ORDER

6750.16D

SITING CRITERIA
FOR
INSTRUMENT LANDING SYSTEMS

February 14, 2005

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

Distribution: A-WXYZ-1; A-FFS-0 (SUPV); A-FIA-0 (SUPV) A-FAS-1 (SUPV); A-FAT-2 (SUPV); A-FAF-0 (LTD)

Initiated By: Technical Operations (AND-720)

RECORD OF CHANGES

DIRECTIVE NO **6750.16D**

CHANGE TO BASIC	SUPPLEMENT			OPTIONAL	CHANGE TO BASIC	SUPPLEMENT			OPTIONAL

FAA FORM 1320-5 (6-80) USE PREVIOUS EDITION

FOREWORD

The material in this order is a result of a total revision of Order 6750.16C. The purpose of the revision is to delete obsolete material that addressed antenna systems and other units that are no longer used, certain practices and requirements that are no longer required, and items of a similar nature.

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CHAPTER 1. GENERAL INFORMATION

1-1. PURPOSE

This order provides guidance to engineering personnel engaged in the siting of Federal Aviation Administration (FAA) instrument landing systems (ILS). Sufficient information, supplemented by relevant drawings, will enable the engineer to select the optimum site, within defined limits, for each of the subsystems that comprise a Category I, II, or III ILS. Because of the wide variation in ILS siting conditions, it is not possible to provide specific instructions on how to overcome or offset the effects of each adverse condition. This order provides guidelines that must be used in conjunction with a thorough understanding of ILS facility operations to arrive at the optimum site and operating parameters.

1-2. DISTRIBUTION

This order is distributed to all heads of offices and services in Washington headquarters, the regions, the Mike Monroney Aeronautical Center, and the William J. Hughes Technical Center; to all supervisors in the Flight Standards Field Offices, International Aviation Field Offices, Airports Field Offices, and Air Traffic Airport Traffic Control Tower Field Offices; and to all Airway Facilities field offices with a limited distribution.

1-3. CANCELLATION

Order 6750.16C, Siting Criteria for Instrument Landing Systems, dated October 31, 1995 is cancelled.

1-4. EXPLANATION OF CHANGES

This revision provides updates and clarification to criteria throughout the Order and deletes material that has become obsolete. Some of the more significant changes include the following:

a. Para 1-13 Computer Modeling. Introduced as an aid in predicting multipath interference sources on an ILS performance.

b. Para 1-14 Interlock. Requirements clarified.

c. Para 1-15 Critical Areas. Clarifications, adds flexibility, reduces areas behind and adjacent to unidirectional localizer antenna arrays.

d. Para 1-16 ILS Shelters. Provides criteria regarding size and material.

e. Para 2-4 Antenna Descriptions. Updated antenna types to those currently available.

f. Para 2-5 Localizer Siting Requirements. Clarified minimum distance criteria and revised antenna height guidance.

g. Para 2-7 Abnormal Case Modulation. Documents the 60 percent maximum requirement on received localizer modulation.

h. Para 3-2 Glide Slope Antenna Array Types. New section describing relative siting considerations for the various glide slope antenna configurations.

i. Para 3-7 GS Location. Updated to new lateral distance criteria with distinction between Cat I and Cat II/III.

j. Para 5-1 Remote Status. Updated to include remote status requirements on all categories of ILS and the limited role of Remote Maintenance Monitoring (RMM).

k. Appendix 4 RDH/ARDH Considerations. Flight Inspection measurements and their impact on glide slope threshold crossing height.

1-5. APPLICATION

The criteria set forth in this Order apply only to new establishments or relocated ILS facilities to include Localizer, Glide Slope, Marker Beacon, Localizer Type Directional Aids, and Offset Localizers. Additional criteria are presented for Non-Directional Beacon and Distance Measuring Equipment specific to collocation with ILS facilities. Changes to existing facilities for the sole purpose of obtaining compliance with these criteria are not required but are acceptable.

1-6. DIRECTIVE VERBS

The material in this Order contains FAA criteria, recommended practices, and other guidance material, which require the use of certain directive verbs such as, **MUST, SHOULD, WILL,** and **MAY.** In this Order the explicit meaning of the verbs is as follows:

a. MUST. The action is mandatory. For example: "The localizer station **MUST** automatically shutdown if the monitor detects an out-of-tolerance condition."

b. SHOULD. The action is desirable or recommended. For example: "The glide slope **SHOULD** be located 400 feet from the runway centerline."

c. WILL. The action is to be taken in the future. For example: "Some facilities **WILL** be programmed for upgrading to provide Category II performance.

d. MAY. The action is permissible. For example: "Parking of unattended vehicles or aircraft within this area is prohibited at all times, except for maintenance technician vehicles, which MAY be parked adjacent to the equipment shelter."

1-7. PROCEDURES

a. Safety. Personnel must use caution in working on ILS equipment, particularly radio transmitters, since the voltages presented are dangerous to life. Observance of precautions necessary to avoid electrical shock is the direct responsibility of the individual. No one must perform work on the equipment without full knowledge of the dangers involved. An individual should not attempt work on high-voltage circuits without the services of an assistant.

b. Standards and Tolerances. The standards and tolerances for the ILS are contained in Order 6750.49 Maintenance of Instrument Landing Systems (ILS) Facilities, and the applicable instruction books. Note that for installation purposes, the initial tolerance must apply.

c. Airborne Performance Requirements. The airborne requirements in this Order are based on information available at the time of publication. FAA Order 8200.1 continues to be the final source for current airborne performance requirements.

NOTE: See Appendix 1 for glossary and acronyms.

1-8. INTRODUCTION

a. ILS Function. The ILS provides guidance to pilots of properly equipped aircraft to assist them in landing safely under conditions of reduced ceilings and lowered visibility. The use of an ILS materially aids the service to airports under all weather conditions.

b. Categorization of ILSs. The ILS is categorized according to the minimum visibility conditions under which aircraft landings are permissible. The criteria specified in this Order apply to Category I, Category II, and Category III systems.

c. ILS Siting and Installation. The goal of the ILS installation is to provide an all-weather ILS that, with the possible use of ancillary equipment, will provide information sufficient to guide the aircraft down to the runway and along the runway surface regardless of weather conditions. The ability to attain this objective depends to a great extent on the proper siting and performance of each ILS subsystem.

1-9. ILS ESTABLISHMENT CRITERIA

a. ILS Establishment Assignments. ILS establishment assignments are made by the Washington office from regional office selections in accordance with the current ILS establishment policy. Assignments should be supported by a fully documented staff study, including a benefit/cost analysis. Consideration is also given to the reduction in the existing landing minimums, which an ILS will permit. At some locations other factors may preclude any improvement in the minimums; however, the assignment may be approved on the basis of the improved margin of safety provided by an ILS.

b. Runway Selection Considerations. The particular runway that the ILS will serve is selected in conjunction with the airport assignment. This choice is based on the following considerations:

(1) Runway length and width.
(2) Compliance with the minimum obstruction clearance criteria.
(3) Alignment with respect to the prevailing low visibility wind.
(4) Orientation with respect to the traffic procedures of the airport and airway concerned.
(5) Missed approach procedures.

c. Physical Requirement Considerations. The location of the electronic systems should be considered when making the ILS runway selection. It is impractical to designate a runway for the establishment of an ILS without giving consideration to the physical space requirements, accessibility, and the operating environment for each of the subsystems. When these factors appear to negate the establishment of an ILS, the cost of providing satisfactory facility locations should be weighed against the improvement in weather minimums, safety, and service that the ILS will provide. Siting within restricted areas should only be considered when standard installations are not practical.

d. Back-course Coverage Considerations. The newer localizer antenna systems, using uni-directional antennas, will not provide a useable back-course. If an instrument approach is required in that direction, other means should be considered, such as 1) a facing localizer on the opposite end of the runway, or 2) a 14-element V-ring array, or 3) procedures based on other type navigational systems, or 4) modification to the uni-directional Log Periodic Dipole (LPD) antennas.

e. Equipment Type and Configuration Considerations. Equipment type and configuration used in ILS establishments should be carefully chosen for the environment in which it is installed. Consideration should be given not only to siting ILS equipment to account for current terrain, obstructions, etc., but also for airport expansion and other developments around the airport environment. Type and configuration include single versus dual frequency equipment, narrow versus wide aperture antenna arrays, capture-effect versus null-reference, etc. An example is the airport where a single frequency, narrow aperture, localizer will function satisfactorily, but airport plans indicate a large hangar construction project. In this example, the siting engineer should consider siting a more complex localizer system to protect future facility performance. The glide slope example can be more demanding. If a null-reference glide slope is sited and subsequent changes to the airport environment require change to a capture-effect configuration, the modification to capture-effect could involve more than simply reconfiguring the transmitting equipment. Since a capture-effect configuration requires an additional antenna and mast height, the modification could actually require moving the glide slope site to allow adequate clearance of the Obstacle-Free Zone (OFZ). In this example, major issues in the future can be avoided with prudent siting.

1-10. ILS COMPONENTS AS OBSTRUCTIONS

The siting engineer considers the effects of the ILS components themselves as obstructions. These considerations should include guidance given in FAA Order 8260.3, 14 CFR Part 77, and applicable Advisory Circulars such as AC 150/5300-13, 70/7460-1. Both the Airport division office and Regional flight procedures office should be consulted and provide approval and/or waiver for any penetrations as part of the required airspace review. Failure to obtain approval or a waiver will preclude installation of that component.

1-11. NATIONAL AIRSPACE SYSTEM CHANGE PROPOSAL (NCP)

If in the process of planning or locating the ILS facilities it is determined that the siting criteria set forth in this Order cannot be followed, an NCP must be submitted in conformance to the latest edition of Order 1800.66 National Airspace System Configuration Management. An NCP to the siting criteria should be submitted a minimum of 60 days prior to construction. The facility must not be commissioned without an approved NCP.

1-12. GENERAL DESCRIPTION OF THE ILS

The ILS provides the aircraft with three basic types of navigational information as outlined below.

a. Lateral Guidance. Lateral guidance information indicates to the aircraft whether it is to the right, left, or aligned with the approach course line. The ILS localizer provides this information.

b. Vertical Guidance. Vertical guidance information indicates the aircraft position above, below, or along the proper descent angle towards the runway touchdown point. The ILS glide slope provides this information.

c. Distance Information. Distance information allows determination of the aircraft's approximate distance from the runway threshold. This information is provided indirectly by the ILS outer, middle, and inner markers and/or directly by installation and use of distance measuring equipment (DME) in conjunction with the applicable instrument approach procedure chart.

d. Additional Equipment. Additional equipments supporting the ILS include Supplementary Aids, Monitor and Control Equipment, and Remote Maintenance Monitoring.

(1) Supplementary Aids. Compass locators are sometimes provided at the middle or outer marker sites to assist the aircraft in locating the ILS course. Other types of navigational aids may also be used for this purpose. Approach lighting systems with sequenced flashers and other visual aids are usually provided to work in conjunction with the ILS.

(2) Monitor and Control Equipment. Each ILS component is continuously monitored at the site with automatic equipment provided to shut down the facility if the signal parameters exceed established limits. Remote status indicators, located at a manned Air Traffic (AT) monitoring location, provide air traffic control (ATC) personnel with an indication of the system status at all times except when the status unit is located in a facility that is not manned 24 hours per day. At these locations, the ILS continues to operate, but the particular airport cannot be designated as an alternate flight terminus during the period of time the ILS components are not being remotely monitored. At some locations, remote control equipment is also provided to turn the equipment on and off from the remote monitor point (see Paragraph 5-1).

(3) Remote Maintenance Monitoring. Some ILS equipment provides for remote maintenance monitoring (RMM) capabilities, which allow the maintenance technician to perform most maintenance tasks remotely via a computer (see Paragraph 5-1.d). The RMM equipment can either be built into the ILS equipment, or may be retrofitted to existing ILS equipment (e.g., airport remote monitoring system – ARMS). Most RMM systems are designed to connect with the maintenance processor system (MPS) equipment. RMM does not fulfill the Air Traffic requirement regarding remote status and control capabilities. Typical RMM equipment will include environmental sensors.

1-13. SITING EFFECTS ON ILS OPERATIONS

The ability of each subsystem that comprises the ILS to provide reliable and accurate guidance information depends primarily upon the proper formation of its respective radiation patterns. The greatest detriment to the formation of the desirable patterns is the presence of reflecting objects such as uneven terrain, power lines, buildings, dense vegetation, ground vehicles, water, snow, and ice conditions, and aircraft moving in the vicinity of the sites. The following siting requirements for each type of facility should enable the responsible engineer to choose the optimum site. Math modeling techniques can be employed to predict the probable location, magnitude, and duration of ILS disturbances caused by multipath conditions, whether from structures or from aircraft of various sizes and orientation at different locations. Issues involved with these techniques are outlined below.

a. Computerized Math Models. Computerized math models are widely available and usable by personnel with a wide variety of experience levels; however, engineering knowledge of and judgment about the appropriate assumptions and limitations of the various models are required when applying such models to specific multipath environments. It should be noted that modeling results do not consider other operational issues such as snow banks, aircraft or vehicular movement, aircraft hold areas, or increase to aircraft taxi times due to ILS critical areas. Additionally, the modeling tends to simplify the topography and surrounding environment.

b. New Facility Math Modeling. For new siting, and particularly for challenging siting conditions, siting engineers with little modeling and validating field experience should be cautious about performing their own modeling. It is recommended that these engineers seek modeling assistance from the FAA Technical Center, outside engineering sources, or other more experienced FAA engineers for peer review of modeling results before making siting recommendations (see Appendix 2, Paragraph A2-2).

c. Existing Facility Math Modeling. Where an ILS has been installed and found satisfactory, computers and simulation techniques can be employed to predict the probable extent of ILS disturbance, which may arise as a result of proposed new construction. Wherever possible, the results of such computer-aided simulation should be validated by direct comparison with actual flight measurements of the results of new construction. Again, it is recommended that the engineer with little modeling and validating field experience should seek modeling assistance from the FAA Technical Center, outside engineering sources, or other more experienced FAA engineers.

1-14. MULTIPLE ILS ESTABLISHMENTS

When planning ILS establishments (full or partial) for airports already having one or more commissioned systems, consideration is given to the compatibility of the multiple systems, in addition to their individual compliance with the standard siting criteria (see Figure 1-1). This compatibility is assured to a great extent by assignment of non-interfering frequencies and distinctly different identification codes, and the development of standard instrument approach procedures for each of the multiple systems. When identical frequencies are used, or interference effects are encountered, an interlock system is also required.

a. Interlock requirements for multiple establishments. The installation of multiple ILSs at an airport may require an interlock system to prevent simultaneous radiation.

(1) Interlock System Requirements. An interlock system is required when:

(a) Two ILSs (full or partial) share a common frequency, regardless of runway geometry. The interlock is required to prevent destructive interference from simultaneous co-channel operation of the localizers and glide slopes.

(b) Facing localizers, on common or dissimilar frequencies, are installed on a common runway (see Figure 1-1B). The interlock is required to prevent destructive interference or aircraft receiver cross modulation effects during over flights, and must be installed and used to deactivate the localizer that serves the inactive runway.

(c) Interference effects, typically from aircraft receiver cross modulation, are encountered from other than co-channel or facing ILS facilities. Interlocking of these facilities is required on a case-by-case basis, based on frequency modeling, confirmed user reports, or flight inspection results (see Figure 1-1C).

(2) The interlock system must be:

(a) Remotely controlled.

(b) Interlock Activation Delayed. The ILS interlock system must have a 20-second (minimum) time delay for control point commands. This delay is from the time the active ILS shuts down to the time the newly selected ILS activates.

(c) Failsafe Designed. Failure of any interlock component to include the interfacility connection must ensure equipment shut down or no change in radiating status.

(3) Temporary override of interlock systems. Interlocked ILSs must not be active at the same time except when work is actually being performed and NOTAMS issued to properly address the possibility of hazardously misleading information (HMI). An interlock system must be utilized (refer to FAA Order 6750.49A, Paragraph 1-16) for operational conditions and requirements. Typical reasons for simultaneous operation include facility installation, maintenance, or flight inspections.

b. Non-interlock requirements for multiple establishments. In addition to any interlock requirements, consideration is given to simultaneous operation of markers for parallel approaches (see Figure 1-1A). The outer markers serving parallel runways, whether staggered or abeam of each other, are not always separated sufficiently to preclude interference at altitudes intended for use. If interference is unavoidable, the keyed identification of the two markers must be synchronized by the use of a single common keyer, and the operating frequencies must be separated by 8 kHz (i.e., 75.004 MHz. and 74.996 MHz). There are no additional criteria for the middle or inner markers in a parallel approach configuration, since the respective patterns at lower heights are non-interfering.

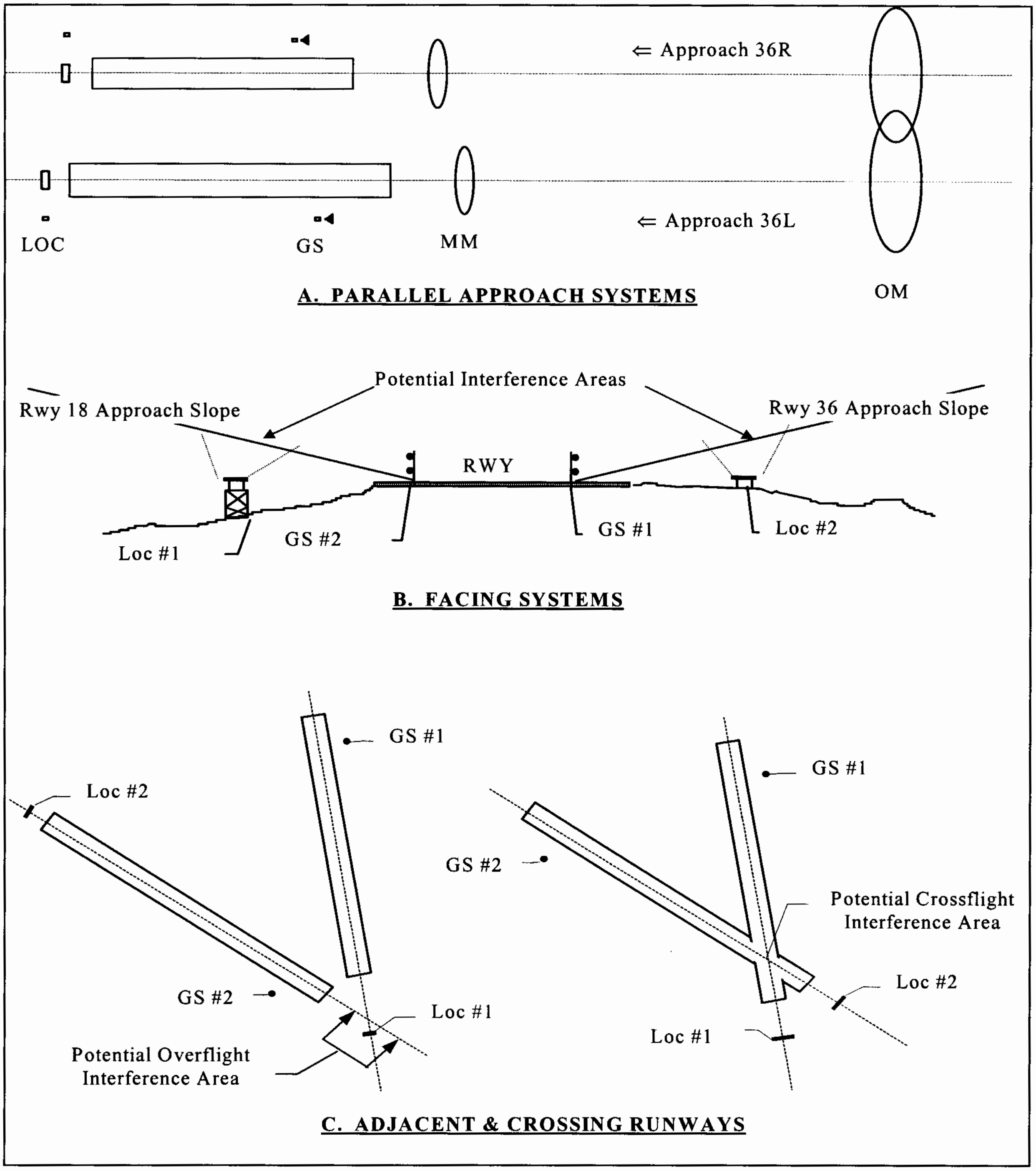


Figure 1-1. Multiple ILS Configurations

1-15. ILS CRITICAL AREAS

a. Definition. A critical area is a specific ground area near a radiating localizer or glide slope antenna array, which must be protected from aircraft and vehicle parking and the unlimited movement of surface and air traffic, to ensure the continuous integrity of the signal received by the user aircraft.

b. Application. The critical area is intended to protect the ILS facility from moving and stopped aircraft and vehicles, and does not apply to stationary objects whose permanent effects on the signals have been flight inspected.

(1) Evaluation of Permanent Objects. The possible deleterious effects of permanent objects planned for placement in the critical area should be analyzed and/or mathematically modeled prior to construction. If this is not possible prior to construction, a confirming flight inspection must be conducted to determine the effects, if any, on the ILS subsystems. Note that placing an object outside the critical area does not guarantee non-interference with the ILS signal in space.

(2) Critical Area Dimensions. Critical area dimensions have been determined for the different facility antenna configurations and categories of operation by mathematical modeling and empirical validation using various sized aircraft. For a particular localizer or glide slope installation, the critical area must be marked/signed according to the worst-case condition feasible in that portion of the overall critical area, i.e., Aircraft holdlines on taxiways may be more restrictive than those critical area signs installed to restrict access of mowers or maintenance vehicles.

(3) Critical Area Size Considerations. Critical area sizes need not be considered fixed for a particular localizer or glide slope. For example, although a 747 aircraft may routinely taxi near a glide slope, which has been marked for an appropriately large critical area, a grass mower, which has a much smaller profile, can penetrate the outer portions of the large (aircraft) critical area without significant effect. In this case, the mower need only remain outside the critical area boundaries defined for a small aircraft. FAA provided signage must be installed accordingly and maintained to control this smaller critical area from the penetration of surface vehicles.

(4) Allowance. Allowance can be made on a temporary basis to permit penetrations of the critical area based on engineering decisions (which may include modeling) regarding the specific vehicles and operations, with appropriate controls imposed.

(5) Longitudinal Axis. Critical area dimensions are based on the assumption that the entire longitudinal axis of the aircraft is clear of the critical area. For the purposes of this assumption, an aircraft whose longitudinal axis lies on the boundary of the critical area (e.g., where a taxiway centerline coincides with the critical area boundary) is not considered to be violating the critical area.

c. Localizer Critical Area. The critical area dimensions and the corresponding protection requirements depend on several factors. These include size and orientation of interfering parked or moving aircraft and vehicles, localizer course width, category of operation, and antenna directional characteristics.

(1) Localizer critical area dimensions are defined in Figure 1-2.

(2) Installation of the localizer antenna system on an elevated platform does not negate the requirements of the critical area.

(3) Localizer installations for public Category II or III approaches are not authorized using single frequency antenna arrays, as the critical areas become too large to feasibly protect.

d. Glide Slope Critical Area. As in the case of the localizer, the size of the glide slope critical area is affected by several factors including type of radiating array, category of operation, and size and orientation of interfering parked or moving aircraft and vehicles.

(1) The critical area for image glide slopes is identified in Figure 1-3.

(2) The critical area for endfire glide slopes is shown in Figure 1-4.

e. Critical Jet Blast Areas. In addition to safeguarding the ILS guidance information from surface traffic interference, the system must be protected from long term deterioration resulting from accumulation of jet engine exhaust residue. Therefore, jet aircraft must not be permitted to operate with its jet exhaust directed toward the facility, within 600 feet of the ILS equipment shelters, the localizer antenna array, or the glide slope antennas. This distance is measured from the individual ILS component to the nearest aircraft engine.

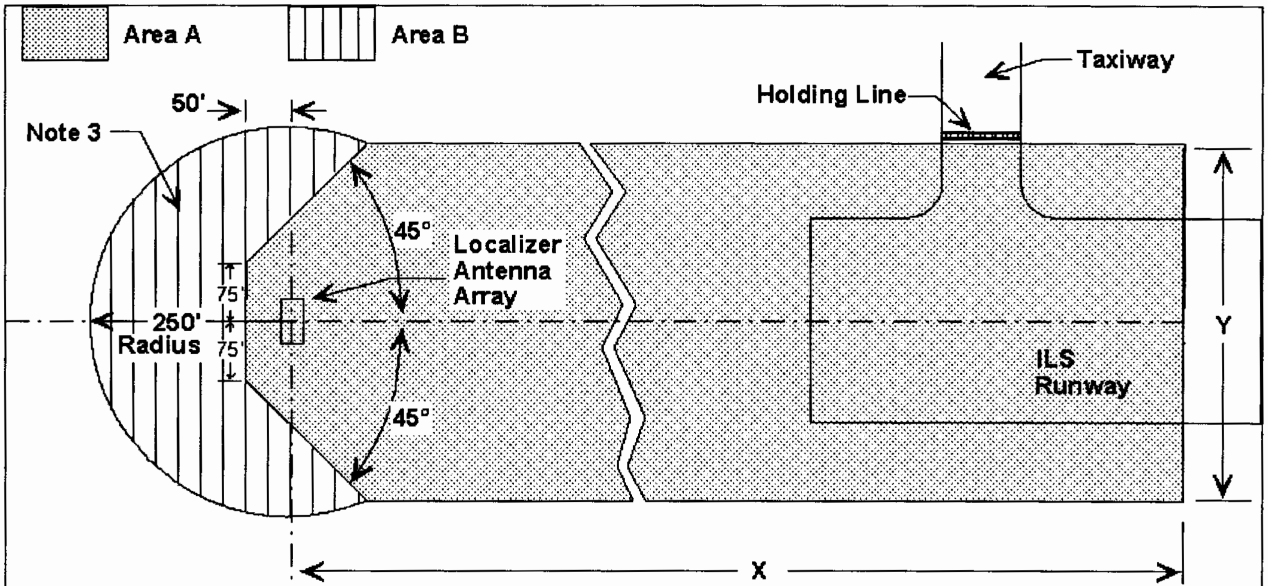
f. Restrictions. Although it is desirable to completely restrict the critical areas from all surface traffic, this is generally not feasible since access to and from the runway, terminal areas, ramp, and hangar areas may necessitate traffic movement through these regions. The restrictions must therefore be sufficiently permissive, as delineated in the following subparagraphs, to permit this traffic flow under controlled conditions.

(1) Surface Traffic. Except as provided below, and in the latest edition of Order 7110.65, Air Traffic Control, all surface traffic must remain clear of the localizer and glide slope critical areas whenever the equipment is in operation. Parking of unattended vehicles or aircraft within this area is prohibited at all times, except for maintenance technician vehicles, which may be parked adjacent to the equipment shelter.

(2) Non-Aviation Users. Where non-aviation users pass through the critical area and unacceptable degradation is expected from traffic movement along these routes (e.g., on roads, highways, railroad tracks, etc.), effective measures must be taken to overcome the condition. Such measures may include math modeling and/ or flight inspection (to determine the magnitude of the degradation), controlling traffic along the route, or elevation/ relocation of the antenna array.

(3) Maintenance Vehicles. Maintenance vehicles may pass through the critical area along access roads when traveling to and from the equipment shelter, provided they do not stop and the route does not pass in the immediate vicinity of the antenna.

g. Vegetation Control. Lease agreements should contain provisions to control vegetation growth. Vegetation should not be permitted to exceed 12 inches in height in the ILS critical areas within 2000 feet of the localizer and 800 feet of glide-slope antennas. Action must be initiated when observed vegetation growth exceeds this height. Growth of crops of any type must not be permitted. Mowing operations should be coordinated for a time to coincide with scheduled facility maintenance.

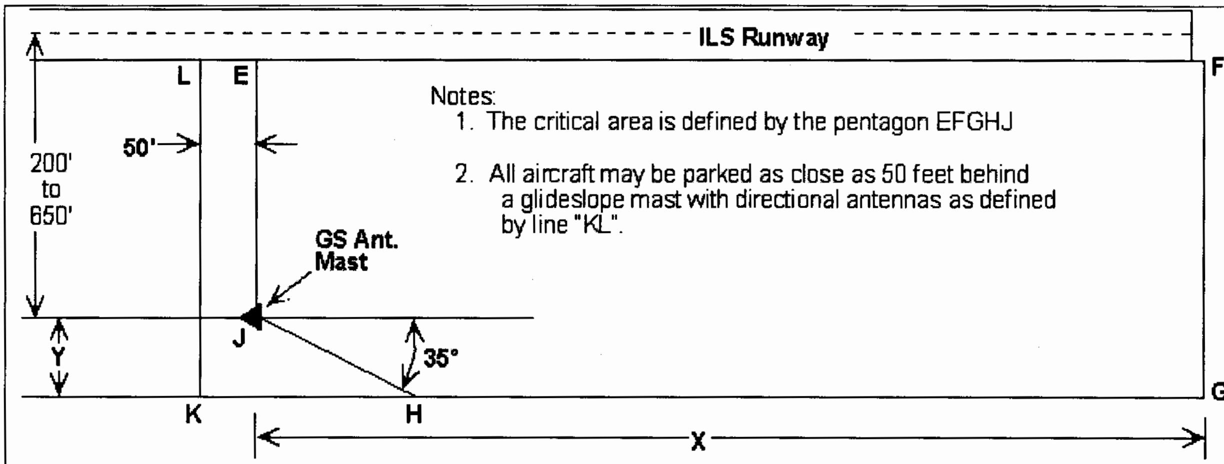


	X	Y	
Category I	2000	400	Note 4
Category II/III	2000	400	Note 5
Category II	4000	500	
Category III	7000	500	

Notes:

1. Critical area is indicated by shaded zones.
2. Hold line/signs indicate the position beyond which aircraft/vehicles will require ATCT authorization before proceeding on or across runway.
3. Area B is deleted from the critical area when a unidirectional localizer antenna is installed. The standard log-periodic dipole antenna array is in this category.
4. For 8-element localizer array with course widths less than 4 degrees and runways which operate B-747-size and larger aircraft, the Y dimension shall be 600 feet.
5. These dimensions apply where aircraft size is equal to or less than 135 feet in length or 42 feet in height; e.g., B-727.
6. Critical areas for LDA, SDF, and Offset Localizer facilities are the same as for Category I, but are centered about the course line.

Figure 1-2. Category I, II, & III Localizer Critical Area



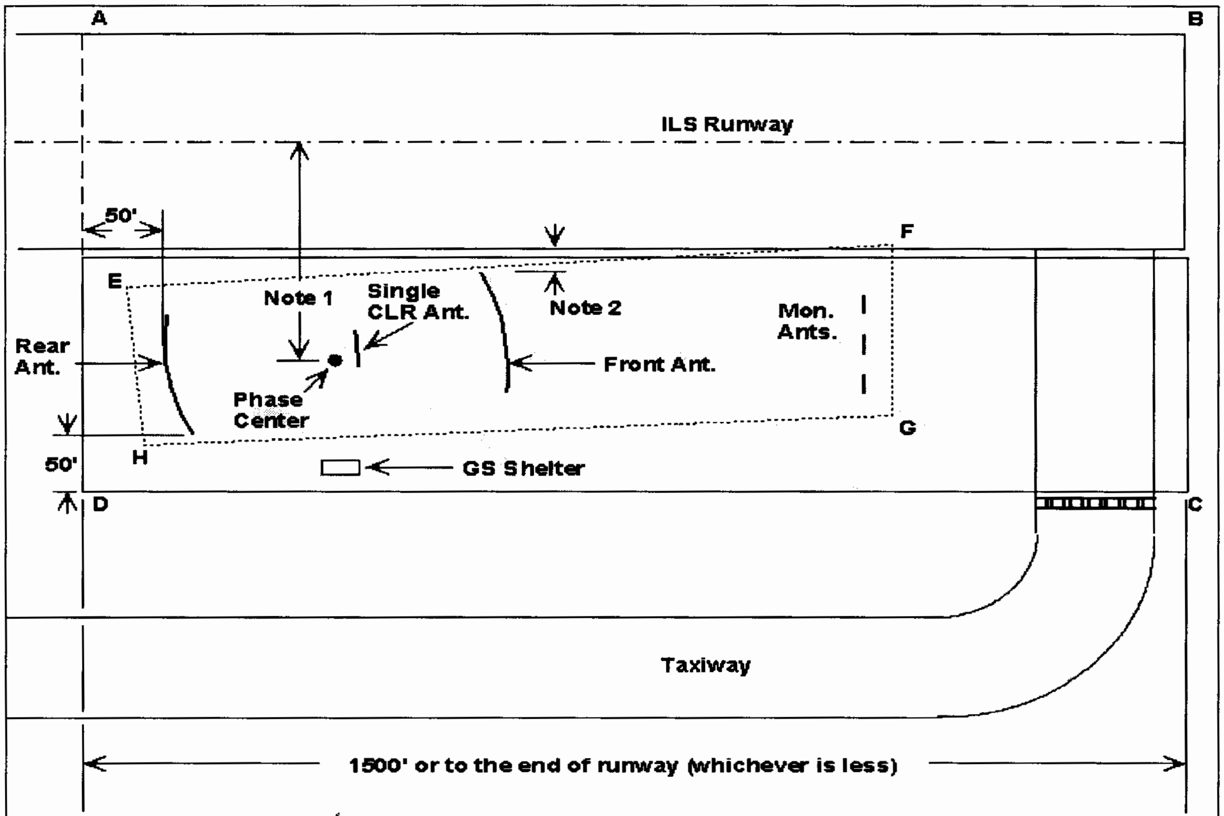
Not To Scale

FACILITY TYPE	CATEGORY I X	CATEGORY I Y	CATEGORY II/III X	CATEGORY II/III Y
ALL IMAGE GLIDE SLOPES				
Small Aircraft 2/	800	100	800	100
NULL REFERENCE				
Medium Aircraft 3/	2000	200	2500	200
Large Aircraft 4/	3100	200	3200	200
SIDEBAND REFERENCE & CAPTURE EFFECT				
Medium and Large Aircraft 3/ 4/	1300	200	1300	200

Notes:

1. All distances are in feet and represent the minimum allowable distances from the nearest point on the aircraft longitudinal axis (line from nose to tail) to the glide slope antenna, as defined in figure 1-3.
2. Small aircraft are defined as aircraft with dimensions less than 60' in length and 20' in height; i.e., Kingair. This includes all surface vehicles and helicopters.
3. Medium aircraft are defined as aircraft with dimensions less than 160' in length and 38' in tail height; i.e., B-727, MD-80.
4. Large aircraft are defined as all aircraft greater than 160' in length or greater than 38' tail height.
5. The small, medium and large aircraft sizes are based upon the dimension used in computer modeling of critical areas and apply to this document only.

Figure 1-3. Image Glide Slope Critical Area



Notes:

1. This distance is approximately 200 feet depending on runway width. Refer to FAA drawings D-6226-1 and D-6226-2 for installation layout.
2. This distance shall not be less than 25 feet.
3. The critical area is defined by the area "ABCD". Unrestricted taxiing or holding aircraft is permitted in unshaded area.
4. Snow removal area "EFGH".

Figure 1-4. End Fire Glide Slope Critical Area

h. Implementation. Effective implementation of the critical area restrictions requires a coordinated effort by several regional and field offices as follows:

(1) Airport Management. Advise airport management authorities of these criteria and request that they provide and maintain the necessary signs, holding lines, and other markings delineating the critical areas. In addition, new establishments should be planned to avoid critical area encroachment of existing runways and taxiways if possible. (See latest edition of Advisory Circular 150/5340-1, Standards for Airport Marking, Marking of Paved Areas on Airports, for marking information.)

(2) Airway Facilities. When advised by Air Traffic that the implementation of this Order impacts airport operations or capacity, Airway Facilities should request assistance from the regional and national office to obtain site-specific math modeling or flight inspection of any proposed reduction in critical area dimensions.

(3) Air Traffic. Where an ATCT is in operation, and the airport management has provided the required markings and signs, tower personnel will not clear aircraft or vehicular traffic into the ILS critical areas, except as provided in Paragraph 1-15f, in accordance with FAA Order 7110.65, Air Traffic Control, FAA Order 7210.3 Facility Operation and Administration, and applicable letters to airmen and letters of agreement.

(4) Aviation Standards. Conduct flight checks to ascertain whether the exceptions under Paragraph 1-15f are permissible.

1-16. ILS SHELTER STANDARDS

ILS shelters are allowed in the runway vicinity by exception to typical building restrictions on airports. As such, ILS shelters should be reasonably limited in size and mass to minimize risk.

a. ILS shelters within designated Object Free Areas or Safety Areas must be limited to a size required to provide for the intended function.

b. Concrete shelters must not be used for ILS facilities within airport operations area (AOA).

c. Shelters located off airport include security fencing.

d. ILS facilities must be painted and marked in accordance with Advisory Circular 70/7460-1.

1-17. RESERVED

CHAPTER 2. THE ILS LOCALIZER

2-1. GENERAL DESCRIPTION

a. Channel Assignments. ILS Localizers operate on one of 40 channels within the frequency band of 108 to 112 MHz. Individual channel assignments are made in accordance with frequency management procedures. Each localizer is assigned a four-letter identification code: an "I", to distinguish the ILS from other navigational aids, followed by a three-letter code, which identifies the particular ILS. The identification is accomplished by modulation of the localizer transmitter with a 1020 Hz tone keyed in accordance with the assigned four-letter code, at the rate of approximately eight identification signals per minute. Where DME is used in conjunction with the ILS, every fourth localizer identification signal is used to key the DME transponder.

b. Localizer Course Guidance. The localizer course guidance information is provided by the modulation of the transmitted signal with audio signals of 90 Hz and 150 Hz. The antenna radiation pattern is designed so that the 150 Hz signal is predominant to the right side of the front course approach, and the 90 Hz signal is predominant to the left of the approach. The localizer course itself is a theoretically straight, but in reality it is formed by the locus of the points where equal levels of 90 and 150 Hz signals are received and detected by the aircraft. The localizer course is usually adjusted to coincide with the runway centerline and centerline extended. The course may lie in two directions, forming both a front course and a back course; however, the back course localizer is the exception and is not provided unless essential from an operational standpoint. Localizer antenna systems, which provide bi-directional radiation, should not be installed unless the back-course approach is to be commissioned.

c. Localizer Receiving Equipment. The localizer receiving equipment generates a meter deflection indication, which corresponds to differences in depth of modulation. When the aircraft is on course there will be a zero-centered meter. When the aircraft is left side of the course, the Course Deviation Indicator (CDI) needle will deflect to the right and when the aircraft is right side of the course, the needle deflects to the left. The CDI is calibrated so that 150 micro amps (.155DDM) represent full-scale deflection on each side of the course centerline. The angular value corresponding to the 150-0-150- micro amp values is defined as the course width. The standard or "tailored" course width provides for 700 feet between the full-scale deflection points at the runway threshold. When the localizer antenna to threshold distance is less than 6678 feet, the course width is capped at a maximum of 6.0 degree. Localizers used for Category I service only may be "non-tailored" if necessary within the limits of 6.0 degrees maximum and 400 feet at threshold minimum. Localizers supporting Category II/III service must be "tailored."

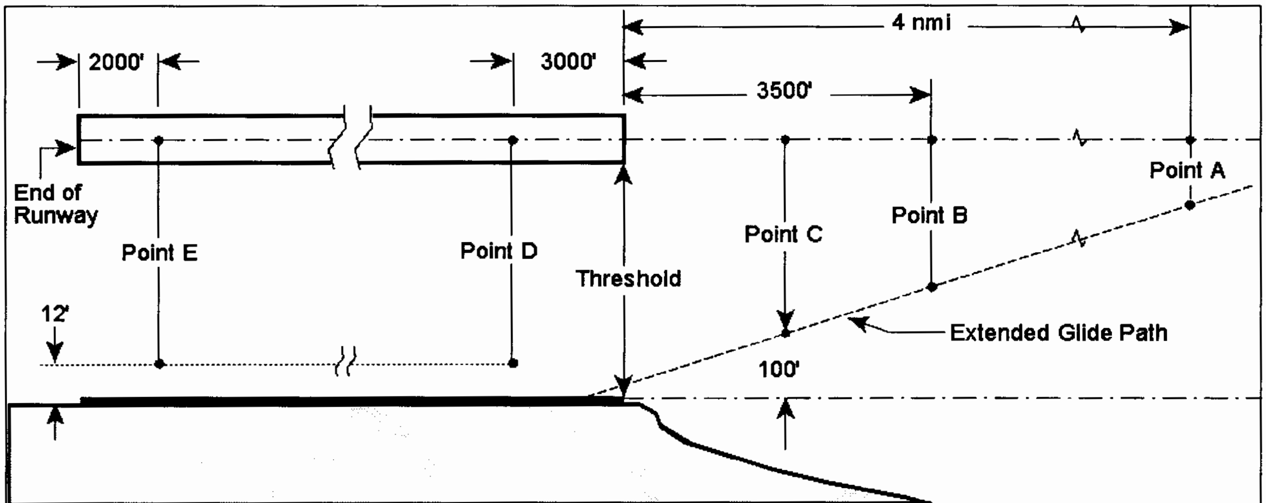
NOTE: Where the Localizer course is offset from runway centerline, the alignment and width measurements are relative to the localizer course rather than the runway centerline.

d. Clearance Signal Sectors. In areas beyond the course width limits, the clearance signal sectors are defined (with respect to the localizer front or back-course on each side) as follows for the purpose of establishing minimum clearance requirements:

Sector	Defined Area	Minimum Normal Clearance
1	± 10°	Linear increase to 175μA and maintain at least 175μA
2	± 10°to ± 35°	150 μA [1]

NOTE: With the course width broadened to monitor limits, a 15 micro amp reduction is permissible. Additional momentary deviations to as low as 100 micro amps may be permissible (see FAA Order 8200.1, the United States Standard Flight Inspection Manual for guidance.

e. Straight Line Course. It is also highly desirable for the localizer course to be a straight line, which coincides with the runway centerline extended to permit maximum use of automatic approach equipment (see Figure 2-1). In addition to increasing the difficulty of a manual approach, severe course aberrations such as roughness, scalloping, or bends may preclude the use of automatic approach equipment. Departure of the actual localizer course from a theoretical straight line will, to some extent, determine the landing minimums. The permissible course displacement varies with the distance from runway threshold and is tabulated in Section 217 of FAA Order 8200.1.



Notes:

Point A is located on the glide path 4 nautical miles outbound from the runway approach threshold, measured along the runway centerline extended (or the localizer approach azimuth).

Point B is located on the glide path 3500 feet outbound from the runway approach threshold, measured along the runway centerline extended (or the localizer approach azimuth).

Point C is located at the intercept of the downward-extended straight portion of the glide path (at the commissioned angle), the verticle plane containing the runway centerline extended (or the localizer approach azimuth), and the horizontal line 100 feet above the horizontal plane containing the runway threshold.

Point D is a point 12 feet above the runway centerline and 3000 feet from the threshold in the direction of the localizer.

Point E is a point 12 feet above the runway centerline and 2000 feet from the stop end of the runway in the direction of the threshold.

Figure 2-1. ILS Course Displacement Reference Points

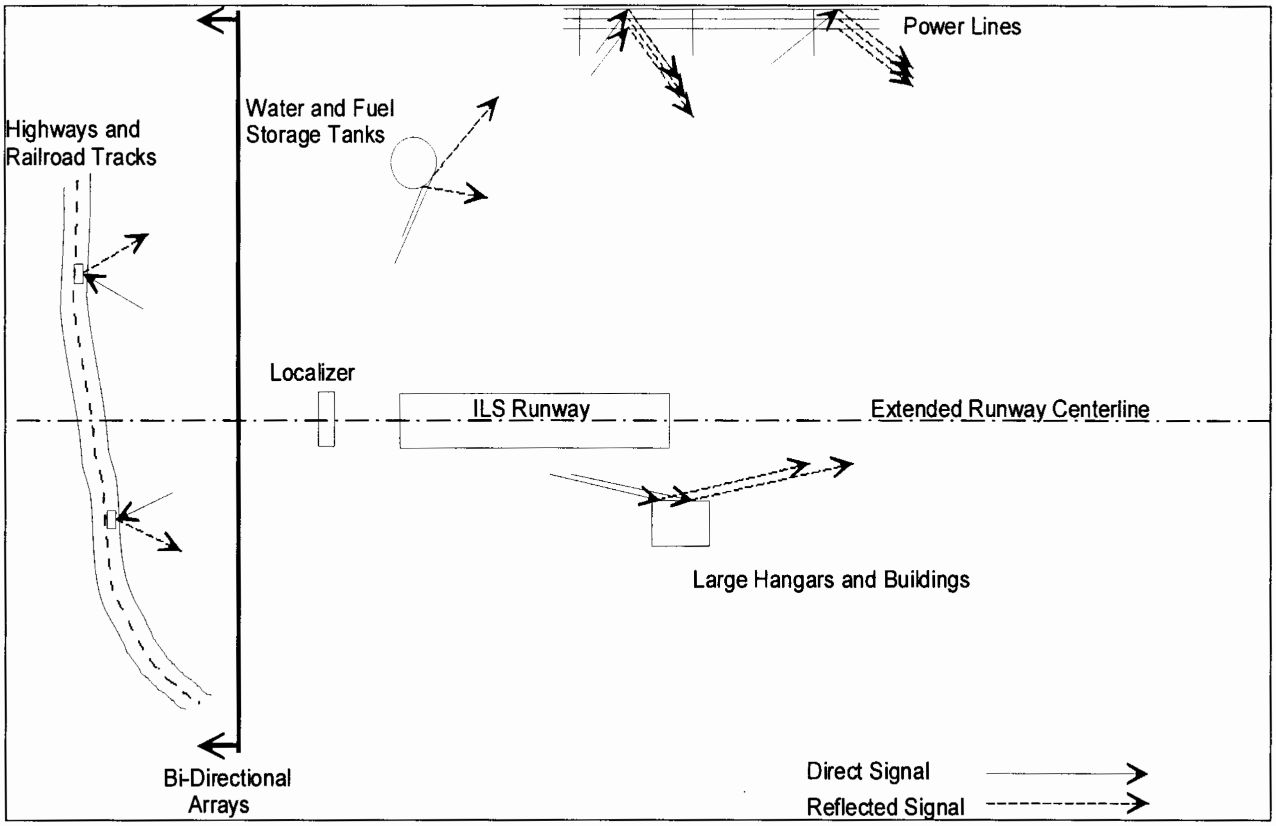


Figure 2-2. Typical Localizer Degrading Sources

f. Low Clearance Areas. The principal cause of localizer course deviations and low clearance areas is the distortion of the antenna system radiation pattern by signal reflections from nearby objects such as hangars, power lines, vehicular traffic, wire fences, and buildings (see Figure 2-2). It may not be possible to remove these objects from the area; however, by judicious siting of the localizer antenna system, the effects of the degrading sources may in many cases be minimized. The use of math modeling as an engineering tool is recommended during these types of siting activities (see Paragraph 1-13). Unidirectional arrays are much less sensitive to reflecting sources behind them. Little significant energy exists beyond 50 feet to the rear of these arrays.

g. Standard Service Volume. The localizer Standard Service Volume (SSV), which is required to have a minimum receiver input signal level of five microvolts, in addition to the minimum flag current and clearance signal requirements, is measured with the transmitter power reduced to the monitor alarm level. The minimum coverage requirements are 18 nautical miles (NM) within clearance sector 1 and 10 NM within clearance sector 2. Vertical coverage is required below line 7 degrees from horizontal (referenced at the localizer antenna) to 4500 feet above site elevation.

2-2. LOCALIZER LOCATION AND TYPES

a. Localizer Equipment. The ILS localizer consists of an antenna array, electronic equipment, integral detectors, and an equipment shelter. Category II and Category III localizer systems also include a far field monitor (FFM), which is sited near the inner or middle marker or both. The localizer is normally located near the stop end of the runway. The antenna array is the prime consideration and will, to a certain extent, fix the location of the shelter.

b. Antenna Systems. There are several types of FAA-procured localizer antenna systems in present use. The more familiar ones are the V-ring, and the log-periodic dipole antenna. The V-ring array is essentially bi-directional and was formerly the FAA standard system, whereas the other types are unidirectional systems originally used to overcome V-ring siting problems caused by reflecting objects. The criteria contained in the following paragraphs apply generally to all systems. A more thorough description of each system is given in Paragraph 2-4.

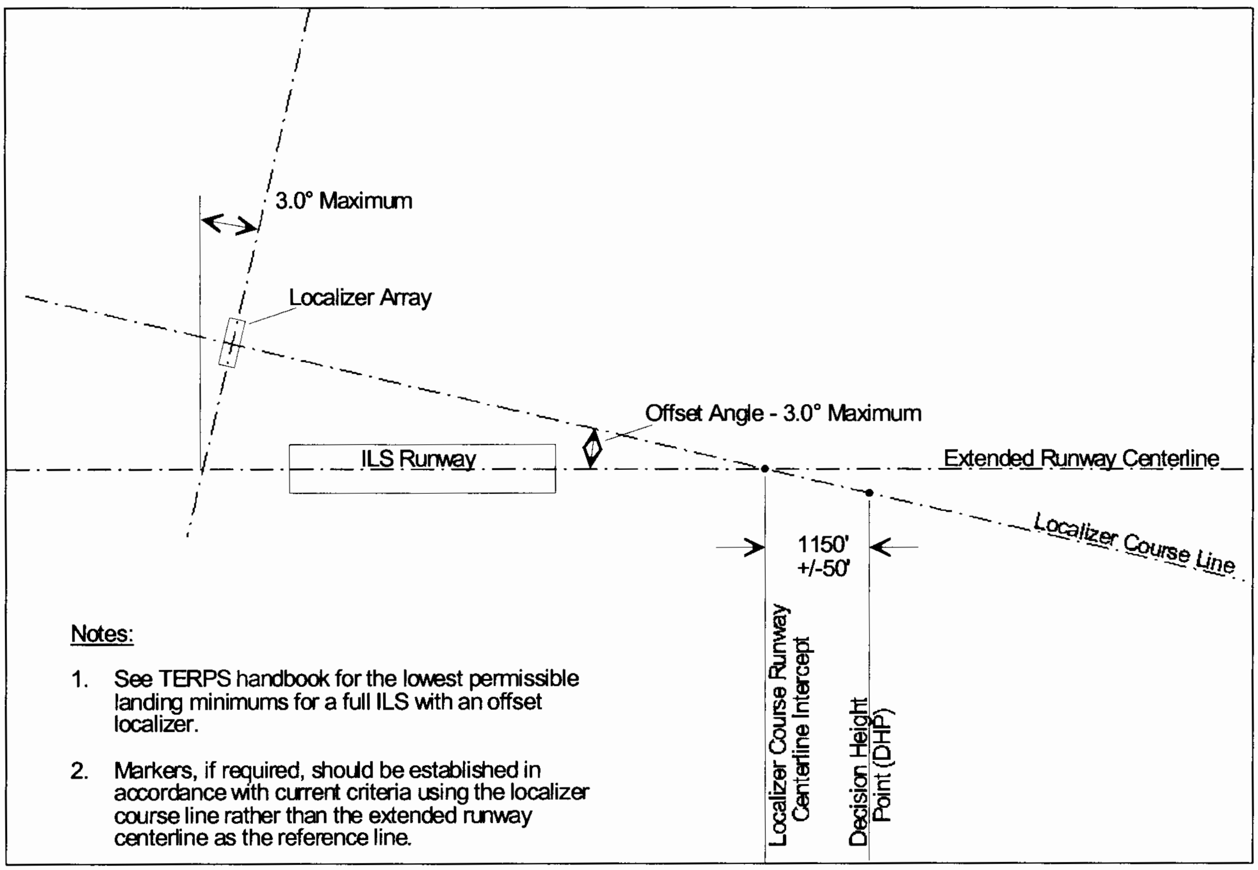


Figure 2-3. Offset Localizer Configuration

2-3. LOCALIZER EQUIPMENT SHELTER

a. Centerline Localizer. The localizer electronic equipment shelter must be located a minimum distance of 250 feet from the center of the runway and should be within 30 degrees of the longitudinal axis of the array. When a V-ring antenna system is used, it is preferable to locate the shelter in the minimum signal area that exists at 105 degrees from the front course line and at the above distances. The maximum distance to the building is limited by the attenuation of the antenna feed lines. The building may be situated on either side of the antennas depending on the local terrain, access roads, and power line connections. The criteria for location of the shelter must apply to both permanent buildings and portable shelters (see Paragraph 1-16 of this Order for shelter information).

b. Offset Localizer/ LDA. The equipment shelter must be located outside the runway/ taxiway safety areas, no closer than 250 feet from centerline extended, and must not be located in critical area (see to Figure 1-2).

c. Platform Mounted Arrays. If an elevated array is installed, the shelter may be located directly behind the platform, provided the elevation of the top of the shelter does not exceed the level of the platform.

2-4. DESCRIPTION OF THE ANTENNA SYSTEMS

a. Single-Frequency Arrays. Single-frequency arrays operate on the assigned carrier frequency and are used for Category I operations.

b. Dual-Frequency Arrays. Dual-frequency arrays operate on two frequencies, with the course signal on a carrier frequency offset 4 KHz above the station frequency and a clearance signal offset 4 KHz below the assigned station frequency. This frequency difference is within the receiver's pass-band so the AM-detector principle determines what signal (typically stronger) is captured (used). The course distribution is designed to confine the radiation near the runway centerline and the clearance signal is designed to provide the fly-left, fly-right guidance in the clearance sector.

c. Unidirectional antenna Arrays. Unidirectional antenna arrays are designed to provide coverage to ±35 degrees on the front course and typically use the log periodic dipole antenna (LPD). The LPD antenna incorporates integral monitoring and has a nominal front-to-back radiation ratio of 28 dB. The horizontal beam-width is 45° and signal beyond the coverage sector is greatly reduced. The LPD antenna is used for both the single-frequency arrays and dual-frequency arrays. The table below lists the various combinations of antenna array distributions.

Table 2-1. Localizer Antenna Arrays

Number of Antenna Elements	Frequency	Aperture Size(s) (ft)
8	Single	45, 50
14	Single	86, 100
14	Dual	86, 100, 126
20	Dual	150

d. Bi-Directional Antenna Arrays. Bi-Directional Antenna Arrays provide a useable back-course. Two examples are as follows:

(1) V-Ring Array. The directional radiation pattern of the V-Ring array is obtained from a system of eight or fourteen antennas. The individual V-Ring antennas have a front-to-back pattern ratio of about 6 dB and have a broader beam width than the LPD antenna. Off-course reflections will be of higher amplitude for these arrays as compared to an LPD array.

(2) Modified Log Periodic Dipole. A modification was developed for localizer LPD antenna elements in order to reduce the front-to-back ratio of the LPD antennas from 28 dB to about 12 dB without significantly compromising front course horizontal pattern and signal strength. This results in lower amplitude reflections and less roughness and scalloping as compared to V-ring antenna arrays. The trade-off, due to the sharper array pattern, is typically procedural restrictions beyond 20 degrees each side of the back-course centerline. A modification authorization can be requested through the National Airspace System Change Proposal (NCP) process.

2-5. SITING REQUIREMENTS

a. Localizer Antenna System. The localizer antenna system must be symmetrically positioned about the extended runway centerline (or approach azimuth for offset or Localizer Directional Aid (LDA) configuration) with the longitudinal axis of the array perpendicular to the runway centerline (or approach azimuth). The optimum distance from the stop end of the runway to the localizer array for each site must be determined by consideration of several factors:

(1) Required obstruction clearance criteria.

(2) Usable distance and signal coverage requirements.

(3) Presence of reflecting or reradiating objects in the vicinity.

(4) Safety considerations and the Runway Safety Area (RSA).

(5) Anticipated facility upgrading and/or airport expansion.

(6) Establishment costs.

b. Minimum Antenna Distance from Runway Stop End. Minimum antenna distance from the stop end of the runway to the localizer array should consider the distance, which precludes penetration of the approach plane surface (Federal Aviation Regulation, FAR Part 77), TERPS surfaces, the RSA, the light plane of a Cat II/III system. The obstruction requirements to all approach lighting systems should be met. For centerline extended localizer antennas, the minimum distance from the stop end of the runway must be the greater of 600 feet or the end of the runway safety area. All points of the localizer array must remain outside the runway safety area. Additional criteria pertaining to the minimum distance requirements are as follows:

(1) When a cleared and graded area extending from the stop end of the runway a distance of 1100 feet or more can be provided, the localizer array must be located beyond 1000 feet from the stop end of the runway.

(2) To assure protection from the effects of aircraft engine jet blasts, the minimum distance a localizer must be located from the end of a runway where jet aircraft are in operation, not precluding RSA requirements of Advisory Circular 150/5300-13, must be 600 feet. Where siting conditions preclude adherence to the 600-foot limitation, consideration will be given to locating the array beyond the maximum standard distance, to an offset location, or inside this limitation with adequate protection to personnel and equipment.

(3) Locating localizer arrays inside the RSA is permissible when the array is frangible at or below 3 inches, 14 CFR Part 139.309 (4), either by design or application of approved frangible bolt couplings at the base of the array.

c. Maximum Standard Distance from Runway Stop End. The maximum standard distance from the stop end of the runway to the localizer array is 2000 feet; however, location of the array beyond this distance is permissible where significant advantages can be obtained.

(1) When the localizer will serve a relatively short runway requiring a wide course width (5 to 6 degrees) to provide the 700-foot tailored width at threshold, the array may be located beyond the 2000-foot distance.

(2) Location of the localizer beyond the 2000-foot limit is permissible when airport expansion includes a runway extension, which would necessitate future localizer relocation. Planned taxiway and building construction should also be considered in this regard.

d. ILS Category II/III Localizers. ILS Category II/III localizers must be located on the runway centerline extended. When planning a CAT I ILS and the potential for future upgrading to Category II/III operation exists, consideration should be given to the CAT II/III requirements.

e. Elevation. The elevation of the array must be considered in conjunction with the distance requirement. Although a ground-mounted array is usually adequate at most facilities, at some locations an elevated array may be necessary to provide the required minimum signal coverage and performance. This may occur where runway discontinuities exist (humps, elevation changes, or runway safety area grading) or the presence of hills, trees, buildings, or other obstructions in the vicinity cause a shadow effect. As an elevated antenna structure on the extended runway centerline is quite massive, other options should be considered to include placing the antenna on additional fill or moving the antenna array to a higher elevation within the runway safety area.

(1) Antenna Height. The array should be mounted so that the antenna-radiating element is in line of sight with threshold crossing height (TCH) at the approach end of the runway. With the lower minimums and more stringent tolerances associated with Category II/III sites it is more essential to satisfy these criteria. At those locations where future upgrading to Category II/III is not programmed or considered feasible, i.e., runway length/width, presence of obstructions, annual instrument approaches, etc., the array may be mounted to provide line-of-sight to a point 100 feet over the threshold. This should be done after a complete site analysis has been completed that indicates satisfactory facility performance can be obtained with the lower antenna height. In the localizer frequency band, VHF propagation techniques may be used to find the usable distance for any given site and antenna height.

(2) Vertical Radiation Pattern. The vertical radiation pattern must be considered when installing an antenna array on a platform or on a rise significantly above a defined reflection ground plane. With increased elevation above the reflection ground plane, the angle of the first vertical null (or minimum) of the antenna array lowers. The upper limit of the standard localizer service volume extends to 7 degrees above the antenna elevation. It is imperative that a null not pass through the service area of the localizer system, as reflections will likely cause unacceptable aberrations due to the decrease in direct signal strength. The first vertical null is of special concern in the siting of localizer antenna arrays close to the approach end of the runway or for use as a back-course, particularly when minimums are relatively high and the missed approach point is relatively close to the facility. Localizer elements at a height of 35 feet above the extension of a reflecting plane will produce a null at an angle of about 7.3 degrees above that reflection plane. By contrast, the first vertical null of a ground-mounted installation, with elements at approximately 7 feet above the extended ground plane, will be at approximately 39 degrees above the ground plane. The formula for calculation of the first vertical null is as follows:

$$\theta = \arcsin [490 / (F \times H)]$$

where;
θ = the angle of the first null relative to the ground plane (must be added or subtracted to the angle of the ground plane to achieve the null angle relative to horizontal.
H= the height of the antenna elements above the ground plane in feet
F= the localizer frequency in megahertz.

f. Specular Reflection. The presence of signal reflecting objects in the vicinity (see Figure 2-2), to include critical area concerns (see Paragraph 1-15), may place an additional restriction on the location of the localizer antenna system. By application of the principles of specular reflection, the areas that will be affected by the reflected signals may be predicted by math modeling techniques available through the Office of Integrated Product Team for Navigation and Landing, HQ FAA Washington, DC.

g. Front Course Quality. The quality of the front course and clearance areas is the primary consideration when establishing the localizer and should not be compromised for the sole purpose of obtaining a usable back-course approach. Expenditure of additional funds to upgrade the back-course, even without degrading the front course, cannot generally be justified.

h. Terrain. The terrain between the antennas and the end of the runway should not contain severe irregularities or obstructions that may affect the localizer signal quality. Existing obstructions should be removed and, if possible, the area graded (see Figure 2-4). Minor terrain irregularities and isolated small objects close to the array will not usually affect the radiated signal quality. Clearing should be limited to the removal of large shadowing objects such as dense trees, shrubs, and hillocks from in front of the array and any significant signal reflectors in the vicinity of the array. It is suggested that modeling and flight test be applied to difficult sites before attempting to commission.

i. Cost Considerations. When a tentative antenna location (based on the signal coverage, obstruction criteria, and other requirements) has been chosen for a localizer, the establishment costs will be estimated. Items to be considered include the cost of installing power lines and control cables, where required; the cost of site grading or landfill; the cost of the antenna support (concrete slab versus elevated platform); and the cost of constructing site access roads. The exact location of the array should be the least costly site consistent with the required level of service.

j. Offset Localizers. At some runways, terrain may prevent the localizer antennas from being positioned on the extended runway centerline. Where this occurs, and landfill or tall supportive structures are impractical, the localizer antenna array may be offset so that the course does not lie along runway centerline but rather intercepts the centerline at a point determined by the amount of angular offset and the glide path angle. To be classified as an "offset localizer", this offset angle can be up to 3 degrees. When offset angles greater than 3 degrees are necessary, the facility must be classified as a "localizer directional aid" (LDA). The landing minimums prescribed for an offset localizer vs. a LDA are prescribed in the latest edition of FAA Order 8260.3, United States Standard for Terminal Instrument Procedures (TERPS). The localizer offset angle (see Figure 2-3) is formed by the vertical plane containing both the decision height point (DHP) and the point on the runway centerline that is 1150 +/- 50 feet inbound from the DHP (with the latter point also containing the localizer course line). The criteria for standard localizer facilities must also apply to offset localizers with the following exceptions:

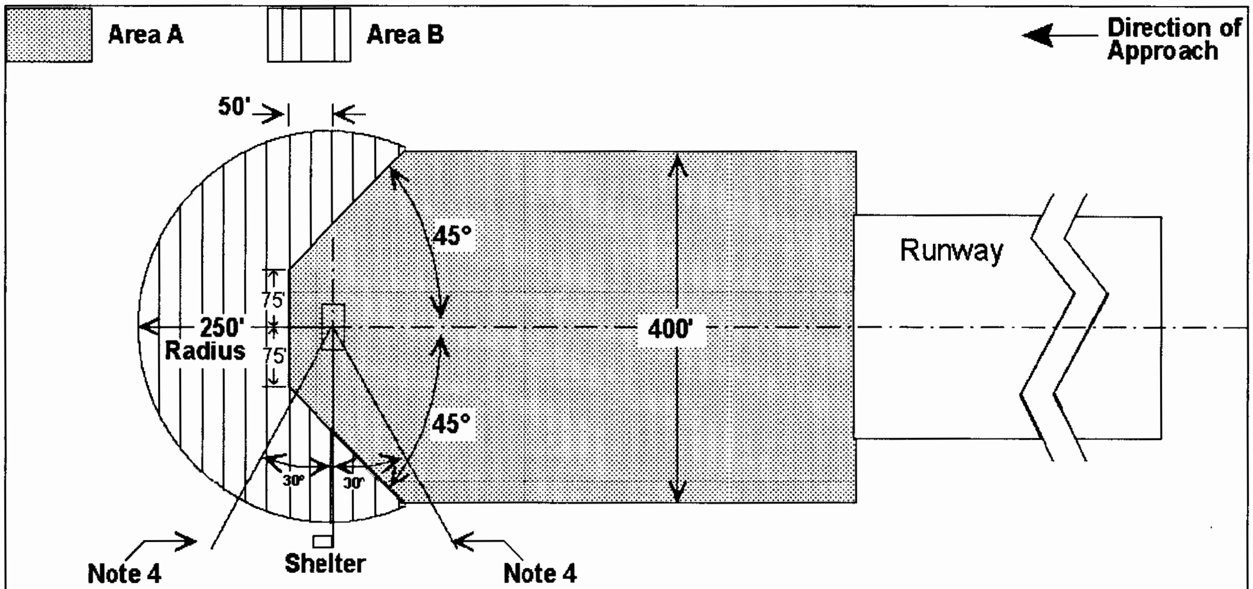
(1) The antenna array should be offset in the direction that will offer the least signal interference from movement or obstructions.

(2) An offset localizer or LDA facility must be located outside the runway safety area.

(3) The distance from the runway centerline to the nearest element of the array must comply with the obstacle free zone (OFZ) criteria of AC 150/5300-13, Airport Design.

(4) The entire array must be located outside the applicable taxiway safety area as defined in AC 150/5300-13, Airport Design.

(5) The antenna array must be sited to provide vertical and horizontal clearance to taxiing aircraft on adjacent taxiways.



Notes:

1. Areas A & B should be free of localizer interference sources (trees, buildings,fences, etc.)
2. Grading in Area A should have a negative gradient between 0.5% and 3.0% from runway centerline extended to the outer edges. This grading should be as symmetric as possible across runway centerline. Area B should be graded similar to Area A for bi-directional or omni-directional arrays.
3. The size and configuration of Area A is applicable to all facilities. Area B may be deleted at facilities that have uni-directional antennas; i.e., unmodified Log Periodic Dipole arrays.
4. Refer to Paragraph 2-4

Figure 2-4. Typical Localizer Plot Layout and Site Grading Requirements

2-6. GROUND CHECK POINTS (SEE FIGURE 2-5.)

To facilitate the establishment of the facility parameters and to provide reference points from which the parameters can be periodically verified, ground checkpoints must be established at each localizer facility. Because of the different types of localizer arrays and the unique terrain and siting conditions at each facility, it is not possible to specify the exact location and number of checkpoints. For the establishment of ground checkpoints refer to current version FAA Order 6750.49.

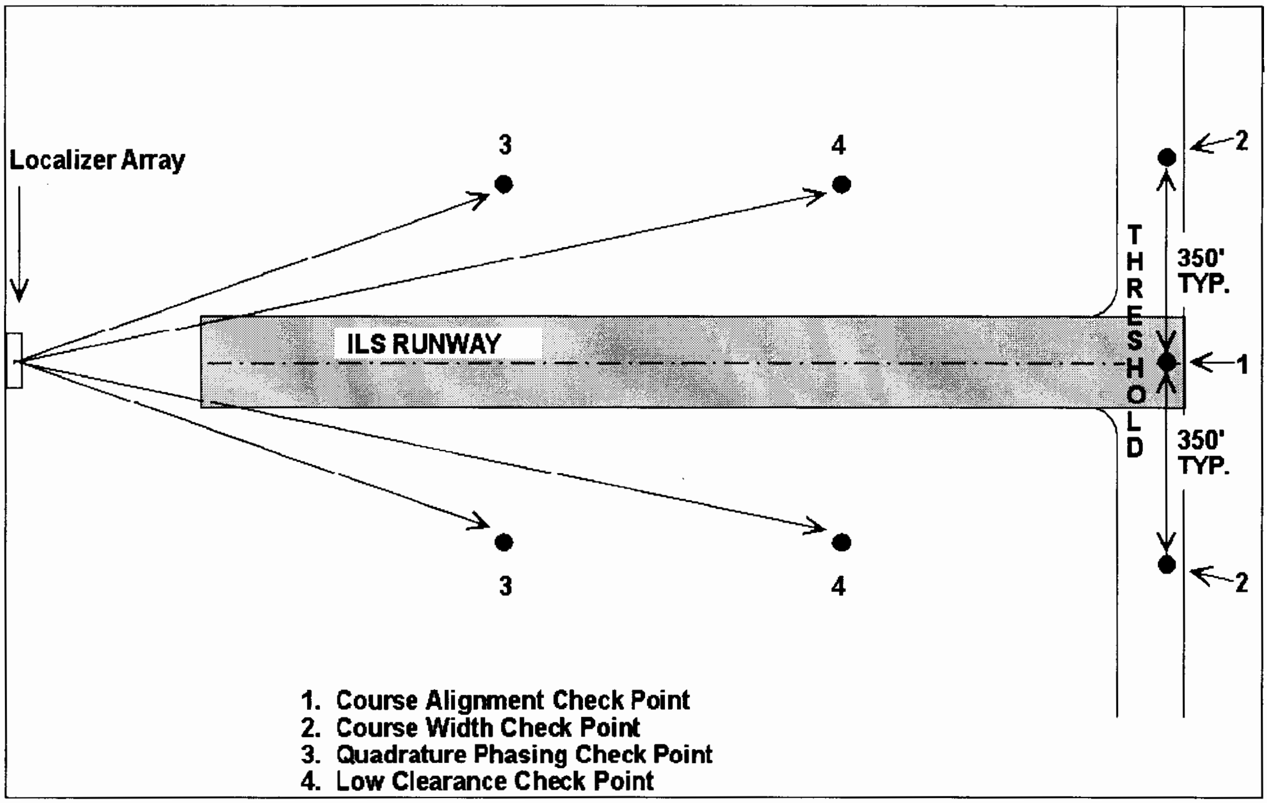


Figure 2-5. Localizer Ground Check Points

2-7. SITE EFFECTS ON LOCALIZER PERFORMANCE

a. Operating Environment Considerations. The quality of an ILS localizer course and clearance signals is to a large extent determined by the operating environment of the system. Environmental factors, which should be considered when siting a localizer facility, include large buildings (such as hangars and terminal complexes), power and tree lines, metallic fences, cylindrical structures (such as water towers and fuel tanks), and terrain. A thorough analysis will help determine the optimum antenna location within the defined limits and will permit an accurate prediction of the system's performance at a particular site. If it is not possible to make an accurate prediction of the system's performance from the information available, a request for mathematical modeling assistance should be submitted in accordance with Appendix 2, Paragraph 2-2.

b. Theoretical Considerations. Analysis of site effects on a localizer system's performance requires a thorough theoretical knowledge of the system. Since this information is available elsewhere, this section provides guidance on anticipated performance based on the patterns of the antenna elements as well as the nominal CSB and SBO patterns.

(1) Antenna Element Pattern. Performance can be improved by the selection of the antenna element type. In general, the uni-directionality of the LPD antenna suppresses the energy outside the localizer service volume and behind the array. Whereas the V-Ring antenna element has a broad pattern and signal behind the array, Figure 2-6 shows a comparison between these element patterns. Based only on the antenna element patterns, the LPD array would provide improved course guidance signal over the V-Ring array.

(2) SBO Pattern Comparison. Structure roughness is typically the result of the SBO signal being reflected back into the course line resulting in degradation to the minimum or SBO null for the course line. Figure 2-7 shows a comparison between the course transmitter SBO of various single- and dual-frequency arrays. Figure 2-7 shows the dramatic reduction in SBO signal between the 8 and 14 element single frequency arrays between 7 and 16 degrees off-course – greater than 6 dB reduction in signal strength, as well as reduced signal strength at all other azimuths. All three of the dual frequency arrays show even more dramatic reduction in Course SBO signal levels, with extremely low SBO levels beyond 11.5, 10.0 and 7.0 for the 14/6, 14/10 and 20/10, respectively.

(3) Dual-Frequency Consideration (Course-to-Clearance Power Ratios). Degradation to the guidance performance in ILS Zone 4 or 5 (FAA Order 8200.1b, Figure 217-1a) of dual-frequency arrays used for Category II/III operation is typically caused by reflections of clearance signals onto the course centerline. Newer localizer arrays provide additional immunity by tailoring the clearance signal to have little energy outside the clearance sector. If roughness is found, the clearance transmitter parameters can be adjusted to minimize the roughness.

(4) Single-Frequency Considerations (Abnormal Case DDM).

(a) CDI Normalization. When single-frequency arrays are used for installation on long runways, resulting in narrow course widths, the separate sideband components are greater than the carrier sidebands. Where this condition occurs, space modulation is greater than transmitter modulation thus resulting in the measured total modulation exceeding 40 percent (see Figures 2-8 and 2-9). Certain ILS receivers, mostly digital processing receivers, use algorithms, which expect the received total modulation (i.e., -sum depth of modulation or SDM) to be 40 percent throughout the coverage area and use this value to normalize the calculated cross pointer deflection indicator (CDI). This normalization process reduces the CDI reading.

(b) Maximum Limit Requirements. Recent requirements have placed a maximum limit on the received SDM of 60 percent for new and relocated localizers. Those arrays in our current inventory that have the characteristic where received SDM may exceed 60 percent are the single frequency 8 and 14 element systems based on a 45 foot and a 86 foot aperture, respectively. Table 2-2 exhibits the narrowest course width at which these antenna arrays are modeled to achieve this tolerance. As modeling assumes perfect power and phasing, the practical limit for acceptable course widths of these arrays could be up to 0.50° greater. Ultimate acceptance is determined by flight inspection. Mitigation options include commissioning at a wider than tailored course width or a restriction of the localizer at and beyond those azimuths affected.

Table 2-2. Minimum Normal Course Width for Single-Frequency Localizer Arrays for which Greater Than 60 Percent Abnormal Case DDM will not occur

Type Array	Array aperture (ft)	60 % SDM Width	Worst-case Azimuth
8	45	3.63	29°
14	86	4.04	30°

(5) Low Clearance Areas. Low clearance areas (below 150 μA) usually are caused by the reflection of signals from one side of the radiation pattern into the opposite side (i.e., 90 Hz signal reflected into the 150 Hz sectors or vice versa), the extent of the clearance signal reduction varying inversely with the ratio of direct-to-reflected signal amplitude. Reflection problems may be resolved by selection of the optimum location of the antenna array and by altering or removing the reflection source. It is imperative that adequate clearances be obtained in sector 1. Full-scale clearances in sector 2 are also desirable but not mandatory if an additional navigational aid is available to guide the aircraft into the usable sectors.

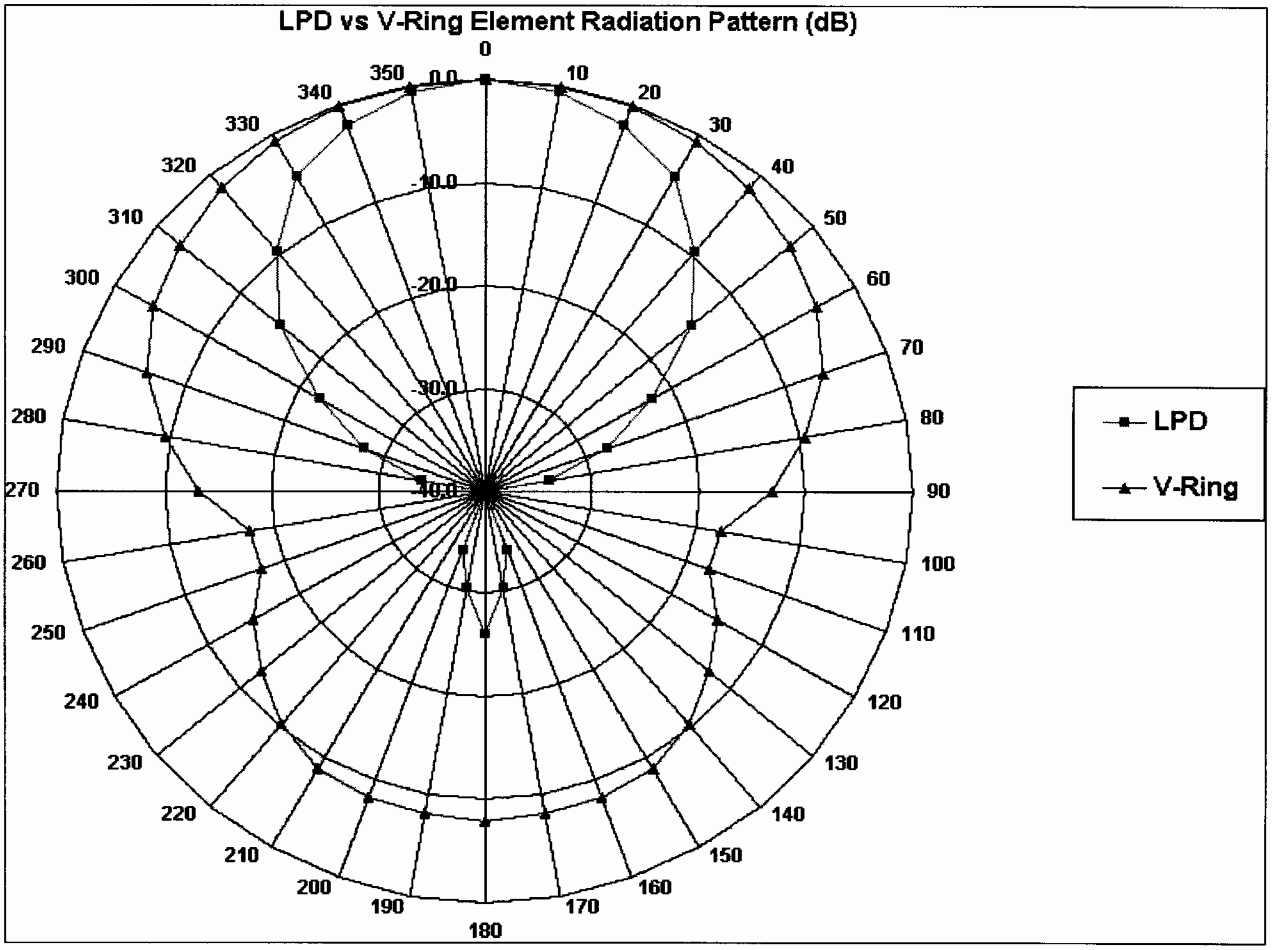


Figure 2-6. LPD vs. V-Ring

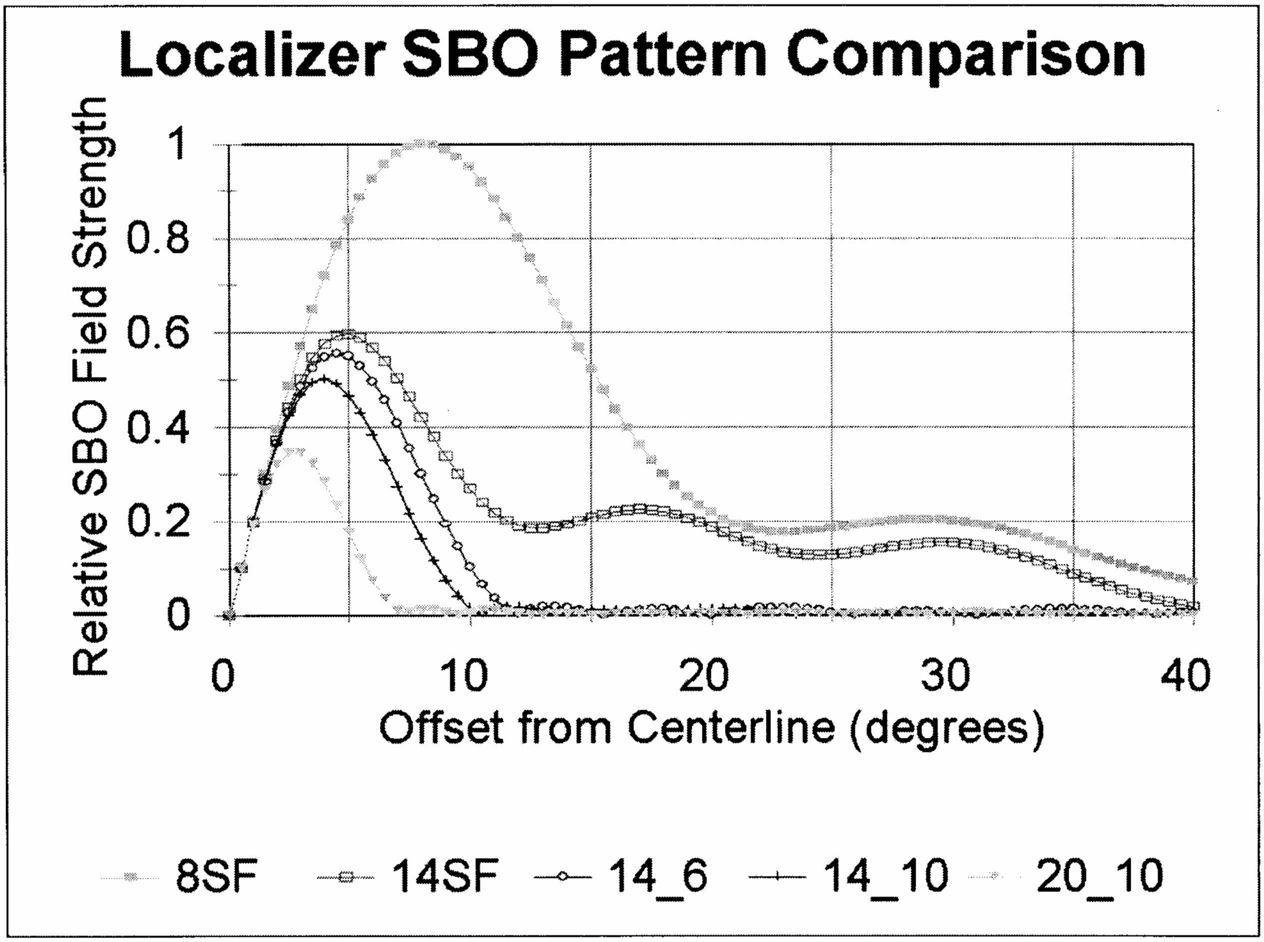


Figure 2-7. SBO Pattern Comparison

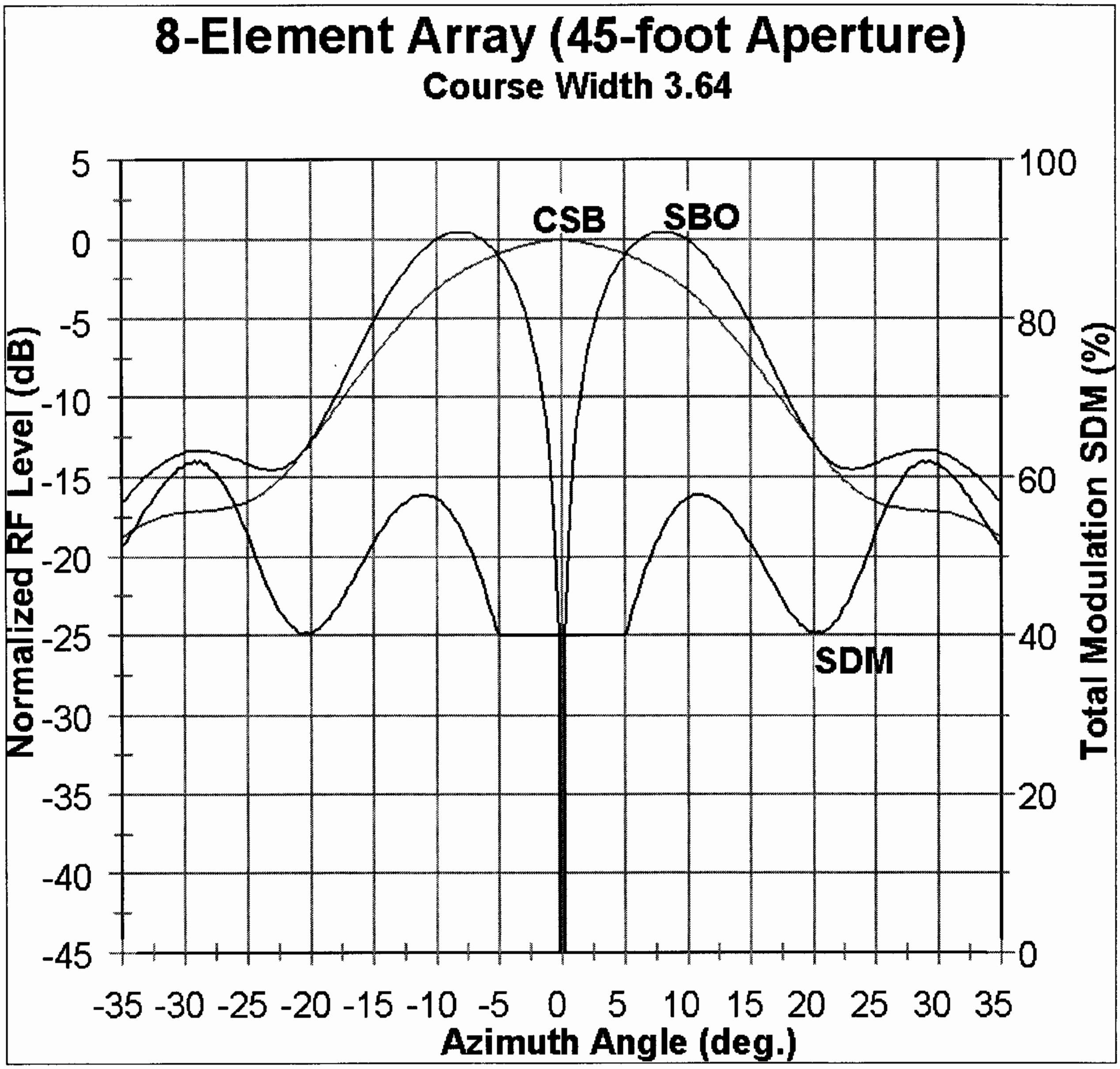


Figure 2-8. 8-Element Array (45-Foot Aperture)

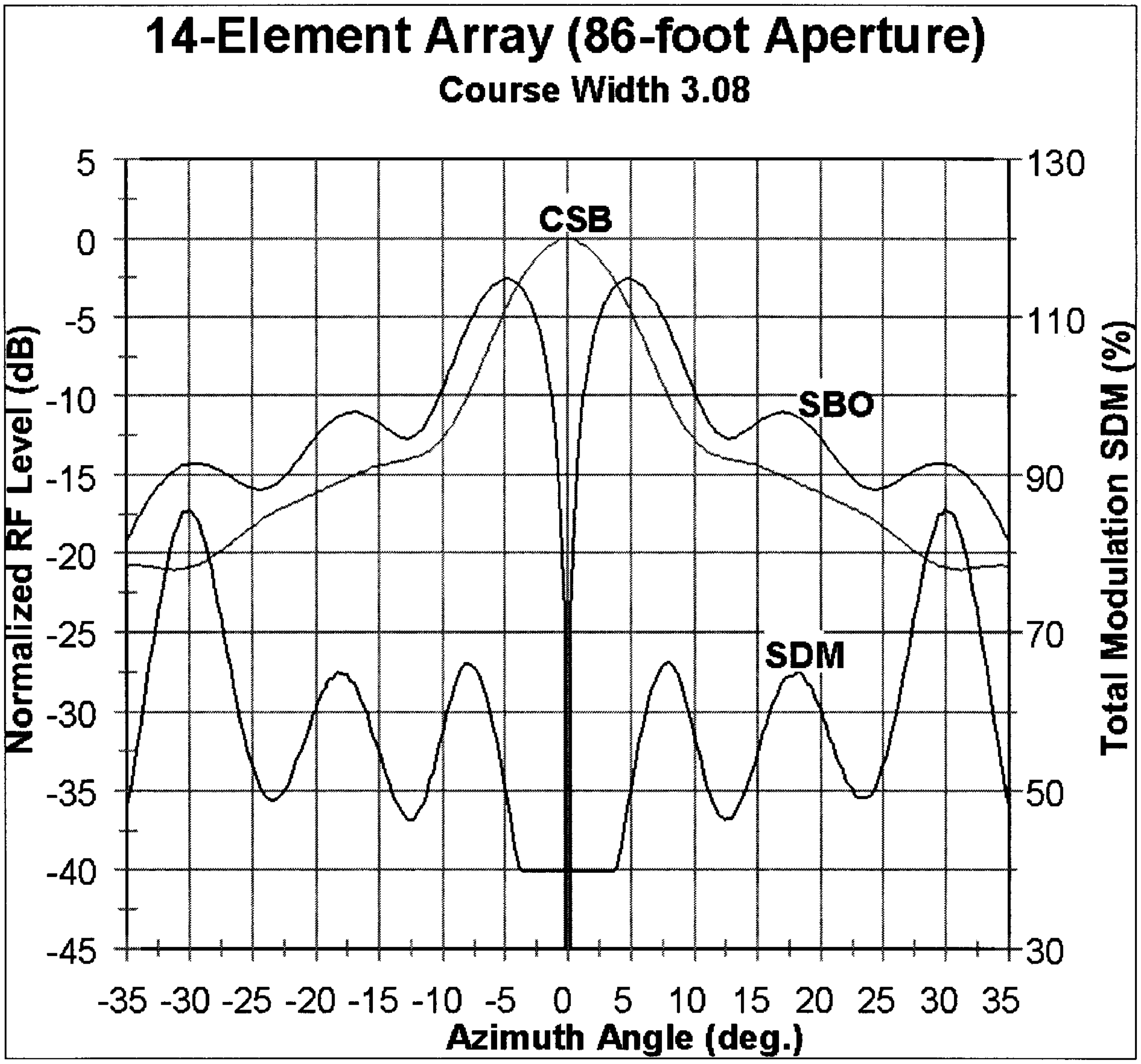


Figure 2-9. 14-Element Array (86-Foot Aperture)

2-8. RESERVED

CHAPTER 3. THE ILS GLIDE SLOPE

3-1. GENERAL DESCRIPTION

a. Glide Slope Frequency. The ILS glide slope operates in the frequency band of 329.15 through 335.0 MHz, with 40 discrete frequencies available within this band. Each glide slope frequency is uniquely paired with a given localizer frequency, forming one ILS channel. The glide slope's guidance information is also provided by 90 HZ and 150 Hz modulation components. Identification signals are not provided with the glide slope.

b. Glide Slope Antenna System Location. The glide slope antenna system is located near the runway approach end at a distance from the threshold to provide optimum threshold crossing height. The preferred offset distance from the runway centerline is 400 feet. An exception is the end-fire glide slope where the antenna array typically extends to 25 feet from the runway edge and is allowed due to antenna frangibility.

c. Glide Slope Siting. The glide slope site may be located on either side of the runway. The most reliable operation will occur when it is located on the side that provides the least interference from buildings, power lines, moving vehicles, and aircraft and which has the greatest extent of smooth terrain outbound from the antennas. Category II and Category III glide slopes should be located at a minimum of 400 feet from the runway centerline.

d. Vertical Radiation Lobe Structure. Proper operation of the glide slope is primarily a function of the quality of the vertical radiation lobe structure. The system is designed so the radiation pattern has a predominance of 150 Hz signal below the glide path and conversely, a greater level of 90 Hz signal above glide path. The glide path itself is the locus of the points where equal levels of 90 and 150 Hz signals exist. The elevation angle of the glide path is a function of the antennas' heights above ground in the image systems. For the end-fire system, the relative phase of the RF radiation from the rear and front course antennas determines the glide path angle.

e. Glide Slope Receiver. The aircraft glide slope receiver responds to the difference in detected levels of the 90 Hz and 150 Hz signals. When the aircraft is on the glide path, the glide path cross-pointer receives equal levels of 90 Hz and 150 Hz signals and remains at mid-scale; the cross-pointer deflects downward when the aircraft is above path (90 Hz predominate) and upward when below path (150 Hz predominate) indicating "fly-down" and "fly-up," respectively. The vertical angle corresponding to full-scale deflection for the cross pointer (+150μA & -150μA on a calibrated receiver) is defined as the glide path sector width.

f. Smooth Line Approach. It is desirable that the glide path be a smooth line approaching a theoretical hyperbolic curve. In the area above and below the path sector width (the clearance signal area), the differences in the detected 90 Hz and 150 Hz signals must be sufficient to maintain the cross-pointer in a fully deflected position. The latter is of particular importance in the below-path areas. The glide slope Standard Service Volume is 10 nautical miles, with a horizontal coverage of 8 degrees on each side of the localizer course, abeam the glide slope origination point.

g. Displacement. The maximum permissible displacement of the glide path due to bends, scalloping, or roughness in Category I, II, and III operations is tabulated in Section 217 of FAA Order 8200.1.

h. Terrain Conditions. The capability of the glide slope to meet the operational requirements depends to a great extent on the terrain conditions between the antenna system and the receiving aircraft and the absence of objects that may reflect undesirable energy into the glide path region.

3-2. GLIDE SLOPE ANTENNA ARRAY SELECTION

The selection of antenna array is highly dependent on the near-field and far-field terrain characteristics in front of the glide slope. Refer to Figures 3-7 and 3-8 regarding typical ground plane requirements and far-field considerations.

a. Image type glide slopes.

(1) Null Reference. The null reference is the simplest of glide slopes; however, it requires a more extensive smooth ground plane and is the most affected by rising terrain or reflectors in the far-field.

(2) Sideband Reference. The sideband reference can operate with the least amount of smooth ground plane due to lower antenna heights; however, the immediate ground plane has more stringent smoothness criteria. Sideband reference works well where terrain drops after a short ground plane and has minimal rising terrain beyond.

(3) Capture Effect. Capture effect is the most tolerant to far-field reflectors and rising terrain. It is also more complex in that it uses separate transmitters to provide the course and clearances. It is generally the system of choice for difficult sites.

b. Non-Image type glide slopes.

(1) End-fire Glide Slope. Unlike image type glide slopes, the end-fire does not use a ground plane to form the pattern. Since siting is close to the runway edge, the end-fire is ideally suited to locations where the lateral terrain is limited, or extensive site preparation would be required for an image system.

(2) RESERVED

3-3. TERRAIN CONSIDERATIONS FOR IMAGE-TYPE GLIDE SLOPES

a. Basic Theory. The glide slope guidance signal depends on the terrain conditions due to the inherent image antenna concept: radiation from an antenna located above a reflecting surface. The reflected signal appears to emanate from an "image" antenna along the same vertical plane as the real antenna and at a distance below the reflecting surface equal to the distance of the real antenna above the surface (see Figure 3-1). The signals from the real and image antenna combine vectorially in space; therefore, the three types of glide slopes are often referred to as "image" systems. The glide path information (null reference system) is formed by the vector sum of four different signals: the direct and reflected signals from the carrier antenna and the direct and reflected signals from the sideband antenna.

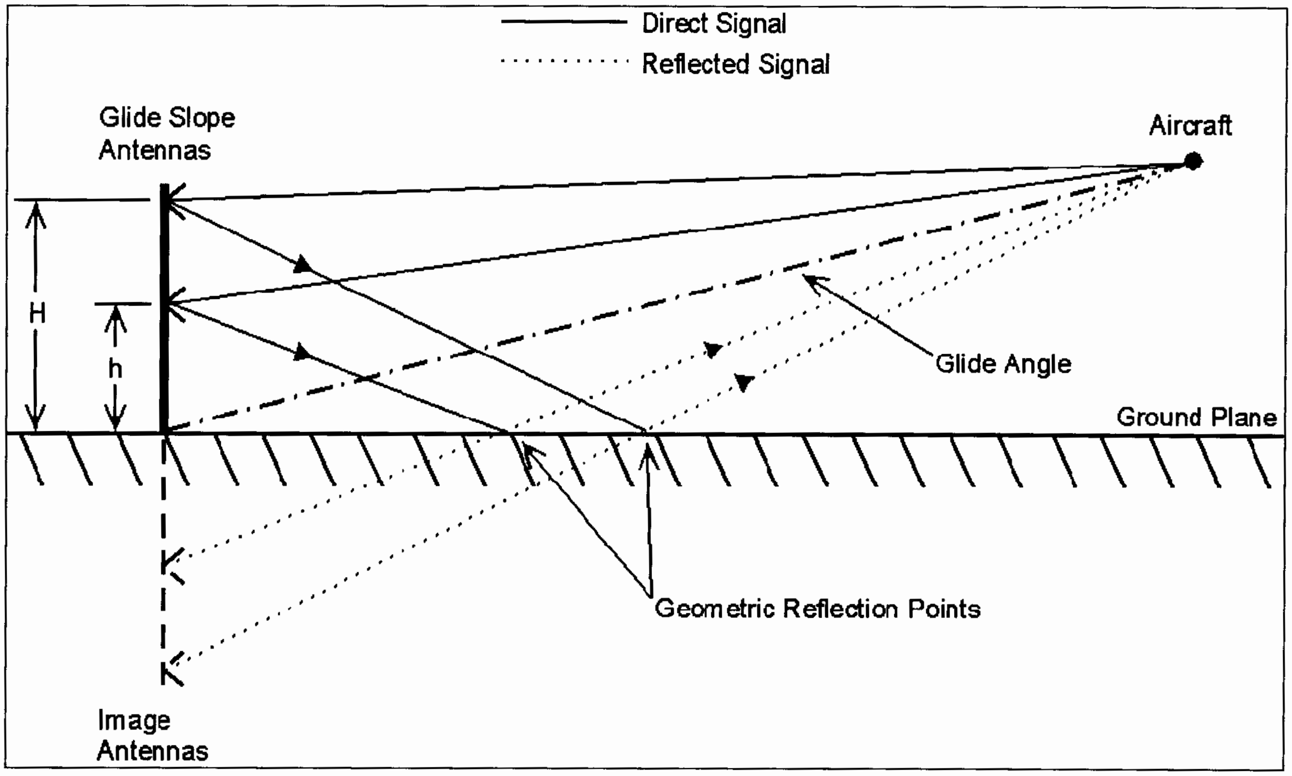


Figure 3-1. Image Antenna Concept

b. Fresnel Zone Considerations. Although Figure 3-1 indicates a single point of reflected energy, reflection actually occurs from the entire area, which is illuminated by the signals from the antenna. The area of reflection consists of a number of concentric zones called Fresnel zones (see Appendix 3), which are numbered outward. The extent of each Fresnel zone is determined by the phase lag of the reflected signal from that zone. The phase lag is a function of the differential path length between the direct and reflected signals, with the phase from each zone lagging that from the next inner zone by pi radians or 180 degrees. Signals from the second and succeeding zones, being of approximately the same amplitude but opposite in phase, cancel almost completely; therefore, when siting the glide slope, only the first Fresnel zone normally needs to be considered.

c. Fresnel Zone Size and Position. The size and position of the glide slope Fresnel zone is a function of the glide path angle and the aircraft's elevation and distance from the facility. When an aircraft is over the outer marker, the Fresnel zone appears as a long narrow ellipse. As the aircraft approaches the runway, the ellipse becomes continuously smaller and gradually migrates as depicted in Figure 3-2. The distance to the geometric ground reflection point and the distance to the Fresnel zone center are plotted in Figures 3-3 and 3-4 respectively for various glide path angles. The length and width of the Fresnel zone are plotted in Figures 3-5 and 3-6 respectively. These graphs are for the sideband (upper) antenna, for a null reference system, and for ideal reflecting terrain.

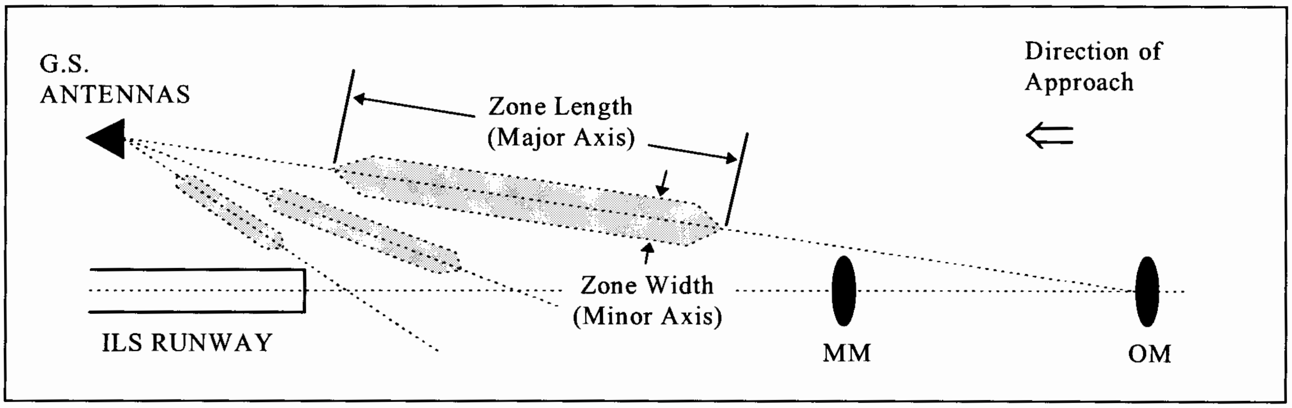


Figure 3-2. First Fresnel Zones for ILS Glide Slope

d. Fresnel Zone Terrain Conditions. The quality of the glide slope information, the smoothness of the glide path, the linearity of the normal approach envelope transitions, and the adequacy of the off-path clearances, are a function of the Fresnel zone terrain conditions. Where the terrain encompassing all of the Fresnel zone is level and uniform, the glide slope signals will approach the theoretical values; where the terrain is irregular or non-uniform, the glide slope will deteriorate accordingly. It is necessary, therefore, to determine whether the terrain's departure from the perfect ground plane can still provide a satisfactory glide slope facility.

e. Fresnel Zone Terrain Considerations. Items to consider when determining the extent of departure of the glide slope terrain from a perfect ground plane include the consistency of the terrain and its coefficient of reflection, the terrain slope or departure of the terrain from the horizontal plane, and the magnitude and extent of broken or irregular terrain or terrain roughness.

(1) Glide Angle and Graze Angle Considerations. For the horizontally polarized glide slope radiation and the low grazing angle of the ground-reflected far-field signal, the ground plane coefficient of reflection has a range of 0.94 for dry, sandy soil to 1.0 for seawater. Therefore, if the Fresnel zone surface is smooth and constant, the coefficient of reflection can be assumed to equal one (R=1) without introducing significant error. Where the Fresnel zone is smooth but not consistent, as where the approach path is partially over water, a change may be encountered in the received signal as the coefficient of reflection changes abruptly. This effect is unavoidable; however, it can be minimized by establishing the lowest possible glide angle (and, therefore, the lowest possible grazing angle) and/or locating the glide slope antennas within the specified criteria, so that the change in the received signal does not occur within a critical part of the approach.

(a) Two additional problems encountered with above-water approaches are the vertical shift in the plane of the Fresnel zone resulting from tides and the dispersion of the ground plane signal by high waves or choppy water. Where these conditions are encountered, the antennas should be located to take advantage of the greatest amount of soil reflection, and possible use of a sideband reference or end-fire system may be required.

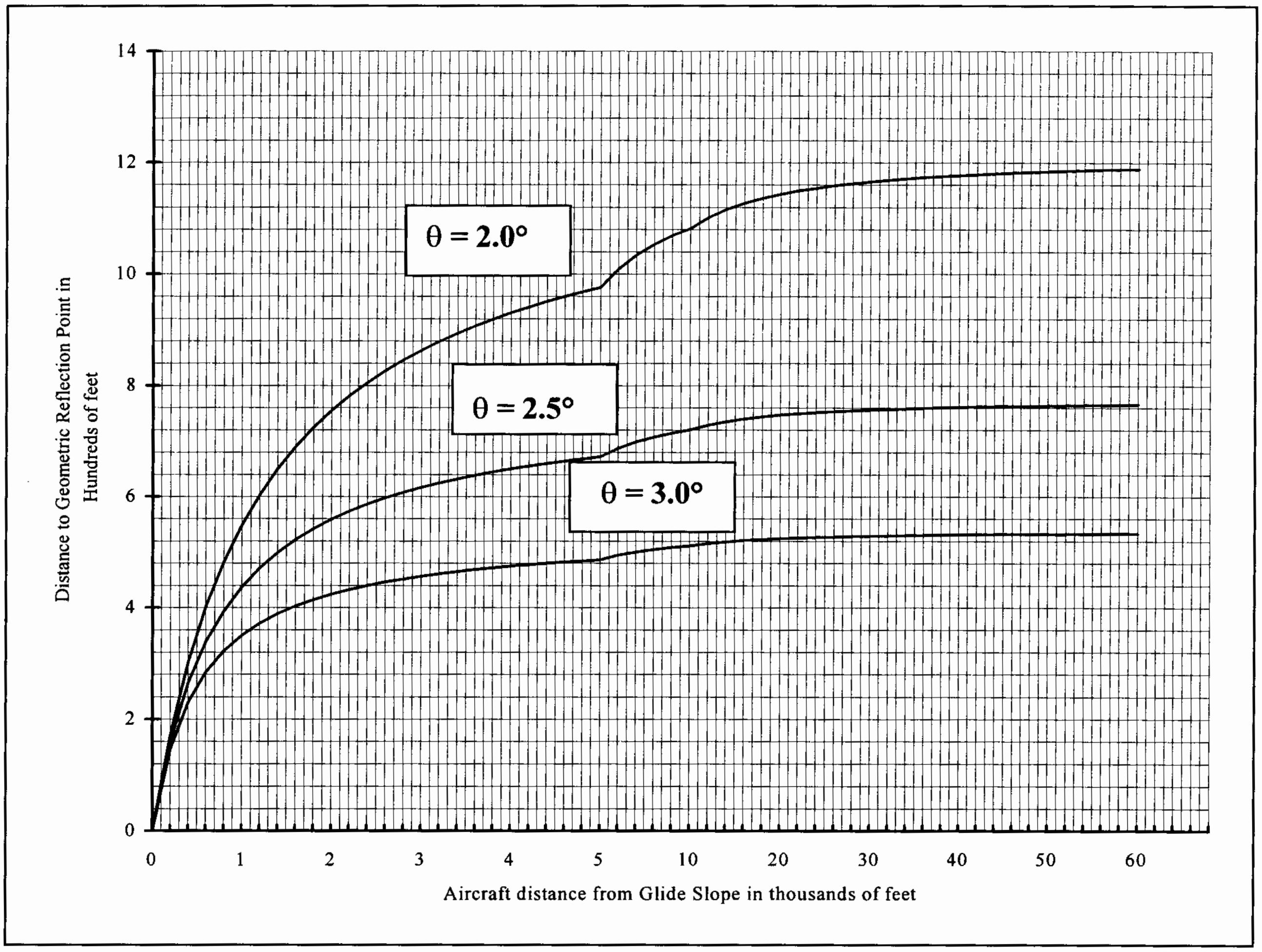


Figure 3-3. Location of Glide Slope Geometric Ground Reflection Points

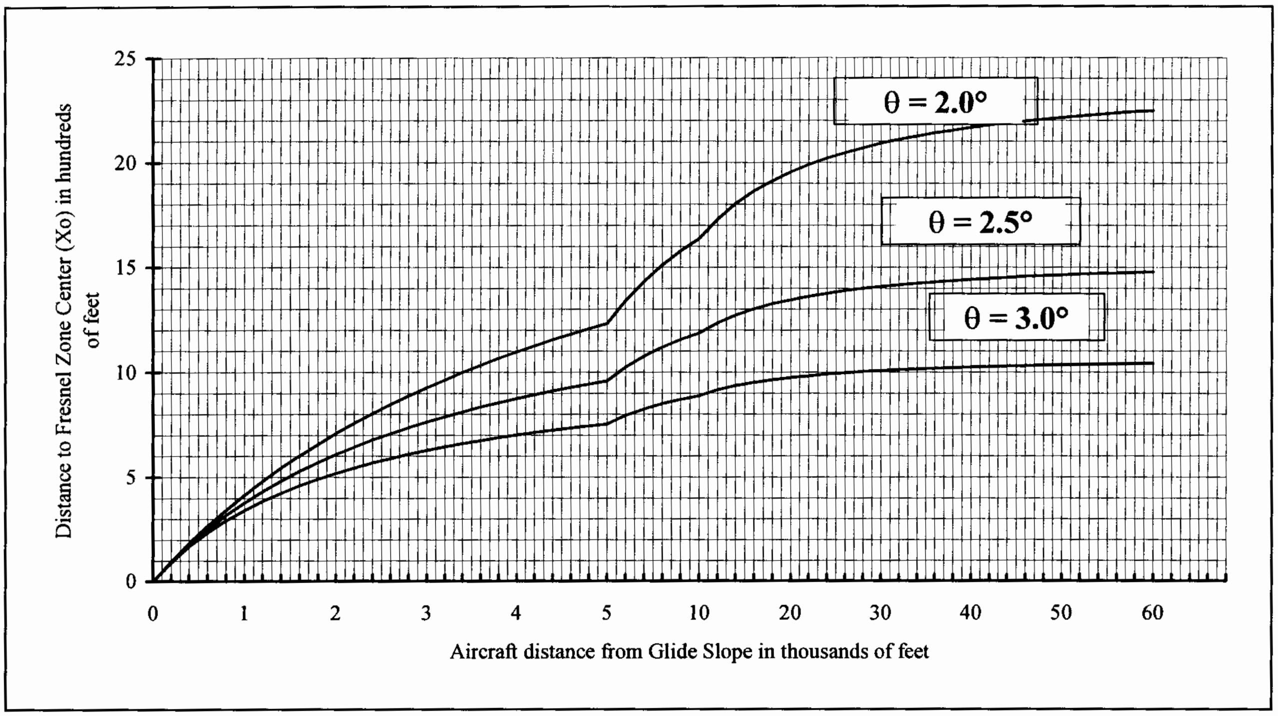


Figure 3-4. Location of Glide Slope Fresnel Zone Centers

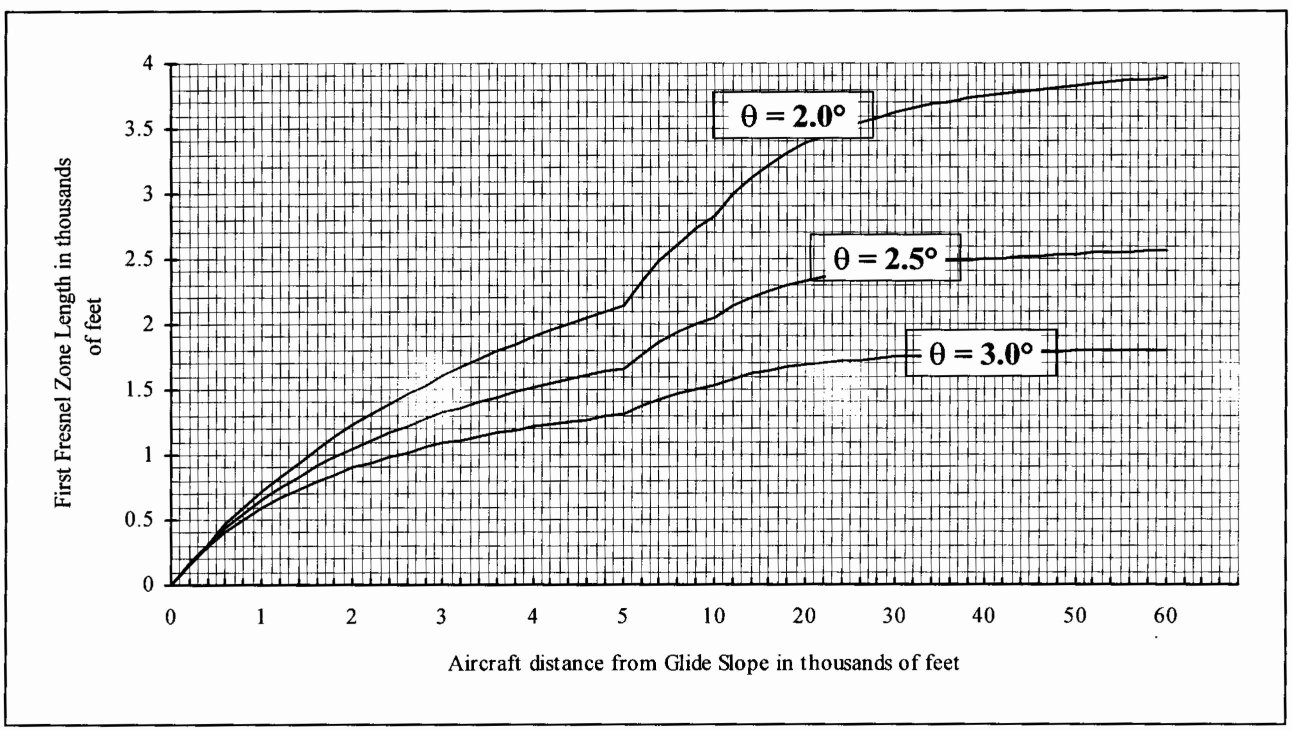


Figure 3-5. First Fresnel Zone Length As Function of Glide Angle and Aircraft Distance from Glide Slope

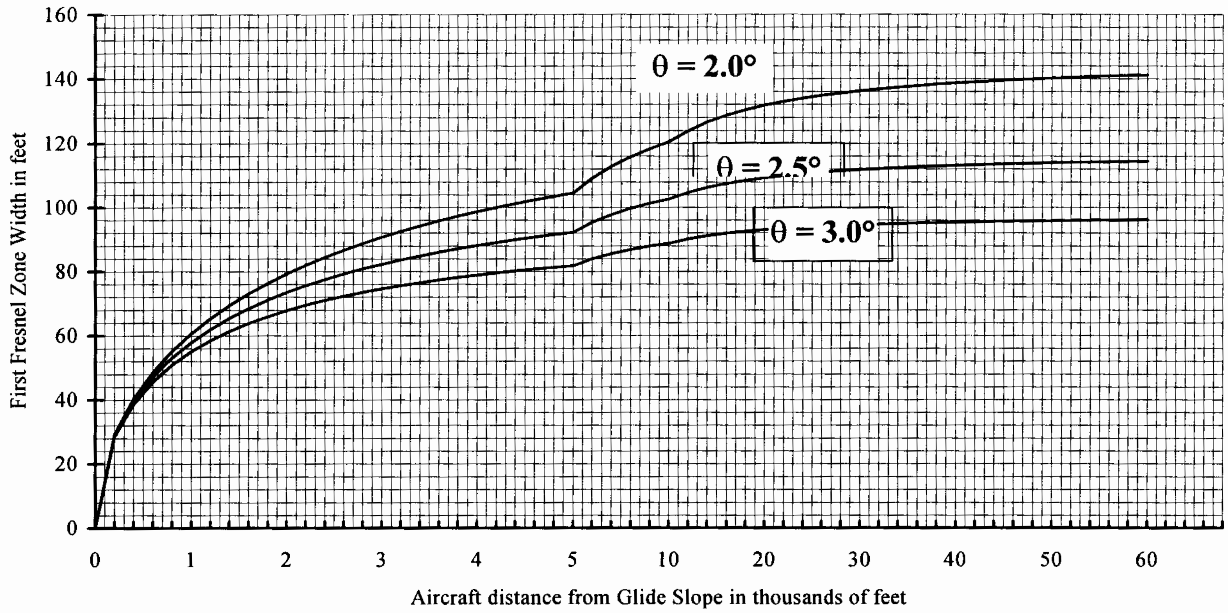


Figure 3-6. First Fresnel Zone Width as Function of Glide Angle and Aircraft Distance from Glide Slope

(2) Terrain Slope Considerations. The theoretically evolved glide slope assumes that the ground surface lies in the horizontal plane. In practice, this is seldom the case, because the terrain at and in the vicinity of most airports generally has some slope. As a result, the radiation patterns will be rotated either up or down relative to the horizontal plane through the base of the antenna mast in the same direction and by the same amount as the terrain's longitudinal slope. With the slope at a constant rate, the effect is overcome by adjustment of the glide angle in a direction opposite to and by the same amount as the slope angle.

(3) Terrain Roughness Considerations. Terrain irregularity or roughness is the worst and most common glide slope siting deficiency. The degrading effect of rough terrain results from the random dispersion and/or phase shift of the ground plane signal, which precludes formation of the desired glide slope pattern. Since it is obviously not feasible to provide a smooth ground plane for the entire glide slope Fresnel surface, it is necessary to establish a terrain roughness that can be tolerated.

(a) Criterion for Roughness. Terrain is considered to be rough if the phase shift in the ground-reflected signal caused by the change in the average path length would result in an out-of-tolerance glide slope. Considering the general case of the null reference glide slope then by application of terrain roughness criteria to the glide slope (see Appendix 3):

$$Z \leq (.0117)\,(T/H)$$

Where: Z = height of irregularity (in feet)

T = distance from glide slope antenna to irregularity (in feet)

H = height of sideband antenna in wavelengths.

Hence, irregular terrain roughness is a function of both the distance to the irregularity and the antenna height or glide angle. For a 3.0 degree glide angle, terrain irregularities exceeding 1.22 feet per 1000 feet from the antennas would be considered as roughness: for a 2.5 degree glide angle, the limit on terrain variations would be 1 foot per 1000 feet. This methodology is in general applicable to other type glide slopes as well.

(b) Extent of Terrain Roughness. Because the terrain reflects the ground signal in a specular manner, slight departures from the smooth terrain for small distances (about 10 feet or less) will not usually have an adverse effect on the glide slope signal. The smooth terrain terminates when it encounters extensive roughness or singular roughness of a large magnitude such as a wide ditch, a hill, or valley. The reflected signal contribution must be continuous for the terrain to be considered smooth; therefore, the smooth surface terminates at the point where roughness is encountered even though a smooth reflecting surface exists beyond the roughness. Contributions from the latter surface must be considered a second order effect.

3-4. SITE PREPARATION

The ideal siting environment is a perfectly smooth, level ground surface both laterally and longitudinally, and an infinite ground plane extent. Although this is desirable to provide an ideal operating environment for each glide slope facility, at most locations considerations such as drainage requires compromise. To the extent practical, grading contours should be straight, parallel, and equally spaced, within grading lateral slope limits, to provide a consistent ground plane throughout the approach. When preparing a given site, several factors must be considered:

a. Grading criteria. Unique Fresnel Zones exist for each observation point. On an approach inbound to threshold, the Fresnel Zone rotates inward and decreases in both length and width. As indicated by Figures 3-2, 3-3, 3-4, 3-5, and 3-6, the first Fresnel zone extends from the antennas outward for up to 3000 feet and up to 130 feet wide. It would be desirable to grade the entire area encompassing the Fresnel zones to provide a smooth ground plane. In accordance with the roughness criteria and economic feasibility, this should be done; however, at most locations the Fresnel zone extends beyond the airport boundaries. This limits the terrain that can be graded. A site conforming to the minimum grading criteria as depicted in Figure 3-7, will generally provide a satisfactory glide slope if the terrain beyond the specified limits does not contain severe irregularities or interference sources.

(1) Optimum Values. Several requirements are implicitly related, with each affecting the computation of the correct longitudinal distance and limiting the permissible values of the remaining items. However, by initially using the ideal or optimum values for the more critical items, the longitudinal distance, which will satisfy the optimum conditions, can be determined. Then by incrementally adjusting the values and the longitudinal distance within the assigned limits, compliance with the remaining requirements can be attained.

(2) Maximization of Smooth Terrain. Where there is a limited amount of smooth terrain in front of the ideal location, the longitudinal distance should be increased, with a corresponding adjustment in the remaining parameters, within the defined limits, to provide the greatest extent of smooth terrain. In addition, where the smooth terrain is limited, a sideband reference, capture effect, or end-fire system will generally be required (see Figure 3-8). If a sideband reference system is used, the lower antenna height requirements may permit a reduction in the lateral distance and, thereby, a possible increase in the extent of smooth terrain. Since a capture effect system requires a higher antenna mast than a null reference system, a greater distance may be required.

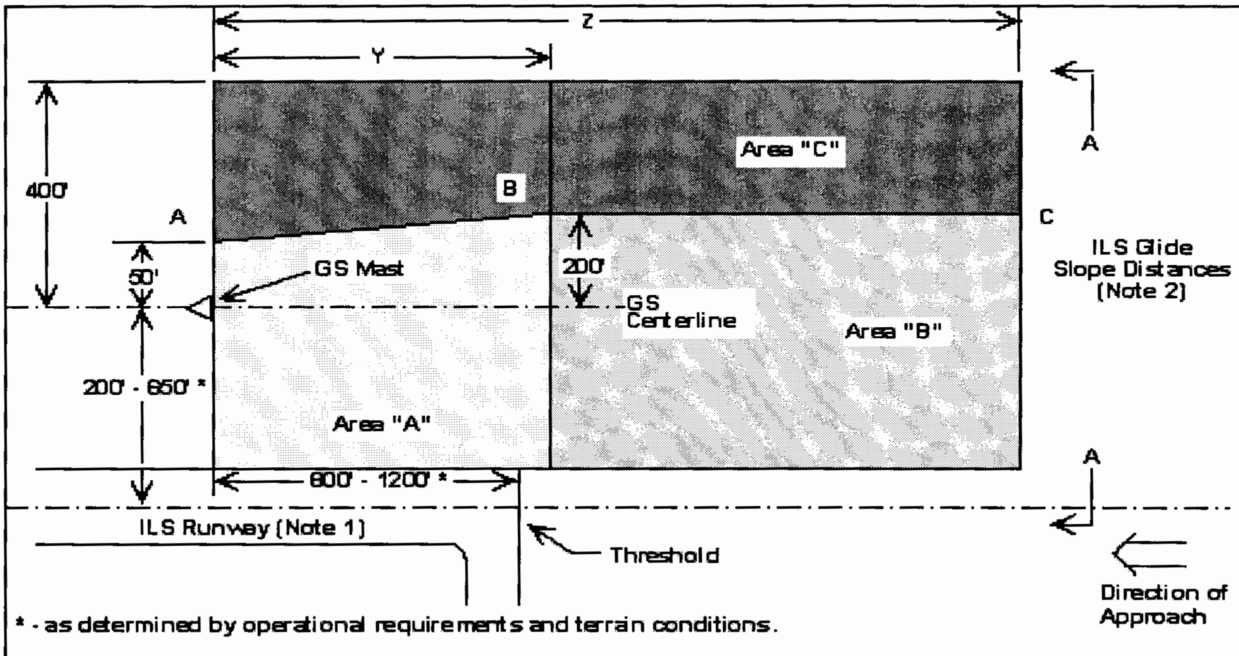
(3) Longitudinal Placement. The glide slope must be established between 2.0 and 4.0 degrees and is typically established with a path angle of 3.00 degrees. Obstacle consideration may dictate a higher angle. Glide slope longitudinal placement is derived from the path angle and threshold crossing height as defined by FAA Order 8260.3, TERPS. Regional Flight Procedures Office (FPO) personnel can provide the angle and threshold crossing height.

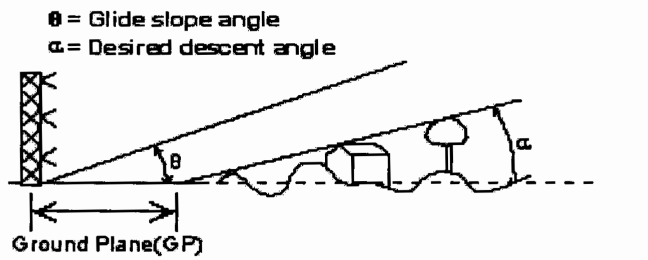
b. Severe Terrain Discontinuities. Severe terrain discontinuities, which would require extensive and infeasible landfill or cutting operations to provide the required smooth terrain, limit the use of the null-reference glide slope. Where this type of siting condition is encountered, the use of an alternate image type glide slope or end-fire glide slope must be considered during the analysis. Where the smooth terrain extends for a distance of less than 2000 feet, a sideband reference system may provide satisfactory operation; if terrain roughness is severe throughout the Fresnel zone area, a capture effect or endfire glide slope should be considered. If the costs of site preparation to install an image antenna system are excessive, comparative costs of an endfire system should be considered.

c. Signal Interference Sources. The presence of signal interference sources (such as power lines, fences, buildings, and other metallic structures), which may reflect the glide slope signal into the usable sector should be considered during the site analysis. When feasible, all such objects should be removed, particularly those in the approach zone. If removal is impossible and the interference source is sufficiently low, a capture effect system will partially overcome the effects of the low-angle reflections.

d. Glide Slope Location. The glide slope may be located on either side of the runway; therefore, all other siting factors (terrain, accessibility, etc.) being equal, the glide slope should be located on that side of the runway which is free of taxiways, runways, helicopter pads, and other potential sources of traffic interference (see Paragraph 1-15). To preclude relocations necessitated by new construction, future airport expansion plans should also be considered when determining the site selection.

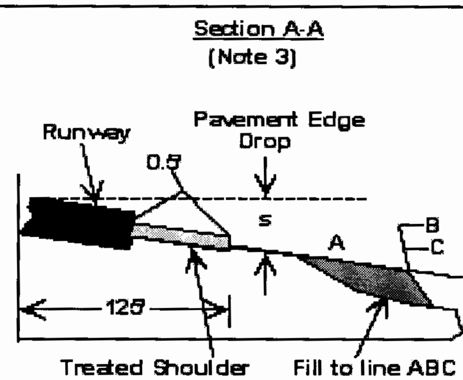
e. Exclusion. If the siting conditions offer no satisfactory alternatives, exclusion of the glide slope and the establishment of a partial ILS should be considered. Every effort, however, should be made to site a glide slope because the presence of the vertical guidance provides a stabilized descent. The partial ILS consisting of a localizer and outer marker may provide sufficient improvement in the landing minimums or the safety factor to justify omission of the vertical guidance information provided by the glide slope.





System	GP (Feet)	α Max	GP Smoothness (Area "A")
NR	1500-2000	θ/5	±6" from Avg Grade
SBR	800	θ/4	±4" from Avg Grade
CEGS	1200	θ/3	±6" from Avg Grade

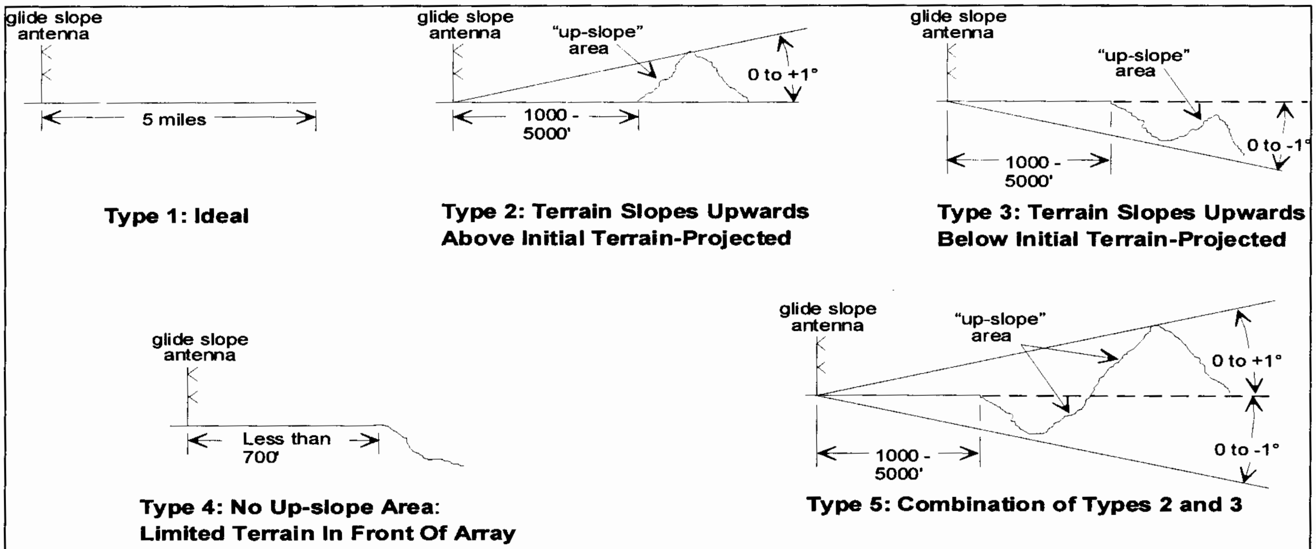
(All Values Typical)



Terrain slope, s, = 3.0% max.
Terrain smoothness: ±0.5 foot

NOTES:
1. Locate glide slope on runway side away from taxiways, roads, etc.
2. Distances
   Y - The greater of 1200 feet or the setback of the glide slope from threshold
   Z - The least of : (a) 3000 feet; (b) distance to the airport property line; (c) distance to where smooth terrain terminates.
3. Grading and obstruction removal
   a. Area A should be uniformly graded and should have the same longitudinal slope as the runway.
   b. Area B should be smoothly graded to comply with terrain roughness criterion of paragraph 3-3e(3)(a). Extensive landfill operations determined by feasibility.
   c. Area C grading may be limited to removal of hills which would reflect the glide slope signal into the usable area.
   d. All possible interference sources (metallic structures, fences, etc.) should be removed from areas A, B, and that portion of C that is within 250 feet of the antenna centerline extended. (Refer to paragraph 3-4c.)

Figure 3-7. Grading Criteria for Image-Type ILS Glide Slopes



	Type 1	Type 2	Type 3	Type 4	Type 5
Percent of Total Sites	5	20	15	15	45
Null Reference	all	very few	few	none	very few
Sideband Reference	all	few	many	very few	few
Capture Effect	all	most	most	none	most
End Fire	all	many	all	all	many

Figure 3-8. Expected Applicability of Glide Slope Systems to Different Siting Conditions

3-5. RESERVED

3-6. ENDFIRE GLIDE SLOPE CRITERIA

a. System Description. The endfire glide slope is a non-image system, meaning that the ground plane is not essential to the formation of the glide path. The principal purpose of the end-fire glide slope is to provide conventional glide slope service at locations where conformance to the image system siting criteria is impractical or expensive. The endfire glide slope is especially useful at sites where there is limited lateral ground plane. A terrain upslope of 1.0 degree should be considered as the practical limitation of an upslope with an endfire system.

b. Configuration. There are two main antennas that provide course guidance within the approach region, a clearance antenna that provides fly-up signal outside the approach region, and three field monitors for verifying signal integrity. The endfire glide slope antenna interfaces with the standard dual-frequency glide slope station. The phase center is an imaginary point from which the antenna radiation in the far field appears to radiate and corresponds in some aspects to the base location of an image-type antenna mast. The phase center is nominally located directly opposite the runway point of intercept (RPI). Phase center setback is dependent on the lateral ground slope. Phase center offset is typically 103 feet from runway edge for model 105, and 75 feet for model 106.

(1) Main Antennas. The front and rear main antennas are typically separated by 450 feet. Each main antenna has a feed-point end connected to a buried RF transmission cable from the shelter and a load end towards the runway side for termination to an RF cable serving as monitor input at the shelter. The main antenna lengths are 75 feet and 120 feet for the Model 106 and 105 respectively.

(2) Clearance Antenna. The clearance antenna is located between the main antennas and is 15 feet long.

(3) Monitor Antennas. Three mid-field monitor antennas are located approximately 800 feet in front of the antenna phase center, and are 6 feet long.

c. Terrain Effect. The radiation in the horizontal plane is very directional, which means that rising terrain with reflecting objects to the side about ±10 to ±15 degrees and beyond are of reduced importance. Except for high rising ground or obstructions below path, the terrain beyond the monitor antennas is of little concern. The endfire glide slope antennas should follow the existing runway shoulder grade, provided there is line-of-sight to the field monitors. Terrain undulations beneath the antennas exceeding 5 inches over any 7.5-foot span should be removed. Where this cannot be achieved, non-standard pedestal heights may be used to accommodate the minimum bend radius for the end-fire glide slope antenna. The antenna cannot be bent more than 5 inches over a span of 7.5 feet.

(1) Site Selection Considerations. For the antenna location, an area is needed free from line-of-sight blockage between the rear main antennas and the monitor antennas. Longitudinal slopes may be compensated for by adjusting the glide path angle and phase center location. Lateral runway shoulder slopes up to 5 percent may be compensated for by adjusting the antenna phase center and relative antenna spacing. A constant terrain slope is not required, so that, for example, water drainage may be provided without concern for the antenna operation.

(2) Snow Site Consideration. When the end-fire glide slope is to be installed at locations where snow accumulation can be expected to exceed 12 inches, consideration should be given to having the area identified as "EFGH" in Figure 1-4 paved and a snow removal agreement reached with the airport sponsor. Consideration should also be given to where snow from the runway, runway shoulder, and endfire glide slope area can be displaced so that line-of-sight can be maintained between the glide slope and field monitors. In areas where significant snowfall is expected, consideration should be also given to installing a load-bearing surface from 50 feet behind the rear antenna of the end-fire to 50 feet beyond the field monitors in order to facilitate snow removal.

3-7. LOCATING THE GLIDE SLOPE FACILITY

a. Definitions and terminology. Several terms and abbreviations are used when locating the glide slope facility (see Figure 3-9 through Figure 3-17).

Threshold (T). The beginning of that portion of the runway usable for landing.

Approach Surface Base Plane (ASBP). An imaginary horizontal reference plane at the threshold elevation.

Approach Surface Base Line (ASBL). An imaginary horizontal reference line formed by the interception of the ASBP and the vertical plane containing the runway centerline and centerline extended.

Glide Path Height (GPH). The height of the glide path above a reference point.

Extended Glide Path. Imaginary extension of the straight-line portion of the glide path coinciding with the glide path over the outer marker and intercepting the ASBL at a point not less than 775 feet down the runway from the threshold. Ideally it is the asymptote of the glide path hyperbola.

Glide Angle (θ). The elevation angle of the glide path with respect to the ASBP; ideally, the angle formed by the ASBL and the extended glide path.

Ground Point of Intercept (GPI). The point where the extended glide path intercepts the ASBL.

Threshold Crossing Height (TCH). The trigonometrically calculated height of the glide path above the runway threshold. The published TCH on standard instrument approach plates (SIAPs) may be either the TCH, RDH, or ARDH. (Typically, Category I SIAPs publish the TCH value, while Category II and III SIAPs publish the RDH or ARDH value. Additional details may be found in Appendix 4 and Order 8420.47.)

ILS Reference Datum Height (RDH). A flight inspection computed height above threshold of the projection of a best-fit straight line (BFSL) derived from the measured data between ILS Points "A" and "B".

ILS Achieved Reference Datum Height (ARDH). A flight inspection computed height above threshold of the projection of a best-fit straight line (BFSL) derived from the measured data between 6000 feet prior to threshold and Point C.

Runway Point of Intercept (RPI). The point where the extended glide path intercepts the runway surface.

"d". Longitudinal distance between point "r" and the glide slope antenna (or point "m").

"d_1". Distance from the threshold to the RPI. (Used only when the "d" does not coincide with the RPI distance.)

"D". Distance from the GPI to an obstacle.

"D_1". Distance from the GPI to the threshold.

"LD". Lateral perpendicular distance between the glide slope antenna and the runway centerline.

"m". The glide slope antenna mast location or the endfire antenna phase center.

"r". References point on terrain directly abeam the threshold at a lateral distance, LD.

"Runway Safety Area (RSA)". A defined surface (see AC 150/5300-13) surrounding the runway prepared or suitable for reducing the risk of damage to airplanes in the event of an undershoot, overshoot, or excursion from the runway.

"Wheel Crossing Height (WCH)". The height of the aircraft's wheels when it crosses the threshold.

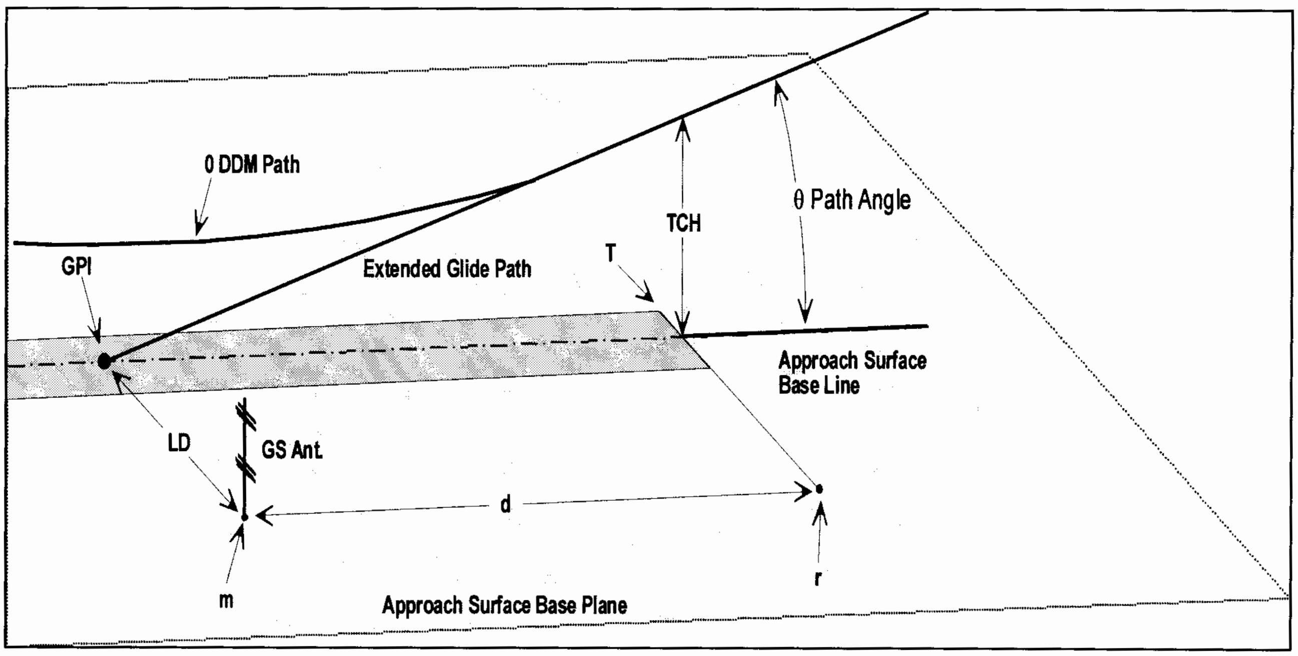


Figure 3-9. Identification of Glide Slope Siting Parameters

b. Glide Slope Siting Criteria. An initial step in siting a glide slope is to determine where the facility should be located in relation to the runway and other movement areas. Obstacle clearance with respect to adjacent taxiways or adjacent runway operations may impact approach minimums or airport capacity. The location of potential glide slope interference sources (e.g., aircraft on taxiways, holding aprons, and parking ramps) should also be considered. The glide slope should be located on the side of the runway free from such interference. If terrain or other factors preclude locating the facility away from these areas, it may be necessary to restrict the flow of ground traffic to prevent glide slope interference (see Figure 1-3 Image GS Criteria and Figure 1-4 Endfire GS Criteria).

c. Lateral Distance Criteria

(1) Site-Specific Data. Site-specific data must be obtained from the appropriate sources, as glide slope siting is dependent on specific Airport parameters in addition to detailed grading elevations. This information is typically documented on the Airport Layout Plan; however, coordination with the FAA's Airport District Office is recommended to assure currency of existing conditions and future projections. The following are Airport criteria required prior to site engineering.

(a) Airplane Design Group (ADG). The Airport is classified with an ADG based on the critical aircraft designated for the airport. This designation is based on the maximum wingspan of aircraft meeting a minimum number of operations at that airport. For the purposes of glide slope offset, the maximum wingspan of the designated group is utilized as one consideration in the determination of the minimum glide slope offset. See Airport Design Standards, AC 150/5300-13, for the maximum wingspans for each group.

(b) Runway Safety Area (RSA). The portion of the RSA to be considered in glide slope siting is a surface area designated for a particular runway, which extends to typically 250 feet either side of the runway centerline that cannot be penetrated by the glide slope installation.

(c) Obstacle Free Zone (OFZ). The OFZ is a volume of space centered above a particular runway that cannot be penetrated by the glide slope tower. The floor of the OFZ is variable dependent on the offset from runway centerline. To define the OFZ, aircraft size (weight), approach category of operation, ADG wingspan category, and airport elevations must be obtained. Refer to Airport Design Standards, AC 150/5300-13, Paragraph 306, for appropriate criteria.

(2) Image Systems:

(a) Safety Area Considerations. The glide slope facility (mast, antenna, and shelter) must be located on a longitudinal reference line that is parallel to the runway centerline and at a lateral distance as determined by applying the obstacle-free zone (OFZ) criteria (AC150/5300-13). The antenna mast, for non-frangible systems, must be located outside the OFZ, must be located outside the runway safety area (RSA), and must be located within 650 feet from runway centerline. The glide slope facility should be optimally located outside the object free area (OFA), but ultimately determined by site analysis. The object free area typically extends out to 400 feet from the runway centerline.

(b) Lateral Distance Criteria Limits. If the glide slope facility cannot be located within the lateral distance criteria limits, an NCP is required. Siting facilities beyond 650 feet is not recommended as the decision height may be impacted due to the hyperbola effect (see Figure. 3-9).

(c) Antenna Height. In conjunction with the siting conditions, the required height of the glide slope antenna mast must be considered when determining the lateral distance. The glide slope antenna mast height must comply with the lateral distance criteria.

When applying the lateral distance criteria, the elevation of the runway centerline abeam of the antenna mast must be used as the vertical reference point or the Ground Point of Intercept (GPI).

(d) Precision Obstacle Clearance Surface (POCS). Category II/III glide slope facilities should be located at a lateral distance at least 400 feet from centerline and must not penetrate the Precision Obstacle Clearance Surface (POCS) defined in FAA Order 8260.3. The POCS is an imaginary surface, for Category II/III approach areas only, starting at centerline abeam elevation and remaining at this elevation for 200 feet perpendicular to centerline. The height and characteristics of the POCS are also adjusted for elevation above mean sea level (MSL). For runways at an elevation less than 1000 feet MSL, the POCS allows the top of the mast and appurtenances to be at a height of 55 feet above the centerline abeam elevation at a lateral distance of 400 feet from centerline. Actual height of the POCS where glide slopes are located can be determined from the following formulas:

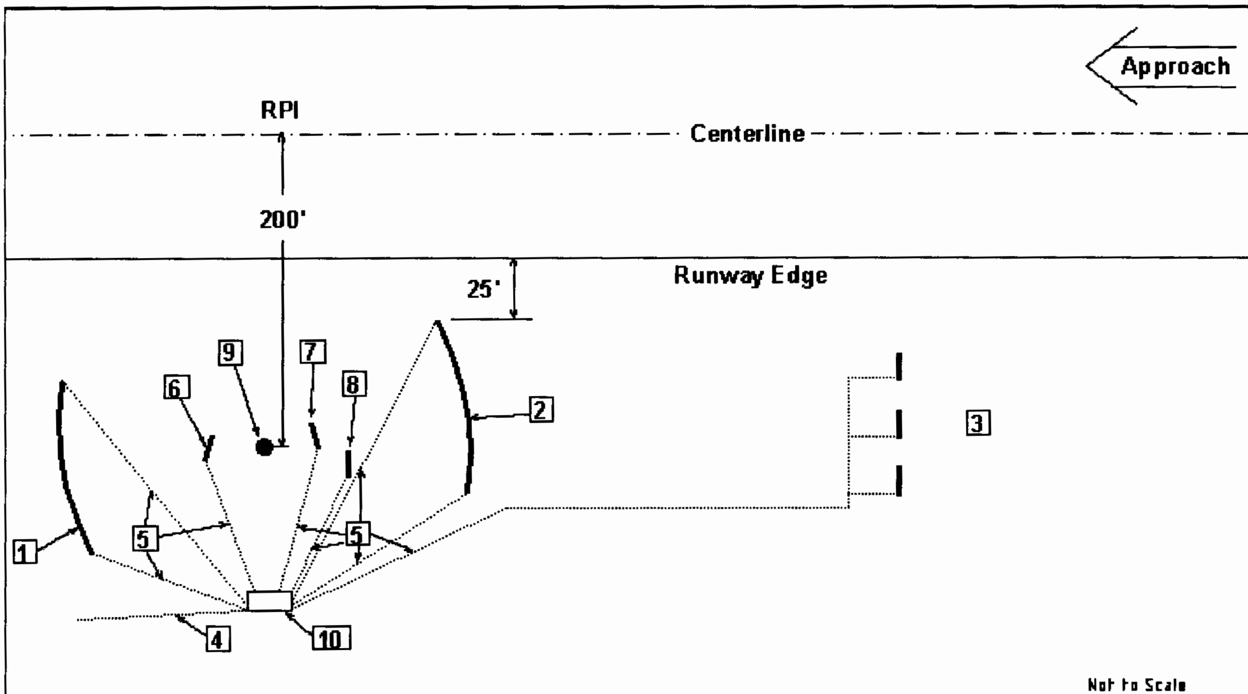
h = MSL height of POCS
Y = Lateral distance (feet) from runway centerline
e = Centerline Abeam elevation (MSL)
k = Increase in surface width due to altitude: If $e \leq 1000$ then $k = 0$, If $e > 1000$ then $k = 0.01(e-1000)$

For $(200 + k) < Y \leq (400 + k)$: $h = (11\ (Y - (200 + k)) / 40) + e$
For $Y > (400 + k)$: $h = (7\ (Y - (400 + k)) / 40) + 55 + e$

(3) Endfire Glide Slope System:

(a) Endfire Glide Slope Antenna. The endfire glide slope antenna, by design and frangibility, is installed within the RSA.

(b) Lateral Distance. The lateral distance between any antenna in the endfire system and the runway edge must be not less than 25 feet (see Figures 3-10a and 3-10b).



Legend:

1. Rear Course Antenna
2. Front Course Antenna
3. Midfield Monitor Antennas
4. Buried Power Line
5. Buried RF Cables (and Power Cables when required for Obstruction Lights)
6. Rear Clearance Antenna
7. Front Clearance Antenna
8. Clearance Monitor
9. Phase Center
10. Equipment Shelter

(a) Dual-Clearance Configuration

Figure 3-10a. Typical End-Fire Glide Slope Equipment Layout, Dual-Clearance Configuration

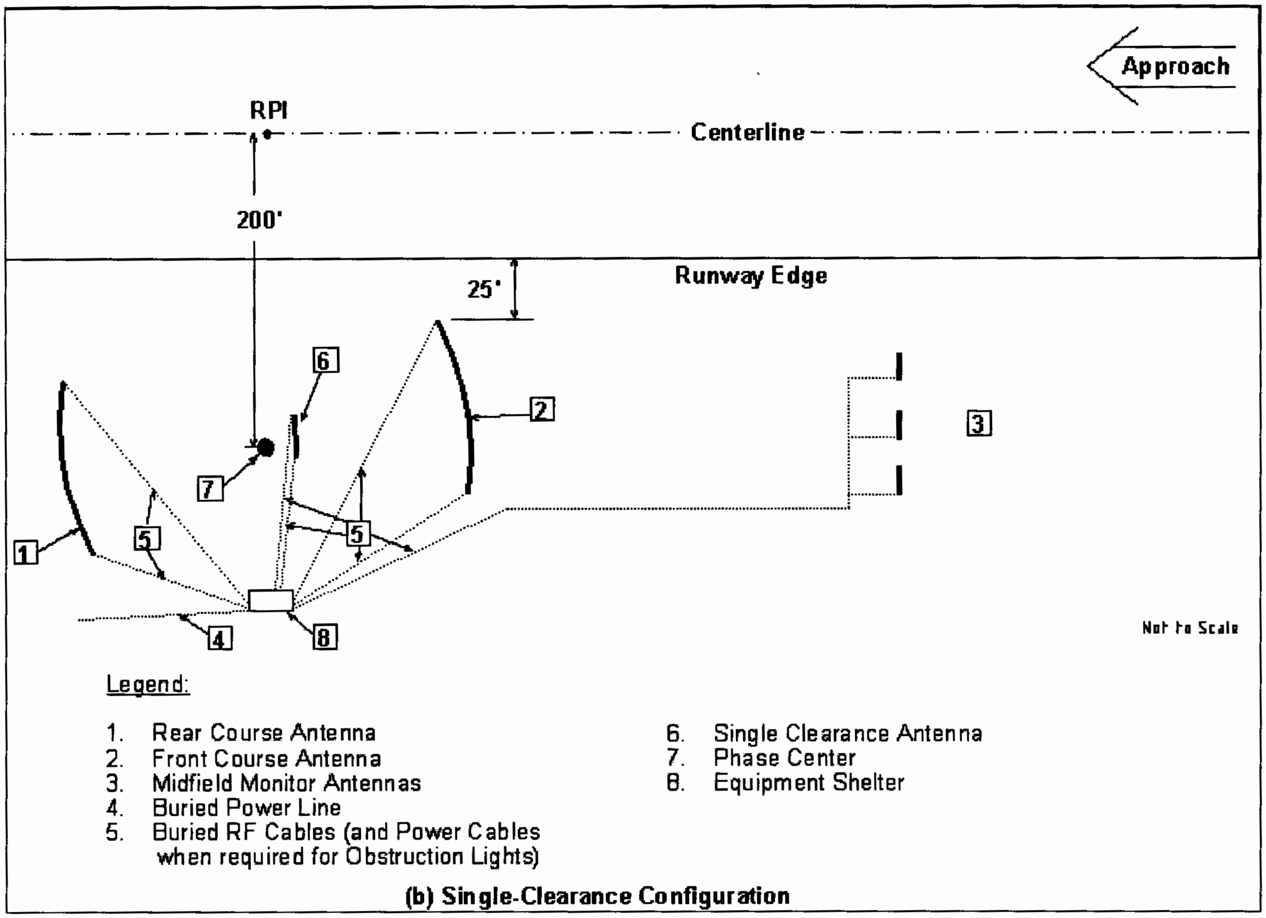


Figure 3-10b. Typical End-Fire Glide Slope Equipment Layout, Single-Clearance Configuration

e. Longitudinal Distance Requirements. The contents of this section should be integrated with the concepts in Appendix 4 when determining longitudinal siting.

(1) Phase Center. Positioning the phase center of the array (for image systems this is the mast location) must be done taking into account the desired glide slope angle, which is normally 3.00 degrees, the TCH, and the longitudinal and lateral terrain profiles. (Typically, Category I SIAPs publish the TCH value, while Category II and III SIAPs publish the RDH or ARDH value. Additional details may be found in Appendix 4 and Order 8420.47.)

(2) Transverse Slope. Theory reveals that if the lateral (transverse) slope is uniform, i.e., there are no steps or discontinuities, then the placement of the image glide slope mast can be identical to that as if the site were ideal, (flat). In effect, lowering the base of the mast lowers the glide slope conic, but this is essentially compensated by the conic being tipped with the ground plane slope. The glide slope on runway centerline will be essentially that of the glide slope generated there if the ground was flat. This transverse slope will cause the glide slope to be measured higher on the side of the localizer away from the mast and lower on the mast side as might be deduced using intuition. The tilt tolerances imposed by flight inspection limit the amount of transverse slope. The reasonable maximum transverse slope is 3 percent down away from the runway.

(3) Site Topography Considerations. Given the design TCH obtained from FAA Order 8260.3, the next step is to assess the topography of the prospective site. Both the lateral slope and longitudinal slopes are very important. If there are no slopes, which is seldom the case because of the need for drainage, the glide slope site is located as shown in Figure 3-11. Given the TCH, the setback distance of the image glide slope mast is simply the TCH divided by the tangent of θ (typically 3 degrees). If the longitudinal slope is down from the glide slope point abeam to the threshold, then

d = TCH/(tan θ + tan of slope). (See Figure 3-12.)

If the slope is upwards from the glide slope point abeam to the threshold, then

d = TCH/(tan θ - tan of slope). (See Figure 3-13.)

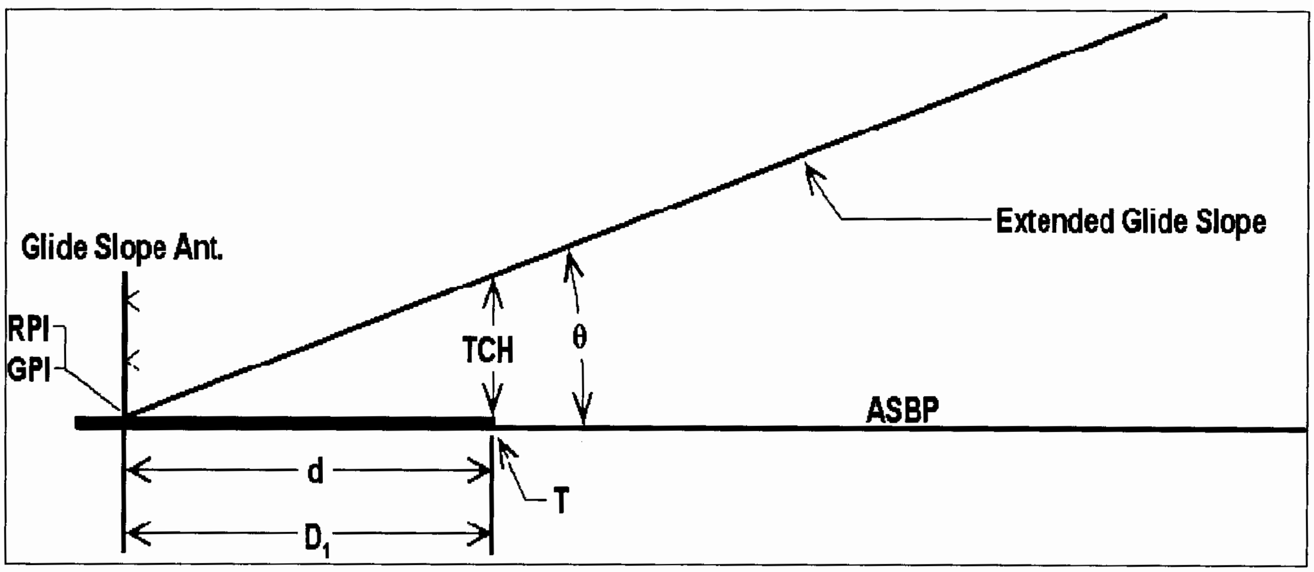


Figure 3-11. Glide Slope Site with Ideal Terrain

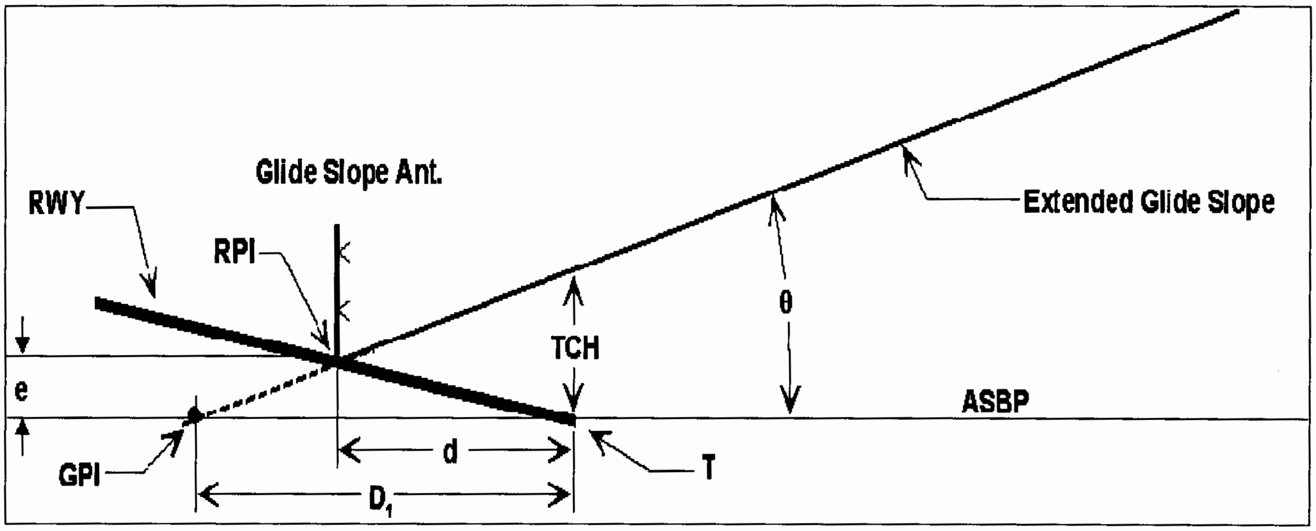


Figure 3-12. Longitudinal Terrain Slope Down from Glide Slope to Threshold

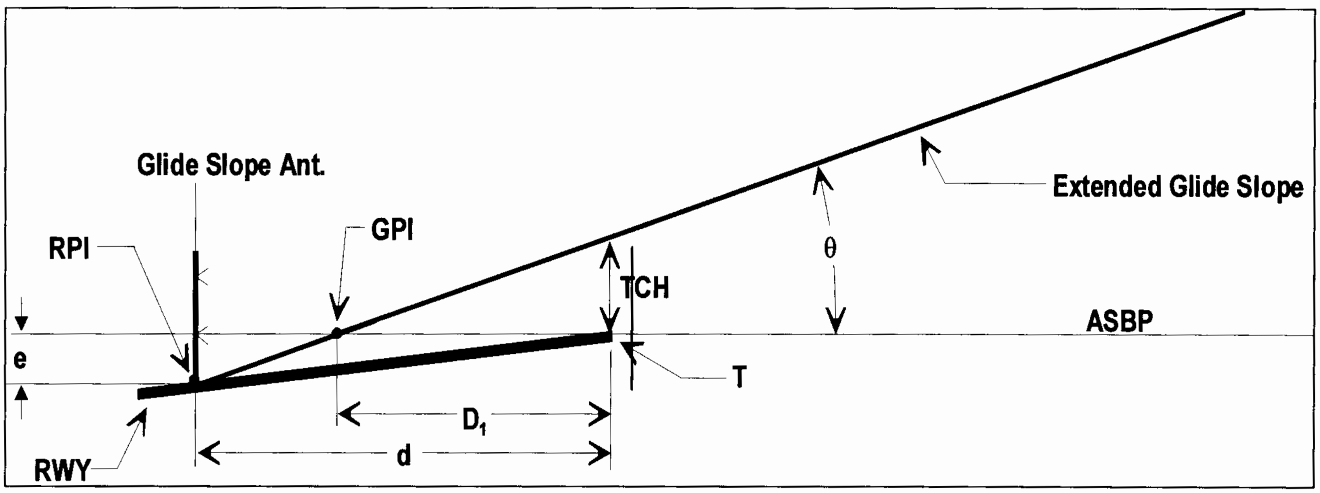


Figure 3-13. Longitudinal Terrain Slope Up from Glide Slope to Threshold

(4) Pedestal Case. Some sites will be found to be graded such that the ground steps down from the runway thus putting the runway effectively on a pedestal (see Figure 3-14). This requires consideration of the height of the pedestal "a". The height of the pedestal requires the phase center to be moved back away from the threshold by an amount equal to the height of the pedestal divided by the tangent of the glide path angle (θ).

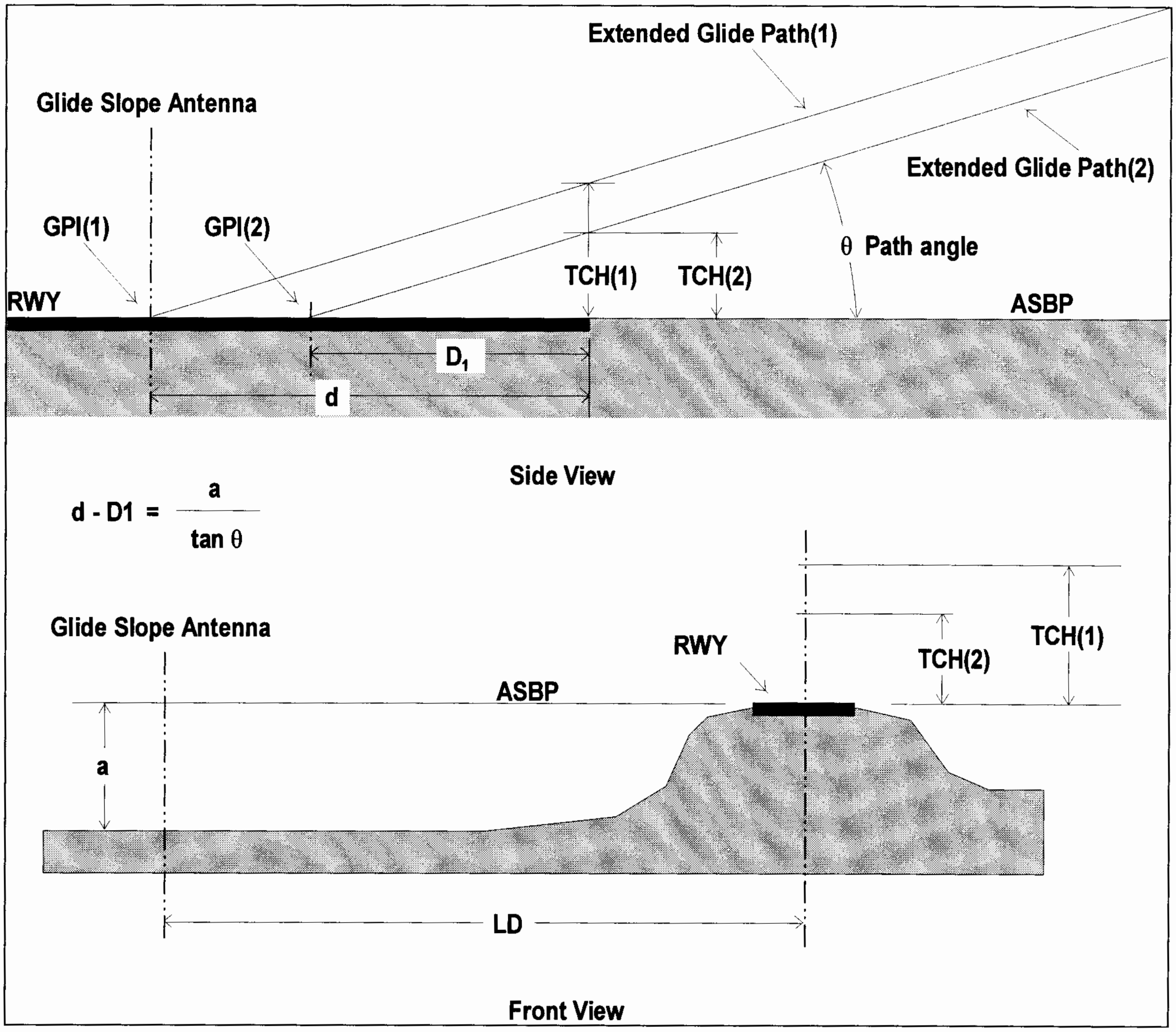


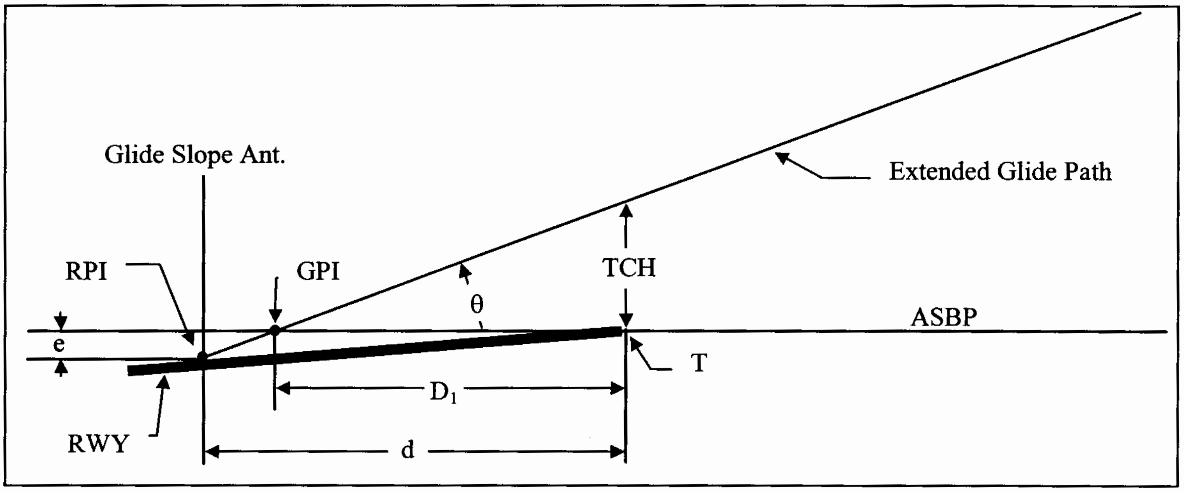
Figure 3-14. Pedestal Case, Height A

(a) Endfire. With the endfire sites, there is no compensating tip of the glide slope conic so that the setback of the phase center "d" (Figure 3-11 through 3-14) is increased by the height of the pedestal divided by the tangent of the glide slope angle regardless of the terrain slope along the LD (the lateral offset distance) line.

(b) Blended Characteristics. If the pedestal is not distinct or the transverse slope is not uniform, the engineer will be required to calculate for the special cases of pedestal and uniform slope, interpolate, apply good judgment (possible math modeling, Appendix 3), and make a determination as to the location of the glide slope phase center. In the case of the image systems, this is the location of the mast. For the endfire, it is identified in the technical instruction manual.

f. Site Test. The optimum site, glide slope system, and operational parameters for each establishment or relocation must be determined by a thorough engineering analysis of the particular siting conditions in accordance with the principles described in this Order. Where severe site conditions are encountered, a site test may be conducted to measure the deviations from the ideal path and off-path clearances and to determine the exact facility site. Where establishment of a satisfactory glide slope requires deviation from the siting criteria or operational parameters, an approved NCP will be obtained prior to commissioning the facility.

g. Examples. For Glide Slope Siting examples see Figures 3-15, 3-16, and 3-17.



(a) A site has a longitudinal terrain slope of 0.5 percent; determine "d" required to establish the optimum glide path angle of 3.0 degrees and a threshold crossing height of 50 feet.

given: s = .005, θ = 3.0°, TCH = 50'

$$d = \frac{TCH}{\tan\theta - s}$$

$$d = \frac{50}{.05241 - .005}$$

$$d = 1055 \textit{ feet}$$

(b) Determine "d" if the terrain slope is 1.0 percent and a glide path angle of 3.0 degrees with a threshold crossing height of 55 feet.

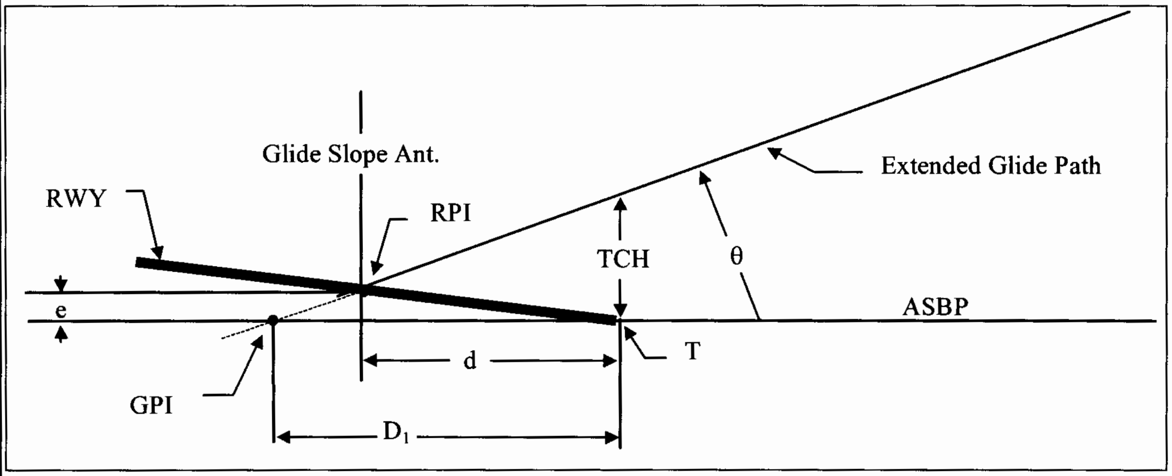
given: s = .01, θ = 3.0°, TCH = 55′

$$d = \frac{55}{\tan 3° - .01}$$

$$d = \frac{55}{.05241 - .01}$$

$$d = 1297 \textit{ feet}$$

Figure 3-15. Glide Slope Site with Positive Terrain Slope



(a) A site has a longitudinal terrain slope of 0.5 percent; determine longitudinal distance required to establish the optimum conditions of θ = 3.0 degrees and a TCH = 50 feet.

given:

s = -0.005, θ= 3.0°, TCH = 50'

$$d = \frac{TCH}{\tan\theta - s}$$

$$d = \frac{50}{.05241 - (-.005)}$$

$$d = 871 \textit{ feet}$$

(b) Determine "d" if the terrain slope is -.75 percent and a glide path angle is 3.0 degrees with a threshold crossing height of 52 feet.

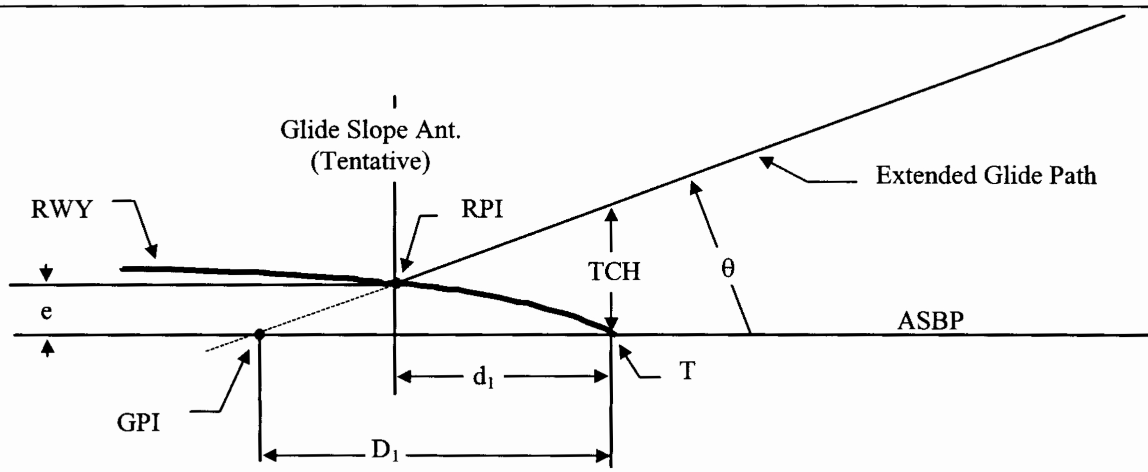
given: s = -0.0075, θ = 3.0°, TCH = 52′

$$d = \frac{52}{\tan 3° - (-.0075)}$$

$$d = \frac{52}{.05241 + .0075}$$

$$d = 868 \textit{ feet}$$

Figure 3-16. Glide Slope Site with Negative Terrain Slope



A glide slope of 3.0 degrees and a TCH of 52 feet are to be established at the depicted site, which has a nonlinear terrain slope. Initially, the longitudinal distance with ideal terrain is determined.

From d = TCH / Tan (θ): d = 992 feet (Ideal)

Since the runway has a negative gradient, a distance less than the ideal should be used:

d_1 = 950 feet (first assumption)

From the topographical data, the relative elevation at "d" is ascertained. Assume this elevation to be 8 feet. An average slope is determined using:

$$s_{avg} = \frac{e_T - e_d}{d_1} = \frac{0-8}{950} = -0.0084$$

The longitudinal distance for a constant slope equal to the average slope is computed by:

$$d = \frac{TCH}{\tan\theta - s}$$

$$d_1 = \frac{52}{.05241-(-.0084)} = 855\ feet$$

Next the required elevation at "d_1" is determined using:

$$d \tan\theta = TCH - e$$

$$855 \tan 3.0° = 52 - e$$

$$e = 7.2\ feet$$

If the relative elevation at "d_1" equals this value (7.2 feet), then the computed distance is satisfactory. If the actual elevation differs considerably from the computed requirement, then a second distance should be assumed and the computations repeated so that the distance and elevation correlate in the previous equation.

Figure 3-17. Site with Irregular Slope

3-8. PHYSICAL REQUIREMENTS

a. Equipment. The glide slope consists of the antennas, antenna mast, equipment shelter, electronic equipment, and the interconnecting cables. The glide slope mast heights may vary from 25 feet for a sideband reference to 50 feet or higher for a capture effect system. The top of the mast excluding the obstruction light must be less than 5 feet above the center of the upper antenna. Every effort should be made to obtain correct lengths of tower sections rather than cutting tower sections.

NOTE: The mast heights listed above are for a glide slope angle of 3.0 degrees. If a glide slope beyond these limits is required, refer to FAA Order 6750.54, Electronic Installation Instructions for Instrument Landing Systems (ILS) Facilities.

b. The Equipment Shelter. Refer to Paragraph 1-16 of this Order for shelter information.

(1) Image Glide Slope Equipment Shelter. The image glide slope equipment shelter is located 10 feet behind (in the direction opposite the approach threshold) and on the same reference line as the antenna mast.

(2) Endfire Glide Slope Equipment Shelter. It is desirable to locate the shelter close to the antenna array in order to keep the buried transmission and monitor RF cable lengths to a minimum. Since equal length cables are desirable, the shelter should be placed symmetrically between the front and rear main antennas. Refer to Manufacturer's Technical Instruction book.

3-9. RESERVED

3-10. REQUIRED OBSTRUCTION CLEARANCE (ROC)

In the initial process of siting, coordination with the flight procedure office is necessary to assure TERPS compliance of approach surface criteria. Penetrations must be addressed and resolved prior to facility construction.

3-11. SUMMARY

As indicated in the examples, it may sometimes be necessary, because of the interdependence of the various siting and operational parameters, to make several calculations for the optimum glide slope location and operational values. The calculations can be greatly reduced by initially assuming a value of 1100 feet to 1200 feet for D and noting that the greatest effect in raising the Glide Path Height (GPH) is obtained by changing the glide path angle. If it is not possible to comply with the ROC criteria within the permissible limits of the glide angle and TCH, then the following alternatives should be considered:

a. Removal of obstructions.
b. Displacement of runway threshold.
c. Establishment of landing minimums higher than desired.

d. Using a glide path greater than 3.0 degrees.

e. Using a Wheel Crossing Height (WCH) higher than specified in FAA Order 8260.3, Glide Slope Threshold Crossing Height Requirements requires an approved NCP.

CHAPTER 4. MARKER BEACONS AND ANCILLARY AIDS

4-1. MARKER BEACONS

a. General Information. The primary function of ILS markers is to designate specific points in the ILS approach path. To accomplish this function, the markers radiate a highly directional vertical pattern at 75 MHz, which has an elliptical shape in the horizontal plane. The marker antenna is oriented so that the ILS approach path passes through the minor axis of the pattern. The detected modulation signal causes an instrument panel light of a particular color to flash, and/or a coded audible signal to sound as the aircraft passes through the radiation pattern, thus indicating a fix that can be used to determine the position of the aircraft on the ILS approach course. See Table 4-1 for operational characteristics.

Table 4-1. Typical ILS Marker Characteristics

TYPE	FUNCTION	LOCATION	MODULATION FREQUENCY	Code
Outer Marker	May mark final approach fix or point of Glide Slope Intercept	4 to 7 nautical mile from threshold	400 HZ	2 dashes/sec continuously
Middle Marker	May mark a point 200 feet above the highest elevation in the touchdown zone	2000 to 6000 feet from threshold	1300 HZ	Alternate dots and dashes at a rate of 95 combinations per minute
Inner Marker	May mark decision height point 100 feet Above the highest elevation in the Touchdown zone	800 to 1500 feet from threshold	3000 HZ	6 dots/sec continuously

b. Requirements. A method to identify the final approach fix or point of glide slope intercept is required for ILS installations. The Regional Flight Procedures Office provides the location of the final approach fix or point of glide slope intercept and type of fix required. An outer marker or an alternate fix (e.g., DME, crossing VOR radial, RADAR, NDB, RNAV fix, etc.) satisfies the requirement to identify the final approach fix or point of glide slope intercept. Category II/III ILS additionally requires an inner marker. Marker beacon antennas used in Category II/III operation must not penetrate the approach light plane. (Additional discussion can be referenced in FAA Order 6850.2, Visual Guidance Lighting Systems.) The middle marker is sited to identify the point in space that is 200 feet above touch down zone elevation on the glide path. The inner marker is sited to identify the point in space that is 100 feet above touch down zone elevation on the glide path. If installed, marker beacon locations must meet the tolerances in Paragraph 4-1c.

c. Location Tolerances. Since it is not always possible to physically locate markers beneath the desired point in space, the following permissible variations have been established:

Outer Marker:	+/- 800 feet both longitudinal and lateral
Middle Marker:	+/- 500 feet longitudinal and +/- 300 feet lateral
Inner Marker:	+/- 50 feet both longitudinal and lateral

NOTE: Longitudinal – along localizer course. Lateral – perpendicular to localizer course.

(1) The markers should not be arbitrarily located within the tolerable limits; consideration is given to the vertical shift in the marker/glide path intercept point which deviation from the nominal location will cause.

(2) When an inner marker cannot be sited within the above location tolerances due to a displaced threshold, a lateral tolerance of +/- 200 feet is allowed contingent on the facility meeting flight inspection requirements of FAA Order 8200.1. The inner marker must not be sited closer than 50 feet from the edge of the runway and must be mounted on frangible couplings.

(3) Under no circumstances must the outer marker be located so that an inbound aircraft flying at the minimum approach altitude intercepts the outer marker prior to intercepting the glide path.

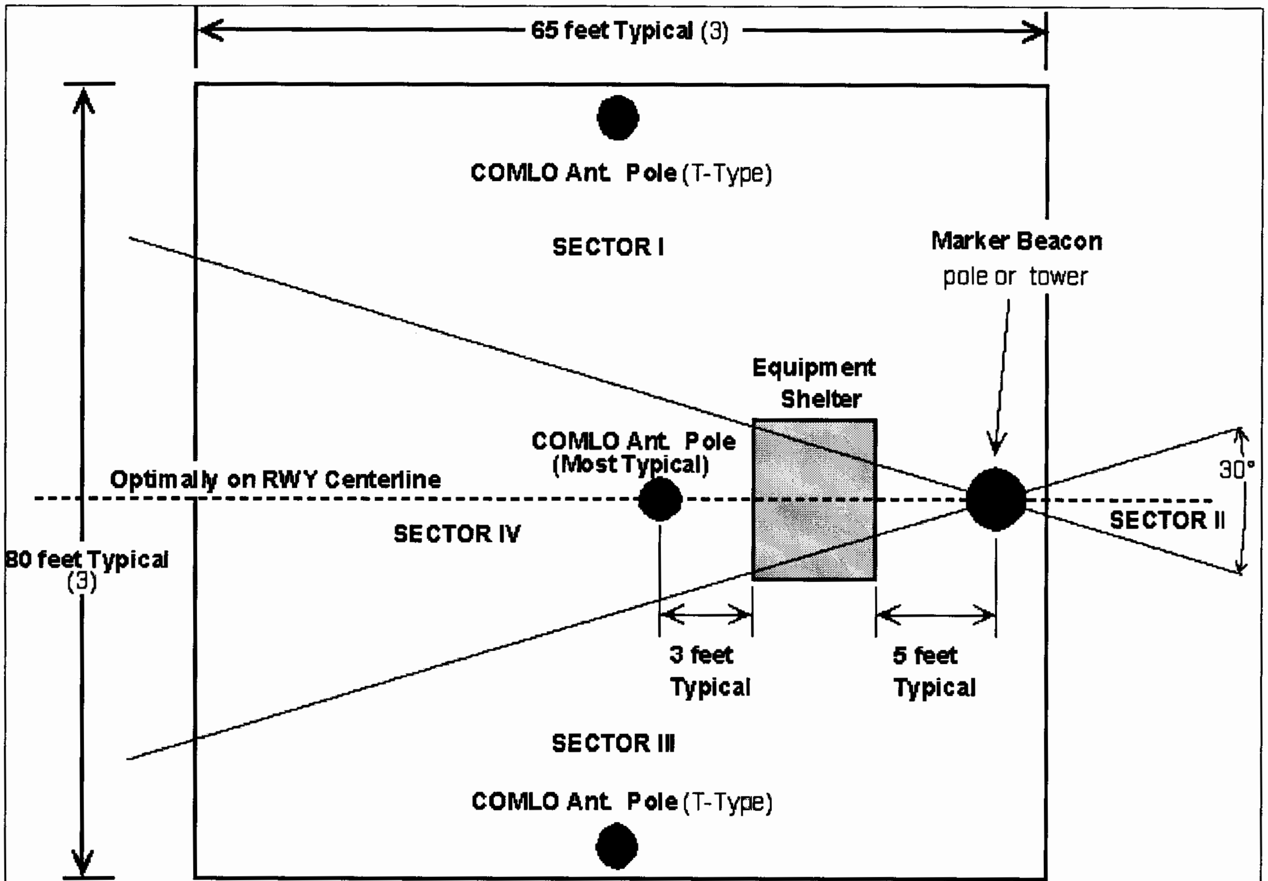
d. Supplementary Requirements. The establishment requirements for markers used in conjunction with offset localizer and parallel ILS approaches are provided in the paragraphs concerning those ILS configurations. For partial ILS (localizer only), an outer marker is generally established using the same criteria as for a full ILS.

e. Back-Course Markers. To obtain the full operational benefits of the localizer, it may be desirable to establish position markers on the back-course approach. Back-course markers are identified by a tone of 3000 Hz keyed by a pair of dots at 95 per minute.

f. Marker Shelters. Refer to Paragraph 1-16 of this Order for shelter information.

g. Collocated Facilities. Figure 4-1 illustrates a typical plot plan and some constraints for a collocated marker and COMLO facility. The marker equipment will be installed in the shelter and the antenna will remain mounted on the pole or tower.

h. Obstruction Criteria. To function properly, the marker antenna must be provided with obstruction-free zones. Figure 4-1 specifies the criteria for all marker beacon systems.



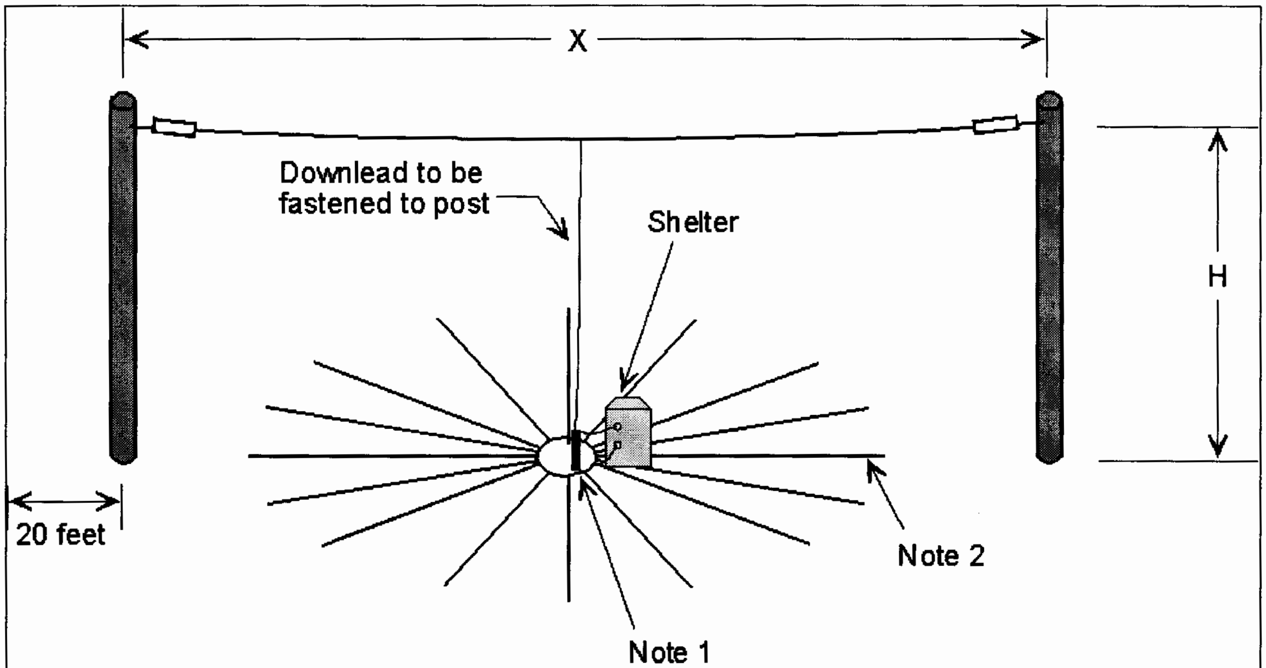
NOTES:

1. Sectors I and III are critical pattern forming areas for marker major axis coverage. Interference sources in these areas within 100 feet of the antenna and protruding above a 20-degree angle with respect to the lower antenna element should be removed. Sectors II and IV are critical path forming areas for minor axis coverage. Interference sources in these areas within 100 feet of the antenna and protruding above a 45-degree angle with respect to the lower antenna element should be removed.

2. The designation COMLO applies only to those facilities where the output power does not exceed 25 Watts. Higher power facilities are designated as MH (25 to 50MW) or H(above 50W). At H locations, the depicted plot should be enlarged if it is necessary to increase the antenna pole spacing.

3. If a colocated COMLO is not used with the marker, the depicted plot size may be reduced to approximately 20 feet by 20 feet.

Figure 4-1. Siting Criteria for Marker/ NDB



NOTES:

1. Ring buss is typically constructed from No. 2 AWG SD solid copper wire in a three-foot diameter circle.

2. A minimum of sixteen equally spaced radials as long as or longer than the COMLO antenna height should be installed. Radials are typically buried from 2 to 6 inches below ground on the plot owned or leased by the FAA and a minimum of 6 inches below ground off the plot and are typically No. 6 AWG SD solid copper wire. See manufacturer's instruction book for additional details.

3. Typical Antenna Dimensions (T-Type). Use guy wires as appropriate.

	X (feet)	H (feet)
COMLO	60-80	25-50
MH	120-250	30-50
H	250	50-70

Figure 4-2. Typical NDB Layout and Plot Size Requirements

4-2. DISTANCE MEASURING EQUIPMENT (DME)

DME may be installed as an ancillary aid to the ILS. Generally, the DME is collocated at the localizer when used as a component of the ILS. DME provides a means to identify the final approach fix or point glide slope intercept and can provide radio navigation for the missed approach procedure. A DME may be used in lieu of an outer marker when approved by the Regional Flight Procedures Office and sited so divergence is in accordance with FAA Order 8260.3. The DME zero reference point must be established at the DME site. A single DME may be used to serve opposing localizers on the same runway when all of the following criteria are met:

a. The DME is collocated with the localizer serving the primary approach
b. Both localizers are on the same radio frequency
c. The DME identification is the same as the radiating localizer

4-3. COMPASS LOCATORS

a. Non-Directional Beacons. If operationally required, non-directional beacons (NDB) used as a compass locator may be installed at the outer marker site as an ancillary aid to an ILS. Compass locators provide a means to identify the final approach fix or point of glide slope intercept, a means for an aircraft to transition from the en route environment to the terminal environment, and radio navigation for the missed approach procedure. These facilities are designated as locator outer marker (LOM) when meeting the siting requirements for outer markers contained in Paragraph 4-1c.

b. Power Output. Compass Locators are limited to an output power of 25 watts. If a standard compass locator will not meet operational requirements, the compass locator can be changed to a Medium Powered Homing (MH) class NDB. The MH facility operates with a power of 25 to 50 watts, and the H facility operates at power greater than 50 watts. Change in class from a compass locator to an MH or H requires approval from Spectrum Management and may require a change in antenna configuration.

c. Morse Code. The compass locators transmit a 1020 Hz identification tone that modulates a two-letter Morse code signal consisting of the first two letters of the ILS identification. If an MH facility is required, a 400 Hz identification tone modulates a unique three-letter Morse code signal.

d. Antennas. The compass locator normally uses a flattop "T" antenna 25 to 50 feet high and 80 feet long. The vertical wire is the radiator and the horizontal wire(s) serve to capacitively load the antenna. A vertical "Top Hat" mast antenna can also be used. Both of these antennas require ground radials to function properly. When an MH facility is required, the flattop "T" antenna dimensions should be increased to 50 feet high and 250 feet long.

4-4. RESERVED

4-5. RESERVED

CHAPTER 5. MONITOR AND CONTROL REQUIREMENTS

5-1. GENERAL REQUIREMENTS

a. Executive Monitoring. Local monitoring and control, including the capability to detect and shutdown the equipment in prescribed alarm conditions, must be provided at all ILS facilities. This requirement applies to all ILS navigational equipment to include localizer, glide slope, markers, distance-measuring equipment (DME), and associated non-directional beacons (NDB).

b. Remote Status Monitoring by Air Traffic Personnel. ILS remote status indication is a requirement for all Cat I/II/III ILS installations. ILS status must be available without delay to the Air Traffic control facility that is involved in the final phase of the ILS approach. The requirement for remote status has been expanded to include Category I ILS (International Civil Aviation Organization, ICAO Annex 10, 1999),

(1) For the purposes of authorizing alternate minimums (this consideration to be obsolete when ILS remote statusing is fully implemented):

(a) Alternate minimums will not be authorized at times when the ILS status indication is unmonitored.

(b) All equipment required for operation of the approach must have remote status monitoring. Determination as to the necessity of particular equipment for the alternate procedure will be made by the Flight Procedures Office.

(2) Cat II/III remote status and control equipment must be located in the local air-traffic control tower for immediate status indication. Required control capability includes on/off, reset, interlock, and far-field monitor bypass. Refer to Paragraph 1-14a regarding interlock requirements.

(3) Cat I (or less) remote status monitoring equipment must, as a minimum, consist of a failsafe on/off indication, to include an aural alert, and be located at an air traffic facility.

(a) The preferred location of Cat I ILS status monitoring is at the local ATCT. If there is no ATCT or the ATCT is a part-time facility, status monitoring must be remoted to a 24-hour Air Traffic facility (TRACON, Automated Flight Service Station (AFSS)). Air Traffic contracted services (i.e., non-fed ATCT, weather observation) can include provisions for the air traffic monitoring.

(b) Control capability is required only if there is an interlock requirement as defined by Paragraph 1-14.

c. Remote Status Monitoring by Non-FAA personnel. As an option, to help restore an ILS following an outage at locations without a local AT facility and not authorized for alternate minimums, the assistance of a responsible person such as the airport manager or fixed based operator should be solicited. Permission should be obtained to locate the status indicating equipment in their quarters, and request that the responsible maintenance office be alerted whenever an alarm occurs. It should be emphasized that no liability is attached and that the function is strictly for expeditious maintenance action. (This paragraph will be obsolete upon full implementation of full ILS monitoring by Air Traffic.)

d. Remote Maintenance Monitoring (RMM). Remote maintenance monitoring equipment (e.g., ARMS) or integrated RMM provides remote access to the facility. Benefits of RMM include enabling remote periodic maintenance and some certifications, reset capability, remote fault isolation, alarm/event history, and pre-alarm notification. RMM systems do not fulfill the requirements for remote status monitoring by AT personnel.

5-2. EQUIPMENT REQUIREMENTS

ILS remote status monitoring equipment must be installed as designed by the equipment manufacturer except where multiple ILS and/or ATCT space confinements warrant consolidation. Approved consolidated monitor and control equipment can be installed in lieu of some or all of the factory-designed components. Consolidation of ATCT cab display indicators that maintain the original failsafe design features can be regionally approved. Consolidated systems that involve complex design changes require national approval. Typical monitoring systems include:

a. Through the Air Remote Monitoring. A receiver detects loss of the radiated RF signal due to a facility shutdown and provides a remote indication at the remote monitor point. This type of monitoring is typical at single ILS airports where there is no need for remote control of the facilities. Through the air remote monitors are available for localizer, glide slope, DME, and NDB. Use of radio monitoring precludes the necessity of landline connectivity to the ILS facilities on the airfield.

b. Remote Status and Control Equipment. Monitoring and control are accomplished by two-way communication, typically on landlines, using tone or digital communication. With landline systems, a failsafe feature is employed that will initiate a remote alarm due to a loss of communication.

c. Integrated Systems. Systems that combine control, monitor, and display of multiple airport functions that reduce hardware requirements and controller workload at higher-level airports have been installed in the ATCT. In addition to ILS, integrated systems typically include approach lights and other visual aids, RVR, and runway lighting.

d. Remote Maintenance Monitoring. RMM, when installed, requires a concentrator that has connectivity to an AF Control Center. A concentrator combines multiple data inputs from separate facilities for easy transmission across single phone lines. The concentrator connects to the various ILS components by either radio link or landline. The concentrator is often shared with other facilities under FAA RMM.

5-3. CONNECTIVITY REQUIREMENTS

In addition to FAA owned and maintained multi-pair copper cable, connectivity options include fiber-optic and/or radio link systems, multiplexing networks, and connectivity through airport or commercially provided cabling or systems.

a. Description. The typical ILS subsystem interface requires a single bi-directional pair between each monitored facility and the remote status and control equipment. An additional single bi-directional pair is also used for RMM connectivity, as required. For localizers that operate as Cat II or III, two far-field monitors are typically installed. Locations may vary but are typically installed at the inner and/ or middle marker, each requiring a single pair connection to the localizer. In cases where a DME is shared by the opposite end localizer, identification keying from the remote localizer must be routed to the DME by a single pair. The DME and/or NDB are typically monitored as an auxiliary input into the collocated ILS equipment.

b. Failsafe Requirement. In all cases, failsafe design must be maintained so that a failure of the inter-site communications will initiate an alarm indication at the control point.

5-4. RESERVED

CHAPTER 6. ILS POWER REQUIREMENTS

6-1. FACILITY REQUIREMENTS

All units of the ILS operate on single phase, 60 Hz power. The localizer, glide slope, and marker/COMLO each require 120/240-volt service. Pole mounted markers, marker only locations, and the remote control and monitoring equipment require 120-volt service.

6-2. RESERVED

6-3. INSTALLATION REQUIREMENTS

a. Underground Cable. When the cable route is on airport property power to the individual sites must be underground. It is also desirable to use underground cable where the routing is adjacent to the airport property. This prevents the cable from becoming an obstruction hazard, signal reflector source. The cables for the marker/COMLO should be underground for a minimum distance of 250 feet from the building. The cables to the pole mounted marker may be routed overhead.

b. Transformers. Transformers are to be located near the equipment building on the side opposite the antenna array. If standby power is used at the site, the transformer should be located near the standby power equipment.

6-4. STANDBY POWER

Standby power will be provided in accordance with the latest edition of FAA Order 6950.2, Electrical Power Policy Implementation at National Airspace System Facilities.

a. Backup Power Operation. The ILS subsystems are each provided with batteries for backup power operation. The batteries will operate the various subsystems for a site-specific period of time in the event of a power failure. The charge on the batteries is maintained during normal conditions by a charging circuit connected across the input power source.

6-5. CONTINUOUS POWER AIRPORT

A continuous power airport is an airport equipped with an emergency power source that maintains power for facilities on a selected runway. This sustains operations in visual flight rules (VFR) or instrument flight rules (IFR) conditions in the event of an area wide or catastrophic prime power failure. Continuous power airports are identified in the latest edition of FAA Order 6030.20, Electrical Power Policy.

6-6. RESERVED

CHAPTER 7. PROJECT ENGINEERING AND FACILITY ESTABLISHMENT

7-1. GENERAL PROCEDURE

When an ILS or one of its subsystems has been programmed for a particular location, engineering activities should be conducted according to an established schedule based on the estimated commissioning date, equipment availability, etc.

7-2. PRELIMINARY SURVEY

The initial phase of the project engineering schedule is comprised of the compilation and study of all the necessary data and siting information. This phase should include:

a. Definition of Requirements. Existing flight operations and instrument approach procedures for the airport and other airports in the vicinity should be scrutinized. Items to be considered for the proposed facility include any required procedure turn, the minimum approach altitude, availability of radar vectoring and/ or other navigational aids that may be used in conjunction with the ILS, the intercept altitude for the glide path, the types of aircraft that will use the facility, and the desirable landing minimums.

b. Map and Data Analysis. Compile and study current airport maps, obstruction charts, topographic and obstruction data for the airport and surrounding area, and if available, a horizontal profile of the ILS approach zone.

c. Visual Survey. A visual site survey by qualified engineering personnel is strongly recommended. During the survey, terrain characteristics, obstructions, and possible sources of ILS signal degradation should be noted and approximate site locations determined. The angular width, height, and position of potentially derogating objects relative to potential sites should be determined by actual survey.

d. Liaison with Local Authorities. The airport manager or other local authority should be kept fully informed on the status of the ILS project. It will be necessary to confer regarding the location of the ILS facilities, marking of critical areas, removal of obstructions, etc. It should also be determined whether there are any plans for airport expansion or other major changes, which may affect the operation of the ILS.

e. Real Property Planning and Acquisition. The real property acquisition office should be advised of tentative sites so that they may initiate preliminary negotiations with property owners for use of the land. Economic considerations may determine the location of off-airport sites and thereby affect the system's effectiveness.

7-3. PRELIMINARY REPORT

a. Contents. After the information obtained in the preliminary survey has been carefully analyzed, the project engineer will prepare a report summarizing the results of the survey. The report will recommend the appropriate antenna systems (e.g., 14-element localizer array, null-reference glide slope array). It should also provide the potential locations necessary to achieve satisfactory operation. In addition, the report should include a prediction (including confidence level) of the expected performance of the facilities based on the presence of reflection sources and terrain conditions in the vicinity, and describe other problem areas or operational limitations which may affect the ILS establishment. The report should recommend site testing when it is difficult to predict accurately the quality of a facility's performance. The preliminary report will include the analysis and recommendations regarding site acquisition in accordance with the latest edition of FAA Order 4660.1, Real Property Handbook.

b. Concurrence. The preliminary report will be coordinated with all concerned organizations (Flight Procedures, Airports, AF Operations, etc.). Any non-concurrence, objections, or reservations will be resolved. For example, if the report indicates that it would not be possible to attain the desired landing minimums (because of obstructions, terrain roughness, etc.), it may be necessary to compromise between the cost of improving the site and the extent to which such improvement will lower the minimums. Any changes to the preliminary report and its recommendations should be incorporated into the report.

7-4. FINAL ENGINEERING ACTIVITIES

When concurrence has been obtained on the preliminary report and its supplements, the final project engineering may commence. This phase of the project includes:

a. Determining the exact location of the ILS facilities - localizer, glide slope, markers, etc.

b. Coordinating with the real property contracting officer to ensure that the FAA's access and use rights for permanent or long term (or short term as required for site testing) have been established.

c. Scheduling the installation of any power cables, monitoring and control lines to the site.

d. Coordinating special engineering to overcome peculiar siting conditions. This includes arranging for removal or repositioning of power lines or other potential interference sources.

e. Preparing instructions for the field installation engineer. This includes the localizer course width setting, glide slope angle setting, and special instructions and/or tests to overcome degrading site conditions.

7-5. SITE TESTING

It is not necessary to conduct site tests at all locations, because modern modeling software can readily predict the effect of various siting conditions on facility performance, if terrain and reflecting objects are properly defined in the model (see Appendix 2). There will, of course, be locations where site testing may be advisable; for example, a highly congested area where interference sources make it impossible to predict facility performance with confidence. If site testing is required, it should be deferred until at least preliminary grading and obstruction removals have been completed.

APPENDIX 1. GLOSSARY

μA – Micro Amps

AC – Advisory Circular

AF – Airways Facilities

AFSS – Automated Flight Service Station

ADG – Airplane Design Group

ALS - Approach Lighting System

ALSF - Approach Lighting System with Flashers

AM – Amplitude Modulation

ARDH – Achieved Reference Datum Height

ARMS – Airport Remote Monitoring System

ASBL - Approach Surface Base Line

ASBP - Approach Surface Base Plane

AT – Air Traffic

ATC - Air Traffic Control

ATO - Air Traffic Organization

ATCT - Airport Traffic Control Tower

BFSL – Best-Fit Straight Line

CAA – Civil Aviation Authority

CAT - Category

CDI – Course Deviation Indicator

CFR – Code of Federal Regulations

CEGS – Capture Effect Glide Slope

COMLO - Compass Locator

CSB – Carrier Side Bands

dB - Decibels

DDM - Difference in Depth of Modulation

DHP - Decision Height Point

DME - Distance Measuring Equipment

EFGS- End-Fire Glide Slope

FAA - Federal Aviation Administration

FAR – Federal Aviation Regulation

FFM – Far Field Monitor

FPO – Flight Procedures Office

FSS – Flight Service Station

GA – Glide Angle

GNAS – General National Airspace System

GPH – Glide Path Height

GPI - Ground Point of Intercept

GS - Glide Slope

HMI- Hazardously Misleading Information

HQ - Headquarters

IFR - Instrument Flight Rules

ILS – Instrument Landing System

IM - Inner Marker

KHz – Kilo Hertz

LD – Lateral perpendicular Distance

LDA - Localizer Directional Aid

LMM - Compass Locator at the Middle Marker Site

LOC - Localizer

LOM - Compass Locator at the Outer Marker Site

LPD – Log Periodic Dipole

MSL – Mean Sea Level

MH – Medium Powered Homer

MM - Middle Marker

MPS – Maintenance Processor System

NAS – National Airspace System

NCP - National Airspace System Change Proposal or NAS Change Proposal

NDB – Non Directional Beacon

NM – Nautical Mile

NOTAM - Notice to Airmen

NR – Null Reference

OFA – Object Free Area

OFZ - Obstacle-Free Zone

OM - Outer Marker

POCS – Precision Obstacle Clearance Surface

RADAR – Radio Detecting and Ranging

RDH - Reference Datum Height

RF – Radio Frequency

RMM – Remote Maintenance Monitoring

RNAV – Area Navigation

ROC - Required Obstacle Clearance

RPI - Runway Point of Intercept

RSA – Runway Safety Area

RVR - Runway Visual Range

RWY – Runway

SBO – Side Band Only

SBR – Side Band Reference

SDM – Sum of the Depths of Modulation

SIAP – Standard Instrument Approach Procedure

SMO – System Management Office

SSC – System Support Centers

SSV – Standard Service Volume

T - Threshold

TCH - Threshold Crossing Height

TERPS - United States Standard for Terminal Instrument Procedures (FAA Order 8260.3)

TRACON – Terminal Radar Approach Control

TVOR - Terminal VHF Omnidirectional Range

VFR - Visual Flight Rules

VOR – VHF Omnidirectional Range

VSWR – Voltage Standing Wave Ratio

WCH - Wheel Crossing Height

APPENDIX 2. LOCALIZER SITE EFFECTS

A2-1. DISCUSSION

The quality of an ILS localizer course and clearance information is to a large extent determined by the operating environment of the system. Environmental factors, which should be considered when siting a localizer facility, include large buildings (such as hangars and terminal complexes), power lines, metallic fences, cylindrical structures (such as water towers and fuel tanks), and hilly or mountainous terrain.

A2-2. THEORETICAL CONSIDERATIONS

Analysis of site effects on a localizer system performance requires a thorough theoretical knowledge of the system. This information is available to those individuals who perform mathematical modeling of site effects on ILS performance. When a difficult site is encountered, the site engineer is encouraged to seek mathematical modeling assistance through the Program Office. When a request for assistance is submitted, the program office will advise the site engineer of the topographical and other information that is required in order to perform the site analysis. The results of the mathematical modeling, together with recommendations concerning the type of localizer antenna and the siting location, will be provided to the site engineer.

A2-3. IDENTIFICATION OF REFLECTION SOURCES

At most localizer sites the presence of an extensive number of buildings, hangars, fuel tanks, and other reflecting surfaces may require considerable analysis and flight testing to determine the exact interference source for a given area in space. Methods of conducting this analysis are provided here.

a. Reflected Signal. The effect that a reflected signal has on localizer guidance information is depicted in Figure A2-1. As the aircraft moves along the orbital flight path, its distance from the reflection source varies while its distance from the antenna array is constant. The composite signal at the aircraft, which is the vector sum of the direct and reflected signals, varies per the path length or relative phase of the reflected signal. A change in path length of one wavelength results in a single sine wave type variation in the composite signal. As the flight path proceeds through a sector encompassing several one wavelength incremental path changes, repeated sine wave variations will occur. This effect will also occur under the conditions depicted in Figures A2-2 and A2-3, where both the direct and reflected signal path lengths are changing along the flight path, but at a different rate.

b. Scalloping. At locations where scalloping is encountered, analysis of the flight inspection recordings and position information, and application of one or more of the following equations (which are derived in Figures A2-1, A2-2, and A2-3) may be used to determine the reflection source.

Orbital Flight: $\sin \theta = \lambda/s$

Radial Flight: $\cos \theta = 1-(\lambda/s)$

Angular Flight: $\cos \theta = \cos \phi - (\lambda/s)$

where:

θ = angle formed by direct lines from the measuring point to the antenna array and to the reflector.
s = length of one scallop.
n = number of scallop
λ = Wavelength at operating frequency in same units as s.
ϕ = angle formed by flight track and line from the flight track to the antenna array.

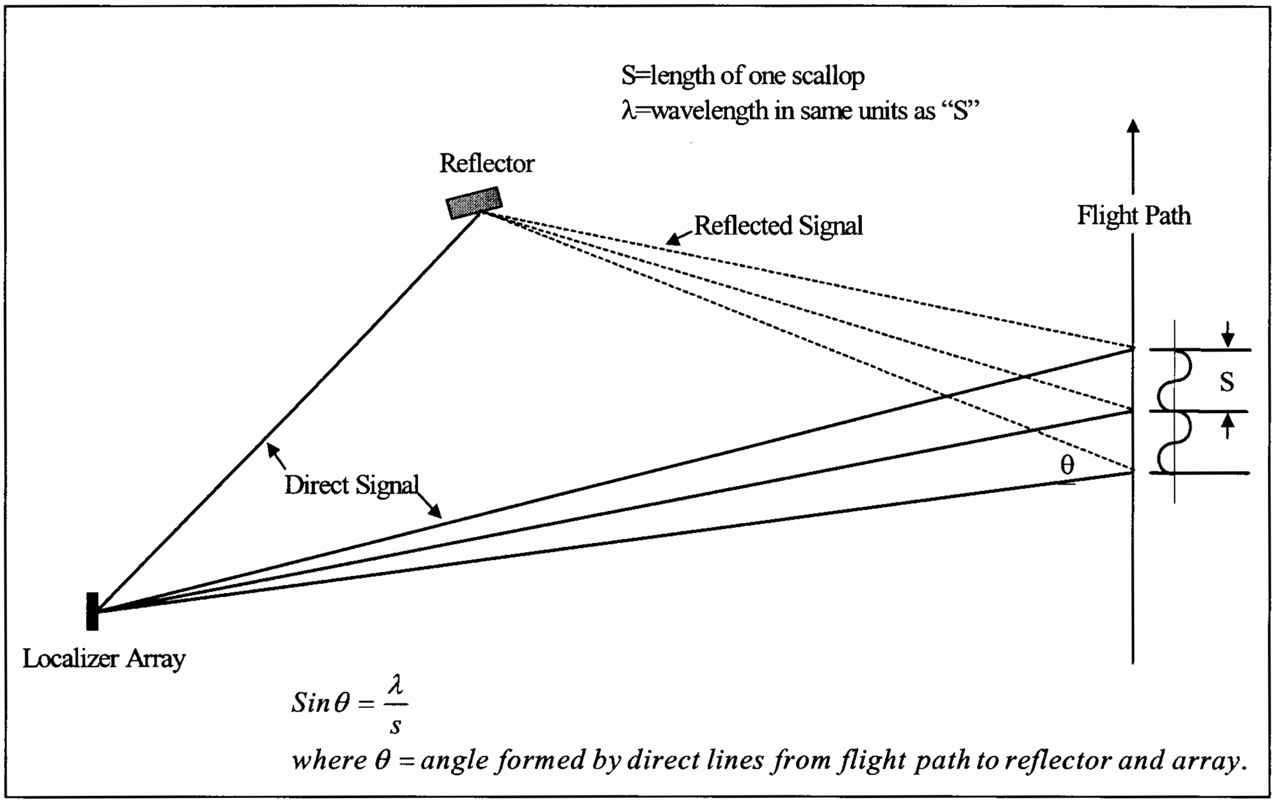


Figure A2-1. Scalloping Effect - Orbital Flight

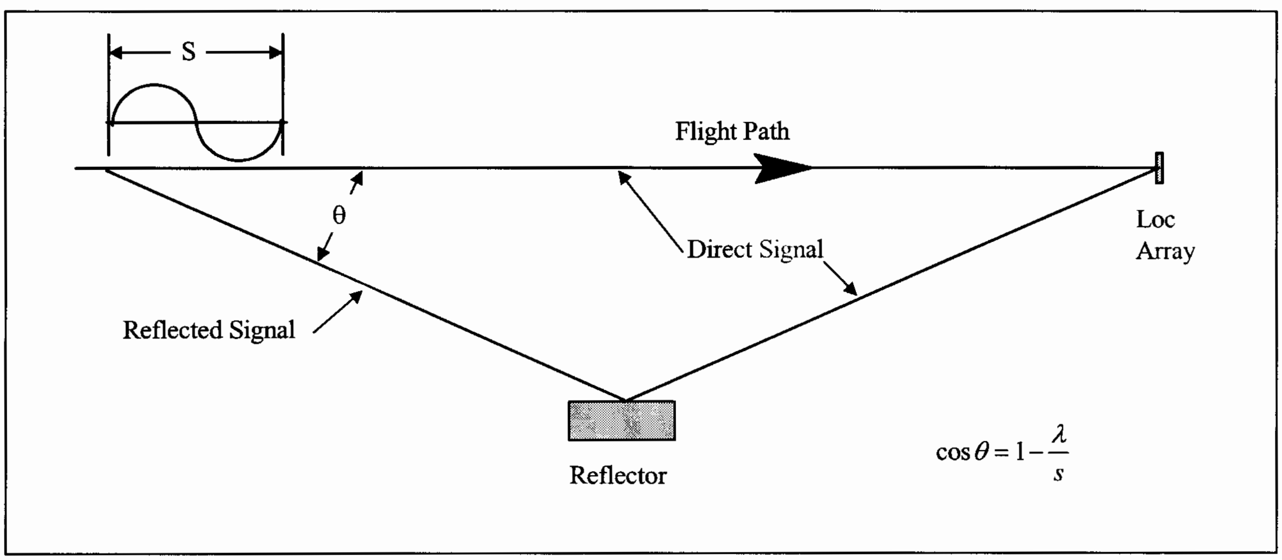
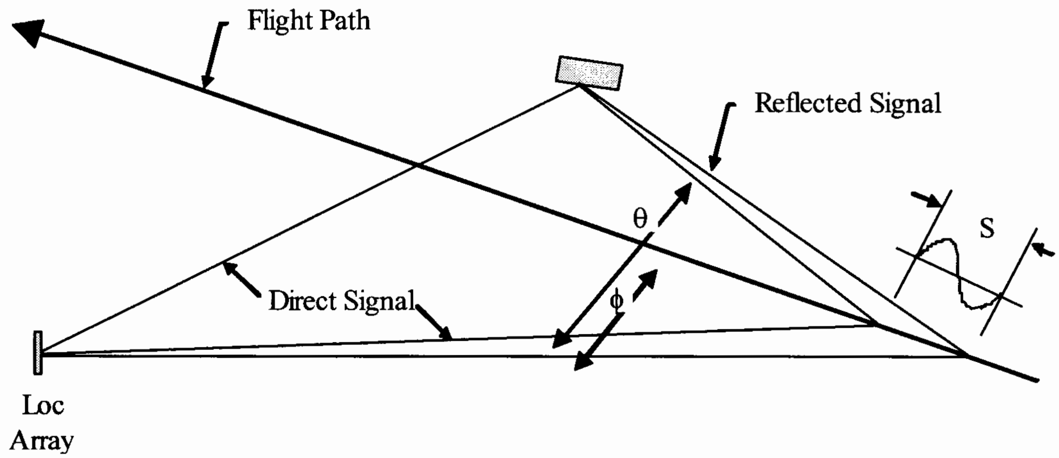


Figure A2-2. Scalloping Effect – Radial Flight



$$\cos \theta = \cos\phi - (\lambda / s)$$

where:
ϕ= angle formed by flight path and line from flight path to array.

θ = angle formed by direct lines from the measuring point to the antenna array and to the reflector.

Figure A2-3. Scalloping Effect - Angular Flight

Applications for these equations are illustrated by the following examples.

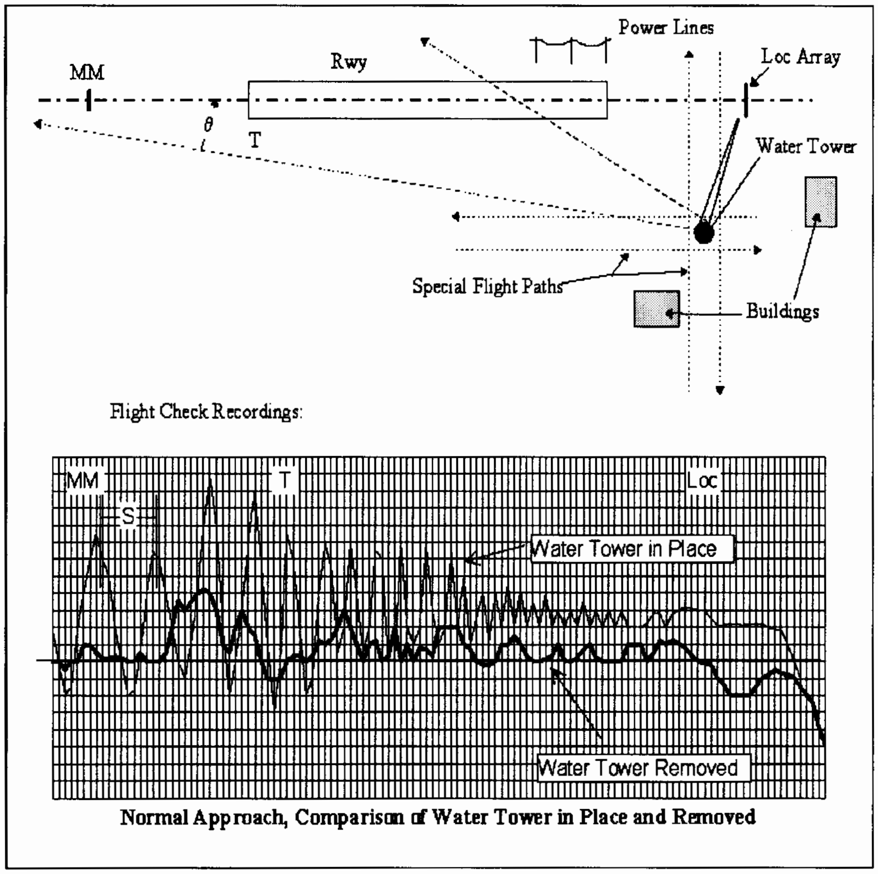


Figure A2-4. Analysis of Scalloping - Example 1

(1) Example 1. At a localizer facility depicted in Figure A2-4, severe scalloping was encountered along the course line beginning inside the outer marker and continuing inside the runway threshold. Analysis of the flight recordings, including highly sensitive Automatic Gain Control (AGC) recordings made on special flight tracks, indicated that the interfering reflections were originating from a large water tower. Removal of the water tower eliminated the scalloping and resulted in an acceptable facility.

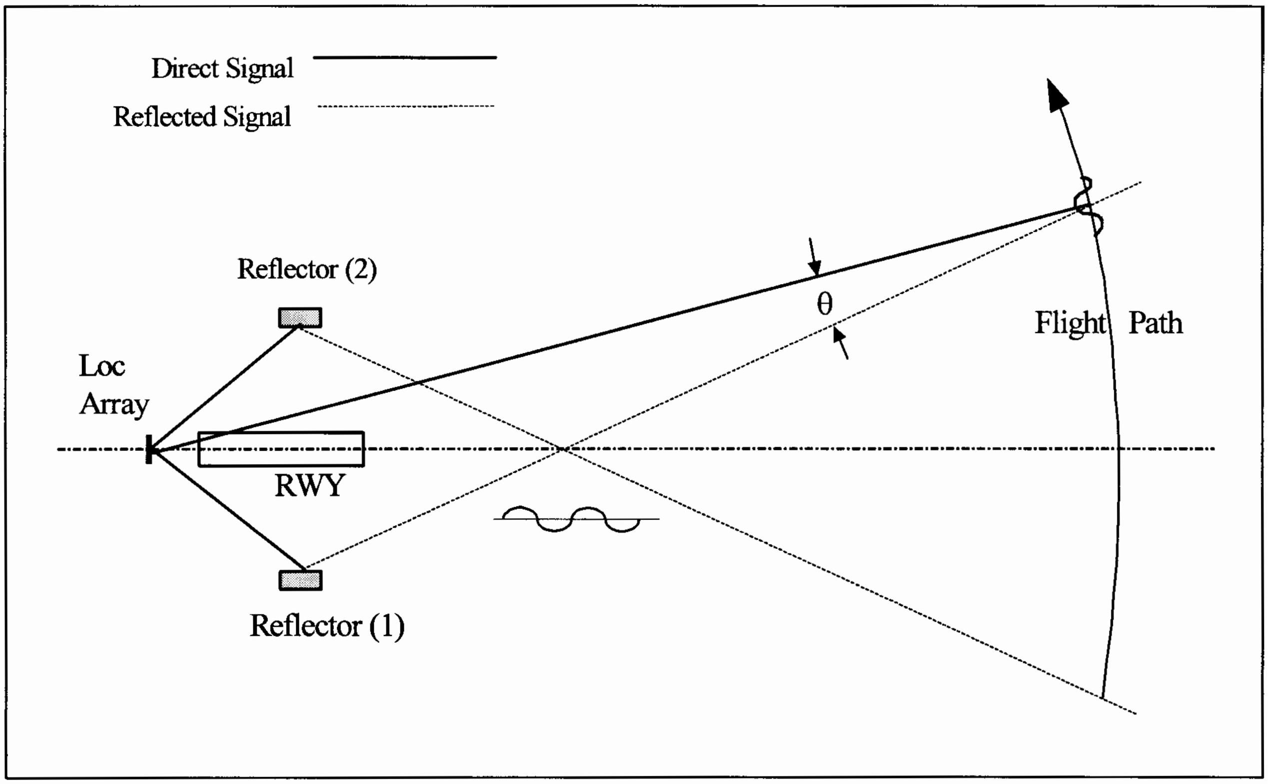


Figure A2-5. Analysis of Scalloping - Example 2

(2) Example 2. Severe scalloping on the localizer approach was encountered at the facility depicted in Figure A2-5. Analysis of the scalloping and siting conditions indicated two potential reflecting objects of unknown quantity at ±θ. To ascertain which object was the interference source, an orbital flight check was conducted as shown in Figure A2-5.

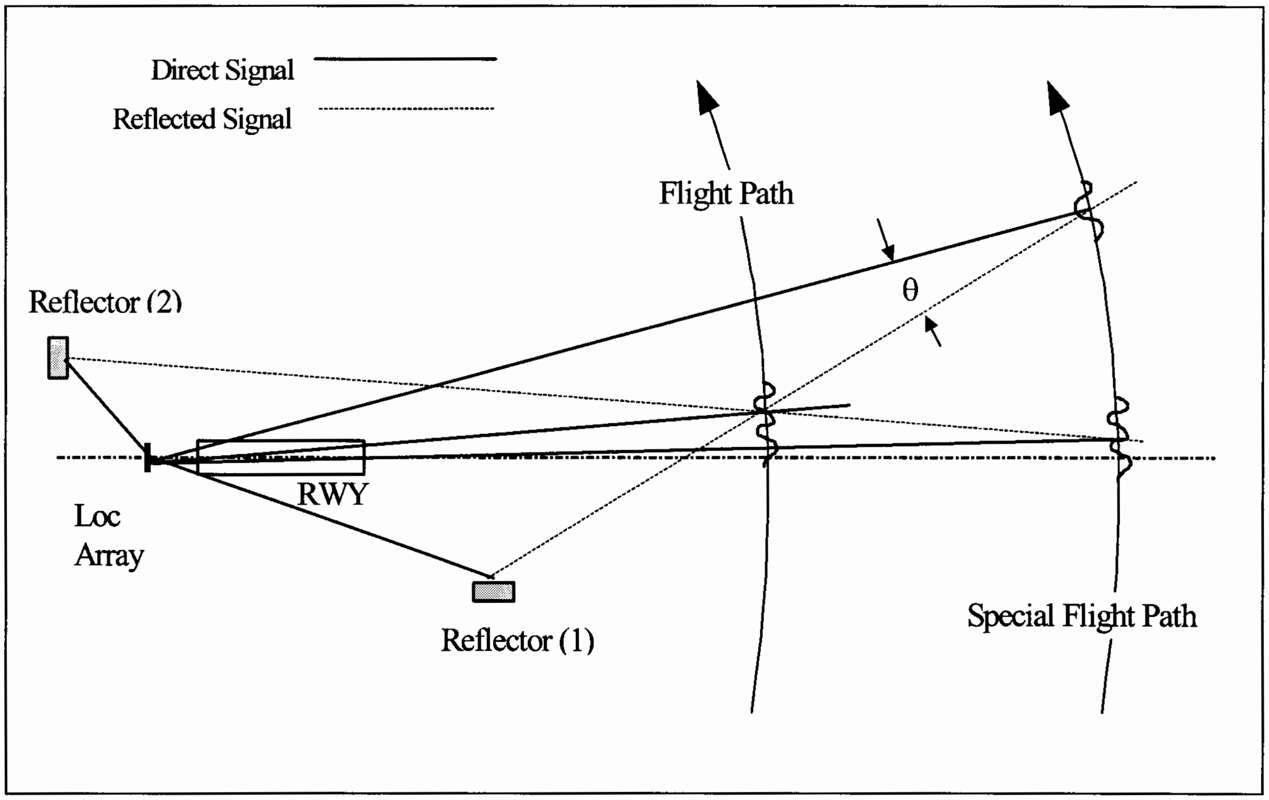


Figure A2-6. Analysis of Scalloping - Example 3

(3) Example 3. On an orbital flight check of the facility depicted in Figure A2-6, low clearances were measured in a sector of the orbit. The low clearances appeared to be caused by signal reflections; however, because of the random nature of the reflections, the location of the reflection source was not readily identifiable. Additional orbital checks showed that the low clearances were caused by two reflecting sources, with the random deflections resulting from combined individual scalloping.

A2-4. REDUCTION OF INTERFERENCE EFFECTS

When the interference-producing reflector has been located and complete removal is not possible, corrective action must be taken to overcome the degrading effects.

a. Replacement. The most obvious solution is to replace the array with a more directive system. Where reflections are extreme, a capture effect system may be required.

b. Signal Cancellation Techniques. One method of reducing interference is to use signal-canceling techniques at the reflector or secondary source. Field strength measurements in the vicinity of reflecting sources indicate the presence of very strong standing waves in space, with the VSWR decreasing as the distance toward the source is increased. By the introduction of a secondary reflector at a controlled distance in front of the primary reflector, the interference producing reflections from the latter can be cancelled or significantly reduced. The controlled reflector can be a single wire placed 90 electrical degrees in front of the primary reflector. This space, S, is a function of the incident angle of the radiated signal as depicted in Figure A2-7, and reflects a signal 180 degrees out of phase with the primary reflected signal. Figure A2-8 depicts test results for reflections from a single wire.

NOTE: It is not feasible to attempt interference reduction control beyond the near field of either the primary or secondary sources.

c. AC power lines. AC power lines are a common source of localizer signal reflections, particularly when they consist of several wires oriented in a vertical plane. The type of reflector lends itself to the application of the cancellation technique by reorienting the wires to the horizontal plane and space the individual wires so that reflected signals are self-canceling (see Figure A2-9).

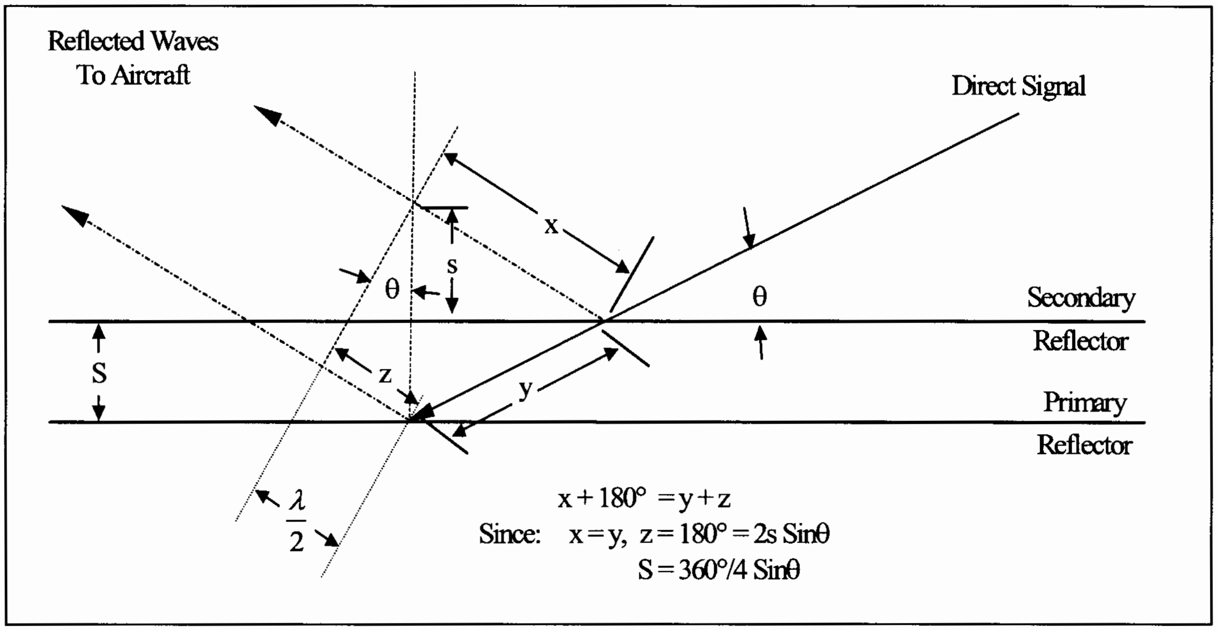


Figure A2-7. Signal Cancellation Concept

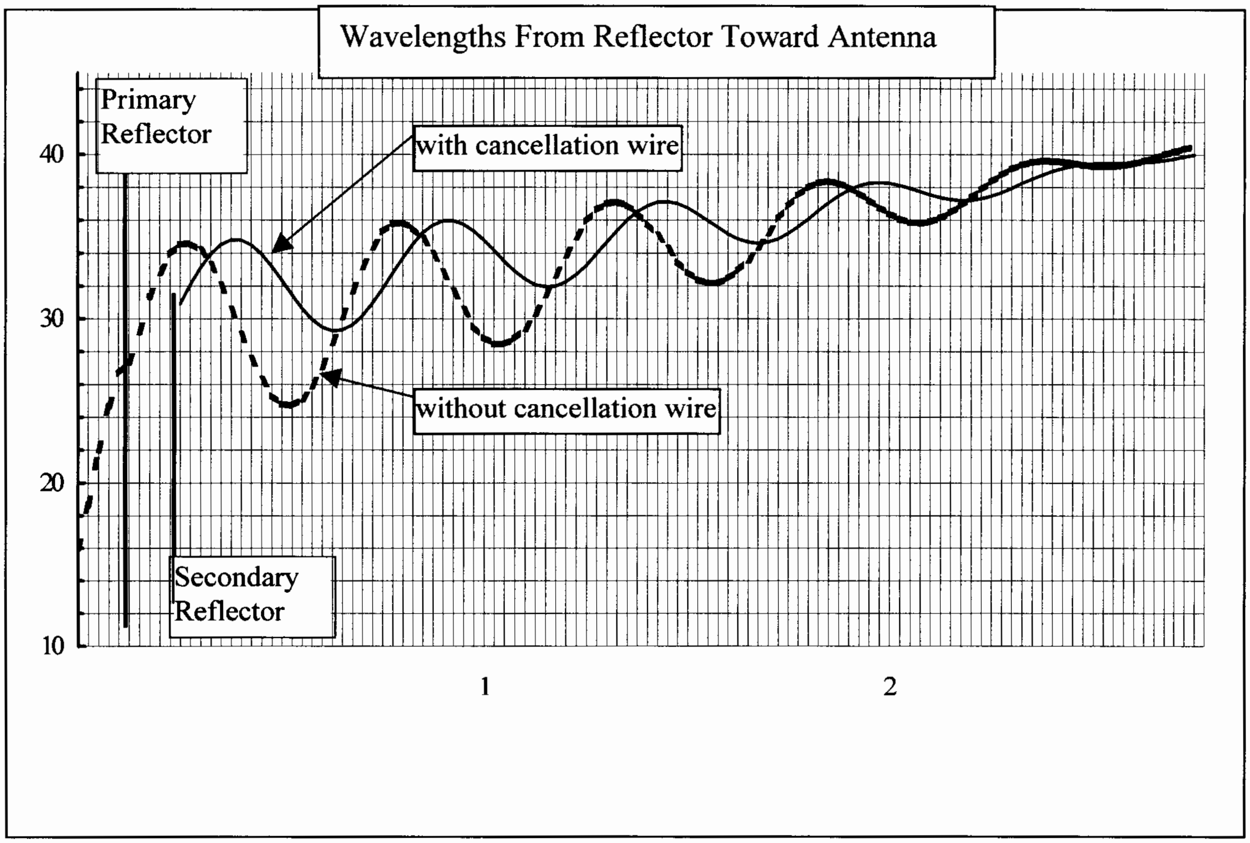


Figure A2-8. Effect of a Cancellation Wire on a Reflected Signal

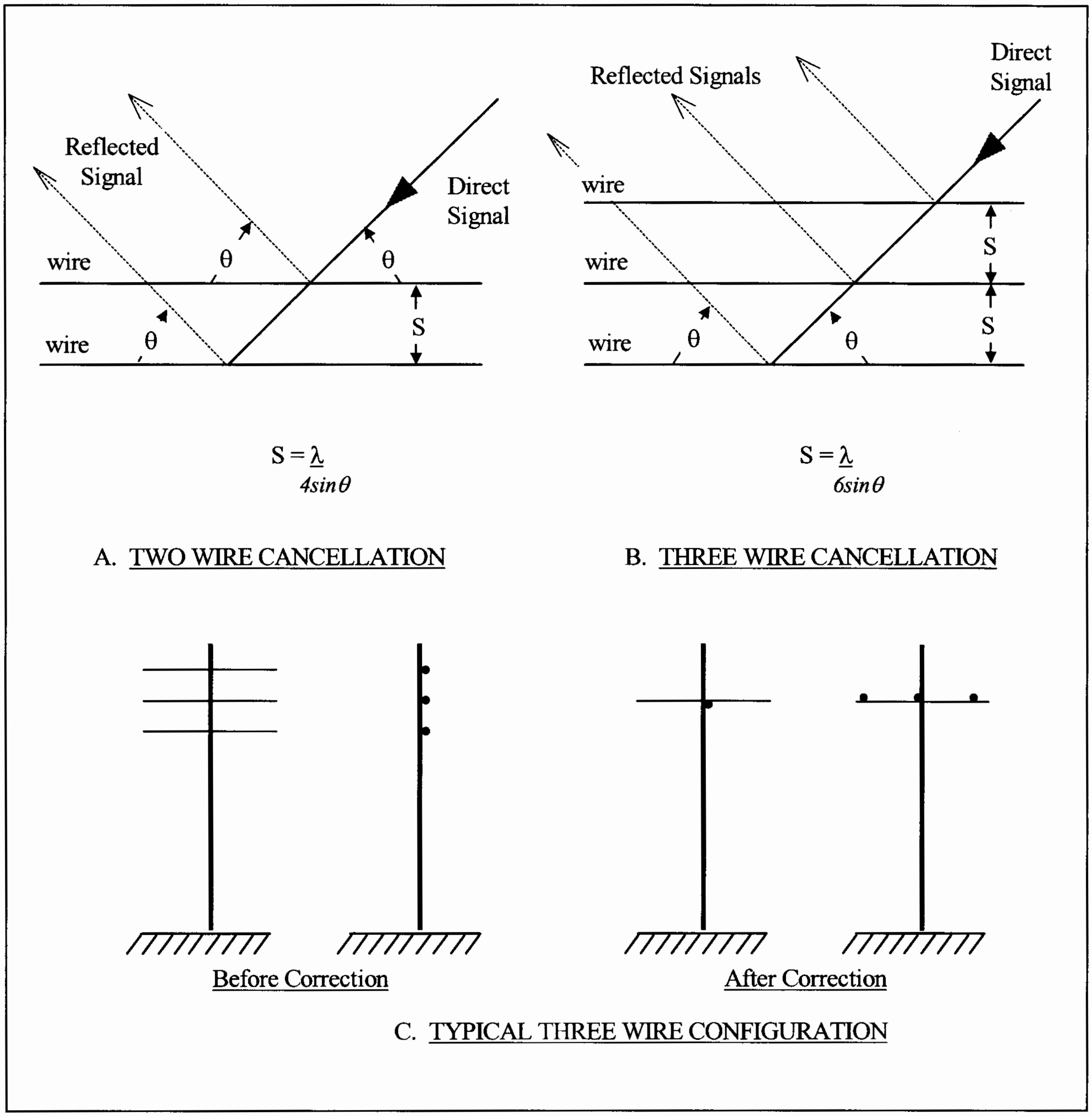


Figure A2-9. AC Power Line Signal Reflection Cancellation

APPENDIX 3. GLIDE SLOPE SITE EFFECTS

A3-1. GROUND PLANE REFLECTIONS

The size and location of the Fresnel zones for the ILS glide slope may be determined by the following formulas used in conjunction with Figure A3-1. (Refer to MIT Radiation Laboratory Series, Volume 13, "Propagation of Short Radio Waves, " and "Final Report on Site Reflections on ILS Glide Slope Facilities," October 1953, CAA Report No. 830-2, for a comprehensive Fresnel zone analysis.)

a. Fresnel Zone Longitudinal Limits. The distance from the glide-slope facility to the points where the elliptical Fresnel zone on the approach terrain crosses the line of approach may be determined as follows:

$$Xo = \frac{D}{2}\left[\frac{1+\frac{2h_1(h_1+h_2)}{n\lambda D}}{1+\frac{(h_1+h_2)^2}{n\lambda D}}\right] \qquad (1)$$

$h_1 = \frac{\lambda}{20}$ for a null-reference facility)

$h_2 = D\theta_p$ (where $\theta_p =$ elevation angle of aircraft)

Substituting appropriate values and dropping negligible terms:

$$Xo = \frac{D}{2}\left[\frac{n+\frac{\theta_p}{\theta}}{n+\frac{\theta_p}{\theta}+\frac{D\theta_p^2}{\lambda}}\right]$$

(n = Fresnel zone number)

For an aircraft on the glide path ($\theta_p = \theta$) and the first Fresnel zone (n =1):

$$Xo = \frac{D}{2}\left[\frac{2}{2+\frac{D\theta^2}{\lambda}}\right] \qquad (2)$$

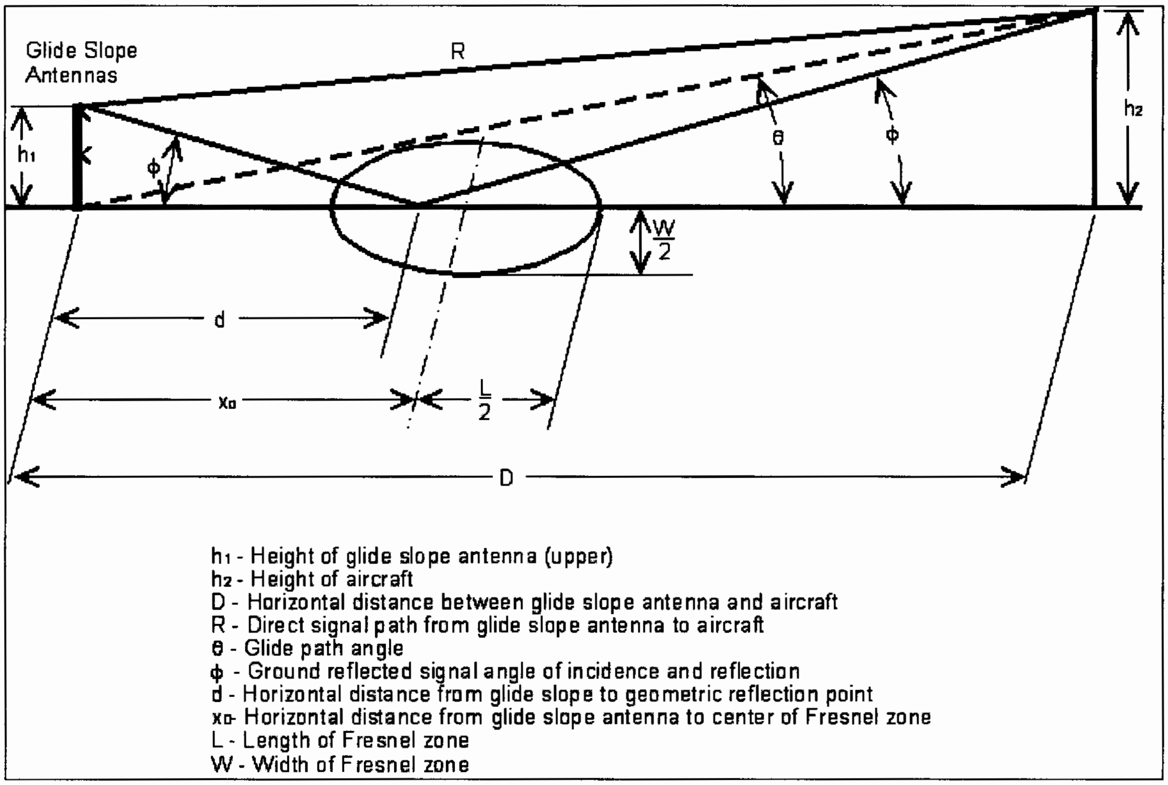


Figure A3-1. Fresnel Zone for ILS Glide Slope

The near and far limits of the Fresnel zone may now be determined:

$$x = x_o \pm \frac{L}{2} \qquad (3)$$

$$\frac{L}{2} = \frac{D}{2}\left[\frac{\sqrt{1+\frac{2}{n\lambda}\times\frac{2h_1h_2}{D}}}{1+\frac{(h_1+h_2)^2}{n\lambda D}}\right]$$

$$= \frac{D}{2}\left[\frac{\sqrt{n^2+2n}}{n+1+\frac{D\theta^2}{\lambda}}\right] \qquad (4)$$

$$x_o \pm \frac{L}{2} = \frac{D}{2}\left[\frac{n+1\pm\sqrt{n^2+2n}}{n+1+\frac{D\theta^2}{\lambda}}\right]$$

For the first Fresnel zone (n = 1) and at the glide slope frequency (λ = 2.96 feet: $1/\lambda$ = .338):

$$x_o \pm \frac{L}{2} = \frac{D}{2}\left[\frac{2 \pm \sqrt{3}}{2 + .338 D\theta^2}\right] \qquad (5)$$

(with D expressed in feet and θ in radians)

From these formulas, the distance from the base of the glide slope antenna mast to the Fresnel zone center, and the near and far Fresnel zone limits, and the Fresnel zone length may be determined for any given glide path angle and aircraft position.

b. Fresnel Zone Lateral Limits. The lateral limits of the Fresnel zone or the zone width at the minor axis may be determined by application of analytic geometry to the elliptical shaped zones. This yields the following equations:

$$\frac{W}{2} = \pm \frac{\sqrt{n\lambda D}}{2}\sqrt{\frac{1 + 2\frac{\frac{2h_1h_2}{D}}{n\lambda}}{1 + \frac{(h_1 + h_2)^2}{n\lambda D}}} \qquad (6)$$

expanding and collecting terms:

$$\frac{W}{2} = \pm \frac{\sqrt{n\lambda D}}{2}\sqrt{\frac{n + 2}{n + 1 + \frac{D\theta^2}{\lambda}}}$$

For the first Fresnel zone and glide slope frequency:

$$\frac{W}{2} = \pm \frac{\sqrt{2.96D}}{2}\sqrt{\frac{3}{2 + .338 D\theta^2}}$$

$$= \pm \frac{1}{2}\sqrt{\frac{8.88D}{2 + .338 D\theta^2}} \qquad (7)$$

$$= \pm \frac{1}{2}\sqrt{\frac{4.44}{\frac{1}{D} + .169\theta^2}}$$

And the total minor axis length:

$$W = \sqrt{\frac{4.44}{\frac{1}{D} + .169\theta^2}} \qquad (8)$$

c. Geometric Reflection Point. The distance from the glide slope antenna mast to the point of geometric reflection and the angle of reflection may be determined as follows:

$$\tan\theta = \frac{h_1}{d} = \frac{h^2}{D-d}$$

$$d = \frac{h_1 D}{h_1 + h_2} \qquad (9)$$

$$\tan\theta = \frac{h_1 + h_2}{D}$$

A3-2. CRITERION FOR TERRAIN ROUGHNESS

Terrain irregularities have the effect of changing the path length and, thereby, the relative phase of the ground reflected signal. The amount of terrain roughness that can be tolerated is determined by the effect of the resulting phase shift on the aircraft cross pointer indicator.

Tolerance for path deviations = ± 25 µA.

= ± .0292 DDM.

a. To determine the terrain roughness which would result in an on-path deflection of ± 25 µA, it is assumed that the carrier signal is not affected by the irregularity and, except for the irregularity, the ground plane is an ideal mirror surface. For a null reference glide slope with a normal path angle of 2.5 degrees, the roughness criterion is determined as follows:

$$DDM = 2m\,(E_{ss}/E_{cs})$$

$$\pm .0292 = 2(.4)(E_{ss}/1.0)$$

$$E_{ss} = \pm .0365 \text{ (90 Hz or 150 Hz)}$$

b. Hence, with E_{cs} assigned a value of $1\angle 0°$, the 25µA deflection is caused by a relative E_{ss} level of 0.0365. Referring to Figure A3-2, the phase shift of the ground reflected signal which results in an on path E_{ss} level of this value can be determined. For the ideal glide path:

$$E_{ss} = I(\angle 0°-(R-H\sin\theta)) + I(\angle 180°-(R+H\sin\theta))$$

$$= 2I\sin(H\sin\theta)$$

$$=0\ @\ H = 4120°,\ \theta = 2.5°$$

Where terrain roughness occurs:

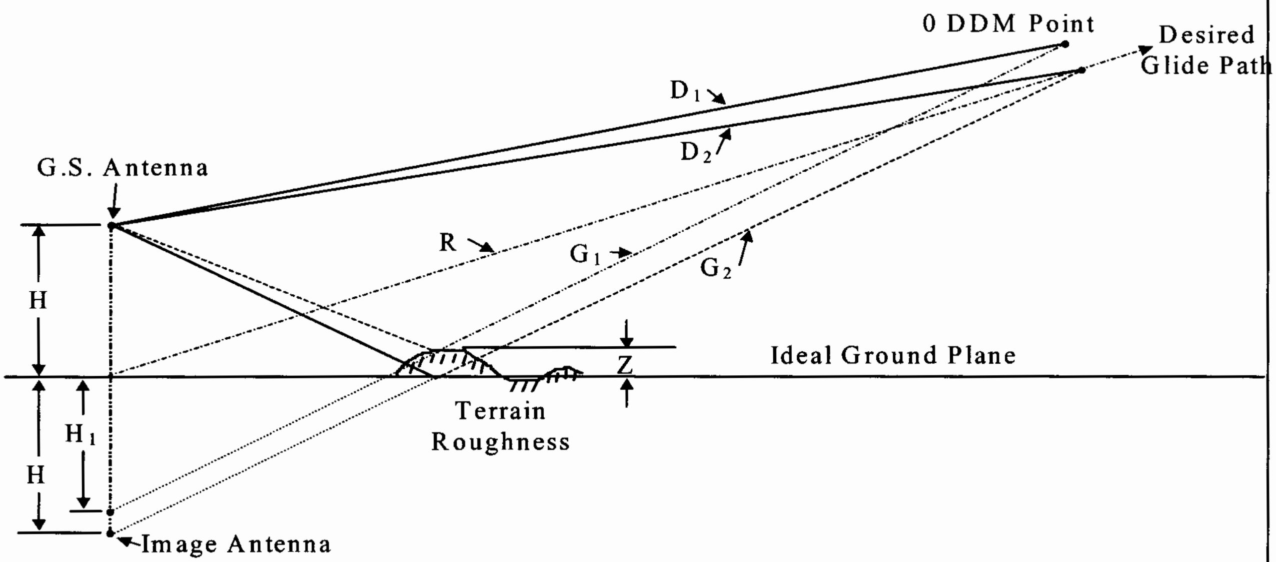
$$E_{ss} = I\angle H\sin\theta + I(\angle 180°\ H_l\sin\theta)$$

$$= I\angle 4120\sin 2.5° - I\angle -H_l\sin 2.5°$$

$$= I\angle 180° - I\angle -0.0436H_l$$

$$= 0 - I\sin(-0.0436H_l)$$

(The cosine or quadrature terms dropping out.)



R - distance to aircraft.
H - Height of glide slope antenna and ideal image antenna
H_1 - Height of actual image antenna.
D_1 - Direct signal path, Ideal.
D_2 - Direct signal path, Actual.
G_1 - Ground reflected signal path, Ideal.
G_2 - Ground reflected signal path, Actual.
Z - Height of terrain roughness.

Figure A3-2. Effect of Rough Terrain on Glide Path

c. Since I = 0.255, relative value, for a normal path width of 1.4 degrees:

$$E_{ss} = I \sin(.0436H_1)$$

$$\pm 0.0365 = .255 \sin(.0436H_1)$$

$$\pm 0.143 = \sin(.0436H_1)$$

$$0.0436H_1 = 171.7°/188.3°$$

$$= 180 \pm 8.3 \text{ degrees}$$

Since the term $0.0436H_1$ represents the equivalent electrical path length and normally equals 180 degrees (H_1 - H), the maximum permissible path length differential resulting from terrain roughness is 8.3 degrees.

d. Referring to Figure A3-3, the terrain roughness criterion for a 2.5 degree path angle that causes an 8.3 degree change in the ground-reflected signals path length can be determined:

Permissible path length differential = 8.3 degrees

Path length differential = $2\ \Delta\ L$

$$2\Delta L = 2\ Z\ H/d$$

$$8.3° = 2Z\ (4120)/d$$

$$Z = .0010\ d$$

Hence, the criterion for terrain roughness is a function of the distance of the roughness from the antenna. For a 2.5-degree glide angle, the roughness criterion is approximately 1 foot per 1000 feet from the antenna. For a glide angle of 3.0 degrees, the criterion is approximately 1.25 feet per 1000 feet.

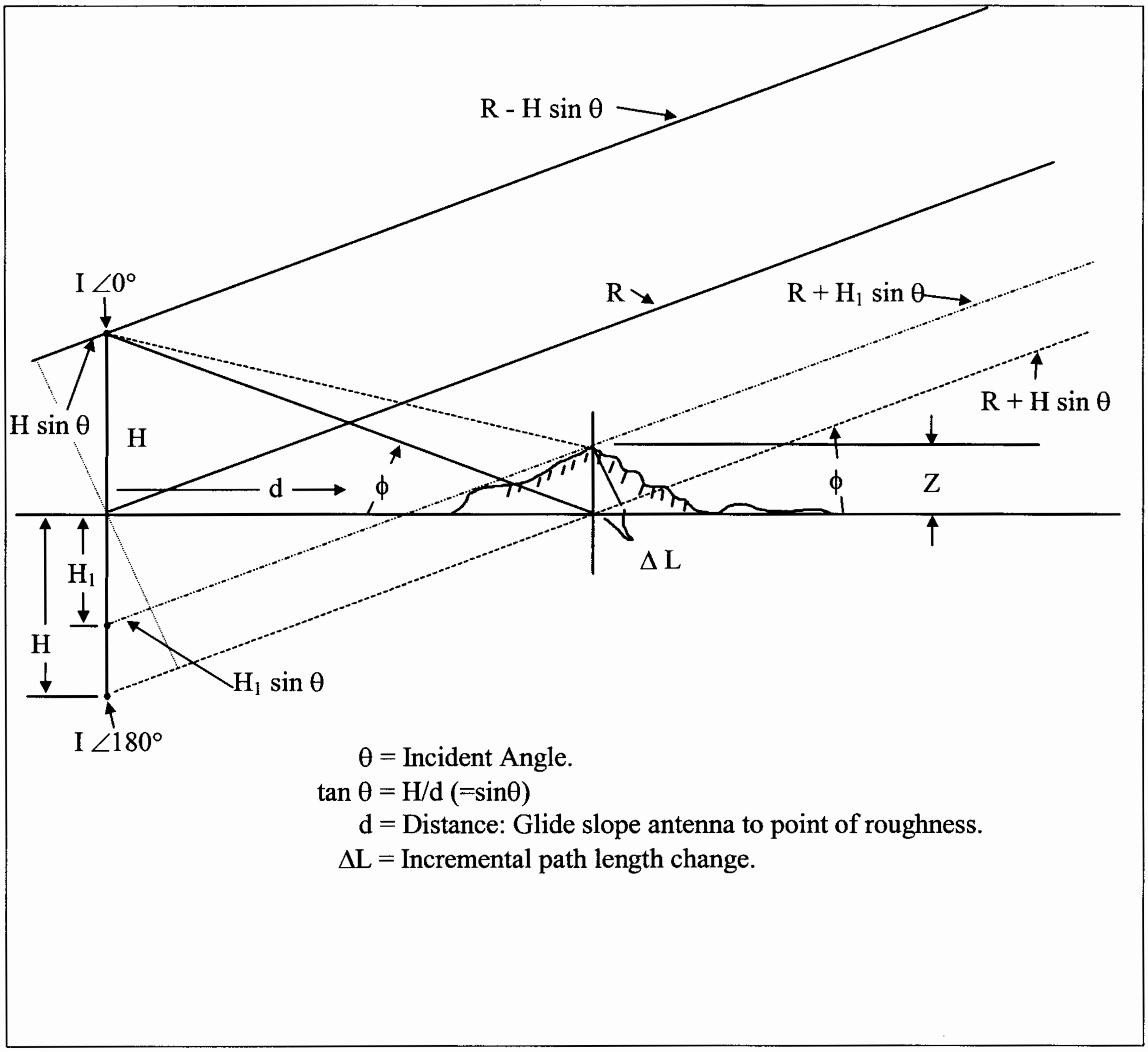


Figure A3-3. Terrain Roughness Criterion

APPENDIX 4. RDH/ARDH CONSIDERATIONS

A4-1. DISCUSSION.

When a site is nearly ideal, the reference datum height (RDH) will be nearly the same as the calculated threshold crossing height (TCH) value. Achieved reference datum height (ARDH) will typically be slightly higher due to slant range flare. At sites where irregular terrain is present, the reference datum heights (RDH/ARDH) will sometimes vary significantly from the ideal values. Longitudinal terrain slopes also will affect the RDH/ARDH. This appendix describes the various types of terrain and how that terrain may impact the RDH/ARDH. The definitions for RDH/ARDH are given in Paragraph 3-7b of this Order. Refer to Order 8240.47, Determination of Instrument Landing System (ILS) Glidepath Angle, Reference Datum Heights (RDH), and Ground Point of Intercept (GPI), for a more detailed description of RDH/ARDH and how they are measured.

A4-2. IDEAL GROUND PLANE.

For this discussion, an ideal ground plane is defined as a flat plane with both the lateral and longitudinal gradients being zero. As the lateral antenna distance from runway centerline increases, the hyperbolic effect of the radiated signal on RDH and ARDH will be presented.

a. Description. The values of RDH/ARDH for glide slopes operating over an ideal ground plane with a path angle of 3.0 degrees are plotted versus antenna location in Figures A4-1a and A4-1b. These plots should be used as a first approximation in predicting if the chosen antenna location will produce the required RDH/ARDH. The effects of any irregular terrain on the RDH/ARDH must then be considered.

b. Hyperbolic Effect. Hyperbolic effect has only a minor impact on RDH, since even for an offset value of 650' from centerline, it results in no change at point A and an increase of about 7 uA at Point B. However, it is of concern for ARDH, since it causes upward flare of the glide slope as the aircraft approaches the threshold. For a typical optimized glide slope located at 400 feet offset and 1000 feet setback from threshold, the upward flare is only about 50 uA at threshold, which is within tolerance and requires no further adjustment. However, when offsets of 500feet or greater from runway centerline are required, upward flare is a concern that must be addressed. Reducing upper antenna offset on capture-effect glide slopes can be an option to mitigate excessive flare.

A4-3. UNIFORM TERRAIN SLOPES. The effects of uniform terrain slopes on the RDH/ARDH are easily accounted for in siting a glide slope. These effects are described below.

a. Longitudinal Slopes. A longitudinal slope results in an elevation difference between the runway threshold and the runway point of intercept (RPI). Assuming the antenna heights are properly chosen to provide the desired path angle with respect to the horizontal (see Figure A4-2), the RDH is given by the equation:

$$RDH = RDH_{(ideal)} - d \tan \alpha$$

$= RDH_{(ideal)} - e$

where e is the threshold elevation minus the RPI elevation.

b. Lateral Slopes. The effects on RDH caused by uniform allowable slopes in the lateral direction can be neglected.

A4-4. IRREGULAR TERRAIN. The effects of irregular terrain are considered below.

a. Elevated Terrain. In general, as the distance to the elevated terrain from the mast is increased, the terrain effect on the path in space is decreased. For elevated terrain beyond threshold with a longitudinal extent of 10 feet. and maximum elevation of 10 feet., the RDH/ARDH is not generally influenced more than +/- 2 feet. and 1.5 feet., respectively.

b. Depressed Terrain. Simple depressions with longitudinal extent of 100feet and 200feet are considered. More complex depressions, such as for drainage collection areas, may involve slopes.

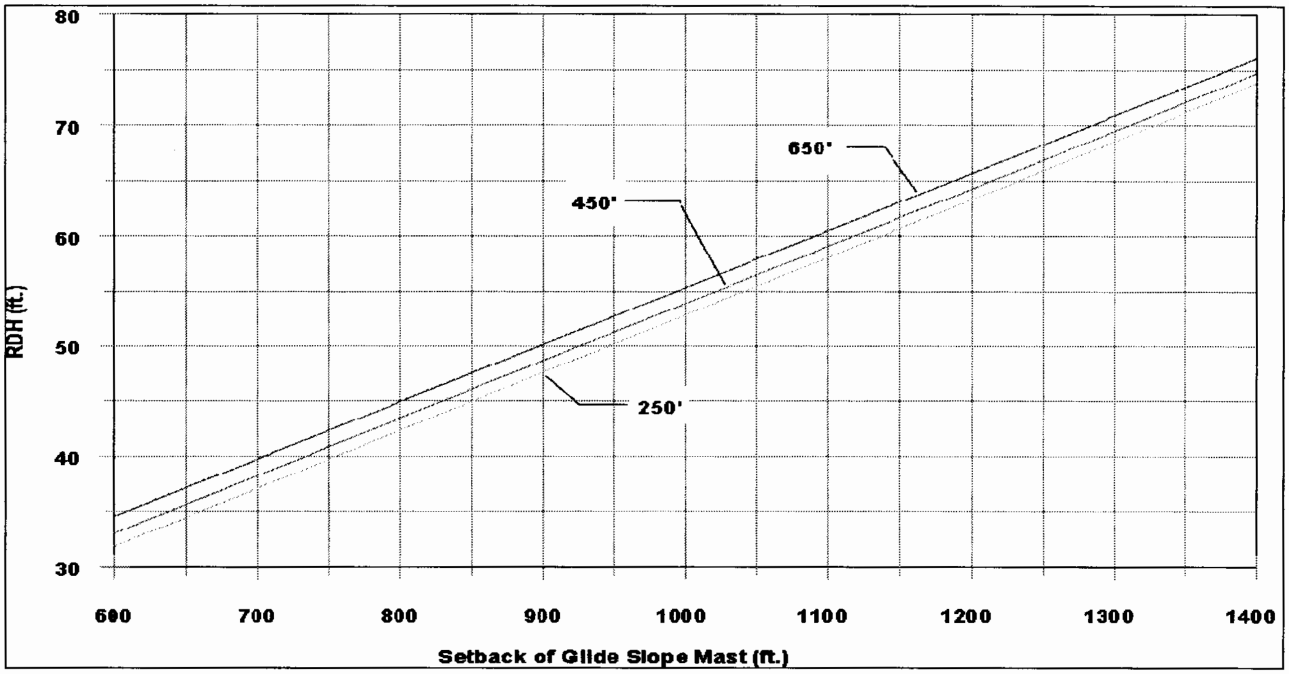
(1) 100 Feet Depression. As the depth of the depressed terrain (centered as close as 500' from the glide slope mast) with up to 10 feet below the average grade, neither RDH or ARDH should vary more than +/- 1.5' from the ideal values.

(2) 200 Feet Depression. Since calculations show that depressions of 200feet extent can cause variations of up to +/- 9 feet in RDH and +/- 5 feet in ARDH, mathematical modeling is recommended to assess the effect on the radiated signal.

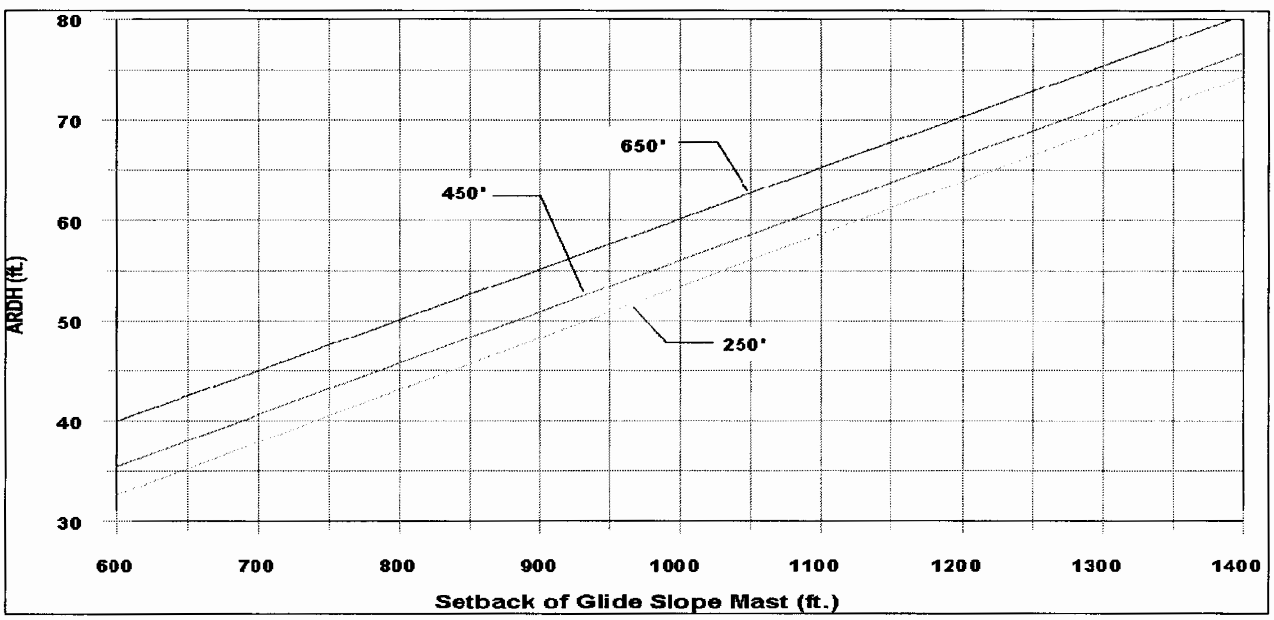
c. Stepped Terrain. This terrain is formed of two or more distinct ground planes, each with its own slope. A typical example is a ground plane prepared with fill from glide path mast to threshold, with a lower natural elevation ground plane prior to threshold but continuing generally at the same slope (see Figure A4-3(a)). As the aircraft approaches the runway, the glide path Fresnel zones migrate from being located predominately on one to another of the ground planes. When the aircraft is distant, the Fresnel zones extend well beyond the filled ground plane onto the natural terrain. Because the antennas are higher above the natural terrain than the filled terrain, the zero DDM position occurs at lower elevation angles for the distant aircraft, and at smoothly increasing higher elevation angles for a close aircraft. The Fresnel zones eventually are fully contained on the prepared (higher) ground plane when the aircraft nears the runway threshold. For these conditions, the best-fit straight line for the zero DDM locations will project to an RDH/ARDH that is higher than the calculated TCH.

d. Multiple Slopes. This terrain also involves Fresnel zones that migrate from one ground plane to another, but a change in slope is encountered in the transitions. Multiple slopes occur where a prepared ground plane is nominally horizontal from glide path mast to the threshold, but changes into either an upslope or downslope for a significant extent beyond threshold (see Figure A4-3(b)). This typically occurs when a runway and the close-in ground plane are built on fill. Beyond the threshold, the terrain drops at the maximum grade allowed by Runway Safety Area criteria (5 percent) for the next 1,000 feet. Predicting general trends in RDH/ARDH for multiple slopes is difficult, and mathematical modeling should be used.

e. Combinations of the above. Many sites have multiple irregular conditions that may exceed modeling capability. Such sites should be tested with a temporarily established glide slope.



(a)



(b)

Figure A4-1. RDH and ARDH versus Longitudinal Distance from the Antenna Mast to Threshold, for Antenna Mast Offset Distances from Centerline of 250, 450, and 650 Feet, for a Path Angle of 3.00 Degrees

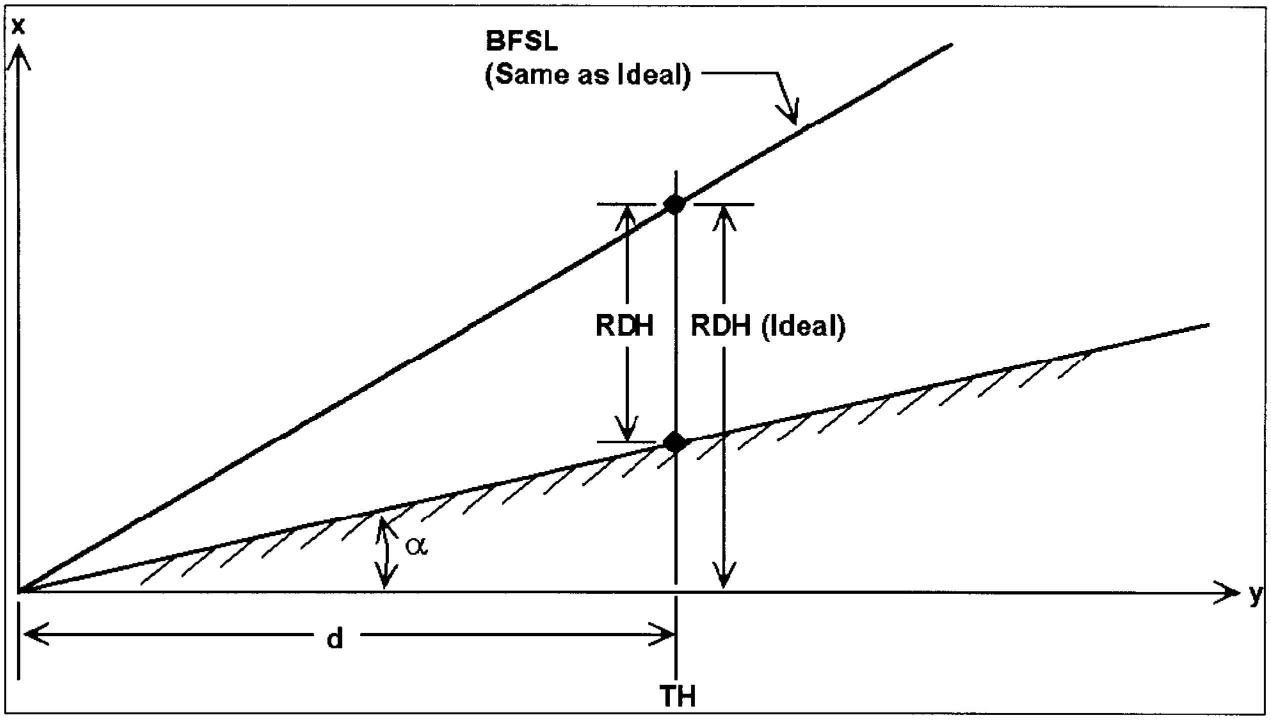
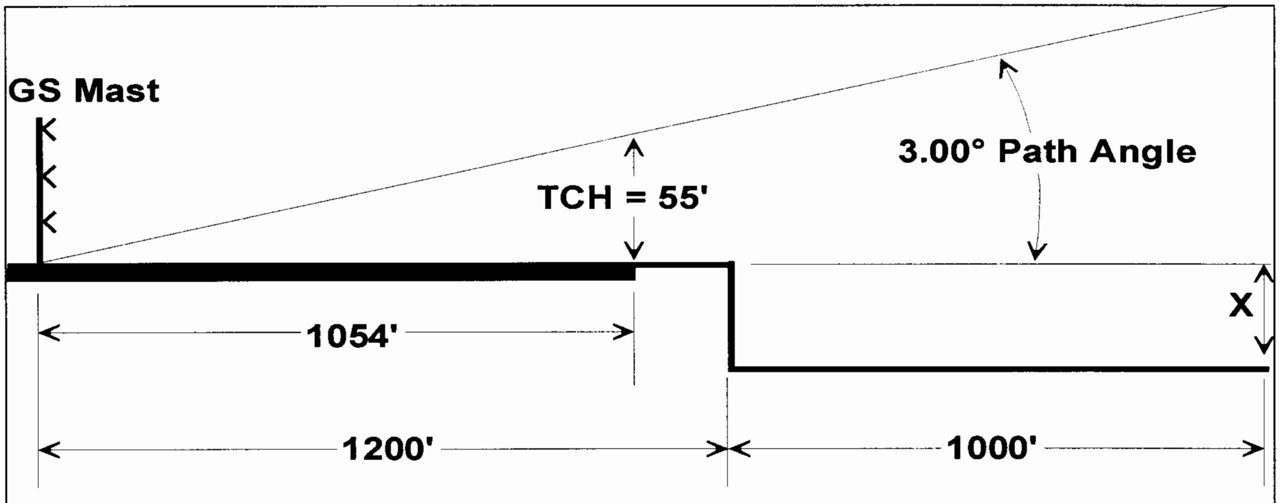
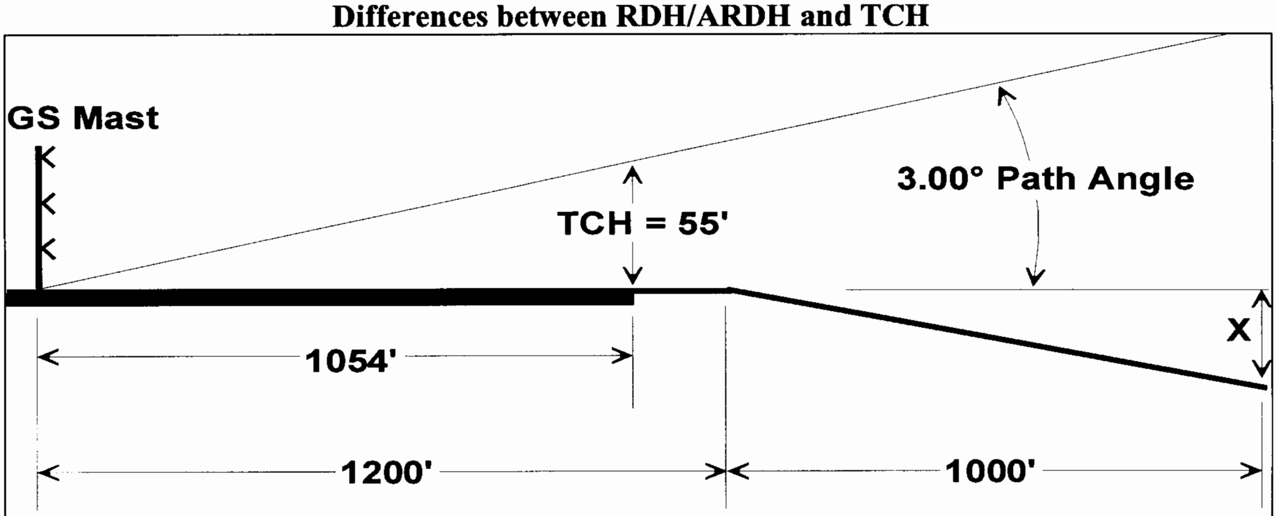


Figure A4-2. Illustration of the Effect of a Uniform, Longitudinal, Up-Sloping Terrain Gradient on the RDH



X(ft)	DRDH(ft)	DARDH(ft)
-5	-3.6	-0.7
-10	-5.0	+0.7
-15	+2.9	0
-20	+1.3	+0.6
-25	-0.1	+0.7

Figure A4-3a. Illustration of a CEGS with Stepped Terrain, Depicting the Modeled Differences between RDH/ARDH and TCH



X(%)	DRDH(ft)	DARDH(ft)
+2.0	+8.8	+1.4
-2.5	-1.5	+0.2
-5.0	-1.7	+0.1

Figure A4-3b. Illustration of a CEGS with Multiple Slope Terrain, Depicting the Modeled Differences between RDH/ARDH and TCH