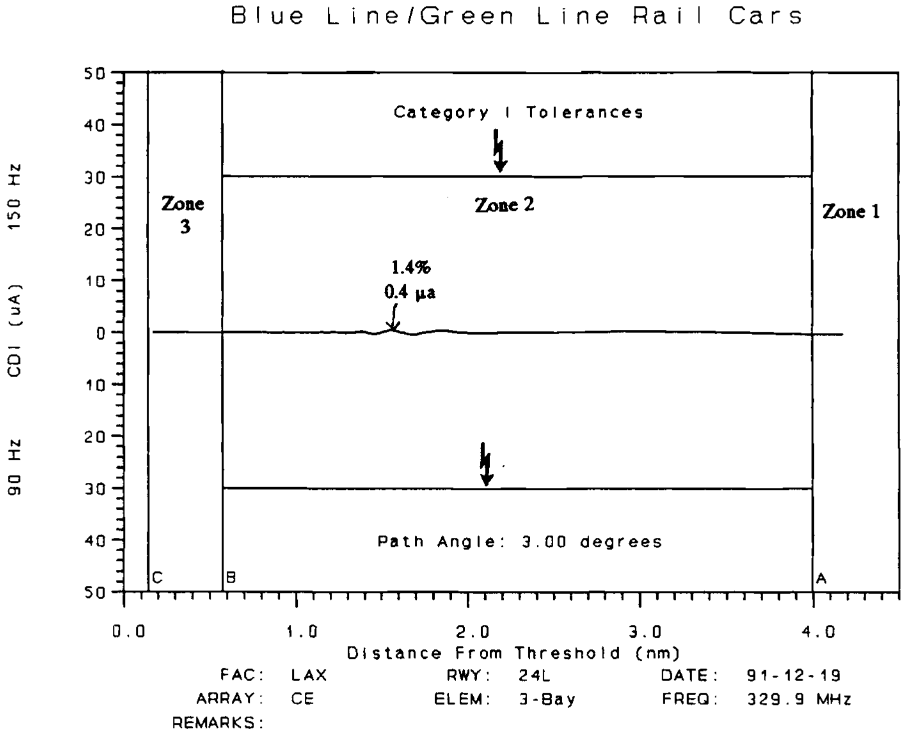


Figure 4-25. Predicted Course Roughness Produced by the Metro Green Line Station in Parking Lot C in Front of the Capture-effect Glide Slope that Would Serve Runway 24L.

For execution of the calculations performed as a part of the modeling programs, the dimensions and locations of the railcars and the station, together with other specific physical details, several parameters were taken into account. These were:

Height of the tracks above the airport,
Angle the tracks make with the centerline of the runway,
Specific offsets of the glide slope masts from the runway centerline,
  including the proposed collocation of the antennas for 24L and 24R,
Specific antenna offsets on the respective antenna masts.

With respect to the north complex, the Runway 24R glide slope already has a capture-effect system. Accordingly, principal attention is given to the Runway 24L system because it is the far more vulnerable system. It is most vulnerable to disturbance because it is presently operating as a null-reference type system and the station and masses of railcars are located closer to this facility.

Figures 4-14A and 4-14B show the predicted course roughness due to the effects of the 6 cars and the station. The figures present the worst-case locations of the cars. The path perturbations are found to be 61.0% of Category I tolerance limits with the null-reference system and 5.3% for a capture-effect system at the same location.

Every attempt was made to determine what would be the most devastating effect that would be produced by the railcars and the station. Over 60 scenarios were run to develop the most conservative case to present, i.e., what is the physical scene that would produce the most adverse affect on the navigation system performance. For comparison purposes some other scenarios were modeled and effects on the glide slope system performance predicted. Further, to check the validity of the model, another type model was used. The more recently developed Geometrical Theory of Diffraction (GTD) was applied and results noted.

For the purpose of analyzing the effects of different combinations of cars, additional calculations were made. Figures 4-18, 4-19 and 4-20 show the predictions for the existing null-reference system for two, three and six car cases, all with no station. The worst locations determined by numerous calculations, again have been sought. The exact positioning of the cars is found to be very important in determining the magnitude of the path perturbation. The findings are that the railcar position can be critical to within about 10 feet. The time needed to identify the precise worst case has been extensive. For example, the worst-case position for the six-car section gives path roughness of 63.1% of Category I tolerances. Interestingly, the calculation for the six cars plus the station give roughness of 61.0% which is slightly less, probably due to some signals from the station providing cancellation. The effects of the station alone have also been calculated to be 7.9% with the null-reference system. This plot is shown in Figure 4-21.

Calculations with these scenarios have all been repeated for the capture-effect system and the results are shown in Figures 4-22, 4-23, 4-24 and 25.

A summary of all of the quantitative results from the preceding calculations is shown in Table 4-2. The maximum effect of the railcars alone is predicted to be with the null-reference system operating on Runway 24L with the worst calculated case consuming 63.1% to which must be added 2.4% for the OCS giving a total of 65.5% of Category I tolerances. If a change to a capture-effect system is made, the prediction for the roughness is that it will be reduced to only 6.8% of the tolerance.

TABLE 4-2. Peak Path Roughness in Microamperes of CDI Variation and Per Cent of the Category I and III Tolerance Limits are Shown for Runway 24L.

REFLECTORS	APPLICABLE FIGURE		PEAK CDI		% CAT I		% CAT II / III
	N-R	CEGS	N-R	CEGS	N-R	CEGS	CEGS
2 Cars	4-18	4-22	17.4	1.2	58.1	4.1	5.7
3 Cars	4-19	4-23	15.8	1.4	59.5	4.6	6.3
6 Cars	4-20	4-24	18.9	1.5	63.1	5.0	6.7
Station	4-21	4-25	2.4	0.4	7.9	1.4	1.8
6 Cars + Station	4-14A	4-14B	18.3	1.6	61.0	5.3	7.0

Based on these data the proposed solution, viz., converting to the capture-effect system, is deemed correct.

For drawing the final conclusions, one must add the effects of the OCS, the railcars, and the station to the present environment. Conveniently, the effects occur in the same ILS zone and this allows for simple addition. Table 4-3 gives the effects of the environment and Table 4-4 combines the effects of the OCS and the Railcars and Station. The final results are shown in Table 4-5 where the total effects are presented.

Table 4-3. Present Environment Given by FAA Flight Check Records.

RUNWAY	ZONE 1 ua / % tol	ZONE 2 ua / % tol	ZONE 3 ua / % tol
25L Cat II	2 / 13	6 / 29	4 / 20
25R Cat I	2 / 13	5 / 17	6 / 20
24L Cat I	15 / 50	23 / 77	10 / 33
24R Cat II/III	8 / 27	6 / 30	6 / 30

Note: Zone 1 is from 10 to 4 miles from the runway; Zone 2 is from 4 miles to 3500 feet and Zone 3 is closer to the runway than 3500 feet.

Table 4-4. Summary of Calculated Path Roughness in Zone 2 due to the Environment, the Presence of the OCS, and 6 Railcars plus the Station.

RUNWAY		OCS		6 RAILCARS + STATION		TOTAL %
		APPLICABLE FIGURE	VALUES µA / % TOL	APPLICABLE FIGURE	VALUES µA / % TOL	
25L CAT II		4-11	0.8 / 3.9 (ZONE 3)	4-17	4.9 / 24.0	27.9
25R CAT I		4-10	0.1 / 0.2	4-16	4.3 / 14.4	14.6
24L CAT I	NULL -REF	4-9	0.7 / 2.4	4-14A	18.3 / 61.0	63.4
	CEGS	4-8	0.5 / 1.8	4-14B	1.6 / 5.3	7.1
24R CAT II/III		4-7	0.5 / 2.6	4-13	1.1 / 3.8	6.4

Table 4-5. Total Path Roughness in Zone 2 due to the Environment, the OCS, and 6 Railcars and a Station.

RUNWAY		TOTAL
25L CAT II		56.9%
25R CAT I		31.6%
24L CAT I	NULL-REF	140.4%
	CEGS	37.1%*
24R CAT II/III		36.4%

*Based on measured CEGS performance on Runway 24R.

Note should be made that the overall performance figure for the Runway 24L null-reference system in Zone 2 is predicted to be 140.4% of Category I tolerances. The estimate for performance with a capture-effect system is 37.1% or a factor of 3.8 improvement.

In summary, the conclusion is reached that the multipath effect of the railcars will have a minimal impact on the operational capability, provided that capture-effect type systems are used on every runway. This is true even with the maximum number of railcars. The predicted effects of the Metro Green Line itself are, in general, much less than 30% of allowable tolerances. Runway 25L will be most affected, assuming that the Runway 24L system has been converted from its present null-reference configuration to a capture-effect system. This is principally due to the railcars being physically closer to the Runway 25L glide slope transmitting system and Category II tolerances being applied. The total roughness due to railcars, the OCS, the station and the present environment is expected to be 56.9% for Runway 25L, whereas the changeover to a capture effect on Runway 24L is expected to give 37.1% of Category I tolerances. Both of these are acceptable operational values.

3. Recommended Further Action.

The recommended action is that the 24L glide slope be converted to a capture-effect type. This is essential to keep the course perturbations caused by the railcars small enough to allow Category I tolerance to be met.

Table 4-5. Total Path Roughness in Zone 2 due to the Environment, the OCS, and 6 Railcars and a Station.

RUNWAY		TOTAL
25L CAT II		56.9%
25R CAT I		31.6%
24L CAT I	NULL-REF	140.4%
	CEGS	37.1%*
24R CAT II/III		36.4%

*Based on measured CEGS performance on Runway 24R.

Note should be made that the overall performance figure for the Runway 24L null-reference system in Zone 2 is predicted to be 140.4% of Category I tolerances. The estimate for performance with a capture-effect system is 37.1% or a factor of 3.8 improvement.

In summary, the conclusion is reached that the multipath effect of the railcars will have a minimal impact on the operational capability, provided that capture-effect type systems are used on every runway. This is true even with the maximum number of railcars. The predicted effects of the Metro Green Line itself are, in general, much less than 30% of allowable tolerances. Runway 25L will be most affected, assuming that the Runway 24L system has been converted from its present null-reference configuration to a capture-effect system. This is principally due to the railcars being physically closer to the Runway 25L glide slope transmitting system and Category II tolerances being applied. The total roughness due to railcars, the OCS, the station and the present environment is expected to be 56.9% for Runway 25L, whereas the changeover to a capture effect on Runway 24L is expected to give 37.1% of Category I tolerances. Both of these are acceptable operational values.

3. Recommended Further Action.

The recommended action is that the 24L glide slope be converted to a capture-effect type. This is essential to keep the course perturbations caused by the railcars small enough to allow Category I tolerance to be met.

4. References.

[4A-1] Constantine A. Balanis, "Advanced Engineering Electromagnetics", John Wiley and Sons, New York, 1989, p. 717-720.

[4A-2] Robert W. Redlich, "Internal Memo", Ohio University Avionics Engineering Center, Athens, Ohio, September 1991.

[4A-3] Constantine A. Balanis, "Antenna Theory, Analysis and Design", Harper and Row, New York, 1982, p. 107.

[4A-4] Phipps, Walter and Simbo Odunaiya, "A User's Guide to the Ohio University Geometric Theory of Diffraction Glide Slope Model (OUGS), Version 2.0", Technical Memorandum OU/AEC 57B-88TM/1-4, Avionics Engineering Center, Department of Electrical and Computer Engineering, Ohio University, Athens, Ohio, February 1988, Rev. July 1988.

[4A-5] Phipps, Walter D. and Simbo A. Odunaiya, "A User's Guide to the Modified Physical Optics Instrument Landing System Mathematical Model, Version 2.01", Technical Memorandum OU/AEC 56-88TM/33-2, Avionics Engineering Center, Department of Electrical and Computer Engineering, Ohio University, Athens, Ohio, Jan. 1988, Rev. Aug. 1988, Rev. June 1989.

B. Design for Improving the Quality of Runway 24L Glide Slope Performance.

1. Statement of the Problem.

As indicated earlier, planned alignment of the Metro Green Line results in the rail right-of-way cutting perpendicularly across in front of all glide slopes serving landings to the west at Los Angeles International Airport. These would be Runways 24R & L referred to as the north complex and 25R & L constituting the south complex. From proximity considerations the glide slopes serving Runways 25L and 25R are the most vulnerable to derogation because of multipath effects created by the two conductors, specifically the Overhead Conductor System (OCS) and the messenger that will be permanently located approximately 20 feet above the runway elevation under the approach path. [4B-6] Fortunately the 25R & L Runways already have the most capable glide slope system, viz., the capture effect type, presently in place, to minimize the effects of potential multipath from conductors located below the approach path.

Runway 24L in the north complex, has the only null-reference system providing glide slope information to pilots approaching from the east. The null-reference system is a much less capable system for protecting the path guidance information from corruption that is produced when signals arrive at the aircraft from other than a direct route. The present Runway 24L path is presently operating at 77% of Category I tolerance limits. This is in contrast to 20% of Category I limits which is experienced with the 24R capture effect located at essentially the same location. A conversion to a capture-effect system for 24L can realistically be expected to provide at least the same quality signal which is better than a 2 to 1 improvement.

An obvious question is, why has there not been a capture-effect system installed before this time. The answer that was obtained during this investigation was that many years ago, one had been installed but was removed probably when Runway 24R was upgraded to Category III status. The FAA insists on a 400-foot separation between the mast and centerline for the Category III operations.

The reason for the removal was that the 50% greater tower height required for the capture-effect system was not acceptable when the mast could only be located approximately 290 feet from the centerline of Runway 24L and maintain 400 feet from the centerline of Runway 24R. It is useful to note that the centerline-to-centerline spacing of Runways 25L and 25R is approximately 740 feet.

Some background data may be helpful for this to make sense to the reader. Figure 4-20 shows a photograph of the two glide slope transmitting antenna systems located on adjacent masts. The mast on the left, in the photo, supports two antennas for the null-reference system that serves Runway 24L. The mast on the right, in the photo, supports the three antennas of the capture-effect system which is set to provide service for the Category III system on Runway 24R. With almost identical environments the capture-effect system provides a factor of at least 2 and more generally a factor of 4 improvement over the null-reference in course quality. This is a typical and certainly realistic improvement factor to expect from the capture-effect system based on both theoretical results and results obtained in 30 years of experience with the capture-effect type system.

2. Proposed Solution to the Problem.

All experience indicates that the quality of the existing Runway 24L glide path can be improved significantly by going to a capture-effect type. The objection of a mast height great enough to accommodate the capture-effect system antennas can be negated by eliminating the dedicated mast for Runway 24L and utilizing the mast that is now in place for the 24R capture-effect glide slope to support the Runway 24L system antennas. Simply stated, the recommended solution is to use the present capture-effect mast for two systems. This eliminates the need for one of the present masts and eliminates an obstruction.

The mounting of two sets (3 each) of Model FA 8976 glide slope antennas on the same mast requires some special engineering. Both systems require the same path angle; hence, the height of the antennas normally would be expected to be identical. This obviously presents some problems when only a single vertical mast is considered.

The proposed solution to this problem is to stiffen the mast and mount two of the three pairs of capture-effect antennas adjacent to each other horizontally. This apparently simple geometry is complicated by the fact that an image glide slope, such as the capture-effect type, must have what is called antenna offset. This term is used to indicate that the set of three capture-effect antennas are not mounted vertically, one above the other. The radiated glide slope radio frequency energy must, in effect, be focused, not in front of the antennas, but on the flight track of the aircraft, along the localizer centerline. This requires that the antennas be offset, i.e., the antennas are located on the arc of a circle whose center is on the runway at a point opposite the mast. This means when there are two runways on opposite sides of the mast involved, the lower antennas must be close together and the top antennas are farther apart. In a practical sense an overlap in the lower antennas should be present in order to avoid excessive spacing of the upper antennas that would require great structural reinforcement to accommodate forces coming from wind loading. With a 400-foot spacing from the runway, the offset results in the upper antenna and middle antennas being 14.9 and 9 inches respectively closer to the runway than the lower antenna. With the present 290-foot spacing of the mast from the runway, the offsets are 20.6 and 12.4 inches for upper and middle antennas respectively. These would become 19.8 and 11.9 inches respectively for location on the common tower 300 feet from the Runway 24L centerline.

Figure 4-20. Glide Slope Antenna Masts for the Systems Serving Runways 24L and 24R.

3. Discussion and Data Supporting Recommendation.

There are two principal issues, one mechanical and one electrical. The first, can appropriate mechanical strength be provided to allow antennas to be mounted on the standard contemporary glide slope mast and withstand 100 mph winds? The second is, will needed non-standard physical placements of the FA-8976 glide slope antenna compromise significantly the electrical performance of the glide slope systems?

A structural analysis has been performed which shows that reinforcement of the Antenna Products Mast (Antenna Products Corp., Mineral Wells, Texas Tower Kit 1000-0563-202) is necessary to prevent rotational motion of the whole structural unit containing the FA-8976 antennas. This can be accomplished by modifications shown in a plan view depicted in Figures 4-21 and 4-22. Additional members to prevent rotation exist from the ends of the antenna bays to an anchor point at least 9 feet to the rear of the antenna mast. Each bay would be effectively reinforced by the addition of two horizontal members of aluminum channel to carry loads not only of the antenna weight but of torsional moments. These members would be tied to the aft portion with added central members. This, in effect, creates a tower with an effective increase in cross-sectional area compared to the original tower. This alteration could be a field modification made without removal of the tower from its base.

The second issue to be addressed is whether the displacement of the lower antenna from its ideal location offers significant changes to the vertical path structure in space. The vertical arrangement of the three capture-effect antennas is depicted with the side view shown in Figure 4-22a. Two cases as depicted in an arrangement shown in Figure 4-23 plus a normal case were calculated and the results are shown in Figures 4-24, 4-25 and 4-26. These two cases relate only to non-standard placement of the lower antennas with the middle and upper antennas in the normal locations for a capture-effect system with a flat, infinite ground plane.

Case 1.	Lower antenna displaced 26 inches upward; The character of the normal system is shown in Figure 4-24 and the response for this case is given in Figure 4-25.
Case 2.	Lower antenna displaced 26 inches downward; See Figure 4-26.

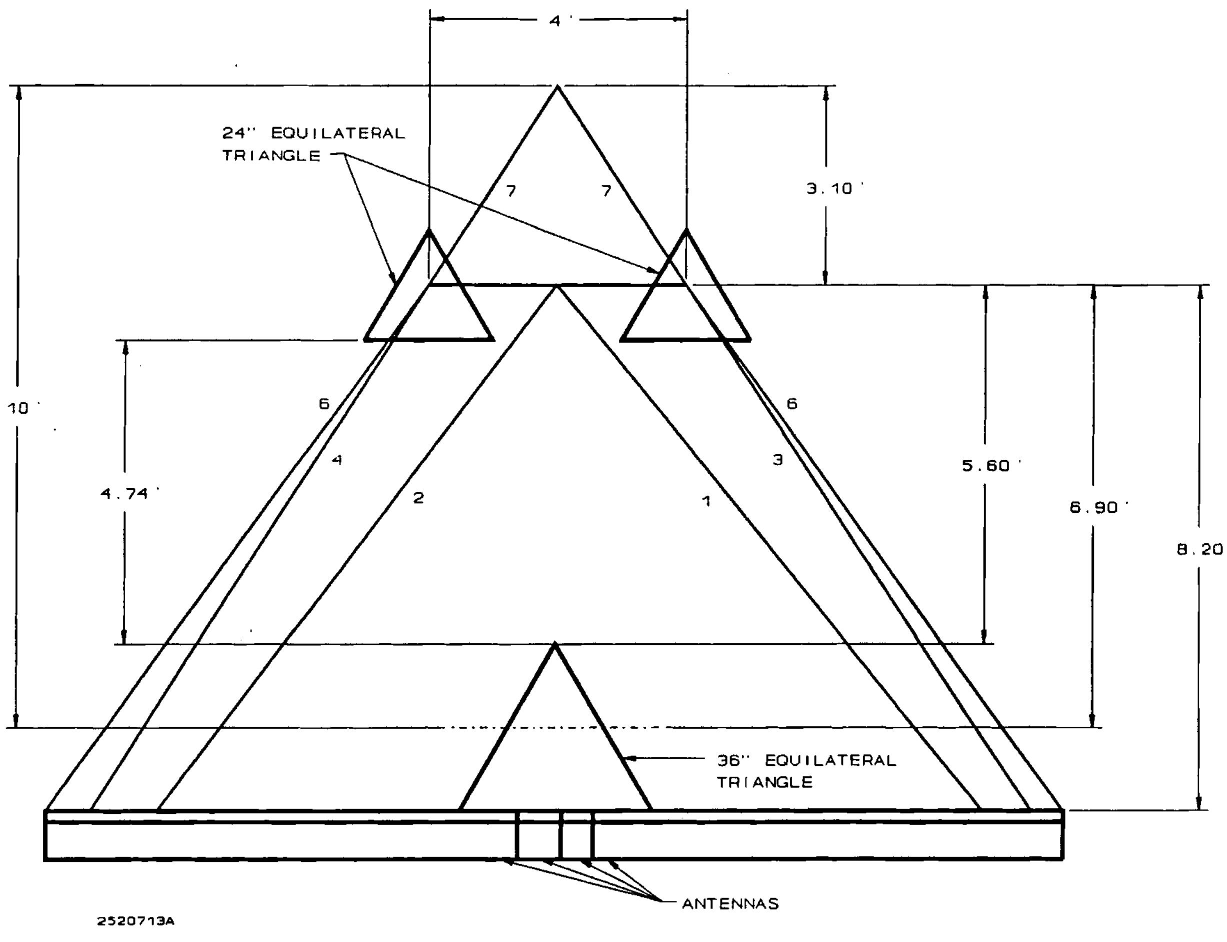


Figure 4-26. Plan View of Proposed Modification to the Standard Glide Slope Tower.

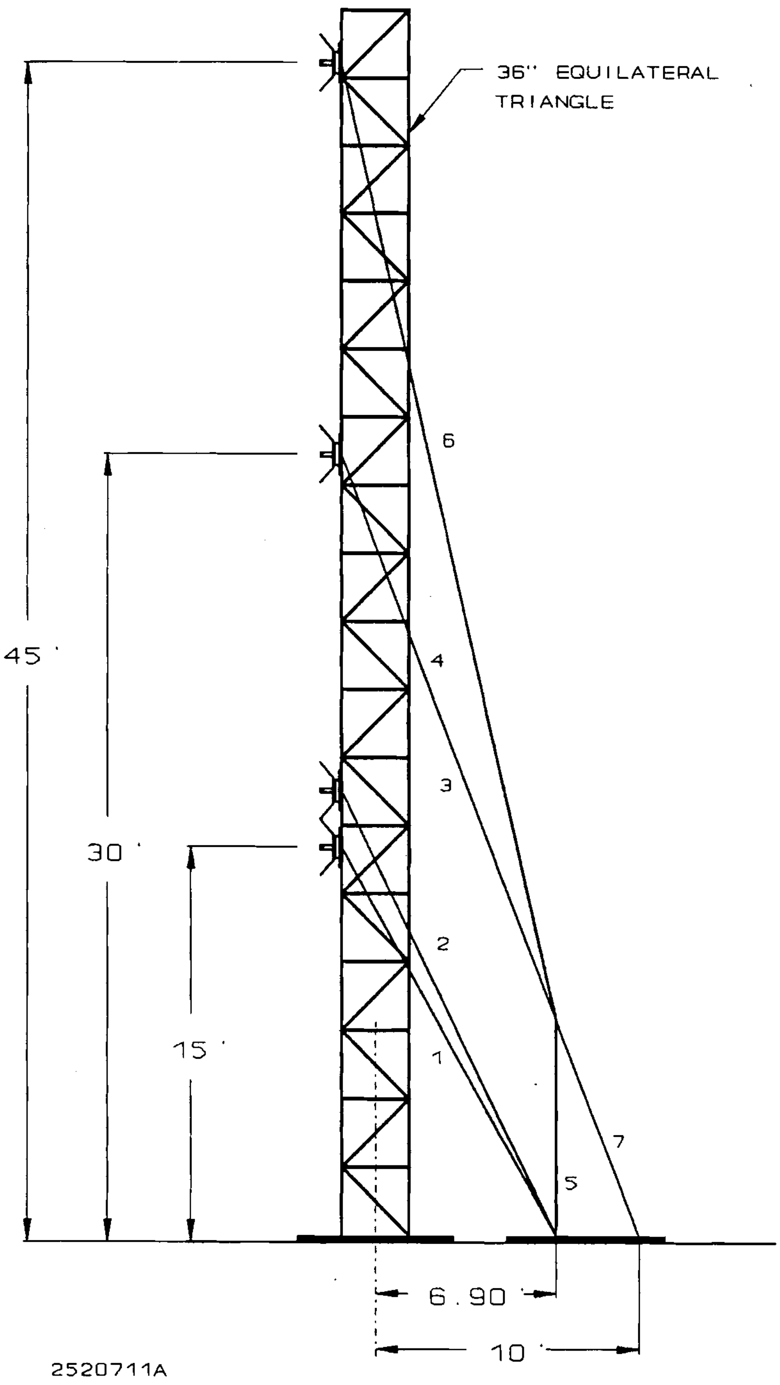
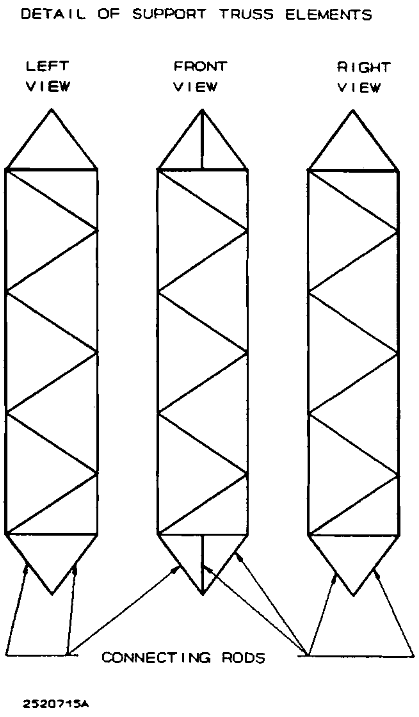


Figure 4-27. Sketch of Vertical Profile Looking Toward the Runway.



SUPPORT TRUSS ELEMENT GEOMETRY

ELEMENT NUMBER	ELEMENT LENGTH	ELEMENT GEOMETRY
1	18.13'	18" EQUILATERAL TRIANGLE
2	19.78'	18" EQUILATERAL TRIANGLE
3	24.24'	18" EQUILATERAL TRIANGLE
4	24.19'	18" EQUILATERAL TRIANGLE
5	8.16'	24" EQUILATERAL TRIANGLE
6	38.31'	18" EQUILATERAL TRIANGLE
7	8.96'	18" EQUILATERAL TRIANGLE

Figure 4-27a. Details of Support Truss Elements.

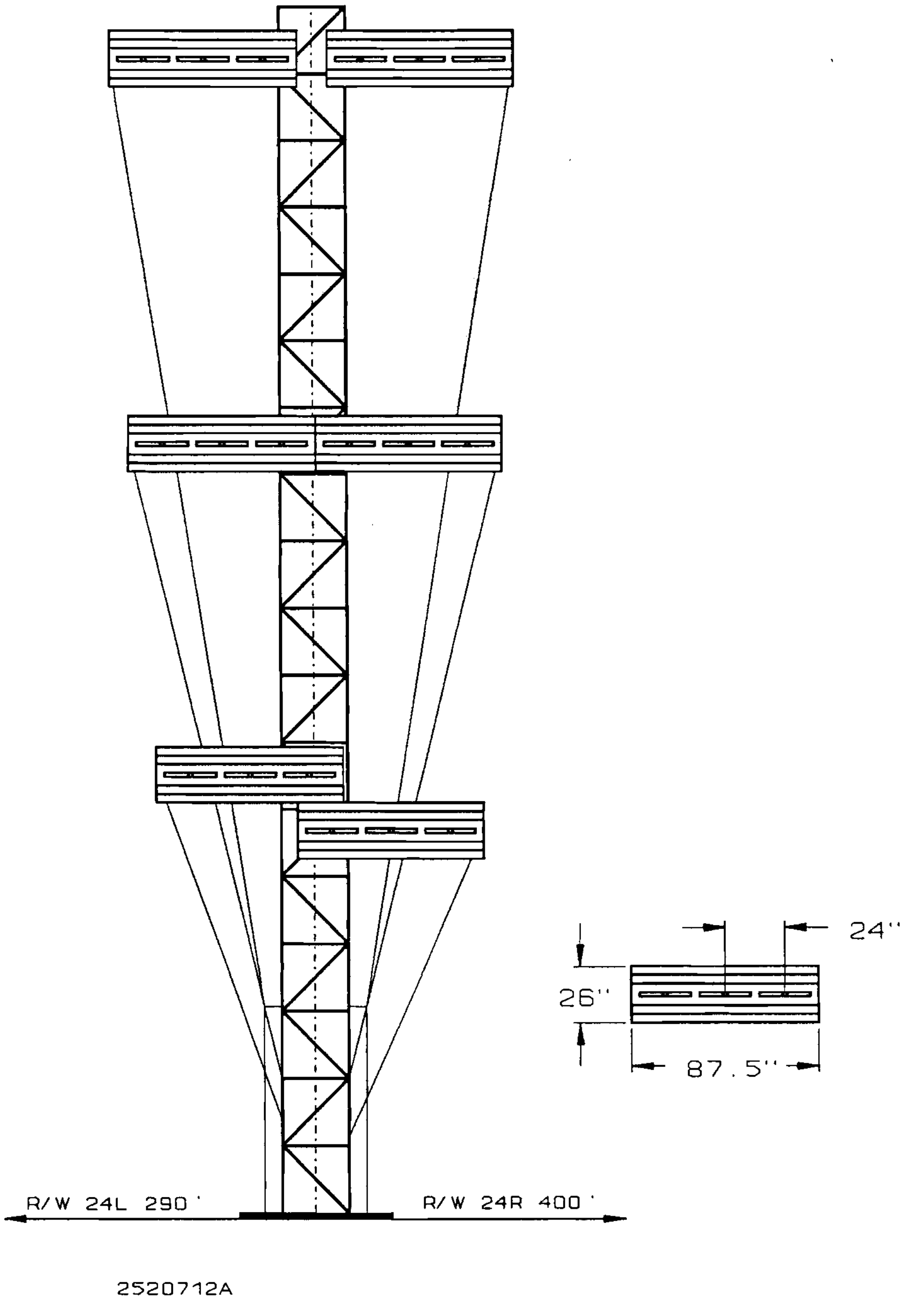


Figure 4-28. Sketch of Vertical View of Dual System Mast.

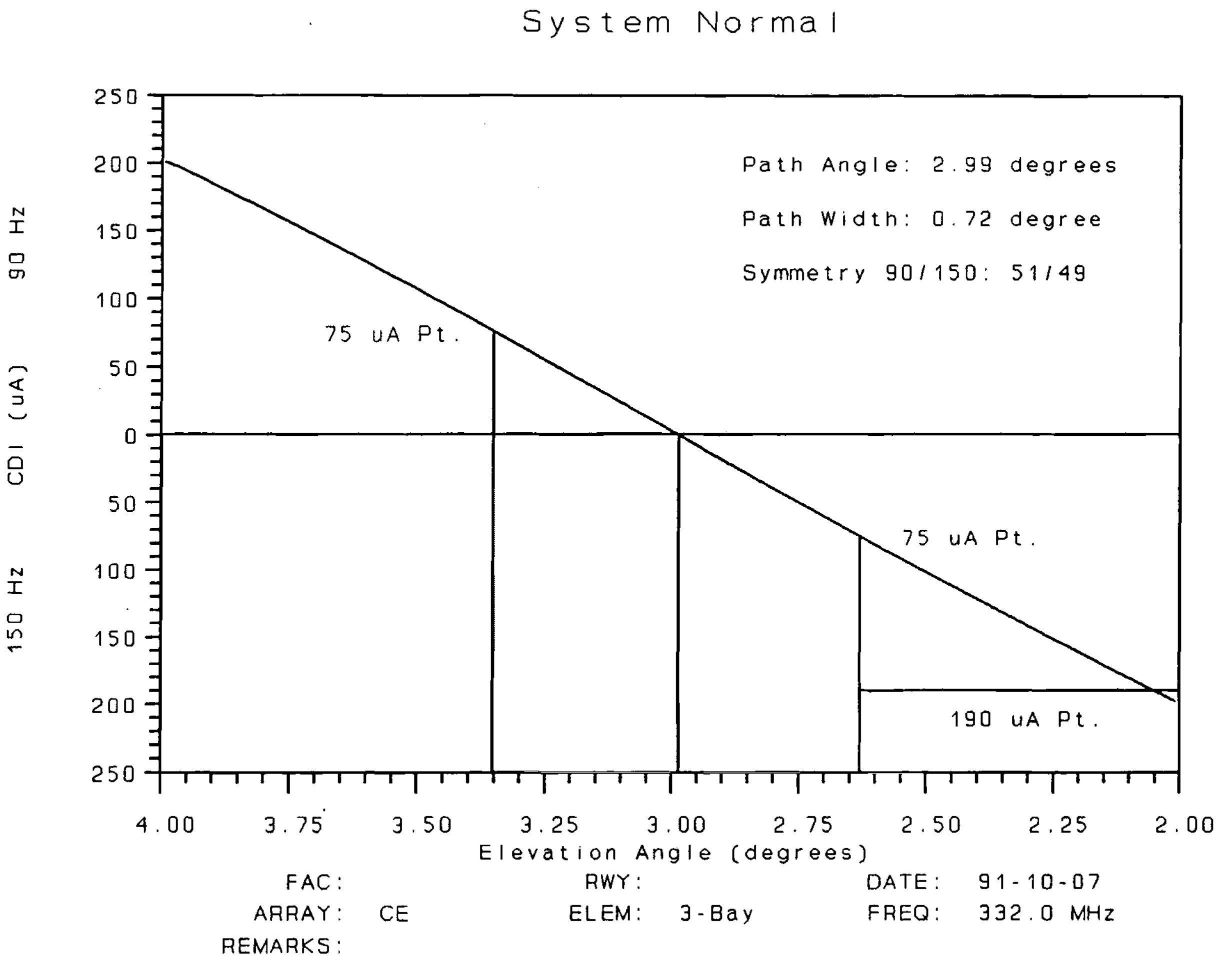


Figure 4-29. Normal Vertical Structure.

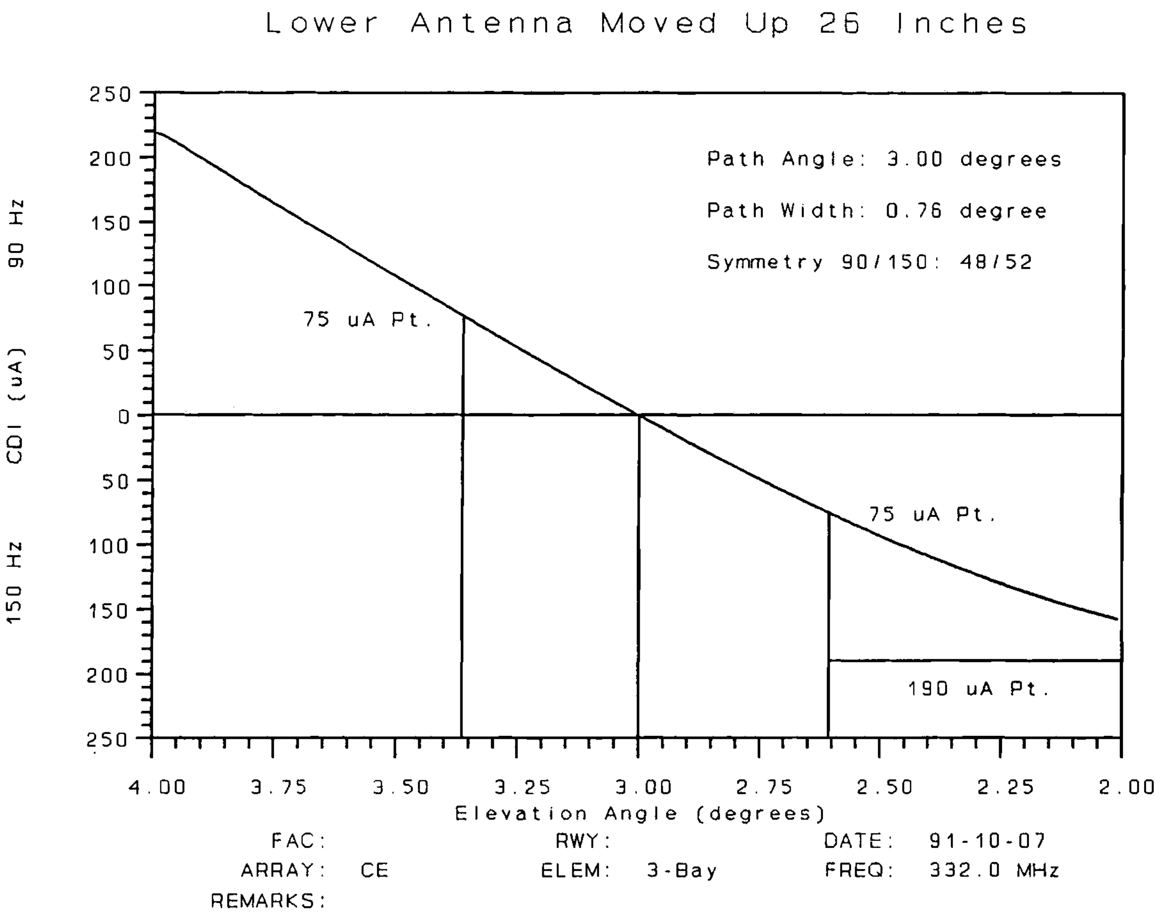
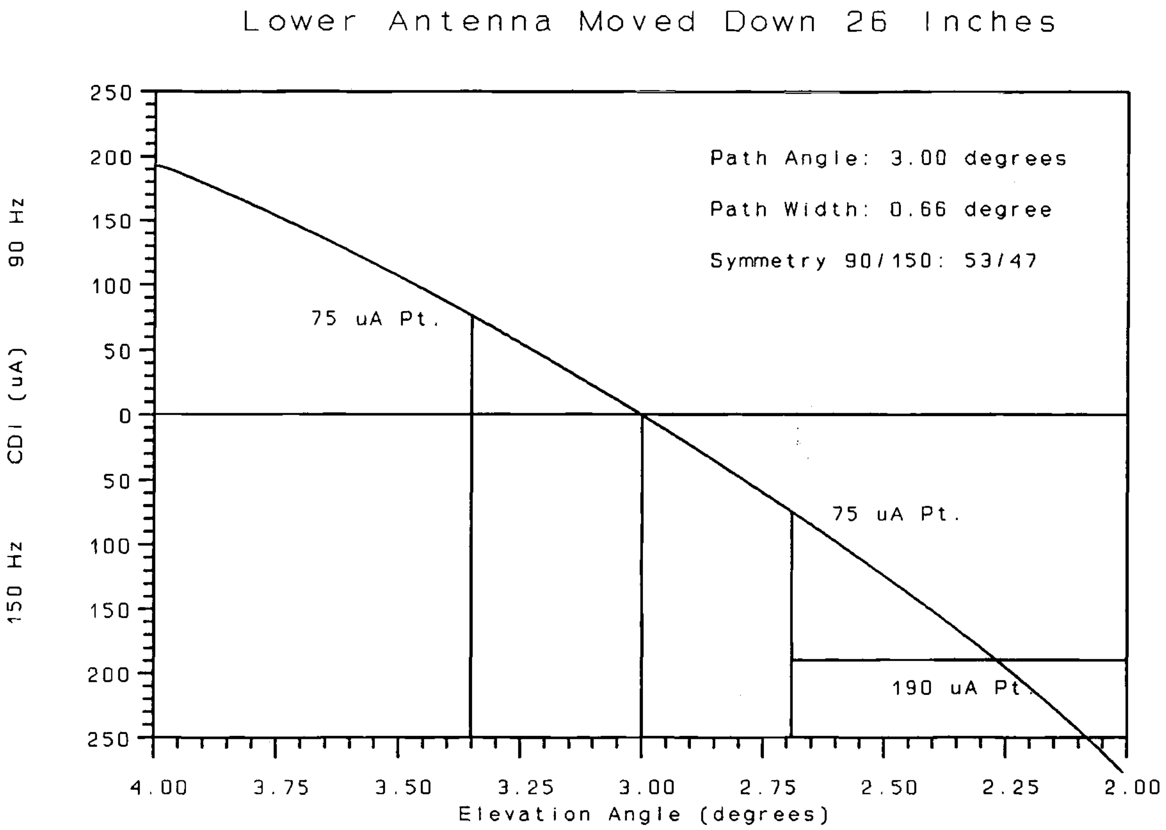


Figure 4-30. Vertical Glide Slope Structure for a Capture-Effect System with Lower Antenna Displaced 26" Upward.



FAC: RWY: DATE: 91-10-07
ARRAY: CE ELEM: 3-Bay FREQ: 332.0 MHz
REMARKS:

Figure 4-31. Vertical Glide Slope Structure for a Capture-Effect System with Lower Antenna Displaced 26" Downward.

Table 4-5 summarizes the results. Symmetry, at worst is disturbed to within 12% of the tolerance limit for Category I. Width values can be adjusted electronically back to normal values.

TABLE 4-5. Summary of Calculational Results with Physical Optics Mathematical Model.

CONDITION	ANGLE/WIDTH	SYMMETRY	% CAT I
Normal	2.99 / 0.72	51:49	0
Case 1; Up 26"	3.00 / 0.76	48:52	12
Case 2; Down 26"	3.00 / 0.66	53:47	18

Again the strategy is to perturb only the Category I system antennas so that there will be no requirement for NCPs for the Category II system.

4. Recommended Further Action.

There are two important action items to be accomplished. First, the FAA needs to process an NCP to allow for non-standard placement above ground of the capture-effect glide slope antennas for Runway 24L. The calculations performed and given in this report should be used to justify the issuance of an NCP. Second, detailed structural drawings need to be prepared to allow for construction of the modified tower.

5. References.

[4B-6] Bechtel Corporation Drawing 25, Structure Plan No. 6 of 15, dated 03-07-91.

V. ALLEVIATION OF CONFLICTING VISUAL CUES

A. Statement of the Problem.

1. Visual Distractions.

The proposed Metro Green Line alignment (See Figure 1-1) results in the presence of light-rail passenger vehicles to the east of Los Angeles International Airport (LAX) Runway pairs 24 and 25. Concerns have been raised by the Air Transport Association (ATA) [5-1] over the potential for confusion or distraction of flight crews by the light from rail vehicle windows, running lights and reflection of sunlight from the rail vehicle tops. Los Angeles press reports have also cited similar concerns, that the rail system may "...distract pilots with its lights..." and terming the trains and lights "...confusing and hazardous..." [5-2, 5-3].

2. Potential Blockage of Approach Lighting Systems.

The elevated Metro Green Line passes to the east of the approach lighting systems (ALS) for Runways 24R and 24L. The MALSR ALS for Runway 24L is a short system, which even a brief inspection shows will not be optically blocked by the rail system. The ALSF-2 ALS serving Runway 24R extends to within 300 feet of the Metro Green Line, and the potential for blockage of any approach lights must be checked.

All Metro Green Line components pass well below ALS lines-of-sight for Runways 25L and 25R.

B. Proposed Solution to the Problem.

Options are given for each of the visual-cues issues which have been raised. None of these options should require major redesign of rail vehicles or the guideway, and should be implemented only if aircrews report significant problems after Metro Green Line operations begin. For each section, one or more of the options may be chosen.

1. Interior Rail Vehicle Lights:

a. Construct a fence with light baffles east of the tracks crossing Runway 25L and 25R centerlines.

b. Tint the rail vehicle windows.

c. Provide for dimming interior lights during operations passing Runways 25L and 25R centerlines.

2. Sunlight:

   a. Paint the car tops a dark color.

   b. Cover the smooth areas on the car tops with corrugated metal material, on stand-offs. This method should minimize added load on car air-conditioning while scattering the sunlight reflection and reducing glare.

   c. Use a brushed-metal finish on car tops to reduce glare.

3. Rail Vehicle Exterior Lights:

   a. Provide small metal shields above the side-lights, to limit visibility above the horizontal plane.

This investigation revealed that no approach lights for any of the four runways are blocked by the Metro Green Line structure or vehicles.

C. Discussion and Data Supporting Recommendations.

1. General.

In the case of Runways 25L and 25R, the Metro Green Line vehicles pass within 1300 feet of the runway thresholds. For Runways 24L and 24R, the rail alignment is removed to a point near the middle marker facilities, over 2,600 feet from the thresholds. Speeds are projected to be 45 to 55 mph as the rail vehicles pass through the centerlines of Runways 25L and 25R, and 55 mph crossing the centerlines of Runways 24L and 24R. Potential effects of changes in the visual scene were considered for approaches to both ends of the four east-west runways at LAX. Trains of from one to three vehicle units are planned.

Aircrews approaching from the west will see the rail vehicles side-on, more than two miles distant, against the backdrop of the existing city environment to the east of the airport. For Runways 07L and 07R, the rail vehicle lights will be merged with lights from traffic on the existing Aviation Boulevard. For Runways 06L and 06R, rail vehicle lights will be merged with lights from traffic on Sepulveda Boulevard, Parking Lot C and other streets to the east.

Rail vehicle window and running lights are not likely to be confused with the airport environment at the distances and positions encountered. Sunlight reflections during approach are unlikely to be a factor.

Rail vehicle lights or reflections are no factor during missed approaches or takeoffs toward the east due to the distances and deck angles typical for such operations. As before, the rail lights will be merged with existing lights from the city and from traffic on streets east of the airport. Rail system lights are similarly no factor during takeoffs or missed-approaches toward the west.

For aircraft approaching from the east to Runways 24R and 24L, the Metro Green Line railcars are on an elevated guideway in the vicinity of the middle markers and near the ends of the approach lighting systems for these runways. There is a large "dark" area between the rail system location and the runway threshold, and it is unlikely that any confusion between rail and airport lights occur in clear conditions. For low-ceiling approaches to these runways, by the time the aircraft breaks out of the clouds, the rail system is below the line-of-sight of the aircrew. In any case, the approach lighting system will clearly dominate the visual scene in the nearly 1/2-mile distance between the rail system and the runways.

The significant remaining potential for conflicting visual cues or distractions therefore comes from railcar windows or rooftop reflection of sunlight. These conditions are present only on approaches from the east to Runways 25R and 25L during the visual-flight portion of an approach at night or during the late afternoon.

2. Rail Vehicle Interior Lights.

The most intense light source emanating from the sides of Metro Green Line vehicles is the interior lighting system showing through the vehicle's windows. These windows are scheduled to be tinted to reduce heat loads. The effect at night is the familiar line of lighted rectangles, in this case traveling perpendicular to the aircraft approach path at some 45 to 55 mph. It is this light source, suddenly apparent when the aircraft "breaks out" of a low cloud layer, which prompted the "visual distraction" item in the ATA letter to FAA [5-1, Item 4].

Again, several solutions are possible, some of which are not costly and which may be implemented as retrofits after the Metro Green Line begins operations:

i. Construct a fence to the east of the Metro Green Line tracks, as the tracks cross the Runways 25L and 25R approach zone, with appropriate opaque baffles to shield the approaching aircraft from the lighted windows. The baffles should be continuous, since flashing the light from the windows through a "picket fence" as the train moves could be worse than continuous visibility.

   The fence and baffles must be able to withstand the jet blast from aircraft taking off on these two runways.

Note that this option would also remove any concern about rail vehicle exterior running lights presenting distractions to approaching aircrews.

ii. Further, tint the rail vehicle windows to limit the light which escapes.

This option is judgmental in nature; testing would likely be required to determine the degree of tint required to reduce aircrew distraction, if any, while retaining a desirable level of outside visibility for the rail system passengers.

iii. Arrange for interior light dimming as the railcars pass Runways 25L and 25R.

This option requires additional system design and installation on the railcars and guideways, and is likely to be the most expensive. It is also possible that rail passengers might be concerned or alarmed about sudden lighting level changes on a fully-automated system.

3. Sunlight Reflections from Railcar Tops.

It has been mentioned in various discussions concerning the Metro Green Line that late-afternoon sunlight might reflect from the smooth portions of the car tops, causing a distracting flash of light toward the aircraft. Considering the nature of light reflections, for such a flash to reach the aircrew, the sun's position would be approximately three to four degrees above the horizon, with the sun setting nearly on runway centerline. These conditions are met for a few days twice each year, as the sun's apparent seasonal motion carries it to the north and south, and for a few minutes during each of these days, at a time approximately 15 minutes prior to sunset. It is likely that the sun's intensity at this time of day will be such that the reflection from the car tops is not operationally significant to the aircrew.

If, subsequent to initiation of Metro Green Line operations, aircrews report car-top reflections as a problem, several retrofit solutions are possible:

i. Any smooth areas of the car tops could be painted a dark, flat color. While this would reduce the reflection at low initial cost, it would likely add to the heat load on the car's air conditioning system.

ii. The car tops could be "brushed" to dull the finish. This would be somewhat more expensive, cause less heat load, but might expose the car skin to more rapid corrosion.

iii. A corrugated plate could be affixed to the car with standoffs. This plate would scatter the sunlight, while permitting free air flow under the plate to retain a relatively low heat load. This option would obviously be more expensive initially.

4. Rail Vehicle Exterior Lights.

Figure 5-1 shows an outline drawing of a light-rail vehicle typical of those planned for the Metro Green Line [5-4]. There are no unusually bright lights on the sides of the cars. The principal light sources which may cast light in the direction of an approaching aircraft are the railcar windows and the possibility of reflected sunlight from any smooth surfaces on top of the car.

The rail vehicles have a variety of lighting systems [5-5]. Note that Figure 5-1 does not show all lights which are specified for the Metro Green Line railcars. The turn signals shown in Figure 5-1 are not specified for Metro Green Line railcars. All lights are described in the following paragraphs.

A "platform light" is located on the side of the car, near each door. The light is illuminated only when the door is open.

Viewed from the side, there is a small amber marker light at the top front corner and a red marker light at the rear top corner.

The red "door open" light over each door will not be illuminated while the car is in motion.

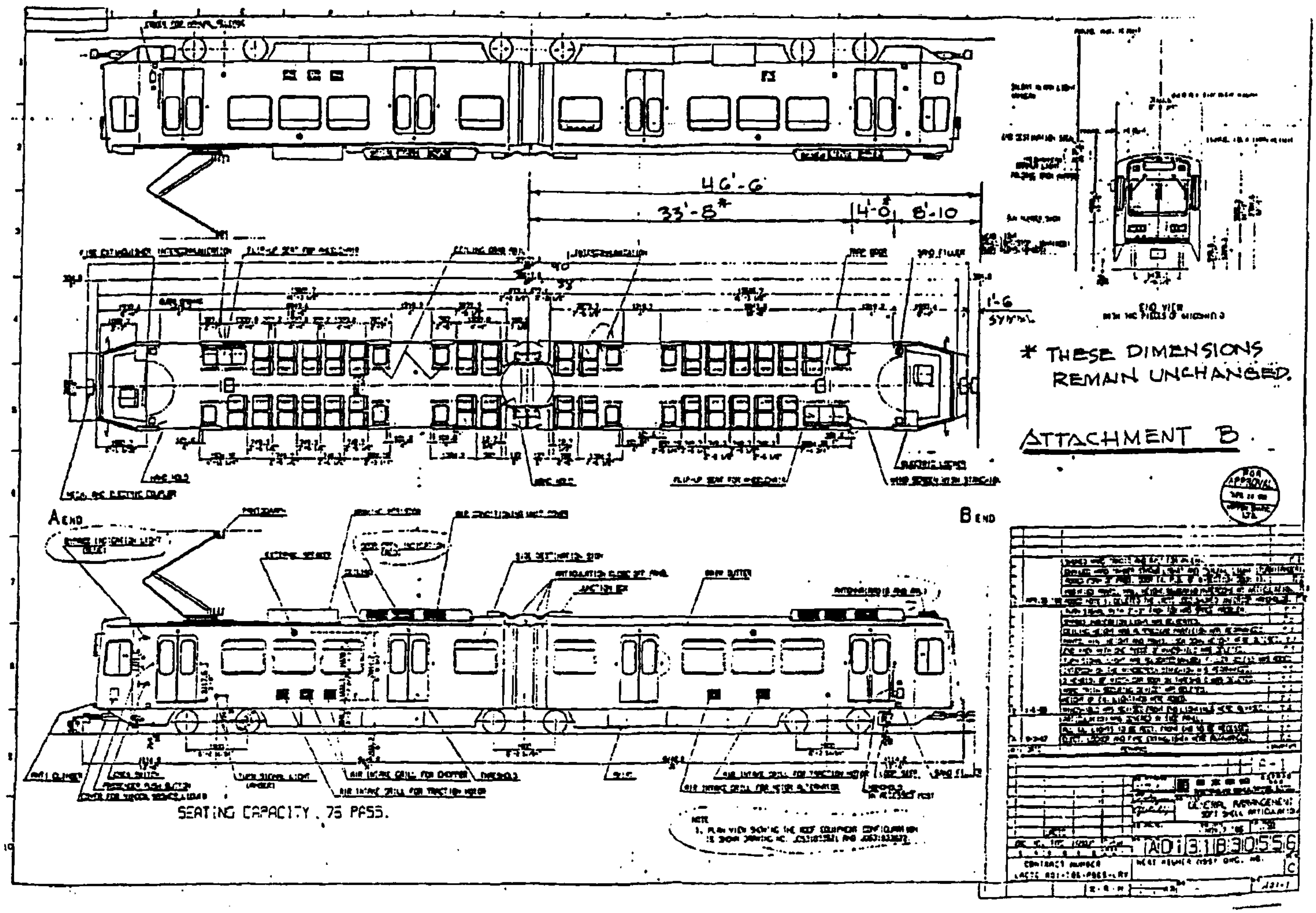
The blue "bypass" light is illuminated when the door interlock is bypassed, and may be on while the car is moving.

An amber "passenger alarm" light mounted on the car roof flashes when a passenger alarm switch has been operated.

The lights described above should not be a problem for approaching aircrews, even if they are illuminated. Their small size and relatively dim illumination compared to airport approach or obstruction lights should not cause distractions or confusion with airport lighting.

Destination signs, lighted by fluorescent bulbs, are mounted on the front and rear of each car, and on the sides at the top of a side window. The shape of this sign and its small size should render it easily separable from airport lighting.

The remaining exterior lighting consists of head and tail lights, which are similar to lights of existing traffic on Aviation and Sepulveda Boulevards. These lights are



* THESE DIMENSIONS REMAIN UNCHANGED.

ATTACHMENT B.

Figure 5-1. Outline Drawing of a Typical Light Rail Vehicle, for Reference.

aimed nearly at right angles to the approach path and thus should not represent new distractions.

While a variety of lights appear on the exterior of the rail vehicle, these lights are generally of small size and low brightness compared to airport lighting. Should their presence be reported as a distraction by approaching aircrews, it is recommended that small metal "eyebrow" shields be attached, to limit the projection of light above the horizontal plane. These shields would minimize light reaching the aircraft while not restricting the visibility of the lights for their intended use by the rail system and its passengers.

5. Potential Blockage of Runway 24R Approach Lighting System.

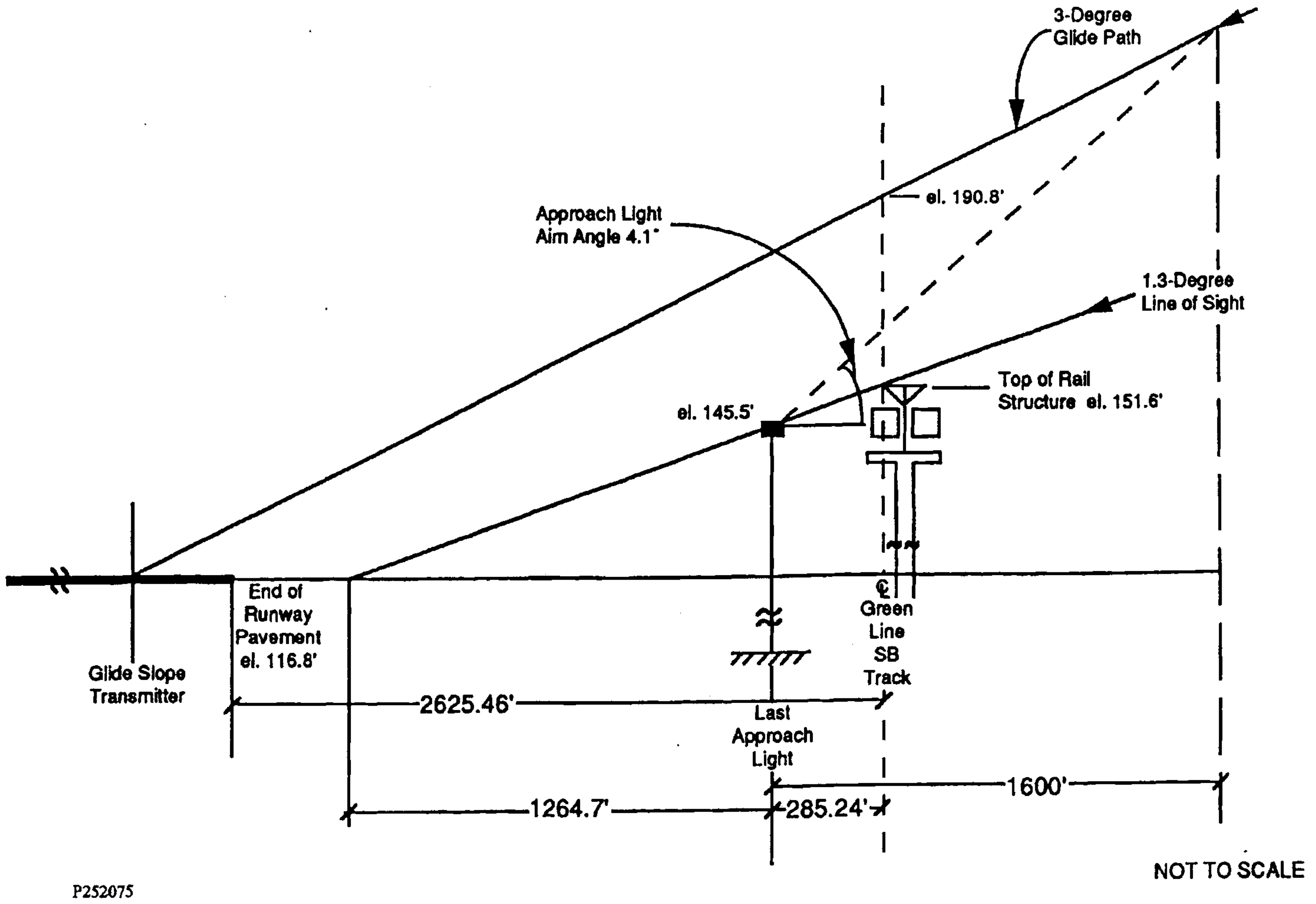
A study of the cross-section drawings [5-5], for the Metro Green Line as it passes the Runway 24R centerline extended, revealed that the line-of-sight passing through the last approach light and the top of the Metro Green Line structure rises at an angle of 1.3 degrees. See Figure 5-2. This line-of-sight intersects the runway elevation at 1264.7 feet toward the runway from the last approach light. Therefore, this line never crosses the 3-degree approach path (in fact, it never crosses the 50:1 approach slope).

The aiming point for this last approach light is specified as a point on the (3-degree) approach path 1,600 feet in front of the light [5-7]. This requirement results in an upward tilt of the light of 4.1 degrees, well above the Metro Green Line structure.

For all categories of ILS approaches to Runway 24R, the angle to all navigation fixes is at 3.0 degrees or above. For the published visual approach, the suggested glide angle is 3 degrees. Therefore, blockage of the approach lights by the Metro Green Line does not occur during an approach to Runway 24R.

D. <u>Recommended Further Action.</u>

If visual-cues concerns persist, it is recommended that a visual simulation be carried out, at a facility such as NASA Ames Research Center, where realistic cockpit and out-the-window views may be created and evaluated by aircrews.



Figures 5-2. Metro Green Line Structure and Closest ALSF-2 Approach Light Station, LAX Runway 24R.

E. References.

[5-1] Letter from Mr. George H. Carver, ATA, to Mr. Carl B. Schellenberg, AWP-1, FAA Western Pacific Region, April 22, 1991, and a telephone conversation with Mr. Carver on October 9, 1991.

[5-2] Los Angeles Times, "Airport: Danger from Train Feared", June 26, 1991.

[5-3] Los Angeles Times, "LAX Metro Line", letter to the editor from Abraham Falick, Chairman, Coalition for Rapid Transit, Los Angeles, July 8, 1991.

[5-4] Drawing A0131B30556, provided by Transit Consultants of Southern California, August 22, 1991.

[5-5] Railcar Specifications, Section 8, "Lighting System", dated February 28, 1990. Provided by TransCal on October 9, 1991.

[5-6] Drawings 24R-3 and 24R-5, Dated 11 September, 1991, produced by the Bechtel Corporation and provided by TransCal.

[5-7] "United States Standard Flight Inspection Manual", Third Edition with Changes to No. 45, Paragraph 218.3, FAA Handbook OA P 8200.1, Washington, DC, May 1963, Reprinted January 1984.

Similarly, the temporary use of track and guideway west of Westchester Station for storage of rail vehicles must conform to the radar clear-zone requirements, if the recommended solution given above is taken.

E. References.

[6-1] Letter from Mr. George H. Carver, ATA, to Mr. Carl B. Schellenberg, AWP-1, FAA Western Pacific Region, April 22, 1991, and a telephone conversation with Mr. Carver on October 9, 1991.

[6-2] Federal Aviation Administration, Western Pacific Region, "Los Angeles International Airport ASR-4 Relocation, Addendum #2".

[6-3] The Bechtel Corporation, "Alignment Study Beyond the Westchester Station", Prepared for TransCal and RCC, August 6, 1991.

[6-4] Letter, J. Sheard, TransCal, to D. Sievers, RCC, transmitting NE21 study report from Bechtel Corp., August 23, 1991.

[6-5] Letter, FAA AWP-453.23, to E. Plottner, LA Dept. of Airports, January 10, 1991, confirming extents of ASR clearance zone.

[6-6] Drawings F-CE-210 through F-CE-216 and SF-CE-211 through SF-CE-216 Dated 6 August, 1991, "Westchester to Marina Del Rey, Future Alignment Study", produced by the Bechtel Corporation and provided by TransCal.

[6-7] Federal Aviation Administration, "Primary/Secondary Terminal Radar Siting Handbook", Order 6310.6, July 20, 1976, with updates.

[6-8] Facsimile from FAA AWP-454 to A. Raval, TransCal, August 2, 1991, giving LAX north side ASDE location.

[6-9] Facsimile from FAA AWP-454 to A. Raval, TransCal, August 12, 1991, giving details of north side ASDE location.

VII. INVESTIGATION OF RAIL LINE ON ALL OTHER FAA FACILITIES INCLUDING COMMUNICATIONS

A. Statement of the Problem.

There are at least 52 aids to navigation and flight operations with discrete equipment units based at the Los Angeles International Airport. It is rather clear that the proposed Metro Green Line alignment has a high probability of affecting the operation of some of these, either directly or indirectly, through their communication links to the control facility. For those cases where it is clear, special sections in this report have been dedicated to a discussion of the problems, their proposed solutions, and recommended actions. In this section, discussions are presented that relate to the items that are not as clear and perhaps not even considered with airport operations. The intent is to provide some omnivision on any prospective problem areas.

The following are considered as important systems associated with operations at the Los Angeles International Airport. The problem, or perhaps best stated here as a question, is there a probability or even a possibility that the Metro Green Line with its planned alignment will cause a negative impact on the performance of any system serving the pilots landing at Los Angeles, and if so, which of the systems?

The following systems are considered in this section. Reference is made to Figures 7-1 and 7-2 which show relative positions of many of these facilities by placement of the dots shown.

1. The Los Angeles Very High Frequency Omni Range (VOR).
2. The Los Angeles TACAN. (This includes distance measuring equipment (DME).
3. Non-directional Beacons (NDB's).
4. Localizers on Runways 25L, 25R, 24L, 24R, 06L and 06R.
5. Glide Slopes on Runways 06L, 06R, 07L and 07R.
6. The 4 DME's associated with the ILS Localizers serving Runways 07L and 07R; serving Runways 06R and 06L; serving Runways 25L and 25R; and Runways 24L and 24R.
7. Voice Communications.
8. Data links from the Radar sites to the Tower and Tracons.
9. Magnetic field indicators such as aircraft compasses.
10. Low Level Wind Advisory System data links (LLWAS).
11. Monitor Remote Status Indicators.

There are basically two types of interference. One is commonly called RFI or EMI for Radio Frequency Interference or Electromagnetic Interference. This

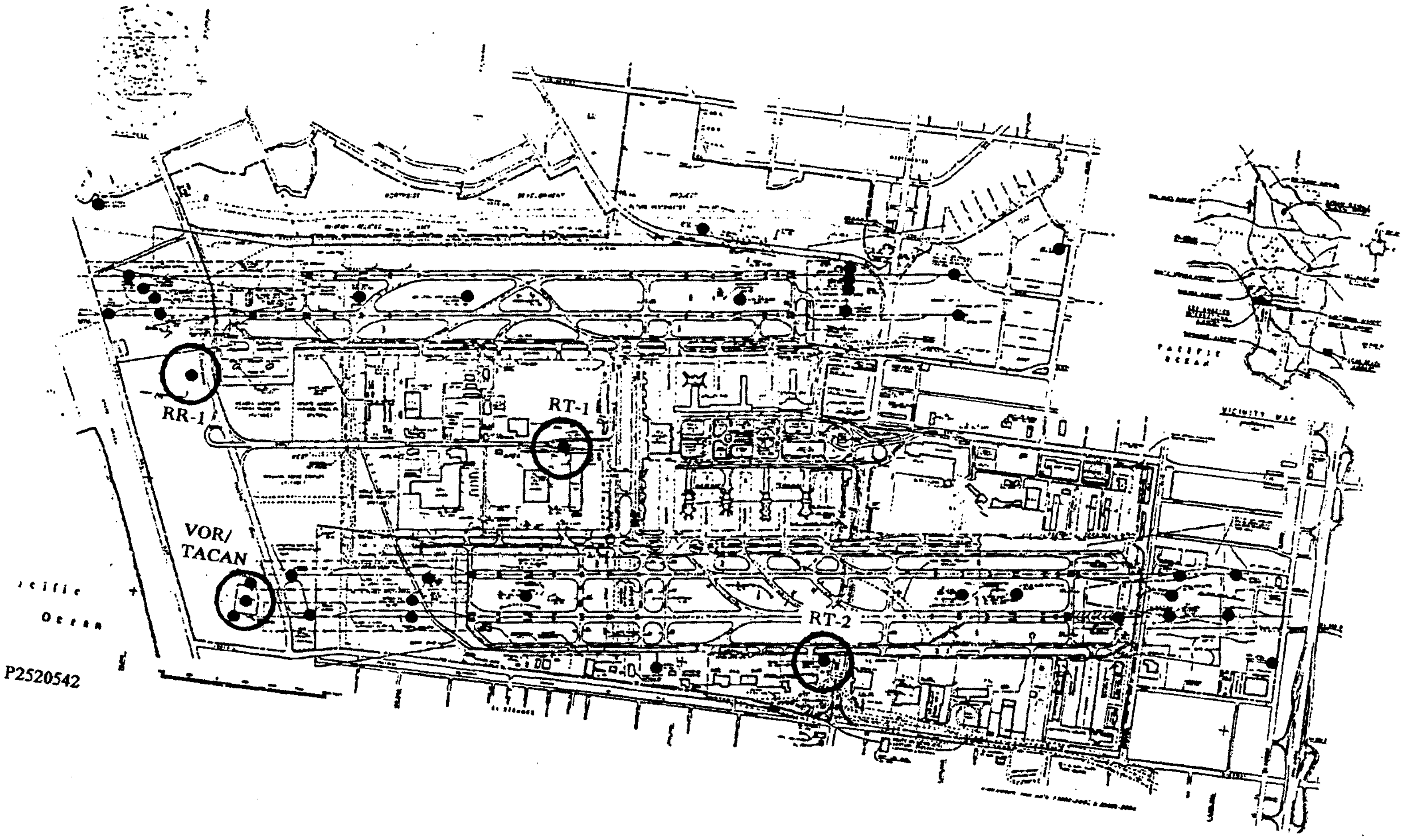


Figure 7-1. Relative Locations of the Many Radio Facilities on the Los Angeles International Airport.

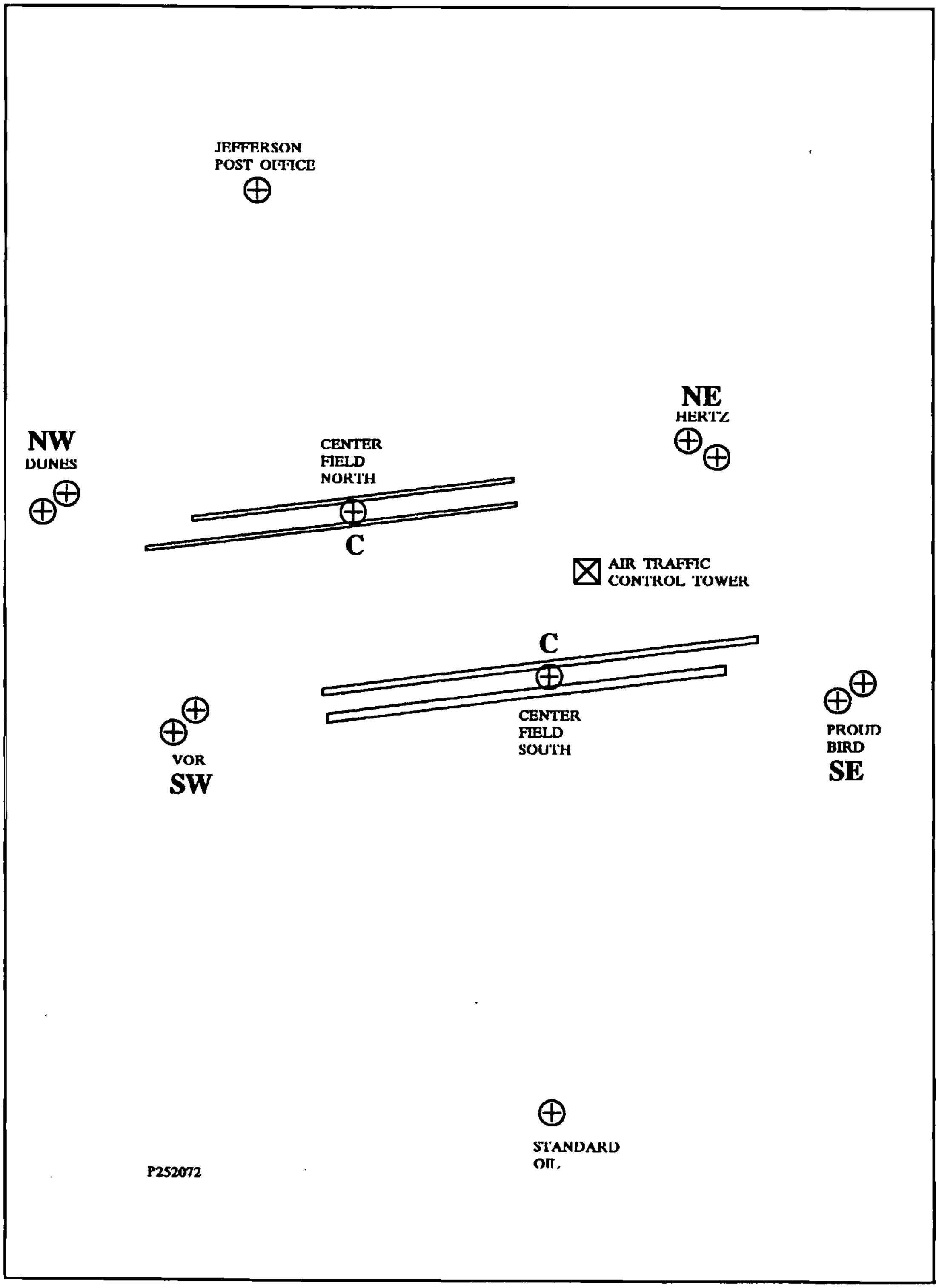


Figure 7-2. Low Level Wind Advisory System, Each Station of Which has a VHF Link to the Air Traffic Control Tower Shown.

interference takes place when the energy source is other than the source of the desired signal. For example RFI commonly takes place when one radio transmitting station provides a signal that interferes with the desired signal from the station tuned. The concern with the Metro Green Line is that because it is a heavy user of direct-current (DC) type electrical energy, some of that DC energy may be converted to radio frequency energy that can affect performance of aircraft systems. The negative aspect is that aircraft receivers are sensitive devices that can detect small amounts of energy, but offsetting this is that the noise generated would probably be relatively broad band, in a frequency sense, and the receivers are very narrow band, thus rejecting most of the noisy energy.

The second type of interference is called multipath and occurs when the interfering radio frequency energy is generated by the same source that produces the desired, useful navigation information, and arrives at the user aircraft via different routes or paths. Many of the airborne receivers obtain the navigation information by processing the signals that are vulnerable to multipath. This is because they are amplitude-sensitive, i.e., the multipath signal is alternately constructive and destructive to the desired signal. The result is often a significant effect in the course information provided, for example, by the localizer and glide slope receivers. The Metro Green Line, with relatively large conducting car surfaces and overhead catenary wires, must be considered as a potential source of multipath.

There are several clearly identifiable bands or portions of the radio spectrum which are of interest here. They are:

Low Frequency - The Romen NDB operating on 278 KHz serving as an outer compass locator for Runway 24R. It is the only low-frequency beacon associated with LAX operations.

Very High Frequency - VOR 113.6 MHz, Localizers (108-112 MHz), Markers (75 MHz), LLWAS data Links 164.250 MHz and 169.375 MHz.

Ultra High Frequency - Glide slopes (329 MHz to 335 MHz); Receiver Site on the sand dunes (northwest) link to the Control Tower, DME, Radar Beacon Transponders, Tacan.

Microwave Frequencies - Surveillance Radars and the radar-type airport surface detection equipment (ASDE), and some microwave communications relay links.

With respect to RFI/EMI it is important to note that there are no planned power line carrier-type frequencies superimposed on the Metro Green Line overhead catenary system, which is, of course, the power feed to the railcar operation. One must consider, however, that because the bounce of the contactors in the power feed to the cars, arcs will be produced. These must be considered as possibilities for interference because arcs (such as lightning, for example) are well known to be radio frequency noise sources.

The best justifications for determining the extent of the Metro Green Line as a source of noise which would interfere with airport operations is to look at the;

1) basic theory,
2) experience with other systems,
3) specifications for the railcar manufacture.

Theory and the basic knowledge of arcing indicates that the portion of the spectrum most affected is the low frequency portion. This is consistent with intuition since most people have experienced lightning effects on their standard broadcast receivers. Fortunately, for the Los Angeles Airport/Metro Green Line considerations, the only station operating in the low frequency band is the Romen outer compass location approximately 5 miles east of the airport.

Experience is an important basis for determining possible effects. There are 12 examples of rail systems operating in the United States near airports that may be used for establishing an experience base. TransCal surveyed these cases shown in Table 7-1. Importantly, in none of these cases of specific sites has there been a known report of RFI/EMI produced by the system or trains. Reports also from examples in Europe indicate no interference is produced by rail lines.

Specifications for the manufacture of the railcar components are strict with respect to electromagnetic radiation. Los Angeles will insist on rigid adherence to the specifications given in Specification No. 2168.01, Section 2.1.8.3.4, dated November 1990. Specimen vehicles tested at the American Association of Railroads test site in Pueblo, Colorado, indicate that measurement values specified at 100 feet are so small that the range must be reduced to 50 feet in order to obtain measurable values for examination with respect to the specifications. In sum, the radiation emitted by the railcars is expected to be embedded in the ambient noise and not even detectable with specialized test equipment at a 100-foot range. This being the case, there should be absolutely no effect on airborne equipment passing overhead. The airborne receivers are narrow band and the antennas are also band limiting.

There is a question as to what effects might be observed if the 12-phase AC system develops a fault. A conceivable fault is the Metro Rail harmonic content of the signals that result from a failure in the rectifiers. When operating normally, the 720 Hz harmonic cannot be measured in terms of radiated signal. There is no experience recorded where there is interference even with high direct currents

Table 7-1. Summary of Survey run by TransCal Concerning Other Airports with Nearby Rail Lines.

CITY	AIRPORT	ELEVATION	DISTANCE TO RUNWAY	RAIL SYSTEM	COLLECTOR SYSTEM	TRACTION POWER	DATE INSTALLED
BALTIMORE	MARTIN STATE	GRADE	750 FT.	AMTRAK	CATENARY	25 KV	----
CLEVELAND	HOPKINS	GRADE	1750 FT.	HEAVY	CATENARY	600 VDC CAM	1970
NEW YORK	JFK	GRADE	3500 FT.	HEAVY	3RD RAIL	600 VDC CAM	----
NEWARK	NEWARK	GRADE	5000 FT.	HEAVY	3RD RAIL	600 VDC CAM	----
ST. LOUIS	LAMBERT	GRADE	1650 FT.	LIGHT	CATENARY	800 VDC	1993
BALTIMORE	BWI	GRADE	2000 FT.	AMTRAK	CATENARY	25 KV	----
BOSTON	LOGAN	GRADE	2375 FT.	HEAVY	CATENARY	600 VDC CAM	1952
CHICAGO	MEIGS	GRADE	8500 FT.	COMMUTER	----	----	----
CHICAGO	O'HARE	GRADE	32R 1700 FT.	HEAVY	3RD RAIL	600 VDC CAM	----
ATLANTA	HARTSFIELD	40 FT. AERIAL	2800 FT.	HEAVY	3RD RAIL	600 VDC CAM	1988
WASHINGTON	NATIONAL	AERIAL	1375 FT.	HEAVY	3RD RAIL	750 VDC CHOPPER	1981
LOS ANGELES	LAX	AERIAL	1250 FT.	LIGHT	CATENARY	750 VDC AC DRIVE	1994

of 9000 amperes. There is considerable selectivity in the airborne receivers that would allow the receiver to reject the fundamental and higher harmonics that are present, should signals be radiated. There is no experience or theory that suggests these types of signals to be of practical concern for aircraft operators.

There is a plan in place to take measurements of the ambient noise levels at different points around the airport. Should any question of noise develop, this base line will allow a comparison and an assessment. There is high confidence from the experiences and calculations cited previously, that there should be no measurable change with the addition of the Metro Green Line.

A discussion of each of the facilities follows:

1) Los Angeles VOR - This is an enroute navigation aid operating on a carrier frequency of 113.6 MHz which is received by narrow band receivers (6 dB at ±34 KHz) on board the aircraft. The justification for discounting RFI is experience, and for discounting multipath is the 2-mile range separation of the rail from the VOR station. With a 20-foot height of the rail system this results in a very low elevation angle, on the order of 0.1 degree. This means that very little incident energy from the VOR reaches the potential reflector, viz., the side or roof of the railcar or the OCS.

2) Los Angeles Tacan - This also is an enroute navigation aid but with a higher frequency of operation, 1107 MHz. The Metro Green Line is not expected to have any effect on aircraft using this navigation aid because it operates on an ultra high frequency carrier with a narrow band receiver. Multipath effects will not be significant for the same reason as that for the VOR.

3) NDB - This low-frequency beacon might be one of the most potentially vulnerable navigation aids except for there being only one for LAX, and it being located 5 miles from the Metro Green Line. Engineering judgement based on known performance of other beacons in the presence of rail lines leads to the conclusion that there is no risk in expecting the Green Line to operate on a non-interfering basis with this outer compass locator for the ILS's on Runways 24R and 24L called Romen.

4) Localizers - There are 8 of these VHF navigation aids at LAX. See Table 7-2. Two of these are discussed in Sections II and IX of this report. The signals produced by four of these, viz., those serving Runways 25L, 25R, 24L and 24R will not be affected for the same reasons as given for the VOR. Localizer signals for guidance to Runways 06L and 06R will not be affected because the Metro Green Line will run approximately 2000 feet behind the antennas where the signal level is lower in magnitude by a factor of approximately 1000. A view of two of the most central localizer sites is shown in Figure 7-3.

of 9000 amperes. There is considerable selectivity in the airborne receivers that would allow the receiver to reject the fundamental and higher harmonics that are present, should signals be radiated. There is no experience or theory that suggests these types of signals to be of practical concern for aircraft operators.

There is a plan in place to take measurements of the ambient noise levels at different points around the airport. Should any question of noise develop, this base line will allow a comparison and an assessment. There is high confidence from the experiences and calculations cited previously, that there should be no measurable change with the addition of the Metro Green Line.

A discussion of each of the facilities follows:

1) Los Angeles VOR - This is an enroute navigation aid operating on a carrier frequency of 113.6 MHz which is received by narrow band receivers (6 dB at ±34 KHz) on board the aircraft. The justification for discounting RFI is experience, and for discounting multipath is the 2-mile range separation of the rail from the VOR station. With a 20-foot height of the rail system this results in a very low elevation angle, on the order of 0.1 degree. This means that very little incident energy from the VOR reaches the potential reflector, viz., the side or roof of the railcar or the OCS.

2) Los Angeles Tacan - This also is an enroute navigation aid but with a higher frequency of operation, 1107 MHz. The Metro Green Line is not expected to have any effect on aircraft using this navigation aid because it operates on an ultra high frequency carrier with a narrow band receiver. Multipath effects will not be significant for the same reason as that for the VOR.

3) NDB - This low-frequency beacon might be one of the most potentially vulnerable navigation aids except for there being only one for LAX, and it being located 5 miles from the Metro Green Line. Engineering judgement based on known performance of other beacons in the presence of rail lines leads to the conclusion that there is no risk in expecting the Green Line to operate on a non-interfering basis with this outer compass locator for the ILS's on Runways 24R and 24L called Romen.

4) Localizers - There are 8 of these VHF navigation aids at LAX. See Table 7-2. Two of these are discussed in Sections II and IX of this report. The signals produced by four of these, viz., those serving Runways 25L, 25R, 24L and 24R will not be affected for the same reasons as given for the VOR. Localizer signals for guidance to Runways 06L and 06R will not be affected because the Metro Green Line will run approximately 2000 feet behind the antennas where the signal level is lower in magnitude by a factor of approximately 1000. A view of two of the most central localizer sites is shown in Figure 7-3.

Table 7-2. Summary of Navigation Aids Serving Los Angeles International Airport.

FACILITY	IDENT.	LOC. FREQ. MHz	G-S FREQ. MHz	DME FREQ .MHz	LOM/ OM
LOC 6L	I-UWU	111.7	333.50	1075	-
LOC 6R	I-GPE	111.7	333.50	1075	-
LOC 7L	I-IAS	111.1	331.70	1072	-
LOC 7R	I-MKZ	111.1	331.70	1072	-
LOC 24L	I-HQB	108.5	329.90	1046	ROMEN 278KHz
LOC 24R	I-OSS	108.5	329.90	1046	ROMEN 278KHz
LOC 25L	I-LAX	109.9	333.80	1060	LIMMA
LOC 25R	I-CFN	109.9	333.80	1060	LIMMA
VOR	LAX	113.6	-	1107	-

5) Glide Slopes - The glide slope serving Runway 24L is discussed in Section IV. All glide slopes including those serving Runways 06L, 06R, 07L and 07R are UHF and provide excellent immunity from RFI/EMI. UHF is relatively free from noise from spurious sources and further protection comes because the receivers are narrow band (6 dB at ± 21 KHz).

6) Marker Beacons - These operate universally on a single carrier of 75 MHz. This includes, inner, middle and outer marker facilities. Because the radiated narrow beam of energy is directed vertically over the beacon location, there is low probability that an interference source will produce a level that would interfere unless it were deliberate. There is no case known where RFI/EMI has been a problem. The immunity is enhanced by the bandwidth of the receivers being typically 6 dB at ± 10 KHz. Multipath is not a problem because the specifications for marker beacon facilities can be and are such as to prohibit reflecting structures from being located in the vertical beam. In Section III, Figure 3-5 of this report is a photograph of a typical marker beacon which has the antenna system arranged for typical vertical radiation pattern.

7) DME - This is distance measuring equipment operating 983 - 1170 MHz. The operation is immune to RFI/EMI because of its high carrier frequency and the user is further protected because it is a precisely controlled pulse-type system; plus it has a signal format that is extremely different from broad-band noise. Multipath could be a problem if the reflecting surfaces were

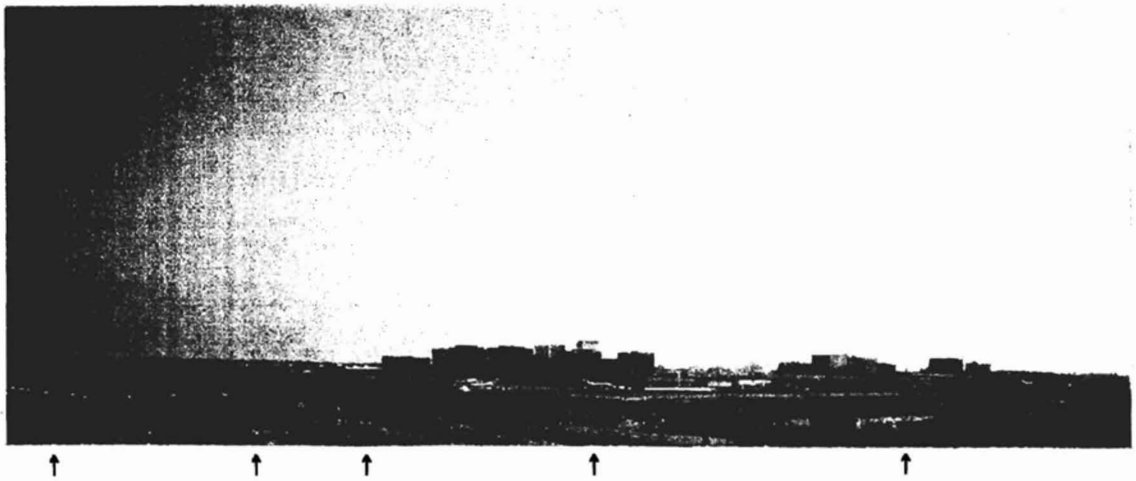


Figure 7-3. Area to Just East of the Thresholds for Runways 25L and 25R and the Middle Markers for These Runways. Also, Indicated are the Localizers for Runways 07L and 07R and Their Common DME.

close and large. Three of the DME stations are over 2 miles from the Metro Green Line and the other 2 are sufficiently far to avoid blockage of signals and significant multipath. The railcar surfaces would have to be at least an order of magnitude larger and located closer to the antennas serving Runways 06L/R and 07L/R to have a detectable effect. The reader is reminded that one DME station serves the left and right runways in each complex and in each direction. This is accomplished by switching identifications as the other nearby parallel runway operation is activated.

There is a long range plan to change this operation of having only one of the two ILS's on the air at any given time. This would mean that 4 of the ILS's would have to be assigned different frequencies from what they are now to allow simultaneous operation. This would be a major undertaking and if it should come to pass, would not alter the conclusions reached under the assumption of the present scheme.

8) Voice Communications - The voice ground-to-air and air-to-ground communications at LAX operate with sensitive, narrow-band Very High Frequency carrier signals giving them great immunity from RFI/EMI noise sources, such as arcs from breaking contacts. Further, calculations show that any radio frequency energy generated by the Metro Green Line would be far below receiver threshold values. The reader should note by referring to Figure 7-1 that the LAX receiver sites are at least a minimum of one mile from the nearest point of the Metro Green Line. With respect to multipath these communication systems are not particularly phase sensitive. There would still be no major problems due to multipath even if the Metro Green Line were much closer to the receiver sites. See Figure 7-4.

9) Data Links from Radar Sites to the Tower and Tracon - Fortunately, all links have been put on cable and run underground for consideration of possible adverse effects of the Metro Green Line on linking information from remote radar facilities to the users in the tower and Tracon. There are no above-ground air links to consider.

10) Magnetic Field Indicators - The basic reference for aircraft headings is the magnetic compass operating with the earth's magnetic field. The above-ground catenary conductor system associated with the Metro Green Line, will produce some strong magnetic fields because it contains large currents on the order of thousands of amperes. The concern then becomes one of whether the aircraft magnetic-field sensing compass will be significantly affected as it passes over the catenary.

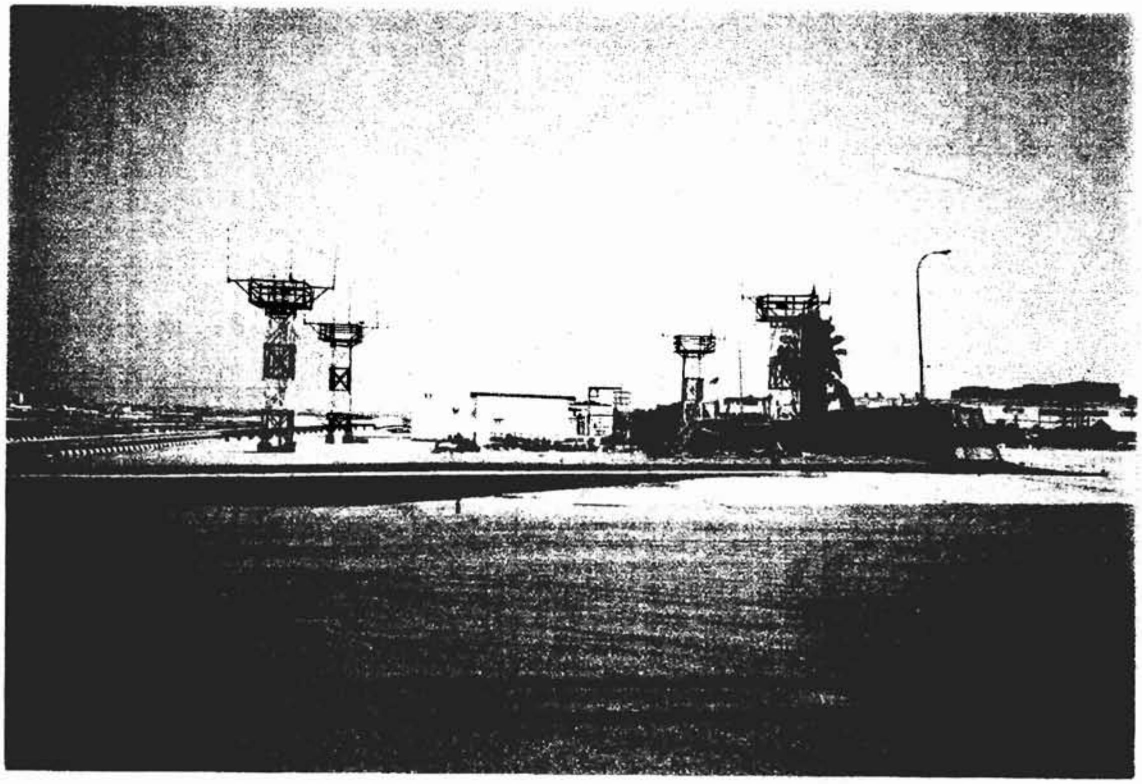


Figure 7-4. Looking East of the RT-2 Communications Site Located on the South Border of the Airport.

$$B = \frac{NI}{2\pi}\cos\gamma\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$
$$R_1 \approx R - h\cos\theta$$
$$R_2 \approx R + h\cos\theta$$

As stated before, magnetic compasses derive their orientation from the Earth's magnetic field. The magnitude of the Earth's magnetic field B_e is 5.7 x 10^{-5} tesla. In order for a compass to be affected, an external field of at least the same order of magnitude as the Earth's must be present. Also, the field must not be aligned with the Earth. Alignment losses are written as cos γ, where γ is the angle the current in the wire makes from magnetic north. See Figure 7-5.

The longest straight section of wire is at least 5000 feet long. Assuming that the aircraft is not near either end of the wire, the wire can be approximated as being infinitely long. The magnetic field from an infinitely long wire is

$$B = \frac{\mu I}{2\pi}\left[\frac{1}{R_1} + \frac{\Gamma}{R_2}\right]$$

where I is a steady electric current, R_1 is the distance from the wire to the aircraft, R_2 is the distance from the image current in the ground plane to the aircraft, and Γ is the reflection coefficient of the ground plane. For the cases of interest, Γ is a complex number whose magnitude is between 0 and 1 and whose real part is negative. Ground images tend to reduce the magnetic field of the wire. In Figure 7-5, the circle with the dot represents a wire carrying current in the direction out of the paper. It is a height h above the ground plane. Its image lies a distance h below the ground and flows into the paper. A plot of the magnetic field intensity versus distance from the wire is given in Figure 7-6 along with the value of the earth's magnetic field.

Assuming worst case alignment and neglecting ground images, the magnetic field from the wire is $B = 2 \times 10^{-4}/R$ tesla. This is less than the earth's magnetic field for distances greater than 12 feet.

Image currents in the soil tend to reduce the magnetic field depending on aircraft angle of incidence. [7-1]

Other considerations are time derivative effects. These cause momentary inductive transient fields which can be even greater in magnitude but are short lived. One inductive transient is the starting and stopping of the train. The time derivative currents set up an additional short-lived magnetic field. Also, the movement of the aircraft in the vicinity of the wire produces small transient fields.

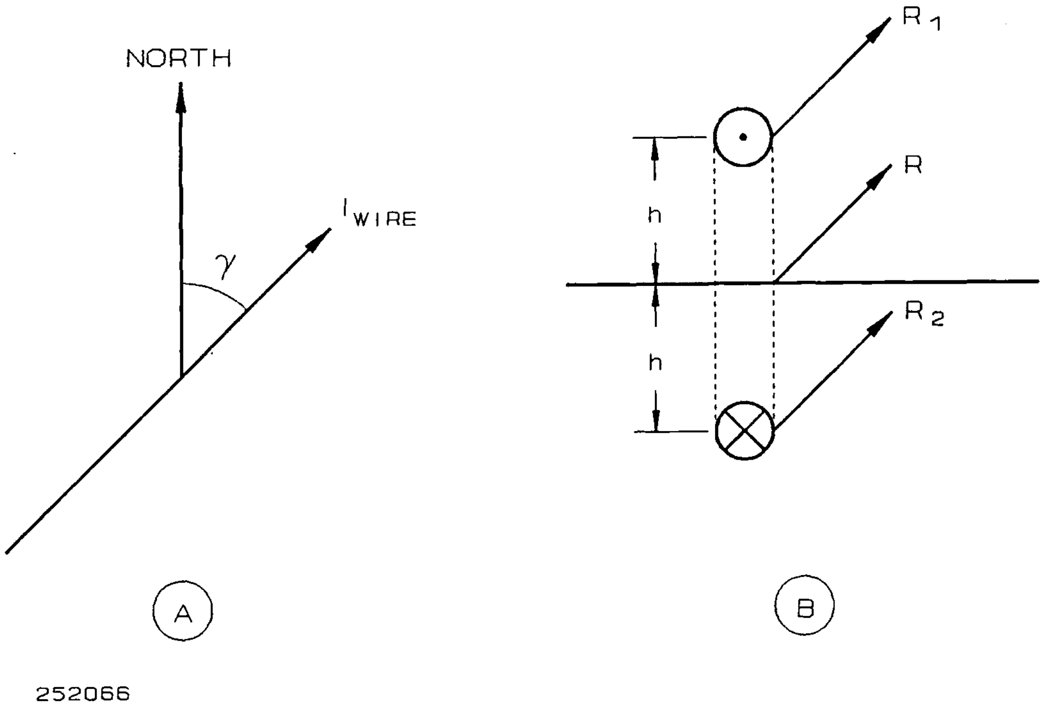


Figure 7-5. Coordinates for the Mathematical Formulation.

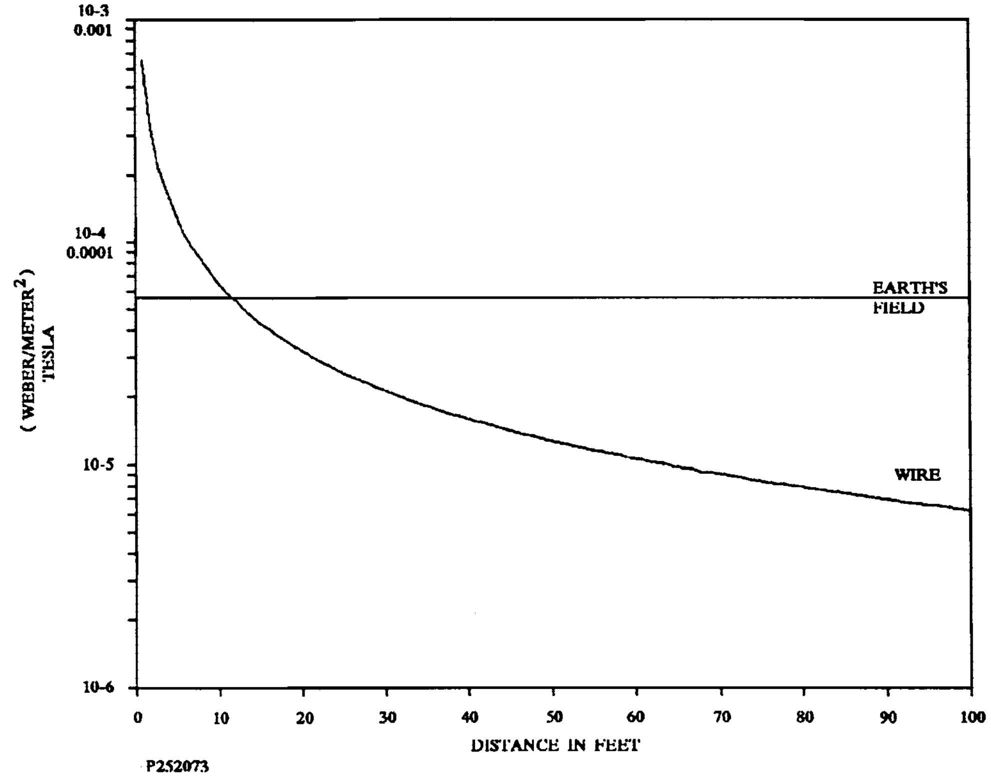


Figure 7-6. Plots of the Magnetic Field From the Catenary Along with the Value Produced by the Earth.

These are considered negligible because of the distance between wire and aircraft, and aircraft speed.

The compass error can be calculated as

$$CE = \tan^{-1}[\frac{k \cos\gamma}{1+k \sin\gamma}]$$

where $k = B/B_e$ and γ is defined in Figure 7-5. For $k=0.1$, the compass error is less than 6 degrees. This means that the aircraft cannot fly within 120 feet of the Metro Green Line. Including the effect of damping will reduce this distance as a function of aircraft speed. See Figure 7-7 for graph of compass error versus wire magnetic field.

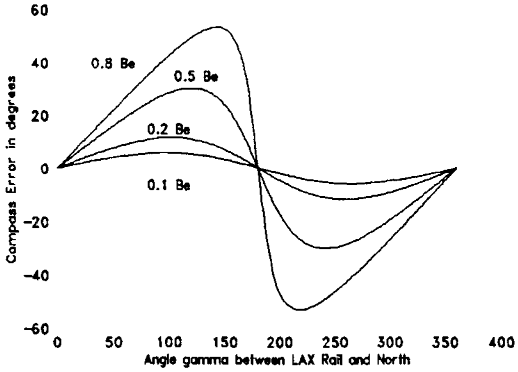


Figure 7-7. Compass Error Versus Magnetic Field from Wire.

11) LLWAS Data Links - Wind shear advisory information is collected at 12 sensors and fed to the control tower over VHF data links with a polling scheme. It is important that these links not be interrupted and be undisturbed. The VHF links currently operate in a satisfactory manner and are not absolutely line-of-sight. Vehicular traffic that presently exists on Aviation Boulevard and the large freight cars that pass on the Santa Fe tracks have had no noticeable effect on the performance of these links. Based on this experience there is no predictable adverse effects due to Metro Green Line cars or the OCS. It is not a phase-sensitive system. The operation at 160 MHz in the VHF band provides for good immunity from the general noise in the spectrum including that which might be generated by the Metro Green Line but not sufficiently great enough to be detected and measured.

12) Monitor Remote Status Indicators - All ILS's have executive monitors. In most all cases, it is important for the air traffic controllers, in particular, to have an indication of what the status is of each of the facilities. Should a fault in a system

develop, the monitor senses this and the executive function provides for the system to shut down, i.e., the transmitter is shut off. At some airports the status, viz., the transmitter is on or off, is provided via a radio link. In the case of all ILS components serving Los Angeles this is not an issue because all status indications are sent to Air Traffic Control via telephone land lines; therefore, the issue of Metro Green Line interference does not exist.

The preceding discussion results from information obtained principally from FAA personnel who have the responsibility of maintaining the specific systems discussed. These people are the first ones to know of problems and certainly are motivated to prevent them. In summary, the conclusion is that the great majority of electronics systems at LAX which exist to serve the aviation user will not be impacted by the Metro Green Line. This section has discussed that majority.

B. <u>References.</u>

[7-1] Halliday, D., and R. Resnick, "Fundamentals of Physics", John Wiley & Sons, Inc., New York, 1970. Appendix B, p. 797.

VIII. MEETINGS AND LIAISON

A major part of this work effort has been to collect data, opinions and concerns, perform appropriate study, and use considered judgement to develop recommendations. The preceding sections of this report have identified specific concerns expressed by a number of individuals and concerned organizations such as the Los Angeles Department of Airports, the Federal Aviation Administration, the Air Transport Association and the Airline Pilot's Association. Those concerns which represented valid technical issues are addressed in specially dedicated sections in this report. In these sections the problem is presented in detail, the recommended solution or solutions are given and data where appropriate are given to support the recommendations.

One of the challenges has been in attempting to become omniscient with respect to potential problems that could affect Los Angeles Airport operations by the Metro Green Line being built. In this attempt many interviews were conducted with people close to the problem and ones who had been identified as having concerns. A number of individual and group meetings were held with people, the majority of these people being FAA personnel.

Another part of the work has been to communicate and educate personnel associated with the Metro Green Line development. Since considerable time and funding were expended in this process, this section will be used to provide in summary form, some documentation of this process.

R. H. McFarland, Ohio University; Meetings in Los Angeles

May 29, 1991	Rail Transportation Systems Frank Doscher, Donn Allen, Charles Edelson, Les Durant, Deepak Shah, Lynn Struthers
May 30, 1991	FAA Regional Office and LAX Sector Office
May 30, 1991	Los Angeles Department of Airports Mal Packer, William Schoenfeld, Robert Millard (with Edelson and Doscher)

R. H. McFarland, R. W Lilley, Ohio University; Meetings in Los Angeles

July 10, 1991	TransCal Joe Sheard, Kirk Rummel, David Sievers

July 10, 1991	Rail Construction Corporation Dave Sievers, Tom Tanke, Ed Cashin, Jerry Chavkin, Kirk Rummel, Charles Edelson
July 11 & 12, 1991	FAA Regional Office, 2 formal meetings Howard Yoshioka plus 9 staff
July 12, 1991	L. A. Department of Airports Mal Packer, William Schoenfeld, Bob Millard, Jack Graham (Dave Sievers, Joe Sheard, Kirk Rummel)

R. H. McFarland, Ohio University; Meetings in Los Angeles

July 31, 1991	FAA and L.A. County Transportation Commission Carl Shellenberg and Neil Peterson plus 20 staff personnel
August 2 & 5, 1991	FAA Regional Office
August 6, 1991	FAA LAX Sector Office
August 7, 1991	FAA Regional Office
August 9, 1991	Wilcox Electric Corp; in Kansas City, Missouri Robert Zimmerman, Executive Vice President; Ed Key, Director of Engineering and staff personnel
September 24, 1991	L. A. County Task Force Meeting in Los Angeles Judy Weiss, Joe Sheard, Al Thiede, plus 20 staff of Dept of Airports, FAA, Gruen Associates, TransCal
September 26, 1991	L.A. County Transportation Commission Briefing for Airline Transport Association and Airline Pilots Association at the Rail Construction Corporation Offices. Judy Weiss, A. L. Pregler, George Carver (Doscher) plus 18 staff personnel
September 27, 1991	FAA Regional Office
September 30, 1991	FAA Regional Office
October 1, 1991	FAA Regional Office and LAX Sector Office

IX. INVESTIGATORS

The following persons have performed tasks and generated technical product related to the sections identified with their names below.

Richard H. McFarland, General, Sections II, IV, and VII

Robert W. Lilley, Sections III, V, and VI

Mohammad Dehghani, Sections IIB and IVB

David Quinet, Sections IVA and IVB

Gary Sims, Section IIB

Frank Marcum, Section VII

Jamie Edwards, Section IVA

John Johnson, Section IVA

Tom Brooks, Section IVA

Simbo Odunaiya, Section IVA

Robert Redlich, Section IVA

Martin Prazsky, Section IVA

Benjamin Bennett, Section IVA

Dr. Richard H. McFarland

Russ Professor Emeritus of Electrical Engineering

Richard H. McFarland founded the Avionics Engineering Center in 1963. Since that time he has been successful in initiating projects for such sponsors as the FAA, NASA, U.S. Army, U.S. Air Force, industrial organizations, and numerous airport commissions and design groups. He holds a B.E. from Ohio University and M.S. and Ph.D. degrees in electrical engineering from Ohio State University.

An active pilot, he holds airline transport pilot and flight instructor certificates with a DC-3 type rating; is qualified for Category II landing operations in a Beechcraft 36; and is rated as a flight instructor for single and multi-engine aircraft and for instrument flight. He is a member of Phi Beta Kappa, Tau Beta Pi, Eta Kappa Nu, and Sigma Xi professional and honor societies. In 1989 he was awarded the FAA's Distinguished Service Medal for his career-long work on Instrument Landing Systems.

Dr. Robert W. Lilley

Director of the Avionics Engineering Center

Robert W. Lilley, director, project engineer, and professor, performs both management and technical functions for the Avionics Engineering Center. Currently, he heads the Loran-C Performance Assurance Program, sponsored by the FAA, and works as a research engineer on projects involving the Microwave Landing Systems (MLS) and the Loran-C Navigation Systems. He led the design and implementation effort which resulted in the center's 3-D aircraft tracking and data collection system.

He earned his Ph.D. from Ohio University. He is an instrument-rated commercial pilot, current president of the WGA International Loran-C Association, a member of both the Aircraft Owners and Pilots Association and the Institute of Navigation, and a member of Tau Beta Pi, Eta Kappa Nu, and Sigma Xi professional societies. He has been with Ohio University since 1963.

Mohammad M. Dehghani, P.E.

Assistant Professor of Mechanical Engineering

Ph.D., Louisiana State University

Dr. Dehghani, who served as a graduate teaching associate at Louisiana State University, joined the Ohio University faculty in 1987. His principal research interests are computer-aided design, metal forming processes, finite element analysis, and theoretical and experimental stress analysis.

He has received professional recognition with the Russ Outstanding Undergraduate Teaching Award, in 1989.

David Quinet
Research Engineer

David Quinet is presently working on Instrument Landing System (ILS) improvements and participating in the development of Differential Global Positioning System (DGPS) air and ground subsystems. His past work includes the development of key elements of a collision warning system, an ILS data collection package, and snow depth monitoring units. He currently is pursuing an M.S.E.E., having earned his B.S.E.E. with honors from Ohio University. As a student intern, David helped with the development of the Digital Radio-Telemetered Theodolite. He is a member of Eta Kappa Nu and Tau Beta Pi professional societies.

Gary Sims
Research Engineer

Gary Sims develops mathematical models of electromagnetic scattering used to predict Radio Frequency Interference (RFI) and the aid in the siting of VHF Omni-range (VOR) and Tactical Air Navigation (TACAN) facilities. He joined the center after serving in the U.S. Air Force as a pilot and as a research engineer in the area of sensory physiology. He has accumulated over 3,000 flying hours in both transport class and high-performance jet aircraft and remains an active member of the Air National Guard. Gary holds an M.S.E.E. from Ohio University. He is a registered professional engineer in Ohio and a member of the Institute of Electrical and Electronic Engineers, the Order of Daedalians, and Eta Kappa Nu professional society.

Frank Marcum
Research Engineer

Frank Marcum provides engineering support to a variety of projects on antenna modeling and scattering problems and on other electromagnetic issues. He currently is working on Instrument Landing System (ILS) and VHF Omni-range (VOR) projects and is responsible for the development of the FAA Radio Site Analysis communications model. Now completing course work toward a Ph.D. in electrical engineering, Frank earned his B.S.E.E. from the University of Michigan in 1984 and his M.S.E.E. from Ohio University in 1988. He was employed at Raytheon's Equipment Division for two years, where he was involved in the design, analysis, and testing of system immunity to the Nuclear Electromagnetic Pulse and lightning. He is a member of Eta Kappa Nu professional society.

Jamie Edwards
Research Engineer

Jamie Edwards uses computer modeling in his work with Instrument Landing Systems (ILS) and helps with flight measurements and data collection as an aircraft panel operator on ILS missions. He earned a B.S.E.E. from Ohio University in 1986 and currently is pursuing his M.S.E.E. As a student intern at the center, he aided in the design and implementation of a Loran-C ground-based monitoring system. He also holds a commercial pilot certificate with instrument rating.

John Johnson
Research Technician

John Johnson works with all types of aviation landing and guidance systems, including fabrication of special aviation data collection equipment. A member of the center's staff since 1986, He received his electronics training in the U.S. Army and gained additional experience while self-employed in trouble-shooting and repair work on satellite systems and computers. John holds an FCC General Radiotelephone Operator's License, an FAA Repairman Certificate, and a Technician's License for Shortwave Communications.

Tom Brooks
Research Technician

Tom Brooks, who joined the center in July 1991, works with aviation landing and navigation electronic systems and is responsible for the repair and calibration of all types of flight instruments on board the airborne laboratories. He is in charge of the center's FAA-approved Repair Stations.

He has earned A.A.S. degrees in electronic engineering technology and broadcast engineering technology from Hocking Technical College. He holds a General Radiotelephone Operator License with Ship Radar Endorsement and has experience in broadcast radio-television and terrestrial microwave systems. He is a member of the advisory council for the Electronics Technology Program at Tri-County Joint Vocational School.

Contributors not pictured:

Simbo Odunaiya is a graduate student who is currently working toward a Ph.D. He specializes in mathematical modeling and holds a M.S.E.E.

Robert Redlich, Ph.D. is an adjunct faculty member of the Department of Electrical and Computer Engineering. He consulted concerning the electromagnetic analyses.

Martin Prazsky is an assistant research engineer who aided in the data collection and analysis of flight recordings. He holds a M.S.E.E. from the Czech Technical University in Prague, Czechoslovakia.

Benjamin Bennett is an undergraduate student intern pursuing a B.S.E.E. He assisted with data collection and digitizing of flight recordings.

X. ACKNOWLEDGEMENTS

There have been many individuals cooperate in helping provide information useful to the authors in preparing the recommendations that are contained in this report. The attempt here is to acknowledge those contributions from outside the sponsoring organizations. If anyone has been overlooked, apologies are hereby extended.

Federal Aviation Administration:

Howard Yoshioka, Airports Division

Mickey Martinez, Airway Facilities

Donald Tom, Airway Facilities

Daniel Olivas, Airway Facilities

Dale Steckel, Airway Facilities

Ed Berns, Airway Facilities

Richard Muckle, LAX AF Sector

John Romero, LAX AF Sector

Henry Tudor, LAX AF Sector

Rod Hanson, LAX AF Sector

Charles Stinnett, LAX AF Sector

Wayne Olson, LAX AF Sector

Don Hayes, LAX AF Sector

Los Angeles Department of Airports:

W. M Schoenfeld, Deputy Executive Director

Mal Packer, Chief Engineer

Robert Millard, Senior Civil Engineer

Consultants:

Jerry Chavkin, JWC Associates, Rancho Palos Verdes, CA
Policy Issues

Charles Edelson, Grover City, CA
Electro Magnetic Interference Issues,

Carlos Miralles, AeroVironment, Inc., Monrovia, CA
Windflow Issues from Jet Engines,

Airline Pilots Association

A. L. Pregler, Safety Coordinator

Air Transport Association

George H. Carver, Director,
Western Regional Office

All have made contributions to this investigation and the authors wish to extend their appreciation.

Finally, appreciation is expressed to ANN-120, National Headquarters, Federal Aviation Administration for making available the glide slope transmitting equipment that was necessary for collecting the field data used for model validation purposes.

APPENDIX A

Recent FAA Flight Check Reports for the ILSs on Runways 24R, 24L 25R and 25L

699155-6 PAGE 1 OF 3

F HT INSPECTION REPORT--INSTRUMENT LANDING SYSTEM

REVIEW INITIALS WF

1. LOCATION: Los Angeles Intl, Los Angeles, CA
2. IDENT: LAX
3. COMMON SYSTEM:
4. DATE/DATES OF INSPECTION: 5/3/91
5. OWNER: F

6. TYPE OF INSPECTION		SITE EVALUATION	X	PERIODIC		SPECIAL
		COMMISSIONING		SURVEILLANCE		INCOMPLETE

7. RUNWAY NO: 25L

8. FACILITY INSPECTED	X	LOCALIZER		SDF	X	GLIDE SLOPE	X	75 MHz MARKERS
		LDA	X	DME	X	LIGHTING SYSTEM		COMPASS LOCATORS

9. LOCALIZER

COM'D WIDTH: 3.33

CATEGORY: II

FRONT COURSE TX 1 OT	TX 1 INITIAL	TX 1 FINAL	TX 2 OT	TX 2 INITIAL	TX 2 FINAL		BACK COURSE TX 1 OT	TX 1 INITIAL	TX 1 FINAL	TX 2 OT	TX 2 INITIAL	TX 2 FINAL
		3.24			3.31	COURSE WIDTH						
		39.4			39.7	MODULATION						
		269/16				CLEARANCE 150						
		260/16				CLEARANCE 90						
		2/5.53			3/5.17	COURSE STRUCTURE - Z1						
		3/0.61			2/0.66	COURSE STRUCTURE - Z2						
		5/0.12			4/0.47	COURSE STRUCTURE - Z3						
X		7/0.06			5/0.10	COURSE STRUCTURE - Z4						
						COURSE STRUCTURE - Z5						
					0/9.2	VERTICAL POLARIZATION						
		50.3			50.6	SYMMETRY						
		1R		3R	2R	ALIGNMENT						
						VOICE						
		5			5	IDENTIFICATION						
						USABLE DISTANCE						
DATE: 5/3/91			DATE: 5/3/91			MONITOR	DATE:			DATE:		
		3.11			3.18	COURSE WIDTH Narrow						
		3.56			3.54	COURSE WIDTH Wide						
		276/15			278/29	CLEARANCE 150						
		285/18			322/16	CLEARANCE 90						
		7			6	ALIGNMENT 150						
		4			5	ALIGNMENT 90						

10. GLIDE SLOPE

COM'D ANGLE: 3.00

CATEGORY: II

TX 1 OT	TX 1 INITIAL	TX 1 FINAL	TX 2 OT	TX 2 INITIAL	TX 2 FINAL	
		3.04			3.04	ANGLE
		81.0			80.0	MODULATION
		0.69			0.68	WIDTH
						CLEARANCE BELOW PATH
		2.23			2.23	STRUCTURE BELOW PATH
		2/6.04			2/5.93	PATH STRUCTURE - Z1
		6/0.78			4/0.41	PATH STRUCTURE - Z2
		4/0.18			4/0.15	PATH STRUCTURE - Z3
						USABLE DISTANCE
		52.2			51.9	SYMMETRY
DATE: 5/3/91			DATE: 5/3/91.			MONITOR

11. GENERAL

	SAT	UNSAT
75 MHz MARKERS	X	
COMPASS LOCATORS		
DME	X	
LIGHTING SYSTEMS	X	

12. FACILITY STATUS

	F/C	G/S	B/C
UNRESTRICTED	X	X	NA
RESTRICTED			
UNUSABLE			

NOTAMS: NOTAM ISSUED THROUGH FDC.
LOC UNUSABLE INSIDE RUNWAY THRESHOLD.

13. REMARKS:

ANGELES INTL CA, ILS RWY 25 (AMDT 2) PUBLIC, SIAP, "S".
" " " " " " " CAII, PUBLIC, SIAP, 'S.'

REGION AWP IFO SAC.	FLIGHT INSPECTOR'S SIGNATURE: Thomas J Brueck.	TECHNICIAN'S SIGNATURE:	AIRCRAFT NO: N75

PAGE 2 OF 3

FLIGHT INSPECTION REPORT--INSTRUMENT LANDING SYSTEM SUPPLEMENTAL SHEET

REVIEW INITIALS

1. LOCATION: Los Angeles Intl, Los Angeles, CA
2. IDENT: LAX

[redacted] 3. DATE/DATES OF INSPECTION: 5/3/91 [redacted]

4. GLIDE SLOPE									
4a. GLIDE SLOPE TYPE CE				PATH ANGLE		PATH WIDTH		STRUCTURE BELOW PATH	
				TX1	TX2	TX1	TX2	TX1	TX2
4b. DEPHASE	ADVANCE	TX1 11	TX2 12	3.03	3.02	0.70	0.85	1.71	1.73
	RETARD	TX1 14	TX2 16	3.05	3.07	0.71	0.71	2.21	2.21
4c. PATH ANGLE LOWERED TO LIMIT									
4d. PATH ANGLE RAISED TO LIMIT									
4e. PATH WIDTH NARROWED TO LIMIT									
4f. PATH WIDTH WIDENED TO LIMIT									
4g. CLEARANCE TX MODULATION DECREASED TO LIMIT - (PRIMARY TX WIDE LIMIT)				3.04	3.06	0.82	0.81	210	2.10
4h. ATTENUATE MIDDLE ANTENNA TO LIMIT		TX1 0.5	TX2 0.6	3.03	3.05	0.78	0.76	2.03	2.05
4i. ATTENUATE UPPER ANTENNA TO LIMIT		TX1 0.5	TX2 0.7	2.85	2.85	0.71	0.69	2.21	2.21

4j. TRANSVERSE STRUCTURE	CRS SECTOR	FAF ALT:	0.3° BELOW PATH:
	EDGE SECTOR	FAF ALT:	0.3° BELOW PATH:
4k. MODULATION BALANCE		TX1	TX2
4l. PHASING		TX1	TX2
4m. FRONT COURSE AREA WHERE PHASING WAS CONDUCTED		NM	MSL
4n. CLEARANCE BELOW PATH		TX1	TX2

5. REMARKS

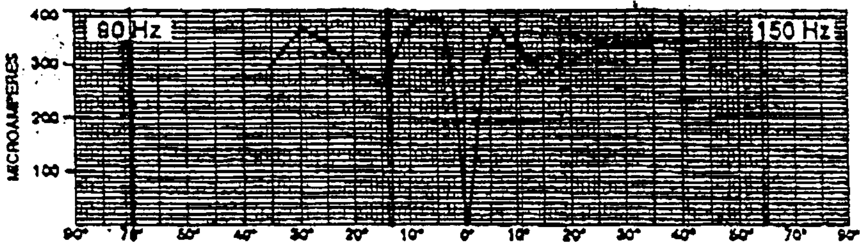
PAGE 3 OF 3

FLIGHT INSPECTION REPORT--LOCALIZER CLEARANCE PLOT

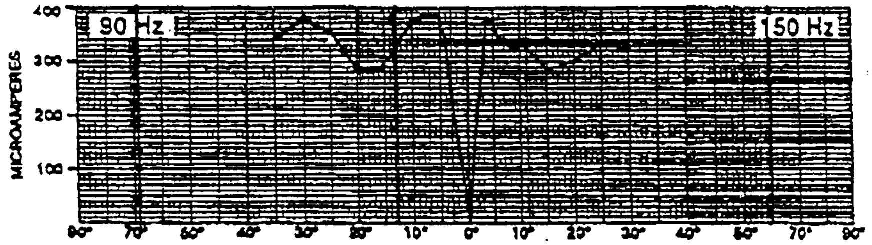
1. LOCATION Los Angeles Intl, Los Angeles, CA		2. IDENT: LAX
3. DATE/DATES OF INSPECTION: 5/3/91	4. ANT TYPE: T.W.	5. SITE ELEV: 117

6. TX	7. CFG	8. ALT	9. RADIUS	10. WIDTH FC	11. WIDTH BC	CODE: FC ——— BC ....
1	N	35	10	3.25		

12.

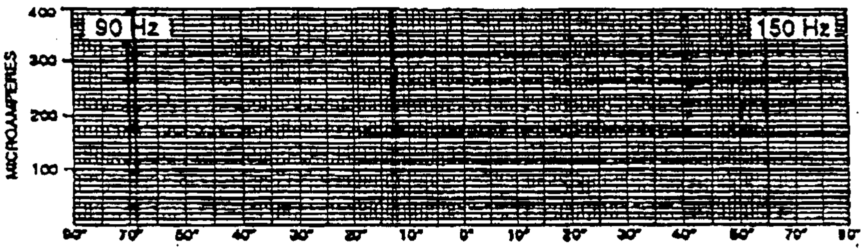


6. TX	7. CFG	8. ALT	9. RADIUS	10. WIDTH FC	11. WIDTH BC	CODE: FC ——— BC ....
1	N	60	10	3.31		



6. TX	7. CFG	8. ALT	9. RADIUS	10. WIDTH FC	11. WIDTH BC	CODE: FC ——— BC ....

12.



REMARKS Localizer course width and clearance capability verified from LCA of 3500 feet MSL up to 6000 feet MSL.

REGION:	FLIGHT INSPECTOR'S SIGNATURE: NA	TECHNICIAN'S SIGNATURE:	AIRCRAFT NO:
FFO:			

NOV 06 1991

99155-6

IGHT INSPECTION REPORT–INSTRUMENT LANDING SYSTEM

REVIEW INITIALS ET [illegible]

1. LOCATION: LOS ANGELES INT'L CA
2. IDENT: CFN
3. COMMON SYSTEM:
4. DATE/DATES OF INSPECTION: 12/28/90
5. OWNER: F

6. TYPE OF INSPECTION

☐	SITE EVALUATION	☒	PERIODIC	☐	SPECIAL
☐	COMMISSIONING	☐	SURVEILLANCE	☐	INCOMPLETE

7. RUNWAY NO: 25R

8. FACILITY INSPECTED

☒	LOCALIZER	☐	SDF	☒	GLIDE SLOPE	☒	75 mHz MARKERS
☐	LDA	☒	DME	☒	LIGHTING SYSTEM	☐	COMPASS LOCATORS

9. LOCALIZER

COM'D WIDTH: 3.39
CATEGORY: I

FRONT COURSE TX 1 OT	FRONT COURSE TX 1 INITIAL	FRONT COURSE TX 1 FINAL	FRONT COURSE TX 2 OT	FRONT COURSE TX 2 INITIAL	FRONT COURSE TX 2 FINAL		BACK COURSE TX 1 OT	BACK COURSE TX 1 INITIAL	BACK COURSE TX 1 FINAL	BACK COURSE TX 2 OT	BACK COURSE TX 2 INITIAL	BACK COURSE TX 2 FINAL
		3.67				COURSE WIDTH						
		19.8				MODULATION						
		24/30				CLEARANCE 150						
		168/30				CLEARANCE 90						
		2/0.15				COURSE STRUCTURE - Z1						
		3/0.58				COURSE STRUCTURE - Z2						
		4/0.47				COURSE STRUCTURE - Z3						
						COURSE STRUCTURE - Z4						
						COURSE STRUCTURE - Z5						
		0/10.0				VERTICAL POLARIZATION						
		50.0				SYMMETRY						
		3R				ALIGNMENT						
						VOICE						
		5				IDENTIFICATION						
						USABLE DISTANCE						
DATE: 7/11/90			DATE:			MONITOR	DATE:			DATE:		
						COURSE WIDTH (Narrow)						
						COURSE WIDTH (Wide)						
						CLEARANCE 150						
						CLEARANCE 90						
						ALIGNMENT 150						
						ALIGNMENT 90						

10. GLIDE SLOPE

COM'D ANGLE: 3.00
CATEGORY: I

TX 1 OT	TX 1 INITIAL	TX 1 FINAL	TX 2 OT	TX 2 INITIAL	TX 2 FINAL	
		2.98				ANGLE
		80.1				MODULATION
		0.70				WIDTH
						CLEARANCE BELOW PATH
		2.20				STRUCTURE BELOW PATH
		3/5.38				PATH STRUCTURE - Z1
		5/0.59				PATH STRUCTURE - Z2
		6/0.2				PATH STRUCTURE - Z3
						USABLE DISTANCE
		51.7				SYMMETRY
DATE: 7/11/90			DATE:			MONITOR

11. GENERAL

	SAT	UNSAT
75 mHz MARKERS	☒	
COMPASS LOCATORS		
DME	☒	
LIGHTING SYSTEMS	☒	

12. FACILITY STATUS

	F/C	G/S	B/C
UNRESTRICTED	☒	☒	N/A
RESTRICTED			
UNUSABLE			

NOTAMS:

13. REMARKS:

REGION AWP
FIFO SAC
FLIGHT INSPECTOR'S SIGNATURE: Thomas W Bunch
TECHNICIAN'S SIGNATURE: [illegible] W. Hunter EFA
AIRCRAFT NO: N71

MICROFILMED BY AVN-200

9155-6

PAGE 1 OF 3

T INSPECTION REPORT--INSTRUMENT LANDING SYSTEM

REVIEW INITIALS: wF

LOCATION: Los Angeles Intl, Los Angeles, CA								2. IDENT: OSS
COMMON SYSTEM:		4. DATE/DATES OF INSPECTION: 4/18/91						5. OWNER: F
TYPE OF INSPECTION			SITE EVALUATION		X	PERIODIC		SPECIAL
			COMMISSIONING			SURVEILLANCE		INCOMPLETE
7. RUNWAY NO. 24R	8. FACILITY INSPECTED	X	LOCALIZER	SDF	X	GLIDE SLOPE	X	75 MHz MARKERS
			LDA	X DME	X	LIGHTING SYSTEM	X	COMPASS LOCATORS

9. LOCALIZER

FRONT COURSE						COM'D WIDTH: 3.37	BACK COURSE					
TX 1			TX 2				TX 1			TX 2		
OT	INITIAL	FINAL	OT	INITIAL	FINAL	CATEGORY: III	OT	INITIAL	FINAL	OT	INITIAL	FINAL
	3.25	3.20			3.23	COURSE WIDTH						
		41.0			38.9	MODULATION						
		220/14			220/14	CLEARANCE 150						
		209/16			206/16	CLEARANCE 90						
		2/6.09			3/6.94	COURSE STRUCTURE - Z1						
		4/0.62			3/0.61	COURSE STRUCTURE - Z2						
		3/0.30			3/0.53	COURSE STRUCTURE - Z3						
		3/0.36			2/0.30	COURSE STRUCTURE - Z4						
		5/0.90			5/0.61	COURSE STRUCTURE - Z5						
					1/9.6	VERTICAL POLARIZATION						
		51.5			51.4	SYMMETRY						
	4R	2R			3R	ALIGNMENT						
						VOICE						
		5			5	IDENTIFICATION						
						USABLE DISTANCE						
DATE: 4/18/91			DATE: 4/18/91			MONITOR	DATE:			DATE:		
		3.05			2.91	COURSE WIDTH						
		3.47			3.38	COURSE WIDTH						
		261/15			215/35	CLEARANCE 150						
		191/11			186/11	CLEARANCE 90						
		6			7	ALIGNMENT 150						
		3			3	ALIGNMENT 90						

10. GLIDE SLOPE

TX 1			TX 2			COM'D ANGLE: 3.00
OT	INITIAL	FINAL	OT	INITIAL	FINAL	CATEGORY: III
		3.02			3.04	ANGLE
		82.2			79.9	MODULATION
		0.72			0.72	WIDTH
						CLEARANCE BELOW PATH
		2.14			2.21	STRUCTURE BELOW PATH
		2/6.40			8/8.61	PATH STRUCTURE - Z1
		3/0.71			6/0.68	PATH STRUCTURE - Z2
		5/0.90			6/0.16	PATH STRUCTURE - Z3
						USABLE DISTANCE
		52.9			51.1	SYMMETRY
DATE: 4/18/91			DATE: 4/18/91			MONITOR

11. GENERAL

	SAT	UNSAT
75 MHz MARKERS	X	
COMPASS LOCATORS	X	
DME	X	
LIGHTING SYSTEMS	X	

12. FACILITY STATUS

	F/C	G/S	B/C
UNRESTRICTED	X	X	NR
RESTRICTED			
UNUSABLE			

NOTAM's:

13. REMARKS:

Angeles Intl, CA ILS RWY 24R (Cat I, II III) (Amdt 20) Public SIAP's.

REGION AWP	FLIGHT INSPECTOR'S SIGNATURE:	BH TECHNICIAN'S SIGNATURE:	AIRCRAFT NO:

JUN 10 1991

JUN 26 1991

PAGE 2 OF 3

FLIGHT INSPECTION REPORT—INSTRUMENT LANDING SYSTEM SUPPLEMENTAL SHEET

REVIEW INITIALS

1. LOCATION: Los Angeles Intl, Los Angeles, CA
2. IDENT: OSS

[redacted]
3. DATE/DATES OF INSPECTION: 4/18/91
[redacted]

4. GLIDE SLOPE

				PATH ANGLE		PATH WIDTH		STRUCTURE BELOW PATH	
4a. GLIDE SLOPE TYPE CE				TX1	TX2	TX1	TX2	TX1	TX2
4b. DEPHASE	ADVANCE	TX1 20	TX2 20	2.98	3.03	0.82	0.77	2.16	2.20
	RETARD	TX1 10	TX2 12	3.04	3.08	0.77	0.73	1.41	1.76
4c. PATH ANGLE LOWERED TO LIMIT									
4d. PATH ANGLE RAISED TO LIMIT									
4e. PATH WIDTH NARROWED TO LIMIT									
4f. PATH WIDTH WIDENED TO LIMIT									
CLEARANCE TX MODULATION DECREASED TO LIMIT - (PRIMARY TX WIDE LIMIT)				3.01	3.02	0.88	0.85	2.05	2.07
4h. ATTENUATE MIDDLE ANTENNA TO LIMIT		TX1 0.8	TX2 1.7	3.01	3.07	0.87	0.86	1.89	1.91
4i. ATTENUATE UPPER ANTENNA TO LIMIT		TX1 1.0	TX2 1.0	2.92	2.98	0.77	0.74	2.13	2.17

4j. TRANSVERSE STRUCTURE	CRS SECTOR	FAF ALT:	0.7° BELOW PATH:
	EDGE SECTOR	FAF ALT:	0.7° BELOW PATH:
4k. MODULATION BALANCE		TX1	TX2
4l. PHASING		TX1	TX2
4m. FRONT COURSE AREA WHERE PHASING WAS CONDUCTED		NM	MSL
4n. CLEARANCE BELOW PATH		TX1	TX2

5. REMARKS

Glideslope TX #1 initially found O.T. advanced 14 degrees at 1.59° path.
width (corrected).

Clearance below path conducted on TX #1 while advanced 10° degrees found satisfactory.

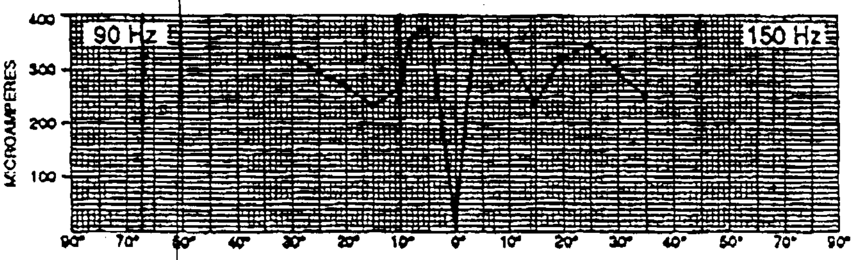
PAGE 3 of 3 ☐

FLIGHT INSPECTION REPORT–LOCALIZER CLEARANCE PLOT

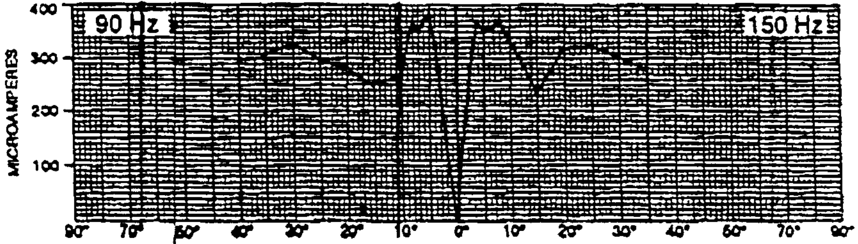
1. LOCATION Los Angeles Intl, Los Angeles, CA		2. IDENT: OSS
3. DATE/DATES OF INSPECTION: 4/18/91	4. ANT TYPE: LP	5. SITE ELEV: 123

6. TX	7. CFG	8. ALT	9. RADIUS	10. WIDTH FC	11. WIDTH BC	CODE:
1	N	22	10	3.25		FC ——— BC ....

12.

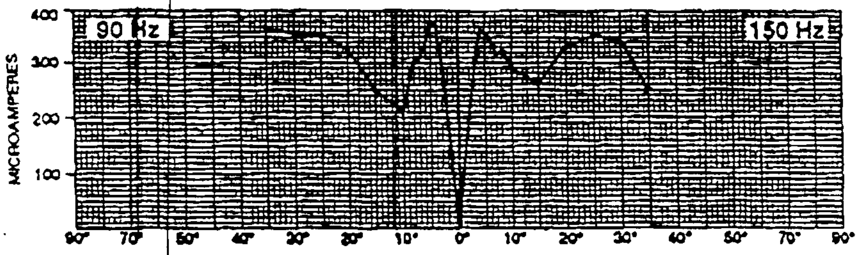


6. TX	7. CFG	8. ALT	9. RADIUS	10. WIDTH FC	11. WIDTH BC	CODE:
1	N	46	10	3.28		FC ——— BC ....



6. TX	7. CFG	8. ALT	9. RADIUS	10. WIDTH FC	11. WIDTH BC	CODE:
1	C	46	10	3.05		FC ——— BC ....

12.



REMARKS LOCALIZER COURSE WIDTH AND CLEARANCE COMPARABILITY VERIFIED FROM LCA OF 2000' MSL UP TO 4,600' MSL.

REGION:	FLIGHT INSPECTOR'S SIGNATURE:	TECHNICIAN'S SIGNATURE:	AIRCRAFT NO:

N 06 1991

699155.06

FLIGHT INSPECTION REPORT--INSTRUMENT LANDING SYSTEM

REVIEW INITIALS: WF FD

LOCATION: LOS ANGELES INT'L, CA.		2. IDENT: HQB
3. COMMON SYSTEM:	4. DATE / DATES OF INSPECTION: 6/14/91	5. OWNER: F

6. TYPE OF INSPECTION: ☐ SITE EVALUATION ☒ PERIODIC ☐ SPECIAL ☐ COMMISSIONING ☐ SURVEILLANCE ☐ INCOMPLETE

7. RUNWAY NO. 24L

8. FACILITY INSPECTED: ☒ LOCALIZER ☐ SDF ☒ GLIDE SLOPE ☒ 75 mHz MARKERS ☐ LDA ☒ DME ☒ LIGHTING SYSTEM ☒ COMPASS LOCATORS

9. LOCALIZER

COM'D WIDTH: 5.47

CATEGORY: I

FRONT COURSE TX 1 OT	TX 1 INITIAL	TX 1 FINAL	TX 2 OT	TX 2 INITIAL	TX 2 FINAL		BACK COURSE TX 1 OT	TX 1 INITIAL	TX 1 FINAL	TX 2 OT	TX 2 INITIAL	TX 2 FINAL
						COURSE WIDTH						
		59.2				MODULATION						
						CLEARANCE 150						
						CLEARANCE 90						
		2/6.15				COURSE STRUCTURE - Z 1						
		4/0.72				COURSE STRUCTURE - Z 2						
		7/0.06				COURSE STRUCTURE - Z 3						
						COURSE STRUCTURE - Z 4						
						COURSE STRUCTURE - Z 5						
		0.0/9.1				VERTICAL POLARIZATION						
						SYMMETRY						
		LK				ALIGNMENT						
						VOICE						
		S				IDENTIFICATION						
						USABLE DISTANCE						
DATE: 12/28/90			DATE:			MONITOR	DATE:			DATE:		
						COURSE WIDTH (Narrow)						
						COURSE WIDTH (Wide)						
						CLEARANCE 150						
						CLEARANCE 90						
						ALIGNMENT 150						
						ALIGNMENT 90						

10. GLIDE SLOPE

COM'D ANGLE: 3.00

CATEGORY: I

TX 1 OT	TX 1 INITIAL	TX 1 FINAL	TX 2 OT	TX 2 INITIAL	TX 2 FINAL	
		2.93				ANGLE
		78B				MODULATION
						WIDTH
						CLEARANCE BELOW PATH
						STRUCTURE BELOW PATH
		15/5.71				PATH STRUCTURE - Z 1
		23/2.74				PATH STRUCTURE - Z 2
		10/0.37				PATH STRUCTURE - Z 3
						USABLE DISTANCE
						SYMMETRY
DATE: 12/28/90			DATE:			MONITOR

11. GENERAL

	SAT	UNSAT
75 mHz MARKERS	☒	
COMPASS LOCATORS	☒	
DME	☒	
LIGHTING SYSTEMS	☒	

12. FACILITY STATUS

	F/C	G/S	B/C
UNRESTRICTED	☒	☒	NA
RESTRICTED			
UNUSABLE			

NOTAM's:

13. REMARKS:
THIS FLIGHTCHECK COMPLETES PERIODIC BEGUN 6/13/91.

REGION AWP	FLIGHT INSPECTOR'S SIGNATURE:	TECHNICIAN'S SIGNATURE: Roger L. Smith	AIRCRAFT NO: 75
FIFO SAC.			

FAA FORM 8240-7 (5/90)

JUL 15 1991

APPENDIX B

Facility Data Sheets for ILSs on Runways

24R, 24L, 25R and 25L

```
B
A311,OSS;P                    DATE= 09/06/91  HOUR= 13:19

                                          * * * ILS   INQUIRY * * *                          LAST UPDATE  7/ 2/91
AIRPORT  LOS ANGELES INTL                ARPT-ID KLAX   RWY 24R  LCTN LOS ANGELES          ST CA  REG WP  FIFO SAC  OWN F
                               * * * AFIS DATA * * *                                         * * * AIRPORT DATA * * *
 ILS-PAGE-1           ILS-PAGE-2            ILS-PAGE-3          ILS-PAGE-4                   ARP-LAT          N33-56-33.10
IDENT      OSS     GLA      N33-57-02.35   GS-OFF      L400    LC-DIS    10859               ARP-LON          W118-24-25.80
RW-BRG 263.00      GLO     W118-24-15.22   ON-DIS     38910    LC-OFF                        FIELD-ELEV            126.0
FREQ   108.50      GS-ALN           3.00 · TH-DIS      1026    LC-FCB   263.00               TH-LAT           N33-57-07.51
MVAR      E14      GS-WID            .70   TH-HGT       117    LC-BCB    82.98               TH-LON           W118-24-03.72
CAT         3      GS-HGT            119   RE-HGT       112    LC-WID     3.37               TH-ELEV          .      117.2
-                  RWY-LDG-LENGTH   8925                                                     RE-LAT           N33-56-56.74
* * * LOCALIZER * * *                                                                        RE-LON           W118-25-48.87
LAT      N33-56-53.17   XMITTERS      DUAL    LOC-RE        2960/  .487   LCW-TAIL         YES   RE-ELEV               111.6
LON     W118-26-23.74   EQUIP-TYPE      WL    LOC-TH       11885/ 1.956   LCW-PT-TH       0699  RWY-LENGTH/WIDTH     8925/150
ELEV            123.0   STBY-POWER    COMM    LOC-IM       12820/ 2.109   DATE-COMM   06/17/81   DSPLCD-TH-DIST
ANT-TYPE      LOG-PER   ESV            YES    LOC-MM       14773/ 2.431   SURVEY-ACCY        6   DSPLCD-TH-LAT    S00-00-00.00
DUAL-FREQ         YES   RESTRICTED      NO    LOC-OM/FAF  49769/ 8.190   AGREE-NO                DSPLCD-TH-LON   E000-00-00.00
US-DIST: FC  25000/85.0   BC       0/  .0     BC-CKPT                     COND-CODE          A   DSPLCD-TH-ELEV           .0
CLRNC-CVG: FC  90/35     150/35   BC  90/ 0  150/ 0   MON-WIDTH  W03.94 N02.79 VOICE    NONE     RWY-LDG-LENGTH          8925
CKPT-DESC: FC  FAF 8.1 DME                          BC                                           TDZ-ELEV               120.4
-
* * * GLIDE SLOPE * * *                                                   GS-ANT-OFF      L400    DECISION-HEIGHTS:
ELEV             114.9   XMITTERS       DUAL   DIS-TH-PT-C  855.4/ .140   MON-ANGLE  H3.30/L2.77    DH       DIST/RALT
ANT-TYPE       CAP-EFF   EQUIP-TYPE        WL  GS-TH             1026/ .168   DATE-COMM   09/16/81    (100)  912 115
CL-ELEV-ABM      118.6   FREQ          329.90  GS-IM             1961/  .322   SURVEY-ACCY        6    (150)  1867 164
TCH               55.2   ESV               NO  GS-MM             3914/  .644   AGREE-NO                (200)
ELEV-USED-TCH    CROWN   RESTRICTED         NO GS-OM/FAF        38910/ 6.403   COND-CODE          A   PERFORMANCE-CLASS
AFIS-CORDS     ANTENNA   GPI-TH         1052.7 RPI-TH                1026.0   STBY-POWER      BATT   GENERAL DATA:
ANT: LAT N33-57-02.35    LON     W118-24-15.22 AIM-PT: LAT N33-57-06.28   LON     W118-24-15.80     YR/MVAR          1980/E14
                                                                                                     ICAO                    K
* ILS-DME/OTHER-DME *      *      OUTER-MKR      *      * MIDDLE-MARKER *      * INNER-MARKER *      COM-SYS               YES
CHAN               022X    LAT          N33-57-53.60       N33-57-11.00       N33-57-08.60          AFCC
LAT       N33-56-50.26    LON          W118-16-37.40      W118-23-29.70      W118-23-52.70          BC-STATUS            NONE
LON      W118-26-19.23    ELEV                 136.0              104.0              105.0         MON-CAT                 1
ELEV              133.0    DIST-TH         37884/ 6.23         2888/  .47           935/  .15        MON-LOC              ATCT
RESTRICTED           NO    DIST-DIR-CL            R52                                                FIFO-PROCEDURES       SAC
XMITTERS         SINGLE    DATE-COMM         06/17/81           01/07/75           01/07/75        ASSOC-FACS:            SIAP
DATE-COMM      00/00/00    NAME/USE             ROMEN                                                 LOM     OSS /278.00  YES
SURVEY-ACCY           6    COND-CODE                A                  A                  A           LMM
AGREE-NO                   SURVEY-ACCY              6                  6                  6           LIM
COND-CODE             A    TAPELINE            2039.2              205.1              102.8           NDB
DME-FAF/CKPT        8.1    EARTH-CURVE           36.2                 .4                 .0           ASSOC-MKR
OTHER-DME                  MSL-ALTITUDE        2194.0              324.1              221.4           APL       C Z A
-
* * * SIAPS * * *                   APL                                    APL                                    APL
     DESCRIPTION        AMDT  PUBL  RMT        DESCRIPTION         AMDT  PUBL  RMT        DESCRIPTION         AMDT  PUBL  RMT
         ILS RWY 24R    20    YES   NO         ILS RWY 24R CAT 2     20   YES  NO         ILS RWY 24R CAT 3     20   YES  NO

RESTRICTION:


     REMARKS:

1 DME LOCATED 2618' OUT SER AND 338' LEFT. DME TO AER 11534'/1.90 NM, DME TO OM 49427'/8.13 NM.
2 LCW/CLR CHECKED AT 4600' MSL. RNA34AF CHECKED SATISFACTORY.
3 NOS SURVEY 11/30/88.
                                        * * *  END OF REPORT * * *
```

```
B
A311,HQB;P                      DATE= 09/06/91  HOUR= 13:20

                                                * * * ILS   INQUIRY * * *                                 LAST UPDATE  7/15/91
AIRPORT  LOS ANGELES INTL                 ARPT-ID KLAX   RWY 24L  LCTN LOS ANGELES                     ST CA  REG WP  FIFO SAC  OWN F
                                 * * * AFIS DATA * * *                                                 * * * AIRPORT DATA * * *
 ILS-PAGE-1             ILS-PAGE-2             ILS-PAGE-3          ILS-PAGE-4                          ARP-LAT             N33-56-33.10
IDENT     HQB    GLA     N33-57-02.25    GS-OFF      R290    LC-DIS     10534                          ARP-LON             W118-24-25.80
RW-BRG 263.00    GLO    W118-24-15.21    OM-DIS     38918    LC-OFF                                    FIELD-ELEV                 126.0
FREQ   108.50    GS-ALN          3.00    TH-DIS      1026    LC-FCB    263.00                          TH-LAT              N33-57-00.64
MVAR      E14    GS-WID           .70    TH-HGT       111    LC-BCB     82.98                          TH-LON              W118-24-02.71
CAT         1    GS-HGT           116    RE-HGT       108    LC-WID      3.47                          TH-ELEV                    111.1
-                RWY-LDG-LENGTH  10285                                                                 RE-LAT              N33-56-48.23
* * * LOCALIZER * * *                                                                                  RE-LON              W118-26-03.87
LAT       N33-56-46.68   XMITTERS     SINGLE   LOC-RE       1275/  .209   LCW-TAIL          YES        RE-ELEV                    108.1
LON     W118-26-18.90    EQUIP-TYPE       WL   LOC-TH      11560/ 1.902   LCW-FT-TH        0700       RWY-LENGTH/WIDTH       10285/150
ELEV             122.0   STBY-POWER     COMM   LOC-IM                     DATE-COMM    08/25/67        DSPLCD-TH-DIST
ANT-TYPE        V-RING   ESV              NO   LOC-MM      14498/ 2.386   SURVEY-ACCY         6        DSPLCD-TH-LAT       S00-00-00.00
DUAL-FREQ           NO   RESTRICTED       NO   LOC-OM/FAF  49452/ 8.138   AGREE-NO           .         DSPLCD-TH-LON       E000-00-00.00
US-DIST: FC  25000/85.0   BC      0/  .0       BC-CKPT                    COND-CODE           A        DSPLCD-TH-ELEV                .0
CLRNC-CVG: FC  90/35    150/35   BC  90/ 0  150/ 0  MON-WIDTH  W04.05 N02.88 VOICE     NONE            RWY-LDG-LENGTH             10285
CKPT-DESC: FC  FAF 8.1 DME                     BC                                                      TDZ-ELEV                   121.0
-
* * * GLIDE SLOPE * * *                                                  GS-ANT-OFF      R290          DECISION-HEIGHTS:
ELEV            114.9    XMITTERS      SINGLE   DIS-TH-PT-C  782.9/ .128  MON-ANGLE  H3.30/L2.77         DH       DIST/RALT
ANT-TYPE     NULL-REF    EQUIP-TYPE        WL  GS-TH          1026/ .168  DATE-COMM    04/30/89         (100)
CL-ELEV-ABM     116.3    FREQ          329.90  GS-IM              /       SURVEY-ACCY         6         (150)
TCH              59.0    ESV               NO  GS-MM          3964/ .652  AGREE-NO                      (200)
ELEV-USED-TCH   CROWN    RESTRICTED        NO  GS-OM/FAF     38918/ 6.405 COND-CODE           A        PERFORMANCE-CLASS
AFIS-CORDS    ANTENNA    GPI-TH        1125.2  RPI-TH            1026.0   STBY-POWER       COMM        GENERAL DATA:
ANT: LAT N33-57-02.25    LON    W118-24-15.21  AIM-PT: LAT N33-56-59.40   LON      W118-24-14.79         YR/MVAR          1980/E14
                                                                                                         ICAO                    K
* ILS-DME/OTHER-DME *     *      OUTER-MKR      *    * MIDDLE-MARKER *     *  INNER-MARKER *             COM-SYS               YES
CHAN             022X     LAT        N33-57-53.60       N33-57-04.20                                     AFCC
LAT      N33-56-50.26     LON       W118-16-37.40      W118-23-28.10                                     BC-STATUS            NONE
LON     W118-26-19.23     ELEV              136.0              103.0                                    MON-CAT              0
ELEV            133.0     DIST-TH     37892/ 6.23         2938/  .48                                     MON-LOC              ATCT
RESTRICTED         NO     DIST-DIR-CL                                                                    FIFO-PROCEDURES       SAC
XMITTERS         DUAL     DATE-COMM      08/25/67           08/25/67                                     ASSOC-FACS:          SIAP
DATE-COMM    08/25/67     NAME/USE          ROMEN                                                          LOM
SURVEY-ACCY         6     COND-CODE             A                  A                                       LMM
AGREE-NO                  SURVEY-ACCY           6                  6                                       LIM
COND-CODE           A     TAPELINE         2039.6              207.7                                       NDB
DME-FAF/CKPT      8.1     EARTH-CURVE        36.2                 .4                                       ASSOC-MKR
OTHER-DME                 MSL-ALTITUDE     2192.1              324.4                                       APL      A
-
* * * SIAPS * * *                    APL                                     APL                                     APL
    DESCRIPTION        AMDT  PUBL  RMT        DESCRIPTION        AMDT  PUBL  RMT        DESCRIPTION        AMDT  PUBL  RMT
        ILS RWY 24L    19    YES   NO

RESTRICTION:


    REMARKS:

 1 DME ALSO SERVES RUNWAY 24R. LOCATED 1259 OUT C/L FORM SER AND 361' RIGHT OF C/L. DME TO ARR = 11544'/1.9 NM; DME TO OM = 49436'/8
   .14 NM.
 2 LOCALIZER COURSE WIDTH AND CLEARANCE COMPARIBILITY ARE SATISFACTORY UP TO 10,000' MSL. RNA34AF IS SAT.
 3 ASSOC-FACS; LOM OSS 278 SIAP YES.
```

```
B
A311,CFN;P               DATE= 09/06/91  HOUR= 13:20

                                         * * * ILS   INQUIRY * * *                                 LAST UPDATE  4/23/91
AIRPORT  LOS ANGELES INTL              ARPT-ID KLAX   RWY 25R  LCTN LOS ANGELES                  ST CA  REG WP  FIFO SAC  OWN P
                           * * * APIS DATA * * *                                                  * * * AIRPORT DATA * * *
 ILS-PAGE-1           ILS-PAGE-2           ILS-PAGE-3         ILS-PAGE-4                         ARP-LAT            N33-56-33.10
IDENT     CFN     GLA    N33-56-17.81   GS-OFF     L334   LC-DIS    10806                        ARP-LON           W118-24-25.80
RW-BRG 263.02     GLO   W118-23-06.93   OM-DIS    33714   LC-OFF                                 FIELD-ELEV                126.0
FREQ   109.90     GS-ALN         3.00   TH-DIS     1039   LC-FCB   263.02                        TH-LAT             N33-56-23.49
MVAR      E14     GS-WID          .70   TH-HGT       94   LC-BCB    83.00                        TH-LON            W118-22-43.89
CAT         1     GS-HGT           98   RE-HGT      119   LC-WID     3.39                        TH-ELEV                    92.0
-                 RWY-LDG-LENGTH  11134                                                          RE-LAT             N33-56-08.93
* * * LOCALIZER * * *                                                                            RE-LON            W118-25-06.33
LAT      N33-56-08.07  XMITTERS    SINGLE  LOC-RE         711/  .117  LCW-TAIL          YES      RE-ELEV                   118.5
LON     W118-25-14.70  EQUIP-TYPE      WL  LOC-TH       11845/ 1.949  LCW-PT-TH        0701     RWY-LENGTH/WIDTH      12091/150
ELEV            119.0  STBY-POWER    COMM  LOC-IM                     DATE-COMM    07/25/87      DSPLCD-TH-DIST              957
ANT-TYPE      LOG-PER  ESV            YES  LOC-MM       14737/ 2.425  SURVEY-ACCY         6      DSPLCD-TH-LAT      N33-56-22.34
DUAL-FREQ         YES  RESTRICTED      NO  LOC-OM/FAF  44520/ 7.327   AGREE-NO                   DSPLCD-TH-LON     W118-22-55.17
US-DIST: FC  4620/85.0  BC      0/  .0     BC-CKPT                    COND-CODE           A      DSPLCD-TH-ELEV             94.0
CLRNC-CVG: FC  90/35    150/35  BC  90/ 0  150/ 0  NOM-WIDTH  W03.96 N02.81 VOICE     NONE       RWY-LDG-LENGTH            11134
CKPT-DESC: FC  DME TO FAF 7.4                  BC                                                TDZ-ELEV                  102.0
-
* * * GLIDE SLOPE * * *                                               GS-ANT-OFF      L334     DECISION-HEIGHTS:
ELEV               95.5  XMITTERS      SINGLE  DIS-TH-PT-C  798.5/ .131  NON-ANGLE  H3.30/L2.77     DH       DIST/RALT
ANT-TYPE        CAP-EFF  EQUIP-TYPE        WL  GS-TH          1039/ .170  DATE-COMM    09/29/87     (100)
CL-ELEV-ABM        97.7  FREQ          333.80  GS-IM               /      SURVEY-ACCY         6     (150)
TCH                58.2  ESV               NO  GS-MM          3931/  .646  AGREE-NO                  (200)
ELEV-USED-TCH     CROWN  RESTRICTED        NO  GS-OM/FAF    33714/ 5.548  COND-CODE           A    PERFORMANCE-CLASS
APIS-CORDS      ANTENNA  GPI-TH        1109.6  RPI-TH              1039.0  STBY-POWER       COMM    GENERAL DATA:
ANT: LAT N33-56-17.81    LON    W118-23-06.93  AIM-PT: LAT N33-56-21.09   LON     W118-23-07.41      YR/MVAR          1980/E14
                                                                                                    ICAO                    K
* ILS-DME/OTHER-DME *    *      OUTER-MKR       *      * MIDDLE-MARKER *     *  INNER-MARKER *      COM-SYS               YES
CHAN              036X   LAT         N33-56-53.40        N33-56-25.80                               AFCC
LAT       N33-56-04.27   LON        W118-16-29.00       W118-22-21.10                               BC-STATUS            NONE
LON      W118-25-16.50   ELEV               127.0                84.7                              MON-CAT                  1
ELEV             126.0   DIST-TH      32675/ 5.37          2892/  .47                               MON-LOC     LAX TWR TRACON
RESTRICTED          NO   DIST-DIR-CL         L832                                                    FIFO-PROCEDURES        SAC
XMITTERS                 DATE-COMM       01/31/69            01/31/69                              ASSOC-FACS:           SIAP
DATE-COMM     02/03/81   NAME/USE           LIMMA                                                    LOM
SURVEY-ACCY          6   COND-CODE              A                   A                                LMM
AGREE-NO                 SURVEY-ACCY            6                   6                                LIM
COND-CODE            A   TAPELINE          1766.9               206.0                                NDB
DME-FAF/CKPT       7.4   EARTH-CURVE         27.2                  .4                                ASSOC-MKR
OTHER-DME                MSL-ALTITUDE      1891.8               304.1                                APL       A
-
* * * SIAPS * * *                  APL                                     APL                                    APL
     DESCRIPTION        AMDT  PUBL  RMT       DESCRIPTION        AMDT  PUBL  RMT       DESCRIPTION        AMDT  PUBL  RMT
         ILS RWY 25R    5     YES   NO

 RESTRICTION:  NONE


    REMARKS:

 1 THE DME USED WITH THIS ILS ALSO USED WITH RWY 25L.
 2 MOS SURVEY 11/30/88.
                                    * * *  END OF REPORT * * *
```

```
B
A311,LAX;P                    DATE= 09/06/91  HOUR= 13:22

                                              * * * ILS   INQUIRY * * *                           LAST UPDATE  7/ 2/91
AIRPORT  LOS ANGELES INTL                ARPT-ID KLAX   RWY 25L  LCTN LOS ANGELES              ST CA  REG WP  FIFO SAC  OWN P
                                * * * APIS DATA * * *                                          * * * AIRPORT DATA * * *
 ILS-PAGE-1            ILS-PAGE-2            ILS-PAGE-3          ILS-PAGE-4                    ARP-LAT          N33-56-33.10
IDENT      LAX    GLA     N33-56-17.71   GS-OFF     R400    LC-DIS     11030                   ARP-LON         W118-24-25.80
RW-BRG 263.01     GLO    W118-23-06.92   OM-DIS    33716    LC-OFF                             FIELD-ELEV              126.0
FREQ   109.90     GS-ALN          3.00   TH-DIS     1001    LC-FCB    263.01                   TH-LAT           N33-56-14.99
MVAR      E14     GS-WID           .70   TH-HGT       95    LC-BCB     82.99                   TH-LON          W118-22-54.55
CAT         2     GS-HGT            97   RE-HGT      118    LC-WID      3.33                   TH-ELEV                  94.9
-                 RWY-LDG-LENGTH  11096                                                        RE-LAT           N33-56-01.61
* * * LOCALIZER * * *                                                                          RE-LON          W118-25-05.25
LAT      N33-56-00.48   XMITTERS      DUAL    LOC-RE        935/  .153   LCW-TAIL         YES  RE-ELEV                 117.9
LON     W118-25-16.26   EQUIP-TYPE      TI    LOC-TH      12031/ 1.980   LCW-FT-TH       0699  RWY-LENGTH/WIDTH   11096/200
ELEV            117.0   STBY-POWER    BATT    LOC-IM      13020/ 2.142   DATE-COMM   02/27/76  DSPLCD-TH-DIST
ANT-TYPE    TRAV-WAVE   ESV            YES    LOC-MM      14905/ 2.453   SURVEY-ACCY        6  DSPLCD-TH-LAT   S00-00-00.00
DUAL-FREQ         YES   RESTRICTED      NO    LOC-OM/FAF  44746/ 7.364   AGREE-NO              DSPLCD-TH-LON  E000-00-00.00
US-DIST: FC  25000/50.0   BC  14500/85.0      BC-CKPT                    COND-CODE          A  DSPLCD-TH-ELEV            .0
CLRNC-CVG: FC  90/35   150/35   BC  90/ 0  150/ 0   MON-WIDTH  W03.89 N02.76 VOICE    NONE     RWY-LDG-LENGTH         11096
CKPT-DESC: FC  OUTER MARKER 7.36 DME            BC                                             TDZ-ELEV               101.0
-
* * * GLIDE SLOPE * * *                                                 GS-ANT-OFF      R400   DECISION-HEIGHTS:
ELEV              95.5   XMITTERS      DUAL   DIS-TH-PT-C  859.4/ .141  MON-ANGLE H3.30/L2.77    DH       DIST/RALT
ANT-TYPE       CAP-EFF   EQUIP-TYPE      TI   GS-TH         1001/ .164  DATE-COMM   03/19/76    (100)  976 111
CL-ELEV-ABM       97.4   FREQ        333.80   GS-IM         1990/  .327 SURVEY-ACCY        6    (150)  1930 163
TCH               55.0   ESV             NO   GS-MM         3875/  .637 AGREE-NO                (200)
ELEV-USED-TCH    CROWN   RESTRICTED      NO   GS-OM/FAF    33716/ 5.548 COND-CODE          A   PERFORMANCE-CLASS
APIS-CORDS     ANTENNA   GPI-TH      1048.7   RPI-TH           1001.0   STBY-POWER      BATT   GENERAL DATA:
ANT: LAT N33-56-17.71    LON    W118-23-06.92 AIM-PT: LAT N33-56-13.78  LON    W118-23-06.34     YR/MVAR          1980/E14
                                                                                                 ICAO                    K
* ILS-DME/OTHER-DME *    *      OUTER-MKR      *    * MIDDLE-MARKER *     *  INNER-MARKER *      COM-SYS               YES
CHAN             036X    LAT        N33-56-53.40       N33-56-18.50          N33-56-16.20        AFCC
LAT      N33-56-04.27    LON       W118-16-29.00      W118-22-20.70         W118-22-42.90        BC-STATUS            NONE
LON     W118-25-16.50    ELEV              127.0               84.0                  90.7       MON-CAT                  1
ELEV            126.0    DIST-TH     32715/ 5.38         2874/  .47             989/  .16        MON-LOC              ATCT
RESTRICTED         NO    DIST-DIR-CL                                                             FIFO-PROCEDURES       SAC
XMITTERS         DUAL    DATE-COMM      02/27/76           02/27/76              02/27/76        ASSOC-FACS:          SIAP
DATE-COMM    04/04/81    NAME/USE          LIMMA                                                  LOM
SURVEY-ACCY         6    COND-CODE             A                  A                     A         LMM
AGREE-NO                 SURVEY-ACCY           6                  6                     6         LIM
COND-CODE           A    TAPELINE         1767.0              203.1                 104.3         NDB
DME-FAF/CKPT      7.4    EARTH-CURVE        27.2                 .4                    .0         ASSOC-MKR
OTHER-DME                MSL-ALTITUDE     1891.6              300.8                 201.7         APL       R A
-
* * * SIAPS * * *                    APL                                 APL                                APL
    DESCRIPTION          AMDT  PUBL  RMT       DESCRIPTION      AMDT  PUBL  RMT      DESCRIPTION      AMDT  PUBL  RMT
        ILS RWY 25L      2     YES   NO

RESTRICTION:  NONE


   REMARKS:

 1 DME 44,719'/7.36 NM TO FAF. DME LOCATED 908' OUT RWY C/L EXTENDED FROM SER AND 382' RIGHT OF RWY C/L EXTENDED.
 2 LOC COURSE WIDTH AND CLEARANCE COMPARIBILITY SAT UP TO 6000 MSL.
 3 NOS SURVEY 11/30/88.
 4 LOC UNUSABLE INSIDE RUNWAY THRESHOLD. (5/3/91)
```

APPENDIX C

Standard ILS Instrument Approach Procedure Charts for the 8 Runways at Los Angeles International Airport

APPENDIX C

Standard ILS Instrument Approach Procedure Charts for the 8 Runways at Los Angeles International Airport

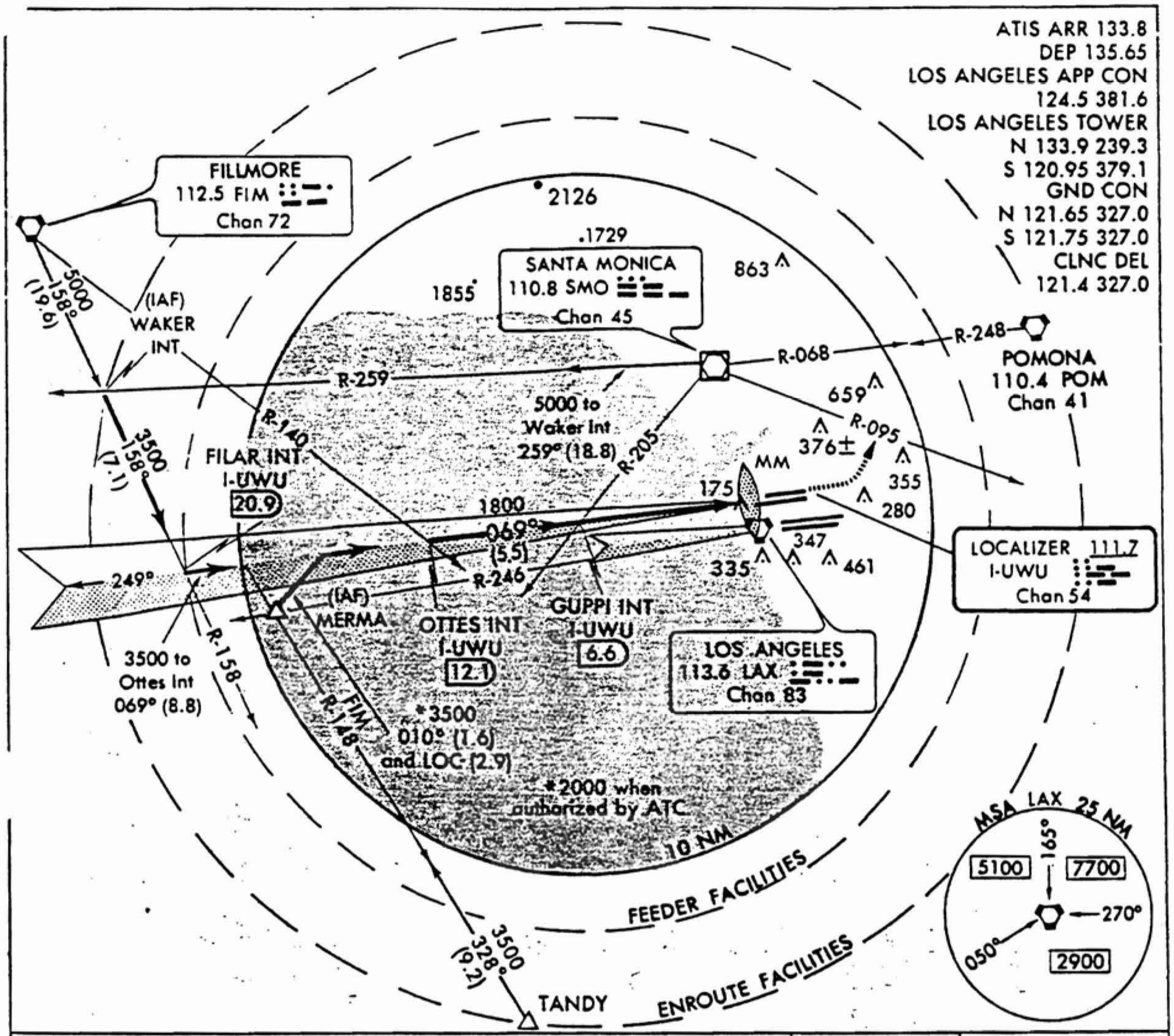
Amdt 7 90235

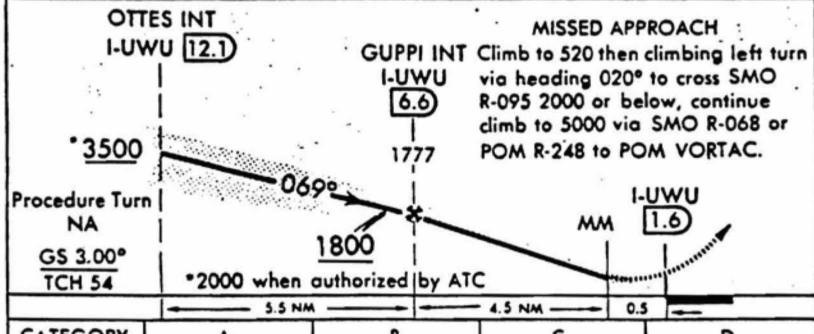
'.S RWY 6L

AL-237 (FAA)

LOS ANGELES INTL (LAX)
LOS ANGELES, CALIFORNIA

ATIS ARR 133.8
DEP 135.65
LOS ANGELES APP CON
124.5 381.6
LOS ANGELES TOWER
N 133.9 239.3
S 120.95 379.1
GND CON
N 121.65 327.0
S 121.75 327.0
CLNC DEL
121.4 327.0





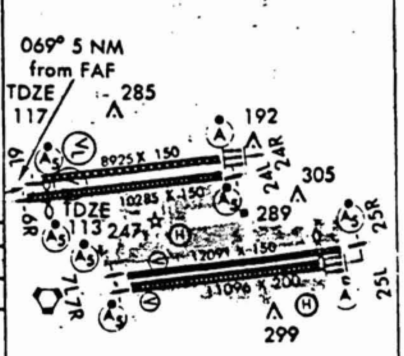
MISSED APPROACH
Climb to 520 then climbing left turn via heading 020° to cross SMO R-095 2000 or below, continue climb to 5000 via SMO R-068 or POM R-248 to POM VORTAC.

CATEGORY	A	B	C	D
S-ILS 6L	317/24 200 (200-½)			
S-LOC 6L	440/24 323 (400-½)			440/40 323 (400-¾)
SIDESTEP • • RWY 6R	440/60 327 (400-1¼)			440-1¾ 327 (400-1¾)

Cat. D S-LOC visibility increased to RVR 5000 for inoperative MALSR.
••Inoperative table does not apply to Categories A and B for inoperative MALSR Rwy 6R.
Simultaneous approaches authorized with Runway 7L/R.
▽

ELEV 126

Rwy 25R ldg 11133'
Rwy 6R ldg 9964'



TDZ/CL Rwys 6R, 24R and 25L
HIRL all rwys

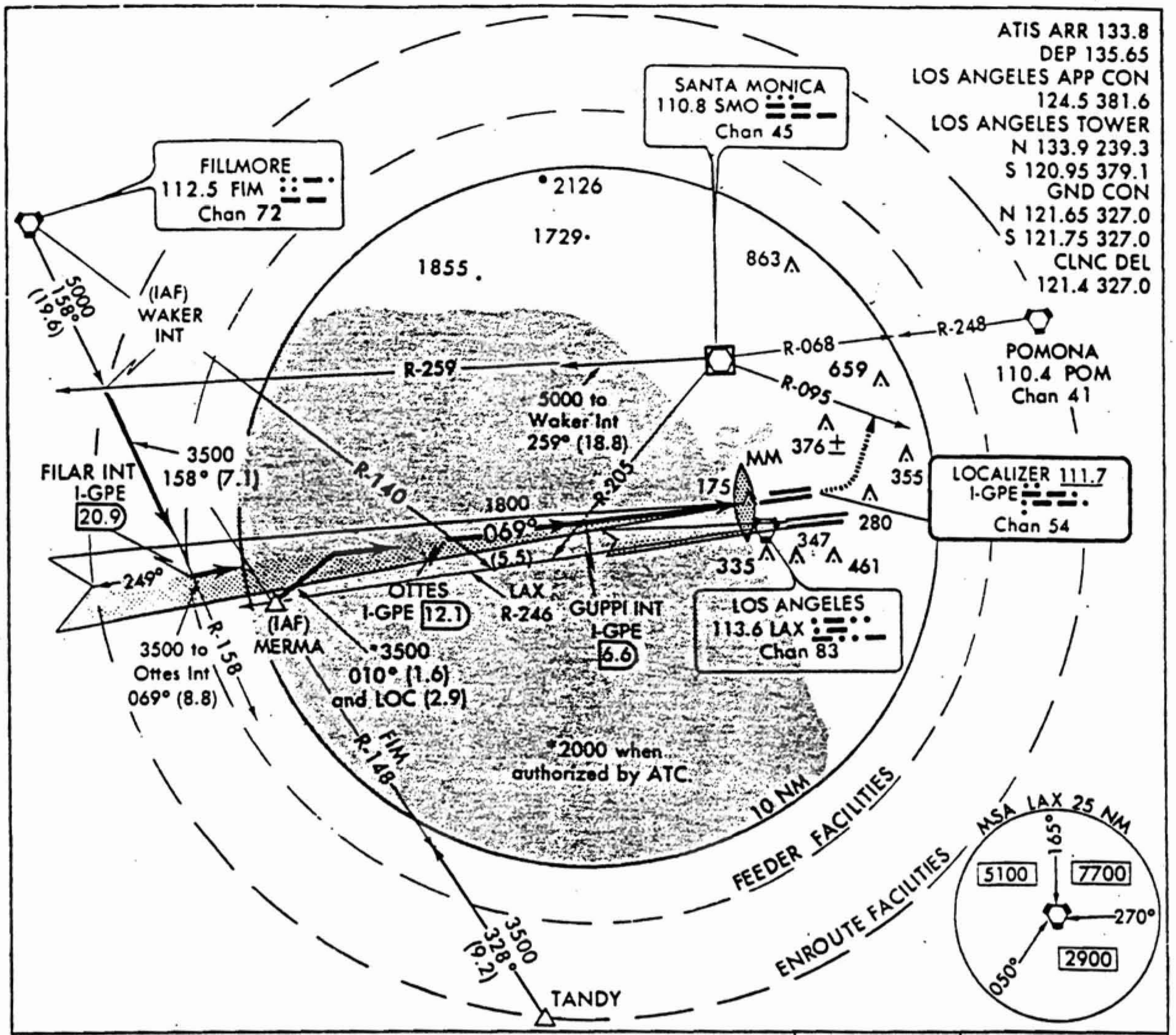
FAF to MAP 5 NM					
Knots	60	90	120	150	180
Min:Sec	5:00	3:20	2:30	2:00	1:40

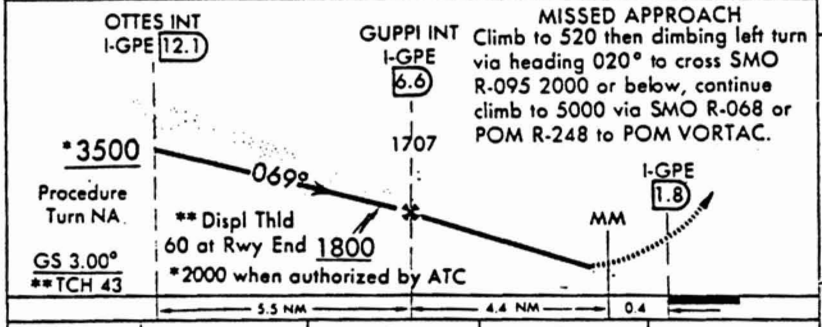
ILS RWY 6R

AL-237 (FAA)

LOS ANGELES, CALIFORNIA

ATIS ARR 133.8
DEP 135.65
LOS ANGELES APP CON
124.5 381.6
LOS ANGELES TOWER
N 133.9 239.3
S 120.95 379.1
GND CON
N 121.65 327.0
S 121.75 327.0
CLNC DEL
121.4 327.0

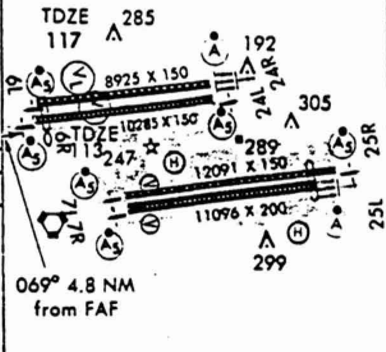




MISSED APPROACH
Climb to 520 then climbing left turn via heading 020° to cross SMO R-095 2000 or below, continue climb to 5000 via SMO R-068 or POM R-248 to POM VORTAC.

ELEV 126

Rwy 25R ldg 11133'
Rwy 6R ldg 9964'



CATEGORY	A	B	C	D
S-ILS 6R	313/18 200 (200-⅜)			
S-LOC 6R	400/24 287 (300-½)			400/40 287 (300-¾)
SIDESTEP† RWY 6L	440/50 323 (400-1)			440-1½ 323 (400-1½)

Cat. D S-LOC visibility increased to RVR 5000 for inoperative MALSR.
†Inoperative table does not apply to Categories A and B for inoperative MALSR Rwy 6L.
Simultaneous approaches authorized with Runways 7L/R.

TDZ/CL Rwys 6R, 24R and 25L
HIRL all rwys

FAF to MAP 4.8 NM

Knots	60	90	120	150	180
Min:Sec	4:48	3:12	2:24	1:55	1:36

ILS RWY 6R

33°57'N - 118°24'W

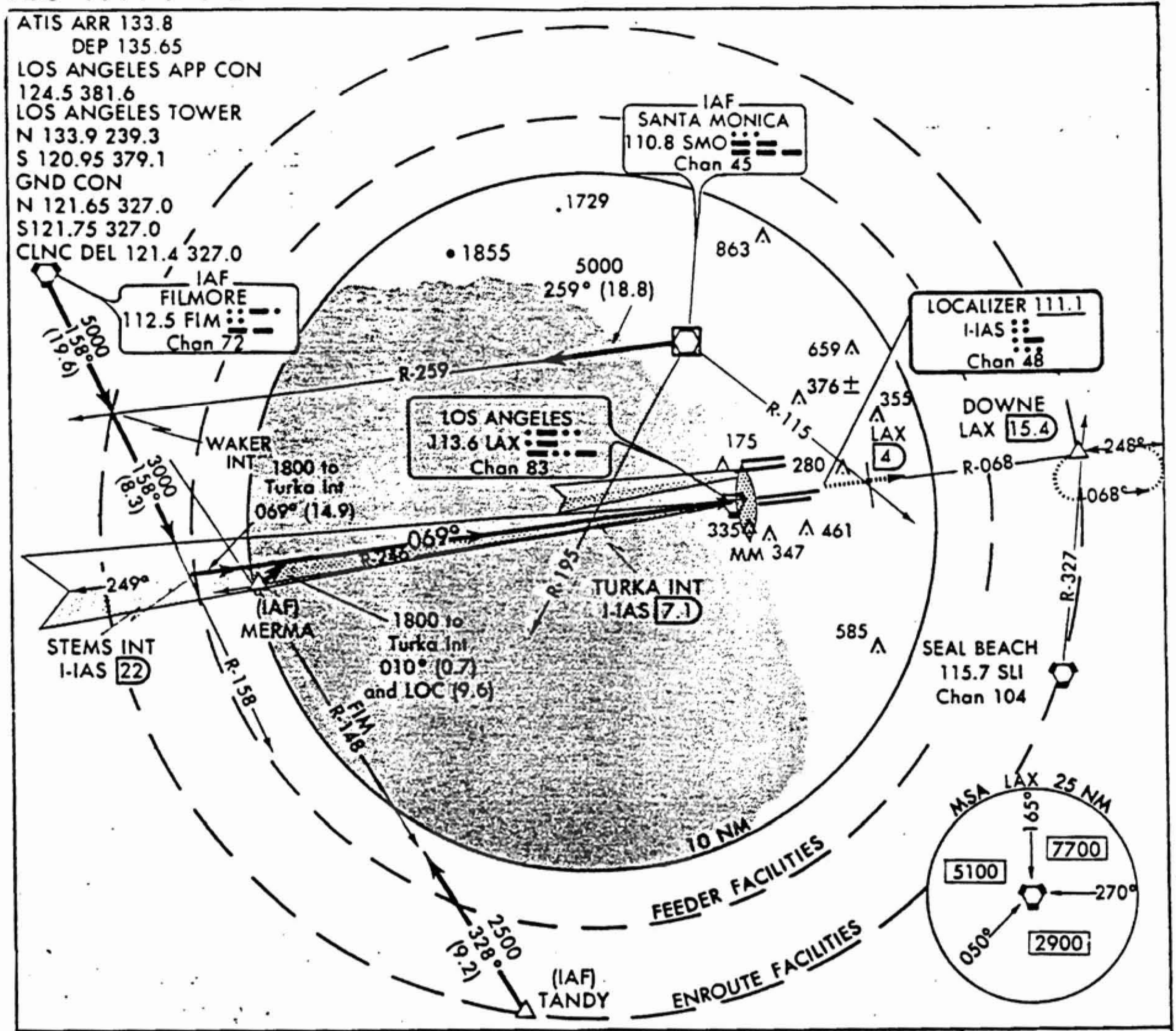
LOS ANGELES, CALIFORNIA
LOS ANGELES INTL (LAX)

Amdt 3 90235

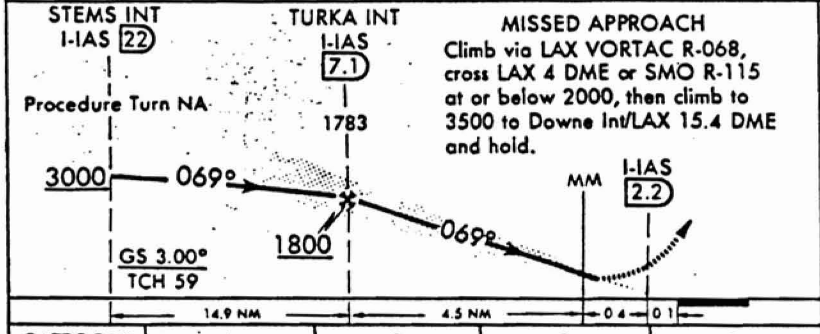
ILS RWY 7L

AL-237 (FAA)

LOS ANGELES INTL (LAX)
LOS ANGELES, CALIFORNIA



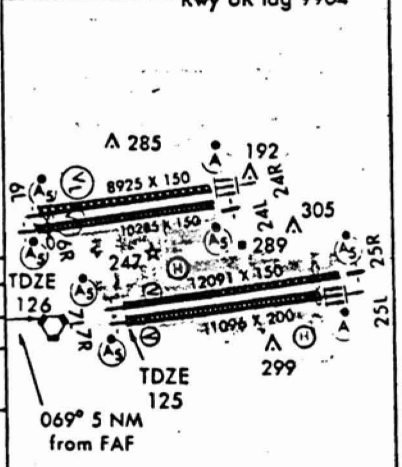
ATIS ARR 133.8
DEP 135.65
LOS ANGELES APP CON
124.5 381.6
LOS ANGELES TOWER
N 133.9 239.3
S 120.95 379.1
GND CON
N 121.65 327.0
S121.75 327.0
CLNC DEL 121.4 327.0



MISSED APPROACH
Climb via LAX VORTAC R-068, cross LAX 4 DME or SMO R-115 at or below 2000, then climb to 3500 to Downe Int/LAX 15.4 DME and hold.

ELEV 126

Rwy 25R ldg 11133'
Rwy 6R ldg 9964'



CATEGORY	A	B	C	D
S-ILS 7L	326/24 200 (200-½)			
S-LOC 7L	460/24 334 (400-½)			460/40 334 (400-¾)
SIDESTEP* RWY 7R	460/50 335 (400-1)			460-1½ 335 (400-1½)

Simultaneous approaches authorized with Runways 6L/6R.
Cat. D S-LOC 7L visibility increased to RVR 5000 for inoperative MALSR.
*Sidestep 7R inoperative table does not apply to Categories A and B.
▽

TDZ/CL Rwys 6R, 24R and 25L
HIRL all Rwys

FAF to MAP 4.9 NM

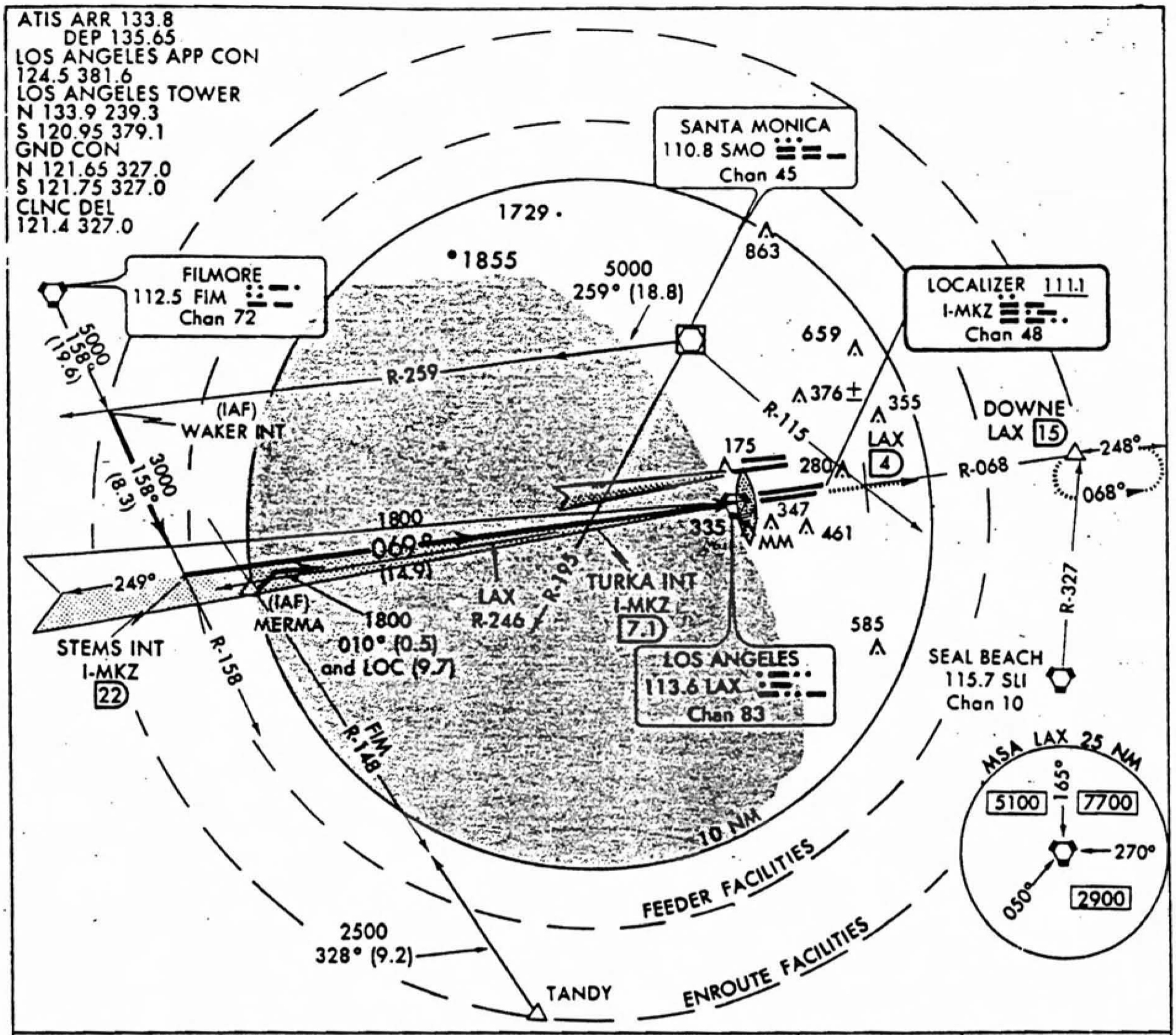
Knots	60	90	120	150	180
Min:Sec	4:54	3:16	2:27	1:58	1:38

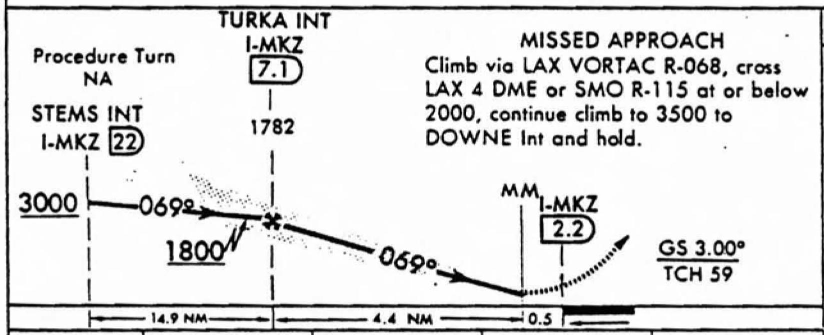
Amdt 1 90263

ILS RWY 7R

AL-237 (FAA)

LOS ANGELES INTL (LAX)
LOS ANGELES, CALIFORNIA





MISSED APPROACH
Climb via LAX VORTAC R-068, cross LAX 4 DME or SMO R-115 at or below 2000, continue climb to 3500 to DOWNE Int and hold.

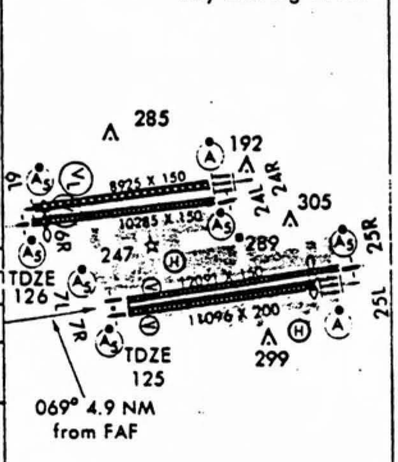
CATEGORY	A	B	C	D
S-ILS 7R	325/24 200 (200-½)			
S-LOC 7R	460/24 335 (400-½)			460/40 335 (400-¾)
SIDESTEP* RWY 7L	460/50 334 (400-1)			460-1½ 334 (400-1½)

Simultaneous approaches authorized with Runway 6L/R.
Cat. D S-LOC visibility increased to RVR 5000 for inoperative MALSR.
*Inoperative table does not apply to Cat. A and B; Cat. C and D increase visibility ½ mile for inoperative MALSR Rwy 7L.

▽

ELEV 126

Rwy 6R ldg 9964'
Rwy 25R ldg 11133'



TDZ/CL Rwys 6R, 24R and 25L
HIRL all rwys

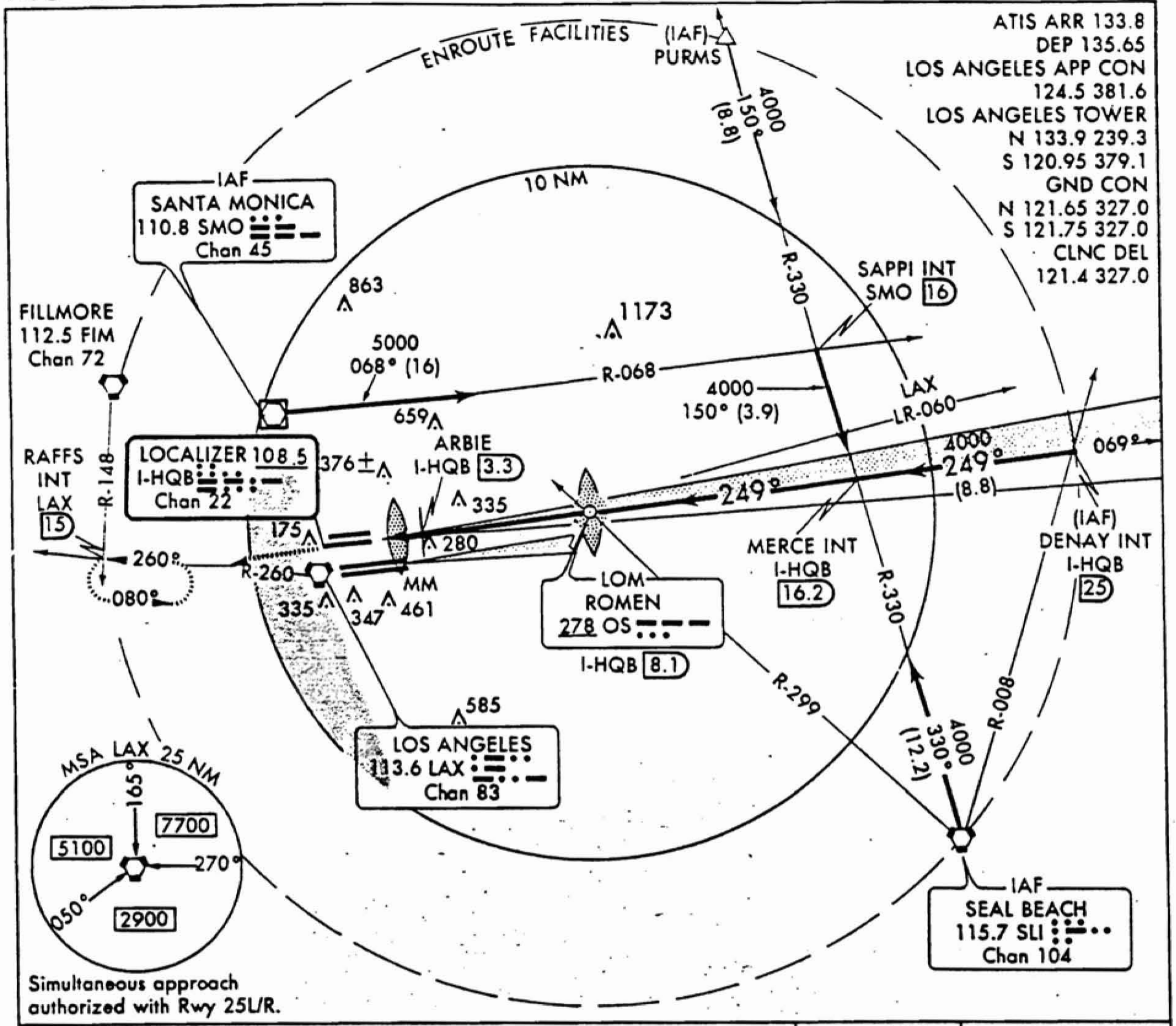
FAF to MAP 4.9 NM					
Knots	60	90	120	150	180
Min:Sec	4:54	3:16	2:27	1:58	1:38

Amdt 19 90235

ILS RWY 24L

AL-237 (FAA)

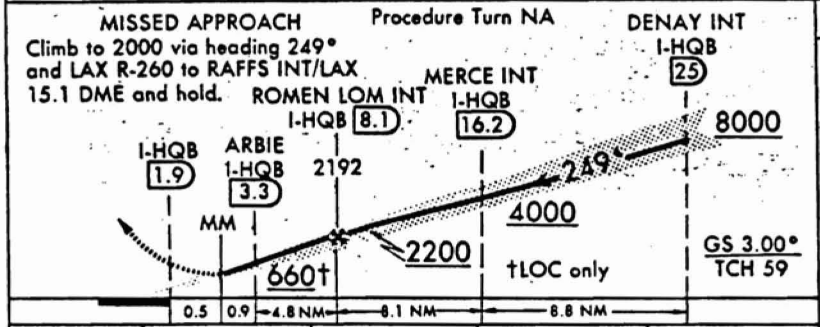
LOS ANGELES INTL (LAX)
LOS ANGELES, CALIFORNIA



Simultaneous approach authorized with Rwy 25L/R.

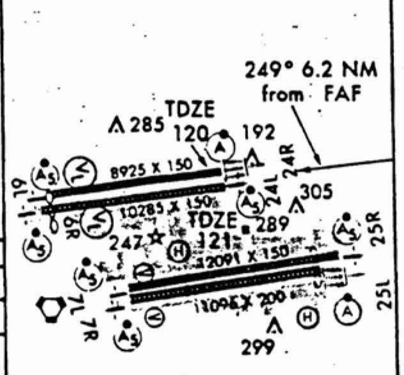
MISSED APPROACH
Climb to 2000 via heading 249° and LAX R-260 to RAFFS INT/LAX 15.1 DME and hold.

Procedure Turn NA



ELEV 126

Rwy 25R ldg 11133'
Rwy 6R ldg 9964'



CATEGORY	A	B	C	D
S-ILS 24L	321/24 200 (200-½)			
S-LOC 24L	660/24 539 (600-½)		660/50 539 (600-1)	660/60 539 (600-1¼)
SIDESTEP RWY 24R*	660/50 540 (600-1)			660-1½ 540 (600-1½)
ARBIE DME MINIMUMS				
S-LOC 24L**	460/24 339 (400-½)			460/40 339 (400-¾)

*Inoperative table does not apply to Categories A and B.
**Cat. D visibility increased to RVR 5000 for inoperative MALSR.
▽

TDZ/CL Rwys 6R, 24R and 25L
HIRL all Rwys

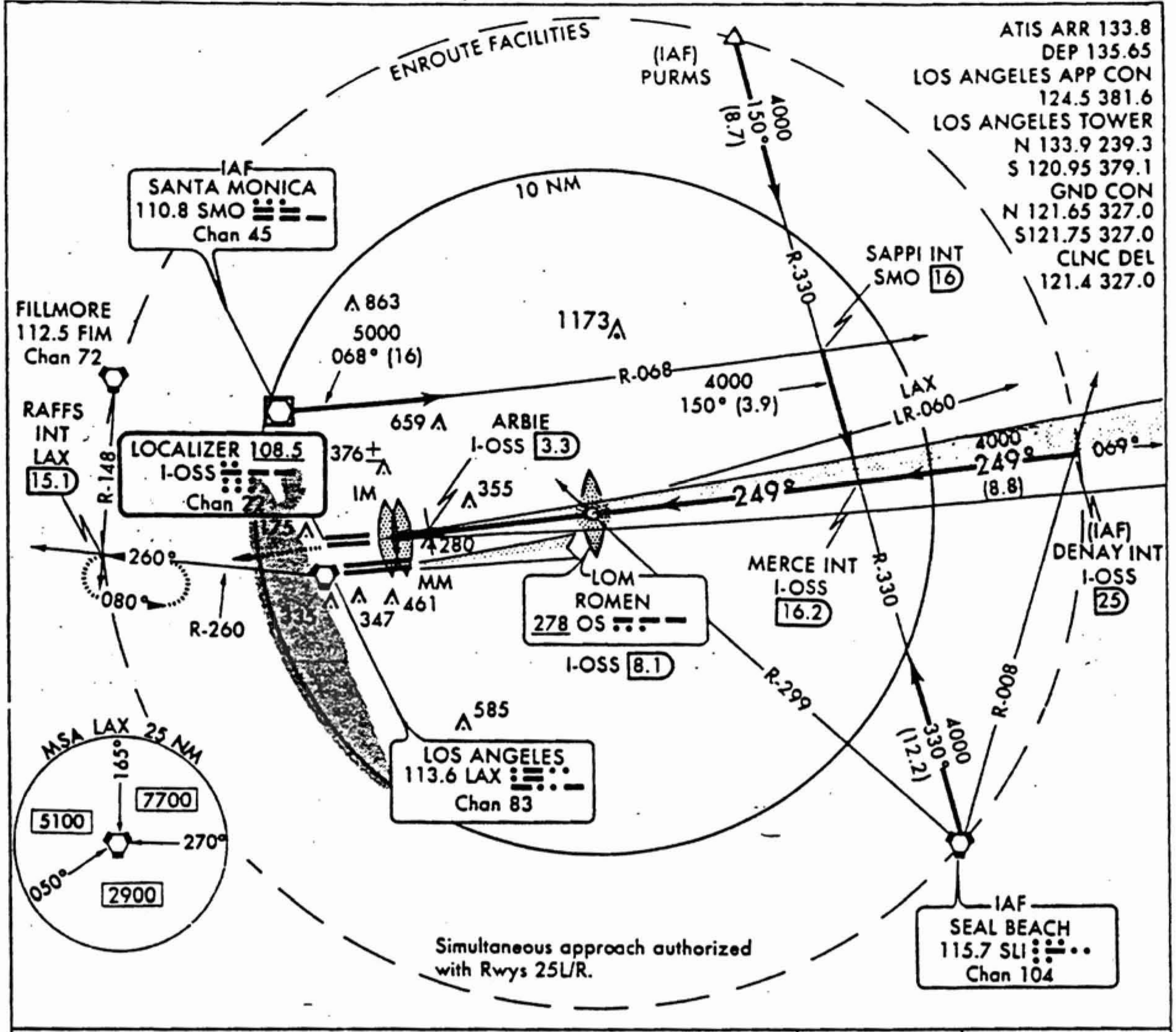
FAF to MAP 6.2 NM

Knots	60	90	120	150	180
Min:Sec	6:12	4:08	3:06	2:29	2:04

ILS RWY 24R

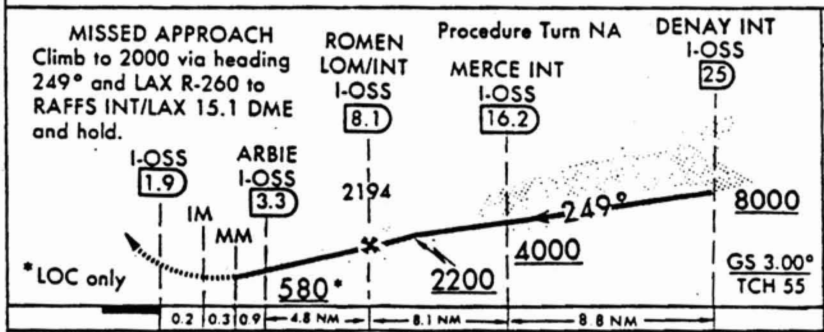
AL-237 (FAA)

LOS ANGELES INTL (LAX)
LOS ANGELES, CALIFORNIA



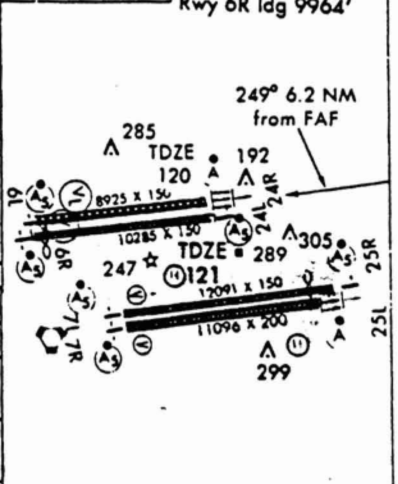
ATIS ARR 133.8
DEP 135.65
LOS ANGELES APP CON
124.5 381.6
LOS ANGELES TOWER
N 133.9 239.3
S 120.95 379.1
GND CON
N 121.65 327.0
S121.75 327.0
CLNC DEL
121.4 327.0

MISSED APPROACH
Climb to 2000 via heading 249° and LAX R-260 to RAFFS INT/LAX 15.1 DME and hold.



ELEV 126

Rwy 25R ldg 11133'
Rwy 6R ldg 9964'



CATEGORY	A	B	C	D
S-ILS 24R	320/18 200 (200-⅜)			
S-LOC 24R	580/24 460 (500-½)		580/40 460 (500-¾)	580/50 460 (500-1)
SIDESTEP RWY 24L••	660/50 539 (600-1)			660-1½ 539 (600-1½)
ARBIE DME MINIMUMS				
S-LOC 24R†	460/24 340 (400-½)			460/40 340 (400-¾)

••Inoperative table does not apply to Cat A and B.
†Cat. D visibility increased to RVR 5000 for inoperative ALSF-2.
▽

TDZ/CL Rwys 6R, 24R and 25L
HIRL all Rwys

FAF to MAP 6.2 NM

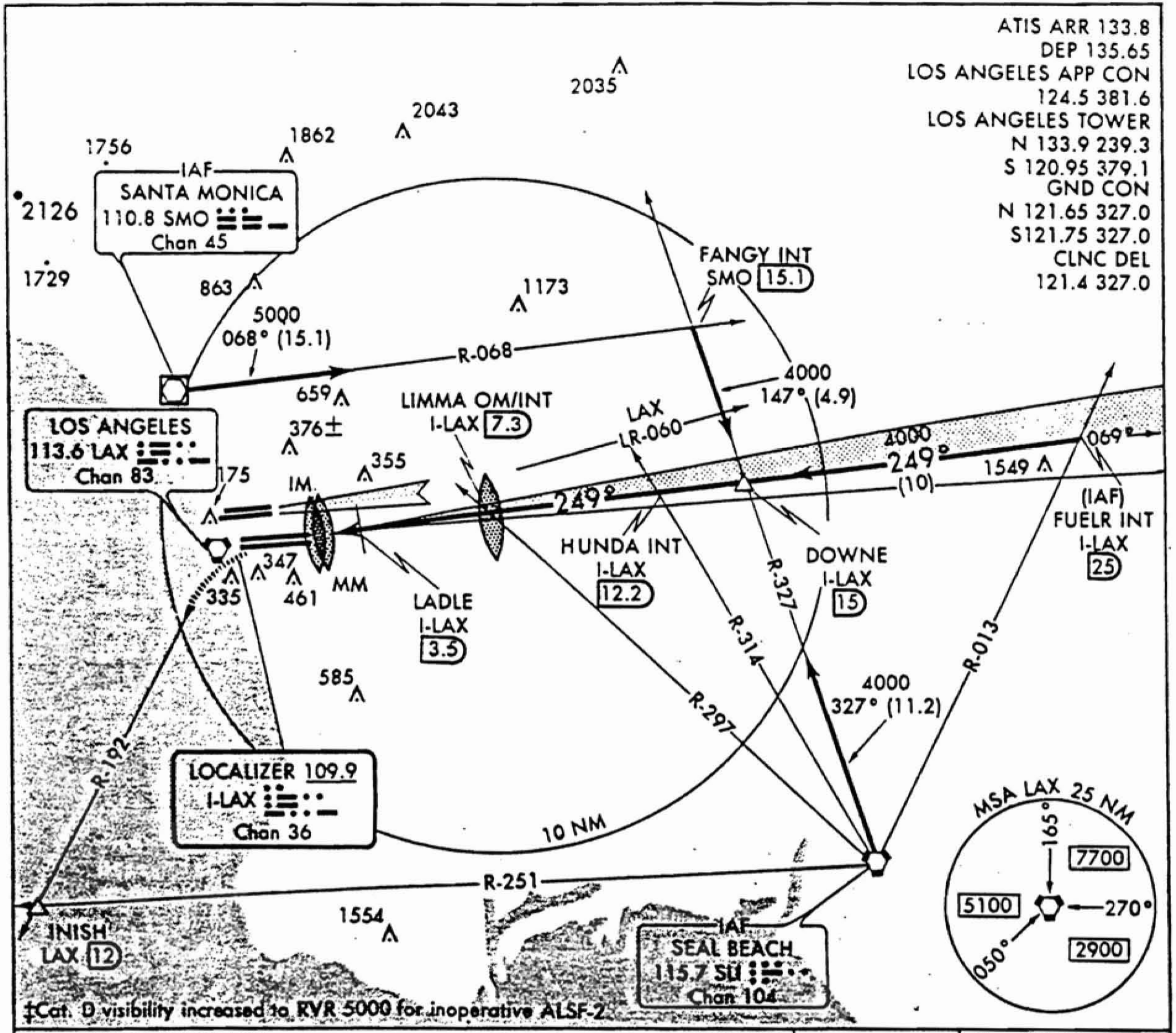
Knots	60	90	120	150	180
Min:Sec	6:12	4:08	3:06	2:29	2:04

Amdt 2 90235

ILS RWY 25L

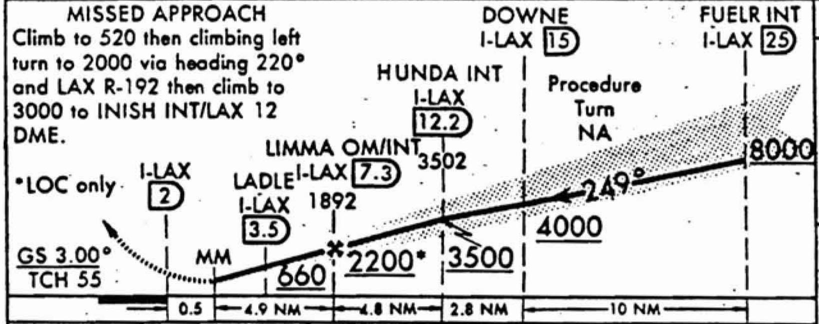
AL-237 (FAA)

LOS ANGELES INTL (LAX)
LOS ANGELES, CALIFORNIA



ATIS ARR 133.8
DEP 135.65
LOS ANGELES APP CON
124.5 381.6
LOS ANGELES TOWER
N 133.9 239.3
S 120.95 379.1
GND CON
N 121.65 327.0
S121.75 327.0
CLNC DEL
121.4 327.0

‡Cat. D visibility increased to RVR 5000 for inoperative ALSF-2.



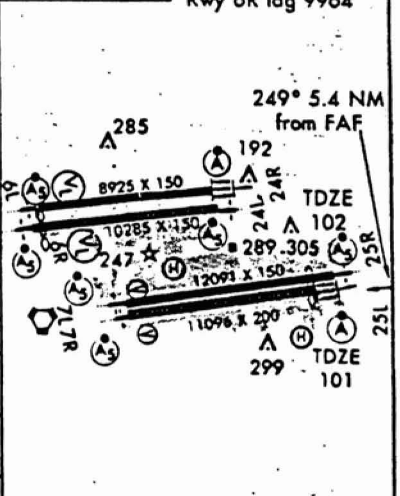
MISSED APPROACH
Climb to 520 then climbing left turn to 2000 via heading 220° and LAX R-192 then climb to 3000 to INISH INT/LAX 12 DME.

CATEGORY	A	B	C	D
S-ILS 25L	301/18 200 (200-⅜)			
S-LOC 25L	660/24 559 (600-½)		660/50 559 (600-1)	660/60 559 (600-1¼)
SIDESTEP** RWY 25R	660/50 558 (600-1)			660-1½ 558 (600-1½)
LADLE DME MINIMA				
S-LOC 25L‡	400/24 299 (300-½)			400/40 299 (300-¾)

**Inoperative table does not apply to Cat. A and B.
Simultaneous approaches authorized with Rwy 24L/R. ▽

ELEV 126

Rwy 25R ldg 11133'
Rwy 6R ldg 9964'



TDZ/CL Rwys 6R, 24R and 25L
HIRL all Rwys

FAF to MAP 5.4 NM					
Knots	60	90	120	150	180
Min:Sec	5:24	3:36	2:42	2:10	1:48

ILS RWY 25L

33°57'N-118°24'W

LOS ANGELES, CALIFORNIA
LOS ANGELES INTL (LAX)

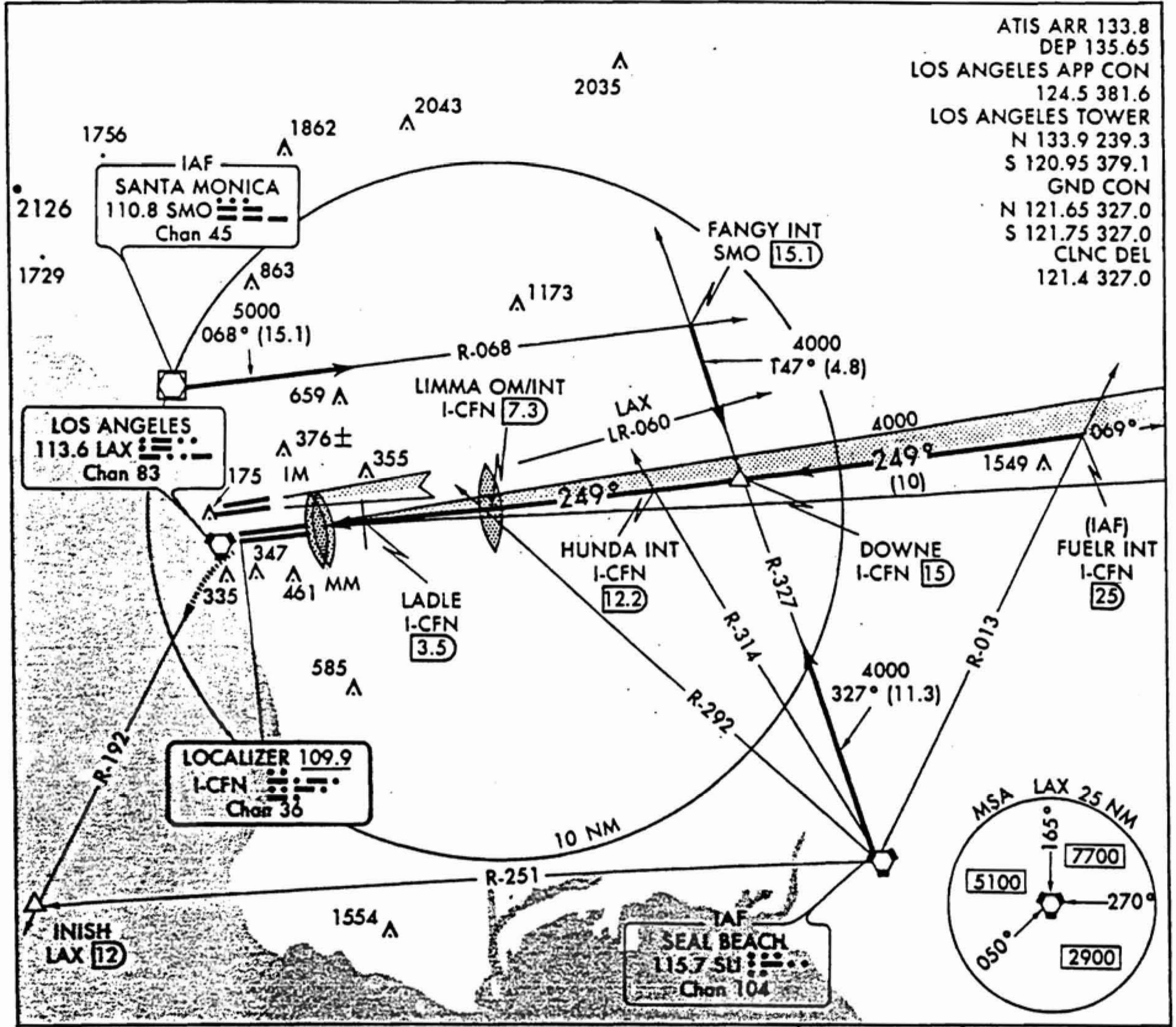
Amdt 5 90235

ILS RWY 25R

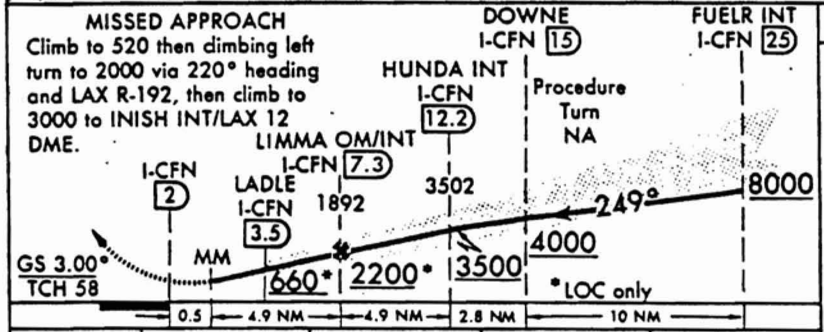
AL-237 (FAA)

LOS ANGELES INTL (LAX)
LOS ANGELES, CALIFORNIA

ATIS ARR 133.8
DEP 135.65
LOS ANGELES APP CON
124.5 381.6
LOS ANGELES TOWER
N 133.9 239.3
S 120.95 379.1
GND CON
N 121.65 327.0
S 121.75 327.0
CLNC DEL
121.4 327.0



MISSED APPROACH
Climb to 520 then climbing left turn to 2000 via 220° heading and LAX R-192, then climb to 3000 to INISH INT/LAX 12 DME.

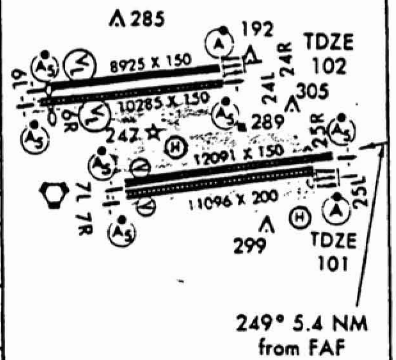


CATEGORY	A	B	C	D
S-ILS 25R	302/24 200 (200-½)			
S-LOC 25R	660/24 558 (600-½)		660/50 558 (600-1)	660/60 558 (600-1¼)
SIDESTEP** RWY 25L	660/50 559 (600-1)			660-1½ 559 (600-1½)
LADLE DME MINIMUMS				
S-LOC 25R	560/24 458 (500-½)		560/40 458 (500-¾)	560/50 458 (500-1)

**Inoperative table does not apply to Categories A and B.
Simultaneous approaches authorized with Rwy 24L/R.

ELEV 126

Rwy 25R ldg 11133'
Rwy 6R ldg 9964'



TDZ/CL Rwys 6R, 24R and 25L
HIRL all Rwys

FAF to MAP 5.4 NM

Knots	60	90	120	150	180
Min:Sec	5:24	3:36	2:42	2:10	1:48

ILS RWY 25R

33°57'N-118°24'W

LOS ANGELES, CALIFORNIA
LOS ANGELES INTL (LAX)

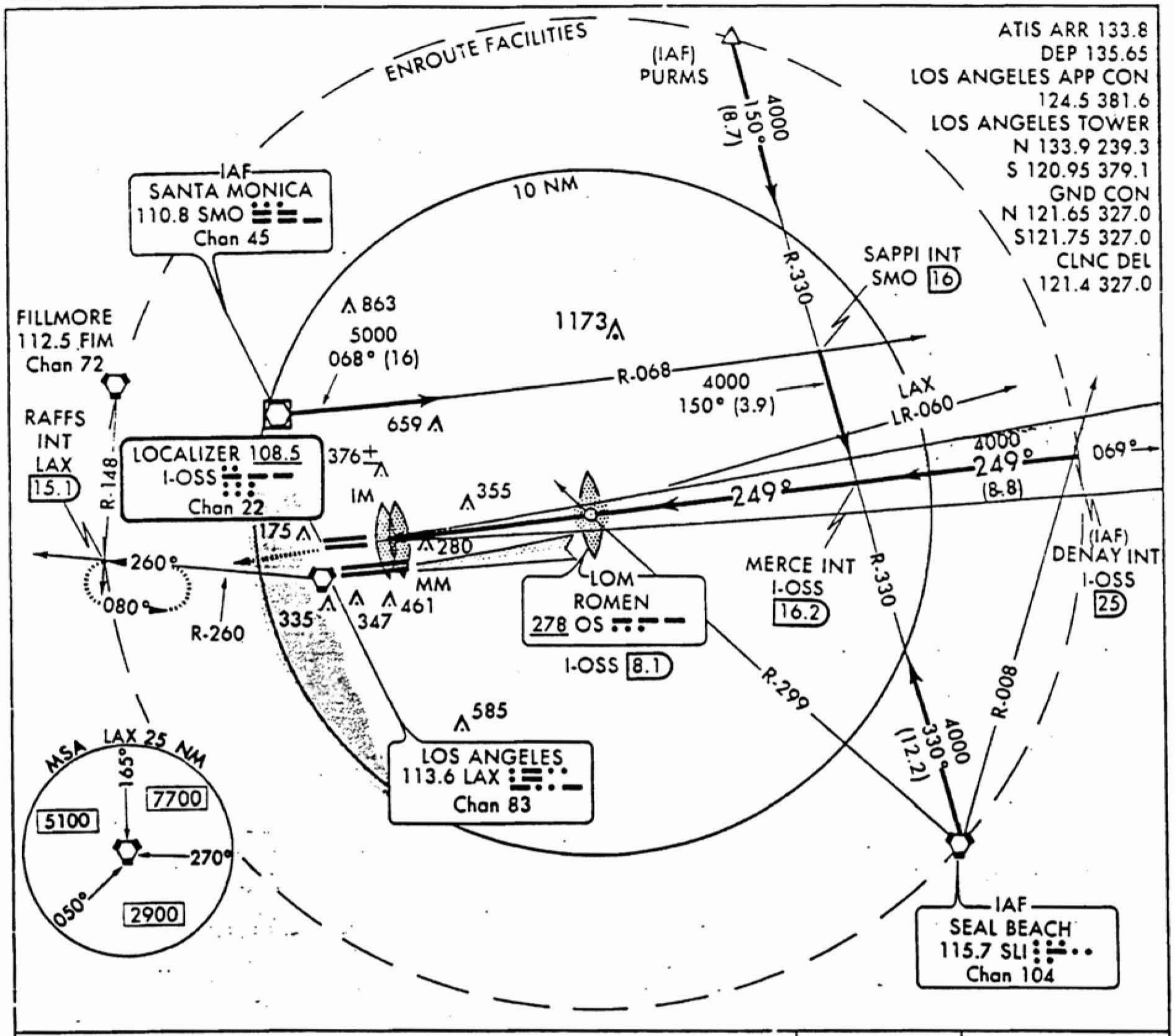
Amdt 20 90235 (CAT II)

ILS RWY 24R

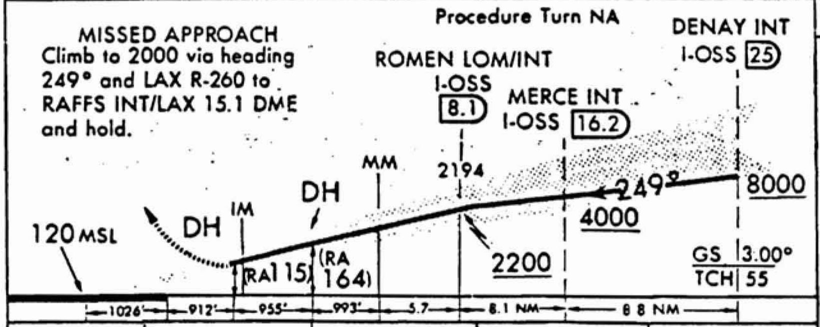
AL-237 (FAA)

LOS ANGELES INTL (LAX)
LOS ANGELES, CALIFORNIA

ATIS ARR 133.8
DEP 135.65
LOS ANGELES APP CON
124.5 381.6
LOS ANGELES TOWER
N 133.9 239.3
S 120.95 379.1
GND CON
N 121.65 327.0
S 121.75 327.0
CLNC DEL
121.4 327.0

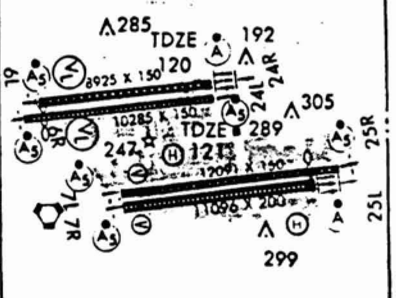


MISSED APPROACH
Climb to 2000 via heading 249° and LAX R-260 to RAFFS INT/LAX 15.1 DME and hold.



ELEV 126

Rwy 25R ldg 11133'
Rwy 6R ldg 9964'



CATEGORY	A	B	C	D
S-ILS 24R	270/16 150 (RA 164)			
S-ILS 24R	220/12 100 (RA 115)			

Simultaneous approach authorized with Rwys 25L/R.
▽

CATEGORY II ILS – SPECIAL AIRCREW & AIRCRAFT CERTIFICATION REQUIRED

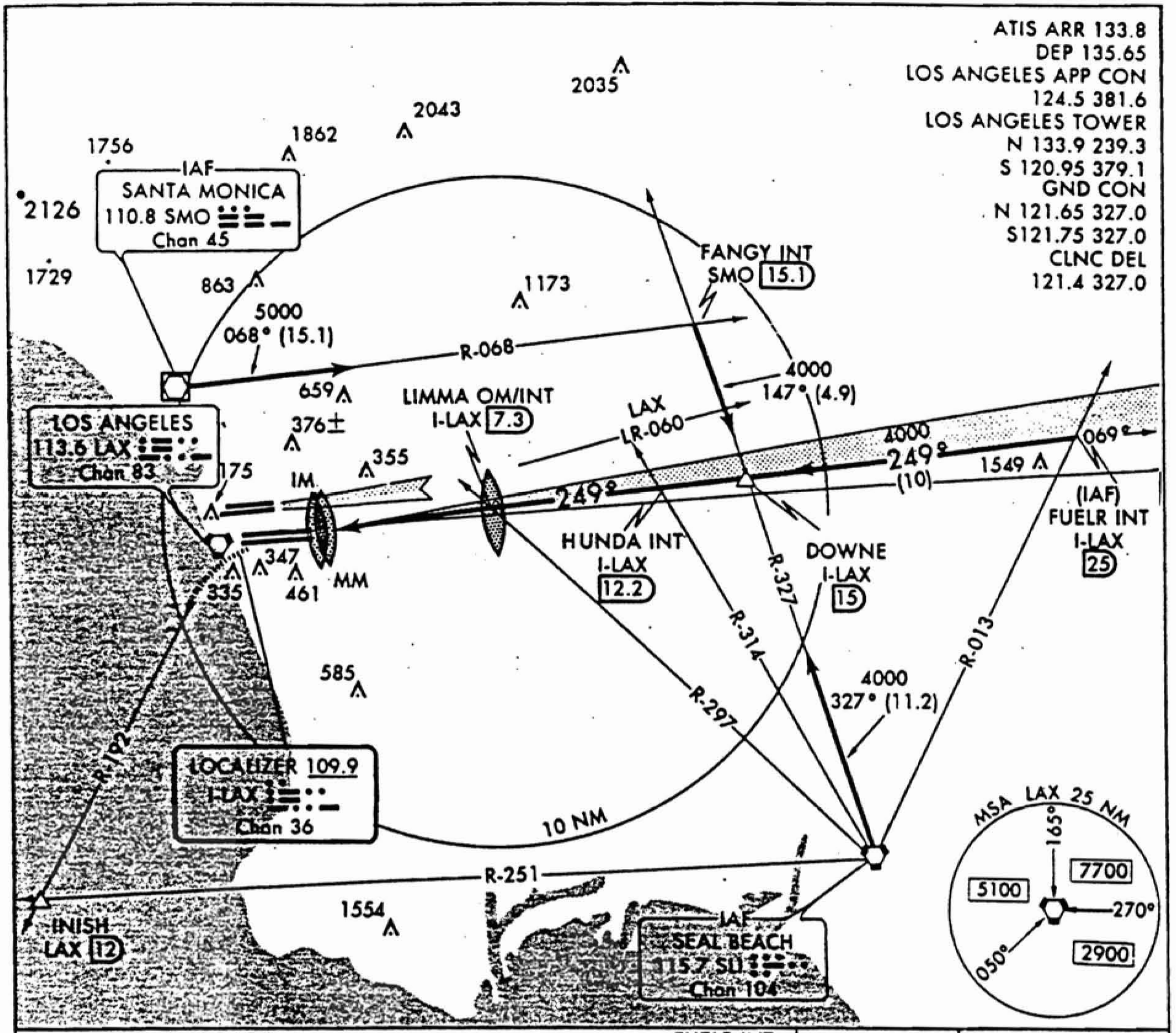
TDZ/CL Rwys 6R, 24R and 25L
HIRL all Rwys

Amdt 2 90347 (CAT II)

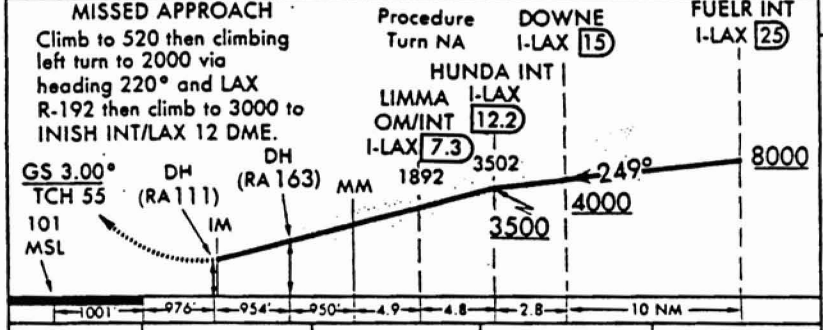
ILS RWY 25L

AL-237 (FAA)

LOS ANGELES INTL (LAX)
LOS ANGELES, CALIFORNIA



MISSED APPROACH
Climb to 520 then climbing left turn to 2000 via heading 220° and LAX R-192 then climb to 3000 to INISH INT/LAX 12 DME.

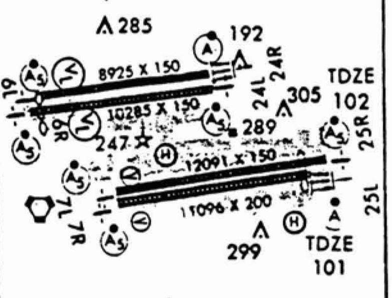


CATEGORY	A	B	C	D
S-ILS 25L	251/16 150 (RA 163)			
S-ILS 25L	201/12 100 (RA 111)			

Simultaneous approaches authorized with Runway 24L/R.

ELEV 126

Rwy 25R ldg 11134'
Rwy 6R ldg 9964'



CATEGORY II ILS-SPECIAL AIRCREW
& AIRCRAFT CERTIFICATION REQUIRED

TDZ/CL Rwys 6R, 24R and 25L
HIRL all rwys

ILS RWY 25L
(CAT II)

33°57'N - 118°24'W

LOS ANGELES, CALIFORNIA
LOS ANGELES INTL (LAX)

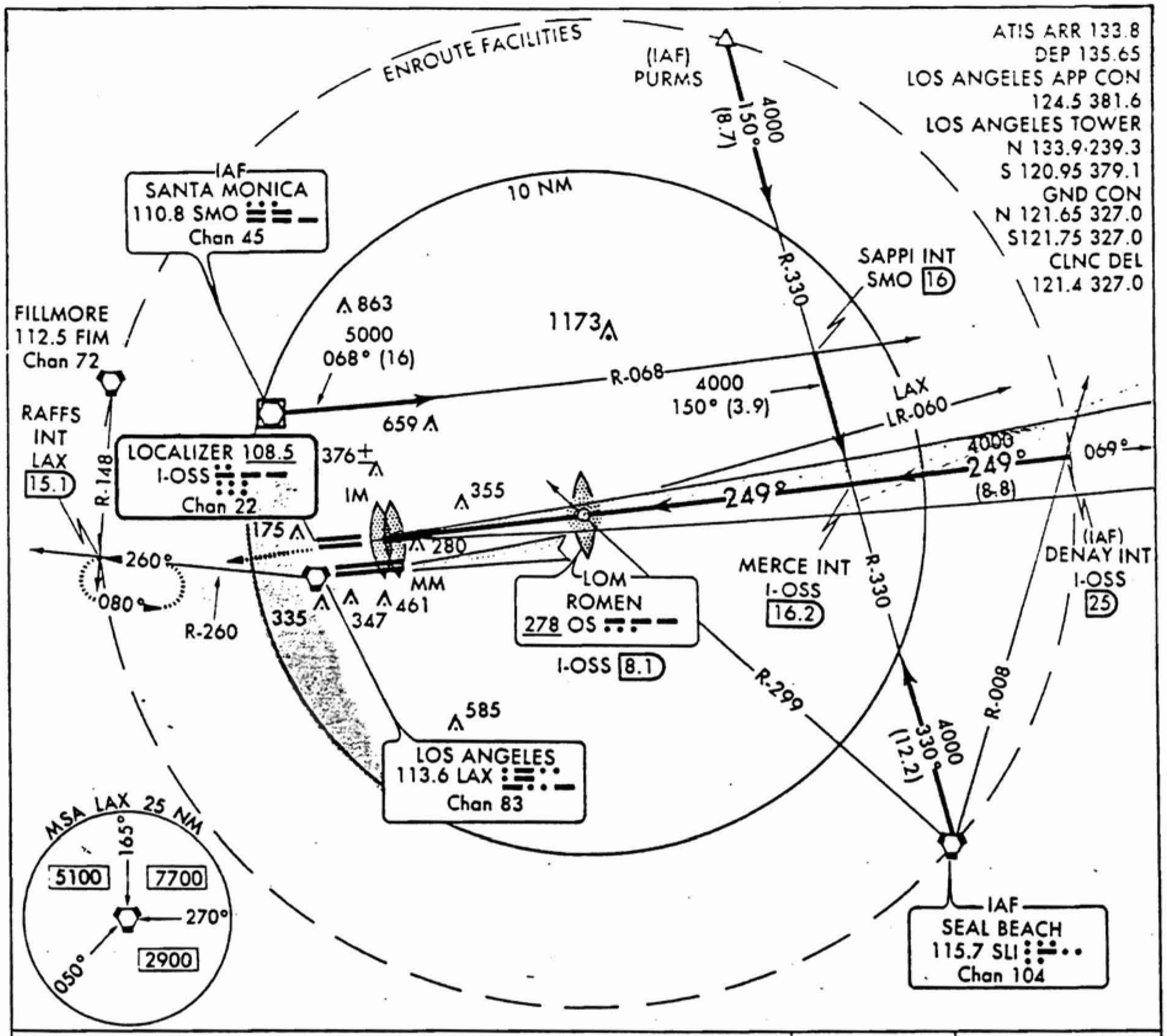
Amdt 20 90235 **(CAT III)**

ILS RWY 24R

AL-237 (FAA)

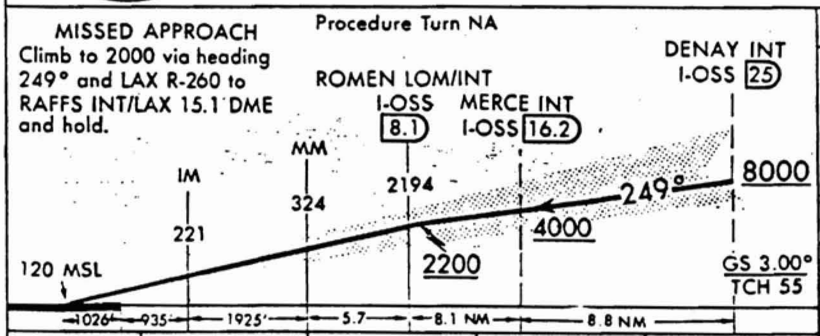
LOS ANGELES INTL (LAX)
LOS ANGELES, CALIFORNIA

ATIS ARR 133.8
DEP 135.65
LOS ANGELES APP CON
124.5 381.6
LOS ANGELES TOWER
N 133.9 239.3
S 120.95 379.1
GND CON
N 121.65 327.0
S 121.75 327.0
CLNC DEL
121.4 327.0



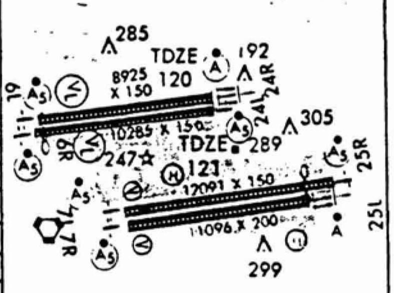
MISSED APPROACH
Climb to 2000 via heading 249° and LAX R-260 to RAFFS INT/LAX 15.1 DME and hold.

Procedure Turn NA



ELEV 126

Rwy 25R ldg 11133'
Rwy 6R ldg 9964'



CATEGORY	A	B	C	D
S-ILS 24R	CAT IIIa	RVR 07		
S-ILS 24R	CAT IIIb	NA		
S-ILS 24R	CAT IIIc	NA		

▽

CATEGORY III ILS-SPECIAL AIRCREW & AIRCRAFT CERTIFICATION REQUIRED

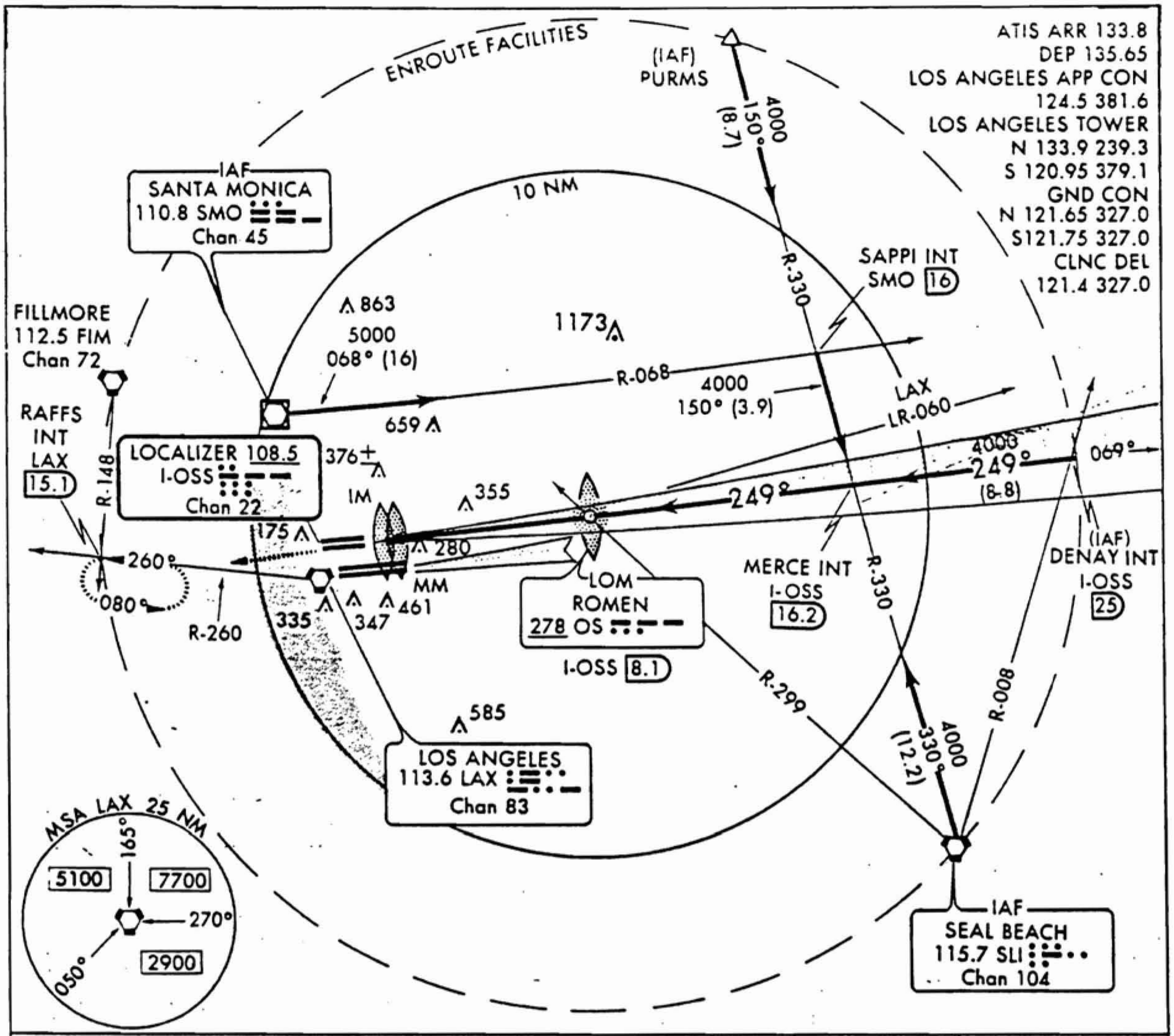
TDZ/CL Rwys 6R, 24R and 25L
HIRL all Rwys

Amdt 20 90235 (CAT III)

ILS RWY 24R

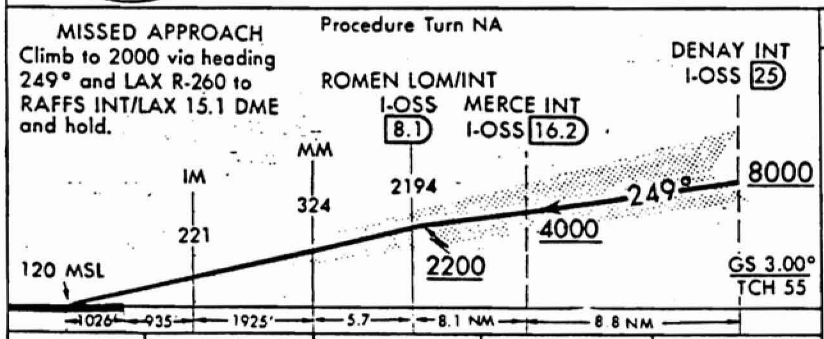
AL-237 (FAA)

LOS ANGELES INTL (LAX)
LOS ANGELES, CALIFORNIA



MISSED APPROACH
Climb to 2000 via heading 249° and LAX R-260 to RAFFS INT/LAX 15.1 DME and hold.

Procedure Turn NA



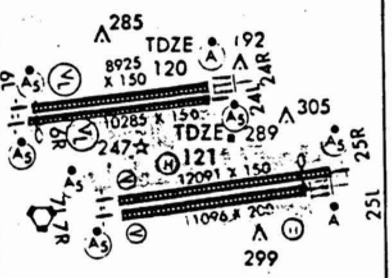
CATEGORY	A	B	C	D
S-ILS 24R	CAT IIIa	RVR 07		
S-ILS 24R	CAT IIIb	NA		
S-ILS 24R	CAT IIIc	NA		

▼

CATEGORY III ILS-SPECIAL AIRCREW & AIRCRAFT CERTIFICATION REQUIRED

ELEV 126

Rwy 25R ldg 11133'
Rwy 6R ldg 9964'



TDZ/CL Rwys 6R, 24R and 25L
HIRL all Rwys

ILS RWY 24R

33°57'N - 118°24'W

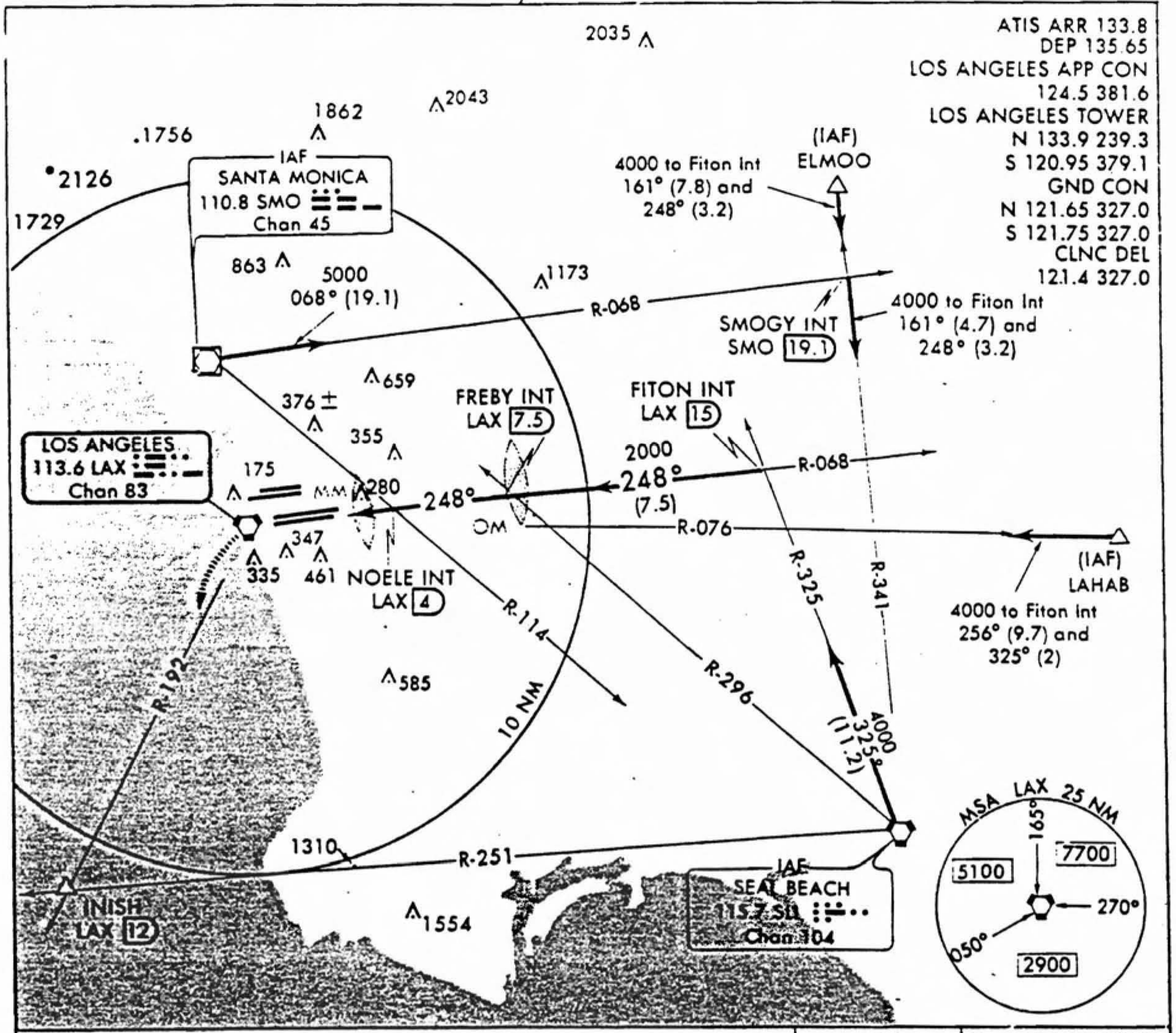
LOS ANGELES CALIFORNIA

Amdt 15 90235

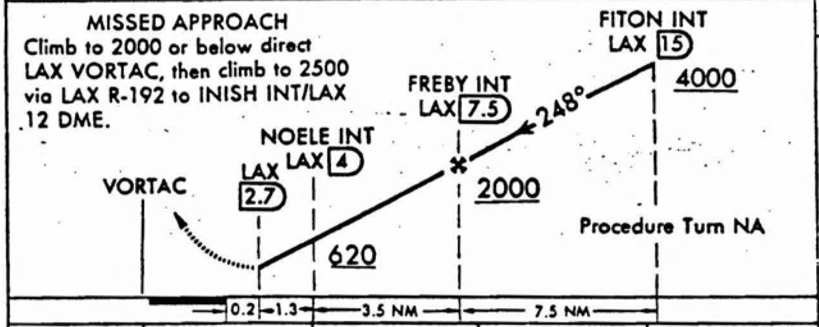
VOR or TACAN RWY 25L/R AL-237 (FAA)

LOS ANGELES INTL (LAX)
LOS ANGELES, CALIFORNIA

ATIS ARR 133.8
DEP 135.65
LOS ANGELES APP CON
124.5 381.6
LOS ANGELES TOWER
N 133.9 239.3
S 120.95 379.1
GND CON
N 121.65 327.0
S 121.75 327.0
CLNC DEL
121.4 327.0



MISSED APPROACH
Climb to 2000 or below direct LAX VORTAC, then climb to 2500 via LAX R-192 to INISH INT/LAX 12 DME.

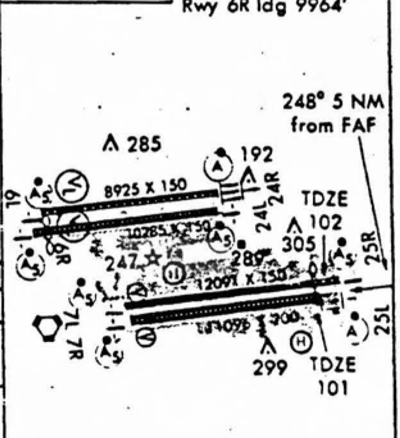


CATEGORY	A	B	C	D
S-25L	620/24 519 (500-½)		620/50 519 (500-1)	620/60 519 (500-1¼)
S-25R	620/24 518 (500-½)		620/50 518 (500-1)	620/60 518 (500-1¼)
DUAL VOR or DME MINIMUMS				
S-25L	540/24 439 (500-½)		540/40 439 (500-¾)	540/50 439 (500-1)
S-25R	540/24 438 (500-½)		540/40 438 (500-¾)	540/50 438 (500-1)

▽

ELEV 126

Rwy 25R ldg 11133'
Rwy 6R ldg 9964'



TDZ/CL Rwys 6R, 24R and 25L
HIRL all rwys

FAF to MAP 4.8 NM

Knots	60	90	120	150	180
Min:Sec	4:48	3:12	2:24	1:55	1:36

VOR or TACAN RWY 25L/R 33°57'N - 118°24'W

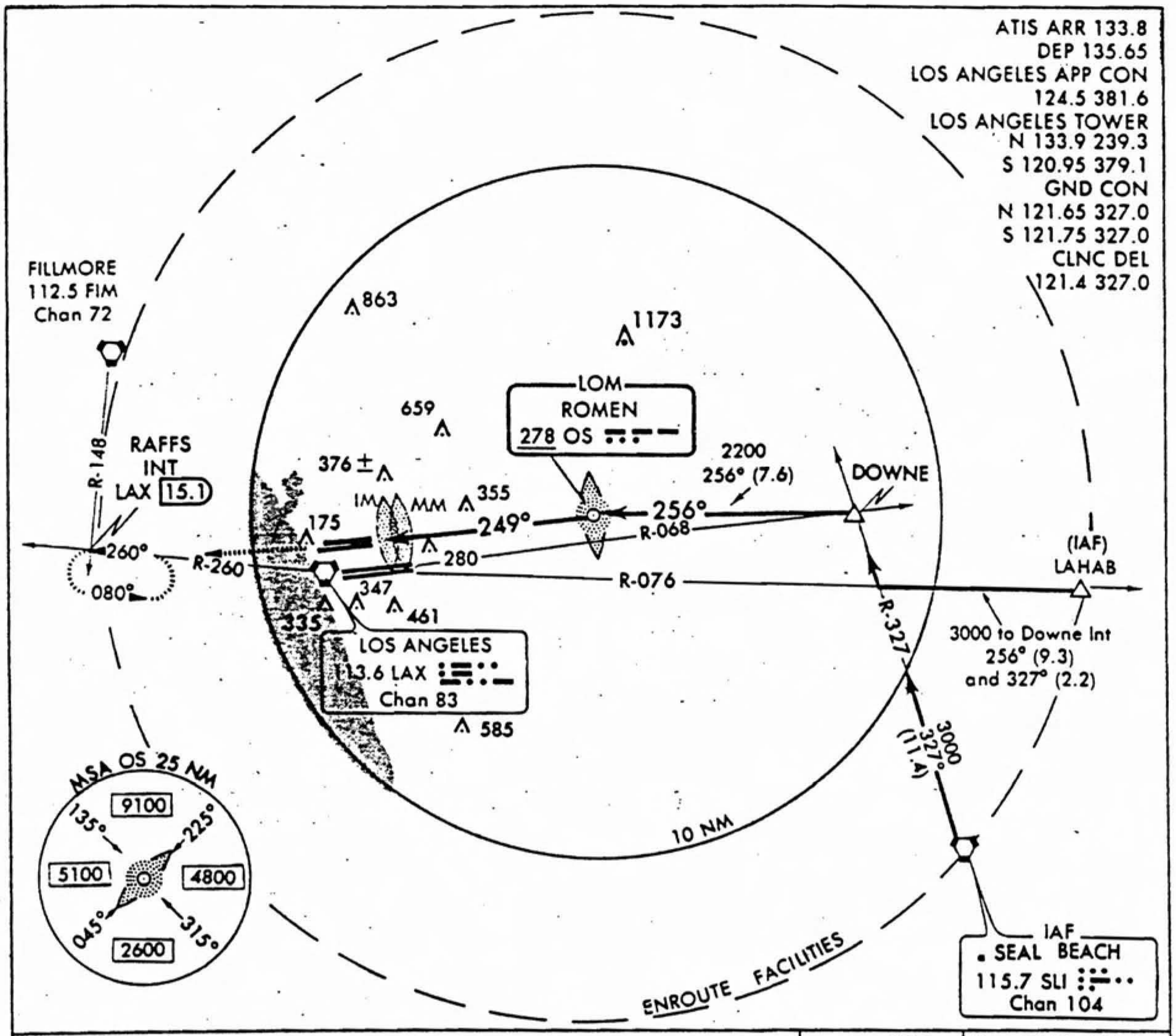
LOS ANGELES, CALIFORNIA
LOS ANGELES INTL (LAX)

Amdt 12 90263

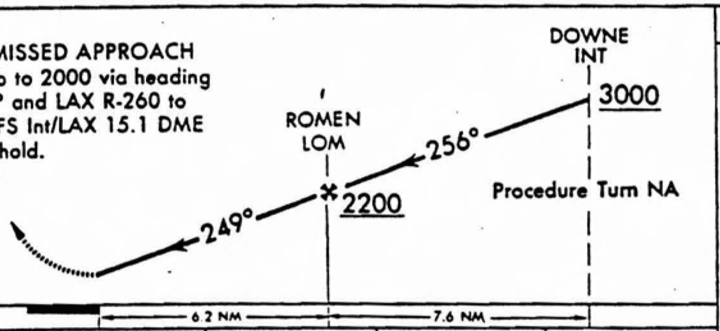
NDB RWY 24R

AL-237 (FAA)

LOS ANGELES INTL (LAX)
LOS ANGELES, CALIFORNIA



MISSED APPROACH
Climb to 2000 via heading 249° and LAX R-260 to RAFFS Int/LAX 15.1 DME and hold.



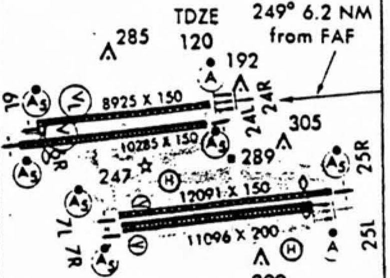
CATEGORY	A	B	C	D
S-24R	680/40 560 (600-¾)		680/50 560 (600-1)	680-1½ 560 (600-1½)
Sidestep 24L	680/50 560 (600-1)			680-1¾ 560 (600-1¾)

Inoperative table does not apply to sidestep catagories A and B.

▽

ELEV 126

Rwy 6R ldg 9964'
Rwy 25R ldg 11133'



TDZ/CL Rwys 6R, 24R and 25L
HIRL all Rwys

FAF to MAP 6.2 NM

Knots	60	90	120	150	180
Min:Sec	6:12	4:08	3:06	2:29	2:04

NDB RWY 24R

33°57'N - 118°24'W

LOS ANGELES, CALIFORNIA
LOS ANGELES INTL (LAX)

APPENDIX D

Sample Calculations for Forces on an Antenna-like Structure

Calculation of the Reynolds number

$$R = \frac{VD}{\nu}$$

Given: $V = 200$ knots - through conversion
$V = 337.56$ ft/s

From J. Holman (643), the properties of air at atmospheric pressure are as follows:

Table 1. Properties of Air at Atmospheric Pressure

T °K	ρ kg/m^3	ν $m^2/s \times 10^6$
200	1.7684	7.490
250	1.4128	11.31
300	1.7740	15.69
350	0.9980	20.76

Translation into the equivalent U.S. Customary System yields

T °F	ρ $slugs/ft^3 \times 10^3$	ν $ft^2/s \times 10^5$
-99.67	3.43	8.062
-9.67	2.74	12.174
80.33	2.28	16.889
170.33	1.94	22.345

Assume that the temperature range for the fluid varies from -20°F to 100°F. Through interpolation, ν is

$$\frac{-20-(-99.67)}{-9.67-(-99.67)} = \frac{\nu-8.062}{12.174-8.062}$$

Determination of the cross-sectional area normal to the direction of the fluid velocity yields:

(a) Section 1 - 4″ diameter pipe by 48″ in length

$$A = (4/12) \times 4 = 1.33 \text{ ft}^2$$

(b) Section 1 - 3″ diameter pipe by 36″ in length

$$A = (3/12) \times 3 = 0.75 \text{ ft}^2$$

The density calculation for air @ -20°F (the lower the Temp, the higher the density) is

$$\frac{-20-(-99.67)}{-9.67-(-99.67)} = \frac{\rho-3.43}{2.74-3.43}$$

$$\rho = 2.82 \times 10^{-3} \text{ slugs/ft3}$$

The drag force for the T-section components are

(a) Section 1 - 4″ diameter pipe by 48″ in length

$$F = 0.84(1.33)(2.82E-3)(337.56)^2/2$$
$$F = 179.5 \text{ lbf}$$

(b) Section 1 - 3″ diameter pipe by 36″ in length

$$F = 0.84(0.75)(2.82E-3)(337.56)^2/2$$
$$F = 101.2 \text{ lbf}$$

$V_{-20}°F = 11.702 \times 10^{-5}$

$V_{100}°F = 18.081 \times 10^{-5}$

Calculation of the Reynolds number yields

(a) Section 1 - 4″ diameter pipe

$$R_{-20}°F = \frac{337.56(4/12)}{11.702 \times 10^{-5}} = 951{,}930 \quad C_d = 0.38$$

$R_{100}°F = 616{,}088 \quad C_d = 0.35$

(b) Section 2 - 3″ diameter pipe

$$R_{-20}°F = \frac{337.56(3/12)}{11.702 \times 10^{-5}} = 721{,}159 \quad C_d = 0.35$$

$R_{-20}°F = 466.733 \qquad C_d = 0.40$

However, the length-diameter ratio is not infinity but 12, so the Cds can be reduced by about **30 per cent.** For future calculations, Cd will be

$C_d = 1.2 - .3(1.2) = 0.84$

*****Note:** The Reynolds number is also dependant upon the velocity of the approaching stream; it will not always remain at 200 knots.

DO NOT REMOVE CARBONS

Form Approved OMB No. 2120-000

US Department of Transportation
Federal Aviation Administration

NOTICE OF PROPOSED CONSTRUCTION OR ALTERATION

Aeronautical Study Number

1. Nature of Proposal

Type ☐ New Construction ☐ Alteration	B. Class ☐ Permanent ☐ Temporary (Duration ______ months)	C. Work Schedule Dates Beginning ____________ End ____________

2. Complete Description of Structure

A. Include effective radiated power and assigned frequency of all existing, proposed or modified AM, FM, or TV broadcast stations utilizing this structure.

B. Include size and configuration of power transmission lines and their supporting towers in the vicinity of FAA facilities and public airports.

C. Include information showing site orientation, dimensions and construction materials of the proposed structure.

(if more space is required, continue on a separate sheet.)

3A. Name and address of individual, company, corporation, etc. proposing the construction or alteration. *(Number, Street, City, State and Zip Code)*

(   ) ____________

area code **Telephone Number**

TO

B. Name, address and telephone number of proponent's representative if different than 3 above.

4. Location of Structure

A. Coordinates *(To nearest second)*	B. Nearest City, Town and State Los Angeles	C. Name of nearest airport, heliport, flightpark, or seaplane base LAX
° ' " Latitude	(1) Distance to 4B Miles	(1) Distance from structure to nearest point of nearest runway 150 feet
° ' " Longitude	(2) Direction to 4B	(2) Direction from structure to airport on airport

5. Height and Elevation *(Complete to the nearest foo*

A. Elevation of site above mean sea level 90	90
B. Height of Structure including all appurtenances and lighting *(if any)* above ground, or water if so situated	2.
C. Overall height above mean sea level *(A + B)*	92.2

D. Description of location of site with respect to highways, streets, airports, prominent terrain features, existing structures, etc. Attach a U.S. Geological Survey quadrangle map or equivalent showing the relationship of construction site to nearest airport(s). *(if more space is required, continue on a separate sheet of paper and attach to this notice.)*

The site is for temporary installation of 2 log periodic dipole localizer antennas and is 3 feet in front of the existing blast fence at the stpp-end of Runway 07L. This places the antennas 160 feet from the R/W 25 threshold.

Notice is required by Part 77 of the Federal Aviation Regulations (14 C.F.R. Part 77) pursuant to Section 1101 of the Federal Aviation Act of 1958, as amended (49 U.S.C. 1101). Persons who knowingly and willingly violate the Notice requirements of Part 77 are subject to a fine (criminal penalty) of not more than $500 for the first offense and not more than $2,000 for subsequent offenses, pursuant to Section 902(a) of the Federal Aviation Act of 1958, as amended (49 U.S.C. 1472(a)).

I HEREBY CERTIFY that all of the above statements made by me are true, complete, and correct to the best of my knowledge. In addition, I agree to obstruction mark and/or light the structure in accordance with established marking & lighting standards if necessary.

Date	**Typed Name/Title of Person Filing Notice**	**Signature**

FOR FAA USE ONLY *FAA will either return this form or issue a separate acknowledgement*

The Proposal:

- ☐ Does not require a notice to FAA.
- ☐ Is not identified as an obstruction under any standard of FAR, Part 77, Subpart C, and would not be a hazard to air navigation.
- ☐ Is identified as an obsrtuction under the standards of FAR, Part 77, Subpart C, but would not be a hazard to air navigation.
- ☐ Should be obstruction ☐ MARKED, ☐ lighted per FAA Advisory Circular 70/7460-1, Chapter(s) ____________
- ☐ Obstruction marking and lighting are not necessary.

Supplemental Notice of Construction FAA Form 7460-2 is required any time the project is abandoned, or

- ☐ At least 48 hours before the start of construction.
- ☐ Within five days after the construction reaches its greatest height.

This determination expires on ______________________________ unles

(a) extended, revised or terminated by the issuing office;
(b) the construction is subject to the licensing authority of the Federal Communications Commission an an application for a construction permit is made to the FCC on or before the above expiration date. I such case the determination expires on the date prescribed by the FCC for completion of cor struction, or on the date the FCC denies the application.

NOTE: Request for extension of the effective period of this determination must be postmarked or delivered t the issuing office at least 15 days prior to the expiration date.

If the structure is subject to the licensing authority of the FCC, a copy of this determination will be sent t that Agency.

Remarks:

ssued In	**Signature**	**Date**

FAA Form 7460-1 (8-85)

DO NOT REMOVE CARBOI