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ANALYTICAL STUDY OF THE ADEQUACY OF VOR/DME AND DME/DME GUIDANCE SIGNALS FOR V/STOL AREA NAVIGATION IN THE LOS ANGELES AREA

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16. Abstract

An analysis was performed by personnel of the National Aviation Facilities Experimental Center (NAFEC) to determine the adequacy of very high frequency omnirange/distance measuring equipment (VOR/DME) guidance signals for vertical/short takeoff and landing (V/STOL) aircraft area navigation (RNAV) in the Los Angeles (LAX) area. Guidance signals were derived from existing VOR/DME and "converted" VOR facilities. It was concluded that: (1) VOR/DME RNAV over seven approved routes was feasible when using the existing VOR/DME facilities; (2) DME/DME RNAV over the approved routes is feasible when using station-pair combinations from existing VOR/DME facilities and certain converted VOR stations; (3) Except for the last segment of the LAX to Van Nuys (VNY) direct route, VOR/DME RNAV over the hypothetical direct routes was feasible when using existing VOR/DME facilities; (4) Except for the last segment of the LAX to VNY direct route, DME/DME RNAV over the direct routes was feasible when using station-pair combinations from existing VOR/DME facilities and certain converted VOR stations; (5) RNAV using DME/DME was potentially more accurate than VOR/DME; and (6) The number of en route station changeovers for VOR/DME and DME/DME RNAV over the approved and direct routes was considered acceptable.

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PREFACE

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INTRODUCTION

Purpose

The purpose of the project is to determine from analytical studies and verification flights the adequacy of very high frequency omnirange/distance measuring equipment (VOR/DME) and DME/DME signals for vertical and short takeoff and landing (V/STOL) aircraft instrument flight rule (IFR) area navigation in certain metropolitan areas and high-density corridors.

Presented herewith are the results of the analytical studies to determine the adequacy of VOR/DME and DME/DME signals for area navigation over approved IFR VTOL and hypothetical direct V/STOL routes in the Los Angeles (LAX) area. The results of LAX verification flights and analytical studies of other high-density metropolitan areas will be reported at a later date.

Background

Area navigation (RNAV) is compatible with present VOR/DME facilities and the National Airspace System (NAS). The RNAV concept based on VOR/DME is presently being implemented in NAS. Federal Aviation Administration (FAA) Advisory Circular AC 90-45 entitled, "Approval of Area Navigation Systems for Use in the National Airspace," and FAA Handbook 7110.18 entitled "Air Traffic Control Service for Area Navigation Equipped Aircraft Operating in the United States National Airspace System," establish procedures for approval of RNAV equipment installations and area navigation routes.

V/STOL-type aircraft have generally operated at relatively low altitudes and usually in congested metropolitan areas. Navigation accuracy and signal coverage requirements for V/STOL aircraft appear to be different than those for conventional takeoff and landing aircraft. Methods of providing increased navigation accuracy and signal coverage for V/STOL aircraft are being investigated, and equipment which implement the various methods are being evaluated. Of particular interest are techniques that provide increased area navigation accuracies for V/STOL operations by optimizing the capabilities of existing and planned VOR/DME installations in the common navigation system. This report analytically considers several of these techniques, i.e., the simultaneous utilization of two DME signals from dual VOR/DME guidance stations to take advantage of the increased position accuracies inherent in the DME component of the combined VOR/DME signal, and the conversion of certain existing VOR's to VOR/DME facilities for increased VOR/DME and DME/DME signal coverage.

DISCUSSION

Route Structure

Analytical studies were performed on the LAX area approved IFR VTOL routes as published in IFR Off-Airway Routes (Non Part 95), dated November 1969, and on hypothetical direct routes connecting the terminal areas serviced by the approved VTOL routes. The approved IFR VTOL routes, hereafter referred to as approved routes, are shown in Figure 1. These routes include two routes, LAX to Van Nuys (VNY) and VNY to LAX; two routes, LAX to Orange County Airport (JOR) and JOR to LAX; one route, LAX to San Bernardino (SBD); one route, LAX to Anaheim (ANA); and one route, JOR/ANA to LAX. The hypothetical direct routes, hereafter referred to as direct routes, are shown in Figure 2. These routes include one route from LAX to VNY, one route from LAX to JOR, one route from LAX to SBD, and one route from LAX to ANA.

General Description of Analytical Methodology

The analysis initially determined the theoretically optimum VOR/DME (or VORTAC) facilities for VOR/DME and DME/DME RNAV. The term "theoretically optimum" only relates to the computer-derived analytical outputs and defines those facilities that, according to the geometric relationship between the aircraft, route, and facility, provided the most accurate navigation signals for RNAV. The VOR/DME case required simultaneous bearing and distance inputs from a single VORTAC guidance station. The DME/DME case required simultaneous distance inputs from two VORTAC guidance stations. The expressions "VOR/DME" and "VORTAC," an acronym for very high frequency omnirange and tactical air-navigation facility, are interchangeable throughout the report.

The VORTAC facilities comprising the theoretically optimum VOR/DME stations and DME/DME station pairs, hereafter referred to as station(s) when relating to both the VOR/DME and DME/DME cases, were further screened to determine the effects of natural terrain obstructions and the restrictions published in the Airman's Information Manual (AIM restrictions) on guidance signal availability and usability. When obstructions or AIM restrictions precluded signal reception from the theoretically optimum guidance stations, the stations so affected were replaced by other less accurate VORTAC facilities. Guidance stations not affected by obstructions or restrictions are hereafter referred to as "optimum" stations. When selecting the optimum station(s), it was assumed that the V/STOL aircraft was operating at the minimum en route altitudes shown in Figures 1 and 2.

Finally, for those routes or route segments not covered by off-route VORTAC station(s) due to obstructions or restrictions, further analytical work was undertaken to study the signal coverage improvements that could be expected from the conversion of existing VOR stations to VORTAC facilities ("converted" VOR's). The location and identification of the VORTAC and VOR stations servicing the LAX area that were considered in this study are shown in Figure 3 and are listed below.

VORTAC	VOR
FIM - Fillmore	NZJ - El Toro
LAX - Los Angeles	RAL - Riverside
OCN - Oceanside	RIV - March
ONT - Ontario	SBD - Norton
POM - Pomona	SMO - Santa Monica
SLI - Seal Beach	SNA - Santa Ana
VNY - Van Nuys	SXC - Santa Catalina
VTU - Ventura	

Computer programs were modified and developed to perform the computations required for the analysis. Of particular interest were the cross-course navigational errors attributable to the VORTAC facilities and the airborne VOR and DME receivers. The basic equations for determining cross-course and along-course errors for navigation over the approved and direct routes were identical to those contained in FAA Final Report RD-66-46, "VORTAC Error Analysis for Helicopter Navigation," dated September 1966. In RD-66-46, the analytical model assumed a two-dimensional horizontal plane with no slant range correction. For these computations, the system DME error (DME ground station and airborne receiver errors combined in a root-sum-squared manner) for a standard deviation (SD) tolerance limit was ± 0.1 nmi, and the system bearing error for an SD tolerance limit was $\pm 1.0°$. These errors are considered representative of the values attainable with present-day ground station and high quality commercial air carrier navigation equipment.

Common to both the DME/DME station pair and the VOR/DME station cases were printouts of the SD, 2SD, and 3SD cross-course and along-course errors. In addition, separate "flags" were presented when (1) the 2SD cross-course error exceeded ± 0.333 nmi (6SD=± 1.000 nmi), or the 2SD along-course error exceeded ± 0.666 nmi (6SD=± 2.000 nmi); (2) the computed distance from the guidance station to the aircraft exceeded the theoretical station-to-aircraft line-of-sight distance; and (3) the computed station-to-aircraft distance exceeded 40 nmi. The SD sum and the variance $(SD)^2$ sum, the 2SD sum and $2(SD)^2$ sum, and the average 2SD and $2(SD)^2$ values for both the cross-course and along-course error computations were included at the end of each route segment-station(s) computation. The

average $2(SD)^2$ cross-course value for each route segment-station(s) combination was used to rate the quality of the station(s) for navigation; the smaller the average $2(SD)^2$ cross-course value, the better the theoretical accuracy of the station(s) for navigational guidance. For each route segment and route, the station(s) were ranked according to the theoretical navigation accuracy.

For the DME/DME station pair analysis, the included angle formed by lines of position from the ground stations to the aircraft is a major influencing factor on the cross-course and along-course errors. Angles close to 90° provide the best geometry; angles approaching 0° and 180°, the worst geometry. The computer program outputted this angle and flags that indicated the geometry segment bracketing the computed angle. The included angle was arbitrarily segmented into five categories, i.e., excellent, good, fair, poor, and unusable, and was flagged accordingly. Included angles between 75° and 105° represented an excellent segment. Angles extending from the excellent segment limits to 60° and 120° represented a good segment. Similarly, angles extending to 45° and 135° were the fair geometry segment; to 30° and 150°, a poor geometry segment; and to 0° and 180°, an unusable geometry segment. Since the 0° and 180° included angles were in the unusable geometry segment, guidance station pair and aircraft geometric relationships that formed included angles at or near these angular limits were not considered in the analysis.

Other programs were developed to meet particular project requirements not covered in RD-66-46. One of these programs simplified the input requirements by performing geometric computations to obtain input values previously measured from sectional charts. Another program automatically analyzed the output data and provided analytical summaries suitable for the selection of theoretically optimum guidance stations. The results of the computerized analysis were responsive to theoretical line-of-sight limitations and the geometric relationships between station(s) and aircraft. The effects of man-made and natural obstructions on the computerized results were ascertained by manually reviewing AIM restrictions, sectional charts, and VORTAC horizon profile drawings. As a minimum, it is expected that the best two station(s) per route segment from this final screening will be flight tested to verify signal coverage. A more detailed description of the computer program and sample data printouts are contained in Appendix A.

Analytical Study Results

As previously stated, the analysis was performed for VOR/DME and DME/DME area navigation over the approved and direct routes in the LAX basin. The routes were segmentized

by heading or altitude changes. The ultimate study result would have been the identifying of a single VORTAC (for VOR/DME RNAV) or single VORTAC pair (for DME/DME RNAV) capable of servicing the total route structure. A less optimum, but satisfactory, alternative would have been the identifying of a single VORTAC or VORTAC pair, as appropriate, to adequately service a particular route consisting of several segments. Early in the project, it became apparent that due to the topographical characteristics of the LAX area and the location of the existing VORTAC facilities with respect to the approved and direct routes, compromises would be necessary. It was found that no single VORTAC or VORTAC pair could service the entire route structure. In fact, in many cases, no single VORTAC or VORTAC pair could service all the segments of a particular route. To perform area navigation over the entire route structure identified in this study, en route VORTAC changeovers would be required. Unless the RNAV system incorporated automatic VORTAC selection from preprogrammed inputs, VORTAC changeovers would increase pilot workload by requiring manual selection of the desired guidance station. The problem is shown in Figure 4 where the mountain ranges, VORTAC's and VOR's, and approved and direct routes are depicted in relationship to each other. Over many portions of the route structure, guidance signals from a particular facility are blocked by terrain obstructions between the relatively low-altitude V/STOL aircraft and the VORTAC or VOR.

With signal coverage of prime importance, less accurate guidance station(s) were selected when obstructions or restrictions precluded the use of the theoretically optimum station(s). The guidance station(s) remaining after the AIM restriction and natural terrain obstruction screening (optimum stations) are tabularly and graphically shown as 2SD cross-course error values in the main body of this report. The 2SD cross-course error plots should be considered as continuous. The "break" in the 2SD envelope at the beginning and/or end of each segment results from the computerized printout being furnished in 1-nautical mile increments starting at 1 nmi and ending at the nearest whole-mile increment before reaching the end of the segment. The optimum gudance station(s) represented in these figures and tables are limited by the theoretical line-of-sight flag, AIM restrictions, and terrain obstructions. The effects of the remaining flag criteria, i.e., 2SD cross-course or along-course errors greater than 0.333 nmi and 0.666 nmi, respectively, and station-to-aircraft distances greater than 40 nmi are not reflected in these figures and tables. However, the remaining flags are considered in the analysis and presented as computer-derived data summaries. The information contained in Appendix A is typical of these summary presentations.

The computerized outputs indicating the ranking order of the theoretical guidance station(s) per route and route segment prior to obstruction screening are tabularly presented in Appendix B.

VOR/DME Analysis: For the VOR/DME analysis, each of the eight VORTAC facilities in the LAX area was considered as a guidance station for all the route segments comprising the approved and direct routes. After the theoretically optimum stations were screened to eliminate those stations from which the guidance signals were blocked by natural terrain obstructions, the remaining stations capable of servicing a particular route segment were placed in ranking order according to the average $2(SD)^2$ cross-course value. The station with the smallest average $2(SD)^2$ cross-course value per route segment was considered to be the optimum facility for that portion of the route structure. For each route, the 2SD cross-course tolerance limit envelopes of the optimum facilities were plotted.

The results of the VOR/DME analysis on the LAX approved route structure are presented in Figures 5 to 11 inclusively and Table 1. Figures 5 (LAX to VNY), 6 (VNY to LAX), 7 (LAX to JOR), 8 (JOR to LAX), 9 (LAX to ANA), 10 (JOR/ANA to LAX), and 11 (LAX to SBD) show the 2SD cross-course tolerance limits for area navigation over the approved routes using the indicated VORTAC guidance stations. Table 1 lists the optimum station per route segment as well as the average and maximum 2SD cross-course errors for each route segment in the approved route structure. The largest average 2SD cross-course value was $\pm$.990 nmi. It is noted that for the VNY to LAX, LAX to JOR, LAX to ANA, and JOR/ANA to LAX routes (Figures 6, 7, 9, and 10, respectively), the indicated optimum guidance stations are identical to the theoretically optimum guidance stations prior to the natural terrain obstruction screening. For these four of seven routes, it is anticipated that natural terrain effects on the signal reception from the theoretically optimum VORTAC's will be minimal. In addition, as shown in Figures 7 ((LAX to JOR), 9 (LAX to ANA), and 10 (JOR/ANA to LAX), a single VORTAC was capable of servicing each route. For these routes, no en route guidance station changeovers were necessary after the selection of the initial VORTAC. Each of the remaining four routes, i.e., LAX to VNY, VNY to LAX, JOR to LAX, and LAX to SBD (Figures 5, 6, 8, and 11, respectively), required one en route station changeover.

TABLE 1 - OPTIMUM VORTAC FACILITIES FOR VOR/DME RNAV OVER APPROVED ROUTES IN LAX AREA

Route	Route Segment	Optimum VORTAC	2SD Cross-Course Error (±nmi)		Reference Figure No.
			Average	Max	
LAX-VNY	1-2	POM	.444	.649	5
	2-3	FIM	.218	.242	
VNY-LAX	3-4	LAX	.371	.507	6
	4-5	LAX	.210	.225	
	5-1	SLI	.334	.430	
LAX-JOR	1-32	SLI	.423	.656	7
	32-27	SLI	.232	.375	
JOR-LAX	28-31	LAX	.990	1.084	8
	31-30	LAX	.778	.830	
	30-7	LAX	.343	.552	
	7-1	SLI	.294	.455	
LAX-ANA	1-25	SLI	.355	.671	9
	25-26	SLI	.201	.202	
JOR/ANA-LAX	27-25	SLI	.236	.315	10
	25-17	SLI	.270	.349	
	17-1	SLI	.339	.602	
LAX-SBD	1-7	SLI	.290	.424	11
	7-9	SLI	.220	.256	
	9-10	ONT	.624	.793	
	10-11	ONT	.260	.380	
	11-13	ONT	.293	.398	

NOTE: Optimum VORTAC facilities are those remaining after screening for obstructions and restrictions.

Similarly, the results of the VOR/DME analysis for the direct routes are shown in Figures 12 (LAX to VNY), 13 (LAX to JOR), 14 (LAX to ANA), and 15 (LAX to SBD). Table 2 lists the optimum station per route segment as well as the average and maximum 2SD cross-course errors for each route segment in the direct route structure. The largest average 2SD cross-course value was ±.532 nmi. None of the eight existing VORTAC stations was capable of servicing the last segment of the LAX to VNY direct route (Figure 12) because of natural terrain obstructions in the vicinity of VNY. For three of the four direct routes, i.e., LAX to JOR, LAX to ANA, and LAX to SBD (Figures 13, 14, and 15 respectively), the optimum VORTAC facilities per route were the same before and after the natural terrain obstruction screening. In addition, as noted in Figures 13 (LAX to JOR) and 14 (LAX to ANA), only an initial VORTAC selection for each route was required. The LAX to SBD route (Figure 15) necessitated one en route station changeover.

DME/DME Analysis: For the DME/DME analysis, the eight VORTAC facilities presently servicing the LAX area were paired for all possible combinations (28 pairs), and each station pair considered as the DME/DME signal source for area navigation over the route segments comprising the approved and direct routes. The same procedures used in the VOR/DME analysis for natural terrain obstruction screening and reporting were applied to the theoretical DME/DME data outputted from the computerized program.

The results of the analytical study on DME/DME area navigation over the approved routes are graphically shown in Figures 16 (LAX to VNY), 17 (VNY to LAX), 18 (LAX to JOR), 19 (JOR to LAX), 20 (LAX to ANA), 21 (JOR/ANA to LAX), and 22 (LAX to SBD), and summarized in Table 3. The largest average 2SD cross-course error was ±1.170 nmi. For the LAX to VNY route (Figure 16), the indicated optimum guidance station pair is identical to the theoretically optimum guidance station pair prior to the obstruction screening. In addition, as shown in Figures 16 (LAX to VNY), 19 (JOR to LAX), and 20 (LAX to ANA), a single VORTAC pair was capable of servicing each route. In considering the remaining four, the VNY to LAX route (Figure 17) required one en route VORTAC changeover; the LAX to SBD route (Figure 22), two changeovers; and no signal coverage was available from any of the 28 station-pair combinations for the last segment of the LAX to JOR route (Figure 18) and the first segment of the JOR/ANA to LAX route (Figure 21).

TABLE 2 - OPTIMUM VORTAC FACILITIES FOR VOR/DME RNAV OVER DIRECT ROUTES IN LAX AREA

Route	Route Segment	Optimum VORTAC	2SD Cross-Course Error (±nmi)		Reference Figure No.
			Average	Max	
LAX-VNY	70-71	POM	.217	.258	12
	71-72	POM	.330	.394	
	72-73	none			
LAX-JOR	70-78	SLI	.322	.694	13
LAX-ANA	70-77	SLI	.345	.686	14
LAX-SBD	70-74	SLI	.330	.577	15
	74-75	POM	.240	.377	
	75-76	POM	.532	.923	

NOTE: Optimum VORTAC facilities are those remaining after screening for obstructions and restrictions.

TABLE 3 - OPTIMUM VORTAC FACILITIES FOR DME/DME RNAV OVER APPROVED ROUTES IN LAX AREA

Route	Route Segment	Optimum VORTAC Pair	2SD Cross-Course Error (±nmi)		Reference Figure No.
			Average	Max	
LAX-VNY	1-2	LAX-POM	.225	.252	16
	2-3	LAX-POM	.169	.173	
VNY-LAX	3-4	LAX-POM	.211	.249	17
	4-5	LAX-POM	.187	.213	
	5-1	LAX-SLI	.242	.275	
LAX-JOR	1-32	LAX-SLI	.501	.779	18
	32-27	none			
JOR-LAX	28-31	LAX-SLI	1.170	1.279	19
	31-30	LAX-SLI	.939	.986	
	30-7	LAX-SLI	.276	.390	
	7-1	LAX-SLI	.229	.286	
LAX-ANA	1-25	LAX-SLI	.497	.997	20
	25-26	LAX-SLI	.186	.229	
JOR/ANA-LAX	27-25	none			21
	25-17	LAX-SLI	.171	.183	
	17-1	LAX-SLI	.294	.473	
LAX-SBD	1-7	LAX-SLI	.226	.273	22
	7-9	LAX-SLI	.200	.211	
	9-10	POM-ONT	.493	.611	
	10-11	POM-ONT	.236	.314	
	11-13	POM-ONT	.296	.390	

NOTE: Optimum VORTAC facilities are those remaining after screening for obstructions and restrictions.

Figures 23 (LAX to VNY), 24 (LAX to ANA), and 25 (LAX to SBD) show the optimum station pairs for DME/DME RNAV over the direct routes. These results are summarized in Table 4. The largest average 2SD cross-course error was ±.754 nmi. The LAX to ANA route (Figure 24) was serviced by the single LAX-SLI VORTAC pair. However, as indicated, no signal coverage from the pairing of the existing VORTAC facilities was available for the last segments of the LAX to VNY route (Figure 23) and the LAX to SBD route (Figure 25). In addition, no station pair was capable of furnishing guidance signals for RNAV on the LAX to JOR route.

Effects of VOR Conversion on DME/DME RNAV: Carrying the study one step further in an attempt to eliminate the signal coverage voids on the approved and direct routes, the local VOR's were analyzed as VORTAC facilities, thus generating new guidance station pairs and new geometry situations from which to select the optimum guidance station pairs for DME/DME RNAV over the previous problem route segments of the approved and direct route structures.

The results of the additional analysis to determine optimum station pair for the LAX to JOR and JOR/ANA to LAX approved routes are shown in Figures 26 and 27 respectively, and are summarized in Table 5. The largest average 2SD cross-course error was ±.296 nmi. As indicated, the LAX to JOR route (Figure 26) which previously was void of signal coverage in the last segment, was now capable of being flown without en route station changeovers after initially selecting for guidance the converted SMO VOR and NZJ VOR station pair. Similarly, all segments of the JOR/ANA to LAX route (Figure 27) were adequately serviced by utilizing the guidance station pair consisting of the LAX VORTAC and the converted SXC VOR.

The voids in the signal coverage along the LAX to JOR direct route and the last segment of the LAX to SBD direct route previously encountered when considering guidance station pairs from existing VORTAC's were eliminated by utilizing converted VOR's SMO and NZJ for the LAX to JOR route, and converted SBD VOR in combination with POM for the final portion of the LAX to SBD route. Figures 28 and 29 show the 2SD cross-course tolerance limits for DME/DME RNAV along the LAX to JOR and LAX to SBD direct routes, respectively, when receiving guidance signals from the indicated optimum station pairs. Table 5 summarizes these analytical results. The average 2SD cross-course error for the LAX to JOR route (Figure 28) was ±.358 nmi. RNAV along this route required no

TABLE 4 - OPTIMUM VORTAC FACILITIES FOR DME/DME RNAV OVER DIRECT ROUTES IN LAX AREA

Route	Route Segment	Optimum VORTAC Pair	2SD Cross-Course Error (±nmi)		Reference Figure No.
			Average	Max	
LAX-VNY	70-71	LAX-POM	.201	.204	23
	71-72	LAX-POM	.210	.217	
	72-73	none			
LAX-JOR	70-78	none			
LAX-ANA	70-77	LAX-SLI	.754	1.645	24
LAX-SBD	70-74	LAX-SLI	.277	.433	25
	74-75	SLI-ONT	.229	.241	
	75-76	none			

NOTE: Optimum VORTAC facilities are those remaining after screening for obstructions and restrictions.

TABLE 5 - OPTIMUM GUIDANCE STATIONS FOR DME/DME RNAV OVER APPROVED AND DIRECT ROUTES IN LAX AREA CONSIDERING EXISTING AND CONVERTED FACILITIES

APPROVED ROUTES					
Route	Route Segment	Optimum RNAV Pair	2SD Cross-Course Error (±nmi)		Reference Figure No.
			Average	Max	
LAX-JOR	1-32	SMO-NZJ	.296	.314	26
	32-27	SMO-NZJ	.262	.281	
JOR/ANA-LAX	27-25	LAX-SXC	.170	.176	27
	25-17	LAX-SXC	.165	.168	
	17-1	LAX-SXC	.239	.289	

DIRECT ROUTES					
Route	Route Segment	Optimum RNAV Pair	2SD Cross Country Error (±nmi)		Reference Figure No.
			Average	Max	
LAX-JOR	70-78	SMO-NZJ	.358	.447	28
LAX-SBD	70-74	LAX-SLI	.277	.443	29
	74-75	SLI-ONT	.229	.241	
	75-76	POM-SBD	1.239	2.084	

NOTE: Optimum guidance stations are those remaining after screening for obstructions and restrictions.

en route station changeovers after the initial selection. The largest average 2SD cross-course error for the LAX to SBD route (Figure 29) was 1.239 nmi. In navigating along this direct route, three en route station changeovers were required after the initial selection.

Guidance signals for DME/DME RNAV along the last segment of the LAX to VNY direct route were not available from any station-pair combinations of local VORTAC and converted VOR facilities. The signal coverage problem due to surrounding terrain obstructions is similar to that encountered for the VOR/DME RNAV case.

En Route Guidance Station Changeovers: When considering the optimum guidance stations for VOR/DME and DME/DME RNAV over the approved and direct routes, the best stations based upon the average $2(SD)^2$ cross-course values were not always selected. To do this in every instance would have required pilot-actuated guidance station changeovers on every segment of every route; a situation considered unrealistic from a pilot's viewpoint. In those instances where the cross-course errors from particular station(s) were not appreciably larger than the best station(s) for a particular segment, the less optimum station(s) were selected if the use of the selected station(s) permitted RNAV over the entire route or more than one route segment. The optimum stations selected and listed in Tables 1 to 5 inclusively were based upon tradeoffs between the $2(SD)^2$ cross-course values and the number of en route station changeovers. Table 6 indicates the number of en route station changeovers per route.

Comparison of VOR/DME and DME/DME Results: The use of DME/DME guidance signals from two VORTAC's rather than VOR/DME from a single VORTAC is intended to provide increased navigation accuracy for V/STOL operations. When comparing the error values associated with the VOR/DME signal from a single VORTAC, the DME linear component of the combined signal provides a smaller error than the VOR angular component. Therefore, space position determined from a DME/DME will be more accurate than that obtainable from VOR/DME. The degree of navigation accuracy improvement is dependent upon the geometric relationships between the aircraft, guidance station(s), and route segment, per the cross-course and along-course error equations previously described. As stated in the analysis, the DME SD error value was ± 0.1 nmi; the VOR SD error value $+1.0°$. These values are considered representative of presently available high quality navigation equipment.

TABLE 6 - NUMBER OF CONVERTED VOR AND/OR VORTAC CHANGEOVERS FOR RNAV IN LAX AREA USING OPTIMUM GUIDANCE STATIONS SCREENED FOR NATURAL TERRAIN OBSTRUCTIONS

	*Number of Guidance Station Changeovers			
	Approved Routes		Direct Routes	
Route	VOR/DME	DME/DME	VOR/DME	DME/DME
LAX-VNY	1	0	(1 of 2)	(1 of 2)
VNY-LAX	1	1		
LAX-JOR	0	0	0	0
JOR-LAX	1	0		
LAX-ANA	0	0	0	0
JOR/ANA-LAX	0	0		
LAX-SBD	1	2	1	3

*Number of guidance station changes after initial selection. For DME/DME RNAV, selecting one guidance station to form a new station pair is considered as one station changeover.

( ) Number of segments with no signal coverage.

Examples of the increased navigation accuracies inherent in the DME/DME technique are shown in Table 7. Table 7 compares VOR/DME and DME/DME cross-course errors for RNAV over the approved routes. Since the intent of this comparison is to demonstrate improved navigation accuracy based upon geometric considerations, only the theoretically optimum guidance stations are considered. Restriction and obstruction effects are not reflected in this comparison. The average 2SD cross-course errors for DME/DME RNAV over 20 of 21 segments of the seven approved routes were less than the cross-course errors for VOR/DME RNAV. Although Table 7 refers to the approved route structure, the same comparative improvements were noted for RNAV over the direct routes.

The accuracy improvements of DME/DME RNAV over VOR/DME RNAV are also shown in Tables 1 to 4, inclusively. These tables, which more realistically relate to the operational environment, indicate the optimum guidance stations for RNAV following screening for obstructions and restrictions. Over the approved routes shown in Tables 1 and 3, there are 19 route segments where both VOR/DME and DME/DME signal coverage is available for RNAV. For 14 of the 19 route segments, the average 2SD cross-course errors for DME/DME RNAV were less than the VOR/DME errors. Similarly, over the direct routes of Tables 2 and 4, the average 2SD cross-course errors for DME/DME RNAV were less than the VOR/DME errors for four of the five route segments common to both area navigation modes.

Suggested Guidance Stations for Verification Flights: The results of the analytical study must be verified by flight inspection of the selected guidance facilities overr the indicated routes and at the minimum en route altitudes. The information in Tables 8 and 9 can be used as a guide in determining the guidance stations to be flight checked. Table 8 identifies in ranking order the facilities to be checked per approved route segment; Table 9, the facilities to be inspected per direct route segment. All the VORTAC and VOR facilities presently servicing the LAX area are listed in Tables 8 and 9. However, as indicated, some of these guidance stations were not selected for flight inspection due to natural terrain obstructions or poor geometry situations.

TABLE 7 - COMPARISON OF VOR/DME AND DME/DME ANALYTICAL RESULTS FOR RNAV OVER THE APPROVED ROUTES WITH GUIDANCE SIGNALS DERIVED FROM THE THEORETICALLY OPTIMUM VORTAC FACILITIES

		VOR/DME			DME/DME		
Route	Route Segment	Guidance Station	2SD Cross-Course Error (±nmi) Average	Max	Guidance Station Pair	2SD Cross-Course Error (±nmi) Average	Max
LAX-VNY	1-2	VNY	.361	.568	LAX-POM	.225	.252
	2-3	FIM	.218	.242	LAX-POM	.169	.173
VNY-LAX	3-4	LAX	.371	.507	LAX-VTU	.188	.195
	4-5	LAX	.210	.225	LAX-VTU	.187	.239
	5-1	SLI	.334	.430	VNY-VTU	.193	.226
LAX-JOR	1-32	SLI	.423	.656	VNY-POM	.194	.199
	32-27	SLI	.232	.375	VNY-POM	.181	.207
JOR-LAX	28-31	POM	.445	.529	POM-ONT	.166	.185
	31-30	POM	.227	.312	POM-ONT	.154	.159
	30-7	POM	.258	.365	VNY-POM	.213	.273
	7-1	VNY	.234	.285	VNY-POM	.217	.266
LAX-ANA	1-25	SLI	.355	.671	VNY-POM	.208	.216
	25-26	SLI	.201	.202	VNY-POM	.227	.238
JOR/ANA-LAX	27-25	SLI	.236	.315	LAX-POM	.210	.237
	25-17	SLI	.270	.349	VNY-POM	.192	.206
	17-1	SLI	.339	.602	VNY-POM	.240	.278
LAX-SBD	1-7	SLI	.290	.424	LAX-SLI	.226	.273
	7-9	SLI	.220	.256	LAX-SLI	.200	.211
	9-10	SLI	.378	.525	POM-OCN	.224	.237
	10-11	ONT	.260	.380	POM-OCN	.202	.205
	11-13	ONT	.293	.398	POM-OCN	.194	.196

NOTE: Theoretically optimum VORTAC facilities are those selected as most accurate from the computer-derived analytical outputs prior to screening for obstructions and restrictions.

TABLE 8 - RANKING ORDER OF GUIDANCE STATIONS REQUIRING FLIGHT INSPECTION PRIOR TO RNAV ALONG APPROVED ROUTES

Route	Route Segment	Existing VORTAC Facilities								Converted VOR Facilities						
		FIM	LAX	OCN	ONT	POM	SLI	VNY	VTU	NZJ	RAL	RIV	SBD	SMO	SNA	SXC
LAX-VNY	1-2	4	*2	5		1	3									
	2-3	1	2			3	5	*4								
VNY-LAX	3-4	3	1			2		*4								
	4-5	5	1			2	4	*3								
	5-1		*2			3	1									
LAX-JOR	1-32		4				1			3				2	5	
	32-27		4				1			3				2	5	
JOR-LAX	28-31		1				*2									
	31-30		1				*2									
	30-7		1				*2									
	7-1		*2			3	1									
LAX-ANA	1-25		*2				1									
	25-26		2				1									
JOR/ANA-LAX	27-25		2				1			5				4	6	3
	25-17		2				1			5				6	4	3
	17-1		*2				1			5				6	4	3
LAX-SBD	1-7		*2			3	1									
	7-9		2		4	*3	1									
	9-10		3		2	*1										
	10-11		3		1	*2										
	11-13				1	2										

*Radial of indicated guidance station.

TABLE 9 - RANKING ORDER OF GUIDANCE STATIONS REQUIRING FLIGHT INSPECTION PRIOR TO RNAV ALONG DIRECT ROUTES

Route	Route Segment	Existing VORTAC Facilities								Converted VOR Facilities						
		FIM	LAX	OCN	ONT	POM	SLI	VNY	VTU	NZJ	RAL	RIV	SBD	SMO	SNA	SXC
LAX-VNY	70-71		*2			1	3									
	71-72	4	2			1	5	*3								
	72-73							*1								
LAX-JOR	70-78		*4				1			3				2	5	
LAX-ANA	70-77		*2				1									
LAX-SBD	70-74		*2				1									
	74-75		*4		3	1	2									
	75-76					1							2			

*Radial of indicated guidance station.

SUMMARY OF RESULTS

1. The FIM, LAX, ONT, POM or SLI VORTAC, as appropriate, provided guidance signals for VOR/DME RNAV over all segments (21) of the seven approved routes.

The guidance signals from the theoretically optimum VORTAC stations servicing the VNY to LAX, LAX to JOR, LAX to ANA, and JOR/ANA to LAX routes were not affected by natural terrain obstructions.

VOR/DME RNAV along each of the LAX to JOR, LAX to ANA, and JOR/ANA to LAX routes required no en route station changeovers after selection of the initial VORTAC. Each of the remaining routes, i.e., LAX to VNY, VNY to LAX, JOR to LAX, and LAX to SBD, required one en route station changeover.

2. With the exception of the last segment of the LAX to VNY route, guidance signals from the POM or SLI VORTAC, as appropriate, permitted VOR/DME RNAV over the four direct routes.

The guidance signals from the theoretically optimum VORTAC stations servicing the LAX to JOR, LAX to ANA, and LAX to SBD routes were not affected by natural terrain obstructions.

VOR/DME RNAV along each of the LAX to JOR and LAX to ANA routes required no en route station changeovers after selection of the initial VORTAC. In regard to the remaining two routes, the LAX to SBD route required one en route changeover; the LAX to VNY route, no en route station changeovers in the first two segments. None of the eight VORTAC facilities or seven converted VOR's was capable of providing guidance signals for the last segment of the LAX to VNY direct route.

3. By selecting, as needed, various station-pair combinations from the LAX, ONT, POM, and SLI VORTAC facilities, and the NZJ, SMO, and SXC converted VOR's, guidance signals for DME/DME RNAV were available over all segments (21) of the seven approved routes.

The guidance signals from the theoretically optimum VORTAC pair servicing the LAX to VNY route were not affected by natural terrain obstruction.

DME/DME RNAV along each of the LAX to VNY, JOR to LAX, and LAX to ANA routes required no en route station changeovers after selection of the initial VORTAC pair. The VNY to LAX route required one en route station changeover; the LAX to SBD route, two changeovers.

No VORTAC pair was capable of providing DME/DME guidance signals for the first segment of the JOR/ANA to LAX route and the last segment of the LAX to JOR route. However, these voids were eliminated by considering the NZJ, SMO, and SXC VOR facilities as VORTAC stations. No en route station changeovers were required after initially selecting the optimum guidance station pair for each of these routes.

4. With the exception of the last segment of the LAX to VNY route, selection of various station-pair combinations from the LAX, ONT, POM, and SLI VORTAC facilities, and the NZJ, SBD, and SMO converted VOR's provided guidance signals for DME/DME RNAV over the four direct routes.

The guidance signals from the theoretically optimum VORTAC pair servicing the LAX to ANA route were not affected by natural terrain obstructions.

DME/DME RNAV along the LAX to ANA route required no en route station changeovers after selection of the initial VORTAC pair.

No VORTAC pair was capable of providing DME/DME guidance signals for the last segments of the LAX to VNY and LAX to SBD routes, and the LAX to JOR route. The signal voids along the LAX to SBD and LAX to JOR routes were eliminated by considering the NZJ, SBD, and SMO VOR facilities as VORTAC stations. No en route station changeovers were required for the LAX to JOR route. Three en route changeovers were needed for the LAX to SBD route. No combination of VORTAC and converted VOR station pairs was capable of servicing the last segment of the LAX to VNY direct route.

5. Considering the theoretically optimum guidance station(s), the average 2SD cross-course errors for DME/DME RNAV over 20 of 21 segments of the seven approved routes were less than the cross-course errors for VOR/DME RNAV.

CONCLUSIONS

The following conclusions are based upon an assessment of the analytical study results as affected by the constraints of the assumed system errors:

1. VOR/DME area navigation over the approved IFR VTOL routes in the LAX basin is feasible when using the existing VORTAC facilities.

2. DME/DME area navigation over the approved IFR VTOL routes in the LAX basin is feasible when using station-pair combinations of the existing VORTAC facilities and certain converted VOR stations.

3. With the exception of the last segment of the LAX to VNY route, VOR/DME area navigation over the hypothetical direct V/STOL routes in the LAX basin is feasible when using the existing VORTAC facilities.

4. With the exception of the last segment of the LAX to VNY route, DME/DME area navigation over the hypothetical direct V/STOL routes is feasible when using station-pair combinations from existing VORTAC facilities and certain converted VOR stations.

5. DME/DME RNAV using guidance signals from two VORTAC facilities can potentially provide more accurate navigation than that obtainable from VOR/DME RNAV with a single guidance station. The degree of navigation improvement is dependent upon the geometric relationships between the aircraft, guidance station(s), and route segment.

6. The number of en route station changeovers for VOR/DME and DME/DME area navigation over the approved IFR VTOL routes and the hypothetical direct V/STOL routes is considered acceptable when the guidance station or station-pair selection is based upon the utilization of existing VORTAC facilities and certain converted VOR stations.

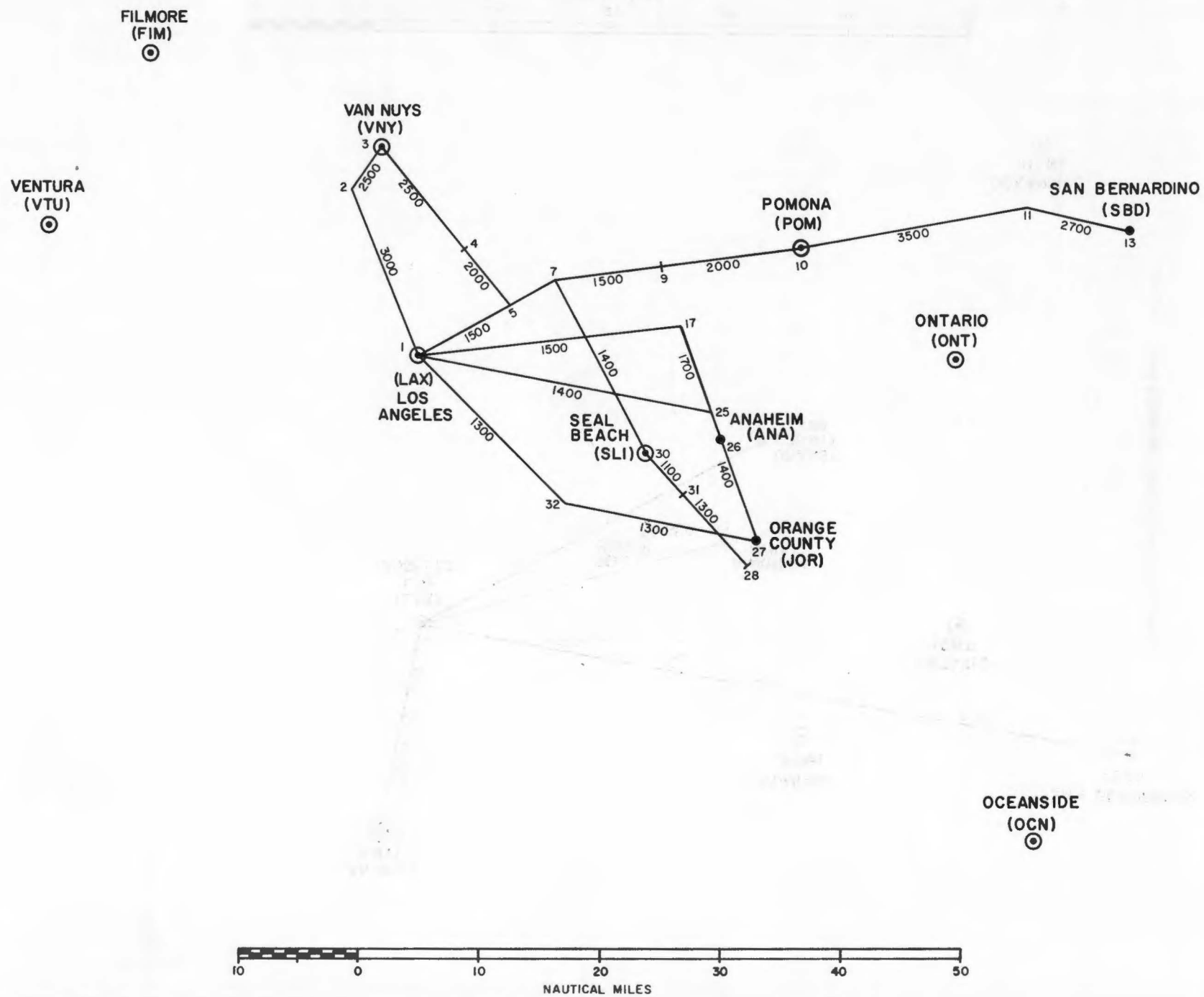


FIGURE 1 - LOS ANGELES APPROVED IFR VTOL ROUTE STRUCTURE

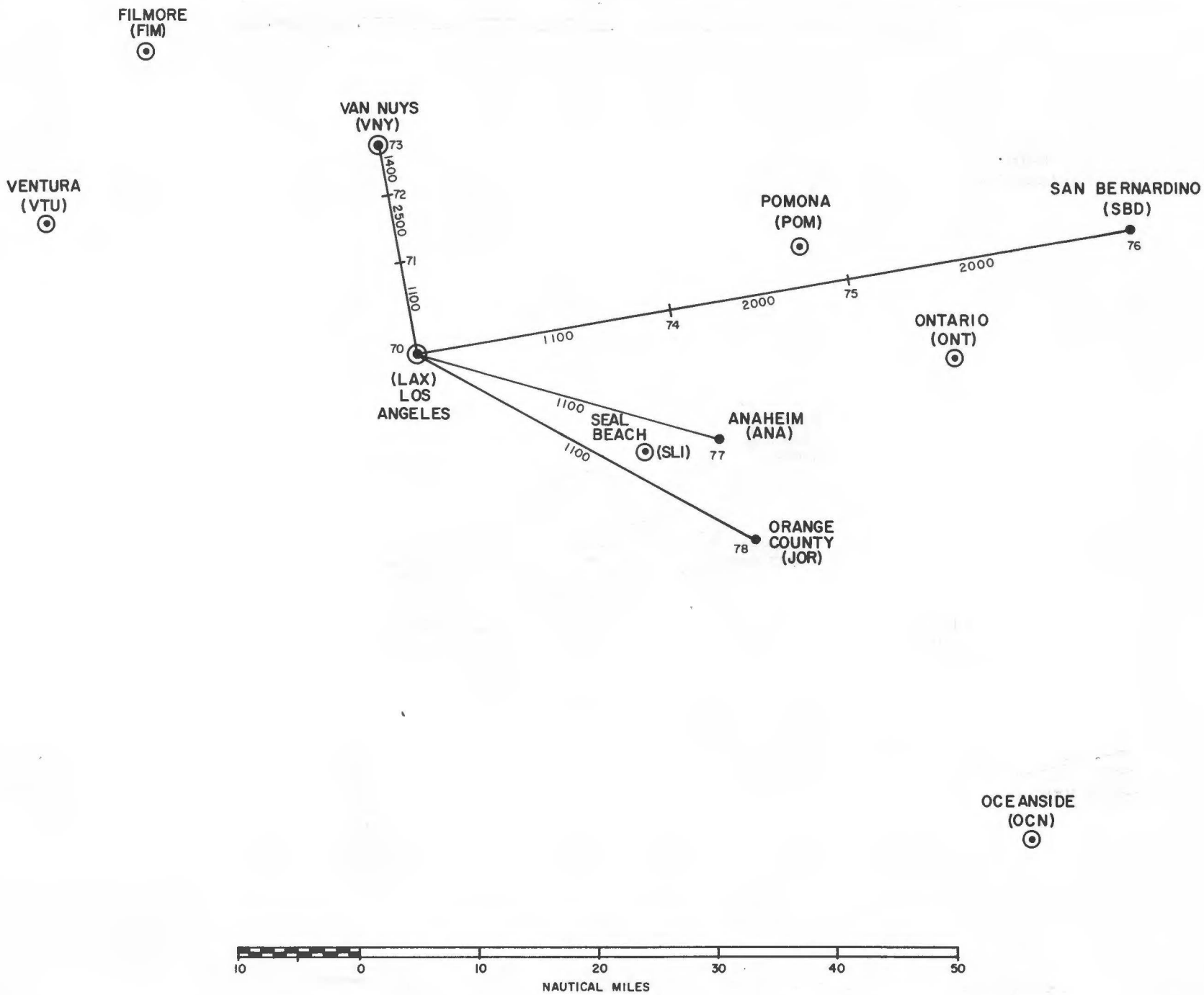


FIGURE 2 - LOS ANGELES HYPOTHETICAL DIRECT V/STOL ROUTE STRUCTURE

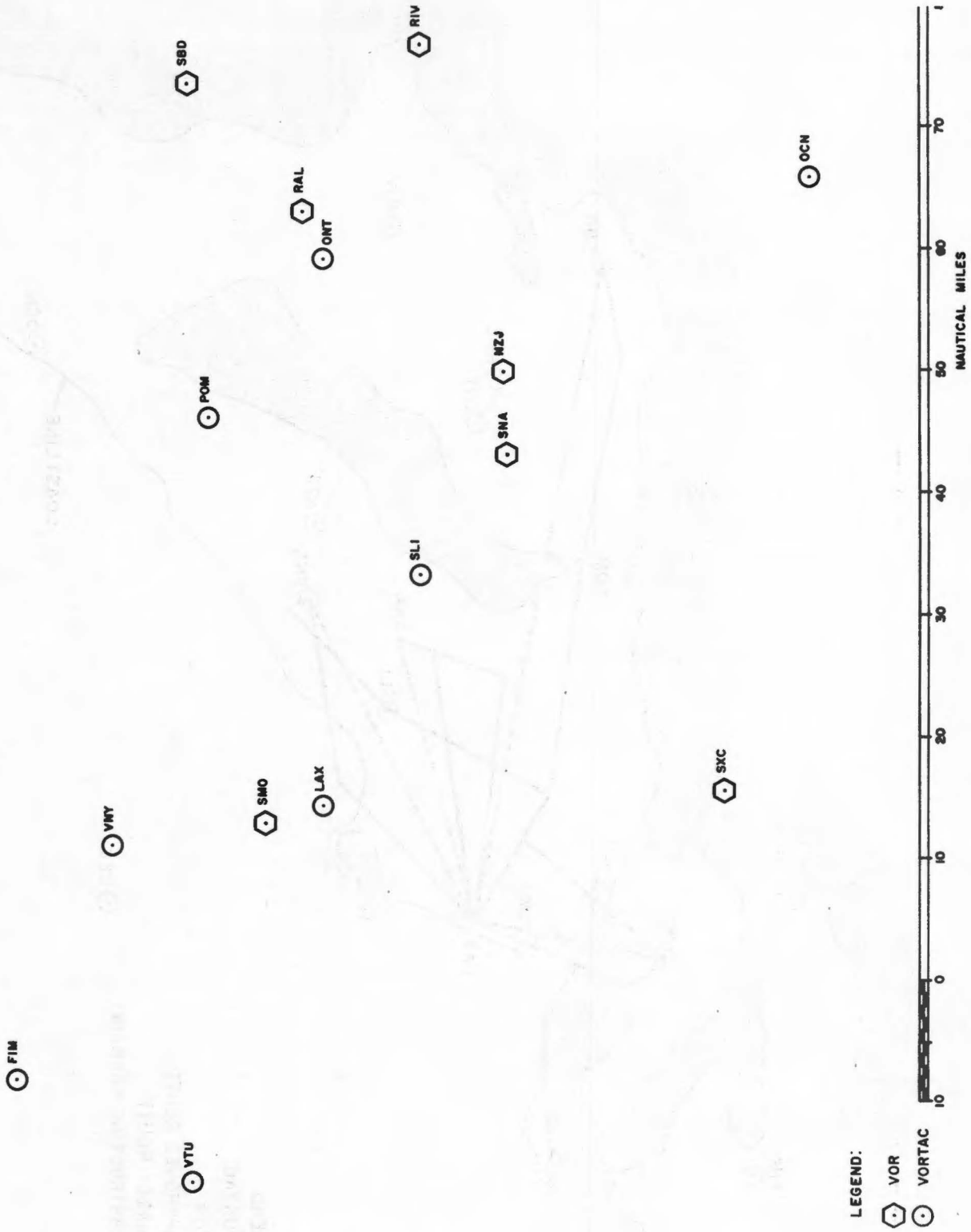


FIGURE 3 - LOCATIONS OF EXISTING VOR AND VORTAC GUIDANCE STATIONS SERVICING THE LOS ANGELES AREA

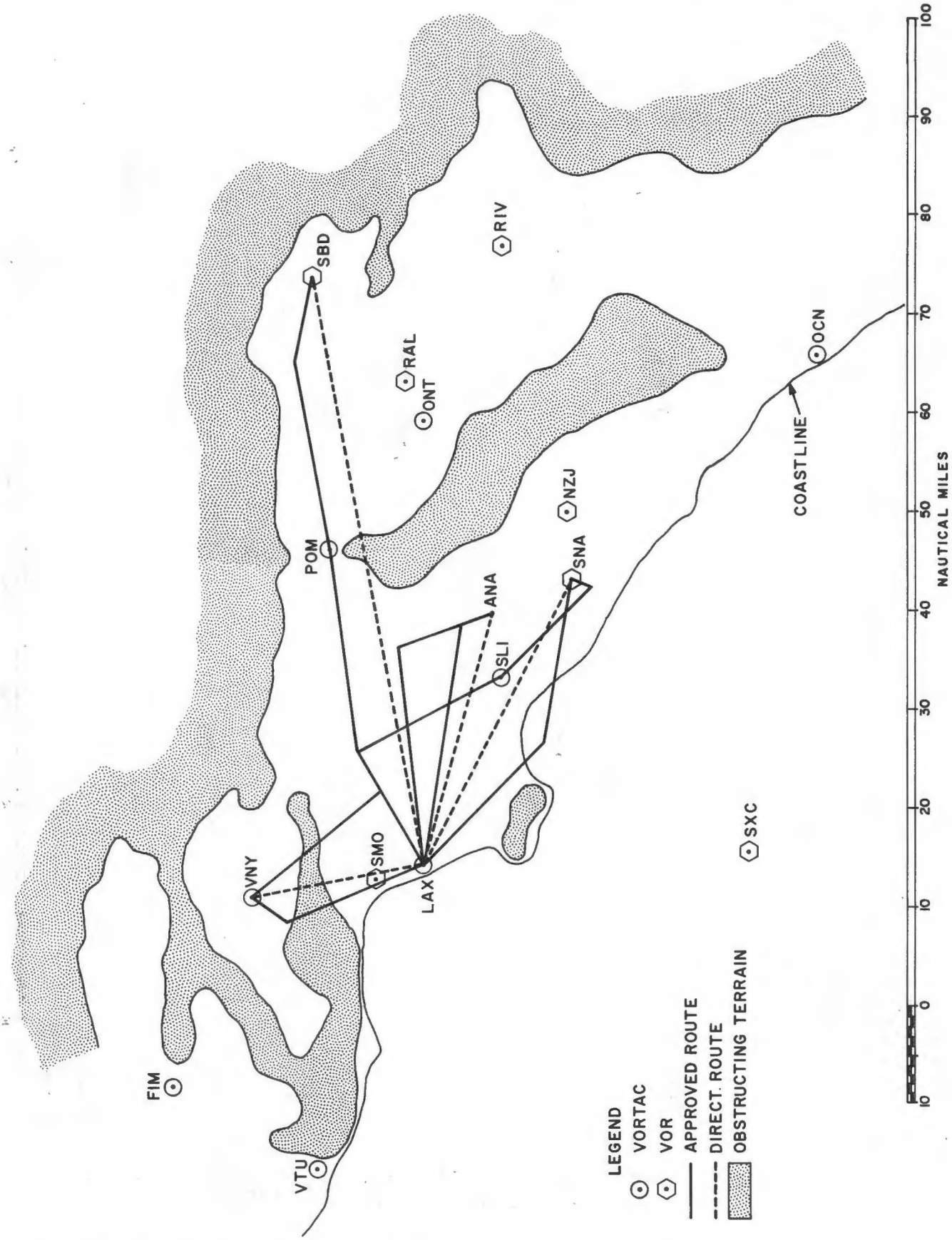
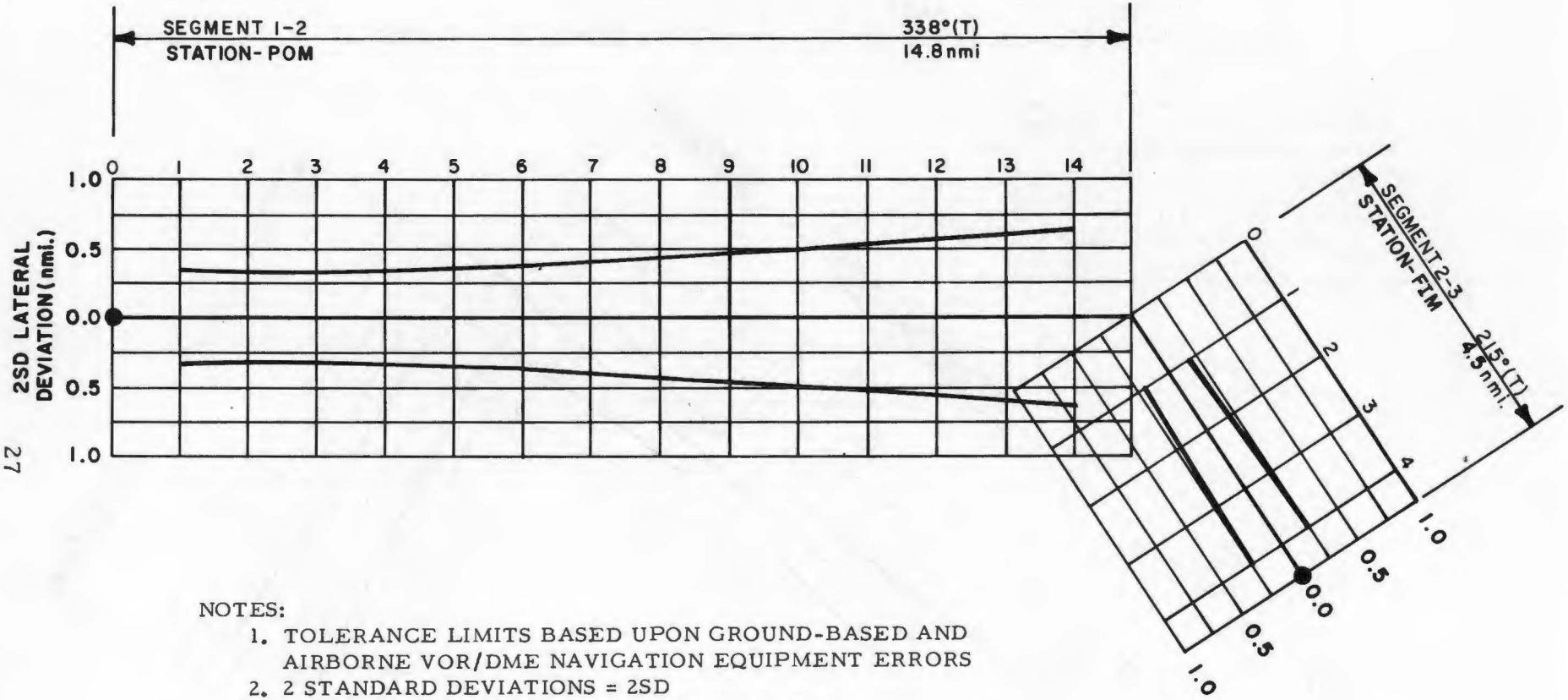


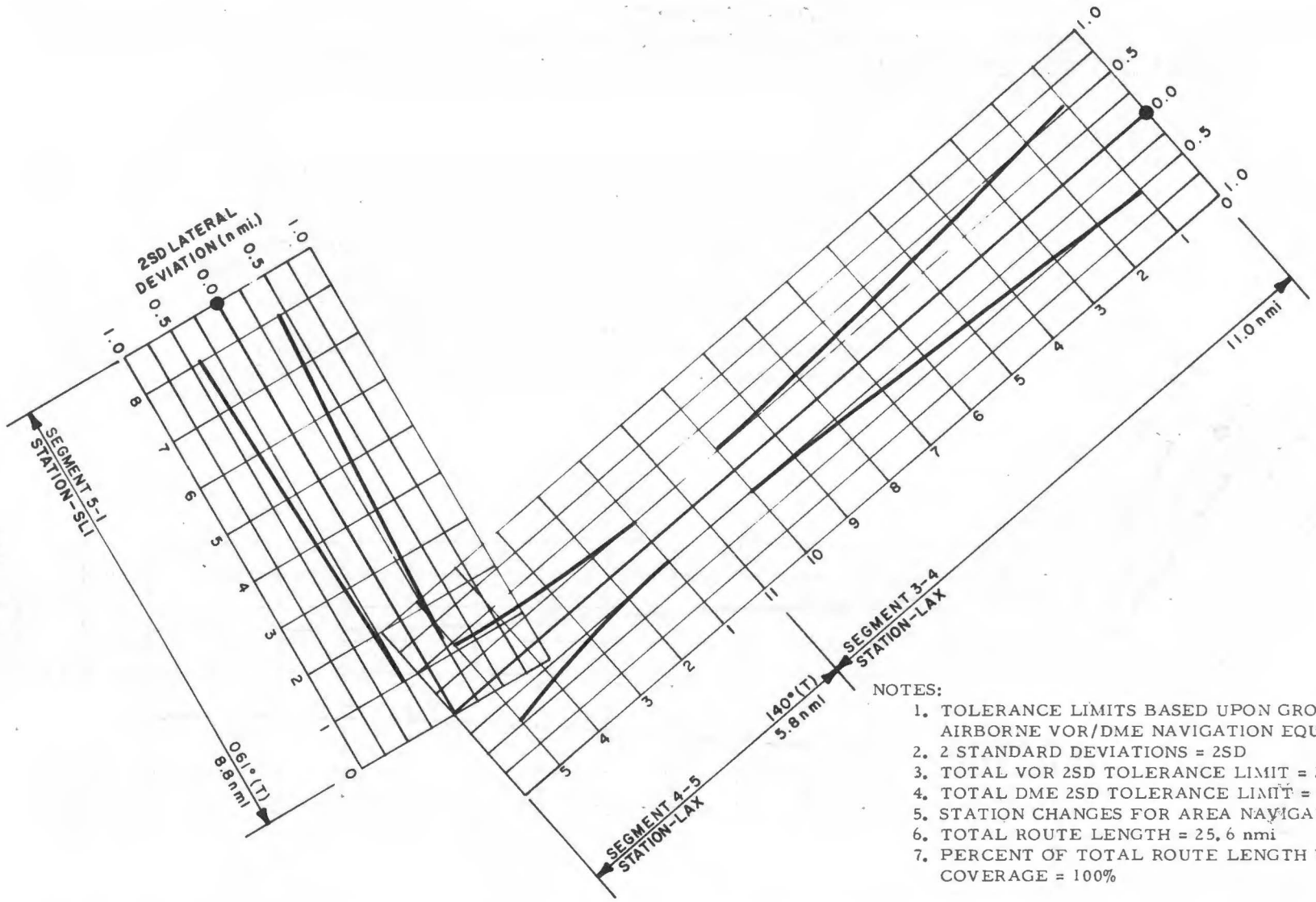
FIGURE 4 - NATURAL TERRAIN OBSTRUCTIONS IN THE LOS ANGELES AREA



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE VOR/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL VOR 2SD TOLERANCE LIMIT = 2.0°
4. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
5. STATION CHANGES FOR AREA NAVIGATION = 1
6. TOTAL ROUTE LENGTH = 23.3 nmi
7. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%

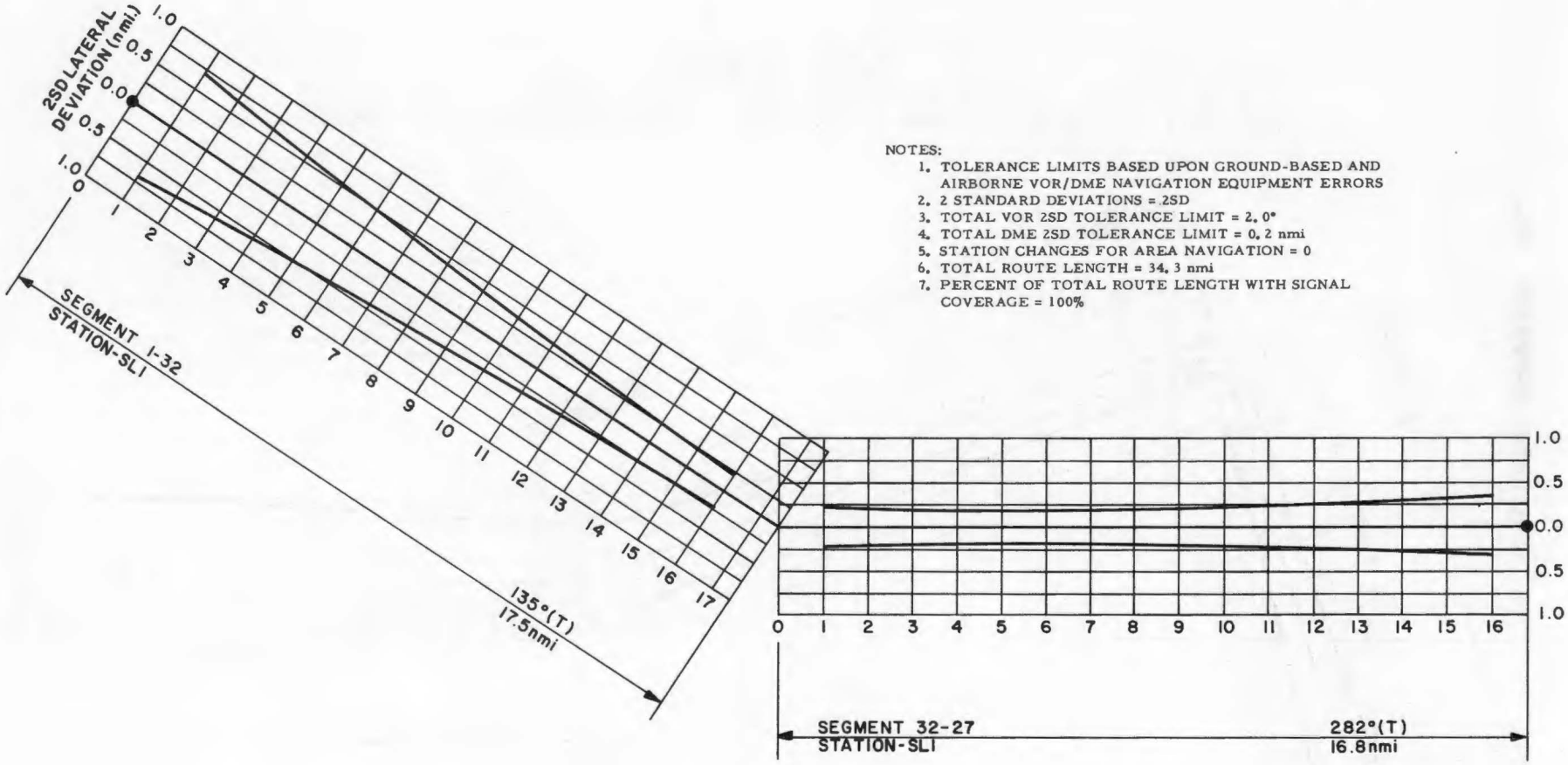
FIGURE 5 - OPTIMUM VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER LOS ANGELES TO VAN NUYS APPROVED ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE VOR/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL VOR 2SD TOLERANCE LIMIT = 2.0°
4. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
5. STATION CHANGES FOR AREA NAVIGATION = 1
6. TOTAL ROUTE LENGTH = 25.6 nmi
7. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%

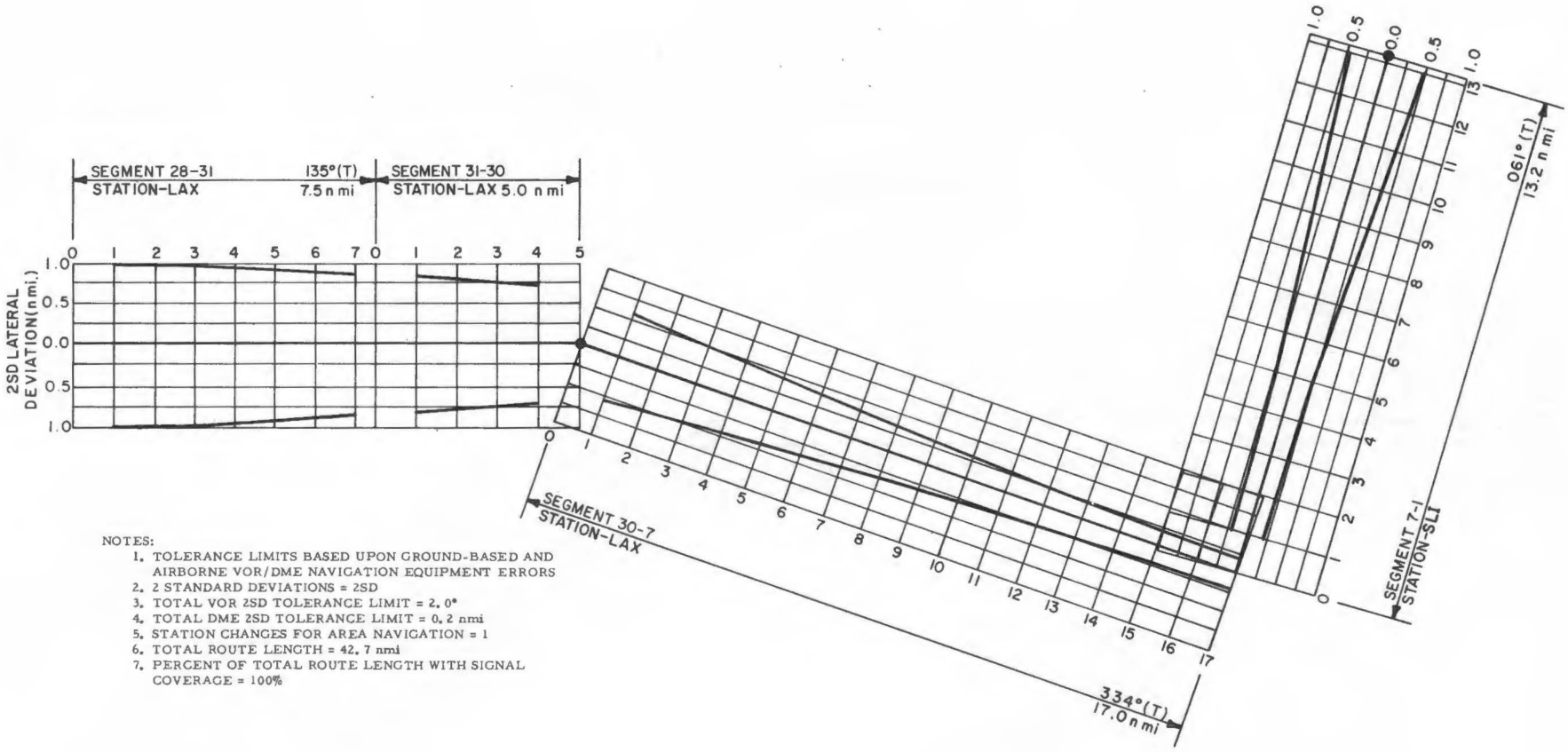
FIGURE 6 - OPTIMUM VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER VAN NUYS TO LOS ANGELES APPROVED ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE VOR/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL VOR 2SD TOLERANCE LIMIT = 2.0°
4. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
5. STATION CHANGES FOR AREA NAVIGATION = 0
6. TOTAL ROUTE LENGTH = 34.3 nmi
7. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%

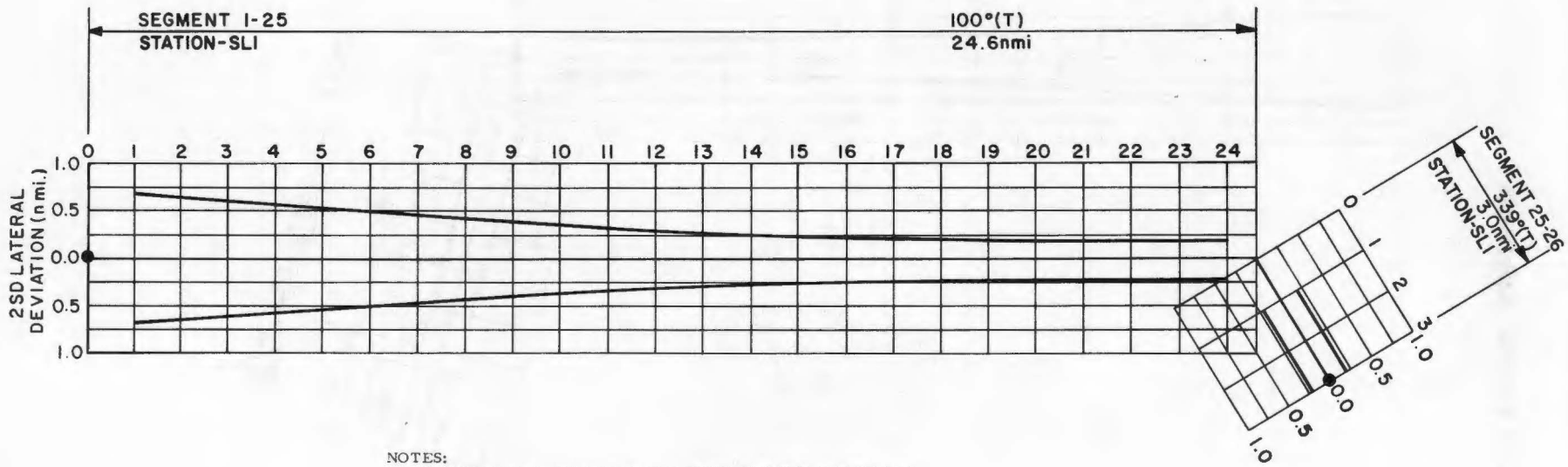
FIGURE 7 - OPTIMUM VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER LOS ANGELES TO ORANGE COUNTY APPROVED ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE VOR/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL VOR 2SD TOLERANCE LIMIT = 2.0°
4. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
5. STATION CHANGES FOR AREA NAVIGATION = 1
6. TOTAL ROUTE LENGTH = 42.7 nmi
7. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%

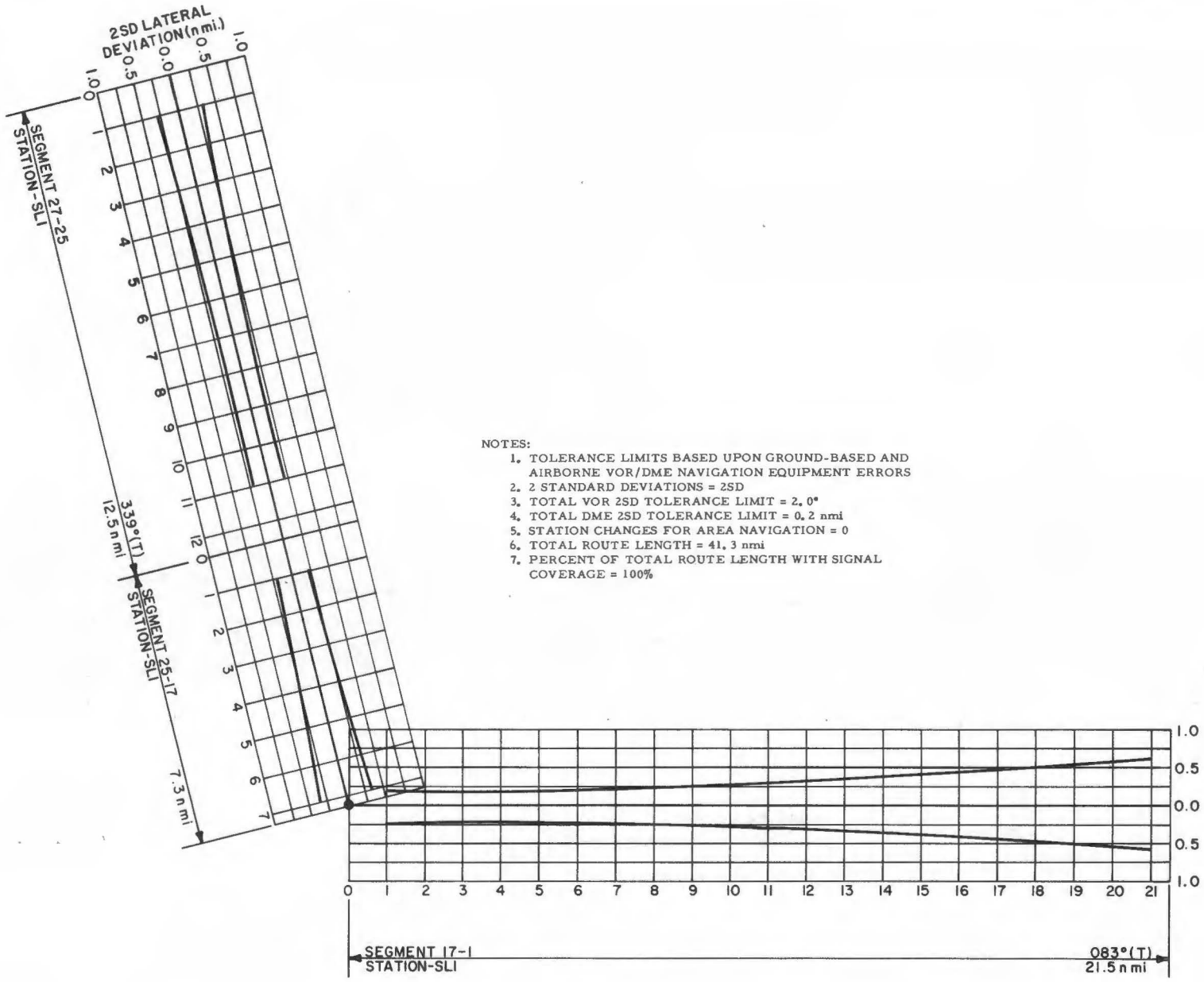
FIGURE 8 - OPTIMUM VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER ORANGE COUNTY TO LOS ANGELES APPROVED ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE VOR/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL VOR 2SD TOLERANCE LIMIT = 2.0°
4. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
5. STATION CHANGES FOR AREA NAVIGATION = 0
6. TOTAL ROUTE LENGTH = 27.6 nmi
7. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%

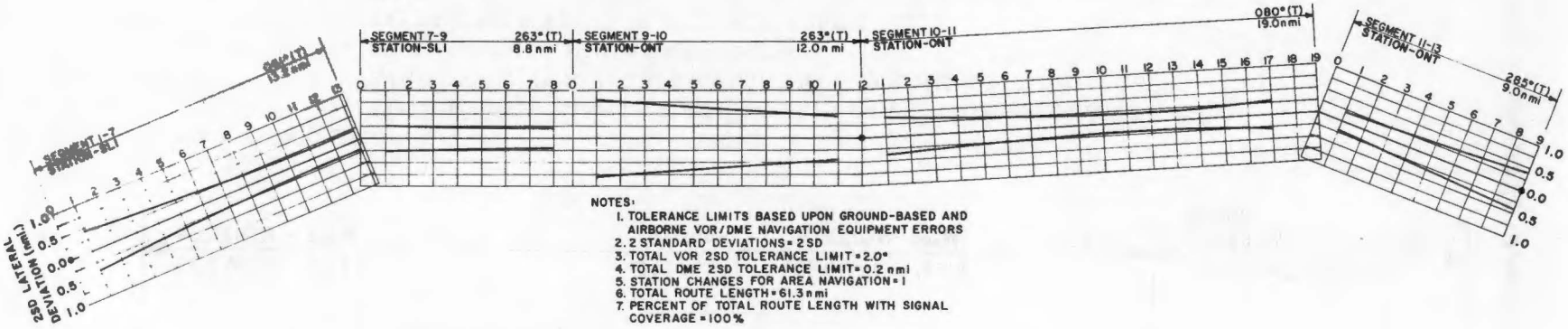
FIGURE 9 - OPTIMUM VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER LOS ANGELES TO ANAHEIM APPROVED ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE VOR/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL VOR 2SD TOLERANCE LIMIT = 2.0°
4. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
5. STATION CHANGES FOR AREA NAVIGATION = 0
6. TOTAL ROUTE LENGTH = 41.3 nmi
7. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%

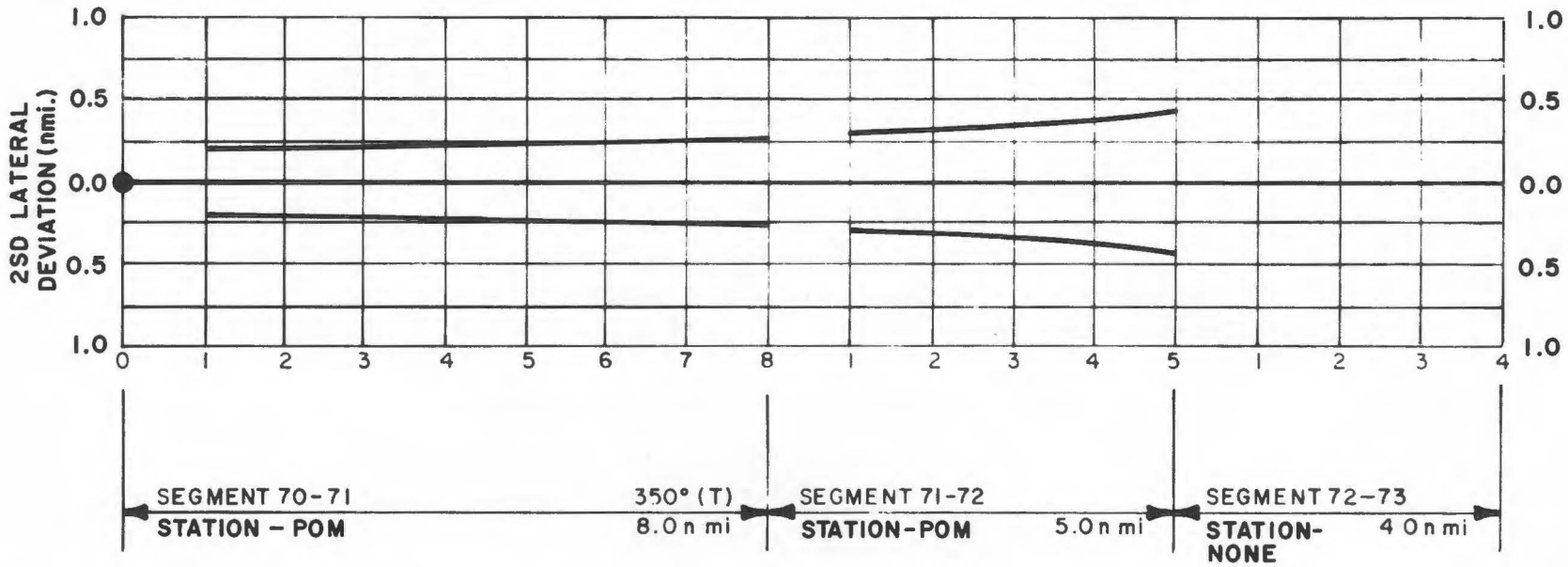
FIGURE 10 - OPTIMUM VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER ORANGE COUNTY/ANAHEIM TO LOS ANGELES APPROVED ROUTE



NOTES:
1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE VOR/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL VOR 2SD TOLERANCE LIMIT = 2.0°
4. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
5. STATION CHANGES FOR AREA NAVIGATION = 1
6. TOTAL ROUTE LENGTH = 61.3 nmi
7. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%

(B) OPTIMUM SIGNAL COVERAGE AFTER SCREENING FOR NATURAL TERRAIN OBSTRUCTIONS

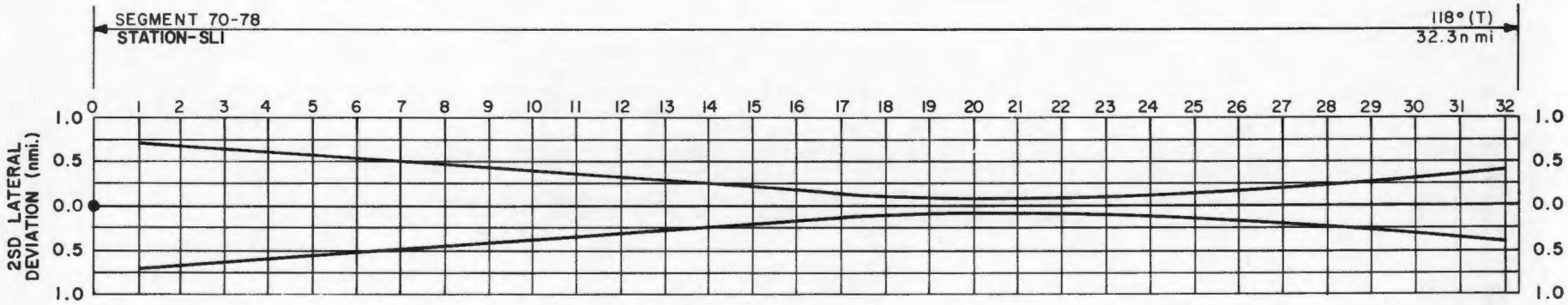
FIGURE 11 - OPTIMUM VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER LOS ANGELES TO SAN BERNARDINO APPROVED ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE VOR/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL VOR 2SD TOLERANCE LIMIT = 2.0°
4. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
5. STATION CHANGES FOR AREA NAVIGATION = 0
6. TOTAL ROUTE LENGTH = 17.0 nmi
7. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 76%
8. NO GUIDANCE STATION SIGNAL COVERAGE FOR SEGMENT 72-73

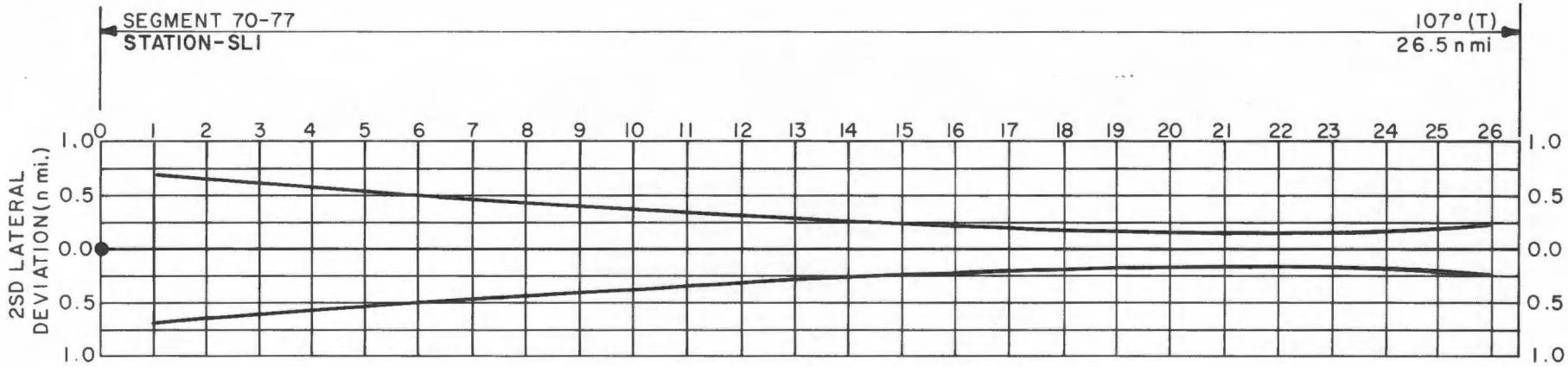
FIGURE 12 - OPTIMUM VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER LOS ANGELES TO VAN NUYS DIRECT ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE VOR/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL VOR 2SD TOLERANCE LIMIT = 2.0°
4. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
5. STATION CHANGES FOR AREA NAVIGATION = 0
6. TOTAL ROUTE LENGTH = 32.3 nmi
7. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%

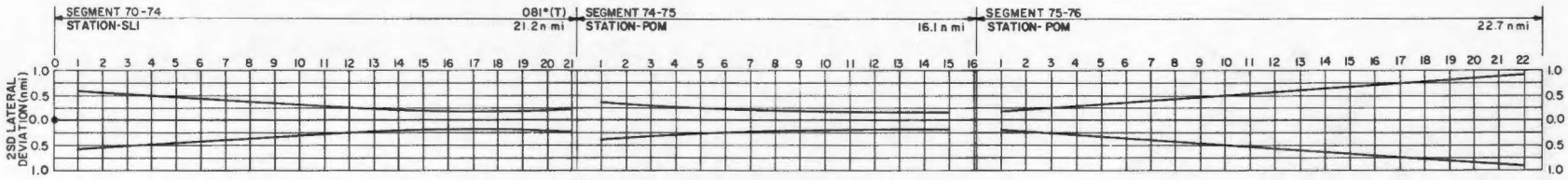
FIGURE 13 - OPTIMUM VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER LOS ANGELES TO ORANGE COUNTY DIRECT ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE VOR/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL VOR 2SD TOLERANCE LIMIT = 2.0°
4. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
5. STATION CHANGES FOR AREA NAVIGATION = 0
6. TOTAL ROUTE LENGTH = 26.5 nmi
7. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%

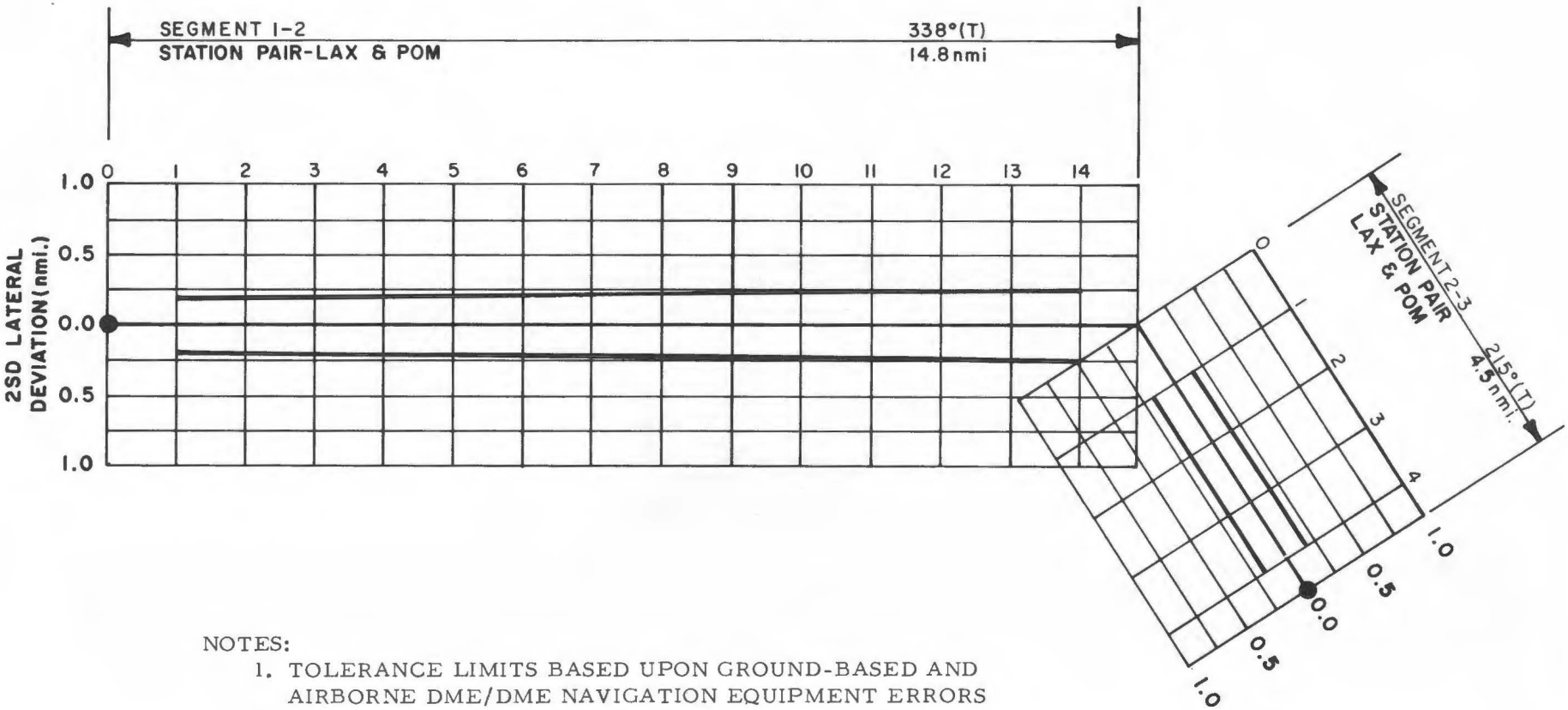
FIGURE 14 - OPTIMUM VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER LOS ANGELES TO ANAHEIM DIRECT ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE VOR/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2 SD
3. TOTAL VOR 2SD TOLERANCE LIMIT = 2.0°
4. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
5. STATION CHANGES FOR AREA NAVIGATION = 1
6. TOTAL ROUTE LENGTH = 60.0 nmi
7. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%
8. SAME GUIDANCE STATIONS FOR OPTIMUM SIGNAL COVERAGE UNDER THEORETICAL AND NATURAL TERRAIN OBSTRUCTION SCREENING CONDITIONS

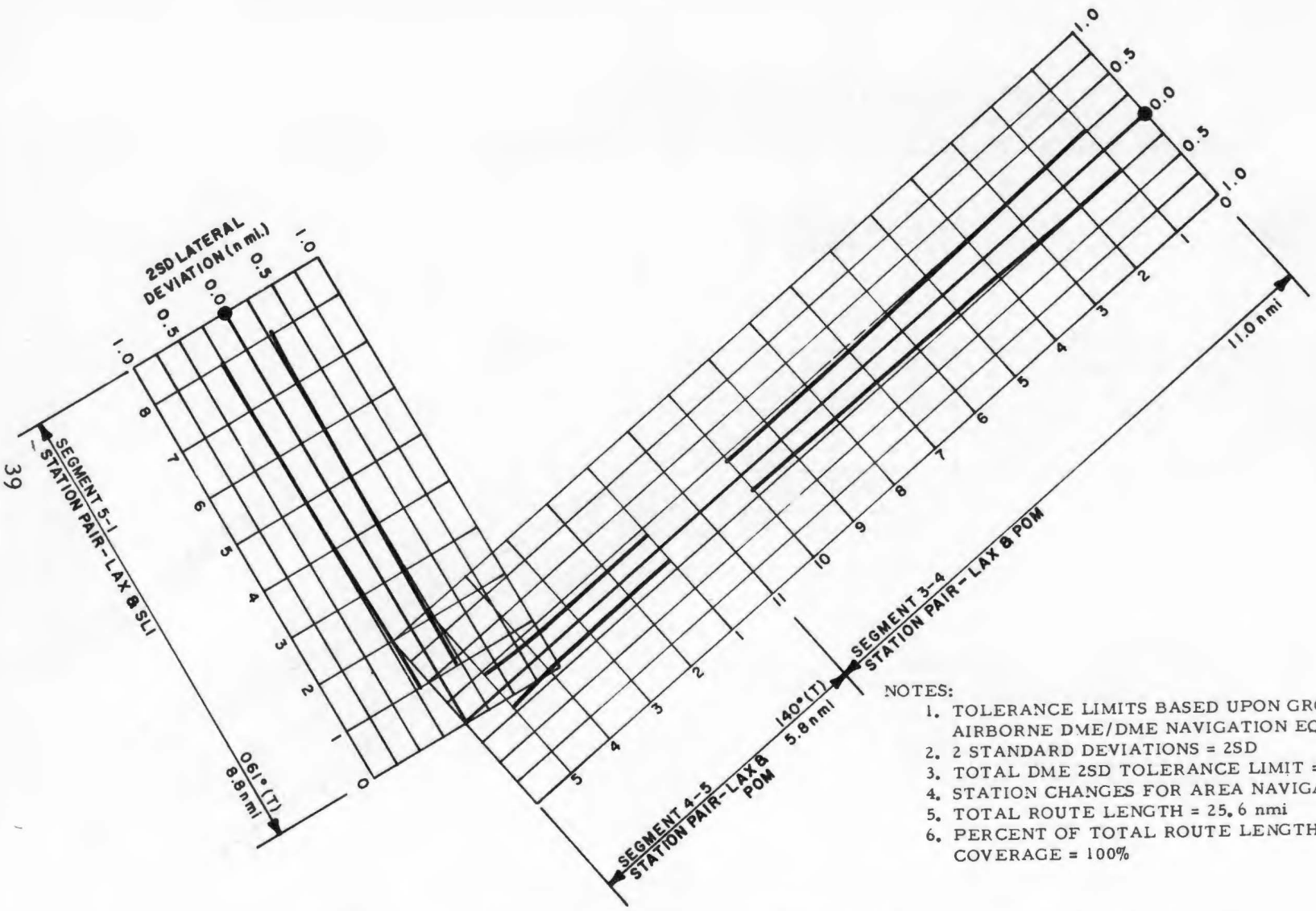
FIGURE 15 - OPTIMUM VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER LOS ANGELES TO SAN BERNARDINO DIRECT ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE DME/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
4. STATION CHANGES FOR AREA NAVIGATION = 0
5. TOTAL ROUTE LENGTH = 19.3 nmi
6. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%

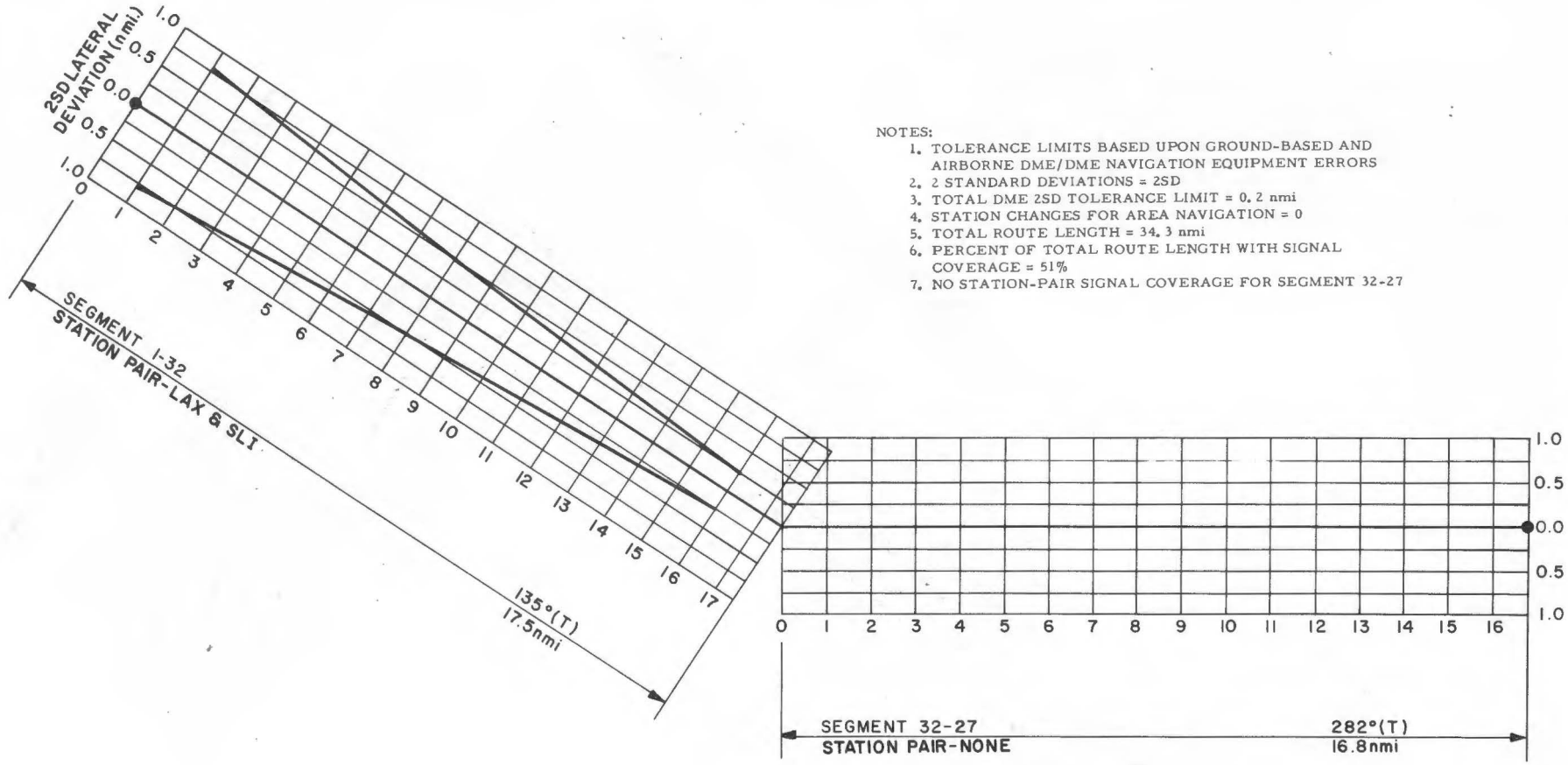
FIGURE 16 - OPTIMUM VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO VAN NUYS APPROVED ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE DME/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
4. STATION CHANGES FOR AREA NAVIGATION = 1
5. TOTAL ROUTE LENGTH = 25.6 nmi
6. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%

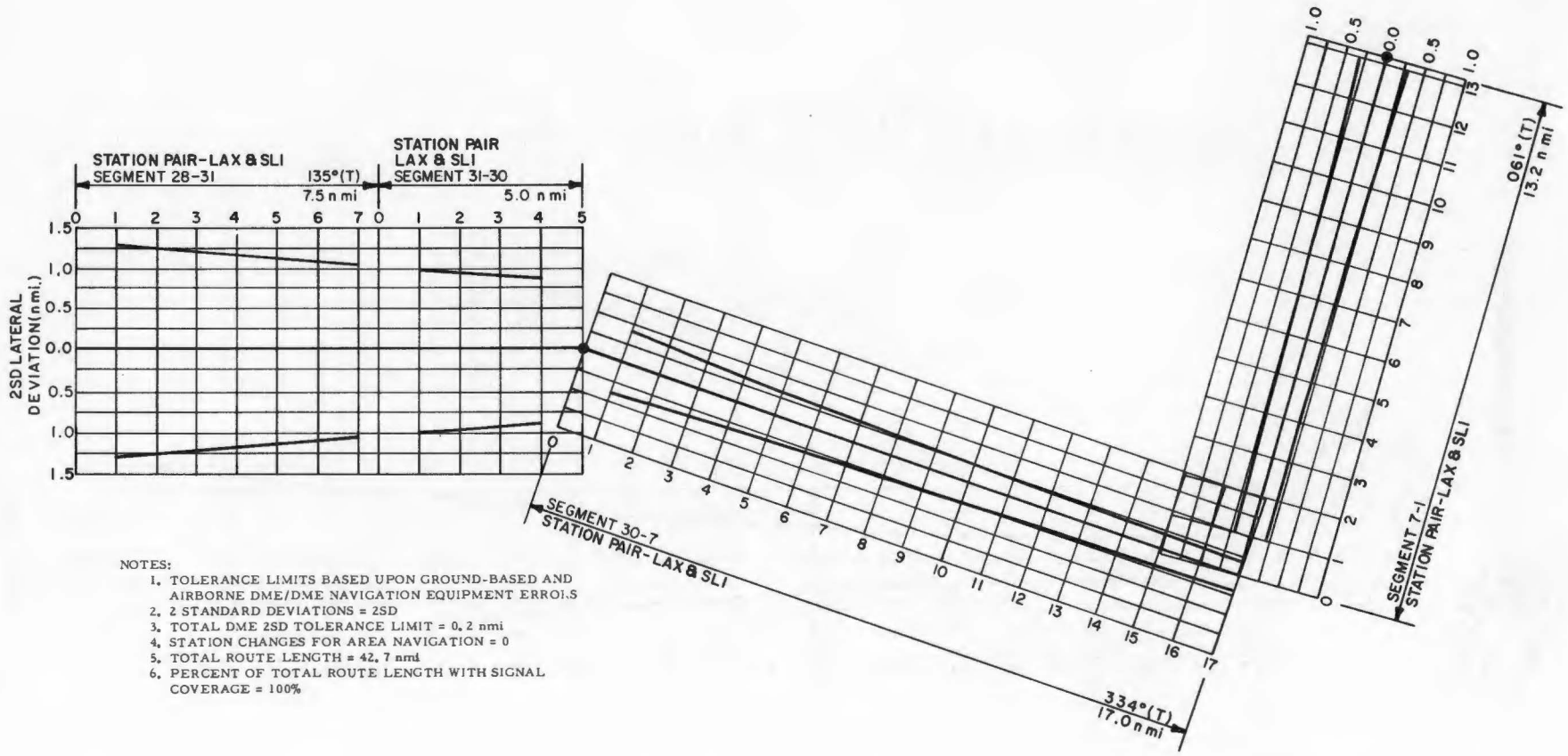
FIGURE 17 - OPTIMUM VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER VAN NUYS TO LOS ANGELES APPROVED ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE DME/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
4. STATION CHANGES FOR AREA NAVIGATION = 0
5. TOTAL ROUTE LENGTH = 34.3 nmi
6. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 51%
7. NO STATION-PAIR SIGNAL COVERAGE FOR SEGMENT 32-27

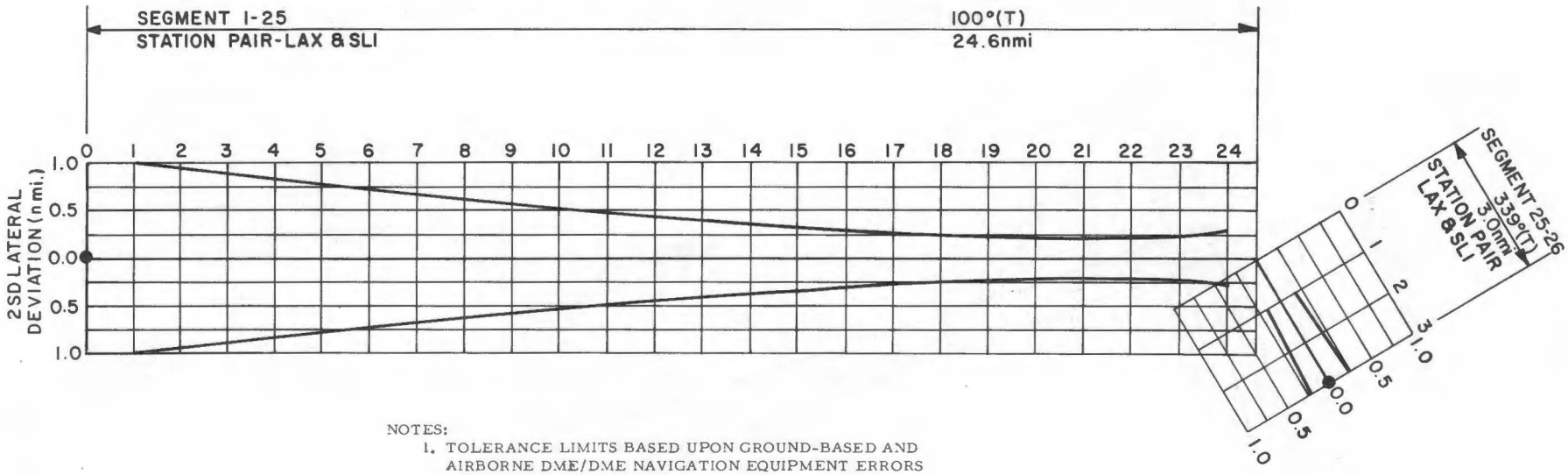
FIGURE 18 - OPTIMUM VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO ORANGE COUNTY APPROVED ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE DME/DME NAVIGATION EQUIPMENT ERROR.S
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
4. STATION CHANGES FOR AREA NAVIGATION = 0
5. TOTAL ROUTE LENGTH = 42.7 nmi
6. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%

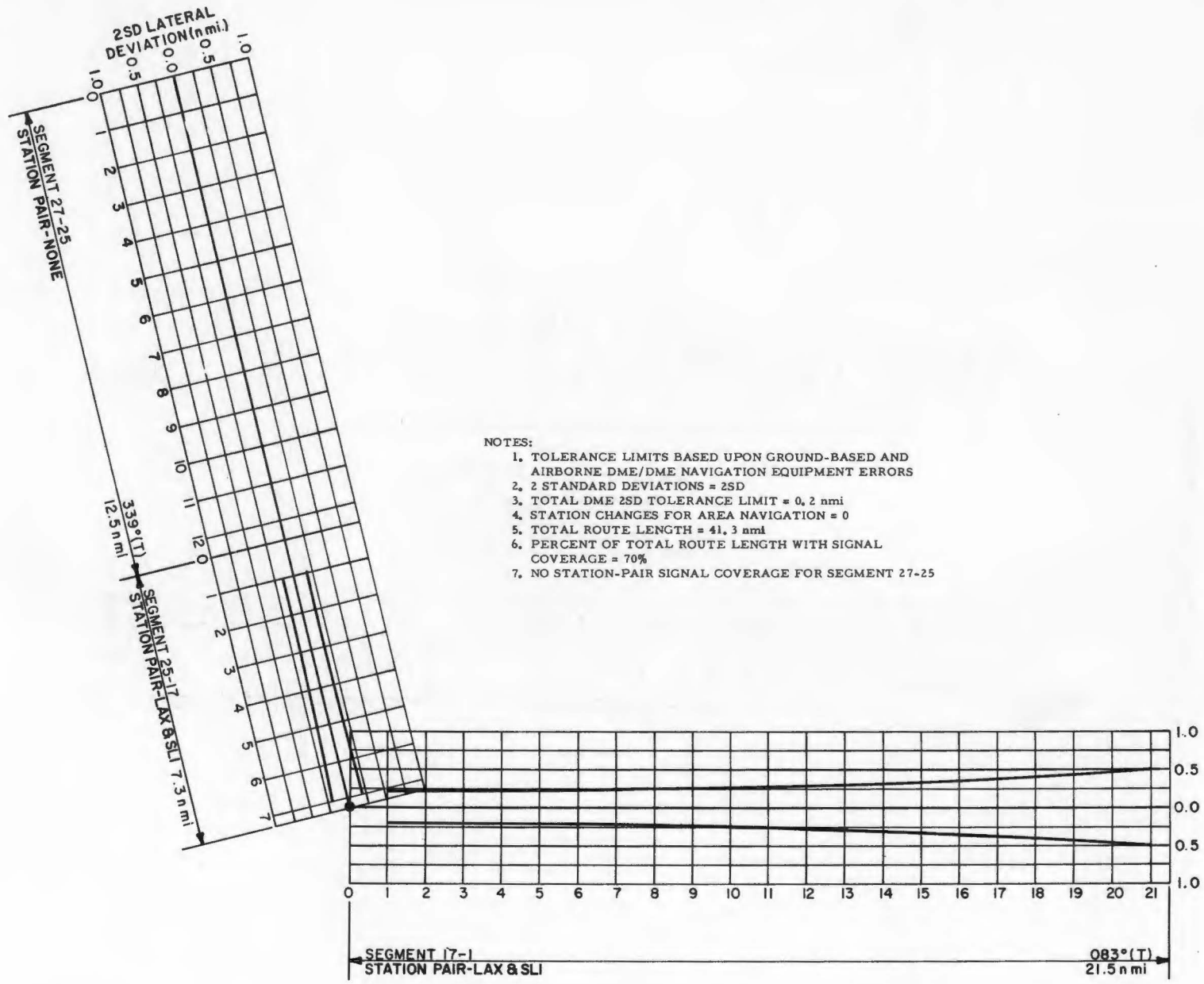
FIGURE 19 - OPTIMUM VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER ORANGE COUNTY TO LOS ANGELES APPROVED ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE DME/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
4. STATION CHANGES FOR AREA NAVIGATION = 0
5. TOTAL ROUTE LENGTH = 27.6 nmi
6. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%

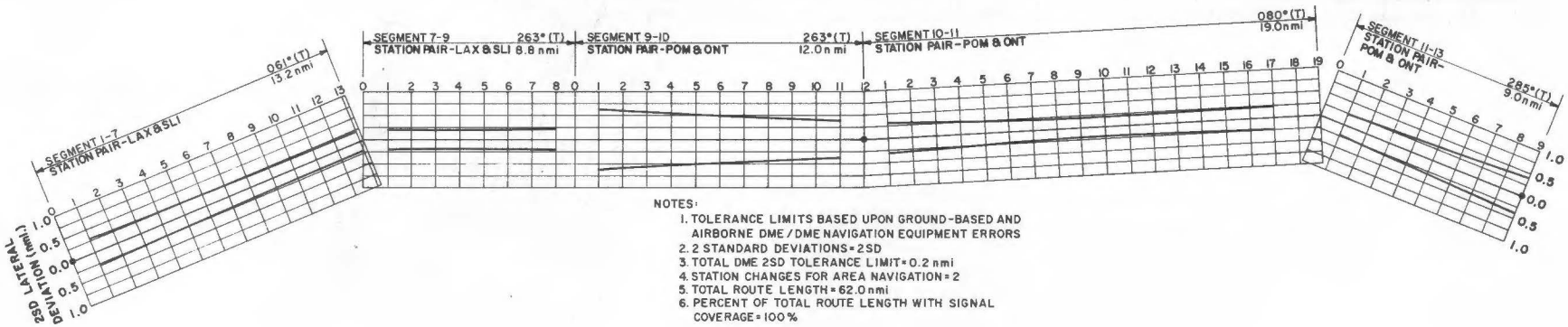
FIGURE 20.- OPTIMUM VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO ANAHEIM APPROVED ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE DME/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
4. STATION CHANGES FOR AREA NAVIGATION = 0
5. TOTAL ROUTE LENGTH = 41.3 nmi
6. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 70%
7. NO STATION-PAIR SIGNAL COVERAGE FOR SEGMENT 27-25

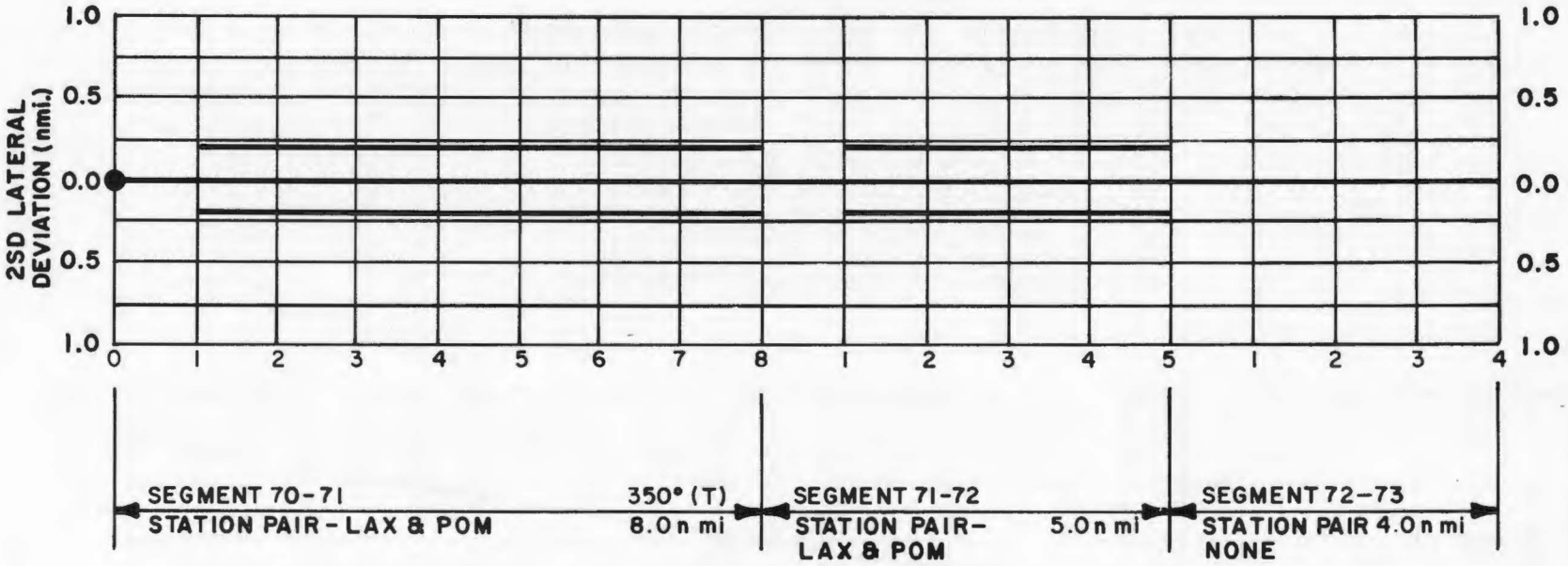
FIGURE 21 - OPTIMUM VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER ORANGE COUNTY/ANAHEIM TO LOS ANGELES APPROVED ROUTE



NOTES:
1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE DME/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
4. STATION CHANGES FOR AREA NAVIGATION = 2
5. TOTAL ROUTE LENGTH = 62.0 nmi
6. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%

(B) OPTIMUM SIGNAL COVERAGE AFTER SCREENING FOR NATURAL TERRAIN OBSTRUCTIONS

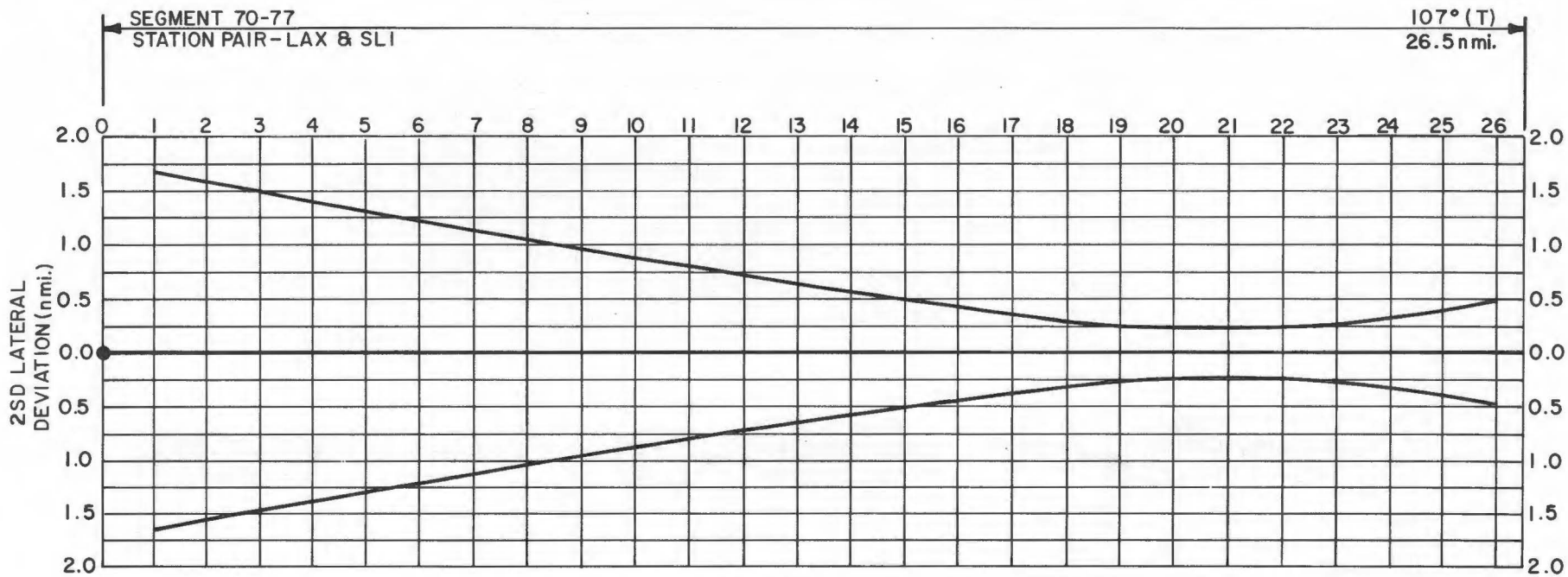
FIGURE 22 - OPTIMUM VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO SAN BERNARDINO APPROVED ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE DME/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
4. STATION CHANGES FOR AREA NAVIGATION = 0
5. TOTAL ROUTE LENGTH = 17.0 nmi
6. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 76%
7. NO STATION-PAIR SIGNAL COVERAGE FOR SEGMENT 72-73

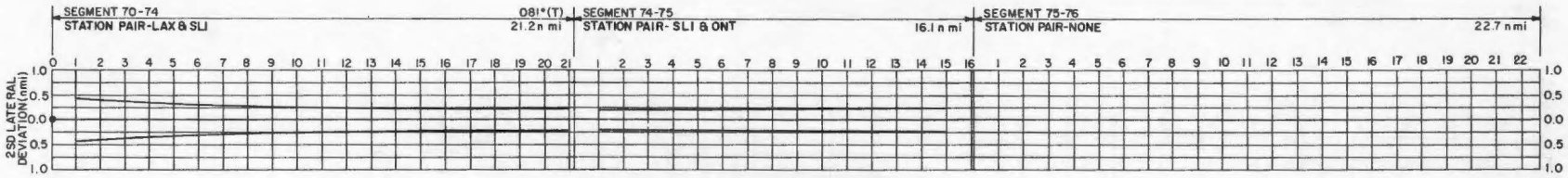
FIGURE 23 - OPTIMUM VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO VAN NUYS DIRECT ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE DME/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
4. STATION CHANGES FOR AREA NAVIGATION = 0
5. TOTAL ROUTE LENGTH = 26.5 nmi
6. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%

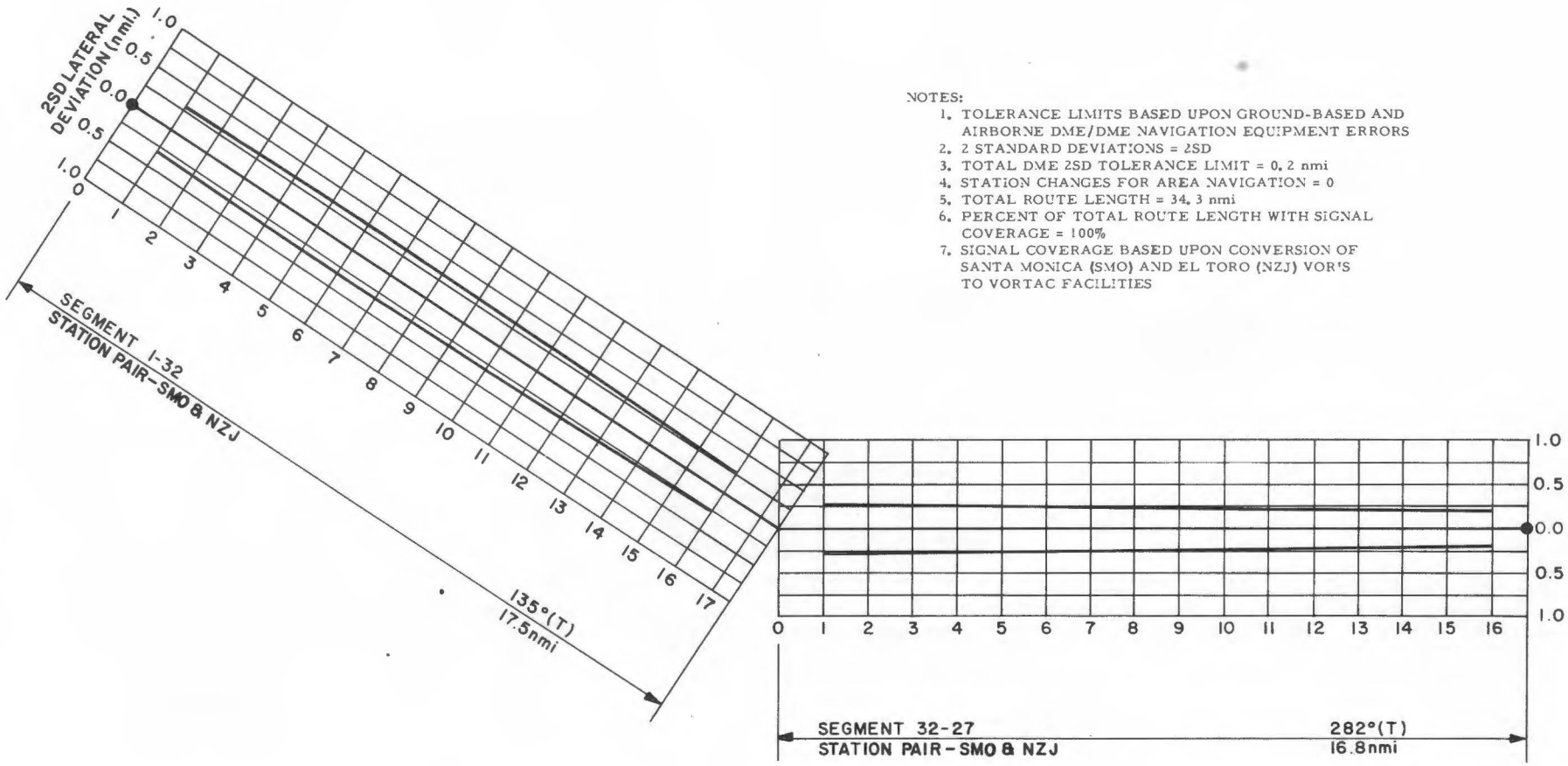
FIGURE 24 - OPTIMUM VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO ANAHEIM DIRECT ROUTE



NOTES:
1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE DME/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
4. STATION CHANGES FOR AREA NAVIGATION = 1
5. TOTAL ROUTE LENGTH = 60.0 nmi
6. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 62 %
7. NO STATION-PAIR SIGNAL COVERAGE FOR SEGMENT 75-76

(B) OPTIMUM SIGNAL COVERAGE AFTER SCREENING FOR NATURAL TERRAIN OBSTRUCTIONS

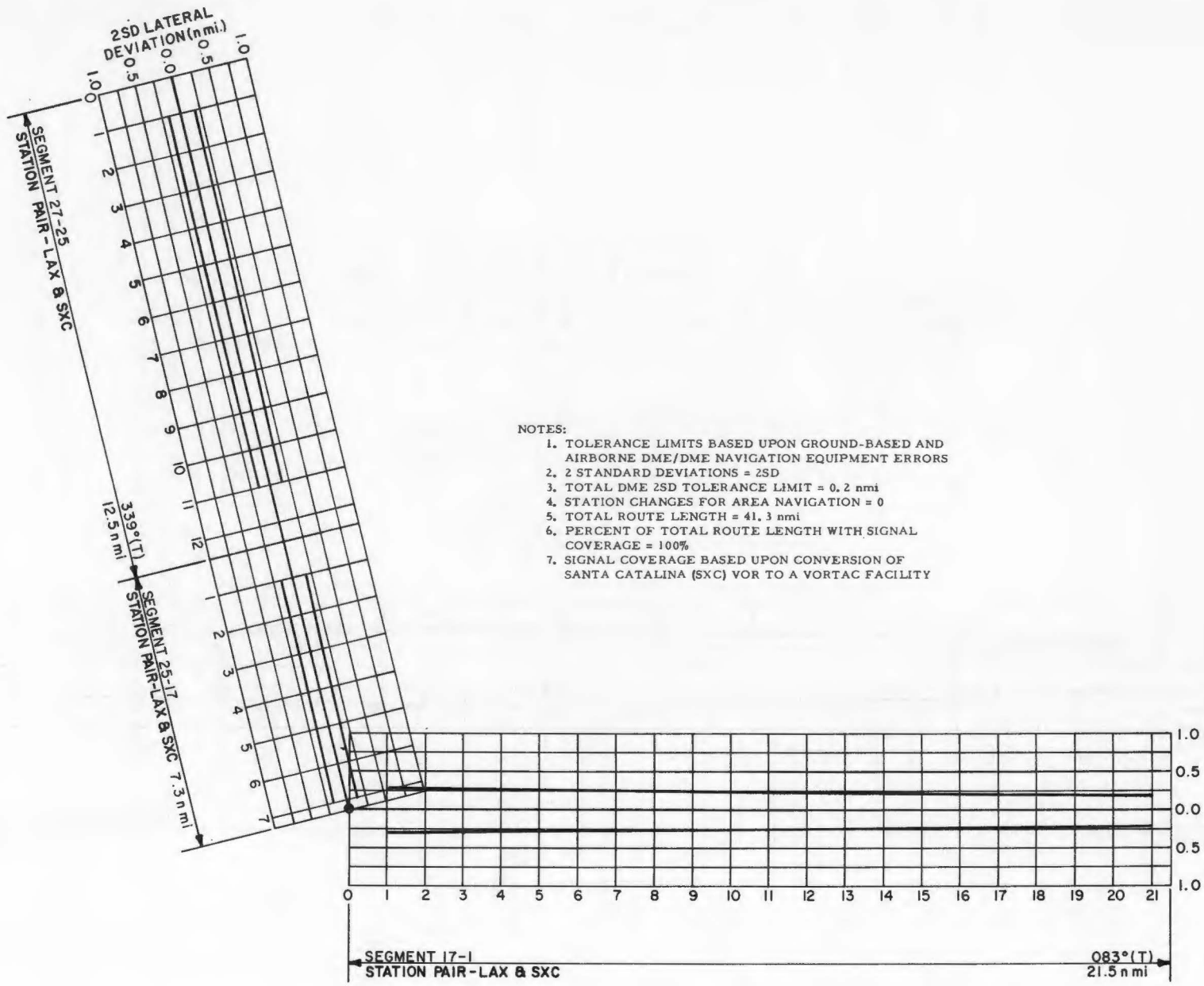
FIGURE 25 - OPTIMUM VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO SAN BERNARDINO DIRECT ROUTE



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE DME/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
4. STATION CHANGES FOR AREA NAVIGATION = 0
5. TOTAL ROUTE LENGTH = 34.3 nmi
6. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%
7. SIGNAL COVERAGE BASED UPON CONVERSION OF SANTA MONICA (SMO) AND EL TORO (NZJ) VOR'S TO VORTAC FACILITIES

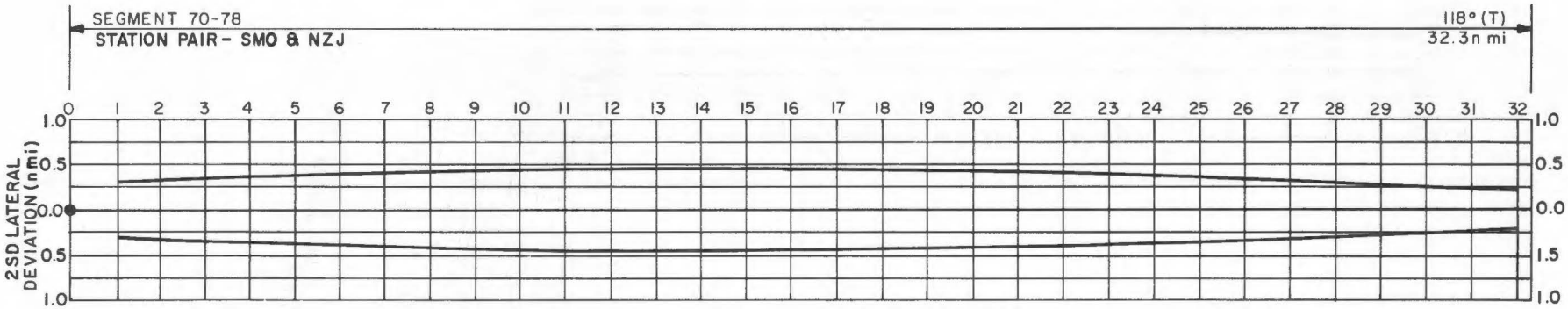
FIGURE 26 - OPTIMUM GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO ORANGE COUNTY APPROVED ROUTE CONSIDERING EXISTING AND CONVERTED FACILITIES



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE DME/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
4. STATION CHANGES FOR AREA NAVIGATION = 0
5. TOTAL ROUTE LENGTH = 41.3 nmi
6. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%
7. SIGNAL COVERAGE BASED UPON CONVERSION OF SANTA CATALINA (SXC) VOR TO A VORTAC FACILITY

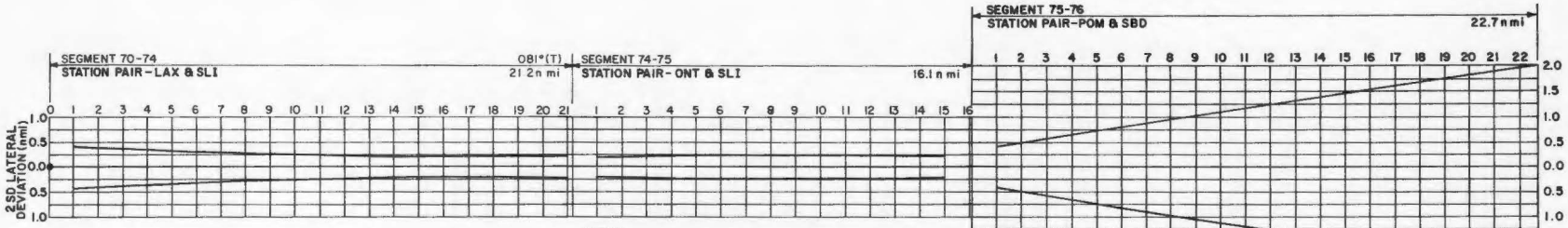
FIGURE 27 - OPTIMUM GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER ORANGE COUNTY/ANAHEIM TO LOS ANGELES APPROVED ROUTE CONSIDERING EXISTING AND CONVERTED FACILITIES



NOTES:

1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE DME/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
4. STATION CHANGES FOR AREA NAVIGATION = 0
5. TOTAL ROUTE LENGTH = 32.3 nmi
6. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%
7. SIGNAL COVERAGE BASED UPON CONVERSION OF SANTA MONICE (SMO) AND EL TORO (NZJ) VOR'S TO VORTAC FACILITIES

FIGURE 28 - OPTIMUM GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO ORANGE COUNTY DIRECT ROUTE CONSIDERING EXISTING AND AND CONVERTED FACILITIES



NOTES:
1. TOLERANCE LIMITS BASED UPON GROUND-BASED AND AIRBORNE DME/DME NAVIGATION EQUIPMENT ERRORS
2. 2 STANDARD DEVIATIONS = 2SD
3. TOTAL DME 2SD TOLERANCE LIMIT = 0.2 nmi
4. STATION CHANGES FOR AREA NAVIGATION = 3
5. TOTAL ROUTE LENGTH = 60.0 nmi
6. PERCENT OF TOTAL ROUTE LENGTH WITH SIGNAL COVERAGE = 100%
7. SIGNAL COVERAGE BASED UPON CONVERSION OF NORTON (SBD) VOR TO VORTAC FACILITY

FIGURE 29 - OPTIMUM GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO SAN BERNARDINO DIRECT ROUTE CONSIDERING EXISTING AND CONVERTED FACILITIES

APPENDIX A

DETAILED DESCRIPTION OF ANALYTICAL STUDY COMPUTER PROGRAM

General

Existing computer programs were modified and two new programs developed in support of the analytical study to determine the adequacy of VOR/DME and DME/DME guidance signals for V/STOL RNAV in the Los Angeles area. One new program simplified the input requirements by performing geometric computations to obtain input values previously measured from sectional charts. The other new program automatically analyzed the output data and provided analytical summaries suitable for the selection of theoretical optimum guidance stations. The results of the computerized analysis were responsive to theoretical line-of-sight limitations and the geometric relationships between guidance station or station pair, aircraft, and route segment. The effects of man-made and natural terrain obstructions on the computerized results were ascertained by manually reviewing AIM restrictions, sectional charts, and VORTAC horizon profile drawings. This appendix describes in detail the computer program methodology.

Cross-Course and Along-Course Error Equations

The basic equations for determining cross-course and along-course errors for area navigation over approved and hypothetical direct routes in the LAX basin are identical to those contained in FAA Final Report RD-66-46, "VORTAC Error Analysis for Helicopter Navigation," dated September 1966. In RD-66-46, the analytical model assumed a two-dimensional horizontal plane with no slant range correction. For these computations, the root-sum-square-combined DME ground station and DME airborne receiver error for a standard deviation (SD) tolerance limit was 0.1 nmi; the combined VOR guidance station and airborne receiver SD bearing error, 1.0°.

- VOR/DME SD Error Equations: The equations to determine the VOR/DME cross-course and along-course SD errors are as follows:

1. $$\sigma_{cc} = \left[\sigma^2 \sin^2\alpha + D^2\sigma_\theta^2 \cos^2\alpha\right]^{1/2}$$

2. $$\sigma_{ac} = \left[\sigma^2 \cos^2\alpha + D^2\sigma_\theta^2 \sin^2\alpha\right]^{1/2}$$

where:

σ_{cc} is cross-course SD in nmi.

σ_{ac} is along-course SD in nmi.

σ is DME distance determination SD error in nmi.

σ_{θ} is VOR bearing SD error in radians.

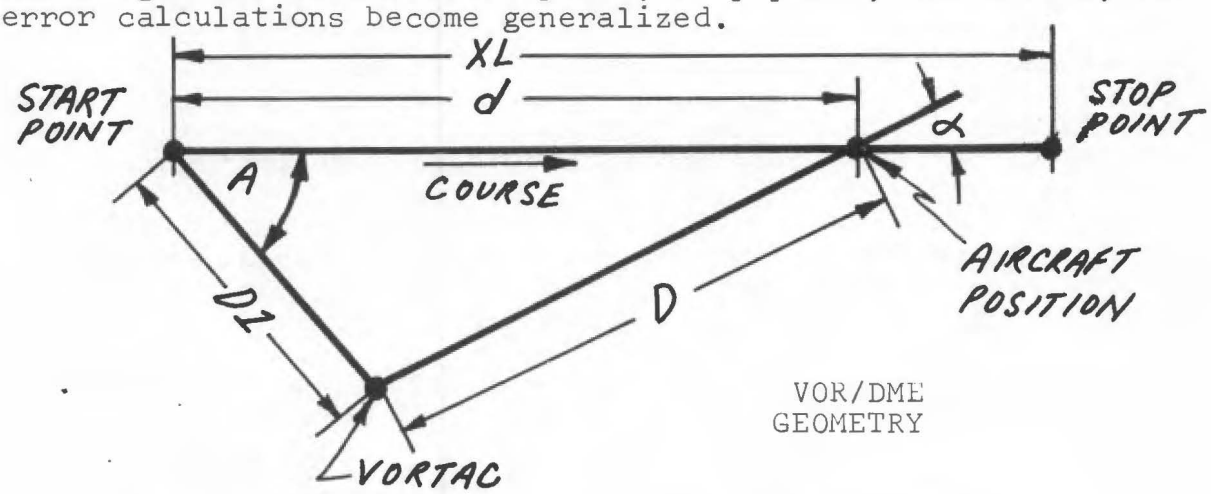
D is the distance from station to aircraft in nmi.

α is the angle formed by the intersection of the course and a line drawn from the VORTAC to the aircraft.

In order to determine the cross-course and along-course SD values for a route segment, it is necessary to compute the following geometric constants:

1. D1 - the distance in nmi from start point to VORTAC station.
2. A - the angle in degrees formed by the intersection of the course and a radial from the station to the start point.
3. XL - the route segment length in nmi.

Once these values are determined from the known latitudes and longitudes of the start point, stop point, and VORTAC, the error calculations become generalized.



VOR/DME GEOMETRY

DME/DME SD Error Equations: The equations to determine the DME/DME cross-course and along-course SD errors are as follows:

$$1.\ \sigma_{cc} = \frac{\sigma\left[\cos^2\alpha_1 + \cos^2\alpha_2\right]^{1/2}}{\sin\theta}$$

$$2.\ \sigma_{ac} = \frac{\sigma\left[\sin^2\alpha_1 + \sin^2\alpha_2\right]^{1/2}}{\sin\theta}$$

where:

σ_{cc} is the cross-course SD in nmi.

σ_{ac} is the along-course SD in nmi.

σ is the DME distance determination SD error in nmi.

α_1 is the angle in degrees formed by the intersection of the course and a radial drawn from Station 1 to the aircraft position.

α_2 is the angle in degrees formed by the intersection of the course and a radial drawn from Station 2 to the aircraft position.

θ is the included angle in degrees formed by the intersection of a line drawn from Station 1 to the aircraft position and a line drawn from Station 2 to the aircraft position (theta value).

R1 is the distance in nmi from Station 1 to aircraft position.

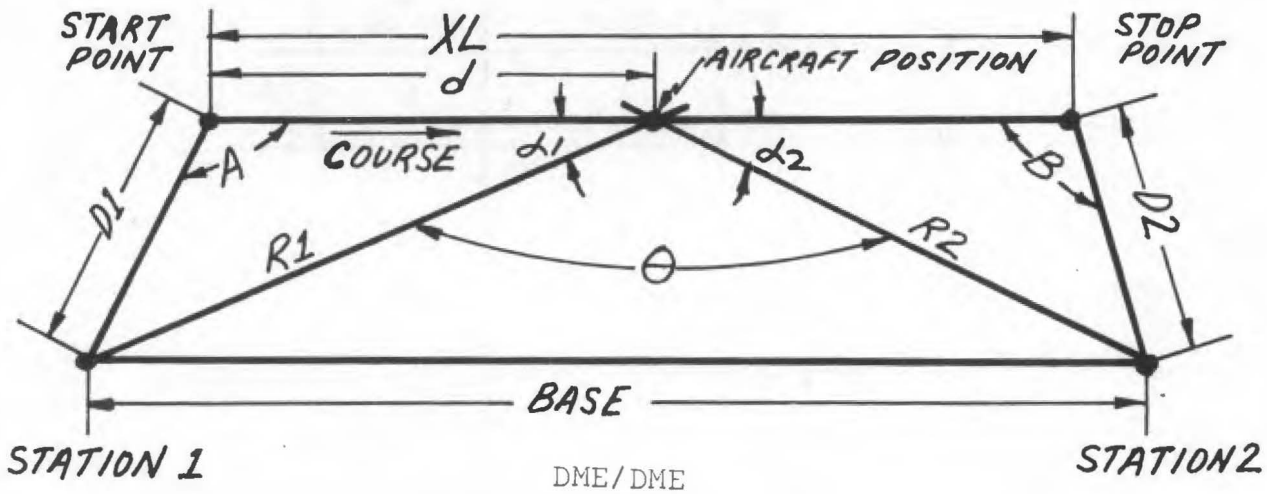
R2 is the distance in nmi from Station 2 to aircraft position.

and: $\sin\alpha_1 = \dfrac{D1 \sin A}{R1}$

$\sin\alpha_2 = \dfrac{D2 \sin B}{R2}$

In order to determine the cross-course and along-course SD values for a route segment, it is necessary to compute the following geometric constants:

1. D1-the distance in nmi from the start point to Station 1.
2. D2-the distance in nmi from the stop point to Station 2.
3. A-the angle in degrees formed by the intersection of the course and a radial drawn from Station 1 to the start point.
4. B-the angle in degrees formed by the intersection of the course and a radial drawn from Station 2 to the stop point.
5. XL-the route segment length in nmi.
6. BASE-the distance in nmi between the stations



DME/DME
GEOMETRY

Internal Program Computations

Input data for the computer program include the aircraft altitude (MSL) per route segment, the assumed VOR and/or DME SD tolerance limits for the computation of the cross-course and along-course errors, a cross-course SD error constant of 0.333 nmi (6SD=1.000 nmi) and an along-course SD error constant of 0.666 nmi (6SD=2.000 nmi) for comparison with computed cross-course and along-course SD values, the computation interval by which the aircraft distance in nmi from start point (d) is varying, and for the VOR/DME case, the class accuracy of the VOR receiver. The latitude, longitude, elevation, and magnetic declination of each VORTAC considered in the analysis are also provided as inputs. The program can accept 36 VORTAC stations for VOR/DME computations, and 10 VORTAC stations (45 station-pairs combinations) for the DME/DME analysis.

Each start and stop point per route segment is identified by a waypoint. The waypoint location is computed by reference to a VORTAC or a point previously defined in latitude, longitude, and elevation. A waypoint position is determined by one of three methods, depending upon the input information available. These methods are (1) magnetic bearing and distance from a known VORTAC, (2) intersection of two radials from two known VORTACs, and (3) the true bearing and distance from a previously defined point. The latitude and longitude of each located waypoint is computed and stored for later use in defining the route. Each route over which error calculations are to be made is defined by a series of segments to a limit of 18 segments. Each segment has an altitude (MSL) associated with it for determining line-of-sight limitations.

Computations are made at 0.2 nmi intervals as the aircraft progresses along the particular route segment under consideration. In addition to the previous calculations, the following computations are made at each interval for both the VOR/DME and DME/DME cases:

1. Cross-course SD, 2SD, and 3SD errors.
2. Along-course SD, 2SD, and 3SD errors.
3. Guidance station-to-aircraft line-of-sight distance.
4. Comparisons of computed cross-course and along-course SD errors with inputted cross-course and along-course SD error constants, guidance station-to aircraft distance with theoretical line-of-sight distance, and guidance station-to-aircraft distance with 40 nmi maximum limit. These comparisons are stored for later flag presentations in the output data sheets and output summaries.

After calculations are completed per guidance station or guidance station pair, average 2SD and $2(SD)^2$ cross-course and along course values are calculated. These values are stored for later use in preparing the summary data. The ranking of the guidance stations or guidance station pairs per route segment in the data summaries is based upon the average cross-course $2(SD)^2$ value, with the smallest average $2(SD)^2$ value denoting the theoretically optimum station or station pair.

For the VOR/DME case, additional computations are made of the following:

1. SD and 2SD cross-course error values for the DME component of the total cross-course error.
2. SD and 2SD cross-course error values for the VOR component of the total cross-course error.
3. SD and 2SD along-course error values for the DME component of the total along-course error.
4. SD and 2SD along-course error values for the VOR component of the total along-course error.

For the DME/DME case, an additional computation is made to indicate the geometry segment of the theta value. The theta values are arbitrarily divided into five geometric segments to denote the theoretical accuracy of guidance signals for RNAV, i.e.; excellent, good, fair, poor, and unusable. Theta values near 90° represent an excellent geometry situation, values near 0° and 180°, an unusable geometry condition.

Output Data Format

Typical examples of the output data are presented in Figures 1-1 to 1-14, inclusively. The notes associated with each figure are self-explanatory and will not be repeated in this narrative. Only "lead-in" information will be presented to provide continuity through the output printouts. The presented figures, although specifically identified as the DME/DME case for the LAX to SBD approved IFR VTOL route, are applicable to VOR/DME RNAV over the approved routes, and VOR/DME and DME/DME RNAV over the direct routes.

Figure 1-1 is a printout of the VORTAC guidance stations and other input data relative to these stations. The output is provided to verify the input data. For the DME/DME analysis pairing of the guidance stations is automatically performed in the program. Figure 1-2 indicates the computed latitudes and longitudes of the waypoints that identify the start and stop points of each route segment in the approved and direct route structures. A typical DME/DME data sheet denoting the computed input variables and constants, theoretical cross-course and along-course errors, flag criteria, geometry segment, guidance station-to-aircraft distance, and theta value at each 1 nmi increment along the route segment is shown in Figure 1-3. For comparison purposes, the output data sheet for the VOR/DME computations is presented in Figure 1-4.

Figure 1-5 is the first summary sheet. In Figure 1-5 are shown the guidance station pairs in ranking order, per route, the maximum guidance station-to-aircraft distance per route segment, the average $2(SD)^2$ cross-course value per route segment per station pair, the ranking of the station pair per route segment, and the flag indications when computed flag criteria exceed selected input limits. The average 2SD cross-course vale per route segment per station pair is shown in Figure 1-6. Figures 1-7 and 1-8 indicate the average $2(SD)^2$ and 2SD along-course values, respectively, per route segment per station pair.

Following the theoretical $2(SD)^2$ and 2SD cross-course and along-course values of Figures 1-5 to 1-8 inclusively, the output program provides summary printouts of the guidance station pairs that meet certain flag criteria. In presented order, the flag conditions tested are station pairs with no flags; station pairs with no cross-course, along-course or line-of-sight flags; and station pairs with no station-to-aircraft distances greater than 40 nmi.

After each tested flag condition, calculations are made and outputs provided that indicate the magnetic bearing sector and distances of each guidance station to the start and stop points of each route segment, the aircraft altitude per route segment, the height of any natural terrain obstruction in the bearing sector of interest, and the distance of the obstruction from the particular guidance station. The magnetic bearing and distance information facilitates manual screening of the theoretical output data for unusable signal coverage sectors published in the AIM restrictions. The aircraft altitude, obstruction height, and obstruction distance information facilitates manually calculating the critical height for guidance signal reception. An aircraft traversing a route segment influenced by an obstruction must be at a higher altitude than the critical height. As a result of these screenings, certain guidance stations initially listed in the various flag condition printouts as servicing a particular route segment were eliminated from final consideration. Figure 1-9 indicates the guidance station pairs and stations per route segment with no flags. Figure 1-10 is typical of the information provided to facilitate the manual restriction and obstruction screening of the guidance stations comprising the no-flag station pairs. Similarly, Figure 1-11 shows the guidance station pairs and stations per route segment with no cross-course, along-course, or line-of-sight flags. Figure 1-12, in part, is typical of the information furnished to manually screen the stations meeting the same flag criteria. The guidance station pairs and stations per route segment with no station-to-aircraft distance greater than 40 nmi are presented in Figure 1-13. Figure 1-14 shows, in part, the associated manual screening printout.

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V/STOL AREA NAVIGATION-DME/DME COVERAGE
****

STATION	LATITUDE	LONGITUDE	MAGNETIC DECLINATION	ELEVATION
LAX	33 56 0.5	118 25 53.4	15.00	180.0
SNA	33 40 43.2	117 51 45.0	15.00	40.0
ONT	33 55 6.0	117 31 44.0	15.00	1430.0
VNY	34 13 24.4	118 29 26.7	15.00	810.0
POM	34 4 42.1	117 47 10.2	15.00	1270.0
SBD	34 5 22.0	117 14 53.7	15.00	1080.0
SLI	33 46 59.8	118 3 13.8	15.00	20.0
VTU	34 6 54.2	119 2 54.8	15.00	1560.0
OCN	33 14 26.2	117 25 0.7	15.00	90.0
FIM	34 21 24.1	118 52 49.3	15.00	2200.0
(1)	(2)		(3)	(4)

NOTES:
1. COMPUTER PROGRAM INPUTS OF VORTAC GUIDANCE STATIONS SERVICING LAX BASIN
2. COMPUTER PROGRAM INPUTS OF VORTAC GUIDANCE STATION POSITIONS IN LATITUDE AND LONGITUDE
3. COMPUTER PROGRAM INPUTS OF VORTAC GUIDANCE STATION MAGNETIC DECLINATIONS
4. COMPUTER PROGRAM INPUTS OF VORTAC GUIDANCE STATION ELEVATIONS ABOVE MSL

FIGURE 1-1 - TYPICAL COMPUTER PRINTOUT OF VORTAC INPUT LISTINGS

PRCJECT 330-014-04X
V/STCL AREA NAVIGATION-DME/DME COVERAGE
****

PCINT	LATITUDE	LCNGITUDE
1	33 56 0.5	118 25 53.4
2	34 9 43.0	118 32 33.2
3	34 13 24.4	118 29 26.7
4	34 5 4.1	118 21 2.5
5	34 -0 16.8	118 16 37.5
7	34 2 18.7	118 12 12.3
9	34 3 13.4	118 1 30.3
10	34 4 42.1	117 47 10.2
11	34 7 47.9	117 25 50.6
13	34 5 22.0	117 14 53.7
17	33 58 36.7	117 59 59.7
25	33 51 40.2	117 56 47.3
26	33 48 37.5	117 55 23.1
27	33 40 43.2	117 51 45.0
28	33 38 16.6	117 52 48.8
30	33 46 59.8	118 3 13.8
31	33 43 27.2	117 58 59.5
32	33 44 15.7	118 11 50.8
70	33 56 0.5	118 25 53.4
71	34 4 0.3	118 27 31.8
72	34 9 19.1	118 28 37.4
73	34 13 24.4	118 29 26.7
74	33 59 27.7	118 -0 23.3
75	34 1 48.6	117 42 26.4
76	34 5 22.0	117 14 53.7
77	33 48 37.5	117 55 23.1
78	33 40 43.2	117 51 45.0
(1)	(2)	

NOTES: 1. COMPUTER PROGRAM INPUTS OF POINTS DEFINING ROUTE SEGMENTS OF APPROVED IFR AND DIRECT VTOL ROUTES IN THE LAX BASIN
2. COMPUTED POSITIONS IN LATITUDE AND LONGITUDE OF ROUTE-SEGMENT POINTS

FIGURE 1-2 - TYPICAL PRINTOUT OF COMPUTER-DERIVED WAYPOINT IDENTIFICATION LOCATION

PROJECT 330-014-04X

V/STOL AREA NAVIGATION-DME/DME COVERAGE

****

APPROVED IFR VTOL ROUTE LAX-SBD ROUTE SEG. 10- 11 VORTACS POM-ONT (1) (2)

H1=1270.FT,H2=1430.FT,H3=3500.FT,A= -0. DEG,B= 59.C5DEG,D1= 0. NM,D2= 13.59NM,BASE= 16.02NM,XL= 17.98NM,SIG=.10NM,D= 0.20NM (3)

D	SIGCC	SIG*2	SIG*3	SIGAC	SIG*2	SIG*3	FLCC	FLAC	THEX	THGD	THFR	THPR	FLV1	FLD1	FLV2	FLD2	R1	R2	THETA
	(4)			(5)			(7)	(8)		(10)			(12)		(14)		(11)	(13)	(9)
1.0	0.157	0.314	0.471	0.100	0.200	0.300					5555						1.00	15.35	130.600
2.0	0.148	0.296	0.444	0.100	0.200	0.300					5555						2.00	14.72	127.645
3.0	0.139	0.279	0.418	0.100	0.200	0.300					5555						3.00	14.13	124.434
4.0	0.131	0.262	0.393	0.100	0.200	0.300					5555						4.00	13.59	120.954
5.0	0.124	0.247	0.371	0.100	0.200	0.300				6666							5.00	13.10	117.202
6.0	0.117	0.234	0.351	0.100	0.200	0.300				6666							6.00	12.68	113.179
7.0	0.111	0.222	0.333	0.100	0.200	0.300				6666							7.00	12.32	108.899
8.0	0.106	0.213	0.319	0.100	0.200	0.300			7777								8.00	12.03	104.389
9.0	0.103	0.206	0.309	0.100	0.200	0.300			7777								9.00	11.82	99.690
10.0	0.101	0.201	0.302	0.100	0.200	0.300			7777								10.00	11.70	94.855
11.0	0.100	0.200	0.300	0.100	0.200	0.300			7777								11.00	11.65	89.950
12.0	0.101	0.201	0.302	0.100	0.200	0.300			7777								12.00	11.70	85.046
13.0	0.103	0.206	0.309	0.100	0.200	0.300			7777								13.00	11.83	80.213
14.0	0.106	0.213	0.319	0.100	0.200	0.300			7777								14.00	12.04	75.517
15.0	0.111	0.222	0.334	0.100	0.200	0.300				6666							15.00	12.32	71.011
16.0	0.117	0.234	0.351	0.100	0.200	0.300				6666							16.00	12.68	66.736
17.0	0.124	0.248	0.371	0.100	0.200	0.300				6666							17.00	13.11	62.718

SIGMA SUMS	CC=	10.25791	2*CC=	20.51582	AC=	8.69993	2*AC=	17.39985	
SIGMA SQUARES	CC=	1.23423	2*CC=	4.93690	AC=	0.86999	2*AC=	3.47994	(6)
AVERAGE SUMS	2*CC=	0.23581	2*AC=	0.20000	*****AVERAGE SQUARES		2*CC=	0.05675	2*AC= 0.04000

NOTES:

1. GUIDANCE STATION NO. 1 COMPRISING GUIDANCE STATION PAIR
2. GUIDANCE STATION NO. 2 COMPRISING GUIDANCE STATION PAIR
3. INPUT PARAMETERS FOR DME/DME GEOMETRIC COMPUTATIONS-
   - H1 = GUIDANCE STATION NO. 1 ELEVATION
   - H2 = GUIDANCE STATION NO. 2 ELEVATION
   - H3 = AIRCRAFT ALTITUDE FOR ROUTE SEGMENT
   - A = INCLUDED ANGLE FORMED BY GUIDANCE STATION NO. 1-TO-ROUTE SEGMENT START POINT PROJECTION AND ROUTE SEGMENT
   - B = INCLUDED ANGLE FORMED BY GUIDANCE STATION NO. 2-TO-ROUTE SEGMENT STOP POINT PROJECTION AND ROUTE SEGMENT
   - D1 = DISTANCE BETWEEN GUIDANCE STATION NO. 1 AND ROUTE SEGMENT START POINT
   - D2 = DISTANCE BETWEEN GUIDANCE STATION NO. 2 AND ROUTE SEGMENT STOP POINT
   - BASE = DISTANCE BETWEEN GUIDANCE STATIONS
   - XL = ROUTE SEGMENT DISTANCE
   - SIG = DME SD TOLERANCE LIMIT
   - D = DISTANCE INTERVAL ALONG ROUTE SEGMENT FOR GEOMETRIC COMPUTATIONS
4. SD, 2SD, AND 3SD CROSS-COURSE ERROR TOLERANCES
5. SD, 2SD, AND 3SD ALONG-COURSE ERROR TOLERANCES
6. ROUTE SEGMENT PER GUIDANCE STATION PAIR STATISTICAL SUMMARY
7. FLAG WHEN 2SD CROSS-COURSE ERROR TOLERANCE EXCEEDS 0.333 NMI
8. FLAG WHEN 2SD ALONG-COURSE ERROR TOLERANCE EXCEEDS 0.666 NMI
9. INCLUDED ANGLE FORMED BY GUIDANCE STATION NO. 1-TO-AIRCRAFT PROJECTION AND GUIDANCE STATION NO. 2-TO-AIRCRAFT PROJECTION
10. THEORETICAL NAVIGATION QUALITY INDICATORS BASED UPON DME/DME GEOMETRY AND RESULTANT THETA VALUE:
    - EXCELLENT (THEX)-THETA BETWEEN 75° AND 105°
    - GOOD (THGD)-THETA BETWEEN 60° AND 75°; 105° AND 120°
    - FAIR (THFR)-THETA BETWEEN 45° AND 60°; 120° AND 135°
    - POOR (THPR)-THETA BETWEEN 30° AND 45°; 135° AND 150°
    - UNUSEABLE (NO INDICATOR) - THETA BETWEEN 0° AND 30°; 150° AND 180°
11. DISTANCE BETWEEN GUIDANCE STATION NO. 1 AND AIRCRAFT (R1)
12. FLAG WHEN R1 EXCEEDS LINE-OF-SIGHT DISTANCE BETWEEN GUIDANCE STATION NO. 1 VOR (V1) OR DME (D1) ANTENNA AND AIRCRAFT
13. DISTANCE BETWEEN GUIDANCE STATION NO. 2 AND AIRCRAFT (R2)
14. FLAG WHEN R2 EXCEEDS LINE-OF-SIGHT DISTANCE BETWEEN GUIDANCE STATION NO. 2 VOR (V2) OR DME (D2) ANTENNA AND AIRCRAFT

FIGURE 1-3 - TYPICAL COMPUTER PRINTOUT OF DME/DME DATA SHEET

PROJECT 330-014-04X

V/STOL AREA NAVIGATION-VOR/DME COVERAGE

****

APPROVED IFR VTOL ROUTE LAX-SBD ROUTE SEG. 10- 11 VORTAC SLI

H1= 20.FT,H2= 3500.FT,A=137.2DEG,D= 22.2NM,XL= 18.0NM,SIGD=0.1NM,SIGV=1.0DEG,DELD=0.2NM,CLASS EQUIP.=3 (1)

D	SIGCC	SIG*2	SIG*3	SIGAC	SIG*2	SIG*3	FCC	FAC	SGDCC	SIG*2	SGVCC	SIG*2	SGDAC	SIG*2	SGVAC	SIG*2	FLV FLD	ALPHA	R
	(2)			(6)			(3)	(7)	(5)		(4)		(9)		(8)		(13)	(11)	(12)
1.0	0.308	0.616	0.924	0.273	0.547	0.820	999		0.066	0.132	0.301	0.602	0.075	C.151	0.263	0.526		41.13	22.90
2.0	0.325	0.650	0.974	0.274	0.548	0.822	999		0.064	0.127	0.319	0.637	0.077	C.154	0.263	0.526		39.54	23.66
3.0	0.342	0.683	1.025	0.274	0.549	0.823	999		0.062	0.123	0.336	0.672	0.079	C.158	0.263	0.526		38.04	24.44
4.0	0.358	0.717	1.075	0.275	0.550	0.825	999		0.060	0.119	0.353	0.707	0.080	C.160	0.263	0.526		36.64	25.24
5.0	0.375	0.751	1.126	0.275	0.551	0.826	999		0.058	0.116	0.371	0.742	0.082	C.163	0.263	0.526		35.33	26.05
6.0	0.392	0.785	1.177	0.276	0.551	0.827	999		0.056	0.112	0.388	0.777	0.083	C.166	0.263	0.526		34.10	26.87
7.0	0.409	0.819	1.228	0.276	0.552	0.828	999		0.054	0.109	0.406	0.812	0.084	C.168	0.263	0.526		32.94	27.70
8.0	0.426	0.853	1.279	0.276	0.553	0.829	999		0.053	0.106	0.423	0.846	0.085	C.170	0.263	0.526		31.85	28.55
9.0	0.444	0.887	1.331	0.277	0.553	0.830	999		0.051	0.102	0.441	0.881	0.086	C.172	0.263	0.526		30.82	29.40
10.0	0.461	0.922	1.382	0.277	0.554	0.830	999		0.050	0.100	0.458	0.916	0.087	C.173	0.263	0.526		29.85	30.26
11.0	0.478	0.956	1.434	0.277	0.554	0.831	999		0.048	0.097	0.476	0.951	0.088	C.175	0.263	0.526		28.93	31.13
12.0	0.495	0.991	1.486	0.277	0.555	0.832	999		0.047	0.094	0.493	0.986	0.088	C.176	0.263	0.526		28.07	32.01
13.0	0.513	1.025	1.538	0.278	0.555	0.833	999		0.046	0.092	0.510	1.021	0.089	C.178	0.263	0.526		27.25	32.90
14.0	0.530	1.060	1.589	0.278	0.555	0.833	999		0.045	0.089	0.528	1.056	0.090	C.179	0.263	0.526		26.47	33.79
15.0	0.547	1.094	1.641	0.278	0.556	0.834	999		0.043	0.087	0.545	1.091	0.090	C.180	0.263	0.526		25.73	34.69
16.0	0.564	1.129	1.693	0.278	0.556	0.834	999		0.042	0.085	0.563	1.126	0.091	C.181	0.263	0.526		25.04	35.59
17.0	0.582	1.164	1.745	0.278	0.556	0.835	999		0.041	0.083	0.580	1.161	0.091	C.182	0.263	0.526		24.37	36.50

SIGMA SUMS	CC=	39.53106	2*CC=	79.06213	AC=	24.58788	2*AC=	49.17576
SIGMA SQUARES	CC=	18.24698	2*CC=	72.98792	AC=	6.79306	2*AC=	27.17224
AVERAGE SUMS	2*CC=	0.88834	2*AC=	0.55254	***** AVERAGE SQUARES	2*CC=	0.82009	2*AC= 0.30531

(10)

NOTES: 1. INPUT PARAMETERS FOR VOR/DME GEOMETRIC COMPUTATIONS-

H1 = GUIDANCE STATION ELEVATION
H2 = AIRCRAFT ALTITUDE FOR ROUTE SEGMENT
A = INCLUDED ANGLE FORMED BY GUIDANCE STATION-TO-ROUTE SEGMENT START POINT PROJECTION AND ROUTE SEGMENT
D = DISTANCE BETWEEN GUIDANCE STATION AND ROUTE SEGMENT START POINT
XL = ROUTE SEGMENT DISTANCE
SIGD = DME SD TOLERANCE LIMIT
SIGV = VOR SD TOLERANCE LIMIT
DELDD = DISTANCE INTERVAL ALONG ROUTE SEGMENT FOR GEOMETRIC COMPUTATIONS
CLASS EQUIP = AIRBORNE VOR EQUIPMENT ERROR CLASS COMBINED RSS WITH GROUND VOR ERROR FOR SIGV SD TOLERANCE LIMIT. CLASS 1=1.1°; CLASS 2=1.0°; CLASS 3=0.25°

2. SD, 2SD, AND 3SD CROSS-COURSE ERROR TOLERANCES
3. FLAG WHEN 2SD CROSS-COURSE ERROR TOLERANCE EXCEEDS 0.333 NMI
4. VOR COMPONENT OF SD AND 2SD CROSS-COURSE ERROR TOLERANCES
5. DME COMPONENT OF SD AND 2SD CROSS-COURSE ERROR TOLERANCES
6. SD, 2SD, AND 3SD ALONG-COURSE ERROR TOLERANCES
7. FLAG WHEN 2SD ALONG-COURSE ERROR TOLERANCE EXCEEDS 0.666 NMI
8. VOR COMPONENT OF SD AND 2SD ALONG-COURSE ERROR TOLERANCES
9. DME COMPONENT OF SD AND 2SD ALONG-COURSE ERROR TOLERANCES
10. ROUTE SEGMENT PER GUIDANCE STATION STATISTICAL SUMMARY
11. INCLUDED ANGLE FORMED BY GUIDANCE STATION-TO-AIRCRAFT PROJECTION AND ROUTE SEGMENT
12. DISTANCE BETWEEN GUIDANCE STATION AND AIRCRAFT
13. FLAG WHEN R EXCEEDS LINE-OF-SIGHT DISTANCE BETWEEN GUIDANCE STATION VOR OR DME ANTENNA AND AIRCRAFT

FIGURE 1-4 - TYPICAL COMPUTER PRINTOUT OF VOR/DME DATA SHEET

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V/STOL AREA NAVIGATION DME/DME COVERAGE
****

APPROVED IFR VTOL ROUTE LAX-SBD CROSS COURSE 2 (SD)**2 PAGE 1 OF 1

(8) 1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX					2 (SD)**2																											TOTAL	RANK
						1- 7			7- 9			9- 10			10- 11			11- 13			-													
LAX-OCN	65	62	57	53	60	0.05	2	23	0.05	5	23	0.04	4	3	0.04	2	3	0.04	3	3													0.22	1
POM-OCN	66	62	57	53	53	0.06	7	23	0.07	8	23	0.05	6	3	0.04	3	3	0.04	4	3													0.25	2
VTU-OCN	66	62	63	80	90	0.10	12	123	0.09	10	23	0.06	7	3	0.04	4	3	0.04	5	3													0.33	3
ONT-OCN	66	62	57	53	53	0.08	11	23	0.11	12	123	0.09	12	3	0.08	11	1 3	0.03	1	1 3													0.39	4
SLI-ONT	45	34	26	37	44	0.10	13	1 3	0.05	4		0.04	2		0.05	7	1	0.30	16	1 3													0.54	5
LAX-ONT	45	34	33	51	60	0.21	18	1 3	0.19	14	1	0.15	14	1	0.06	8	3	0.11	12	1 3													0.71	6
SLI-POM	33	21	22	37	44	0.07	9	1	0.04	2		0.07	9		0.27	17	1	0.35	17	1 3													0.80	7
SLI-VTU	42	51	63	80	90	0.30	19	1 3	0.04	3	3	0.06	8	3	0.16	16	1 3	0.25	15	1 3													0.81	8
VNY-SLI	21	25	36	53	62	0.43	20	1	0.06	7	1	0.05	5		0.11	15	1 3	0.18	14	1 3													0.82	9
LAX-SLI	21	21	33	51	60	0.05	4		0.04	1		0.09	13	1	0.35	19	1 3	0.58	19	1 3													1.11	10
LAX-FIM	39	46	57	73	83	0.06	6		0.11	13	1 3	0.20	15	1 3	0.35	18	1 3	0.52	18	1 3													1.23	11
VNY-OCN	66	62	57	53	62	1.10	24	123	0.27	18	123	0.08	10	1 3	0.04	5	3	0.04	6	3													1.53	12
LAX-VNY	18	25	36	53	62	0.04	1		0.10	11	1	0.22	16	1	0.49	21	1 3	0.78	20	1 3													1.64	13
POM-ONT	45	34	26	18	27	0.70	22	1 3	0.57	22	1	0.25	17	1	0.06	9		0.09	11	1													1.67	14
FIM-POM	39	46	56	73	83	0.08	10	1	0.23	17	1 3	0.34	18	1 3	0.46	20	1 3	1.02	21	1 3													2.13	15
FIM-SLI	39	46	57	73	83	2.43	25	1	0.05	6	3	0.04	3	3	0.10	13	1 3	0.15	13	1 3													2.77	16
SLI-OCN	66	62	57	53	53	2.74	26	123	0.09	9	123	0.03	1	3	0.04	1	3	0.03	2	3													2.92	17
VNY-POM	33	25	35	53	62	0.05	3		0.19	16	1	0.40	19	1	0.70	22	1 3	1.89	23	1 3													3.22	18
FIM-OCN	66	62	57	73	83	3.57	27	123	0.19	15	123	0.08	11	1 3	0.04	6	3	0.04	7	3													3.92	19
LAX-VTU	42	51	63	80	90	0.15	15	1 3	0.34	19	1 3	0.67	21	1 3	1.23	23	1 3	1.83	22	1 3													4.22	20
FIM-VTU	42	51	63	80	90	0.15	17	1 3	0.53	21	1 3	0.85	22	1 3	1.47	24	1 3	2.27	24	1 3													5.27	21
VNY-VTU	42	51	63	80	90	0.05	5	1 3	0.40	20	1 3	1.13	23	1 3	3.50	26	1 3	6.21	25	1 3													11.29	22
POM-VTU	42	51	63	80	90	0.45	21	1 3	1.77	25	1 3	2.45	24	1 3	2.29	25	1 3	11.78	27	1 3													18.75	23
LAX-POM	33	21	33	51	60	0.89	23	1	1.03	23	1	2.81	25	1	17.84	28	1 3	7.72	26	1 3													30.29	24
ONT-VTU	45	51	63	80	90	28.30	28	1 3	3.45	27	1 3	0.56	20	1 3	0.07	10	1 3	0.08	10	1 3													32.46	25
VNY-ONT	45	34	36	53	62	0.06	8	1 3	1.47	24	1	32.15	26	1	0.09	12	1 3	0.07	9	1 3													33.84	26
FIM-ONT	45	46	57	73	83	0.14	14	1 3	2.20	26	1 3	39.89	27	1 3	0.10	14	1 3	0.06	8	3													42.40	27
VNY-FIM	39	46	57	73	83	0.15	16	1	48.98	28	1 3	95.19	28	1 3	13.22	27	1 3	14.54	28	1 3													172.08	28
(1)	(3)					(4)	(6)	(9)																									(5)	(7)

NOTES:
1. GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LAX TO SBD APPROVED IFR VTOL ROUTE
2. SEGMENTS OF LAX TO SBD APPROVED IFR VTOL ROUTE
3. AIRCRAFT-TO-GUIDANCE STATION MAXIMUM DISTANCE PER ROUTE SEGMENT
4. AVERAGE CROSS-COURSE $2(SD)^2$ VALUE PER ROUTE SEGMENT
5. SUM OF AVERAGE CROSS-COURSE $2(SD)^2$ VALUES PER ROUTE SEGMENTS FOR LAX TO SBD APPROVED IFR VTOL ROUTE
6. RANKING OF GUIDANCE STATION PAIRS PER ROUTE SEGMENT BASED UPON AVERAGE CROSS-COURSE $2(SD)^2$ VALUES
7. RANKING OF GUIDANCE STATION PAIRS PER ROUTE BASED UPON SUM OF AVERAGE CROSS-COURSE $2(SD)^2$ VALUES
8. FLAG LEGEND:
   (1) WHEN 2 SD CROSS-COURSE AND ALONG-COURSE ERROR TOLERANCES EXCEED 0.333 NMI AND 0.666 NMI RESPECTIVELY
   (2) WHEN COMPUTED AIRCRAFT-TO-GUIDANCE STATION DISTANCE EXCEEDS LINE-OF-SIGHT DISTANCE
   (3) WHEN COMPUTED AIRCRAFT-TO-GUIDANCE STATION DISTANCE EXCEEDS 40 NMI
9. FLAGS PER ROUTE SEGMENT

FIGURE 1-5 - TYPICAL COMPUTER PRINTOUT OF CROSS-COURSE $2(SD)^2$ SUMMARY SHEET INDICATING GUIDANCE STATION PAIR RANKINGS PER ROUTE SEGMENT AND ROUTE

PROJECT 330-014-04X
V/STOL AREA NAVIGATION DME/DME COVERAGE

APPROVED IFR VTOL ROUTE LAX-SBD CROSS COURSE 2 (SD) PAGE 1 OF 1

	(2) 2 (SD)					
	1- 7	7- 9	9- 10	10- 11	11- 13	-
LAX-OCN	0.22	0.22	0.21	0.20	0.19	
POM-OCN	0.24	0.26	0.22	0.20	0.19	
VTU-OCN	0.32	0.29	0.24	0.20	0.20	
ONT-OCN	0.28	0.34	0.29	0.28	0.16	
SLI-ONT	0.31	0.21	0.20	0.22	0.51	
LAX-ONT	0.45	0.43	0.39	0.23	0.33	
SLI-POM	0.25	0.21	0.26	0.52	0.59	
SLI-VTU	0.45	0.21	0.24	0.39	0.50	
VNY-SLI	0.38	0.23	0.21	0.33	0.42	
LAX-SLI	0.23	0.20	0.30	0.58	0.76	
LAX-FIM	0.23	0.34	0.44	0.59	0.72	
VNY-OCN	0.61	0.50	0.28	0.20	0.20	
LAX-VNY	0.21	0.32	0.47	0.70	0.88	
POM-ONT	0.84	0.75	0.49	0.24	0.30	
FIM-POM	0.28	0.48	0.59	0.68	1.00	
FIM-SLI	0.90	0.22	0.21	0.31	0.39	
SLI-OCN	1.18	0.27	0.16	0.20	0.18	
VNY-POM	0.22	0.43	0.63	0.83	1.35	
FIM-OCN	1.28	0.43	0.28	0.20	0.20	
LAX-VTU	0.38	0.58	0.82	1.10	1.35	
FIM-VTU	0.38	0.73	0.92	1.21	1.51	
VNY-VTU	0.23	0.62	1.05	1.85	2.49	
POM-VTU	0.65	1.33	1.56	1.51	3.21	
LAX-POM	0.94	1.00	1.66	4.19	2.71	
ONT-VTU	3.70	1.79	0.73	0.25	0.28	
VNY-ONT	0.23	1.11	3.86	0.28	0.26	
FIM-ONT	0.36	1.40	4.51	0.29	0.25	
VNY-FIM (1)	0.32 (3)	5.67	9.02	3.62	3.81	

NOTES:
1. GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LAX TO SBD APPROVED IFR VTOL ROUTE
2. SEGMENTS OF LAX TO SBD APPROVED IFR VTOL ROUTE
3. AVERAGE CROSS-COURSE 2 SD VALUE PER ROUTE SEGMENT

FIGURE 1-6 - TYPICAL COMPUTER PRINTOUT OF CROSS-COURSE 2 SD SUMMARY SHEET

PRCJECT 330-014-04X
V/STOL AREA NAVIGATION DME/DME COVERAGE

APPROVED IFR VTOL ROUTE LAX-SBD ALONG COLRSE 2 (SD)**2 PAGE 1 OF 1

	(2) 2 (SD)**2						
	1- 7	7- 9	9- 10	10- 11	11- 13	-	
LAX-OCN	C.04	0.04	0.04	0.04	0.05		
POM-OCN	C.06	0.04	0.04	0.04	0.04		
VTU-OCN	C.22	0.06	0.05	0.04	0.04		
ONT-OCN	C.13	0.09	0.13	15.14	0.25		
SLI-ONT	C.14	0.05	0.04	0.06	0.44		
LAX-ONT	C.04	0.02	0.03	0.04	0.10		
SLI-POM	C.06	0.04	0.04	0.04	0.15		
SLI-VTU	C.52	0.05	0.04	0.03	0.09		
VNY-SLI	11.44	0.11	0.04	0.03	0.06		
LAX-SLI	C.04	0.05	0.05	0.05	0.28		
LAX-FIM	C.04	0.03	0.03	0.03	0.05		
VNY-OCN	18.41	0.33	0.09	0.05	0.04		
LAX-VNY	0.04	0.03	0.03	0.03	0.09		
POM-ONT	C.18	0.04	0.04	0.04	0.07		
FIM-POM	C.07	0.04	0.04	0.04	0.06		
FIM-SLI	16.11	0.09	0.04	0.03	0.05		
SLI-OCN	32.26	0.46	0.12	0.07	0.08		
VNY-POM	C.05	0.04	0.04	0.04	0.13		
FIM-OCN	3C.72	0.20	0.10	0.06	0.04		
LAX-VTU	0.04	0.02	0.02	0.02	0.26		
FIM-VTU	0.26	0.10	0.12	0.16	0.08		
VNY-VTU	C.11	0.09	0.13	0.26	0.26		
POM-VTU	C.15	0.03	0.04	0.04	1.01		
LAX-POM	0.04	0.05	0.04	0.04	1.50		
ONT-VTU	17.31	0.29	0.10	0.05	0.06		
VNY-ONT	C.10	0.41	9.14	0.07	0.05		
FIM-ONT	C.20	0.55	11.88	0.09	0.04		
VNY-FIM (1)	0.93 (3)	17.71	26.98	2.23	0.16		

NOTES:
1. GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LAX TO SBD APPROVED IFR VTOL ROUTE
2. SEGMENTS OF LAX TO SBD APPROVED IFR VTOL ROUTE
3. AVERAGE ALONG-COURSE $2(SD)^2$ VALUE PER ROUTE SEGMENT

FIGURE 1-7 - TYPICAL COMPUTER PRINTOUT OF ALONG-COURSE $2(SD)^2$ SUMMARY SHEET

PROJECT 330-014-04X
V/STCL AREA NAVIGATION DME/DME COVERAGE

APPROVED IFR VTOL ROUTE LAX-SBD ALONG COURSE 2 (SD) PAGE 1 OF 1

	(2) 2 (SD)					
	1- 7	7- 9	9- 10	10- 11	11- 13	-
LAX-OCN	0.20	0.19	0.19	0.20	0.22	
POM-OCN	0.24	0.20	0.20	0.20	0.21	
VTU-OCN	0.46	0.24	0.22	0.21	0.20	
ONT-OCN	0.36	0.29	0.36	2.17	0.49	
SLI-ONT	0.37	0.23	0.20	0.25	0.65	
LAX-ONT	0.20	0.15	0.17	0.20	0.32	
SLI-POM	0.24	0.20	0.20	0.20	0.38	
SLI-VTU	0.61	0.21	0.19	0.16	0.30	
VNY-SLI	1.75	0.32	0.20	0.16	0.24	
LAX-SLI	0.20	0.21	0.23	0.23	0.53	
LAX-FIM	0.20	0.16	0.16	0.18	0.23	
VNY-OCN	2.45	0.55	0.30	0.23	0.20	
LAX-VNY	0.20	0.16	0.16	0.17	0.30	
POM-ONT	0.43	0.19	0.20	0.20	0.27	
FIM-POM	0.26	0.19	0.20	0.20	0.25	
FIM-SLI	2.31	0.29	0.20	0.16	0.22	
SLI-OCN	3.95	0.66	0.34	0.26	0.29	
VNY-POM	0.23	0.20	0.20	0.20	0.36	
FIM-OCN	3.70	0.45	0.31	0.24	0.20	
LAX-VTU	0.20	0.15	0.14	0.16	0.51	
FIM-VTU	0.51	0.32	0.34	0.40	0.27	
VNY-VTU	0.34	0.30	0.36	0.51	0.51	
POM-VTU	0.38	0.18	0.20	0.20	0.96	
LAX-POM	0.20	0.21	0.20	0.20	1.17	
ONT-VTU	2.88	0.52	0.31	0.22	0.24	
VNY-ONT	0.31	0.60	2.09	0.26	0.22	
FIM-ONT	0.43	0.70	2.50	0.28	0.21	
VNY-FIM (1)	0.90 (3)	3.57	4.65	1.46	0.41	

NOTES:
1. GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LAX TO SBD APPROVED IFR VTOL ROUTE
2. SEGMENTS OF LAX TO SBD APPROVED IFR VTOL ROUTE
3. AVERAGE ALONG-COURSE 2 SD VALUE PER ROUTE SEGMENT

FIGURE 1-8 - TYPICAL COMPUTER PRINTOUT OF ALONG-COURSE 2 SD SUMMARY SHEET

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V/STOL AREA NAVIGATION DME/DME COVERAGE
****

STATION PAIRS PER ROUTE WITH NO FLAGS

APPROVED IFR VTOL ROUTE LAX-SBD

STATION PAIRS	(1)										ROUTE SEGMENTS
	*	1	*	7	*	9	*	10	*	11	*
	*	7	*	9	*	10	*	11	*	13	*
SLI-ONT	*		*	X	4*	X	2*		*		*
SLI-POM	*		*	X	2*	X	9*		*		*
VNY-SLI	*		*		*	X	5*		*		*
LAX-SLI	*	X	4*	X	1*		*		*		*
LAX-FIM	*	X	6*		*		*		*		*
LAX-VNY	*	X	1*		*		*		*		*
POM-ONT	*		*		*		*	X	9*		*
VNY-POM	*	[X] (2)	[3]* (3)		*		*		*		*

STATIONS											
LAX	*	X	*	X	*		*		*		*
ONT	*		*	X	*	X	*	X	*		*
VNY	*	X	*		*	X	*		*		*
POM	*	X	*	X	*	X	*	X	*		*
SLI	*	X	*	X	*	X	*		*		*
[FIM] (4)	*	[X] (5)	*		*		*		*		*

NOTES:
1. SEGMENTS OF LAX TO SBD APPROVED IFR VTOL ROUTE
2. ROUTE SEGMENTS FOR WHICH GUIDANCE STATION PAIRS PROVIDE THEORETICAL SIGNAL COVERAGE WITH NO FLAGS
3. RANKING OF GUIDANCE STATION PAIRS PER ROUTE SEGMENT BASED UPON AVERAGE CROSS-COURSE $2(SD)^2$ VALUES
4. GUIDANCE STATIONS COMPRISING GUIDANCE STATION PAIRS THAT PROVIDE THEORETICAL SIGNAL COVERAGE WITH NO FLAGS
5. ROUTE SEGMENTS FOR WHICH GUIDANCE STATIONS PROVIDE THEORETICAL SIGNAL COVERAGE WITH NO FLAGS

FIGURE 1-9 - TYPICAL COMPUTER PRINTOUT OF SUMMARY SHEET INDICATING GUIDANCE STATION PAIRS WITH NO FLAGS

PROJECT 330-014-04X
V/STOL AREA NAVIGATION DME/DME COVERAGE
****

STATIONS AND OBSTRUCTION SECTORS FOR STATION PAIRS WITH NO FLAGS

HC=HEIGHT OF OBSTRUCTION
D=DISTANCE TO OBSTRUCTION
H1=VORTAC ELEVATION + 33FT
H2=CRITICAL HEIGHT

APPROVED IFR VTOL ROUTE LAX-SBD

STATION	ROUTE SEGMENT	START/STOP DIST FROM STATION	MAGNETIC BEARING SECTOR	AIRCRAFT ALTITUDE	HC / D / H1 /	H2	RESTRICTIONS - HORIZON PROFILES
LAX	1- 7	0/ 13	/ 45	1500	/ / 213/		
VNY	1- 7	17/ 18	155/112	1500	1550/ 7 / 843/	2673/2792	BELOW LOS
POM	1- 7	33/ 20	240/248	1500	/ /1303/		
SLI	1- 7	20/ 17	280/319	1500	/ / 53/		
FIM	1- 7	33/ 38	123/104	1500	/ /2233/		
LAX	7- 9	13/ 21	45/ 55	1500	/ / 213/		
ONT	7- 9	34/ 26	267/273	1500	/ /1463/		
POM	7- 9	20/ 11	248/248	1500	/ /1303/		
SLI	7- 9	17/ 16	319/351	1500	/ / 53/		
ONT	9- 10	26/ 16	273/291	2000	/ /1463/		
VNY	9- 10	25/ 36	98/ 88	2000	2500/ 12 / 843/	4510/6387	BELOW LOS
POM	9- 10	11/ 0	248/	2000	/ /1303/		
SLI	9- 10	16/ 22	351/ 22	2000	1416/ 13 / 53/	1762/2491	LOS OBS. (NOTE 5)
ONT	10- 11	16/ 13	291/ 6	3500	/ /1463/		
POM	10- 11	0/ 17	/ 64	3500	/ /1303/		
(1)		(2)	(3)	(4)		(5)	(6)

NOTES:
1. GUIDANCE STATIONS COMPRISING GUIDANCE STATION PAIRS THAT PROVIDE THEORETICAL SIGNAL COVERAGE WITH NO FLAGS
2. ROUTE SEGMENT START/STOP DISTANCES FROM GUIDANCE STATION
3. GUIDANCE STATION MAGNETIC BEARING SECTOR TRAVERSED BY ROUTE SEGMENT
4. ASSIGNED AIRCRAFT ALTITUDE PER ROUTE SEGMENT
5. THEORETICAL MINIMUM AIRCRAFT ALTITUDE PER ROUTE SEGMENT TO CLEAR NATURAL TERRAIN OBSTRUCTIONS. ASSIGNED ALTITUDE MUST BE GREATER THAN H2 FOR SIGNAL RECEPTION.
6. SECTORS OF NATURAL TERRAIN OBSTRUCTIONS FROM SURVEY OF PUBLISHED RESTRICTIONS, GUIDANCE STATION HORIZON PROFILES, AND SECTIONAL CHARTS

FIGURE 1-10 - TYPICAL COMPUTER PRINTOUT OF RESTRICTION AND OBSTRUCTION SCREENING SUMMARY SHEET FOR GUIDANCE STATION PAIRS WITH NO FLAGS

PROJECT 330-014-04X
V/STOL AREA NAVIGATION DME/DME COVERAGE
****

STATION PAIRS PER ROUTE WITH NO CC-AC OR LOS FLAGS

APPROVED IFR VTOL ROUTE LAX-SBD

STATION PAIRS	(1) 1	7	9	10	11	ROUTE SEGMENTS
	7	9	10	11	13	
LAX-OCN			X 4	X 2	X 3	
POM-OCN			X 6	X 3	X 4	
VTU-OCN			X 7	X 4	X 5	
ONT-OCN			X 12			
SLI-ONT	X	X 4	X 2			
LAX-ONT				X 8		
SLI-POM	X	X 2	X 9			
SLI-VTU	X	X 3	X 8			
VNY-SLI			X 5			
LAX-SLI	X 4	X 1				
LAX-FIM	X 6					
VNY-OCN				X 5	X 6	
LAX-VNY	X 1					
POM-ONT				X 9		
FIM-SLI		X 6	X 3			
SLI-OCN			X 1	X 1	X 2	
VNY-POM	X (2)	(3)				
FIM-OCN				X 6	X 7	
FIM-ONT					X 8	

STATIONS										
LAX		X		X		X		X		X
ONT				X		X		X		X
VNY		X				X		X		X
POM		X		X		X		X		X
SLI		X		X		X		X		X
VTU				X		X		X		X
OCN						X		X		X
FIM (4)		X (5)		X		X		X		X

NOTES:
1. SEGMENTS OF LAX TO SBD APPROVED IFR VTOL ROUTE
2. ROUTE SEGMENTS FOR WHICH GUIDANCE STATION PAIRS PROVIDE THEORETICAL SIGNAL COVERAGE WITH NO CROSS-COURSE, ALONG-COURSE, OR LINE-OF-SIGHT FLAGS
3. RANKING OF GUIDANCE STATION PAIRS PER ROUTE SEGMENT BASED UPON AVERAGE CROSS-COURSE $2(SD)^2$ VALUES
4. GUIDANCE STATIONS COMPRISING GUIDANCE STATION PAIRS THAT PROVIDE THEORETICAL SIGNAL COVERAGE WITH NO CROSS-COURSE, ALONG-COURSE, OR LINE-OF-SIGHT FLAGS
5. ROUTE SEGMENTS FOR WHICH GUIDANCE STATIONS PROVIDE THEORETICAL SIGNAL COVERAGE WITH NO CROSS-COURSE, ALONG-COURSE, OR LINE-OF-SIGHT FLAGS

FIGURE 1-11 - TYPICAL COMPUTER PRINTOUT OF SUMMARY SHEET INDICATING GUIDANCE STATIONS PAIRS WITH NO CROSS-COURSE, ALONG-COURSE, OR LINE-OF-SIGHT FLAGS

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****

STATIONS AND OBSTRUCTION SECTORS FOR STATION PAIRS WITH NO CC-AC OR LOS FLAGS

HC=HEIGHT OF OBSTRUCTION
D=DISTANCE TO OBSTRUCTION
H1=VORTAC ELEVATION + 33FT
H2=CRITICAL HEIGHT

APPROVED IFR VTOL ROUTE LAX-SBD

STATION	ROUTE SEGMENT	START/STOP DIST FROM STATION	MAGNETIC BEARING SECTOR	AIRCRAFT ALTITUDE	HC / D / H1 / H2	RESTRICTIONS - HORIZON PROFILES
LAX	1- 7	0/ 13	/ 45	1500	/ / 213/	
VNY	1- 7	17/ 18	155/112	1500	1550/ 7 / 843/ 2673/2792	BELOW LOS
POM	1- 7	33/ 20	240/248	1500	/ /1303/	
SLI	1- 7	20/ 17	280/319	1500	/ / 53/	
FIM	1- 7	33/ 38	123/104	1500	2126/ 22 /2233/ 2313/2451	BELOW LOS
LAX	7- 9	13/ 21	45/ 55	1500	/ / 213/	
ONT	7- 9	34/ 26	267/273	1500	/ /1463/	
POM	7- 9	20/ 11	248/248	1500	/ /1303/	
SLI	7- 9	17/ 16	319/351	1500	/ / 53/	-
VTU	7- 9	42/ 51	80/ 78	1500	/ /1593/	OBS. 080°/078°
FIM	7- 9	38/ 46	104/ 97	1500	2500/ 12 /2233/ 3734/4295	BELOW LOS
LAX	9- 10	21/ 33	55/ 59	2000	/ / 213/	
ONT	9- 10	26/ 16	273/291	2000	/ /1463/	
VNY	9- 10	25/ 36	98/ 88	2000	2500/ 12 / 843/ 4510/6387	BELOW LOS
POM	9- 10	11/ 0	248/	2000	/ /1303/	
SLI	9- 10	16/ 22	351/ 22	2000	1416/ 13 / 53/ 1762/2491	LOS OBS. (NOTE 5)
VTU	9- 10	51/ 62	78/ 76	2000	/ /1593/	OBS. 078°/076°
OCN	9- 10	57/ 53	313/324	2000	/ / 123/	OBS. 313°/324°
FIM	9- 10	46/ 56	97/ 91	2000	2500/ 12 /2233/ 4295/5115	BELOW LOS
LAX	10- 11	33/ 51	59/ 61	3500	/ / 213/	

FIGURE 1-12 - TYPICAL COMPUTER PRINTOUT OF RESTRICTION AND OBSTRUCTION SCREENING SUMMARY SHEET FOR GUIDANCE STATION PAIRS WITH NO CROSS-COURSE, ALONG-COURSE, OR LINE-OF-SIGHT FLAGS

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****

STATION PAIRS PER ROUTE WITH NO LOS FLAGS

APPROVED IFR VTOL ROUTE LAX-SBD

STATION PAIRS	(1) ROUTE SEGMENTS				
	1	7	9	10	11
	7	9	10	11	13
LAX-OCN			X 4*	X 2*	X 3*
POM-OCN			X 6*	X 3*	X 4*
VTU-OCN			X 7*	X 4*	X 5*
ONT-OCN			X 12*	X 11*	X 1*
SLI-ONT	X 13*	X 4*	X 2*	X 7*	X 16*
LAX-ONT	X 18*	X 14*	X 14*	X 8*	X 12*
SLI-POM	X 9*	X 2*	X 9*	X 17*	X 17*
SLI-VTU	X 19*	X 3*	X 8*	X 16*	X 15*
VNY-SLI	X 20*	X 7*	X 5*	X 15*	X 14*
LAX-SLI	X 4*	X 1*	X 13*	X 19*	X 19*
LAX-FIM	X 6*	X 13*	X 15*	X 18*	X 18*
VNY-OCN			X 10*	X 5*	X 6*
LAX-VNY	X 1*	X 11*	X 16*	X 21*	X 20*
POM-ONT	X 22*	X 22*	X 17*	X 9*	X 11*
FIM-POM	X 10*	X 17*	X 18*	X 20*	X 21*
FIM-SLI	X 25*	X 6*	X 3*	X 13*	X 13*
SLI-OCN			X 1*	X 1*	X 2*
VNY-POM	X 3*	X 16*	X 19*	X 22*	X 23*
FIM-OCN			X 11*	X 6*	X 7*
LAX-VTU	X 15*	X 19*	X 21*	X 23*	X 22*
FIM-VTU	X 17*	X 21*	X 22*	X 24*	X 24*
VNY-VTU	X 5*	X 20*	X 23*	X 26*	X 25*
POM-VTU	X 21*	X 25*	X 24*	X 25*	X 27*
LAX-POM	X 23*	X 23*	X 25*	X 28*	X 26*
ONT-VTU	X 28*	X 27*	X 20*	X 10*	X 10*
VNY-ONT	X 8*	X 24*	X 26*	X 12*	X 9*
FIM-ONT	X 14*	X 26*	X 27*	X 14*	X 8*
VNY-FIM	X 16* (2)(3)	X 28*	X 28*	X 27*	X 28*

STATIONS										
LAX	X	X	X	X	X	X	X	X	X	X
ONT	X	X	X	X	X	X	X	X	X	X
VNY	X	X	X	X	X	X	X	X	X	X
POM	X	X	X	X	X	X	X	X	X	X
SLI	X	X	X	X	X	X	X	X	X	X
VTU	X	X	X	X	X	X	X	X	X	X
OCN					X	X	X	X	X	X
FIM (4)	X (5)	X	X	X	X	X	X	X	X	X

NOTES:
1. SEGMENTS OF LAX TO SBD APPROVED IFR VTOL ROUTE
2. ROUTE SEGMENTS FOR WHICH GUIDANCE STATION PAIRS PROVIDE THEORETICAL SIGNAL COVERAGE WITH NO LINE-OF-SIGHT FLAGS
3. RANKING OF GUIDANCE STATION PAIRS PER ROUTE SEGMENT BASED UPON AVERAGE CROSS-COURSE $2(SD)^2$ VALUES
4. GUIDANCE STATIONS COMPRISING GUIDANCE STATION PAIRS THAT PROVIDE THEORETICAL SIGNAL COVERAGE WITH NO LINE-OF-SIGHT FLAGS
5. ROUTE SEGMENTS FOR WHICH GUIDANCE STATIONS PROVIDE THEORETICAL SIGNAL COVERAGE WITH NO LINE-OF-SIGHT FLAGS

FIGURE 1-13 - TYPICAL COMPUTER PRINTOUT OF SUMMARY SHEET INDICATING GUIDANCE STATION PAIRS WITH NO LINE-OF-SIGHT FLAGS

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V/STOL AREA NAVIGATION DME/DME COVERAGE
****

STATIONS AND OBSTRUCTION SECTORS FOR STATION PAIRS WITH NO LOS FLAGS

HC=HEIGHT OF OBSTRUCTION
D=DISTANCE TO OBSTRUCTION
H1=VORTAC ELEVATION + 33FT
H2=CRITICAL HEIGHT

APPROVED IFR VTOL ROUTE LAX-SBD

STATION	ROUTE SEGMENT	START/STOP DIST FROM STATION	MAGNETIC BEARING SECTOR	AIRCRAFT ALTITUDE	HC / D / H1 /	H2	RESTRICTIONS - HORIZON PROFILES
LAX	1- 7	0/ 13	/ 45	1500	/ / 213/		
ONT	1- 7	45/ 34	256/267	1500	1800/ 12 /1463/	3712/2914	LOS OBS. (NOTE 5)
VNY	1- 7	17/ 18	155/112	1500	1550/ 7 / 843/	2673/2792	BELOW LOS
POM	1- 7	33/ 20	240/248	1500	/ /1303/		
SLI	1- 7	20/ 17	280/319	1500	/ / 53/		
VTU	1- 7	32/ 42	94/ 80	1500	/ /1593/		OBS. 094°/080°
FIM	1- 7	33/ 38	123/104	1500	2126/ 22 /2233/	2313/2451	BELOW LOS
LAX	7- 9	13/ 21	45/ 55	1500	/ / 213/		
ONT	7- 9	34/ 26	267/273	1500	/ /1463/		
VNY	7- 9	18/ 25	112/ 98	1500	1665/ 10 / 843/	2418/3147	BELOW LOS
POM	7- 9	20/ 11	248/248	1500	/ /1303/		
SLI	7- 9	17/ 16	319/351	1500	/ / 53/		
VTU	7- 9	42/ 51	80/ 78	1500	/ /1593/		OBS. 080°/078°
FIM	7- 9	38/ 46	104/ 97	1500	2500/ 12 /2233/	3734/4295	BELOW LOS
LAX	9- 10	21/ 33	55/ 59	2000	/ / 213/		
ONT	9- 10	26/ 16	273/291	2000	/ /1463/		
VNY	9- 10	25/ 36	98/ 88	2000	2500/ 12 / 843/	4510/6387	BELOW LOS
POM	9- 10	11/ 0	248/	2000	/ /1303/		
SLI	9- 10	16/ 22	351/ 22	2000	1416/ 13 / 53/	1762/2491	LOS OBS. (NOTE 5)
VTU	9- 10	51/ 62	78/ 76	2000	/ /1593/		OBS. 078°/076°

FIGURE 1-14 - TYPICAL COMPUTER PRINTOUT OF RESTRICTION AND OBSTRUCTION SCREENING SUMMARY SHEET FOR GUIDANCE STATION PAIRS WITH NO LINE-OF-SIGHT FLAGS.

APPENDIX B

THEORETICAL RANKINGS OF GUIDANCE STATIONS FOR VOR/DME AND DME/DME RNAV OVER APPROVED IFR VTOL AND HYPOTHETICAL DIRECT V/STOL ROUTES IN LAX AREA

The theoretical rankings of guidance stations for VOR/DME and DME/DME RNAV over the approved IFR VTOL and the hypothetical direct V/STOL routes in the LAX area are presented in Figures 2-1 to 2-17, inclusively. The maximum guidance station-to-aircraft distance and the statuses of the flag criteria per route segment are also shown. Figures 2-1 to 2-4, inclusively, indicate the guidance station rankings for VOR/DME RNAV over the approved routes. Figures 2-5 and 2-6 indicate the guidance station rankings for VOR/DME RNAV over the direct routes. The ranking order of the guidance station pairs for DME/DME RNAV over the approved routes are shown in Figures 2-7 to 2-13, inclusively; the guidance station pair rankings for DME/DME RNAV over the direct routes, in Figures 2-14 to 2-17, inclusively. Rankings based upon the average $2(SD)^2$ cross-course values are presented for each route segment and route.

It is emphasized that the information provided in these figures are the theoretical outputs of the computerized analysis. Before consideration is given to the utilization of a particular VORTAC or VORTAC pair for a particular route segment, the final analysis must weigh the effects of AIM restrictions and natural terrain obstructions on guidance signal availability. As previously noted, this additional analysis was conducted on the theoretical printout data contained in Figures 2-1 to 2-17, inclusively, and the results presented in the main body of the report. However, by comparing the guidance station and station pair rankings shown in this appendix with the optimum VORTAC selections after the restriction and obstruction screenings (Tables 1, 2, 3, and 4 in the main body of report), an assessment can be made of the extent to which the cross-course accuracies reflected in the theoretically optimum guidance stations or station pairs per route segment were compromised in the interest of route segment signal coverage.

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APPROVED IFR VTOL ROUTE LAX-VNY CROSS COURSE 2 (SD)**2 PAGE, 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX		1- 2	2- 3	-	-	-	TOTAL	RANK
			2 (SD)**2						
VNY	17*	4*	0.15 2 1	0.01 1				0.15	1
LAX	15*	18*	0.09 1 1	0.16 4 1				0.24	2
POM	38*	38*	0.21 3 1	0.32 7 1				0.53	3
VTU	33*	28*	0.30 4 1	0.46 8 1				0.76	4
SLI	33*	34*	0.67 5 1	0.10 3 1				0.76	5
FIM	34*	21*	0.76 6 1	0.05 2 1				0.81	6
ONT	53*	53*	0.81 7 1 3*	0.31 6 1 3*				1.12	7
OCN	79*	80*	5.14 8 1 3*	0.31 5 123*				5.45	8

(a) LOS ANGELES TO VAN NUYS

APPROVED IFR VTOL ROUTE VNY-LAX CROSS COURSE 2 (SD)**2 PAGE, 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX			3- 4	4- 5	5- 1	-	-	-	TOTAL	RANK
				2 (SD)**2							
LAX	17*	10*	9*	0.15 2 1	0.04 1	0.03 1				0.22	1
VNY	11*	17*	18*	0.05 1 1	0.24 2 1	0.05 2				0.34	2
SLI	34*	23*	21*	1.02 6 1	0.50 4 1	0.12 3 1				1.63	3
POM	36*	28*	33*	0.71 4 1	0.28 3 1	0.97 7 1				1.96	4
VTU	35*	39*	39*	0.45 3 1	0.84 5 1	0.84 6 1				2.13	5
FIM	31*	37*	37*	0.72 5 1	1.26 7 1	0.20 4 1				2.19	6
ONT	51*	42*	45*	1.90 7 1 3*	1.09 6 1 3*	1.49 8 1 3*				4.48	7
OCN	80*	69*	66*	6.70 8 123*	5.22 8 123*	0.55 5 123*				12.48	8

(b) VAN NUYS TO LOS ANGELES

FIGURE 2-1 - RANKING ORDER OF VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER LOS ANGELES TO VAN NUYS AND VAN NUYS TO LOS ANGELES APPROVED ROUTES

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V/STOL AREA NAVIGATION VOR/DME COVERAGE

APPROVED IFR VTOL ROUTE LAX-JOR CROSS COURSE 2 (SD)**2 PAGE, 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX					2 (SD)**2								TOTAL	RANK
						1- 32	32- 27	-	-	-	-				
	1*	32*													
	32*	27*													
SLI	21*	11*				0.20 3 1 *	0.06 1 1 *							0.26	1
POM	33*	29*				0.15 2 1 *	0.13 2 1 *							0.28	2
LAX	16*	32*				0.11 1 1 *	0.65 4 1 *							0.76	3
ONT	45*	35*				0.76 5 1 3*	0.63 3 1 *							1.39	4
VNY	32*	45*				0.66 4 1 *	1.06 5 1 3*							1.72	5
FIM	50*	65*				2.18 7 1 3*	3.02 7 1 3*							5.20	6
VTU	48*	65*				1.77 6 1 3*	3.69 8 1 3*							5.46	7
OCN	65*	49*				3.98 8 123*	1.61 6 1 3*							5.59	8

(a) LOS ANGELES TO ORANGE COUNTY

APPROVED IFR VTOL ROUTE JOR-LAX CROSS COURSE 2 (SD)**2 PAGE, 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX					2 (SD)**2								TOTAL	RANK
						28- 31	31- 30	30- 7	7- 1	-	-				
	28*	31*	30*	7*											
	31*	30*	7*	1*											
SLI	12*	5*	17*	21*		0.10 2 1 *	0.01 1 *	0.12 2 1 *	0.09 3 1 *					0.32	1
POM	27*	23*	22*	33*		0.20 3 1 *	0.08 2 1 *	0.07 1 1 *	0.84 6 1 *					1.19	2
LAX	33*	25*	21*	13*		0.98 4 1 *	0.61 4 1 *	0.13 3 1 *	0.07 2 1 *					1.79	3
ONT	25*	27*	34*	45*		0.07 1 1 *	0.16 3 1 *	0.26 4 1 *	1.33 8 1 3*					1.82	4
VNY	46*	39*	34*	18*		2.22 6 1 3*	1.63 5 1 *	0.77 5 1 *	0.06 1 *					4.68	5
OCN	40*	45*	62*	66*		1.67 5 1 3*	2.26 6 1 3*	3.30 8 123*	0.46 5 123*					7.69	6
VTU	65*	58*	53*	42*		4.09 7 1 3*	3.27 7 1 3*	1.24 6 1 3*	0.99 7 1 3*					9.59	7
FIM	66*	58*	53*	39*		4.69 8 1 3*	3.81 8 1 3*	2.03 7 1 3*	0.28 4 1 *					10.81	8

(b) ORANGE COUNTY TO LOS ANGELES

FIGURE 2-2 - RANKING ORDER OF VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER LOS ANGELES TO ORANGE COUNTY AND ORANGE COUNTY TO LOS ANGELES APPROVED ROUTES

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APPROVED IFR VTOL ROUTE LAX-ANA CROSS COURSE 2 (SD)**2 PAGE, 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX					2 (SD)**2						TOTAL	RANK
		1*	25*			1- 25	25- 26	-	-	-	-		
		25*	26*										
SLI	21*	7*				0.15 1 1	0.04 1					0.19	1
LAX	25*	26*				0.25 2 1	0.28 4 1					0.53	2
POM	33*	17*				0.46 3 1	0.17 3 1					0.63	3
ONT	45*	21*				1.32 5 1 3*	0.05 2 1					1.37	4
VNY	35*	38*				0.49 4 1	1.24 5 1					1.73	5
VTU	57*	59*				2.48 7 1 3*	1.59 6 1 3*					4.08	6
FIM	55*	58*				1.90 6 1 3*	2.62 8 1 3*					4.52	7
OCN	65*	45*				2.55 8 123*	2.20 7 1 3*					4.75	8

(a) LOS ANGELES TO ANAHEIM

APPROVED IFR VTOL ROUTE JOR-LAX CROSS COURSE 2 (SD)**2 PAGE, 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX					2 (SD)**2						TOTAL	RANK
		27*	25*	17*		27- 25	25- 17	17- 1	-	-	-		
		25*	17*	1*									
SLI	11*	12*	21*			0.06 2 1	0.08 2 1	0.13 1 1				0.26	1
LAX	32*	25*	21*			0.46 4 1	0.14 4 1	0.19 2 1				0.79	2
POM	24*	15*	33*			0.31 3 1	0.08 1 1	0.65 4 1				1.03	3
ONT	22*	24*	45*			0.06 1 1	0.12 3 1	1.44 6 1 3*				1.62	4
VNY	45*	35*	28*			1.59 5 1 3*	0.86 5 1	0.24 3 1				2.68	5
VTU	65*	57*	53*			1.99 7 1 3*	1.16 6 1 3*	2.0[illegible] 8 1 3*				5.14	6
OCN	46*	53*	66*			1.81 6 1 3*	2.81 8 1 3*	1.55 7 123*				6.18	7
FIM	65*	55*	49*			3.12 8 1 3*	2.05 7 1 3*	1.15 5 1 3*				6.31	8

(b) ORANGE COUNTY/ANAHEIM TO LOS ANGELES

FIGURE 2-3 - RANKING ORDER OF VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER LOS ANGELES TO ANAHEIM AND ANAHEIM TO LOS ANGELES APPROVED ROUTES

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APPROVED IFR VTOL ROUTE LAX-SBD CROSS COURSE 2 (SD)**2 PAGE 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX					2 (SD)**2																											TOTAL	RANK
						1- 7				7- 9				9- 10				10- 11				11- 13				-								
POM	33	21	12	18	27	0.83	6	1		0.34	2	1		0.06	1	1		0.13	3	1		0.56	3	1									1.91	1
SLI	21	17	22	37	44	0.09	3	1		0.05	1			0.15	2	1		0.82	4	1		1.10	4	1	3								2.21	2
OCN	66	62	57	53	53	0.45	5	123		1.13	6	123		0.46	4	1	3	0.07	2	1	3	0.16	2	1	3								2.28	3
ONT	45	34	26	16	17	1.32	8	1	3	0.99	5	1		0.40	3	1		0.07	1	1		0.09	1	1									2.87	4
LAX	13	21	33	51	60	0.07	2	1		0.34	3	1		0.91	5	1		2.20	6	1	3	3.08	5	1	3								6.60	5
VNY	18	25	36	53	62	0.06	1			0.40	4	1		0.96	6	1		2.19	5	1	3	4.01	6	1	3								7.60	6
FIM	39	46	57	73	83	0.28	4	1		1.60	7	1	3	2.59	7	1	3	4.36	7	1	3	7.42	7	1	3								16.26	7
VTU	42	51	63	80	90	1.00	7	1	3	2.58	8	1	3	3.85	8	1	3	6.09	8	1	3	8.33	8	1	3								21.84	8

FIGURE 2-4 - RANKING ORDER OF VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER LOS ANGELES TO SAN BERNARDINO APPROVED ROUTE

PROJECT 330-014-J4X
V/STOL AREA NAVIGATION VOR/DME COVERAGE

DIRECT VTOL ROUTE LAX-VNY CROSS COURSE 2 (SD)**2 PAGE, 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX						2 (SD)**2												TOTAL	RANK
	70*	71*	72*																	
	71*	72*	73*																	
							70- 71		71- 72		72- 73		-		-		-			
VNY	17*	9*	4*				0.23	4 1	0.06	1	0.01	1							0.30	1
VTU	33*	29*	29*				0.21	3 1	0.07	2 1	0.04	2 1							0.33	2
POM	34*	35*	36*				0.05	2 1	0.11	3 1	0.22	3 1							0.38	3
LAX	8*	13*	17*				0.03	1	0.14	4 1	0.3[illegible]	5 1							0.47	4
FIM	34*	27*	23*				0.76	7 1	0.42	5 1	0.24	4 1							1.42	5
ONT	47*	49*	51*				0.23	5 1 3*	0.48	6 1 3*	0.72	6 1 3*							1.43	6
SLI	26*	31*	34*				0.34	6 1	0.65	7 1	0.94	7 1							1.93	7
OCN	72*	76*	80*				3.49	8 123*	4.41	8 123*	5.11	8 123*							13.01	8

(a) LOS ANGELES TO VAN NUYS

DIRECT VTOL ROUTE LAX-SBD CROSS COURSE 2 (SD)**2 PAGE, 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX						2 (SD)**2												TOTAL	RANK
	70*	74*	75*																	
	74*	75*	76*																	
							70- 74		74- 75		75- 76		-		-		-			
POM	33*	12*	27*				0.66	4 1	0.06	1 1	0.33	3 1							1.[illegible]5	1
SLI	21*	23*	44*				0.13	1 1	0.22	2 1	1.23	4 1 3*							1.57	2
OCN	66*	54*	51*				1.39	6 123*	0.32	4 1 3*	0.12	2 1 3*							1.83	3
ONT	45*	24*	17*				1.42	7 1 3*	0.32	3 1	0.1[illegible]	1 1							1.84	4
LAX	21*	36*	60*				0.19	2 1	1.05	5 1	2.88	5 1 3*							4.13	5
VNY	28*	41*	62*				0.22	3 1	1.07	6 1 3*	2.90	6 1 3*							4.19	6
FIM	49*	61*	83*				1.07	5 1 3*	2.73	7 1 3*	5.38	7 1 3*							9.17	7
VTU	52*	67*	90*				1.94	8 1 3*	4.08	8 1 3*	7.23	8 1 3*							13.25	8

(b) LOS ANGELES TO SAN BERNARDINO

FIGURE 2-5 - RANKING ORDER OF VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER LOS ANGELES TO VAN NUYS AND LOS ANGELES TO SAN BERNARDINO DIRECT ROUTES

PROJECT 330-014-04X
V/STOL AREA NAVIGATION VOR/DME COVERAGE

DIRECT VTOL ROUTE LAX-ANA CROSS COURSE 2 (SD)**2 PAGE, 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX	70- 77	2 (SD)**2	TOTAL	RANK
SLI	21	0.15 1 1		0.15	1
LAX	26	0.29 2 1		0.29	2
POM	33	0.38 3 1		0.38	3
VNY	38	0.62 4 1		0.62	4
ONT	45	1.19 5 1 3		1.19	5
FIM	58	2.20 6 1 3		2.20	6
VTU	59	2.64 7 1 3		2.64	7
OCN	65	2.79 8 123		2.79	8

(a) LOS ANGELES TO ANAHEIM

DIRECT VTOL ROUTE LAX-JOR CROSS COURSE 2 (SD)**2 PAGE, 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX	70- 78	2 (SD)**2	TOTAL	RANK
SLI	21	0.14 1 1		0.14	1
POM	33	0.22 2 1		0.22	2
LAX	32	0.43 3 1		0.43	3
ONT	45	0.82 4 1 3		0.82	4
VNY	45	1.00 5 1 3		1.00	5
FIM	65	2.89 6 1 3		2.89	6
OCN	65	2.95 7 123		2.95	7
VTU	65	2.97 8 1 3		2.97	8

(b) LOS ANGELES TO ORANGE COUNTY

FIGURE 2-6 - RANKING ORDER OF VORTAC GUIDANCE STATIONS FOR VOR/DME AREA NAVIGATION OVER LOS ANGELES TO ANAHEIM AND LOS ANGELES TO ORANGE COUNTY DIRECT ROUTES

PROJECT 330-014-04X

V/STOL AREA NAVIGATION DME/DME COVERAGE

APPROVED IFR VTOL ROUTE LAX-VNY CROSS COURSE 2 (SD)**2 PAGE 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX						2 (SD)**2												TOTAL	RANK
							1-	2		2-	3		-		-		-			
LAX-POM	38*	38*	*	*	*	*	0.05	6	*	0.03	8	*	*		*		*		0.08	1
VNY-ONT	53*	53*	*	*	*	*	0.04	2	3*	0.05	16	3*	*		*		*		0.09	2
VNY-POM	38*	38*	*	*	*	*	0.04	1	*	0.06	18	*	*		*		*		0.09	3
LAX-ONT	53*	53*	*	*	*	*	0.07	6	3*	0.03	7	3*	*		*		*		0.10	4
POM-OCN	79*	80*	*	*	*	*	0.08	7 1	3*	0.02	6	23*	*		*		*		0.10	5
LAX-VTU	32*	28*	*	*	*	*	0.07	5	*	0.04	12	*	*		*		*		0.11	6
SLI-POM	38*	38*	*	*	*	*	0.08	9 1	*	0.02	5	*	*		*		*		0.11	7
VNY-SLI	33*	34*	*	*	*	*	0.09	10	*	0.04	15	*	*		*		*		0.13	8
VNY-OCN	79*	80*	*	*	*	*	0.12	11 1	3*	0.04	14	23*	*		*		*		0.16	9
VNY-VTU	33*	28*	*	*	*	*	0.05	3	*	0.12	24 1	*	*		*		*		0.17	10
ONT-OCN	79*	80*	*	*	*	*	0.15	14 1	3*	0.02	1	23*	*		*		*		0.17	11
VNY-FIM	34*	21*	*	*	*	*	0.14	13 1	*	0.04	13	*	*		*		*		0.18	12
FIM-POM	38*	38*	*	*	*	*	0.08	8 1	*	0.10	22 1	*	*		*		*		0.19	13
FIM-VTU	34*	28*	*	*	*	*	0.14	12 1	*	0.05	17	*	*		*		*		0.19	14
VTU-OCN	79*	80*	*	*	*	*	0.17	16 1	3*	0.03	10	23*	*		*		*		0.20	15
SLI-ONT	53*	53*	*	*	*	*	0.19	17 1	3*	0.02	2	3*	*		*		*		0.21	16
LAX-SLI	33*	34*	*	*	*	*	0.26	18 1	*	0.08	20	*	*		*		*		0.34	17
LAX-OCN	79*	80*	*	*	*	*	0.37	19 1	3*	0.08	19	23*	*		*		*		0.45	18
LAX-FIM	33*	21*	*	*	*	*	0.43	21 1	*	0.03	11	*	*		*		*		0.46	19
SLI-VTU	33*	34*	*	*	*	*	0.44	22 1	*	0.03	9	*	*		*		*		0.47	20
FIM-ONT	53*	53*	*	*	*	*	0.16	15 1	3*	0.40	26 1	3*	*		*		*		0.57	21
LAX-VNY	17*	17*	*	*	*	*	0.65	23 1	*	0.09	21 1	*	*		*		*		0.75	22
POM-ONT	53*	53*	*	*	*	*	0.42	20 1	3*	0.57	27 1	3*	*		*		*		0.99	23
POM-VTU	38*	38*	*	*	*	*	3.71	24 1	*	0.24	25 1	*	*		*		*		3.95	24
ONT-VTU	53*	53*	*	*	*	*	7.37	25 1	3*	0.11	23 1	3*	*		*		*		7.48	25
SLI-OCN	79*	80*	*	*	*	*	17.93	26 1	3*	5.94	28	123*	*		*		*		23.87	26
FIM-SLI	34*	34*	*	*	*	*	26.46	27 1	*	0.02	4 1	*	*		*		*		26.48	27
FIM-OCN	79*	80*	*	*	*	*	44.59	28 1	3*	0.02	3	123*	*		*		*		44.61	28

FIGURE 2-7 - RANKING ORDER OF VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO VAN NUYS APPROVED ROUTE

PROJECT 330-014-04X

V/STOL AREA NAVIGATION DME/DME COVERAGE

APPROVED IFR VTOL ROUTE VNY-LAX CROSS COURSE 2 (SD)**2 PAGE 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX						2 (SD)**2												TOTAL	RANK
	3*	4*	5*																	
	4*	5*	1*																	
							3- 4		4- 5		5- 1		-		-		-			
LAX-FIM	31*	37*	37*				0.07 4		0.04 4		0.05 7								0.16	1
LAX-VTU	35*	39*	39*				0.04 1		0.04 1		0.13 18 1								0.20	2
LAX-OCN	80*	69*	66*				0.13 8	123*	0.04 5	23*	0.05 6	23*							0.22	3
LAX-VNY	17*	17*	18*				0.15 11 1		0.05 6		0.04 5								0.23	4
VNY-VTU	35*	39*	39*				0.08 6		0.12 11 1		0.04 1								0.25	5
LAX-SLI	34*	23*	21*				0.15 12 1		0.05 7		0.06 8								0.25	6
VNY-POM	36*	28*	33*				0.14 10 1		0.08 8		0.04 4								0.26	7
SLI-POM	36*	28*	33*				0.14 9 1		0.08 9		0.08 12 1								0.29	8
POM-OCN	80*	69*	66*				0.16 13	123*	0.08 10	23*	0.06 9	23*							0.30	9
LAX-ONT	51*	42*	45*				0.05 3	3*	0.04 3	3*	0.23 20 1	3*							0.32	10
VTU-OCN	80*	69*	66*				0.09 7	123*	0.15 14	123*	0.12 17	123*							0.36	11
VNY-ONT	51*	42*	45*				0.23 16 1	3*	0.15 15 1	3*	0.04 2	3*							0.42	12
SLI-ONT	51*	42*	45*				0.23 15 1	3*	0.15 16 1	3*	0.14 19 1	3*							0.52	13
ONT-OCN	80*	69*	66*				0.28 17	123*	0.18 17	123*	0.08 13	23*							0.54	14
FIM-VTU	35*	39*	39*				0.17 14 1		0.27 18 1		0.12 16 1								0.57	15
SLI-VTU	35*	39*	39*				0.08 5		0.13 12 1		0.49 22 1								0.70	16
FIM-POM	36*	37*	37*				0.67 21 1		0.13 13 1		0.06 11								0.86	17
LAX-POM	36*	28*	33*				0.05 2		0.04 2 1		1.06 24 1								1.14	18
VNY-FIM	31*	37*	37*				0.55 20 1		0.90 21 1		0.04 3 1								1.49	19
POM-ONT	51*	42*	45*				2.04 23 1	3*	0.50 20 1	3*	0.76 23 1	3*							3.30	20
FIM-SLI	34*	37*	37*				0.53 19 1		0.95 22 1		3.54 25 1								5.02	21
FIM-ONT	51*	42*	45*				5.05 24 1	3*	0.39 19 1	3*	0.09 14 1	3*							5.54	22
FIM-OCN	80*	69*	66*				0.73 22	123*	1.53 23	123*	5.13 28	123*							7.38	23
POM-VTU	36*	39*	39*				15.19 25 1		1.83 24 1		0.29 21 1								17.31	24
ONT-VTU	51*	42*	45*				0.45 18 1	3*	42.59 27 1	3*	3.73 26 1	3*							46.77	25
SLI-OCN	80*	69*	66*				25.03 26	123*	21.41 26	123*	4.01 27	123*							50.46	26
VNY-OCN	79*	69*	66*				33.69 27	123*	18.17 25	123*	0.06 10	123*							51.92	27
VNY-SLI	34*	23*	21*				261.22 28 1		259.37 28 1		0.10 15 1								520.69	28

FIGURE 2-8 - RANKING ORDER OF VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER VAN NUYS TO LOS ANGELES APPROVED ROUTE

PROJECT 330-014-04X

V/STOL AREA NAVIGATION DME/DME COVERAGE

APPROVED IFR VTOL ROUTE LAX-JOR CROSS COURSE 2 (SD)**2 PAGE 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX		1- 32			32- 27			2 (SD)**2			TOTAL	RANK
VNY-POM	33*	45*	0.04	1	*	0.03	1	3*				0.07	1
FIM-POM	50*	65*	0.05	2	3*	0.04	2	3*				0.08	2
LAX-POM	33*	32*	0.05	3	*	0.04	4	*				0.09	3
POM-OCN	65*	49*	0.05	5	23*	0.04	3	3*				0.09	4
VNY-ONT	45*	45*	0.05	4	3*	0.05	6	3*				0.10	5
POM-VTU	48*	65*	0.07	6	1 3*	0.04	5	3*				0.11	6
FIM-ONT	50*	65*	0.08	8	3*	0.06	7	3*				0.14	7
LAX-ONT	45*	35*	0.09	10	1 3*	0.07	9	*				0.16	8
ONT-OCN	65*	49*	0.11	11	123*	0.06	8	3*				0.17	9
POM-ONT	45*	35*	0.16	13	1 3*	0.10	11	1 *				0.26	10
ONT-VTU	48*	65*	0.21	14	1 3*	0.10	10	1 3*				0.31	11
VNY-VTU	48*	65*	0.14	12	1 3*	0.29	12	1 3*				0.43	12
LAX-VNY	32*	45*	0.46	18	1 *	0.53	14	1 3*				0.99	13
FIM-VTU	50*	65*	0.49	19	1 3*	0.81	16	1 3*				1.30	14
LAX-SLI	20*	32*	0.28	17	1 *	1.09	18	1 *				1.37	15
SLI-POM	33*	29*	0.07	7	*	1.35	19	1 *				1.42	16
VNY-FIM	50*	65*	0.58	21	1 3*	1.70	20	1 3*				2.28	17
VTU-OCN	65*	65*	1.58	23	123*	1.09	17	1 3*				2.67	18
SLI-ONT	45*	35*	2.87	25	1 3*	0.78	15	1 *				3.65	19
LAX-VTU	48*	65*	0.64	22	1 3*	4.79	22	1 3*				5.43	20
VNY-SLI	32*	45*	0.08	9	*	8.26	23	1 3*				8.34	21
SLI-OCN	65*	49*	0.50	20	123*	8.54	24	1 3*				9.04	22
FIM-SLI	50*	65*	0.23	15	1 3*	17.10	25	1 3*				17.33	23
VNY-OCN	65*	49*	0.27	16	123*	22.46	26	1 3*				22.73	24
SLI-VTU	48*	65*	27.34	27	1 3*	0.46	13	1 3*				27.79	25
LAX-OCN	65*	49*	5.50	26	123*	25.82	27	1 3*				31.32	26
LAX-FIM	50*	65*	30.45	28	1 3*	4.54	21	1 3*				34.99	27
FIM-OCN	65*	65*	2.63	24	123*	38.39	28	1 3*				41.02	28

FIGURE 2-9 - RANKING ORDER OF VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO ORANGE COUNTY APPROVED ROUTE

PROJECT 330-014-04X

V/STOL AREA NAVIGATION DME/DME COVERAGE

APPROVED IFR VTOL ROUTE JOR-LAX CROSS COURSE 2 (SD)**2 PAGE 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX				2 (SD)**2																TOTAL	RANK
	28	31	30	7	28- 31			31- 30			30- 7			7- 1			-	-				
VNY-POM	46	39	34	33	0.07	13	3	0.05	7		0.05	3		0.05	2						0.21	1
POM-OCN	40	45	62	66	0.06	12	3	0.05	6	3	0.04	1	23	0.06	8	23					0.21	2
SLI-POM	27	23	22	33	0.06	11		0.05	5		0.05	2		0.07	9	1					0.22	3
FIM-POM	56	58	53	39	0.06	10	3	0.04	4	3	0.05	4	3	0.08	10	1					0.22	4
VNY-ONT	46	39	34	45	0.04	2	3	0.05	8		0.10	10	1	0.06	7	1	3				0.25	5
ONT-OCN	40	45	62	66	0.04	3	3	0.05	9	3	0.08	9	123	0.08	11	23					0.26	6
SLI-ONT	25	27	34	45	0.04	4		0.05	10		0.06	6		0.11	13	1	3				0.27	7
FIM-ONT	56	58	53	45	0.04	5	3	0.06	11	3	0.15	13	1	3	0.14	14	1	3			0.39	8
POM-VTU	65	58	53	42	0.05	6	3	0.04	2	3	0.06	7	1	3	0.44	21	1	3			0.58	9
POM-ONT	27	27	34	45	0.03	1		0.02	1		0.06	5	1		0.71	22	1	3			0.81	10
VNY-VTU	65	58	53	42	0.45	14	1 3	0.36	14	1 3	0.21	16	1	3	0.05	4	1	3			1.06	11
LAX-POM	33	25	22	33	0.35	9		0.04	3		0.35	19	1		0.93	23	1				1.37	12
VTU-OCN	65	58	62	66	0.64	15	1 3	0.52	16	1 3	0.20	15	123		0.11	12	123				1.46	13
LAX-VNY	46	39	34	18	0.80	17	1 3	0.52	15	1	0.14	12	1		0.04	1					1.50	14
SLI-VTU	65	58	53	42	0.66	16	1 3	0.53	17	1 3	0.10	11	1	3	0.35	19	1	3			1.65	15
LAX-OCN	40	45	62	66	1.30	19	1 3	0.83	18	1 3	0.15	14	123		0.05	3	23				2.34	16
LAX-SLI	33	25	21	21	1.38	20	1	0.88	20	1	0.08	8	1		0.05	5					2.39	17
FIM-VTU	66	58	53	42	1.05	18	1 3	0.85	19	1 3	0.40	20	1	3	0.15	17	1	3			2.45	18
LAX-ONT	33	27	34	45	0.05	7		0.07	12		2.47	25	1		0.21	18	1	3			2.80	19
LAX-FIM	56	58	53	39	2.87	21	1 3	1.60	21	1 3	0.26	17	1	3	0.05	6					4.78	20
VNY-FIM	66	58	53	39	3.48	22	1 3	2.69	22	1 3	2.20	24	1	3	0.14	15	1				8.51	21
VNY-SLI	46	39	34	21	13.44	25	1 3	10.03	23	1	0.84	21	1		0.43	20	1				24.74	22
FIM-OCN	66	58	62	66	12.34	24	1 3	10.40	24	1 3	2.16	23	123		3.52	27	123				28.41	23
FIM-SLI	56	58	53	39	14.55	26	1 3	11.98	27	1 3	0.32	18	1	3	2.41	25	1				29.26	24
ONT-VTU	65	58	53	45	0.05	8	3	0.08	13	3	8.48	26	1	3	29.04	28	1	3			37.65	25
LAX-VTU	65	58	53	42	6.85	23	1 3	11.97	26	1 3	21.24	27	1	3	0.15	16	1	3			40.21	26
VNY-OCN	46	45	62	66	16.23	27	1 3	11.30	25	1 3	59.73	28	123		1.05	24	123				88.31	27
SLI-OCN	40	45	62	66	261.22	28	1 3	261.22	28	1 3	1.06	22	123		2.80	26	123				526.30	28

FIGURE 2-10 - RANKING ORDER OF VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER ORANGE COUNTY TO LOS ANGELES APPROVED ROUTE

PROJECT 330-014-04X

V/STOL AREA NAVIGATION DME/DME COVERAGE

APPROVED IFR VTOL ROUTE LAX-ANA CROSS COURSE 2 (SD)**2 PAGE 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX				2 (SD)**2				TOTAL	RANK
	1	25			1- 25		25- 26			
VNY-POM	35	38			0.04	1	0.05	13	0.09	1
FIM-POM	55	58			0.06	3 3	0.05	10 3	0.11	2
POM-OCN	65	45			0.06	2 23	0.07	16 3	0.13	3
VNY-ONT	45	38			0.09	4 1 3	0.05	11	0.14	4
POM-VTU	57	59			0.13	6 1 3	0.03	3 3	0.16	5
ONT-OCN	65	45			0.12	5 123	0.04	9 3	0.17	6
FIM-ONT	55	58			0.15	7 1 3	0.05	12 3	0.20	7
LAX-POM	33	26			0.18	10 1	0.03	2	0.21	8
SLI-ONT	45	21			0.17	9 1 3	0.14	19 1	0.31	9
LAX-OCN	65	45			0.20	11 123	0.12	18 1 3	0.32	10
LAX-SLI	25	26			0.32	13 1	0.04	4	0.35	11
LAX-VNY	35	38			0.15	8 1	0.22	21 1	0.37	12
POM-ONT	45	21			0.38	16 1 3	0.03	1	0.41	13
VTU-OCN	65	59			0.33	15 123	0.15	20 1 3	0.47	14
VNY-VTU	57	59			0.21	12 1 3	0.30	22 1 3	0.51	15
LAX-FIM	55	58			0.32	14 1 3	0.33	23 1 3	0.65	16
ONT-VTU	57	59			0.66	18 1 3	0.06	14 3	0.72	17
SLI-POM	33	17			0.78	19 1	0.07	17 1	0.85	18
FIM-VTU	57	59			0.53	17 1 3	0.51	24 1 3	1.04	19
SLI-VTU	57	59			1.05	20 1 3	0.04	5 3	1.08	20
LAX-ONT	44	26			1.73	22 1 3	0.07	15 1	1.80	21
VNY-SLI	35	38			4.29	23 1	0.04	7	4.33	22
VNY-FIM	55	58			1.61	21 1 3	4.74	27 1 3	6.35	23
FIM-SLI	55	58			10.17	25 1 3	0.04	6 3	10.21	24
SLI-OCN	65	45			10.46	26 123	0.04	8 3	10.50	25
LAX-VTU	57	59			5.59	24 1 3	9.56	28 1 3	15.15	26
VNY-OCN	65	45			13.97	27 123	1.25	26 1 3	15.22	27
FIM-OCN	65	58			24.43	28 123	0.55	25 1 3	24.99	28

FIGURE 2-11 - RANKING ORDER OF VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO ANAHEIM APPROVED ROUTE

PROJECT 330-014-04X
V/STOL AREA NAVIGATION DME/DME COVERAGE

APPROVED IFR VTOL ROUTE JOR-LAX CROSS COURSE 2 (SD)**2 PAGE 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX			2 (SD)**2				TOTAL	RANK
	27*	25*	17*						
	25*	17*	1*						
				27- 25	25- 17	17- 1			
VNY-POM	45*	35*	33*	0.07 12 3*	0.04 8 *	0.06 1 *		0.17	1
FIM-POM	65*	55*	49*	0.06 10 3*	0.03 7 3*	0.08 4 3*		0.18	2
POM-OCN	46*	53*	66*	0.09 13 1 3*	0.05 11 3*	0.06 2 23*		0.20	3
ONT-OCN	46*	53*	66*	0.04 2 3*	0.07 12 3*	0.11 8 123*		0.22	4
SLI-ONT	22*	24*	45*	0.06 11 1 *	0.03 5 *	0.13 9 1 3*		0.22	5
VNY-ONT	45*	35*	45*	0.04 3 3*	0.11 16 1 *	0.13 10 1 3*		0.29	6
POM-VTU	65*	57*	53*	0.04 5 3*	0.03 3 3*	0.24 14 1 3*		0.31	7
LAX-OCN	46*	53*	66*	0.22 16 1 3*	0.07 13 3*	0.09 6 123*		0.38	8
FIM-ONT	65*	55*	49*	0.04 1 3*	0.14 18 1 3*	0.24 15 1 3*		0.42	9
VTU-OCN	65*	57*	66*	0.20 15 1 3*	0.11 15 1 3*	0.20 13 123*		0.51	10
LAX-VNY	45*	35*	28*	0.36 19 1 3*	0.12 17 1 *	0.08 5 1 *		0.56	11
POM-ONT	24*	24*	45*	0.05 8 *	0.03 2 *	0.55 17 1 3*		0.62	12
VNY-VTU	65*	57*	53*	0.33 18 1 3*	0.27 20 1 3*	0.17 12 1 3*		0.77	13
LAX-FIM	65*	55*	49*	0.72 22 1 3*	0.15 19 1 3*	0.14 11 1 3*		1.00	14
FIM-VTU	65*	57*	53*	0.61 20 1 3*	0.40 22 1 3*	0.39 16 1 3*		1.39	15
LAX-POM	32*	25*	33*	0.04 6 *	0.02 1 1 *	1.89 20 1 *		1.96	16
VNY-SLI	45*	35*	28*	0.25 17 1 3*	0.05 10 *	2.36 22 1 *		2.65	17
SLI-POM	24*	15*	33*	0.05 9 1 *	4.14 26 1 *	0.07 3 1 *		4.26	18
FIM-SLI	65*	55*	49*	0.64 21 1 3*	0.04 9 3*	5.84 25 1 3*		6.52	19
LAX-ONT	32*	25*	45*	0.04 7 1 *	4.45 27 1 *	2.51 23 1 3*		7.00	20
SLI-OCN	46*	53*	66*	0.17 14 1 3*	0.08 14 1 3*	7.77 26 123*		8.01	21
VNY-OCN	46*	53*	66*	4.69 25 1 3*	0.58 23 1 3*	5.55 24 123*		10.82	22
SLI-VTU	65*	57*	53*	10.70 26 1 3*	0.03 6 3*	0.56 18 1 3*		11.29	23
FIM-OCN	65*	55*	66*	0.95 23 1 3*	0.35 21 1 3*	11.04 27 123*		12.35	24
VNY-FIM	65*	55*	49*	4.28 24 1 3*	7.46 28 1 3*	1.98 21 1 3*		13.72	25
LAX-SLI	32*	25*	21*	16.42 27 1 *	0.03 4 *	0.09 7 1 *		16.55	26
ONT-VTU	65*	57*	53*	0.04 4 3*	4.04 25 1 3*	15.36 28 1 3*		19.44	27
LAX-VTU	65*	57*	53*	42.92 28 1 3*	0.80 24 1 3*	0.65 19 1 3*		44.37	28

FIGURE 2-12 - RANKING ORDER OF VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER ORANGE COUNTY/ANAHEIM TO LOS ANGELES APPROVED ROUTE

PROJECT 330-014-04X
V/STOL AREA NAVIGATION DME/DME COVERAGE

APPROVED IFR VTOL ROUTE LAX-SBD CROSS COURSE 2 (SD)**2 PAGE 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX					2 (SD)**2																			TOTAL	RANK
	1*	7*	9*	10*	11*	1- 7			7- 9			9- 10			10- 11			11- 13			-				
	*	*	*	*	*																					
LAX-OCN	65*	62*	57*	53*	60*	0.05	2	23*	0.05	5	23*	0.04	4	3*	0.04	2	3*	0.04	3	3*					0.22	1
POM-OCN	66*	62*	57*	53*	53*	0.06	7	23*	0.07	8	23*	0.05	6	3*	0.04	3	3*	0.04	4	3*					0.25	2
VTU-OCN	66*	62*	63*	80*	90*	0.10	12	123*	0.09	10	23*	0.06	7	3*	0.04	4	3*	0.04	5	3*					0.33	3
ONT-OCN	66*	62*	57*	53*	53*	0.08	11	23*	0.11	12	123*	0.09	12	3*	0.08	11	1 3*	0.03	1	1 3*					0.39	4
SLI-ONT	45*	34*	26*	37*	44*	0.10	13	1 3*	0.05	4	*	0.04	2	*	0.05	7	1 *	0.30	16	1 3*					0.54	5
LAX-ONT	45*	34*	33*	51*	60*	0.21	18	1 3*	0.19	14	1 *	0.15	14	1 *	0.06	8	3*	0.11	12	1 3*					0.71	6
SLI-POM	33*	21*	22*	37*	44*	0.07	9	1 *	0.04	2	*	0.07	9	*	0.27	17	1 *	0.35	17	1 3*					0.80	7
SLI-VTU	42*	51*	63*	80*	90*	0.30	19	1 3*	0.04	3	3*	0.06	8	3*	0.16	16	1 3*	0.25	15	1 3*					0.81	8
VNY-SLI	21*	25*	36*	53*	62*	0.43	20	1 *	0.06	7	1 *	0.05	5	*	0.11	15	1 3*	0.18	14	1 3*					0.82	9
LAX-SLI	21*	21*	33*	51*	60*	0.05	4	*	0.04	1	*	0.09	13	1 *	0.35	19	1 3*	0.58	19	1 3*					1.11	10
LAX-FIM	39*	46*	57*	73*	83*	0.06	6	*	0.11	13	1 3*	0.20	15	1 3*	0.35	18	1 3*	0.52	18	1 3*					1.23	11
VNY-OCN	66*	62*	57*	53*	62*	1.10	24	123*	0.27	18	123*	0.08	10	1 3*	0.04	5	3*	0.04	6	3*					1.53	12
LAX-VNY	18*	25*	36*	53*	62*	0.04	1	*	0.10	11	1 *	0.22	16	1 *	0.49	21	1 3*	0.78	20	1 3*					1.64	13
POM-ONT	45*	34*	26*	18*	27*	0.70	22	1 3*	0.57	22	1 *	0.25	17	1 *	0.06	9	*	0.09	11	1 *					1.67	14
FIM-POM	39*	46*	56*	73*	83*	0.08	10	1 *	0.23	17	1 3*	0.34	18	1 3*	0.46	20	1 3*	1.02	21	1 3*					2.13	15
FIM-SLI	39*	46*	57*	73*	83*	2.43	25	1 *	0.05	6	3*	0.04	3	3*	0.10	13	1 3*	0.15	13	1 3*					2.77	16
SLI-OCN	66*	62*	57*	53*	53*	2.74	26	123*	0.09	9	123*	0.03	1	3*	0.04	1	3*	0.03	2	3*					2.92	17
VNY-POM	33*	25*	35*	53*	62*	0.05	3	*	0.19	16	1 *	0.40	19	1 *	0.70	22	1 3*	1.89	23	1 3*					3.22	18
FIM-OCN	66*	62*	57*	73*	83*	3.57	27	123*	0.19	15	123*	0.08	11	1 3*	0.04	6	3*	0.04	7	3*					3.92	19
LAX-VTU	42*	51*	63*	80*	90*	0.15	15	1 3*	0.34	19	1 3*	0.67	21	1 3*	1.23	23	1 3*	1.83	22	1 3*					4.22	20
FIM-VTU	42*	51*	63*	80*	90*	0.15	17	1 3*	0.53	21	1 3*	0.85	22	1 3*	1.47	24	1 3*	2.27	24	1 3*					5.27	21
VNY-VTU	42*	51*	63*	80*	90*	0.05	5	1 3*	0.40	20	1 3*	1.13	23	1 3*	3.50	26	1 3*	6.21	25	1 3*					11.29	22
POM-VTU	42*	51*	63*	80*	90*	0.45	21	1 3*	1.77	25	1 3*	2.45	24	1 3*	2.29	25	1 3*	11.78	27	1 3*					18.75	23
LAX-POM	33*	21*	33*	51*	60*	0.89	23	1 *	1.03	23	1 *	2.81	25	1 *	17.84	28	1 3*	7.72	26	1 3*					30.29	24
ONT-VTU	45*	51*	63*	80*	90*	28.30	28	1 3*	3.45	27	1 3*	0.56	20	1 3*	0.07	10	1 3*	0.08	10	1 3*					32.46	25
VNY-ONT	45*	34*	36*	53*	62*	0.06	8	1 3*	1.47	24	1 *	32.15	26	1 *	0.09	12	1 3*	0.07	9	1 3*					33.84	26
FIM-ONT	45*	46*	57*	73*	83*	0.14	14	1 3*	2.20	26	1 3*	39.89	27	1 3*	0.10	14	1 3*	0.06	8	3*					42.40	27
VNY-FIM	39*	46*	57*	73*	83*	0.15	16	1 *	48.98	28	1 3*	95.19	28	1 3*	13.22	27	1 3*	14.54	28	1 3*					172.08	28

FIGURE 2-13 - RANKING ORDER OF VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO SAN BERNARDINO APPROVED ROUTE

PROJECT 330-014-24X
V/STOL AREA NAVIGATION DME/DME COVERAGE

DIRECT VTOL ROUTE LAX-VNY CROSS COURSE 2 (SD)**2 PAGE 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX			2 (SD)**2									TOTAL	RANK
	70	71	72	70- 71			71- 72			72- 73				
	70	71	72											
	71	72	73											
VNY-POM	34	35	36	0.04	2		0.04	3		0.05	8		0.14	1
LAX-POM	34	35	36	0.04	1		0.04	4		0.05	9		0.14	2
LAX-VTU	32	29	29	0.05	8		0.04	2		0.04	2		0.14	3
VNY-VTU	33	29	29	0.05	9		0.04	1		0.04	1		0.14	4
VNY-ONT	47	49	51	0.05	6	3	0.05	5	3	0.06	10	3	0.16	5
LAX-ONT	47	49	51	0.05	7	3	0.05	6	3	0.06	11	3	0.16	6
SLI-POM	34	35	36	0.04	4		0.07	11		0.09	14		0.20	7
POM-OCN	72	76	80	0.04	3	23	0.07	9	23	0.09	15	23	0.20	8
FIM-VTU	34	29	29	0.12	17	1	0.07	10		0.04	5		0.23	9
VTU-OCN	72	76	80	0.15	18	123	0.06	7	23	0.04	4	23	0.25	10
ONT-OCN	72	76	80	0.08	13	23	0.12	15	123	0.17	17	123	0.37	11
SLI-ONT	47	49	51	0.10	14	1 3	0.13	16	1 3	0.15	16	1 3	0.38	12
LAX-FIM	33	27	23	0.19	21	1	0.12	14	1	0.08	13		0.40	13
VNY-FIM	34	27	23	0.20	22	1	0.12	13	1	0.08	12		0.40	14
FIM-POM	34	35	36	0.04	5		0.08	12	1	0.29	22	1	0.42	15
SLI-VTU	33	31	34	0.37	23	1	0.06	8		0.04	3		0.47	16
VNY-SLI	26	31	34	0.11	15	1	0.18	17	1	0.24	20	1	0.54	17
LAX-SLI	26	31	34	0.11	16	1	0.18	18	1	0.25	21	1	0.54	18
VNY-OCN	72	76	80	0.16	19	123	0.19	19	123	0.22	18	123	0.57	19
LAX-OCN	72	76	80	0.16	20	123	0.19	20	123	0.22	19	123	0.57	20
POM-ONT	47	49	51	0.06	10	1 3	0.26	23	1 3	0.74	25	1 3	1.06	21
POM-VTU	34	35	36	0.07	11	1	2.32	24	1	0.05	7	1	2.43	22
FIM-ONT	47	49	51	0.08	12	1 3	0.21	21	1 3	2.48	26	1 3	2.76	23
ONT-VTU	47	49	51	4.56	25	1 3	0.24	22	1 3	0.04	6	1 3	4.85	24
FIM-SLI	34	31	34	14.57	26	1	15.87	26	1	0.35	23	1	30.78	25
FIM-OCN	72	76	80	45.17	27	123	3.19	25	123	0.40	24	123	48.76	26
SLI-OCN	72	76	80	3.90	24	123	114.40	27	123	66.79	27	123	185.09	27
LAX-VNY	17	13	17	261.22	28	1	261.22	28	1	261.22	28	1	783.67	28

FIGURE 2-14 - RANKING ORDER OF VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO VAN NUYS DIRECT ROUTE

PROJECT 330-014-04X

V/STOL AREA NAVIGATION DME/DME COVERAGE

DIRECT VTOL ROUTE LAX-ANA CROSS COURSE 2 (SD)**2 PAGE 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX						2 (SD)**2								TOTAL	RANK
	70*															
	77*															
							70- 77									
VNY-POM	58*						0.04	1							0.04	1
POM-OCN	65*						0.06	2	23*						0.06	2
FIM-POM	58*						0.06	3	3*						0.06	3
VNY-ONT	45*						0.08	4	3*						0.08	4
POM-VTU	59*						0.10	5	1 3*						0.10	5
LAX-POM	33*						0.11	6	1 *						0.11	6
ONT-OCN	65*						0.12	7	123*						0.12	7
FIM-ONT	58*						0.13	8	1 3*						0.13	8
LAX-VNY	38*						0.20	9	1 *						0.20	9
VNY-VTU	59*						0.23	10	1 3*						0.23	10
SLI-POM	33*						0.27	11	1 *						0.27	11
POM-ONT	45*						0.31	12	1 3*						0.31	12
LAX-OCN	65*						0.32	13	123*						0.32	13
VTU-OCN	65*						0.39	14	123*						0.39	14
ONT-VTU	59*						0.46	15	1 3*						0.46	15
LAX-FIM	58*						0.48	16	1 3*						0.48	16
FIM-VTU	59*						0.59	17	1 3*						0.59	17
LAX-ONT	44*						0.59	18	1 3*						0.59	18
LAX-SLI	26*						0.78	19	1 *						0.78	19
SLI-VTU	59*						1.49	20	1 3*						1.49	20
VNY-FIM	58*						1.59	21	1 3*						1.59	21
SLI-ONT	45*						4.12	22	1 3*						4.12	22
VNY-SLI	38*						4.25	23	1 *						4.25	23
SLI-OCN	65*						9.52	24	123*						9.52	24
FIM-SLI	58*						10.60	25	1 3*						10.60	25
VNY-OCN	65*						18.30	26	123*						18.30	26
FIM-OCN	65*						31.14	27	123*						31.14	27
LAX-VTU	59*						44.57	28	1 3*						44.57	28

FIGURE 2-15 - RANKING ORDER OF VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO ANAHEIM DIRECT ROUTE

PROJECT 330-014-C4X
V/STOL AREA NAVIGATION DME/DME COVERAGE

DIRECT VTOL ROUTE LAX-JOR CROSS COURSE 2 (SD)**2 PAGE 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX 70	R MAX 78	70- 78	1	2	3	2 (SD)**2	TOTAL	RANK
VNY-POM	45		0.04			3		0.04	1
FIM-POM	65		0.05		2	3		0.05	2
POM-OCN	65		0.05		3	23		0.05	3
VNY-ONT	45		0.06		4	3		0.06	4
LAX-POM	33		0.06	5	1			0.06	5
POM-VTU	65		0.07	6	1	3		0.07	6
SLI-POM	33		0.07	7	1			0.07	7
FIM-ONT	65		0.09	8	1	3		0.09	8
ONT-OCN	65		0.10	9	123			0.10	9
LAX-ONT	45		0.16	10	1	3		0.16	10
POM-ONT	45		0.19	11	1	3		0.19	11
ONT-VTU	65		0.24	12	1	3		0.24	12
VNY-VTU	65		0.26	13	1	3		0.26	13
LAX-VNY	45		0.38	14	1	3		0.38	14
SLI-ONT	45		0.49	15	1	3		0.49	15
VTU-OCN	65		0.63	16	123			0.63	16
FIM-VTU	65		0.71	17	1	3		0.71	17
LAX-OCN	65		1.29	18	123			1.29	18
LAX-FIM	65		1.39	19	1	3		1.39	19
VNY-FIM	65		1.66	20	1	3		1.66	20
VNY-SLI	45		4.32	21	1	3		4.32	21
SLI-OCN	65		6.03	22	123			6.03	22
LAX-SLI	32		8.66	23	1			8.66	23
LAX-VTU	65		8.74	24	1	3		8.74	24
FIM-SLI	65		14.42	25	1	3		14.42	25
VNY-OCN	65		28.28	26	123			28.28	26
SLI-VTU	65		35.76	27	1	3		35.76	27
FIM-OCN	65		54.06	28	123			54.06	28

FIGURE 2-16 - RANKING ORDER OF VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO ORANGE COUNTY DIRECT ROUTE

PROJECT 330-014-04X
V/STOL AREA NAVIGATION DME/DME COVERAGE
****
DIRECT VTOL ROUTE LAX-SBD CROSS COURSE 2 (SD)**2 PAGE 1 OF 1

1 = AC OR CC FLAG
2 = R GREATER THAN LINE OF SIGHT
3 = R GREATER THAN 40 N.M.

	R MAX			70- 74			74- 75			75- 76			2 (SD)**2			TOTAL	RANK
	70*	74*	75*														
	74*	75*	76*														
LAX-OCN	65*	54*	60*	0.08	4	23*	0.05	2	3*	0.04	5	3*				0.17	1
ONT-OCN	66*	54*	51*	0.11	8	123*	0.07	7	3*	0.06	7	1 3*				0.24	2
VTU-OCN	66*	67*	90*	0.18	13	123*	0.06	6	3*	0.04	3	3*				0.28	3
POM-OCN	66*	54*	51*	0.06	2	23*	0.22	15	1 3*	0.04	4	3*				0.32	4
SLI-ONT	45*	24*	44*	0.13	10	1 3*	0.05	3	*	0.31	16	1 3*				0.48	5
SLI-VTU	52*	67*	90*	0.48	17	1 3*	0.08	9	1 3*	0.26	15	1 3*				0.82	6
LAX-SLI	21*	36*	60*	0.08	6	1 *	0.13	14	1 *	0.61	19	1 3*				0.82	7
LAX-FIM	49*	61*	83*	0.12	9	1 3*	0.26	16	1 3*	0.47	18	1 3*				0.85	8
LAX-VNY	28*	41*	62*	0.08	5	1 *	0.26	17	1 3*	0.65	20	1 3*				1.00	9
LAX-ONT	44*	36*	60*	1.48	20	1 3*	0.35	19	1 *	0.11	11	1 3*				1.95	10
VNY-SLI	28*	41*	62*	2.04	21	1 *	0.05	5	3*	0.17	13	1 3*				2.26	11
POM-ONT	45*	24*	27*	0.56	19	1 3*	2.06	23	1 *	0.32	17	1 *				2.94	12
FIM-VTU	52*	67*	90*	0.37	16	1 3*	0.88	20	1 3*	1.74	21	1 3*				2.98	13
LAX-VTU	52*	67*	90*	0.55	18	1 3*	1.11	22	1 3*	1.94	23	1 3*				3.61	14
SLI-POM	33*	23*	44*	0.07	3	1 *	3.73	24	1 *	0.25	14	1 3*				4.05	15
VNY-VTU	52*	67*	90*	0.17	12	1 3*	0.95	21	1 3*	3.64	24	1 3*				4.75	16
VNY-OCN	66*	54*	62*	4.87	24	123*	0.08	10	1 3*	0.04	2	3*				4.99	17
FIM-SLI	49*	61*	83*	5.41	25	1 3*	0.05	4	3*	0.14	12	1 3*				5.60	18
LAX-POM	33*	36*	60*	3.64	23	1 *	0.28	18	1 *	1.85	22	1 3*				5.77	19
SLI-OCN	66*	54*	51*	6.87	26	123*	0.03	1	3*	0.04	6	3*				6.95	20
FIM-OCN	66*	61*	83*	10.02	27	123*	0.08	8	1 3*	0.04	1	3*				10.14	21
FIM-POM	49*	61*	83*	0.09	7	3*	0.09	12	1 3*	14.11	25	1 3*				14.29	22
VNY-POM	33*	41*	62*	0.06	1	*	0.09	11	1 3*	20.81	26	1 3*				20.95	23
VNY-ONT	45*	41*	62*	0.15	11	1 3*	20.84	26	1 3*	0.09	9	1 3*				21.08	24
FIM-ONT	49*	61*	83*	0.27	15	1 3*	23.83	27	1 3*	0.10	10	1 3*				24.20	25
ONT-VTU	52*	67*	90*	39.70	28	1 3*	6.23	25	1 3*	0.09	8	1 3*				46.03	26
POM-VTU	52*	67*	90*	0.26	14	1 3*	0.12	13	1 3*	92.96	28	1 3*				93.34	27
VNY-FIM	49*	61*	83*	2.26	22	1 3*	123.25	28	1 3*	22.83	27	1 3*				148.33	28

FIGURE 2-17 - RANKING ORDER OF VORTAC GUIDANCE STATION PAIRS FOR DME/DME AREA NAVIGATION OVER LOS ANGELES TO SAN BERNARDINO DIRECT ROUTE