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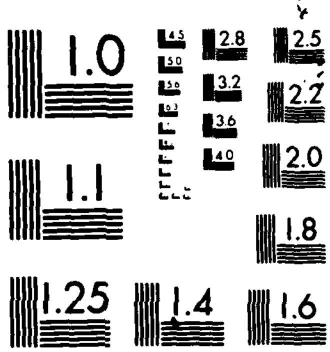
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Siting Criteria for the Microwave Landing System (MLS)

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February 1983

Final Report

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16. Abstract

This report provides guidance in the selection of locations on an airport for installation of MLS antennas. A description of the operation of the Microwave Landing System (MLS) is given and the preferred locations for MLS antennas are described. A discussion of possible interference effects due to reflecting and shadowing objects is presented. Techniques for determining potential interference sources are given.

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CHAPTER 1. GENERAL INFORMATION

1. INTRODUCTION.

a. Purpose. The Microwave Landing System (MLS) provides precision approach and landing guidance signals to properly equipped aircraft to enable pilots to perform safe approaches and landings when low ceilings and poor visibility conditions exist.

The MLS has been adopted in the United States and in the International Civil Aviation Organization (ICAO) as the standard precision approach and landing system and as a replacement for the Instrument Landing System (ILS). The Microwave Landing System Transition Plan (APO-81-1, dated July 1981) establishes the criteria for the phase-in of MLS and the eventual phase-out of ILS. FAA Order 6830.1, System Implementation Plan Microwave Landing System describes management actions necessary to establish MLS at field facilities. System standards and extensive guidance information is now provided by Amendment 63 to ICAO/Annex 10.

b. Operational Capabilities. The MLS system has been designed with a quality and integrity of its guidance signals so that essentially every facility will have the capability to support automatic landing operations. However, the minimum descent altitudes (MDA's) and decision heights (DH's) that will be established in approach plates for each facility will be adjusted on the basis of a number of factors, some of which are:

- Obstruction clearance considerations
- Type and redundancy of avionics
- Aircraft category
- Pilot category
- Ground equipment redundancy
- Supplementary ground equipment (e.g., lighting systems)

The MLS has several ground equipment configurations so that it will be easy to site and perform properly at virtually any airport or heliport. The particular antenna type chosen to adapt the MLS to the particular physical environment of the airport and runway. These configurations are discussed in Chapter 1 paragraphs 3.c and 3.d. In addition, the MLS has several expansion capabilities as discussed in paragraph 2.b.

The MLS provides three dimensional precision guidance in a large volume of airspace. Therefore, many new considerations must be taken into account in siting an MLS facility. Some examples are:

(1) Use of one facility to serve more than one runway (or heliport).

(2) Use of multiple glide paths.

During the ILS to MLS transition period a runway may be served by both ILS and MLS.

2. DESCRIPTION OF THE MLS.

a. General. The MLS provides navigational guidance for precise alignment and descent of aircraft on approach to and landing on a runway. In addition to the azimuth and elevation angle guidance signals, range information is provided

— all of which are interpreted by the aircraft receivers to determine the aircraft's position. In addition to the navigational guidance signals, "Basic Data" is also emitted by the MLS. "Basic data" provides specific information on the MLS such as antenna beamwidths and antenna positional data. The MLS azimuth station is normally located about 1,000 feet beyond the stop end of the runway, and the MLS elevation station is located to the side of the runway near the approach threshold. The precision DME (DME/P) equipment, which provides range information, is normally co-located with the azimuth station. (See Figure 1).

Both lateral (from azimuth antenna) and vertical (from elevation antenna) MLS guidance may be displayed on conventional course deviation indicators or incorporated into multipurpose cockpit displays. Range information also can be displayed by conventional DME indicators or incorporated into multi-purpose displays.

The MLS has the capability to support complex approaches (e.g., curved or segmented) that take advantage of the extensive volumetric coverage of the system.

The MLS will initially supplement and eventually replace existing ILS as the standard precision approach and landing system in the United States (both civil and military use) -- and also for international civil aviation. The MLS Transition Plan assures duplicate ILS and MLS facilities where needed to protect current users of ILS. At international airports, ILS service will be protected to 1995.

The system provides three types of positional guidance as follows:

- Approach-azimuth angle guidance
- Elevation angle guidance
- Range guidance

The FAA standard configuration of the MLS ground equipment includes:

(1) An approach-azimuth station to provide approach-azimuth and range guidance and "basic data". DME/P provides continuous range information that is compatible with standard navigation DME but has improved accuracy and additional channel capabilities.

(2) An elevation station to provide elevation angle guidance. The elevation station guidance signals are synchronized with the azimuth station to ensure that there is no simultaneous radiation between the two stations.

Remote indicators and status units and FAA Remote Maintenance Monitor Subsystem (RMMS) augment the azimuth and elevation stations to provide the necessary control and monitoring of the MLS.

b. MLS Expansion Capabilities. The standard MLS configuration can be expanded by addition of one or more of the following functions.

(1) Back-Azimuth. Where improvements to operational procedures will result, lateral guidance for missed approach and departure navigation can be provided. Back-azimuth information will be provided on runways with dual

MLS (one for each approach direction) - either azimuth station can function as an approach-azimuth station or back-azimuth station, depending on the approach guidance direction selected.

(2) Auxiliary data transmissions. The auxiliary data transmissions provide additional data, which includes refined airborne positioning, meteorological information, runway status, and other supplementary information. The content of the auxiliary data words has not yet been standardized internationally.

(3) Larger azimuth proportional guidance. Additional lateral coverage from $\pm 40^{\circ}$ to $\pm 60^{\circ}$ can be provided for sites with atypical profiles requiring broad or one-sided coverage. This coverage can be obtained by specifying the 1° beamwidth $\pm 60^{\circ}$ lateral proportional coverage azimuth antenna option. (See Chapter 1, paragraph 3c.).

c. Angular Measurement Principle.

(1) Approach-Azimuth. The approach-azimuth antenna generates a narrow vertical fan-shaped beam and sweeps it to and fro across the coverage area shown in Figure 2.

Just prior to the scanning period a test pulse is transmitted. Then, the "TO" scan starts. At the end of this scan, there is a pause before the "FRO" scan starts. A second test pulse occurs after the end of the scanning cycle. During the scanning time slot, the aircraft receives a "TO" pulse and a "FRO" pulse. The time between these two pulses is measured. It can be seen from Figure 3 that the elapsed time between receipt of the "TO" and "FRO" pulses can be used to derive the angular location of the aircraft.

In Figure 3, the full scanning capability of MLS ($\pm 62^{\circ}$) is shown and the normal scan of most FAA installations ($\pm 40^{\circ}$) is shown in solid lines. Some United States installations may scan $\pm 60^{\circ}$ where broad coverage is needed or some may scan as low as $\pm 10^{\circ}$ at locations where special siting or multipath problems exist.

(2) Elevation. The elevation antenna generates a narrow horizontal fan-shaped beam and sweeps it up and down through the coverage area shown in Figure 2. The time difference between receipt of the "TO" (up) and "FRO" (down) pulses is used to determine the elevation angle of the aircraft, and thus the glidepath angle by the pilot.

The elevation beam scans through a much smaller angle than the azimuth beam, thus the elevation scan cycle requires much less time than the azimuth scan cycle.

(3) Back-Azimuth. The back-azimuth antenna generates a narrow fan-shaped vertical beam and sweeps it TO and FRO horizontally through the coverage area shown in Figure 2. The same angular measurement principle used for determining the approach-azimuth angle is used for determining the back-azimuth angle. While the scan convention is the same for all azimuth antennas (i.e., the "TO" scan is clockwise as viewed from above) an algebraic sign reversal is made in the avionics for back azimuth to give consistent course deviation indications in the aircraft.

d. Operational Description. A description of the MLS that is oriented to flight and pilot operations is contained in the Airman's Information Manual. It includes system functions, coverage volumes, frequencies available and the pairing arrangement of the angle guidance and data transmissions with DME/P.

3. MLS SITE-RELATED CHARACTERISTICS.

a. MLS Identification. Each MLS runway will have its own unique MLS identification which consists of a four letter designation starting with the letter "M". This designation is transmitted in International Morse Code approximately six times a minute by the approach-azimuth and back-azimuth (if available) station(s). The MLS identification is also transmitted digitally as part of the basic data. The DME/P is separately identified and transmitted in synchronization with the MLS azimuth transmissions.

b. Proportional Guidance.

(1) Azimuth. To reduce the illumination of signal-reflecting objects, the azimuth-antenna proportional guidance sector is adjustable in small increments so as to provide selectable proportional guidance sectors from a minimum of 10° to the limit of scan, independently on either side of antenna boresight. Whenever the scanning beam antenna design is such that a proportional sector of at least $\pm 40^{\circ}$ cannot be provided, clearance signals are required such that a guidance sector of at least $\pm 40^{\circ}$ results.

(2) Elevation. The elevation antenna lower proportional guidance limit is adjustable in small increments from at least plus 2° to minus $1\frac{1}{2}^{\circ}$. Zero degrees is defined by the horizontal plane containing the antenna phase center.

c. Azimuth Antenna Options. An underlying objective of the FAA is to have as few MLS configurations as possible. With respect to this functional requirement one of the following azimuth antenna types will be selected for each runway:

(1) 2° Beamwidth (BW), plus and minus 40° lateral proportional coverage. For use at typical sites.

(2) 1° BW, plus and minus 40° lateral proportional coverage. For typical sites with long runways.

(3) 1° BW, (low side-lobes) at least plus and minus 10° lateral coverage. Used for atypical sites with large lateral reflectors. Selection of this azimuth antenna requires that the 1.0° BW elevation antenna identified in paragraph 3.d.(2) be used.

(4) 1° BW, plus minus 60° lateral proportional coverage. For sites with atypical approach profiles requiring broad or one-sided coverage. Selection of this azimuth antenna requires that the 1.0° BW elevation antenna identified in paragraph 3.d.(2) be used.

d. Elevation Antenna Options.

One of the following elevation antenna types will be selected for each runway.

(1) 1.5° BW, $+0.9^{\circ}$ to $+15^{\circ}$ vertical coverage. For typical sites.

(2) 1.0° BW, $+0.9^{\circ}$ to $+15^{\circ}$ vertical coverage. For sites with larger lateral reflectors and/or rising terrain in the approach course.

Laterally, the elevation antenna must provide coverage throughout the approach and runway regions within which proportional guidance is provided by the approach-azimuth antenna.

e. Dual-Mode Azimuth Antennas. For dual-MLS runway (one for each approach direction), each azimuth antenna is selectable in function so that it can operate as either an approach-azimuth or a back-azimuth antenna. The antenna will normally be operated on the same frequency when operating in the approach-azimuth mode or in the back-azimuth mode. During the transfer of modes from approach-azimuth to back-azimuth (or the reverse), there will be a period of NO MLS guidance from either approach MLS for a period of 25 $\pm$5 seconds. It is intended that the approach-azimuth station normally operate in the high rate (i.e., 39 Hz) mode. However, provisions will be made for conversion in the field to the 13 Hz rate azimuth under certain conditions where sufficient time is not available in the azimuth function time slot and the 13 Hz rate mode must be used. For example, with the $\pm 60^{\circ}$ antenna as described in paragraph 3.c.(4) above, the azimuth equipment will operate only in the 13 Hz rate mode. In addition, the $\pm 60^{\circ}$ azimuth equipment will not be able to function in the back-azimuth mode. Also, with an azimuth equipment providing $\pm 60^{\circ}$ lateral coverage, the range requirement is reduced to 14 nmi between 40° and 60° angular coverage.

CHAPTER 2. MLS SITING CONSIDERATIONS

1. PREPARATION. Data concerning the proposed site should be gathered in order to become acquainted with the runways and adjacent areas. These data normally consist of:

- Obstruction clearance charts
- Topographic charts of terminal area and airport
- Runway(s) to be served by this MLS and associated existing navaids
- Airport cable conduit and terminal information
- Ground traffic patterns, run up areas, blast fences, etc.
- Type(s) of service
- Type of MLS proposed and associated data
- Proposed approach paths
- Indication of airport property lines

From these data, nominal MLS component sites as specified for the type equipment to be installed can be selected to provide the service desired, once it has been determined that the type of MLS proposed is adequate for that service and any growth potential desired. This will require discussions with airport management personnel and FAA Flight Standards, Air Traffic, Airports, and Airway Facilities Divisions. Discussions should address topics such as utilization, traffic patterns, noise abatement areas, restricted or prohibited areas and other operational requirements associated with the MLS. Discussions should also concern adjustments in the MLS type proposed, alternations of proposed approach paths, or, where these decisions have not been made, recommendation as to MLS type, service available and approach paths compatible with MLS service.

2. GENERAL EVALUATION CRITERIA. Under this paragraph are considerations to be evaluated by the siting engineer prior to the detailed selection of the location for the MLS hardware. The proposed location will probably not be optimum for any one consideration but hopefully will be for the considerations as a whole.

a. Satisfactory Approach Path(s) Capability. The proposed approach paths selected must be feasible from an operational point of view in that they can be easily followed by the class of user for whom they are designed. A number of approaches to the same runway may be necessary to provide the proper service to a number of user classes. If service can be provided to other runways without compromising the service to the primary runway, it should be specified and approaches designed to take advantage of the available guidance. Acceptable missed approach procedures must be included as part of the overall procedure.

b. Satisfactory Obstacle Clearance. Another part of MLS siting is the problem of obstacle clearance, which must be considered when designing flight paths. Normally obstacles are a problem only within a few miles surrounding the airport property, unless there are geographical features of extreme height in relation to the runway, such as hills or mountains. Proposed locations for the MLS hardware should not penetrate the planes defined in FAR Part 77, Subpart C for Precision Approach Runways.

c. Critical Areas. The proposed location of the hardware should take into consideration the effect of parked or taxiing aircraft as well as parked or moving ground vehicles to ensure that the radiated signal will not be degraded.

d. Multipath and Shadowing. Care must be taken to limit signal degradation due to reflection (multipath) and/or blockage (shadowing) by objects in the proportional guidance volume.

e. General Siting Areas. A visit to the proposed component sites should be made to validate the information extracted from the charts and associated data. It will be useful to set up a transit at each site and profile the obstacles to determine where conflicts may exist. Having previously plotted the approach paths with respect to each site, major conflicts with obstacles may be immediately apparent. Those obstacles that present possible multipath sources can also be studied in greater detail to determine more closely their composition and angular relationships with the approach paths and lines of sight. Physical features and recently completed structures not apparent on the charts can be noted and added to the data. Photographs may also be helpful in later studies to refresh one's memory of airport features. The height of terrain at the sites, in relation to the threshold, stop end and direction of coverage, should be recorded for future reference, using the transit.

At this time the suitability of the site for the physical installation of the antennas and enclosures can be determined. Although the site preparation and foundation requirements are not severe for MLS, a check should be made of the ground or other structure where the site is to be located to determine its suitability.

(1) Azimuth Site. The azimuth site is normally located on the runway centerline extended, beyond the stop end of the runway to be served at a distance sufficient to not violate the approach clearance plane of the opposing runway. This clearance plane starts 200 feet from the threshold and rises at a specific ratio (50:1 for precision runways). Local restriction, frangibility and other factors must also be considered. The nominal distance is 1,000 feet which does not restrict usage and is acceptable at most installations. The preferred position projects guidance down the runway centerline for straight-in approach and landing procedures. If the real estate is available and there are no obstacles along the centerline extended, the distance that will keep its base at or above the stop end level, but well below the clearance surface with a clear view of the runway, and not be obstructed by the runway itself, (humped runway) is preferred. Preferred and alternate locations are shown in Figure 4.

(2) Elevation Site. A tentative location for the elevation antenna can be designated based on the following parameters:

- Phase center nominal height
- Overall height
- Approach reference datum height and nominal glidepath
- Presence of ILS glideslope antenna

- Obstacle and traffic pattern in the area
- Height of ground at nominal location

Normally the elevation antenna will be located on the opposite side of the runway from any taxiways, at a distance from threshold so that the minimum glidepath intercepts the approach reference datum. The distance from runway centerline is controlled by the clearance surfaces, which would allow most antennas to be placed a minimum of 250 feet from runway centerline. The nominal distance is 400 feet; however, this distance can be over 500 feet and not effect guidance appreciably on the lower glidepaths or higher decision heights.

f. Co-Location with Existing Airport Facilities.

(1) MLS Azimuth-Antenna with ILS Localizer Station - The MLS azimuth antenna, has been installed both ahead of and behind an ILS localizer without derogation of the ILS or MLS. Since there are various types of localizers (Table 1) with widely different form factors, the statement that MLS/ILS co-location is always compatible cannot be made without qualification. For instance, location of MLS behind one of the large localizers which use a parabolic reflecting screen would not be practicable. Where space allows, location of MLS in front of a localizer seems to be the most appropriate. The MLS azimuth antenna is relatively small, low in height, and is symmetrical about the runway centerline, these features being the prerequisites generally stated for ILS tolerance of such an object in its field of view. A reasonable distance should generally be maintained between MLS and ILS for any such co-located sites; successful demonstrations have been conducted with a six foot wide azimuth antenna 75 feet forward of a localizer array. Also, the site should never be situated such that MLS would exist directly between the localizer array and its monitor, or its reflector (parabolic array). Consideration should likewise be given to the presence of the ILS localizer shelter, which could constitute a blockage for the MLS scanning beam.

Where a problem exists in locating the azimuth site, it may be necessary to have an offset approach path by locating the azimuth site away from the extended centerline. Certain limitations on the amount of offset are dependent on the amount of turn that must be made to the centerline after DH is reached. The offset guidance should cause the aircraft to intercept the extended centerline shortly after decision height is reached in accordance with the FAA Order 8260.30 IFR Approval of Microwave Landing System (MLS), to allow a turn onto centerline. The angle offset is not only restricted by the amount of turn onto centerline but also the availability of a site location.

TABLE I. ILS LOCALIZER ANTENNA CHARACTERISTICS

Types	Height	Length	Expected MLS Characteristics
8-loop	5	40	Transparent
V-ring	7	150	Transparent
Waveguide	6	150	Opaque
Traveling wave antenna array	6	45, 85	Transparent
AN/MRN-7	7	85	Opaque
Parabolic	13	115	Opaque
Typical MLS azimuth	7	7 (2^o BW)	
Typical MLS azimuth	7	13 (1^o BW)	

MLS Azimuth Station/Localizer Identification Sychronization. Provisions are made in the MLS to synchronize the identification information emitted by co-located azimuth DME/P and ILS localizer equipment.

(2) MLS Elevation Antenna/Glide Slope Station. Co-location of the MLS elevation antenna and the ILS glideslope involves other considerations, principally: (a) providing equal glide path angles, consistent with the stated requirements for the appropriate operational category, and (b) location of MLS so as not to affect the performance of ILS. In locating so as to achieve the first requirement, MLS in its preferred location is located 150 feet to 300 feet ahead of the glideslope antenna, and thus present in the ILS "critical area" region. A waiver to allow th elevation antenna to be in the glide slope critical area should be approved prior to installation.

(3) Azimuth Antenna/Approach Light System. Approach light systems (ALS) should not interfere with the azimuth site and vice-versa. Possible interference with each other may require moving the antenna nearer to, further away or higher than the normal location with respect to the stop end of the runway. It is normally possible to relocate ALS bars a small amount if necessary. Installation should be made with the azimuth antenna backed up to the ALS lights at the proper distance from the stop end.

g. Interconnections. During the siting, interconnecting communications and 120/240 volt single phase AC power must be planned to connect the sites and allow for control and monitoring of equipment. The monitoring of equipment includes interfacing with the FAA Remote Maintenance Monitor System. The MLS is a time-multiplex system and thus the synchronizing function is a critical communication between azimuth and elevation stations. Land lines or radio links are possible options for these communications. Larger airports normally have established buried cables with spares or conduit where interconnections can be made available. Smaller facilities may require interconnections and power to be made available at the sites where they do not exist.

CHAPTER 3. SPECIFIC SITING CONCERNS

1. GENERAL. This chapter gives guidance in the selection of MLS antenna locations on the airport. The various factors that are involved in antenna placement, such as the desired approach path, physical constraints and possible sources of error are discussed. Where situations that are beyond the scope of this discussion are encountered, it is recommended that the MLS Program Office, APM-410 be consulted.

Although the MLS has features that permit installation virtually any place where a pad or platform can be installed, in order to optimize performance, care must be taken to avoid the possibility of guidance signal perturbations due to signal reflections (multipath) or blockage (shadowing) by objects in the proportional guidance area. In cases where guidance perturbations seem likely, the situation should be modeled using computer models. The existing computer models can simulate the performance of both ground and airborne MLS and DME at any location. Requests for computer modeling should be made to the MLS Program Office, APM-410.

2. AZIMUTH STATION.

a. Antenna Location. The azimuth antenna should be located off the stop end of the runway on the extended centerline whenever possible. The distance from the stop end of the runway is determined by the standard obstruction criteria as compared with the height of the antenna, as well as the practical considerations of tolerance of the antenna system to jet blast from aircraft on takeoff, and the deposition of oily films on radome surfaces from fuel-rich exhaust. A spacing of 500 feet is a recommended minimum limit.

The azimuth antenna case is typically about 5 feet high, and is generally positioned a minimum of 3 feet above the ground; this allows for an accumulation of snow beneath the antenna without aperture blockage. Typically, the case is supported at each end on vertical posts. Platforms or tower structures may be used to further elevate the antenna if necessary.

In selecting a suitable azimuth antenna height, consider also the runway contour and any other items which might cause signal blockage. While it is generally desirable to keep the overall antenna height to the 8 foot minimum, there are cases where the antenna must be elevated to establish a clear line of sight over obstacles, including runway humps, collocated localizers and approach lights. The azimuth antenna must not violate the approach clearance plane of the opposing runway. The nominal distance of 1,000 feet does not restrict usage and is acceptable at most installations. The preferred position allows guidance down the runway centerline on the 0° azimuth radial for the approach and landing. It is desirable to keep the azimuth equipment base at or above the runway stop end height (but well below the clearance surface) with a clear view of the runway (and not obstructed by the runway itself for the case of a humped runway). Preferred and alternate locations are shown in Figure 4. The DME antenna is normally located near the azimuth antenna site, but may be offset up to 450 feet.

Where one azimuth system is used to serve more than one runway a location must be selected to serve both runways without compromising the primary runway.

b. Multipath. Once the general location of the azimuth antenna has been selected, a determination must be made as to whether any objects in the area will reflect scanning beam signals into the proposed approach path. The search for such objects should not be limited to the airport grounds, but should include any objects within line-of-sight of the MLS ground antenna. Any non-horizontal surface within the proportional guidance region particularly metal or concrete can act as a multipath reflecting surface. In addition, hillsides may act as reflecting surfaces for the short wavelength (about 2 inches) MLS signal.

Because of the characteristics of the MLS scanning beam, only reflections from objects that lie inside an angle of about 1.7 beamwidths of the azimuth radial being flown are likely to cause guidance perturbations. Scanning beam signals that are reflected into the flight path from objects within such an area are referred to as "in-beam" multipath. Signals reflected from outside that area are referred to as "out-of-beam" multipath. Figure 5 shows the location of the multipath regions with respect to the antenna and the flight path.

All situations where azimuth in-beam multipath near the approach path is likely should be investigated thoroughly prior to installation of the antennas. In addition to the geometry of the situation, additional factors such as the reflecting surface roughness, material composition, and vertical angle will affect the attenuation and reflection angle of the signal.

In many cases, the selection of antenna beamwidths and scan control can alleviate potential multipath problems by avoiding illumination of the reflecting surface. Figure 6 gives a formula for determining the maximum antenna beamwidth needed to avoid in-beam multipath for a centerline approach.

c. Shadowing. Shadowing and diffraction of azimuth scanning beam signals by objects that block the line-of-sight between the ground antenna and the airborne receiver antenna are of primary concern. Such objects may include large buildings in the airport area, towers and other antennas or structures on the airport, and runway humps.

Shadowing, (or blockage) of the signal can result in attenuation or loss of guidance information in the shadow region. In addition, the shadowing object can produce guidance perturbations due to diffraction at the edges of the object. Figure 7 depicts the shadow and diffraction regions with respect to the antenna and the shadowing object.

Situations where the approach path passes through a shadow region cannot be permitted because of guidance perturbations that could be caused by diffraction effects. Where a question arises as to the effects of a shadowing object, computer modeling should be used to simulate the performance of the system.

d. Critical Areas. Definitions of MLS "critical areas" are being developed under the MLS Service Test and Evaluation Progam (STEP). In the meantime, care must be taken in siting the antenna so as to avoid situations where objects near the antenna could cause in-beam multipath or signal shadowing. Obviously, the antenna should not be located where a road passes directly in front of it, unless there are assurances that vehicular traffic on the road will not act as multipath or shadowing objects. The azimuth antenna should not be located where a duty taxiway passes close to, and in front of, the antenna. Preliminary estimates of MLS critical areas are shown in Figure 14.

Any objects in front of the azimuth antenna can be considered potential multipath or shadowng objects. Their effects on the MLS guidance signals should be studied prior to installing the antenna.

e. DME/P Multipath. DME signals are also susceptible to multipath from buidings and terrain in the coverage region. Since the DME is located near the azimuth site, the determination of azimuth multipath sources will usually apply to DME. The DME antenna may be located on top an equipment shelter, which would place the base of the antenna approximately ten feet above ground level. Although this height is generally satisfactory, some antenna pattern nulling may occur near ground level in the runway threshold area because of signal reflections off the ground. Therefore, where precision DME guidance is required below 100 feet, the DME antenna may require elevation to a height of 15 to 20 feet above ground.

f. DME/P Shadowing. Shadowing of the DME signals will result in loss or attenuation of the signal. Care must be taken to locate the DME antenna so that aircraft on final approach will not encounter any shadowed areas.

3. ELEVATION STATION.

a. Antenna Location. The elevation antenna is typically located 250 feet to 400 feet from runway centerline, on either side of the runway. The question of which side of the runway to select must consider the space available, the presence of active taxiways, potential signal blockages and multipath reflectors, etc. The antenna phase center should be higher than runway centerline. The support structure beneath the antenna should provide the necessary 3 feet snow clearance. Measured from threshold, the antenna is nominally set back by approximately 860 feet for a 3° minimum glide angle. The minimum glide angle is established by Flight Operations based upon the approach procedure. The Approach Reference Datum is a point on the minimum glide path at a specified height above threshold. It is nominally about 50 feet above the threshold for a 3° glide angle. It is at the Approach Reference Datum that MLS ground systems error limits are applied. The elevation antenna is located to provide zero conical error at that point.

Elevation parameters are shown in Figure 8 and defined in Table 2. FAA Order 8260.30 IFR Approval of MLS, gives the maximum allowable antenna height in relation to the runway centerline. The relatively short height of MLS elevation antennas will normally be well within the allowable height. The minimum distance from centerline (OS) is 250 feet and the maximum distance is restricted only by the errors caused by the projection of the conical beam on the centerline plane. Normally, the antenna should be located no farther than 500 feet from runway centerline unless the terrain, obstacles or service of multiple runways requires the antenna to be farther out. The nominal location area for the elevation antenna is illustrated in Figure 9.

Once the offset distance from runway centerline (OS) and the minimum glide angle (theta) and height above threshold of the Approach Reference Datum are established, the distance for the setback of the antenna (SB) may be determined in the following manner. As shown in Figure 10 the distance (D) from the antenna base (EL) to runway threshold (T) may be calculated using theta and the height of the Approach Reference Datum with respect to the antenna phase center. The setback (SB) may then be found by solving for SB in the right triangle formed by OS, D and SB.

b. Multipath. After a tentative site for the elevation antenna is selected, the area within the proportional coverage area must be studied for potential multipath sources. The study should locate any non-vertical reflecting surfaces within line-of-sight of the antenna. Surfaces such as pitched roofs and hills may reflect the elevation guidance signals into the approach path.

As with the azimuth system, elevation guidance signals can be perturbed only by "in-beam" multipath. In the case of elevation guidance, "in-beam" multipath would result from reflections from surfaces that lie within an angle of about 1.7 beamwidths of the approach angle. Figure 11 depicts the "in-beam" multipath region for elevation guidance. The objects shape and surface roughness, material composition and vertical angle will affect the attenuation and reflection angle of the signal.

In order to make a determination of whether a serious multipath condition exists, the site should be modeled using computer models. In many cases, the selection of antenna beamwidth and scan control can alleviate potential multipath problems by avoiding the illumination of the reflecting surface. Figure 12 gives an equation for determining the beamwidth for situations with rising terrain in the approach zone.

c. Shadowing. Shadowing and diffraction of elevation scanning beam signals must also be considered. Such objects may include hills, towers, and other antennas structures.

Shadowing of the elevation signal can result in attenuation or loss of guidance information in the shadow region. The shadowing object can also cause perturbations of the guidance signals due to diffraction effects at the top edge of the object. Figure 13 shows the shadow and diffraction regions with respect to the antenna and the shadowing object.

Situations where the approach path passes through a shadow or diffraction region cannot be permitted because of guidance pertubations that could be caused by diffraction effects. Where a question arises as to the effects of a shadowing structure, computer modeling should be employed to simulate the performance of the system.

c. Critical Areas. Although the critical areas for MLS antennas have not yet been defined, it is clear that they are smaller than the ILS critical areas for similar approach paths. Until the MLS critical areas are defined, each site should be studied to determine whether objects in front of the antenna will cause multipath, shadowing or diffraction effects. Antenna site and beamwidth selection must take these factors into account. The elevation antenna should not be located where a taxiway or road passes in front of it. Parked or taxiing aircraft, as well as vehicular traffic in front of the elevation antenna can cause guidance anomalies for aircraft on final approach. Aircraft and ground vehicles can act as multipath and shadowing objects. Their effects on the guidance signals must be studied carefully prior to installation. Preliminary estimates of MLS critical areas are shown in Figure 14.

TABLE 2. DEFINITIONS AND TERMINOLOGY

Several terms and abbreviations, defined as follows, are used when locating the elevation facility:

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

Approach Surface Beam 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 Angle (θ). The elevation angle of the glidepath with respect to the ASBP.

MLS Approach Reference Datum. A point on the minimum glide path at a specified height above threshold.

MLS Datum Point. The point on the runway centerline closest to the phase center of the approach elevation antenna.

EL. Location of base of the elevation antenna.

D. Distance along a straight line from EL to T.

OS. Offset; Distance from runway centerline to EL.

SB. Setback; Distance along a line (parallel to centerline) from EL to the threshold.

PCH. Antenna phase center height above ASBP.

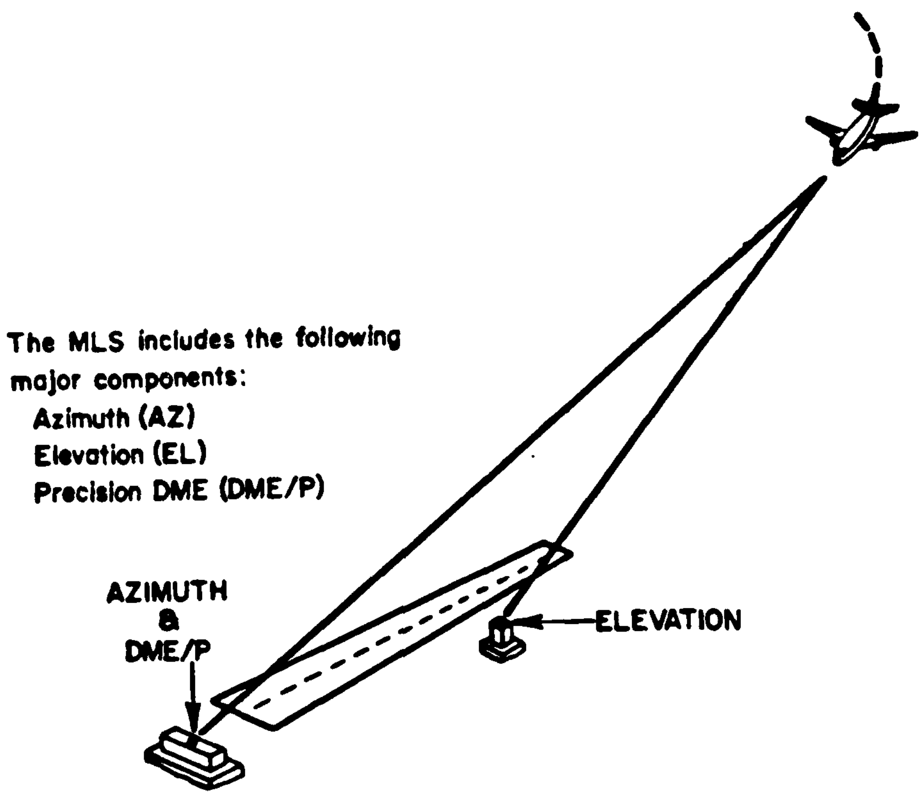


FIGURE 1. GENERAL LAYOUT OF MLS GROUND STATIONS

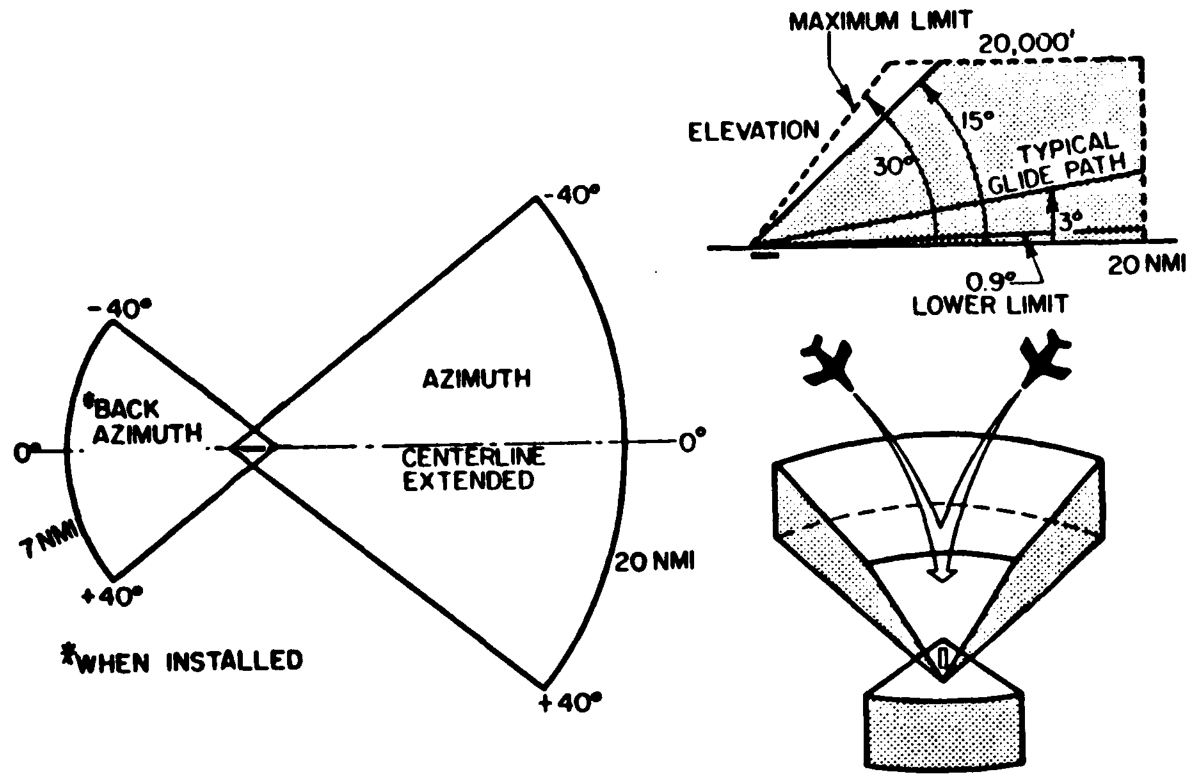


FIGURE 2. SIGNAL COVERAGE FOR AZIMUTH AND ELEVATION ANTENNAS

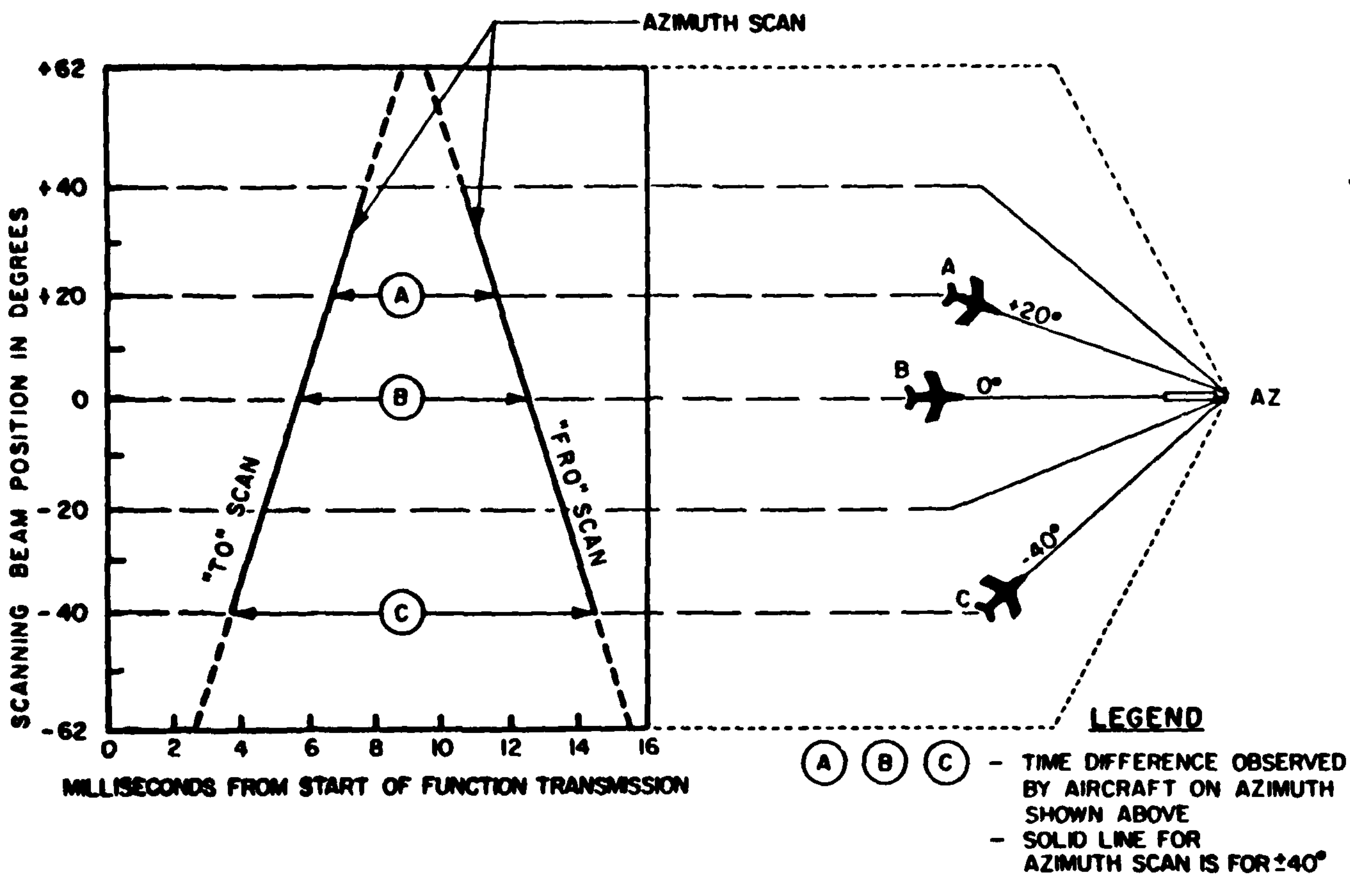


FIGURE 3. ANGULAR MEASUREMENT PRINCIPLE

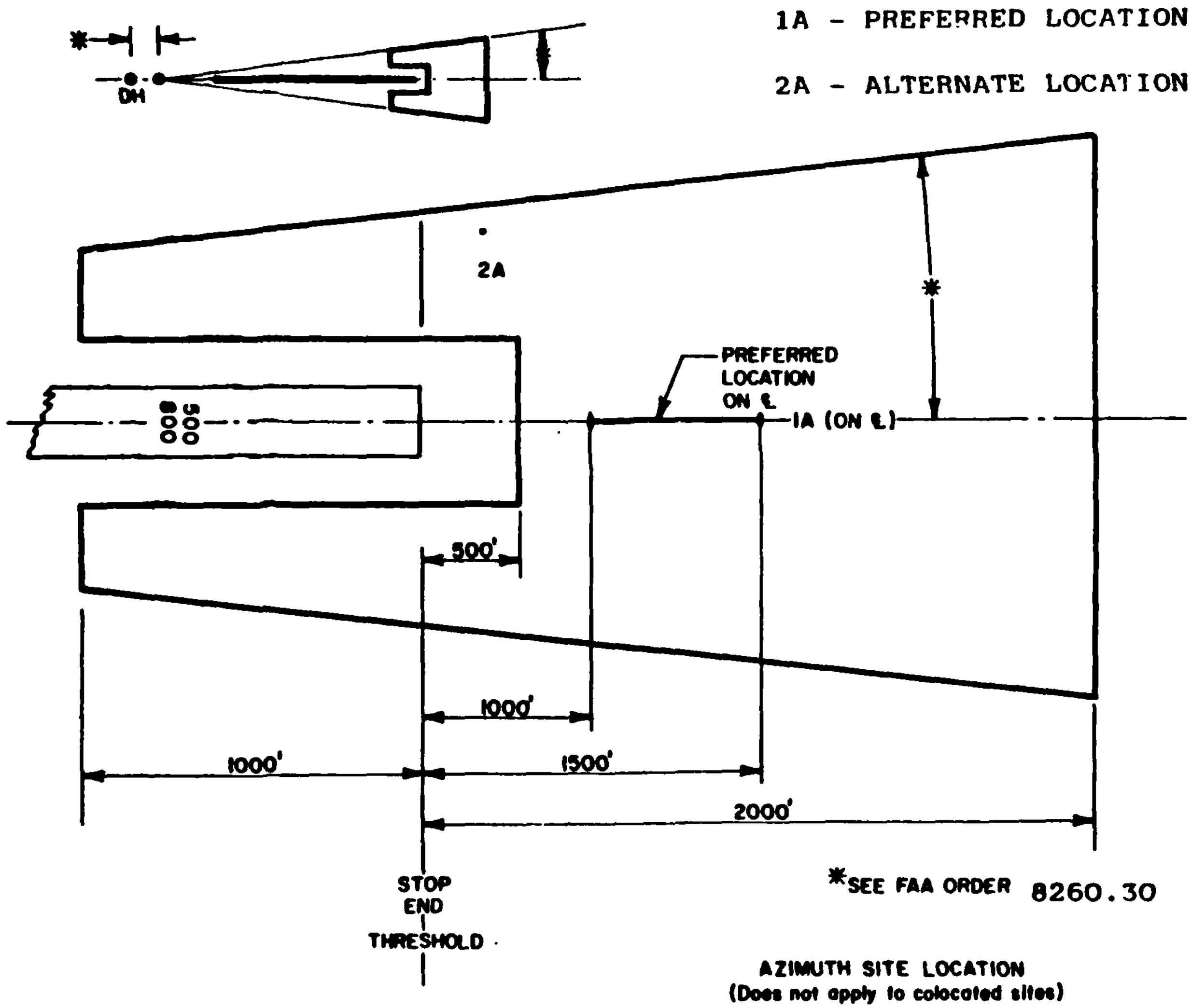


FIGURE 4. AZIMUTH ANTENNA LOCATIONS

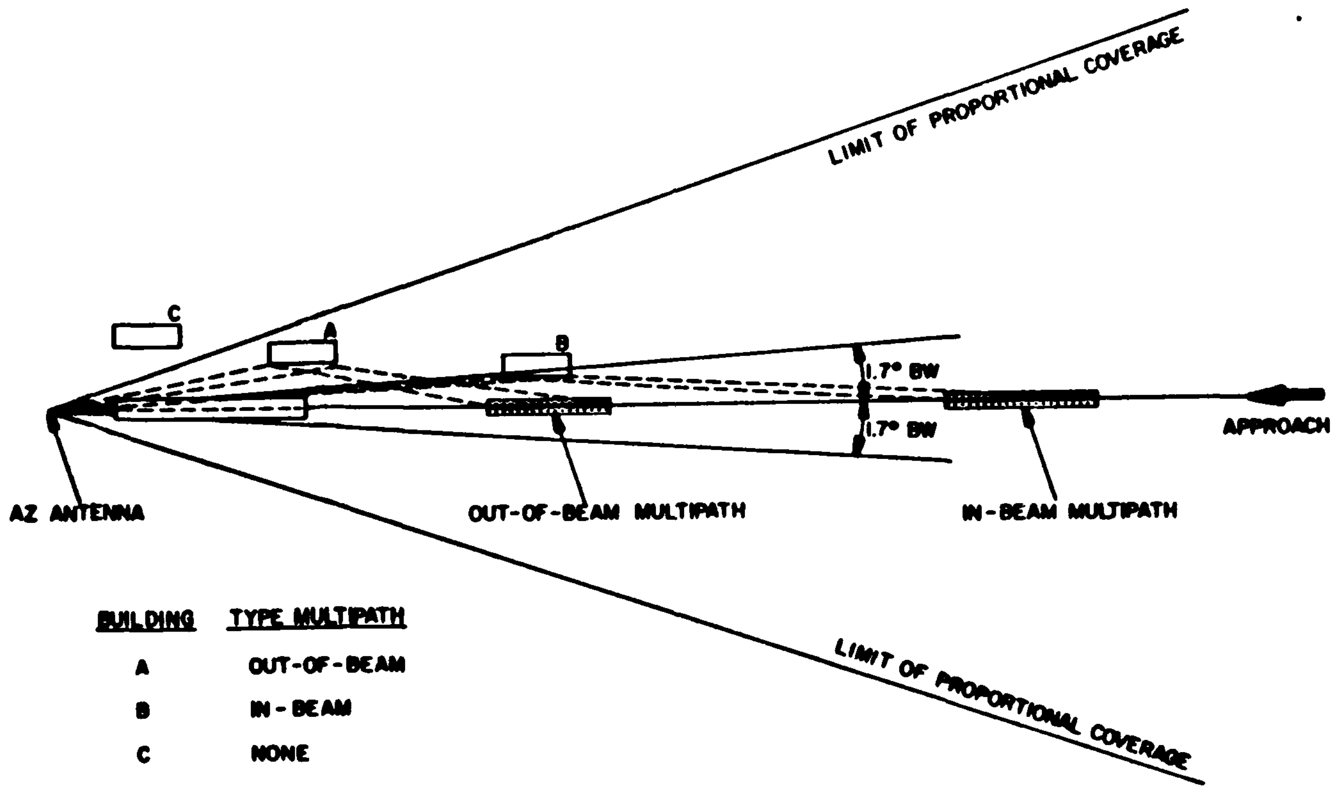
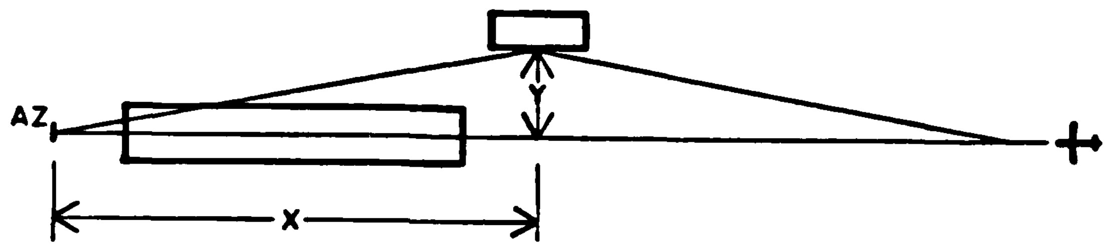


FIGURE 5. AZIMUTH MULTIPATH



$$BW_{max} = \frac{\text{Arc tan } \frac{Y}{X}}{1.7}$$

FIGURE 6. AZIMUTH MAXIMUM BEAMWIDTH

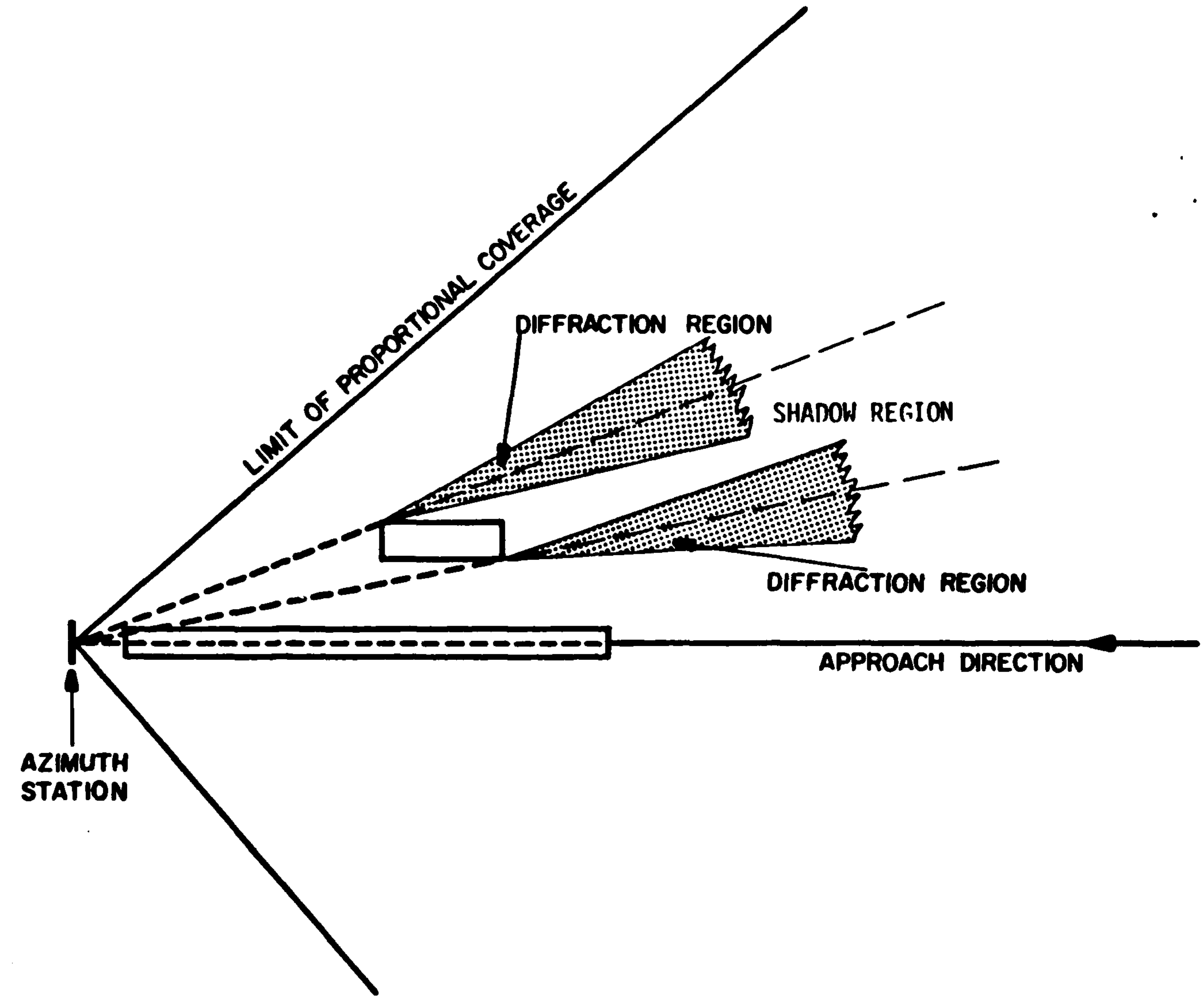


FIGURE 7. AZIMUTH SHADOWING/DIFFRACTION

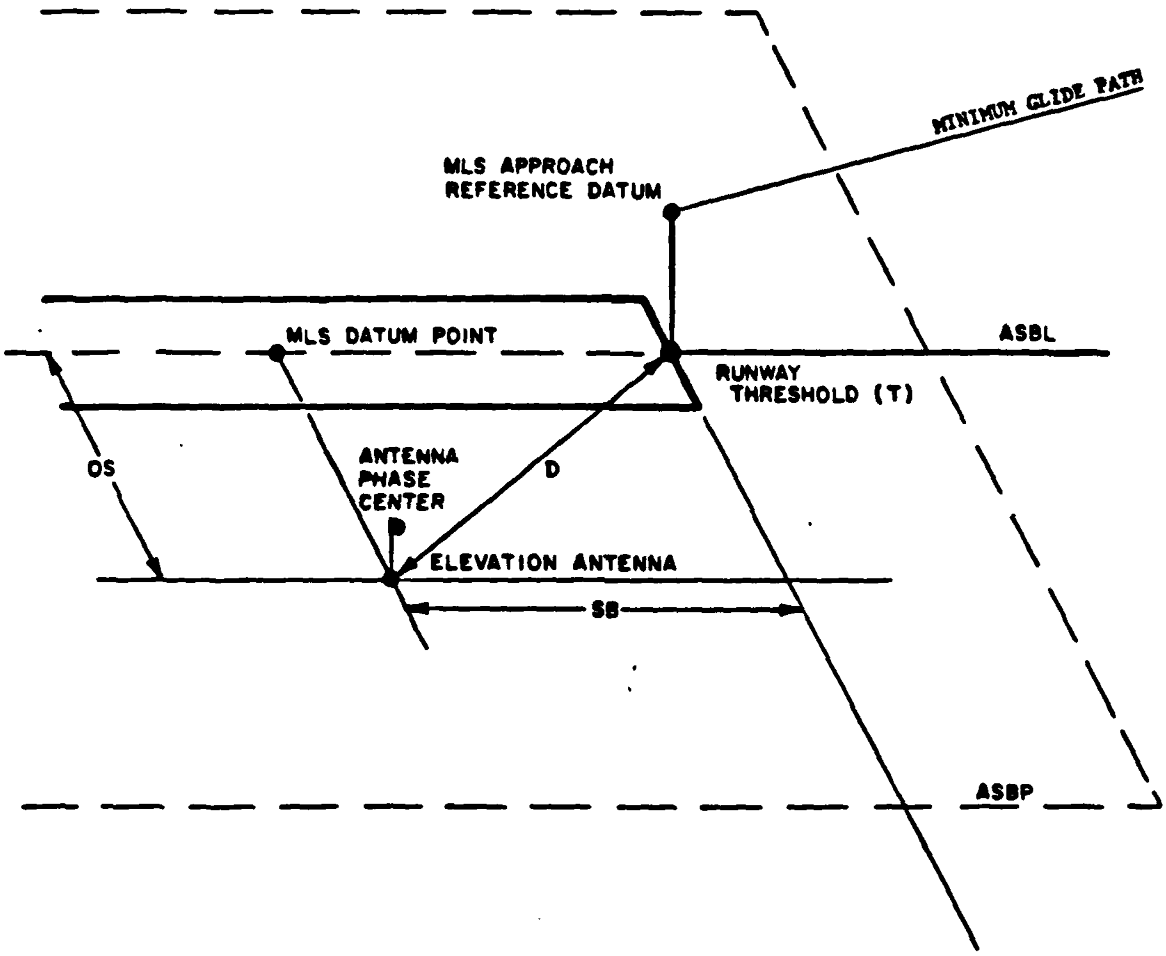
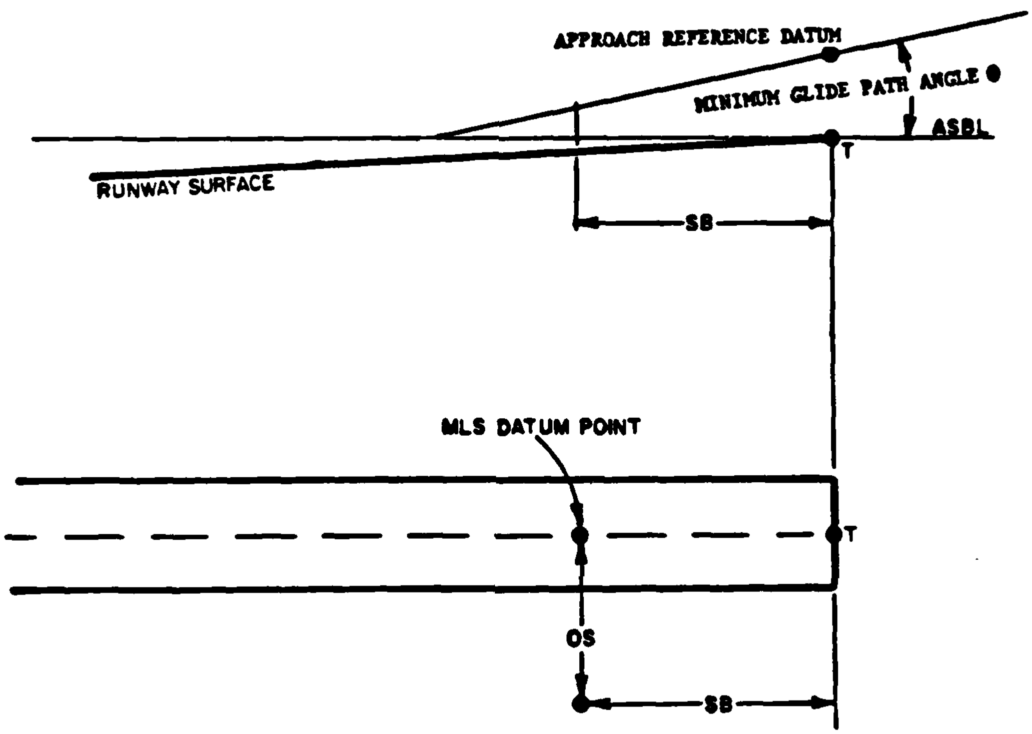


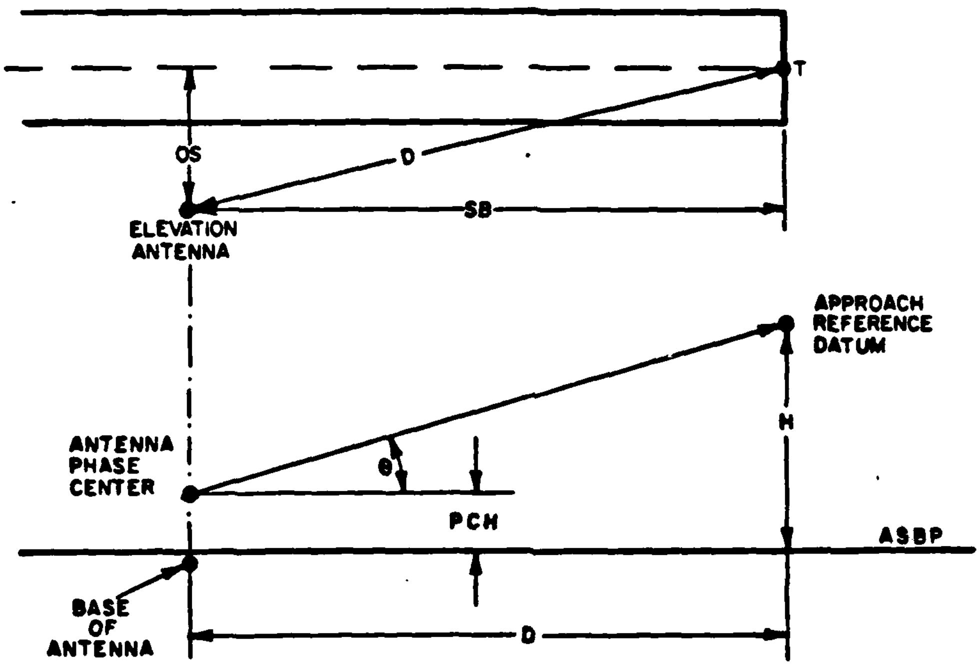
FIGURE 8. ELEVATION ANTENNA LOCATION



OS IS NOMINALLY 400feet (250feet minimum)

SB IS DETERMINED BY MINIMUM GLIDE PATH ANGLE

FIGURE 9. NOMINAL ELEVATION LOCATION AREAS



KNOWN: OS, θ, H, PCH

FIND: SB

FIRST: $D = \frac{H - PCH}{\tan \theta}$

THEN: $SB = \sqrt{D^2 - (OS)^2}$

FIGURE 10. COMPUTATION OF ELEVATION SITE COORDINATES

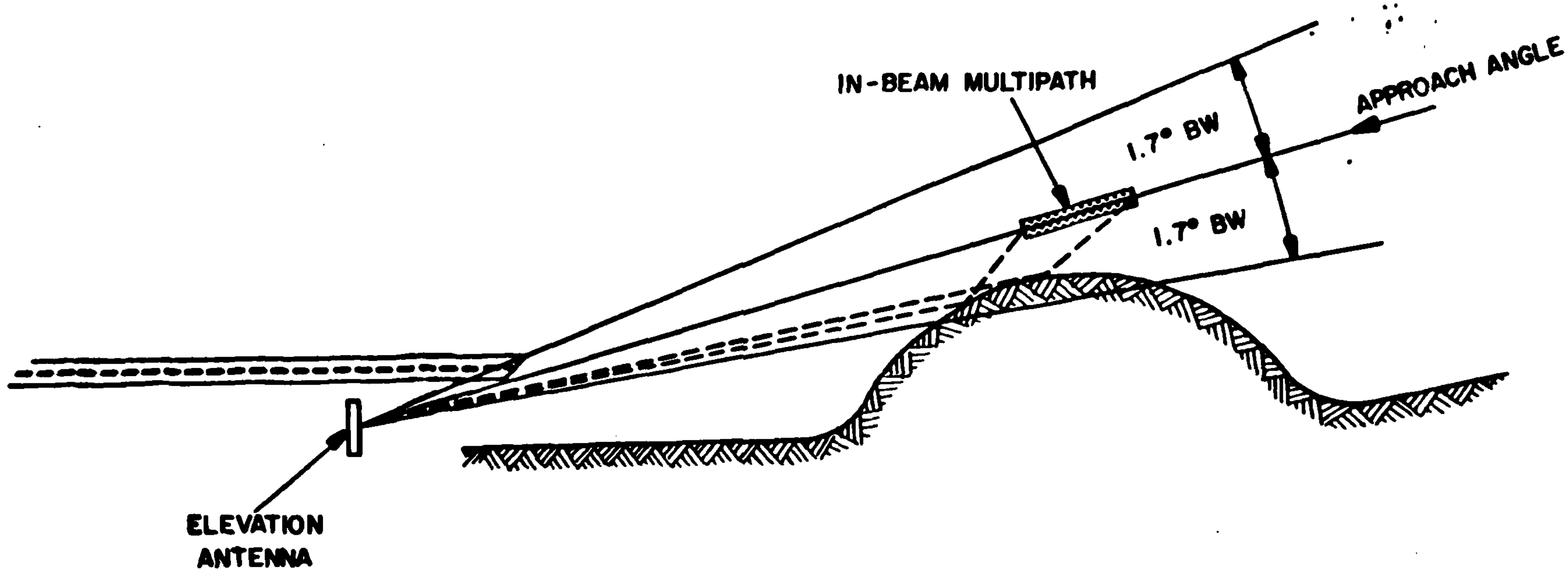
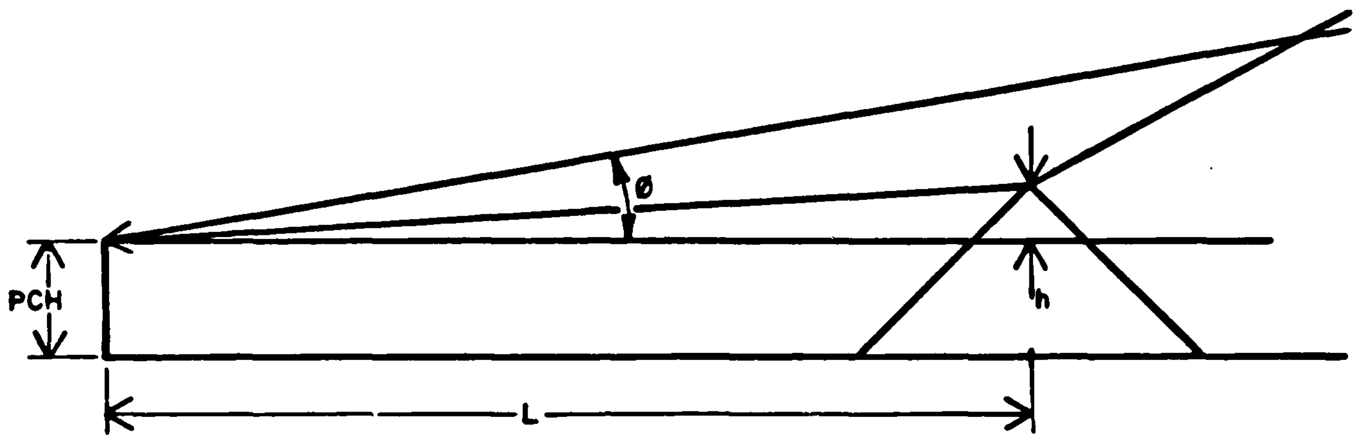


FIGURE 11. ELEVATION MULTIPATH



h = height of reflection point wrt antenna phase center

L = distance from antenna to reflection point

Ø = approach glide angle

$$BW_{max} \leq \frac{Ø - \text{Arc tan}\ \frac{h}{L}}{1.7}$$

FIGURE 12. ELEVATION MINIMUM BEAMWIDTH

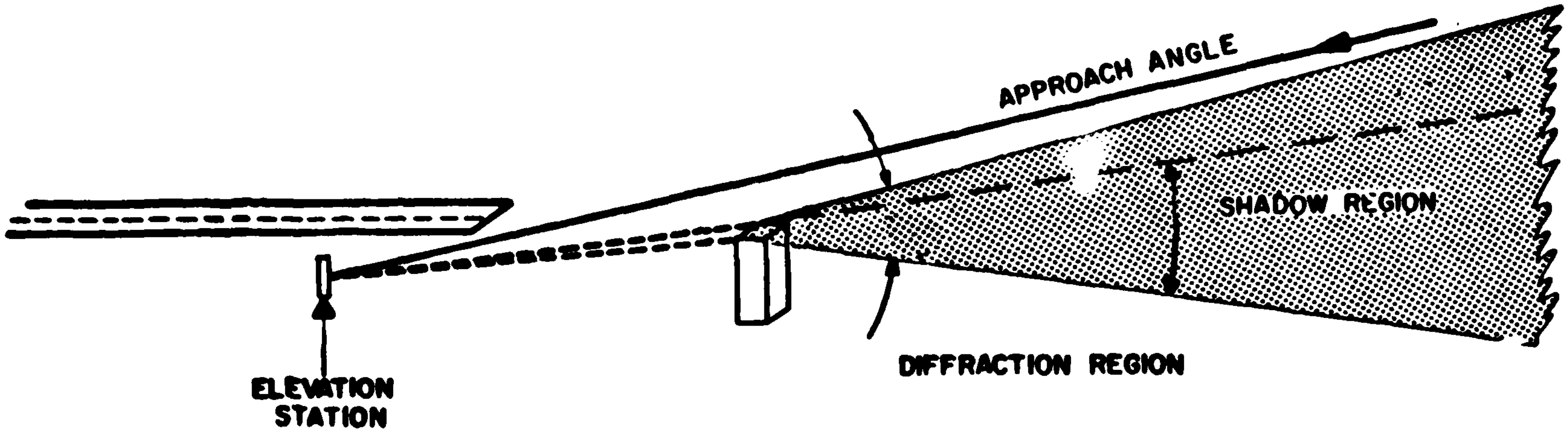
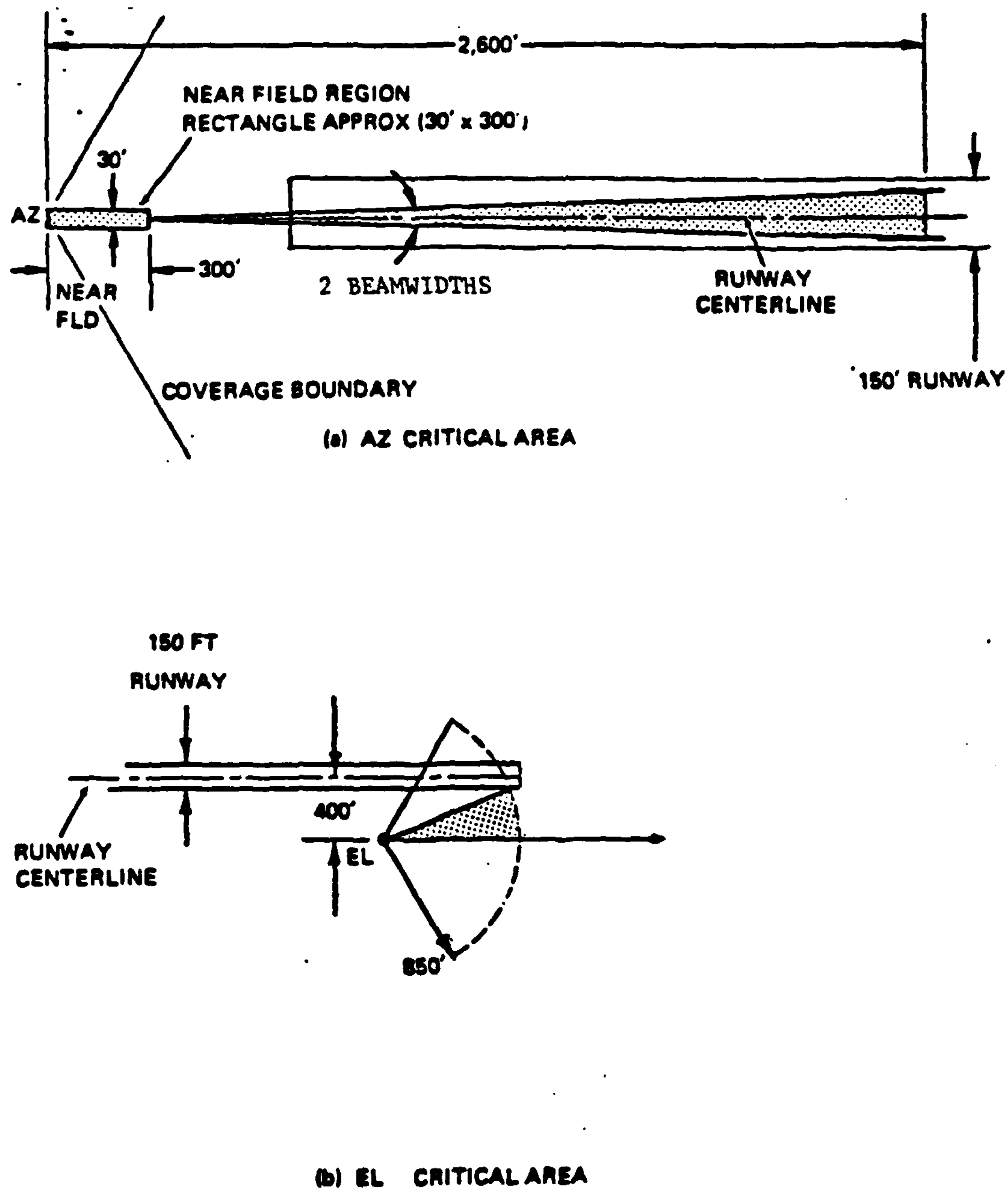


FIGURE 13. ELEVATION SHADOWING/DIFFRACTION



NOTE: These are preliminary estimates for centerline approaches.

FIGURE 14. MLS CRITICAL AREAS

'age 8, Chapter 2, Section 2e. General Siting Areas, (2) Elevation Site: Delete last sentence of paragraph beginning with "The nominal distance...".

Page 12, Chapter 3, Section 3. Elevation Station, a. Antenna Location: Delete and substitute the following therefor:

The elevation antenna is nominally located 250 feet from runway centerline, on either side of the runway. The question of which side of the runway to select must consider the space available, the presence of active taxiways, potential signal blockages and multipath reflectors, etc. The antenna phase center should be higher than the elevation of the runway. The bottom of the antenna aperture should be higher than three feet above ground level to provide snow clearance. Measured parallel to centerline from threshold, the antenna is nominally set back approximately 800 feet for a 3^{0} minimum glide path angle. The exact distance will depend on antenna phase center height and the local terrain.

The MLS approach reference datum is a point at a specified height located vertically above the intersection of the runway centerline and the threshold. The elevation antenna should be sited so that the asymptote of the minimum glide path crosses the threshold at the MLS approach reference datum. The minimum glide path angle and the height of the approach reference datum will be determined by the Office of Flight Operations prior to siting the ground equipment. FAA Order 8260.34 (Glide Slope Threshold Crossing Height Requirements) governs the selection of the height of the approach reference datum. Factors that will be considered in determining these two siting variables are: type of operations (Category I, II, III), types of aircraft utilizing the runway and their desired wheel crossing height, and length of runway.

Elevation parameters are shown in Figure 8 and defined in Table 2. FAA Order 8260.30, IFR Approval of MLS gives the maximum allowable antenna height in relation to the runway centerline. The relatively short height of the MLS elevation antennas will normally allow siting the antenna 250 feet from the runway centerline. The antenna should be located as close to centerline as possible in order to hold to a minimum the difference between the planar and hyperbolic glide paths. Operationally it is desirable that the planar and hyperbolic glide paths be nearly coincident at the threshold. Nominal siting of the elevation antenna is illustrated in Figure 9.

When the MLS is installed on a runway which is already served by an ILS the elevation antenna *should be* sited such that the MLS approach reference datum and the ILS reference datum are coincident within a tolerance of 3 feet. This assumes that the ILS glide slope is sited such that the height of the reference datum meets the requirements of FAA Order 8260.34.

Once the minimum glide path angle and the height of the approach reference datum are established the location of the antenna may be determined in the following manner. As shown in Figure 10 the setback distance (SB) is calculated using the approach reference datum height (H), the antenna phase center height (PCH), and the tangent of the minimum glide path angle (θ). The next computation is of the hyperbolic glide path height at the threshold (HYBH). This is calculated as shown in Figure 10. The result of this calculation should then be compared with the height of the asymptote of the minimum glide path (H). This difference (HDIF) should be kept to a minumum as previously stated. If this difference exceeds 10 feet it could present an operational problem and an alternative siting should be explored.

Page 14, <u>Table 2. Definitions and Terminology.</u>

<u>MLS Approach Reference Datum</u>: Delete and substitute: "A point at a specified height located vertically above the intersection of the runway centerline and the threshold."

Add the following new items:

<u>H</u>: The height of the aymptote of the minimum glide path at the threshold.

<u>HYBH</u>: The height of the hyperbolic minimum glide path at the threshold.

<u>HDIF</u>: The difference between the heights of the hyperbolic and asymptote of the minimum glide path at the threshold.

<u>Figure 10:</u> Delete and replace with new figure.

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