ATTACHMENT C. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE STANDARDS AND RECOMMENDED PRACTICES FOR ILS, VOR, PAR, 75 MHz MARKER BEACONS (EN-ROUTE), NDB AND DME

1. Introduction

The material in this Attachment is intended for guidance and clarification purposes and is not to be considered as part of the specifications or as part of the Standards and Recommended Practices contained in Volume I.

For the clarity of understanding of the text that follows and to facilitate the ready exchange of thoughts on closely associated concepts, the following definitions are included.

Definitions relating to the Instrument Landing System (ILS)

Note.— The terms given here are in most cases capable of use either without prefix or in association with the prefixes "nominal" and "indicated". Such usages are intended to convey the following meanings:

The prefix "nominal": *the design characteristics of an element or concept.*

No prefix: *the achieved characteristics of an element or concept.*

The prefix "indicated": *the achieved characteristics of an element or concept, as indicated on a receiver (i.e. including the errors of the receiving installation).*

Localizer system	ILS glide path system

Slant course line. The line formed at the intersection of the course surface and the plane of the nominal ILS glide path.

False ILS glide path. Those loci of points in the vertical plane containing the runway centre line at which the DDM is zero, other than that locus of points forming the ILS glide path.

Displacement error. The angular or linear displacement of any point of zero DDM with respect to the nominal course line or the nominal ILS glide path respectively.

Linearity sector. A sector containing the course line or ILS glide path, within a course sector or an ILS glide path sector, respectively, in which the increment of DDM per unit of displacement remains substantially constant.

Low DDM zone. A zone outside a course sector or an ILS glide path sector in which the DDM is less than the minimum value specified for the zone.

Note.— The minimum values of DDM related to such zones are specified in Chapter 3, 3.1.3.7 and 3.1.5.6.

Plane of the nominal ILS glide path. A plane perpendicular to the vertical plane of the runway centre line extended and containing the nominal ILS glide path.

<table>
<tr><th>Localizer system</th><th>ILS glide path system</th></tr>
<tr><td>Indicated course line. The locus of points in any horizontal plane at which the receiver indicator deflection is zero.</td><td>Indicated ILS glide path. The locus of points in the vertical plane containing the runway centre line at which the receiver indicator deflection is zero.</td></tr>
<tr><td colspan="2">Indicated slant course line. The line formed at the intersection of the indicated course surface and the plane of the nominal ILS glide path.</td></tr>
<tr><td></td><td>Indicated ILS glide path angle. The angle above the horizontal plane of the indicated ILS glide path.</td></tr>
<tr><td>Indicated course sector. A sector in any horizontal plane containing the indicated course line in which the receiver indicator deflection remains within full-scale values.</td><td>Indicated ILS glide path sector. The sector containing the indicated ILS glide path in which the receiver indicator deflection remains within full-scale values.</td></tr>
<tr><td>Localizer course bend. A course bend is an aberration of the localizer course line with respect to its nominal position.</td><td>ILS glide path bend. An ILS glide path bend is an aberration of the ILS glide path with respect to its nominal position.</td></tr>
<tr><td colspan="2">Incremental sensitivity. The increment of receiver indicator current per unit change of receiver antenna displacement from the nominal course line or nominal ILS glide path.</td></tr>
<tr><td colspan="2">Flat zone. A zone within an indicated course sector or an indicated ILS glide path sector in which the slope of the sector characteristic curve is zero.</td></tr>
<tr><td colspan="2">Reversal zone. A zone within an indicated course sector or an indicated ILS glide path sector in which the slope of the sector characteristic curve is negative.</td></tr>
</table>

2. Material concerning ILS installations

2.1 Operational objectives, design and maintenance objectives, and definition of course structure for Facility Performance Categories

2.1.1 The Facility Performance Categories defined in Chapter 3, 3.1.1 have operational objectives as follows:

Category I operation: A precision instrument approach and landing with a decision height not lower than 60 m (200 ft) and with either a visibility not less than 800 m or a runway visual range not less than 550 m.

Category II operation: A precision instrument approach and landing with a decision height lower than 60 m (200 ft) but not lower than 30 m (100 ft), and a runway visual range not less than 350 m.

Category IIIA operation: A precision instrument approach and landing with:

a) a decision height lower than 30 m (100 ft), or no decision height; and

b) a runway visual range not less than 200 m.

Category IIIB operation: A precision instrument approach and landing with:

a) a decision height lower than 15 m (50 ft), or no decision height; and

b) a runway visual range less than 200 m but not less than 50 m.

Category IIIC operation: A precision instrument approach and landing with no decision height and no runway visual range limitations.

2.1.2 Relevant to these objectives will be the type of aircraft using the ILS and the capabilities of the aircraft flight guidance system(s). Modern aircraft fitted with equipment of appropriate design are assumed in these objectives. In practice, however, operational capabilities may extend beyond the specific objectives given at 2.1.1 above.

2.1.2.1 The availability of fail-passive and fail-operational flight guidance systems in conjunction with an ILS ground system which provides adequate guidance with an appropriate level of continuity of service and integrity for the particular case can permit the attainment of operational objectives which do not coincide with those described at 2.1.1 above.

2.1.2.2 For modern aircraft fitted with automatic approach and landing systems the routine use of such systems is being encouraged by aircraft operating agencies in conditions where the progress of the approach can be visually monitored by the flight crew. For example, such operations may be conducted on Facility Performance Category I — ILS where the guidance quality and coverage exceeds basic requirements given at Chapter 3, 3.1.3.4.1 and extends down to the runway.

2.1.2.3 In order to fully exploit the potential benefits of modern aircraft automatic flight control systems there is a related need for a method of describing ground based ILS more completely than can be achieved by reference solely to the Facility Performance Category. This is achieved by the ILS classification system using the three designated characters. It provides a description of those performance aspects which are required to be known from an operations viewpoint in order to decide the operational applications which a specific ILS could support.

2.1.2.4 The ILS classification scheme provides a means to make known the additional capabilities that may be available from a particular ILS ground facility, beyond those associated with the facilities defined in Chapter 3, 3.1.1. These additional capabilities can be exploited in order to permit operational use according to 2.1.2.1 and 2.1.2.2 above to be approved down to and below the values stated in the operational objectives described in 2.1 above.

2.1.2.5 An example of the classification system is presented in 2.14.3 below.

2.1.3 Guidance material relating to airborne equipment tolerances appropriate to the attainment of the objectives of ILS Operational Performance Categories I and II are given in 2.2.4 and 2.2.5 below. In the case of Category II operations utilizing appropriate ILS facilities, it may be feasible to allow operations by aircraft with low approach speeds and adequate demonstrable manoeuvrability fitted with airborne equipment having tolerances less stringent than those specified for Category II.

Note.— The following guidance material is intended to assist States when they are evaluating the acceptability of ILS localizer courses and glide paths having bends. Although, by definition, course bends and glide path bends are related to the nominal positions of the localizer course and glide path respectively, the evaluation of high frequency aberrations is based on the deviations from the mean course or path. The material in 2.1.6 and Figure C-2 regarding the evaluation of bends indicates how the bends relate to the mean position of the course and path. Aircraft recordings will normally be in this form.

2.1.4 *Course bends.* Localizer course bends should be evaluated in terms of the course structure specified in Chapter 3, 3.1.3.4. With regard to landing and rollout in Category III conditions, this course structure is based on the desire to provide adequate guidance for manual and/or automatic operations along the runway in low visibility conditions. With regard to Category I performance in the approach phase, this course structure is based on the desire to restrict aircraft deviations, due to course bends (95 per cent probability basis) at the 30 m (100 ft) height, to lateral displacement of less than 10 m (30 ft). With regard to Categories II and III performance in the approach phase, this course structure is based on the desire to restrict aircraft deviations due to course bends (95 per cent probability basis) in the region between ILS Point B and the ILS reference datum (Category II facilities) or Point D (Category III facilities), to less than 2 degrees of roll and pitch attitude and to lateral displacement of less than 5 m (15 ft).

Note 1.— Course bends are unacceptable when they preclude an aircraft under normal conditions from reaching the decision height in a stable attitude and at a position, within acceptable limits of displacement from the course line, from which a safe landing can be effected. Automatic and semi-automatic coupling is affected to a greater degree than manual coupling by the presence of bends. Excessive control activity after the aircraft has settled on an approach may preclude it from satisfactorily completing an approach or landing. Additionally, when automatic coupling is used, there may be an operational requirement to continue the approach below the decision height. Aircraft guidance can be satisfied if the specification for course structure in Chapter 3, 3.1.3.4 is met.

Note 2.— Bends or other irregularities that are not acceptable will normally be ascertained by flight tests in stable air conditions requiring precision flight check techniques.

2.1.5 *ILS glide path bends.* Bends should be evaluated in terms of the ILS glide path structure specified in Chapter 3, 3.1.5.4. With regard to Category I performance, this glide path structure is based on the desire to restrict aircraft deviations due to glide path bends (95 per cent probability basis) at the 30 m (100 ft) height, to vertical displacements of less than 3 m (10 ft). With regard to Categories II and III performance, this glide path structure is based on the desire to restrict aircraft deviations due to path bends (95 per cent probability basis) at the 15 m (50 ft) height, to less than 2 degrees of roll and pitch attitude and to vertical displacements of less than 1.2 m (4 ft).

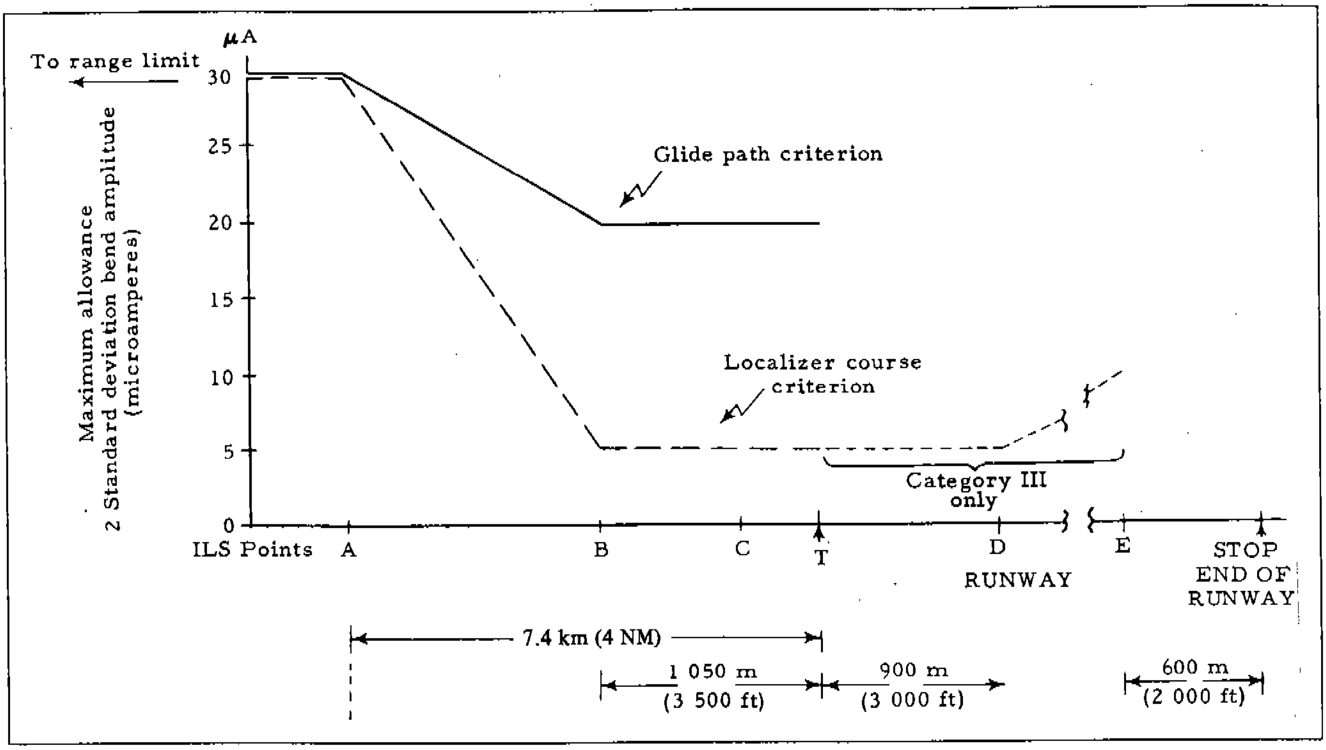
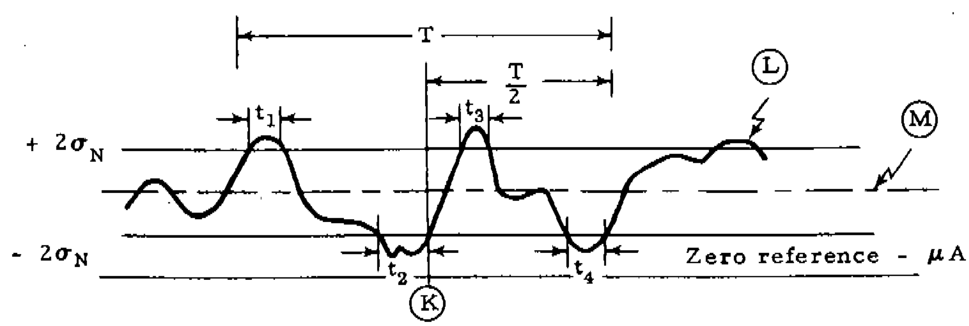


Figure C-1. Categories II and III localizer course and glide path maximum bend amplitude criteria



(L) = Theodolite corrected sample of course/path bends (microamperes)

(M) = Mean value of course/path bends (microamperes)

T = Region to be evaluated ($\pm$ 20 seconds wide)

$\pm 2\sigma_N$ = Max. bend amplitude specification at point (K) (microamperes)

t_1, t_2, t_3, ... = Time intervals that noise exceeds allowable $2\sigma_N$ value. For the facility to be acceptable in this region:

$$100\,\frac{[T - (t_1 + t_2 + t_3 \ldots)]}{T} \geq 95\%$$

Figure C-2. Evaluation of course/path bend amplitude

Note 1.— Path bends are unacceptable when they preclude an aircraft under normal conditions from reaching the decision height in a stable attitude and at a position within acceptable limits of displacement from the ILS glide path, from which a safe landing can be effected. Automatic and semi-automatic coupling is affected to a greater degree than manual coupling by the presence of bends. Additionally, when automatic coupling is used, there may be an operational requirement to continue the approach below the decision height. Aircraft guidance can be satisfied if the specification for ILS glide path structure in Chapter 3, 3.1.4.4, is met.

Note 2.— Bends or other irregularities that are not acceptable will normally be ascertained by precision flight tests, supplemented as necessary by special ground measurements.

2.1.6 *Application of localizer course/glide path bend amplitude Standard.* In applying the specification for localizer course structure (Chapter 3, 3.1.3.4) and ILS glide path structure (Chapter 3, 3.1.5.4), the following criteria should be employed:

— Figure C-1 shows the relationship between the maximum (95 per cent probability) localizer course/glide path bend amplitudes and distances from the runway threshold that have been specified for Categories II and III performance.

— If the bend amplitudes are to be evaluated in any region of the approach, the flight recordings, corrected for aircraft angular position error, should be analysed for a time interval of plus or minus 20 seconds about the midpoint of the region to be evaluated. The foregoing is based on an aircraft ground speed of 195 km/h (105 knots) plus or minus 9 km/h (5 knots).

The 95 per cent maximum amplitude specification is the allowable percentage of total time interval in which the course/path bend amplitude must be less than the amount specified in Figure C-1 for the region being evaluated. Figure C-2 presents a typical example of the method that can be employed to evaluate the course/path bend amplitude at a particular facility. If the sum of the time intervals t_1, t_2, t_3, where the given specification is exceeded, is equal to or less than 5 per cent of the total time T, the region that is being evaluated is acceptable. Therefore:

$$100 \frac{T - [(t_1 + t_2 + ...)]}{T} \geq 95\%$$

Analysis of ILS glide path bends should be made using as a datum the mean glide path and not the downward extended straight line. The extent of curvature is governed by the offset displacement of the ground equipment glide path antenna system, the distance of this antenna system from the threshold, and the relative heights of the ground along the final approach route and at the glide path site (see 2.4 below).

2.1.7 Owing to the complex frequency components present in the ILS beam bend structures, measured values of beam bends are dependent on the frequency response of the airborne receiving and recording equipment. It is intended that beam bend measurements be obtained by using a total time constant (in seconds) for the receiver DDM output circuits and associated recording equipment of $92.6/V$, where V is the velocity in km/h of the aircraft or ground vehicle as appropriate.

2.1.8 *Monitor systems.* Available evidence indicates that performance stability within the limits defined in Chapter 3, 3.1.3.6, 3.1.3.7 and 3.1.5.6, i.e. well within the monitor limit, can readily be achieved.

The choice of monitor limits is based on judgement, backed by a knowledge of the safety requirements for the category of operation. However, the specifications of such monitoring limits do not indicate the magnitude of the normal day-to-day variations in performance which result from setting-up errors and equipment drift. It is necessary to investigate and take corrective action if the day-to-day performance frequently drifts beyond the limits specified in Chapter 3, 3.1.3.6, 3.1.3.7 and 3.1.5.6. The causes of such drifts should be eliminated:

a) to reduce greatly the possibility of critical signal parameters hovering near the specified monitor limits;

b) to ensure a high continuity of ILS service.

Following are some general guidelines for the design, operation and maintenance of monitor systems to meet the requirements in Chapter 3, 3.1.3.11 and 3.1.5.7.

1) Great care should be exercised to ensure that monitor systems respond to all those variations of the ground facility which adversely affect the operation of the airborne system during ILS approach.

2) Monitor systems should not react to local conditions which do not affect the navigational information as seen by airborne systems.

3) Drifts of the monitor system equipment should not appreciably reduce or increase the monitoring limits specified.

4) Special care must be taken in the design and operation of the monitor system with the aim of ensuring that the navigational components will be removed or radiation cease in the event of a failure of the monitor system itself.

5) Some monitors rely on devices which sample the signal in the vicinity of the transmitter antenna system. Experience has shown that such monitor systems require special attention in the following aspects:

   a) where large-aperture antenna systems are used, it is often not possible to place the monitor sensors in such a position that the phase relationship observed in the far field on the course exists at the sensing point. Nevertheless, the monitor system should also detect antenna and associated feeder system changes which significantly affect the course in the far field;

   b) changes in effective ground level caused by snow, flooding, etc., may affect glide path monitor systems, and the actual course in space differently, particularly when reliance is placed on the ground plane to form the desired glide path pattern;

   c) attention should be paid to other causes which may disturb the monitor sensing of the radiated signal, such as icing, birds, etc;

   d) in a system where monitoring signals are used in a feedback loop to correct variations of the corresponding equipment, special care should be taken that extraneous influence and changes in the monitor system itself do not cause course or ILS glide path variations outside the specified limits without alarming the monitor.

6) One possible form of monitor is an integral monitor in which the contribution of each transmitting antenna element to the far-field course signal is measured at the antenna system. Experience has shown that such monitoring systems, properly designed, can give a close correlation between the monitor indication and the radiated signal in the far field. This type of monitor, in certain circumstances, overcomes the problem outlined in 5 a), b) and c) above.

It will be realized that the DDM measured at any one point in space is a function of displacement sensitivity and the position of the course line or ILS glide path. This should be taken into account in the design and operation of monitor systems.

2.1.9 *Radiation by ILS localizers not in operational use.* Severe interference with operational ILS localizer signals has been experienced in aircraft carrying out approaches to low levels at runways equipped with localizer facilities serving the reciprocal direction to the approach. Interference in aircraft overflying this localizer antenna system is caused by cross modulation due to signals radiated from the reciprocal approach localizer. Such interference, in the case of low level operations, could seriously affect approach or landing, and may prejudice safety. Chapter 3, 3.1.2.7, 3.1.2.7.1 and 3.1.2.7.2 specify the conditions under which radiation by localizers not in operational use may be permitted.

2.1.10 *ILS multipath interference due to large reflecting objects and movements on the ground*

2.1.10.1 The occurrence of interference to ILS signals is dependent on the total environment around the ILS antennas, and the antenna characteristics. Any large reflecting objects, including vehicles or fixed objects such as structures within the radiated signal coverage, will potentially cause multipath interference to the ILS course and path structure. The location and size of the reflecting fixed objects and structures in conjunction with the directional qualities of the antennas will determine the static course or path structure quality whether Category I, II or III. Movable objects can degrade this structure to the extent that it becomes unacceptable. The areas within which this degradable interference is possible need to be defined and recognized. For the purposes of developing protective zoning criteria, these areas can be divided into two types, i.e. critical areas and sensitive areas:

a) the ILS critical area is an area of defined dimensions about the localizer and glide path antennas where vehicles, including aircraft, are excluded during all ILS operations. The critical area is protected because the presence of vehicles and/or aircraft inside its boundaries will cause unacceptable disturbance to the ILS signal-in-space;

b) the ILS sensitive area is an area extending beyond the critical area where the parking and/or movement of vehicles, including aircraft, is controlled to prevent the possibility of unacceptable interference to the ILS signal during ILS operations. The sensitive area is protected against interference caused by large moving objects outside the critical area but still normally within the airfield boundary.

Note 1.— The objective of defining critical and sensitive areas is to afford adequate protection to the ILS. The manner in which the terminology is applied may vary between States. In some States, the term "critical area" is also used to describe the area that is referred to herein as the sensitive area.

Note 2. — It is expected that at sites, where ILS and MLS are to be collocated, the MLS might be located within ILS critical areas in accordance with guidance material in Attachment G, Section 4.1.

2.1.10.2 Typical examples of critical and sensitive areas that need to be protected are shown in Figures C-3A, C-3B, C-4A and C-4B. To protect the critical area, it is necessary to normally prohibit all entry of vehicles and the taxiing or parking of aircraft within this area during *all* ILS operations. The critical area determined for each localizer and glide path should be clearly designated. Suitable signal devices may need to be provided at taxiways and roadways which penetrate the critical area to restrict the entry of vehicles and aircraft. With respect to sensitive areas, it may be necessary to exclude some or all moving traffic depending on interference potential and category of operation. It would be advisable to have the aerodrome boundaries include all the sensitive areas so that adequate control can be exercised over all moving traffic to prevent unacceptable interference to the ILS signals. If these areas fall outside the aerodrome boundaries, it is essential that the co-operation of appropriate authorities be obtained to ensure adequate control. Operational procedures need to be developed for the protection of sensitive areas.

2.1.10.3 The size of the sensitive area depends on a number of factors including the type of ILS antenna, the topography, and the size and orientation of man-made objects, including large aircraft and vehicles. Modern designs of localizer and glide path antennas can be very effective in reducing the disturbance possibilities and hence the extent of the sensitive areas. Because of the greater potential of the larger types of aircraft for disturbing ILS signals, the sensitive areas for these aircraft extend a considerable distance beyond the critical areas. The problem is aggravated by increased traffic density on the ground.

2.1.10.3.1 In the case of the localizer, any large objects illuminated by the main directional radiation of the antenna must be considered as possible sources of unacceptable signal interference. This will include aircraft on the runway and on some taxiways. The dimensions of the sensitive areas required to protect Category I, II and III operations will vary, the largest being required for Category III. Only the least disturbance can be tolerated for Category III, but an out-of-tolerance course along the runway surface would have no effect on Category I or II operations. If the course structure is already marginal due to static multipath effects, less additional interference will cause an unacceptable signal. In such cases a larger-size sensitive area may have to be recognized.

2.1.10.3.2 In the case of the glide path, experience has shown that any object penetrating a surface above the reflection plane of the glide path antenna and within azimuth coverage of the antenna must be considered as a source of signal interference. The angle of the surface above the horizontal plane of the antenna is dependent on the type of glide path antenna array in use at the time. Very large aircraft, when parked or taxiing within several thousand feet of the glide path antenna and directly between it and the approach path, will usually cause serious disturbance to the glide path signal. On the other hand, the effect of small aircraft beyond a few hundred feet of the glide path antenna has been shown to be negligible.

2.1.10.3.3 Experience has shown that the major features affecting the reflection and diffraction of the ILS signal to produce multipath interference are the height and orientation of the vertical surfaces of aircraft and vehicles. The maximum height of vertical surface likely to be encountered must be established, together with the "worst case" orientation. This is because certain orientations can cause out-of-tolerance localizer or glide path deviations at greater distances than parallel or perpendicular orientations.

2.1.10.4 Computer or model techniques can be employed to calculate the probable location, magnitude and duration of ILS disturbances caused by objects, whether by structures or by aircraft of various sizes and orientation at different locations. Issues involved with these techniques include the following:

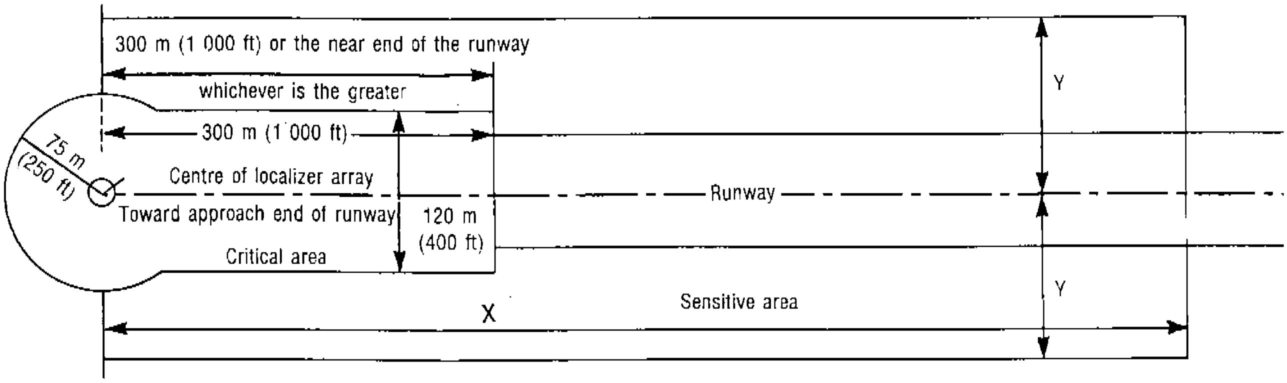
a) computerized mathematical models are in general use and are applied by personnel with a wide variety of experience levels. However, engineering knowledge of and judgement about the appropriate assumptions and limitations are required when applying such models to specific multipath environments. ILS performance information relative to this subject should normally be made available by the ILS equipment manufacturer;

b) 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; and

c) taking into account the maximum allowable multipath degradation of the signal due to aircraft on the ground, the corresponding minimum sensitive area limits can be determined. Models have been used to determine the critical and sensitive areas in Figures C-3A, C-3B, C-4A and C-4B, by taking into account the maximum allowable multipath degradation of ILS signals due to aircraft on the ground. The factors that affect the size and shape of the critical and sensitive areas include: aircraft types likely to cause interference, antenna aperture and type (log periodic dipole/dipole, etc.), type of clearance signals (single/dual frequency), category of operations proposed, runway length, and static bends caused by existing structures. Such use of models should involve their validation, which includes spot check comparison of computed results with actual field demonstration data on parked aircraft interference to the ILS signal.

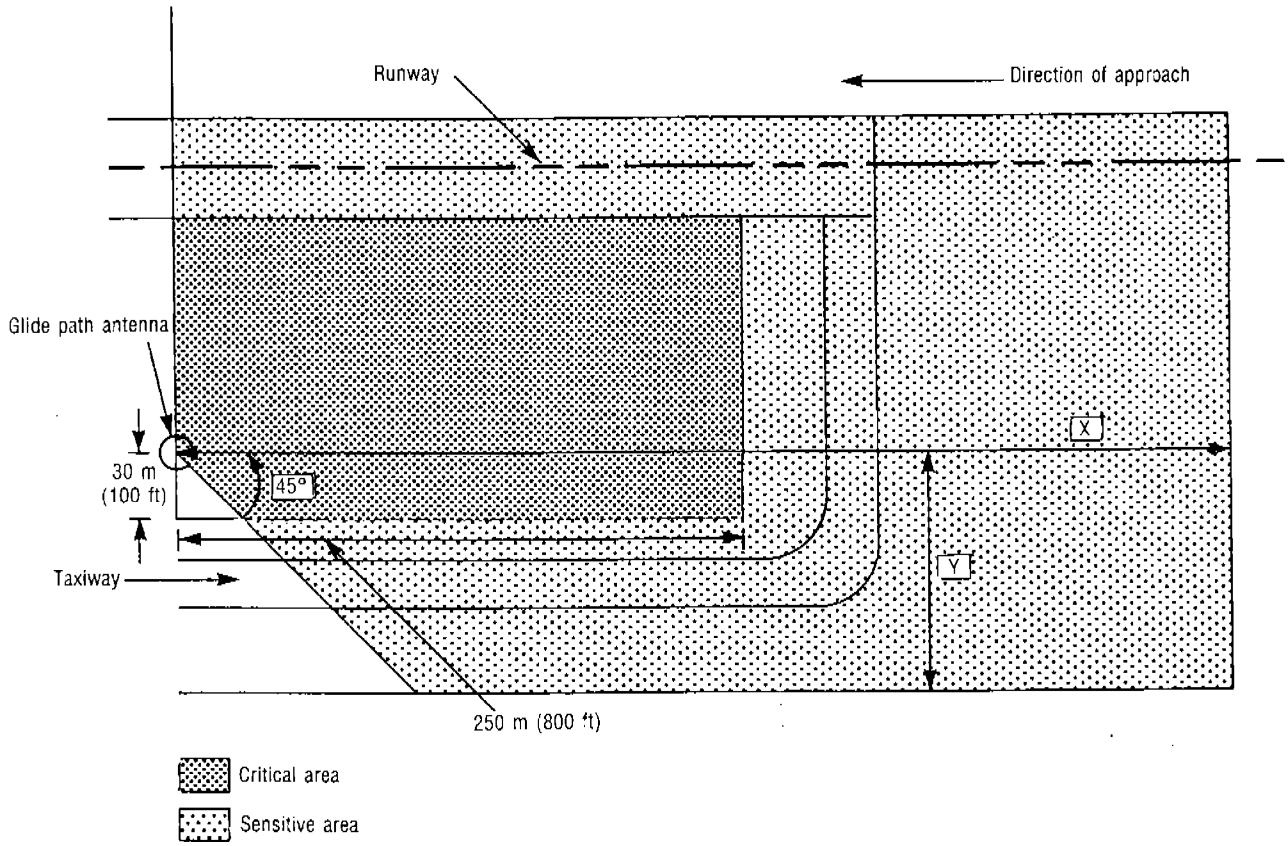
2.1.10.5 Control of critical areas and the designation of sensitive areas on the airport proper may still not be sufficient to protect an ILS from multipath effects caused by large, fixed ground structures. This is particularly significant when considering the size of new buildings being erected for larger new aircraft and other purposes. Structures outside the boundaries of the airport may also cause difficulty to the ILS course quality, even though they meet restrictions with regard to obstruction heights.

2.1.10.5.1 Should the environment of an airport in terms of large fixed objects such as tall buildings cause the structure



		Example 1	*Example 2*	*Example 3*
Aircraft type		B-747	B-747	B-727
Localizer antenna aperture		Typically 27 m (90 ft) (Directional dual freq., 14 elements)	Typically 16 m (50 ft) (Semidirectional, 8 elements)	Typically 16 m (50 ft) (Semidirectional, 8 elements)
Sensitive area (X, Y)				
Category I	X	600 m (2 000 ft)	600 m (2 000 ft)	300 m (1 000 ft)
	Y	60 m (200 ft)	110 m (350 ft)	60 m (200 ft)
Category II	X	1 220 m (4 000 ft)	2 750 m (9 000 ft)	300 m (1 000 ft)
	Y	90 m (300 ft)	210 m (700 ft)	60 m (200 ft)
Category III	X	2 750 m (9 000 ft)	2 750 m (9 000 ft)	300 m (1 000 ft)
	Y	90 m (300 ft)	210 m (700 ft)	60 m (200 ft)

Figure C-3A. Typical localizer critical and sensitive areas dimension variations for a 3 000 m (10 000 ft) runway



		Example 1	*Example 2*	*Example 3*
Aircraft type		B-747	B-727	small & medium*
Category I	X	915 m (3 000 ft)	730 m (2 400 ft)	250 m (800 ft)
	Y	60 m (200 ft)	30 m (100 ft)	30 m (100 ft)
Category II/III	X	975 m (3 200 ft)	825 m (2 700 ft)	250 m (800 ft)
	Y	90 m (300 ft)	60 m (200 ft)	30 m (100 ft)

* Small and medium aircraft here are considered as those having both a length less than 18 m (60 ft) and a height less than 6 m (20 ft).

Note.— In some cases the sensitive areas may be extended beyond the opposite side of the runway.

Figure C-3B. Typical glide path critical and sensitive areas dimension variations

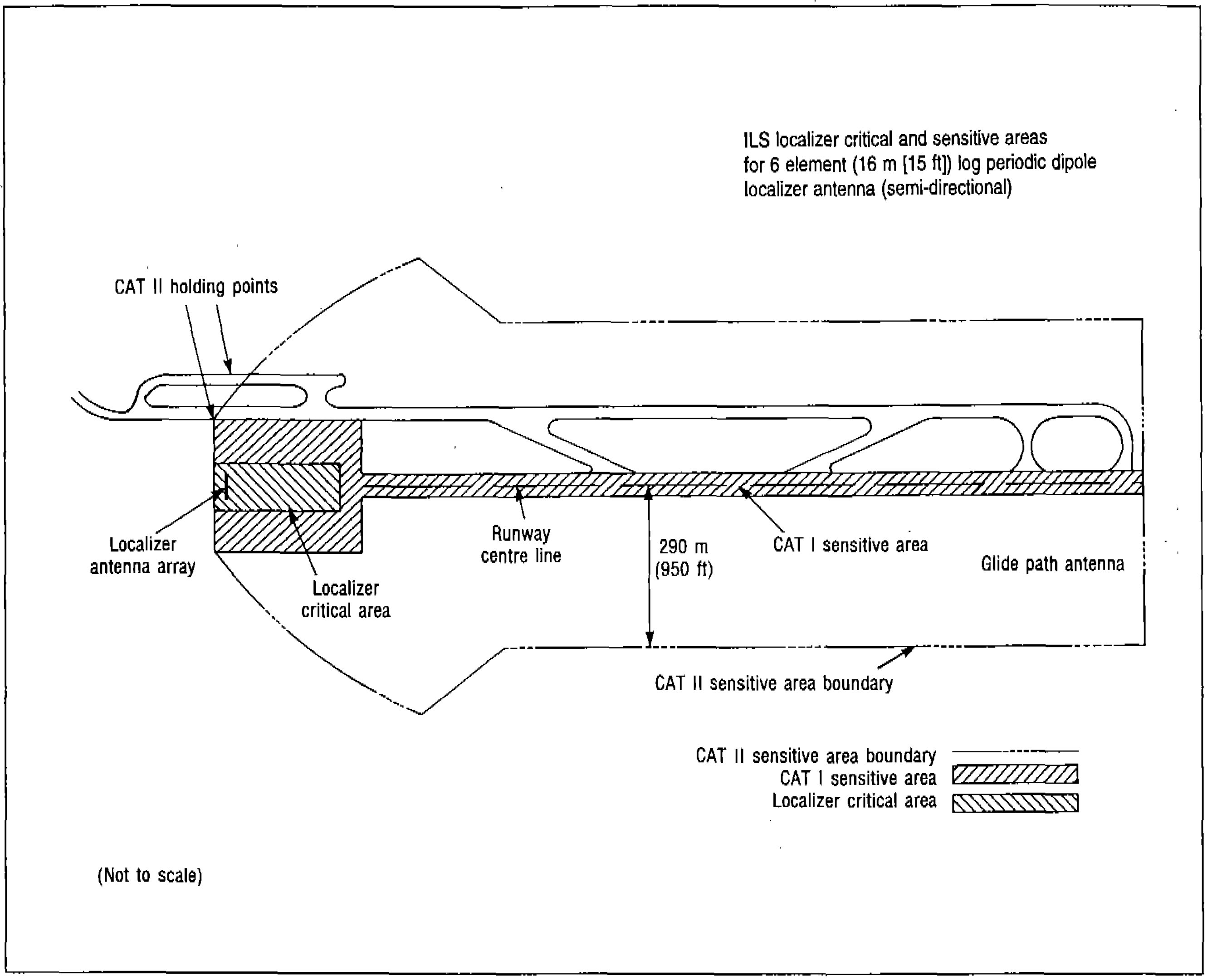


Figure C-4A. Example of critical and sensitive area application at specific sites with B-747 aircraft interference

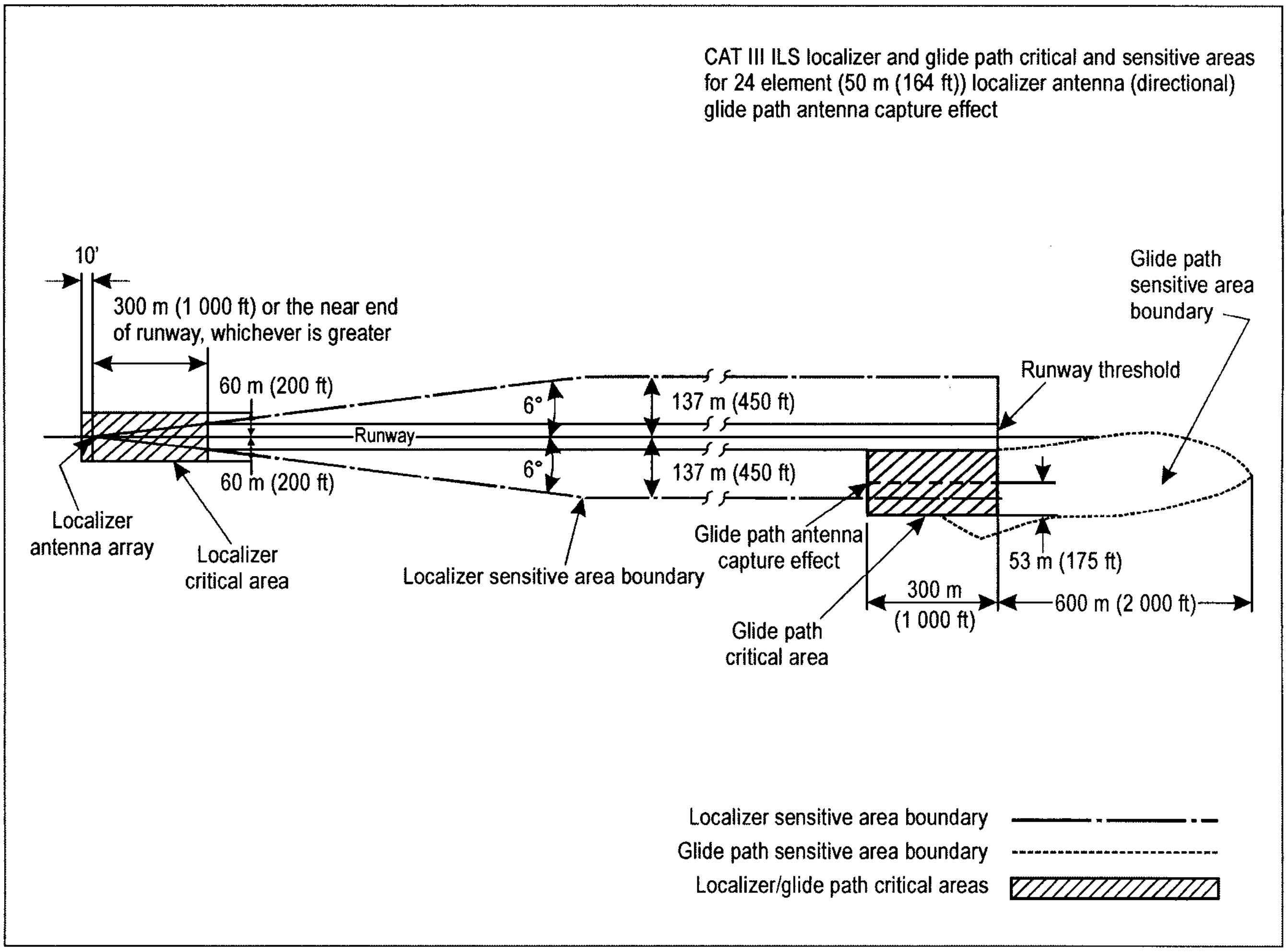


Figure C-4B. Example of critical and sensitive area application at specific sites with B-747 aircraft interference

of the localizer and/or glide path to be near the tolerance limits for the category of operation, much larger sensitive areas may need to be established. This is because the effect of moving objects, which the sensitive areas are designed to protect the ILS against, has to be added to the static beam bends caused by fixed objects. However, direct addition of the maximum bend amplitudes is not considered appropriate and a root sum square combination is felt to be more realistic. Examples are as follows:

a) localizer course bends due to static objects equals plus or minus 1½μA. Limit plus or minus 5μA. Therefore allowance for moving objects to define localizer sensitive area is

$$\sqrt{5^2 - 1.5^2} = 4.77\mu A$$

b) localizer course bends due to static objects equals plus or minus 4μA. Limit plus or minus 5μA. Therefore allowance for moving objects to define localizer sensitive area is

$$\sqrt{5^2 - 4^2} = 3\mu A$$

In case b) the sensitive area would be larger, thus keeping interfering objects further away from the runway so that they produce 3μA or less distortion of the localizer beam. The same principle is applied to the glide path sensitive area.

2.1.11 *Guidance on operational aspects of improving the performance of the ILS localizer in respect to bends*

2.1.11.1 *Introduction.* Owing to site effects at certain locations, it is not always possible to produce with simple standard ILS installations localizer courses that are sufficiently free from troublesome bends or irregularities. At such installations, it will often be possible to reduce bends and irregularities in the localizer course to a satisfactory extent by various methods, most of which require acceptance of some deviation from the specification for ILS set forth in this Annex, together with possible penalties from an operational aspect.

2.1.11.2 *Methods of effecting improvement.* In general, improvements in localizer courses from the aspect of bends or irregularities may be effected by restriction of radiation in particular directions so as to avoid or minimize reflection from objects that give rise to the bends. In the majority of instances where special treatment is required, this may be achieved by screens placed and designed to reduce the radiation in the direction of the object. Where reflecting objects are numerous or of large dimensions, however, it may be necessary to restrict almost all the radiation from the localizer to a narrow sector centred on the course line. Each method introduces certain disadvantages which should be weighed for the individual installation in the light of the specific operational application to be made of the installation and the following considerations.

2.1.11.3 *Disadvantages of methods of effecting improvements mentioned above*

2.1.11.3.1 The use of screens limiting radiation in selected directions will, in general, give rise to a reduction of the clearance between the two modulation signals of the ILS in some other direction, with the consequence that the ILS indicator needle may move towards the centre when the aircraft is passing through areas in that direction. It is considered however that, in general, such deviations are not operationally significant or may be overcome by suitable procedures. In certain applications including the use of screens or reflectors to reinforce signals in the course sector, the use of screens or reflectors will modify the range and characteristics of the back course of the localizer. Here again, it is considered that the effects are unlikely to be operationally significant unless operational use is being made of the back course. In this latter case, it may be necessary to provide an additional facility to supplement or replace the back course.

2.1.11.3.2 Where it is necessary to limit radiation from the localizer over a wide sector and confine most of it to a sector centred on the front course of the localizer in order to reduce bends sufficiently, the disadvantages will, in general, be as follows:

1) Orientation information from the localizer in the sector in which radiation is limited will no longer be available or will be unreliable.

2) It will not be practicable to carry out a preliminary check of the performance of the aircraft receiver through the flag system until the aircraft is within the sector centred on the course line.

3) In the area outside the sector centred on the course line, sufficient radiation may occur in particular directions to operate the ILS indicator in the aircraft in an erratic manner, giving rise to false indications.

4) The loss of the back course.

2.1.11.3.3 In respect to 1), it is considered that orientation information is necessary but that practice has shown that such information is preferably obtained in any event from an auxiliary aid such as a locator. Such an auxiliary aid would be necessary if radiation from the localizer is confined to a narrow sector centred on the course line. In respect to 2), it is considered that the loss of a receiver check prior to entry into the sector centred on the course line could be operationally accepted.

2.1.11.3.4 The disadvantage indicated in 3) may, in some instances, be a serious drawback. In general, it is considered that acceptance of this disadvantage will depend on the extent to which false indications will occur at a particular site and on the procedures established or specified for the use of the ILS installation. In practice, it is possible to establish procedures so that no use is made of the localizer signals until the aircraft is able to check that it is in the usable sector. Experience has shown at one installation in operational use that, procedurally, no difficulty has arisen through the existence of erratic indications in the off-course sector. It is considered that the question of whether or not the off-course signal characteristics due to reduction of radiation in a narrow sector may be accepted operationally is a matter for individual assessment at each location concerned.

2.1.11.3.5 The loss of the back course indicated in 4) may have several disadvantages. At some locations, the back course serves a useful function through intersection with other aids for facilitating procedures in the area concerned. Also, the back course often provides a useful aid in missed approach procedures and can often be used to simplify approach for landing when conditions require that the landing direction be opposite to the direction for which the ILS is primarily installed. Loss of the back course will, in general, require the provision of a substitute aid or aids, and the principal disadvantage in suppressing the back course may be considered in terms of the additional expense of a substitute aid or aids.

2.1.11.4 *Extent to which sector centred on course line may be narrowed.* It is considered that a radiation sector 10 degrees each side of the localizer course line would be the minimum sector that could be accepted operationally. It is desirable that the characteristics of the signal from the localizer be identical with those specified in Chapter 3 within the region in the immediate vicinity (region from DDMs 0.155 to zero) of the course line and approximate closely to them out to 10 degrees, so that the indications of the ILS indicator and the signals fed to a coupling device, if used, will correspond to the standard ILS throughout any manoeuvres necessary in the transition from the approach to the localizer to establishment on course line.

It should be realized, however, that for an increased runway length, the localizer course sector wherein proportional guidance is provided will be narrower as a result of adjusting the localizer to the sensitivity specified in Chapter 3, 3.1.3.7.1. Although a proportional guidance signal is provided on each side of the course line up to a level of 0.180 DDM, the level above 0.150 DDM may not be usable by the automatic airborne system during the intercept manoeuvre unless that system is armed within the sector in which a minimum of 0.180 DDM is provided (e.g. plus or minus 10 degrees). It is advantageous to permit the localizer capture mode of the automatic airborne system to be armed at off-course angles greater than 10 degrees; consequently it is desirable to maintain a minimum DDM of 0.180 through a wider sector than plus or minus 10 degrees wherever practical.

2.1.11.5 *Further possibilities.* If the disadvantages arising from the use of the restricted coverage and modified signal characteristics discussed in 2.1.11.3 above are unacceptable, possibilities exist through the use of two radio frequency carriers to provide the coverage and signal characteristics that would maintain the essential information provided by a standard ILS in the suppressed sector while, at the same time, maintaining in the regions about the course sector the objective of the restricted coverage system. It may be necessary to employ this more elaborate system at aerodromes with high multipath environments. Additional guidance on two radio frequency carrier coverage is provided in 2.7 below.

2.2 ILS airborne receiving equipment

Note.— The specified tolerances are those considered necessary to achieve the operational objective and include allowances, where appropriate, for:

a) variation of relevant ground system parameters within the limits defined in Chapter 3, 3.1;

b) variation of aircraft environment;

c) measurement error; and

d) deterioration in service between maintenance periods.

The words "receiving equipment", as used in this section, include the receiver itself, the antenna(s) and the necessary interconnections in the aircraft.

2.2.1 *General*

2.2.1.1 In order to ensure consistent and reliable operation, the output characteristics of the receiver in respect of course line (centring) and course width (deflection) should be maintained to a degree of accuracy appropriate to the operational objective. Attention is directed towards the need to take into account the variable conditions that may affect such accuracy.

2.2.1.2 Furthermore, in order to ensure that a constant course width is realized by all users of the ILS system, it is necessary to standardize the over-all gain of the localizer receiver. Similar considerations apply in the case of the glide path receiver.

2.2.2 *Localizer receiver audio gain adjustment*

2.2.2.1 The audio gain of the receiver should be such that, with a radio frequency input of 1 000 microvolts modulated 20 per cent by a 90 Hz tone and 20 per cent by a 150 Hz tone, a zero indication is achieved and that, upon a simultaneous increase in one component of 4.65 per cent (i.e. to 24.65 per cent) and a decrease in the other component of 4.65 per cent (i.e. to 15.35 per cent), there is a proportional deflection of 3/5 of the full course width indication but not less than 9.5 mm along its scale. This gain adjustment is to be made with the normal power supply voltage encountered under airborne operating conditions.

2.2.3 *Localizer receiving equipment centring tolerance*

2.2.3.1 To obtain the operational objectives associated with ILS Performance Categories I, II and III and to assure the safe operation of aircraft within the obstacle clearance surfaces, the centring error of the receiving equipment, operating within all the likely aircraft environmental conditions and receiving a zero signal (DDM) within the limits of the ground equipment radio frequency modulation characteristics and identification tolerances, as specified in Chapter 3, 3.1.3 and with an RF field strength of 90 microvolts per metre (minus 107 dBW/m^2), should not exceed the following limits with a 68 per cent probability:

Category I: 4.66 per cent of the full course width indication (0.0072 DDM)

Category II: 2.33 per cent of the full course width indication (0.0036 DDM)

Category III: 1.66 per cent of the full course width indication (0.00258 DDM)

Note.— These requirements are also to be met at larger field strengths up to the maximum field strength likely to be encountered in operational service.

2.2.4 *Localizer course displacement sensitivity (deflection) tolerance*

2.2.4.1 When the receiver audio gain has been adjusted in accordance with 2.2.2 above, and with an increase in one modulation tone of the audio frequency input signal of 4.65 per cent with respect to the nominal value (i.e. 24.65 per cent) and a simultaneous decrease of the other component by 4.65 per cent with respect to the nominal value (i.e. 15.35 per cent), the indicated deflection signal should not vary more than plus or minus 0.019 DDM from the nominal value at a signal strength of 90 microvolts per metre (minus 107 dBW/m^2) up to the maximum field strength likely to be encountered in operational service.

Note.— See 2.2.5 below in respect to signal levels.

2.2.5 *Localizer receiving system minimum signal level sensitivity*

2.2.5.1 The sensitivity of the localizer receiving equipment should be such that in a high percentage of cases, the receiver indicates a usable signal and a substantially steady indication in the presence of the minimum field strength specified in Chapter 3, 3.1.3.3.2 (40 microvolts per metre or minus 114 dBW/m^2).

Note 1.— The maximum signal level likely to be encountered under 2.2.3 and 2.2.4 above is 500 microvolts. Signal levels on the order of 5 000 microvolts may be encountered in the near vicinity of the transmitter (e.g. when flying over the localizer during a missed approach, or when the localizer is used for rollout or take-off guidance).

Note 2.— The two levels of sensitivity addressed in 2.2.4 and 2.2.5 above ensure:

a) a high quality output such as is necessary for approach purposes; and

b) an output of lesser quality adequate for operational usage of the facility in other parts of the coverage volume.

Note 3.— The proper operation of the localizer receiving system in the presence of the specified minimum field strength is to occur independently of the orientation of the aircraft longitudinal axis in the horizontal plane when the aircraft is exposed to roll angles of 20 degrees and pitch angles of 10 degrees.

2.2.6 *Localizer course displacement linearity*

2.2.6.1 The receiver output course displacement signal should be a substantially linear function of the DDM of the receiver input signal. For any input over the range of plus or minus 0.155 DDM, and for any RF signal level likely to be encountered in operational service, the displacement sensitivity should not depart from the nominal DDM/deflection ratio defined in 2.2.2 above by more than plus or minus 20 per cent. Also for an input signal of plus or minus 0.165 DDM or greater, the output must be greater than full course displacement.

Note.— See 2.2.5 above in respect to signal levels.

2.2.7 *Localizer receiver bandwidth*

2.2.7.1 The receiver bandwidth should be such as to provide for the reception of channels having the characteristics defined in Chapter 3, 3.1.3.2.1 after taking suitable account of appropriate receiver tolerances.

2.2.8 *Localizer receiver susceptibility to VOR and localizer signals*

2.2.8.1 The receiver design should provide correct operation in the following environment:

a) the desired signal exceeds an undesired co-channel by 20 dB or more;

b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 34 dB. (During bench testing of the receiver, in this first adjacent channel case, the undesired signal is varied over the frequency range of the combined ground station (plus or minus 9 kHz) and receiver frequency tolerance);

c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;

d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

Note 1.— It is recognized that not all receivers currently meet requirement b); however, all future equipments are designed to meet this requirement.

Note 2.— In some States, a smaller ground station tolerance is used.

2.2.9 *Immunity performance of ILS localizer receiving systems to interference from VHF FM broadcast signals*

2.2.9.1 With reference to Note 2 of 3.1.4.2, Chapter 3, the immunity performance defined there must be measured against an agreed measure of degradation of the receiving system's normal performance, and in the presence of, and under standard conditions for the input wanted signal. This is necessary to ensure that the testing of receiving equipment on the bench can be performed to a repeatable set of conditions and results and to facilitate their subsequent approval. Tests have shown that FM interference signals may affect both course guidance and flag current, and their effects vary depending on the DDM of the wanted signal which is applied. Additional information can be found in ITU Recommendation ITU-R IS.1140, *Test procedures for measuring receiver characteristics used for determining compatibility between the sound-broadcasting service in the band of about 87-108 MHz and the aeronautical services in the band 108-118 MHz*.

2.2.9.2 Commonly agreed methodology and formulae should be used to assess potential incompatibilities to receivers meeting the general interference immunity criteria specified in Chapter 3, 3.1.4. The formulae provide clarification of immunity interference performance of spurious emission (type A1) interference, out-of-band channel (type A2) interference, two-signal and three-signal third order (type B1) interference, and overload/desensitization (type B2) interference. Additional information can be found in ITU Recommendation ITU-R IS.1009-1, *Compatibility between the sound-broadcasting service in the band of about 87-108 MHz and the aeronautical services in the band 108-137 MHz*.

2.2.9.3 The frequency planning criteria given in Recommendation ITU-R IS.1009-1 does not take account of the potential for two-signal and three-signal fifth order (type B1) intermodulation products. Measurements have determined that fifth order intermodulation products created in receiver by FM stations might degrade the performance of ILS receivers conforming to specifications in Chapter 3, 3.1.4. Fifth order intermodulation products can occur without a third order intermodulation product occurring on the same ILS frequency. In the planning of frequencies, and in the assessment of protection from FM broadcast interference, consideration needs to be given to two-signal and three-signal fifth order intermodulation products generated within ILS receivers by FM broadcast stations.

2.2.10 *Glide path receiver audio gain adjustment*

2.2.10.1 The audio gain of the receiver should be such that, with a radio frequency input of 600 microvolts modulated 40 per cent by a 90 Hz tone and 40 per cent by a 150 Hz tone, a zero indication is achieved and that, upon a simultaneous increase in one component of 5.25 per cent (i.e. to 45.25 per cent) and a decrease in the other component of 5.25 per cent (i.e. to 34.75 per cent), there is a proportional deflection of 3/5 of full course width indication but not less than 9.5 mm along its scale. This gain adjustment is to be made with the normal power supply voltage encountered under airborne operational conditions.

2.2.11 *Glide path receiving equipment centring tolerance*

2.2.11.1 To obtain the operational objectives associated with ILS Performance Categories I, II and III and to ensure the safe operation of aircraft within the obstacle clearance surfaces, the centring error of the receiving equipment, operating within all likely aircraft environmental conditions and receiving a zero signal (DDM) within the limits of the ground equipment radio frequency, and modulation characteristics tolerances as specified in Chapter 3, 3.1.5, and with an RF field strength of 400 microvolts per metre (minus 95 dBW/m^2), should not exceed the following limits with a 68 per cent probability:

Category I: 5.33 per cent of the full course width indication (0.0093 DDM)

Category II: 3.33 per cent of the full course width indication (0.0058 DDM)

Category III: 3.33 per cent of the full course width indication (0.0058 DDM)

Note.— These operational requirements are also to be met at larger field strengths up to the maximum field strength likely to be encountered in operational services.

2.2.12 *Glide path course displacement sensitivity (deflection) tolerance*

2.2.12.1 When the receiver audio gain has been adjusted in accordance with 2.2.9 above and with an increase in one modulation tone of the radio frequency input signal of 5.25 per cent (i.e. to 45.25 per cent) and a simultaneous decrease of the other component of 5.25 per cent (i.e. to 34.75 per cent), the displacement signal should not vary more than plus or minus 0.016 DDM from the nominal value at a signal strength of 400 microvolts per metre (minus 95 dBW/m^2) up to the maximum field strength likely to be encountered in operational service.

Note.— See 2.2.13 below in respect to signal levels.

2.2.13 *Glide path receiving system minimum signal level sensitivity*

2.2.13.1 The sensitivity of the glide path receiving system should be such that in a high percentage of cases, the receiver should indicate a usable signal and a substantially steady indication in the presence of the minimum field strength specified in Chapter 3, 3.1.5.3.2 (400 microvolts per metre or minus 95 dBW/m^2).

Note 1.— The maximum level of signal likely to be encountered under 2.2.11 and 2.2.12 above is 2 500 microvolts. This signal level occurs when the aircraft is at the runway threshold.

Note 2.— The two levels of sensitivity addressed in 2.2.12 and 2.2.13 ensure:

a) a high quality output such as is necessary for approach purposes; and

b) an output of lesser quality adequate for operational usage of the facility in other parts of the coverage volume.

Note 3.— The proper operation of the glide path receiving system in the presence of the specified minimum field strength should occur also if the aircraft longitudinal axis is varied plus or minus 10 degrees in the horizontal plane together with 20 degrees roll about the localizer course line and also plus or minus 10 degrees pitch in the vertical plane about the horizontal plane.

2.2.14 *Glide path displacement linearity*

2.2.14.1 The receiver output glide path displacement signal should be a substantially linear function of the DDM of the receiver input signal. For any input over the range plus or minus 0.175 DDM, and for any RF signal strength likely to be encountered in operational service, the displacement sensitivity should not depart from the nominal DDM/deflection ratio defined in 2.2.10 above by more than plus or minus 20 per cent. For an input signal of 0.185 DDM or greater, the output must be greater than full course displacement.

Note.— See 2.2.13 above with respect to signal levels.

2.2.15 *Glide path receiver bandwidth*

2.2.15.1 The receiver bandwidth should be such as to provide for the reception of channels having the characteristics defined in Chapter 3, 3.1.5.2.1 after taking suitable account of appropriate receiver tolerances.

2.2.16 *Glide path receiver susceptibility to glide path signal*

2.2.16.1 The receiver design should provide correct operation in the following environment:

a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired glide path signal, 150 kHz removed from the desired signal, exceeds the desired signal by up to 20 dB. (During bench testing of the receiver, in this first adjacent channel case, the undesired signal is varied over the frequency range of the combined ground station (plus or minus 17 kHz) and receiver frequency tolerance);

c) an undesired glide path signal, 300 kHz or further removed from the desired signal, exceeds the desired signal by up to 40 dB.

Note 1.— It is recognized that not all receivers currently meet requirement b); however, all future equipments are designed to meet this requirement.

Note 2.— In some States, a smaller ground station tolerance is used.

2.2.17 *Localizer and glide path receiver effect from vertical polarization*

2.2.17.1 Over the localizer and glide path frequency bands, respectively, the reception of vertically polarized signals from the forward direction with respect to the localizer and glide path antenna should be at least 10 dB below the reception of horizontally polarized signals from the same direction.

2.2.18 *Localizer and glide path receiver spurious response*

2.2.18.1 The response (indicator deflection) of the localizer receiver to a 150 Hz 30 per cent modulated RF signal at 110 MHz should be greater than the response to a similarly modulated but 60 dB greater amplitude RF signal varied over 90 kHz to 107.8 MHz and 112.2 MHz to 1 500 MHz. The response of the glide path receiver to a 150 Hz 30 per cent modulated RF signal at 332.0 MHz should be greater than the response to a similarly modulated but 60 dB greater amplitude RF signal varied over 90 kHz to 329.0 MHz and 335.3 MHz to 1 500 MHz.

2.3 Malfunctioning alarm in ILS airborne equipment

2.3.1 Ideally, a receiver alarm system such as a visual mechanical flag should warn a pilot of any unacceptable malfunctioning conditions which might arise within either the ground or airborne equipments. The extent to which such an ideal may be satisfied is specified below.

2.3.2 The alarm system is actuated by the sum of two modulation depths and, therefore, the removal of the ILS course modulation components from the radiated carrier should result in the actuation of the alarm.

2.3.3 The alarm system should indicate to the pilot and to any other airborne system which may be utilizing the localizer and glide path data, the existence of any of the following conditions:

a) the absence of any RF signal as well as the absence of simultaneous 90 Hz and 150 Hz modulation;

b) the percentage modulation of either the 90 Hz or 150 Hz signal reduction to zero with the other maintained at its normal 20 per cent and 40 per cent modulation respectively for the localizer and glide path;

Note.— It is expected that the localizer alarm occur when either the 90 Hz or 150 Hz modulation is reduced to 10 per cent with the other maintained at its normal 20 per cent. It is expected that the glide path alarm occur when either the 90 Hz or 150 Hz modulation is reduced to 20 per cent with the other maintained at its normal 40 per cent.

c) the receiver off-course indication 50 per cent or less of that specified when setting the receiver audio gain adjustment (see 2.2.2 and 2.2.10 above).

2.3.3.1 The alarm indication should be easily discernible and visible under all normal flight deck conditions. If a flag is used, it should be as large as practicable commensurate with the display.

2.4 Guidance for the siting, elevation, adjustment and coverage of glide path equipment

2.4.1 The ILS reference datum and the ILS glide path angle setting are the primary factors influencing the longitudinal location of the ILS glide path equipment with respect to the threshold.

2.4.2 The lateral placement of the glide path antenna system with respect to the runway centre line is normally not less than 120 m (400 ft). In deciding the lateral placement of the glide path antenna, account should be taken of the appropriate provisions of Annex 14 with regard to obstacle clearance surfaces and objects on strips for runways.

2.4.3 In selecting the ILS glide path antenna location and glide path angle, the aim should be to place the ILS reference datum as close as possible to the appropriate nominal value. The actual selection of the ILS glide path antenna location and glide path angle are governed by a number of factors, including:

a) acceptable rates of descent and/or approach speeds for the type of operations envisaged at the particular aerodrome;

b) the position of obstacles in the final approach area, the aerodrome sector and the missed approach area, and the resulting obstacle clearance limits;

c) technical siting problems.

2.4.4 The selection of the antenna location and the angle, and the resulting ILS reference datum height, will also be affected by:

a) the runway length available;

b) the operating limits envisaged.

Where the application of the foregoing criteria permits, the preferred angle of the ILS glide path would be 3 degrees.

2.4.5 An ILS reference datum and glide path should then be selected, having regard to the foregoing criteria, and the ability of the site to provide the clearance required by the *Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS, Doc 8168) should be determined by calculation and confirmed, where possible, by flight test.

2.4.6 Where the selected ILS reference datum, the ILS glide path angle and the other relevant equipment characteristics do not provide the required clearances, the following alternative course of action should be investigated:

1) removal of the offending obstacle;

2) selection of an alternative height for the ILS reference datum, taking into account the criteria indicated in 2.4.3 and 2.4.5 above;

3) selection of an alternative acceptable ILS glide path angle;

4) variation of the obstacle clearance limit to cater for the offending obstacle.

2.4.7 To enable more effective use of land adjacent to Category III — ILS glide path sites and to reduce siting requirements and sensitive areas at these sites, it is desirable that the signals forming the horizontal radiation pattern from the Category III — ILS glide path antenna system be reduced to as low a value as practicable outside the azimuth coverage limits specified in Chapter 3, 3.1.5.3. Another acceptable method is to rotate in azimuth the glide path antennas away from multipath sources thus reducing the amount of radiated signals at specific angles while still maintaining the azimuth coverage limits.

2.4.8 ILS glide path curvature. In many cases the ILS glide path is formed as a conic surface originating at the glide path aerial system. Owing to the lateral placement of the origin of this conic surface from the runway centre line, the locus of the glide path in the vertical plane along the runway centre line is a hyperbola. Curvature of the glide path occurs in the threshold region and progressively increases until touchdown.

2.4.9 Relationship between siting of glide path antenna and glide path threshold crossing height. The longitudinal position of the glide path antenna should be selected so as to meet the recommendation made in Chapter 3, 3.1.5.1.4, in respect to the height of the ILS reference datum above the runway threshold. The height of the ILS reference datum above the runway threshold is then a function of the longitudinal position of the glide path antenna, of the longitudinal slope of the glide path reflection plane and of the position of the runway threshold in respect to the glide path reflection plane. This situation is described pictorially in Figure C-5. The longitudinal position of the glide path antenna is then calculated as follows:

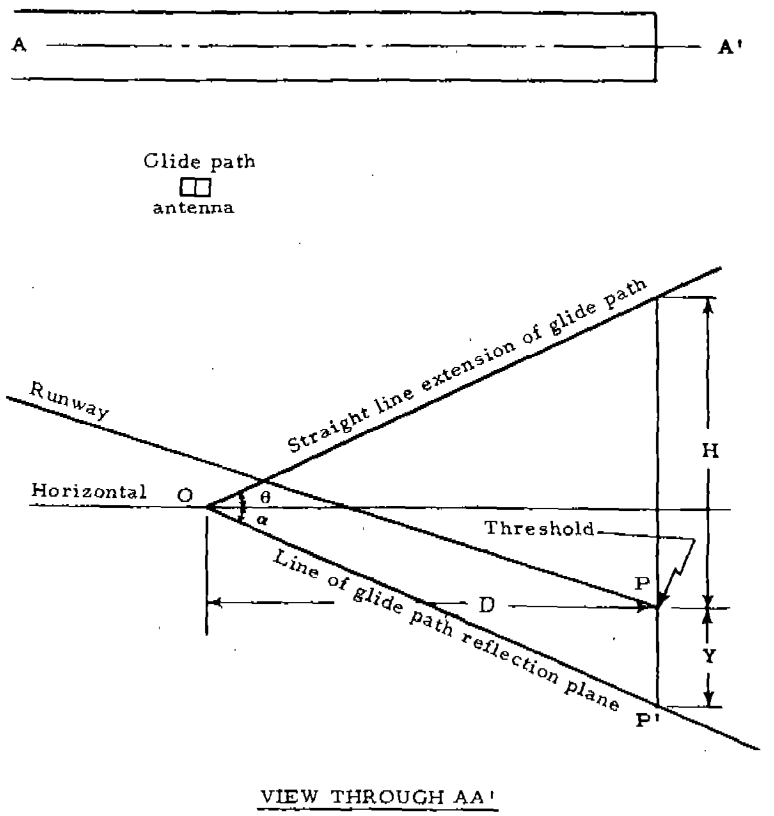
$$D = \frac{H + Y}{\tan(\theta + \alpha)}$$

where

D = the horizontal distance between O and P;

H = the nominal threshold crossing height;

Y = the vertical height of the runway threshold above P′;



Note.—The line OP′ represents the intersection of the glide path reflection plane and the vertical plane through AA′.

Figure C-5. Glide path siting for sloping runway

θ = the nominal ILS glide path angle;

α = the longitudinal downslope of the glide path reflection plane.

Note.— In the above formula a is to be taken as positive in the case of a downslope from the antenna towards the threshold. Y is taken as positive if the threshold is above the reflection plane intersection line.

2.4.10 The foregoing guidance material in respect of the longitudinal placement to the glide path antenna in relation to the runway threshold, which takes into account the fact that the runway may not be in the glide path reflection plane, and that the glide path reflection plane may be sloped, is based on geometrical abstractions. The material implicity assumes that the glide path locus in the vertical plane, containing the runway centre line, is a perfect hyperbola; consequently, the glide path extension is implicitly assumed as the asymptote to this hyperbola.

2.4.11 In fact, however, the glide path is often quite irregular. The mean ILS glide path angle can be ascertained only by flight tests; the mean observed position of that part of the glide path between ILS Points A and B being represented as a straight line, and the ILS glide path angle being the angle measured between that straight line and its vertical projection on the horizontal plane.

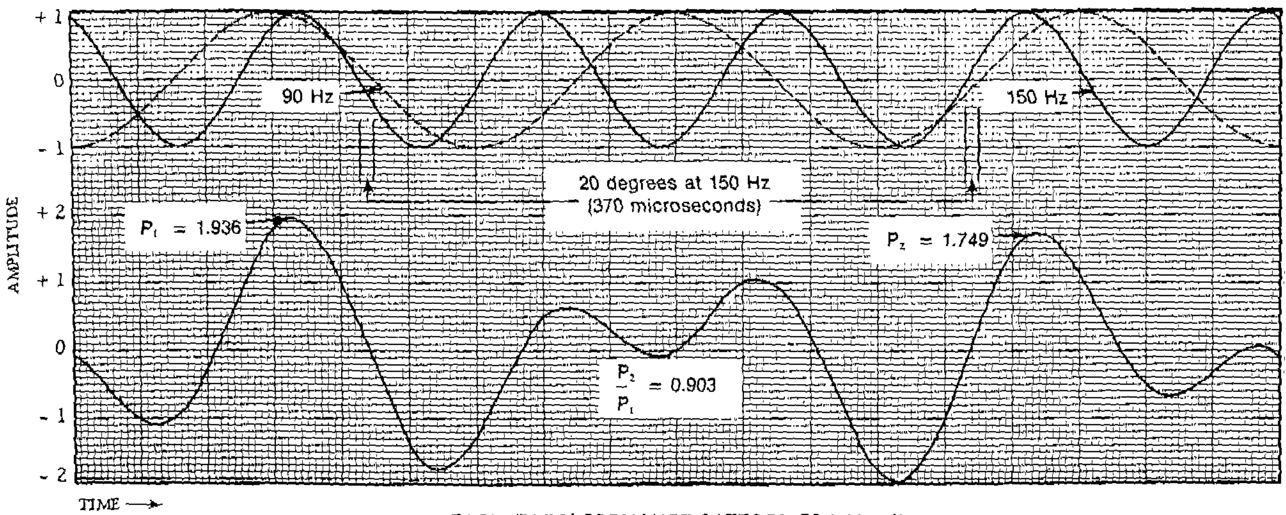
2.4.12 It is important to recognize that the effect of glide path irregularities if averaged within the region between the middle marker and the threshold will likely tend to project a reference datum which is actually different from the ILS reference datum. This reference datum, defined here as the achieved ILS reference datum, is considered to be of important operational significance. The achieved ILS reference datum can only be ascertained by flight check, i.e. the mean observed position of that portion of the glide path typically between points 1 830 m (6 000 ft) and 300 m (1 000 ft) from the threshold being represented as a straight line and extended to touchdown. The point at which this extended straight line meets the line drawn vertically through the threshold at the runway centre line is the achieved ILS reference datum.

Note.— Further guidance on the measurement of the glide path angle and the achieved ILS reference datum is given in Doc 8071.

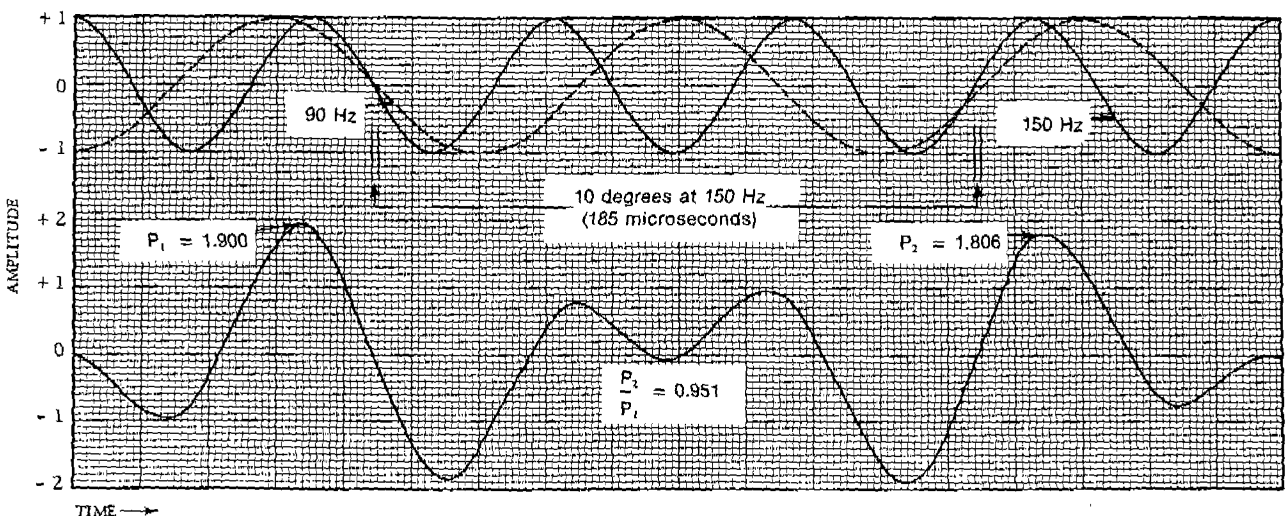
2.4.13 Chapter 3, 3.1.5.3.1 indicates the glide path coverage to be provided to allow satisfactory operation of a typical aircraft installation. The operational procedures promulgated for a facility must be compatible with the lower limit of this coverage. It is usual for descents to be made to the intercept altitude and for the approach to continue at this altitude until a fly-down signal is received. In certain circumstances a cross-check of position may not be available at this point. Automatic flight control sysstems will normally start the descent whenever a fly-up signal has decreased to less than about 10 microamperes.

2.4.14 The objective is, therefore, to provide a fly-up signal prior to intercepting the glide path. Although under normal conditions, approach procedures will be accomplished in such a way that glide path signals will not be used below 0.45 θ, or beyond 18.5 km (10 NM) from the runway, it is desirable that misleading guidance information should not be radiated in this area. Where procedures are such that the glide path guidance may be used below 0.45 θ, adequate precautions must be taken to guard against the radiation of misleading guidance information below 0.45 θ, under both normal conditions and during a malfunction, thus preventing the final descent being initiated at an incorrect point on the approach. Some precautions which can be employed to guard against the radiation of misleading guidance include the radiation of a supplementary clearance signal such as provided for in Chapter 3, 3.1.5.2.1, the provision of a separate clearance monitor and appropriate ground inspection and setting-up procedures.

2.4.15 To achieve satisfactory monitor protection against below-path out-of-tolerance DDM, depending on the antenna system used, the displacement sensitivity monitor as required in Chapter 3, 3.1.5.7.1 e) may not be adequate to serve also as a clearance monitor. In some systems, e.g. those using multi-element arrays without supplementary clearance, a slight deterioration of certain antenna signals can cause serious degradation of the clearance with no change or only insignificant changes within the glide path sector as seen by the deviation sensitivity monitor. It is important to ensure that monitor alarm is achieved for any or all possible deteriorated antenna and radiated signal conditions, which may lead to a reduction of clearance to 0.175 DDM or less in the below-path clearance coverage.



FACILITY PERFORMANCE CATEGORIES I AND II
LOCALIZERS AND GLIDE PATHS

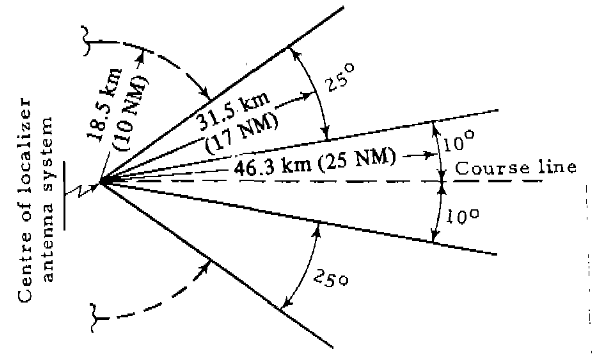


FACILITY PERFORMANCE CATEGORY III
LOCALIZERS AND GLIDE PATHS

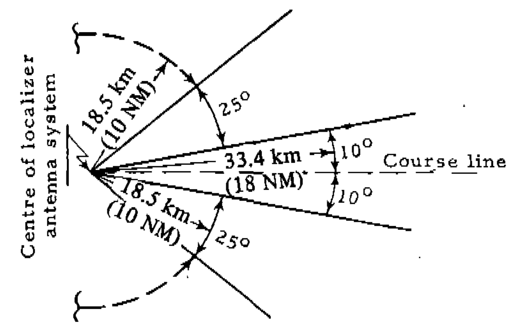
The accompanying graphs illustrate a method that can be used to measure the relative phase relationship between the 90 Hz and 150 Hz tones. The upper portion of each graph shows the individual waveforms and their relationship at the limit of phase differences allowed by Chapter 3, 3.1.3.5.3.3 and 3.1.5.5.3. The lower portion shows the combined waveforms as would be seen on an oscilloscope. By taking the ratio of P_1 and P_2, which gives a value equal to or less than unity, it is possible to determine if the phasing is within tolerance. For Categories I and II ILS the ratio should be greater than 0.903 and for Category III the ratio should be greater than 0.951.

Figure C-6. ILS wave forms illustrating relative audio phasing of the 90 Hz and 150 Hz tones

2.5 Diagrams (Figures C-7 to C-12 illustrate certain of the standards contained in Chapter 3)

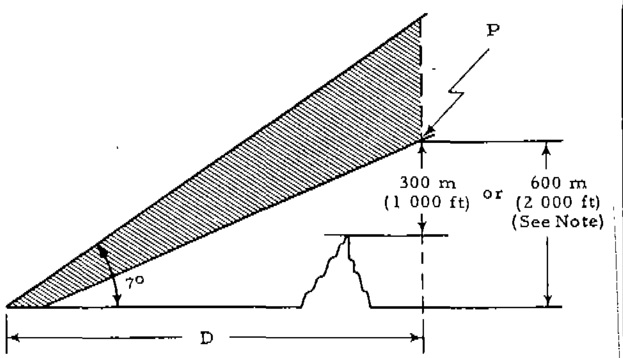


When topographical features dictate or operational requirements and alternative navigation facilities permit, the following coverage may be provided:



Note.— If coverage as prescribed in Chapter 3, 3.1.3.3.1 is required outside the plus or minus 35-degree sector, this is provided to 18.5 km (10 NM), as indicated by the broken arc above.

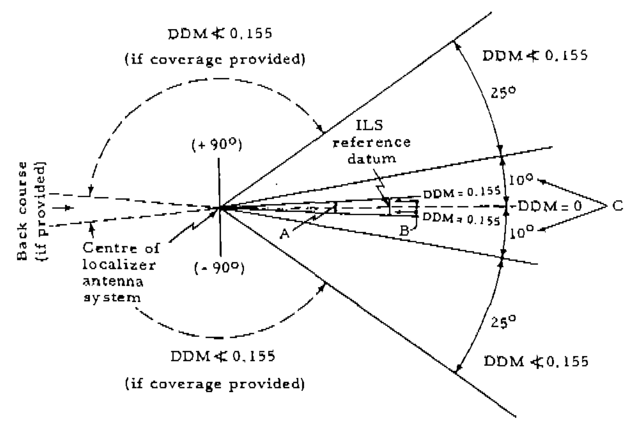
Figure C-7. Localizer coverage with respect to azimuth



D = Distances and azimuths specified in 3.1.3.3.1

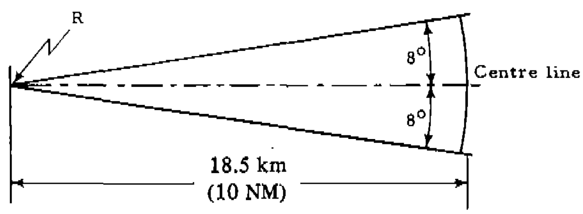
Note.—The point P is either 600 metres (2 000 feet) above the elevation of the threshold, or 300 metres (1 000 feet) above the elevation of the highest point within the intermediate and final approach areas, whichever is the higher.

Figure C-8. Localizer coverage with respect to elevation

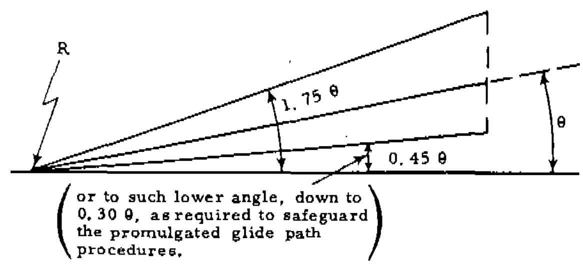


A - Course sector ≯ 6 degrees
B - Displacement sensitivity = 0.00145 DDM/metre (0.00044 DDM/foot) at the ILS reference datum
C - DDM increases linearly from zero to value of 0.180, and then ≮ 0.180

Figure C-9. Difference in depth of modulation and displacement sensitivity



(a) Azimuthal cover

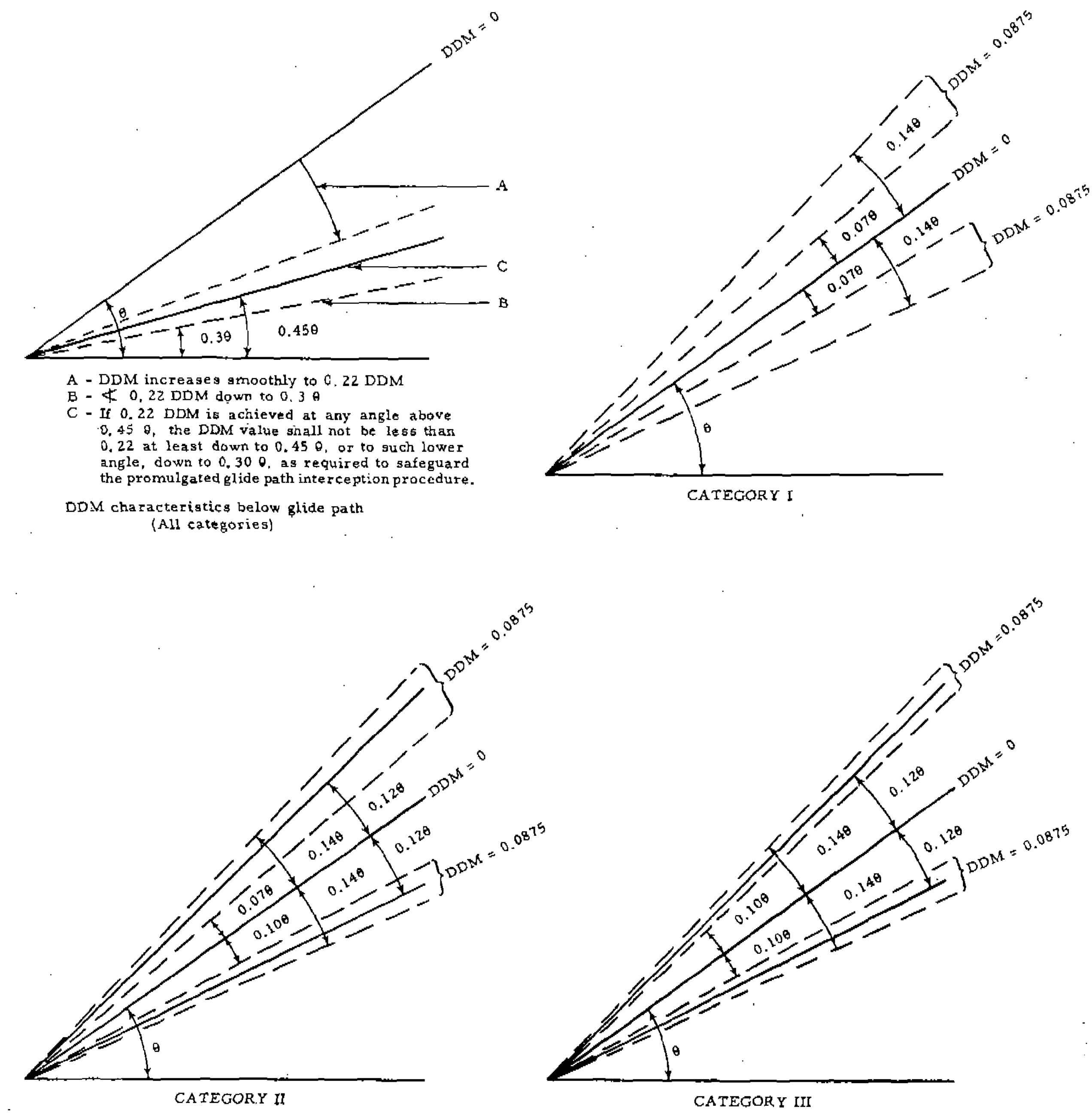


(b) Elevation cover

R = Point at which the downward-extended straight portion of the ILS glide path intersects the runway centre line.

θ = (ILS) glide path angle adjustable between 2° and 4°.

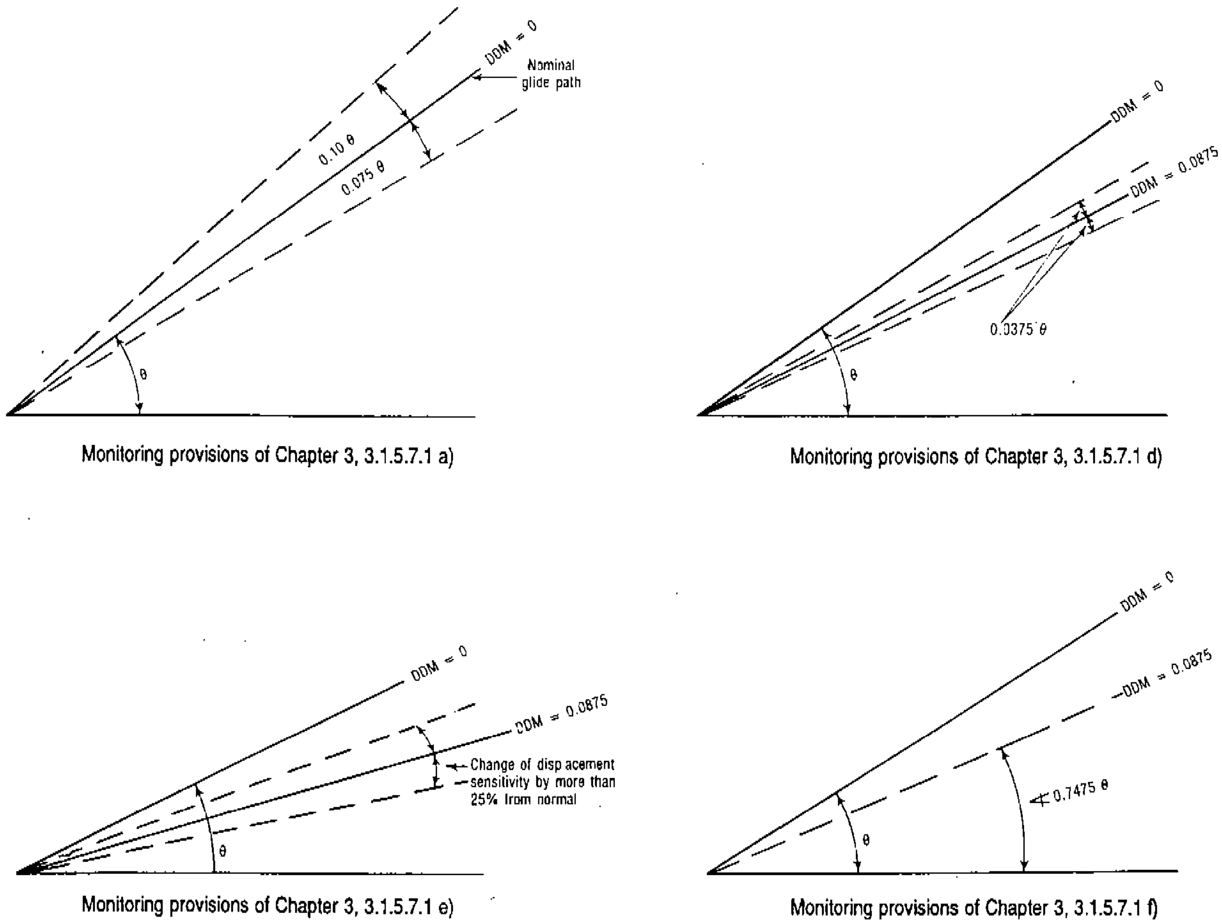
Figure C-10. Glide path coverage



θ = Nominal glide path elevation angle - adjustable between 2° and 4°.
(Broken lines show limits between which the DDM of 0.0875 is to be realized for Categories I, II and III.)

Note.— Figure C-11 depicts the tolerances for the radiated space pattern specified in Chapter 3, 3.1.5.6; however, this space pattern should not be interpreted as being representative of any one particular ground equipment. In this connection, it should be noted that there are several known types of ILS glide path ground equipment having different characteristics but which can satisfy the requirements of Chapter 3, 3.1.5.6. Therefore, wherever there is a requirement to know the tolerances applicable to a specific equipment, reference should be made to the manufacturer's technical data rather than the ICAO systems specification.

Figure C-11. Glide path — difference in depth of modulation



Note.— The broken lines represent the permissible limits of deviation before monitoring action is required.

Figure C-12. Glide path monitoring provisions

2.6 Deployment of ILS frequencies

2.6.1 In using the figures listed in Table C-1, it must be noted that these are related to ensuring freedom from interference to a point at the protection height and at the limit of service distance of the ILS in the direction of the front beam. If there is an operational requirement for back beam use, the criteria would also be applied to a similar point in the back beam direction. Frequency planning will therefore need to take into account the localizer azimuthal alignment. It is to be noted that the criteria must be applied in respect of each localizer installation, in the sense that while of two localizers, the first may not cause interference to the use of the second, nevertheless the second may cause interference to the use of the first.

2.6.2 The figures listed in Table C-1 are based on providing an environment within which the airborne receivers can operate correctly.

2.6.2.1 *ILS localizer receivers*

2.6.2.1.1 In order to protect receivers designed for 50 kHz channel spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 34 dB;

c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;

d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

Table C-1. Required distance separations

	Frequency separation	Minimum separation between second facility and the protection point of the first facility km (NM)		
		List A	List B	List C
Localizer	Co-channel	148 (80)	148 (80)	148 (80)
	50 kHz	—	37 (20)	9 (5)
	100 kHz	65 (35)	9 (5)	0
	150 kHz	—	0	0
	200 kHz	11 (6)	0	0
Glide path	Co-channel	93 (50)	93 (50)	93 (50)
	150 kHz	—	20 (11)	2 (1)
	300 kHz	46 (25)	2 (1)	0
	450 kHz	—	0	0
	600 kHz	9 (5)	0	0

List A refers to the use of localizer receivers designed for 200 kHz channel spacing coupled with glide path receivers designed for 600 kHz channel spacing and applicable only in regions where the density of facilities is low.
List B refers to the use of localizer receivers designed for 100 kHz channel spacing coupled with glide path receivers designed for 300 kHz channel spacing.
List C refers to the use of localizer receivers designed for 50 kHz channel spacing coupled with glide path receivers designed for 150 kHz channel spacing.

Note 1.— The above figures are based on the assumption of protection points for the localizer at 46 km (25 NM) distance and 1 900 m (6 250 ft) height and for the ILS glide path at 18.5 km (10 NM) distance and 760 m (2 500 ft) height.

Note 2.— States, in applying the separations shown in the table, have to recognize the necessity to site the ILS and VOR facilities in a manner which will preclude the possibility of airborne receiver error due to overloading by high unwanted signal levels when the aircraft is in the initial and final approach phases.

Note 3.— States, in applying the separations shown in the table, have to recognize the necessity to site the ILS glide path facilities in a manner which will preclude the possibility of erroneous glide path indications due to reception of adjacent channel signals when the desired signal ceases to radiate for any reason while the aircraft is in the final approach phase.

2.6.2.1.2 In order to protect receivers designed for 100 kHz channel spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 7 dB;

c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;

d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

2.6.2.2 *ILS glide path receivers*

2.6.2.2.1 In order to protect receivers designed for 150 kHz spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) a desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired glide path signal, 150 kHz removed from the desired signal, exceeds the desired signal by up to 20 dB;

c) an undesired glide path signal, 300 kHz or further removed from the desired signal, exceeds the desired signal by up to 40 dB.

2.6.2.2.2 In order to protect receivers designed for 300 kHz spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) a desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired glide path signal, 150 kHz removed from the desired signal, does not exceed the desired signal (0 dB signal ratio);

c) an undesired glide path signal, 300 kHz removed from the desired signal, exceeds the desired signal by up to 20 dB;

d) an undesired glide path signal, 450 kHz or further removed from the desired signal, exceeds the desired signal by up to 40 dB.

2.6.3 The calculations are based on the assumption that the protection afforded to the wanted signal against interference from the unwanted signal is 20 dB. This corresponds to a disturbance of not more than 15 microamperes at the limit of the service distance of ILS.

2.6.4 In so far as the wanted and unwanted carriers may produce a heterodyne note, the protection ratio ensures that the instrumentation is not affected. However, in cases where a voice facility is used, the heterodyne note may interfere with this facility.

2.6.5 In general, when international use of ILS systems is confined to the pairings listed in Chapter 3, 3.1.6.1.1, the criteria are such that, provided they are met for the localizer element, the glide path element is automatically covered. At certain congested locations, where it is necessary to make assignments in both the first ten and the second ten sequence pairings, it may be necessary to select certain pairings out of sequence in order to meet the minimum geographical separation in 2.6.6 below.

Example: Referring to Chapter 3, 3.1.6.1.1, it will be noted that ILS Sequence Number 2 pairs the localizer frequency of 109.9 MHz with glide path frequency 333.8 MHz. Sequence Numbers 12 and 19, however, although providing wide frequency separation from Sequence Number 2 in the case of the localizers, assign frequencies of 334.1 MHz and 333.5 MHz, respectively, for the glide paths, both being first adjacent channels (300 kHz spacing) to the Sequence Number 2 glide path channel. If selection of ILS channels is confined to either the first ten or the second ten pairings, then the minimum glide path frequency separation will be 600 kHz.

2.6.6 *Table of required distance separations*
[See Table C-1.]

2.6.7 The application of the figures given in Table C-1 will only be correct within the limitations set by the assumptions which include that facilities are essentially non-directional in character, that they have similar radiated powers, that the field strength is approximately proportional to the angle of elevation for angles up to 10 degrees, and that the aircraft antenna is essentially omnidirectional in character. If more precise determination of separation distances is required in areas of frequency congestion, this may be determined for each facility from appropriate propagation curves, taking into account the particular directivity factors, radiated power characteristics and the operational requirements as to coverage. Where reduced separation distances are determined by taking into account directivity, etc., flight measurements at the ILS protection point and at all points on the approach path should be made wherever possible to ensure that a protection ratio of at least 20 dB is achieved in practice.

2.7 Localizers and glide paths achieving coverage with two radio frequency carriers

2.7.1 Localizer coverage may be achieved by using two composite radiation field patterns on different carrier frequencies spaced within the localizer frequency channel. One field pattern gives accurate course and displacement indications within the front course sector; the other field pattern provides ILS indications outside the front course sector to meet the coverage requirements in Chapter 3, 3.1.3.3 and 3.1.3.7. Discrimination between signals is obtained in airborne receivers by the stronger signal capturing the receiver. Effectiveness of capture depends on the type of detector used but, in general, if the ratio of the two signals is of the order of 10 dB or more, the smaller signal does not cause significantly large errors in demodulated output. For optimum performance within the front course sector, the following guidance material should be applied in the operation of two carrier frequency localizer systems.

2.7.2 The localizer should be designed and maintained so that the ratio of the two radiated signals-in-space within the front course sector does not fall below 10 dB. Particular attention should be directed to the vertical lobe structure produced by the two antenna systems which may be different in height and separated in distance, thus resulting in changes in ratio of signal strengths during approach.

2.7.3 Due to the 6 dB allowance for the receiver pass-band filter ripple, localizer receiver response variations can occur as the clearance frequency is displaced from the course frequency. To minimize this effect, particularly for Category III operations, the course-to-clearance signal ratio needs to be increased from 10 dB to 16 dB.

2.7.4 To minimize further the risk of errors if the ratio of the two radiated signals falls below 10 dB within the front course sector, the difference in alignment of the radiation field patterns of the two signals should be kept as minimal as practicable.

2.7.5 Glide paths which employ two carriers are used to form a composite radiation field pattern on the same radio frequency channel. Special configurations of antennas and the distribution of antenna currents and phasing may permit siting of glide path facilities at locations with particular terrain conditions which may otherwise cause difficulty to a single-frequency system. At such sites, an improvement is obtained by reducing the low angle radiation. The second carrier is employed to provide coverage in the region below the glide path.

2.8 Integrity and continuity of service — ILS ground equipment

2.8.1 *Introduction*

2.8.1.1 This material is intended to provide clarification of the integrity and continuity of service objectives of ILS localizer and glide path ground equipment and to provide guidance on engineering design and system characteristics of this equipment. The integrity and continuity of service must of necessity be known from an operational viewpoint in order to decide the operational application which an ILS could support.

2.8.1.2 It is generally accepted, irrespective of the operational objective, that the average rate of a fatal accident during landing, due to failures or shortcomings in the whole system, comprising the ground equipment, the aircraft and the pilot, should not exceed 1×10^{-7}. This criterion is frequently referred to as the global risk factor.

2.8.1.3 In the case of Category I operations, responsibility for assuring that the above objective is not exceeded is vested more or less completely in the pilot. In Category III operations, the same objective is required but must now be inherent in the whole system. In this context it is of the utmost importance to endeavour to achieve the highest level of integrity and continuity of service of the ground equipment. Integrity is needed to ensure that an aircraft on approach will have a low probability of receiving false guidance; continuity of service is needed to ensure that an aircraft in the final stages of approach will have a low probability of being deprived of a guidance signal.

2.8.1.4 It is seen that various operational requirements correspond to varied objectives of integrity and continuity of service. Paragraph 2.14 below identifies and describes four levels of integrity and continuity of service.

2.8.2 *Guidance material concerning the achievement and retention of integrity and continuity of service levels*

2.8.2.1 An integrity failure can occur if radiation of a signal which is outside specified tolerances is either unrecognized by the monitoring equipment or the control circuits fail to remove the faulty signal. Such a failure might constitute a hazard if it results in a gross error.

2.8.2.2 Clearly not all integrity failures are hazardous in all phases of the approach. For example, during the critical stages of the approach, undetected failures producing gross errors in course width or course line shifts are of special significance whereas an undetected change of modulation depth, or loss of localizer and glide slope clearance and localizer identification would not necessarily produce a hazardous situation. The criterion in assessing which failure modes are relevant must however include all those deleterious fault conditions which are not unquestionably obvious to the automatic flight system or pilot.

2.8.2.3 It is especially important that monitors be designed to provide fail-safe operation through compliance with the Standards of Chapter 3, 3.1.3.11.4 and 3.1.5.7.4. This often requires a rigorous design analysis. Monitor failures otherwise may permit the radiation of erroneous signals. Some of the possible conditions which might constitute a hazard in Operational Performance Categories II and III are:

a) an undetected shift of course line significantly outside the monitor limits for localizer and glide path;

b) an undetected fault that significantly changes the course width and glide path sensitivity;

c) an undetected fault causing slow cyclic movements of the course, producing apparent course bends as seen by the approaching aircraft significantly exceeding in amplitude the figures specified in Chapter 3, 3.1.3.4.2 for the localizer and Chapter 3, 3.1.5.4.2 for the glide path between ILS points "B" and "T".

2.8.2.4 The highest order of protection is required against the risk of undetected failures in the monitoring and associated control system. This would be achieved by careful design to reduce the probability of such occurrences to a low level and by carrying out maintenance checks on the monitor system performance at intervals which are determined by the design analysis. Such an analysis can be used to calculate the level of integrity of the system in any one landing. The following formula applies to certain types of ILS and provides an example of the determination of system integrity, I, from a calculation of the probability of transmission of undetected erroneous radiation, P.

(1) $I = 1 - P$

$$P = \frac{T_1 T_2}{\alpha_1 \alpha_2 M_1 M_2} \quad \text{when } T_1 < T_2$$

where

I = integrity

P = the probability of a concurrent failure in transmitter and monitor systems resulting in erroneous undetected radiation

M_1 = transmitter MTBF

M_2 = MTBF of the monitoring and associated control system

$\frac{1}{\alpha_1}$ = ratio of the rate of failure in the transmitter resulting in the radiation of an erroneous signal to the rate of all transmitter failures

$\frac{1}{\alpha_2}$ = ratio of the rate of failure in the monitoring and associated control system resulting in inability to detect an erroneous signal to the rate of all monitoring and associated control system failures

T_1 = period of time (in hours) between transmitter checks

T_2 = period of time (in hours) between checks on the monitoring and associated control system

When $T_1 \geq T_2$ the monitor system check may also be considered a transmitter check. In this case, therefore $T_1 = T_2$ and the formula would be:

(2) $$P = \frac{T_2^2}{\alpha_1 \alpha_2 M_1 M_2}$$

2.8.2.5 With regard to integrity, since the probability of occurrence of an unsafe failure within the monitoring or control equipment is extremely remote, to establish the required integrity level with a high degree of confidence would necessitate an evaluation period many times that needed to establish the equipment MTBF. Such a protracted period is unacceptable and therefore the required integrity level can only be predicted by rigorous design analysis of the equipment.

2.8.2.6 The MTBF and continuity of service of equipment is governed by basic construction and operating environment. Equipment design should employ the most suitable engineering techniques, materials and components, and rigorous inspection should be applied during manufacture. It is essential to ensure that equipment is operated within the environmental conditions specified by the manufacturer. The manufacturer is required to provide the details of the design to enable the MTBF and continuity of service to be calculated. It is expected that the equipment MTBF is confirmed by evaluation in an operational environment to take account of the impact of operational factors, i.e. airport environment, inclement weather conditions, power availability, quality and frequency of maintenance, etc. For integrity and continuity of service Levels 2, 3 or 4 the evaluation period should be sufficient to determine achievement of the required level with a high degree of confidence. The following considerations apply:

a) the minimum acceptable confidence level is 60 per cent. Depending on the service level of the ILS, this may result in different evaluation periods. To assess the influence of the airport environment, a minimal evaluation period of one year is typically required for a new type of installation at that particular airport. It may be possible to reduce this period in cases where the operating environment is well controlled and similar to other proven installations. Subsequent installation of the same type of equipment under similar operational and environmental conditions may follow different evaluation periods. Typically, these minimal periods for subsequent installations are for Level 2, 1 600 hours, for Level 3, 3 200 hours and for Level 4, at least 6 400 hours. Where several identical systems are being operated under similar conditions, it may be possible to base the assessment on the cumulative operating hours of all the systems. This will result in a reduced evaluation period; and

b) during the evaluation period, it should be decided for each outage if it is caused by a design failure or if it is caused by a failure of a component due to its normal failure rate. Design failures are, for instance, operating components beyond their specification (overheating, overcurrent, overvoltage, etc. conditions). These design failures should be dealt with such that the operating condition is brought back to the normal operating condition of the component or that the component is replaced with a part suitable for the operating conditions. If the design failure is treated in this way, the evaluation may continue and this outage is not counted, assuming that there is a high probability that this design failure will not occur again. The same applies to outages due to any causes which can be mitigated by permanent changes to the operating conditions.

2.8.2.7 Continuity of service performance may also be demonstrated by means of MTBO (mean time between outages) where an outage is defined as any unanticipated cessation of signal-in-space. It is calculated by dividing the total facility up-time by the number of operational failures. MTBF and MTBO are not always equivalent, as not all equipment failures will necessarily result in an outage, e.g. an event such as a failure of a transmitter resulting in the immediate transfer to a standby transmitter. The minimum MTBO values expected for the continuity of service in 2.14 below have been derived from several years of operational experience of many systems. To determine whether the performance record of an individual ILS system justifies its assignment to levels 2, 3 or 4 requires a judicious consideration of such factors as:

1) the performance record and experience of system use established over a suitable period of time (see 2.8.2.6);

2) the average achieved MTBO established for this type of ILS; and

3) the trend of the failure rates.

An assigned designation should not be subject to frequent change. A suitable method to assess the behaviour of a particular installation is to keep the records and calculate the average MTBO over the last five to eight failures of the equipment. A typical record of this method is given in Figures C-12A and C-12B.

2.8.2.8 During the equipment evaluation, and subsequent to its introduction into operational service, records should be maintained of all equipment failures or outages to confirm retention of the desired continuity of service.

2.8.2.9 The following configuration is an example of a redundant equipment arrangement that is likely to meet the objectives for integrity and continuity of service levels 3 or 4. The localizer facility consists of two continuously operating transmitters, one connected to the antenna and the standby connected to a dummy load. With these transmitters is associated a monitor system performing the following functions:

a) monitoring of operation within the specified limits of the main transmitter and antenna system by means of majority voting among redundant monitors;

b) monitoring the standby equipment.

2.8.2.9.1 Whenever the monitor system rejects one of the equipments the facility continuity of service level will be reduced because the probability of cessation of signal consequent on failure of other equipment will be increased. This change of performance must be automatically indicated at remote locations.

2.8.2.9.2 An identical monitoring arrangement to the localizer is used for the glide path facility.

2.8.2.9.3 To reduce mutual interference between the main and standby transmitters any stray radiation from the latter is at least 50 dB below the carrier level of the main transmitter measured at the antenna system.

2.8.2.9.4 In the above example the equipment would include provision to facilitate monitoring system checks at intervals specified by the manufacturer, consequent to his design analysis, to ensure attainment of the required integrity level. Such checks, which can be manual or automatic, provide the means to verify correct operation of the monitoring system including the control circuitry and changeover switching system. The advantage of adopting an automatic monitor integrity test is that no interruption to the operational service provided by the localizer or glide path is necessary. It is important when using this technique to ensure that the total duration of the check cycle is short enough not to exceed the total period specified in Chapter 3, 3.1.3.11.3 or 3.1.5.7.3.

2.8.2.9.5 Interruption of facility operation due to primary power failures is avoided by the provision of suitable standby supplies, such as batteries or "no-break" generators. Under these conditions, the facility should be capable of continuing in operation over the period when an aircraft may be in the critical stages of the approach. Therefore the standby supply should have adequate capacity to sustain service for at least two minutes.

2.8.2.9.6 Warnings of failures of critical parts of the system, such as the failure of the primary power supply, must be given at the designated control points.

2.8.2.10 In order to reduce failure of equipment that may be operating near its monitor tolerance limits, it is useful for the monitor system to include provision to generate a pre-alarm warning signal to the designated control point when the monitored parameters reach a limit equal to a value in the order of 75 per cent of the monitor alarm limit.

2.8.2.11 Protection of the integrity of the signal-in-space against degradation which can arise from extraneous radio interference falling within the ILS frequency band or from re-radiation of ILS signals must also be considered. Measures

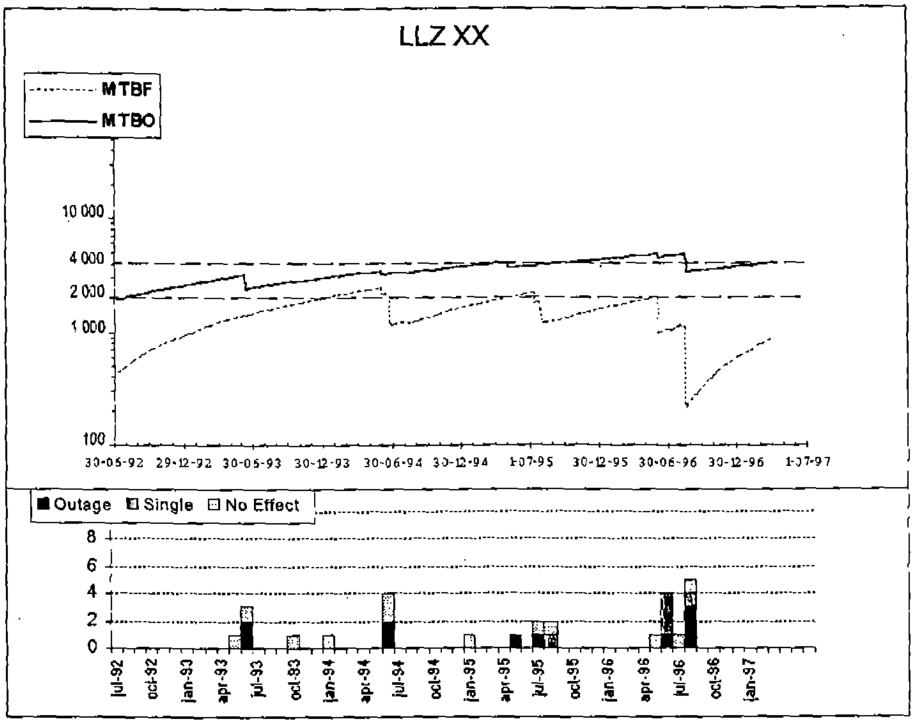


Figure C-12A. Example of a localizer outage record

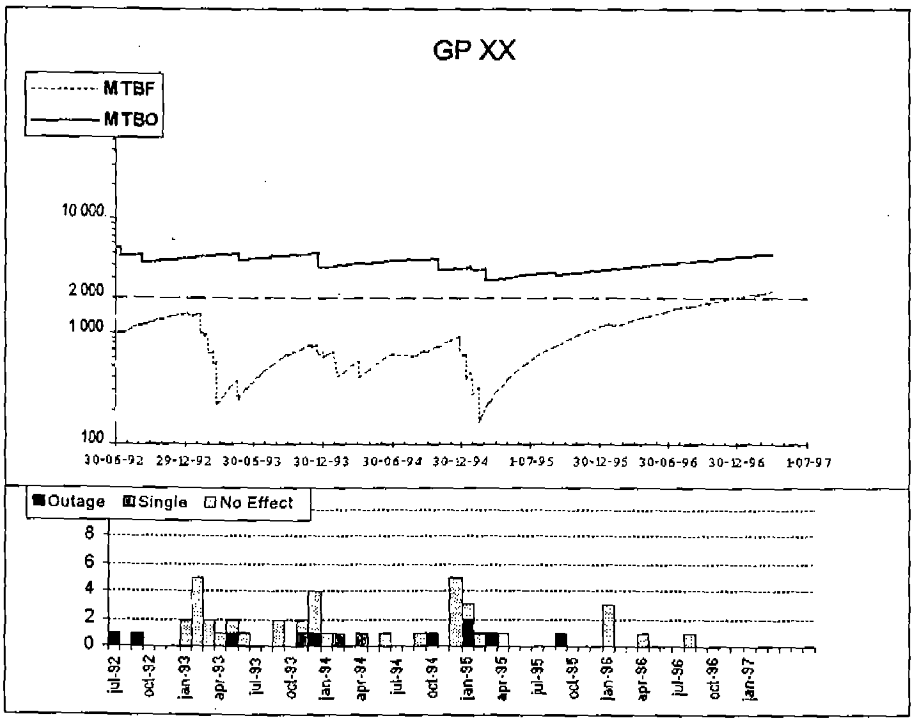


Figure C-12B. Example of a glide path outage record

to prevent the latter by critical and sensitive area protection are given in general terms at 2.1.10. With regard to radio interference it may be necessary to confirm periodically that the level of interference does not constitute a hazard.

2.8.2.12 A far field monitor can provide additional protection by providing a warning against the extremely remote probability of the radiation of false information from a localizer facility, as indicated in 2.8.5.

2.8.2.13 In general, monitoring equipment design is based on the principle of continuously monitoring the radiated signals-in-space at specific points within the coverage volume to ensure their compliance with the Standards specified at Chapter 3, 3.1.3.11 and 3.1.5.7. Although such monitoring provides to some extent an indication that the signal-in-space at all other points in the coverage volume is similarly within tolerance, this is largely inferred. It is essential therefore to carry out rigorous flight and ground inspections at periodic intervals to ensure the integrity of the signal-in-space throughout the coverage volume.

2.8.2.14 An equipment arrangement similar to that at 2.8.2.9, but with no transmitter redundancy, and the application of the provisions outlined in 2.8.2.11, 2.8.2.12 and 2.8.2.13, would normally be expected to achieve the objectives for integrity and continuity of service Level 2.

2.8.2.15 An analysis of the factors involved in different types of operations allows the determination of desired values for the integrity, expressed in terms of the probability in any one landing, to be determined from the allowable global risk factor criterion. See 2.14.2 c).

2.8.3 The stringent requirement for integrity and high continuity of service essential for Category III operations requires the use of ILS Facility Performance Category III equipment having adequate assurance against failures. A failure is taken to be performance outside the monitor system tolerances specified in Chapter 3, 3.1.3.11 for Category III localizers and 3.1.5.7 for Category III glide paths. Reliability of ground equipment operation must be very high, so as to ensure that safety during the critical phase of approach and landing is not impaired by a ground equipment failure when the aircraft is at such a height or attitude that it is unable to take safe corrective action. A high probability of performance within the specified limits has to be ensured. Facility reliability in terms of mean time between failure (MTBF) clearly has to be related on a system basis to the probability of failure which may affect any characteristic of the total signal-in-space. The system must ensure the highest degree of protection against failure of the monitors to detect a failure in performance of the ground equipment. It is suggested that States endeavour to achieve reliability with as large a margin as is technically and economically reasonable.

2.8.3.1 The following configuration is an example of a redundant arrangement suitable for Category III operations. The localizer facility consists of two continuously operating transmitters, one connected to an antenna load. With these transmitters is associated a monitor system performing the following functions:

a) monitoring of operation within the specified limits of the main transmitter and antenna system by means of a majority voting among redundant monitors;

b) monitoring of the standby equipment.

2.8.3.1.1 Whenever the monitor system rejects one of the equipments the facility will no longer have Category III status because the probability of cessation of signal consequent on failure of other equipment will be too high. This reversion to a lower category is automatically indicated at remote locations.

2.8.3.1.2 An identical monitoring arrangement is used for the glide path facility.

2.8.3.1.3 To reduce mutual interference between the main and standby transmitters, any stray radiation from the latter should be at least 50 dB below the carrier level of the main transmitter measured at the antenna system.

2.8.3.2 The highest order of protection is required against the consequence of undetected monitor system failures. This should be achieved by careful design to reduce the probability of such occurrences to a low level and by carrying out maintenance checks on the monitor system performance at intervals which are determined by the design analysis.

2.8.4 Additional guidance material applicable to Categories II and III — ILS localizer and glide path ground equipment is given below.

2.8.4.1 Reliability of equipment is governed by basic construction and operating environment. Equipment design should employ the most suitable engineering techniques, materials and components, and rigorous inspection should be applied in manufacture. Equipment should be operated in environmental conditions appropriate to the manufacturers' design criteria. It is expected that the equipment reliability be established by evaluation before introduction into Categories II and III service. Design analysis should verify the predicted performance of the equipment.

2.8.5 Guidance relating to localizer far field monitors is given below.

2.8.5.1 Far field monitors are provided to monitor course alignment but may also be used to monitor course sensitivity. A far field monitor operates independently from integral and near field monitors. Its primary purpose is to protect against the risk of erroneous setting-up of the localizer, or faults in the near field or integral monitors. In addition, the far field monitor system will enhance the ability of the combined monitor system to respond to the effects of physical modification of the radiating elements or variations in the ground reflection characteristics. Moreover, multipath effects and runway area disturbances not seen by near field and integral monitors, and some occurrences of radio interferences may be substantially monitored by using a far field monitoring system built around a suitable receiver(s), installed under the approach path.

2.8.5.2 A far field monitor is generally considered essential for Category III operations, while for Category II it is generally considered to be desirable. Also for Category I installations, a far field monitor has proved to be a valuable tool to supplement the conventional monitor system.

2.8.5.3 The signal received by the far field monitor will suffer short-term interference effects caused by aircraft movements on or in the vicinity of the runway and experience has shown that it is not practical to use the far field monitor as an executive monitor. When used as a passive monitor, means must be adopted to minimize such temporary interference effects and to reduce the occurrence of nuisance downgrade indications; some methods of achieving this are covered in 2.8.5.4 below. The response of the far field monitor to interference effects offers the possibility of indicating to the air traffic control point when temporary disturbance of the localizer signal is present. However, experience has shown that disturbances due to aircraft movements may be present along the runway, including the touchdown zone, and not always be observed at the far field monitor. It must not be assumed, therefore, that a far field monitor can provide comprehensive surveillance of aircraft movements on the runway.

2.8.5.3.1 Additional possible applications of the far field monitor are as follows:

a) it can be a useful maintenance aid to verify course and/or course deviation sensitivity in lieu of a portable far field monitor;

b) it may be used to provide a continuous recording of far field signal performance showing the quality of the far field signal and the extent of signal disturbance.

2.8.5.4 Possible methods of reducing the occurrence of nuisance downgrade indications include:

a) incorporation of a time delay within the system adjustable from 30 to 240 seconds;

b) the use of a validation technique to ensure that only indications not affected by transitory disturbances are transmitted to the control system;

c) use of low pass filtering.

2.8.5.5 A typical far field monitor consists of an antenna, VHF receiver and associated monitoring units which provide indications of DDM, modulation sum, and RF signal level. The receiving antenna is usually of a directional type to minimize unwanted interference and should be at the greatest height compatible with obstacle clearance limits. For course line monitoring, the antenna is usually positioned along the extended runway centre line. Where it is desired to also monitor displacement sensitivity, an additional receiver and monitor are installed with antenna suitably positioned to one side of the extended runway centre line. Some systems utilize a number of spatially separated antennas.

2.9 Localizer and glide path displacement sensitivities

2.9.1 Although certain localizer and glide path alignment and displacement sensitivities are specified in relation to the ILS reference datum, it is not intended to imply that measurement of these parameters must be made at this datum.

2.9.2 Localizer monitor system limits and adjustment and maintenance limits given in Chapter 3, 3.1.3.7 and 3.1.3.11 are stated as percentage changes of displacement sensitivity. This concept, which replaces specifications of angular width in earlier editions, has been introduced because the response of aircraft guidance systems is directly related to displacement sensitivity. It will be noted that angular width is inversely proportional to displacement sensitivity.

2.10 Siting of ILS markers

2.10.1 Considerations of interference between inner and middle markers, and the minimum operationally acceptable time interval between inner and middle marker light indications, will limit the maximum height marked by the inner marker to a height on the ILS glide path of the order of 37 m (120 ft) above threshold for markers sited within present tolerances in Annex 10. A study of the individual site will determine the maximum height which can be marked, noting that with a typical airborne marker receiver a separation period of the order of 3 seconds at an aircraft speed of 140 kt between middle and inner marker light indications is the minimum operationally acceptable time interval.

2.10.2 In the case of ILS installations serving closely spaced parallel runways, e.g. 500 m (1 650 ft) apart, special measures are needed to ensure satisfactory operation of the marker beacons. Some States have found it practical to employ a common outer marker for both ILS installations. However, special provisions, e.g. modified field patterns, are needed in the case of the middle markers if mutual interference is to be avoided, and especially in cases where the thresholds are displaced longitudinally from one another.

2.11 Use of DME as an alternative to ILS marker beacons

2.11.1 When DME is used as an alternative to ILS marker beacons, the DME should be located on the airport so that the zero range indication will be a point near the runway.

2.11.2 In order to reduce the triangulation error, the DME should be sited to ensure a small angle (e.g. less than 20 degrees) between the approach path and the direction to the DME at the points where the distance information is required.

2.11.3 The use of DME as an alternative to the middle marker beacon assumes a DME system accuracy of 0.37 km (0.2 NM) or better and a resolution of the airborne indication such as to allow this accuracy to be attained.

2.11.4 While it is not specifically required that DME be frequency paired with the localizer when it is used as an alternative for the outer marker, frequency pairing is preferred wherever DME is used with ILS to simplify pilot operation and to enable aircraft with two ILS receivers to use both receivers on the ILS channel.

2.11.5 When the DME is frequency paired with the localizer, the DME transponder identification should be obtained by the "associated" signal from the frequency- paired localizer.

2.12 The use of supplementary sources of orientation guidance in association with ILS

2.12.1 Aircraft beginning an ILS approach may be assisted by guidance information provided by other ground referenced facilities such as VORs, surveillance radar or, where these facilities cannot be provided, by a locator beacon.

2.12.2 When not provided by existing terminal or en-route facilities, a VOR, suitably sited, will provide efficient transition to the ILS. To achieve this purpose the VOR may be sited on the localizer course or at a position some distance from the localizer course provided that a radial will intersect the localizer course at an angle which will allow smooth transitions in the case of auto coupling. The distance between the VOR site and the desired point of interception must be recognized when determining the accuracy of the interception and the airspace available to provide for tracking errors.

2.12.3 Where it is impracticable to provide a suitably sited VOR, a compass locator or an NDB can assist transition to the ILS. The facility should be sited on the localizer course at a suitable distance from the threshold to provide for optimum transition.

2.13 The use of Facility Performance Category I — ILS for automatic approaches and landings in visibility conditions permitting visual monitoring of the operation by the pilot

2.13.1 Facility Performance Category I — ILS installations of suitable quality can be used, in combination with aircraft flight control systems of types not relying solely on the guidance information derived from the ILS sensors, for automatic approaches and automatic landings in visibility conditions permitting visual monitoring of the operation by the pilot.

2.13.2 To assist aircraft operating agencies with the initial appraisal of the suitability of individual ILS installations for such operations, provider States are encouraged to promulgate:

a) the differences in any respect from Chapter 3, 3.1;

b) the extent of compliance with the provisions in Chapter 3, 3.1.3.4 and 3.1.5.4, regarding localizer and glide path beam structure; and

c) the height of the ILS reference datum above the threshold.

2.13.3 To avoid interference which might prevent the completion of an automatic approach and landing, it is necessary that local arrangements be made to protect, to the extent practicable, the ILS critical and sensitive areas.

2.13.4 Where two separate ILS facilities serve opposite ends of a single runway, an interlock should ensure that only the localizer serving the approach direction in use should radiate.

2.14 ILS classification — supplementary ILS description method with objective to facilitate operational utilization

2.14.1 The classification system given below, in conjunction with the current facility performance categories, is intended to provide a more comprehensive method of describing an ILS.

2.14.2 The ILS classification is defined by using three characters as follows:

a) I, II or III: this character indicates conformance to Facility Performance Category in Chapter 3, 3.1.3 and 3.1.5;

b) A, B, C, T, D or E: this character defines the ILS points to which the localizer structure conforms to the course structure given at Chapter 3, 3.1.3.4.2, except the letter T, which designates the runway threshold. The points are defined in Chapter 3, 3.1.1.

c) 1, 2, 3 or 4: this number indicates the level of integrity and continuity of service given in Table C-2.

Note.— In relation to specific ILS operations it is intended that the level of integrity and continuity of service would typically be associated as follows:

1) Level 2 is the performance objective for ILS equipment used to support low visibility operations when ILS

Table C-2. Integrity and continuity of service objectives

Level	Localizer or glide path		
	Integrity	Continuity of service	MTBO (hours)
1	Not demonstrated, or less than required for Level 2		
2	$1 - 10^{-7}$ in any one landing	$1 - 4 \times 10^{-6}$ in any period of 15 seconds	1 000
3	$1 - 0.5 \times 10^{-9}$ in any one landing	$1 - 2 \times 10^{-6}$ in any period of 15 seconds	2 000
4	$1 - 0.5 \times 10^{-9}$ in any one landing	$1 - 2 \times 10^{-6}$ in any period of 30 seconds (localizer) 15 seconds (glide path)	4 000 (localizer) 2 000 (glide path)

Note.— For currently installed systems, in the event that the Level 2 integrity value is not available or cannot be readily calculated, it is necessary to at least perform a detailed analysis of the integrity to assure proper monitor fail-safe operation.

guidance for position information in the landing phase is supplemented by visual cues. This level is a recommended objective for equipment supporting Category I operations;

2) *Level 3 is the performance objective for ILS equipment used to support operations which place a high degree of reliance on ILS guidance for positioning through touchdown. This level is a required objective for equipment supporting Category II and IIIA operations; and*

3) *Level 4 is the performance objective for ILS equipment used to support operations which place a high degree of reliance on ILS guidance throughout touchdown and rollout. This level basically relates to the needs of the full range of Category III operations.*

2.14.3 As an example, a Facility Performance Category II — ILS which meets the localizer course structure criteria appropriate to a Facility Performance Category III — ILS down to ILS point "D" and conforms to the integrity and continuity of service objectives of Level 3 would be described as class II/D/3.

2.14.4 ILS classes are appropriate only to the ground ILS element. Consideration of operational categories must also include additional factors such as operator capability, critical and sensitive area protection, procedural criteria and ancillary aids, such as transmissometers and lights.

2.15 ILS carrier frequency and phase modulation

2.15.1 In addition to the desired 90 Hz and 150 Hz AM modulation of the ILS RF carriers, undesired frequency modulation (FM) and/or phase modulation (PM) may exist. This undesired modulation can cause centring errors in ILS receivers due to slope detection by ripple in the intermediate frequency (IF) filter pass-band.

2.15.2 For this to occur, the translated RF carrier frequency must fall on an IF frequency where the pass-band has a high slope. The slope converts the undesired 90 Hz and 150 Hz frequency changes to AM of the same frequencies. Similarly, any difference in FM deviation between the undesired 90 Hz and 150 Hz components is converted to DDM, which in turn produces an offset in the receiver. The mechanism is identical for PM as for FM, since PM causes a change in frequency equal to the change in phase (radians) multiplied by the modulating frequency.

2.15.3 The effect of the undesired FM and/or PM is summed by vector addition to the desired AM. The detected FM is either in phase or anti-phase with the AM according to whether the pass-band slope at the carrier's IF is positive or negative. The detected PM is in quadrature with the AM, and may also be positive or negative according to the pass-band slope.

2.15.4 Undesired FM and/or PM from frequencies other than 90 Hz and 150 Hz, but which pass through the 90 Hz and 150 Hz tone filters of the receiver, can also cause changes to the desired 90 Hz and 150 Hz AM modulation of the ILS RF carrier, resulting in a DDM offset error in the receiver. Thus, it is essential that when measuring undesired FM and PM levels, audio band-pass filters with a pass-band at least as wide as that of the tone filters of ILS receivers be used. These filters are typically inserted in commercial modulation meter test equipment between the demodulation and metering circuits, to ensure that only spectral components of interest to ILS applications are measured. To standardize such measurements, the filter characteristics are recommended as shown below:

Frequency (Hz)	*90 Hz band-pass filter attenuation, dB*	*150 Hz band-pass filter attenuation, dB*
≤45	–10	–16
85	–0.5	(no specification)
90	0	–14
95	–0.5	(no specification)
142	(no specification)	–0.5
150	–14	0
158	(no specification)	–0.5
≥300	–16	–10

2.15.5 The preferred maximum limits, as shown below, are derived from ILS receiver centring error limits specified in EUROCAE documents ED-46B and ED-47B, based on the worst-case-to-date observed correlation between undesired modulation levels and centring errors:

Facility type	*90 Hz peak deviation, FM Hz/PM radians (Note 1)*	*150 Hz peak deviation, FM Hz/PM radians (Note 2)*	*Deviation difference, Hz (Note 3)*
Localizer, Cat I	135/1.5	135/0.9	45
Localizer, Cat II	60/0.66	60/0.4	20
Localizer, Cat III	45/0.5	45/0.3	15
Glide path, Cat I	150/1.66	150/1.0	50
Glide path, Cat II or III	90/1.0	90/0.6	30

Note 1.— This column applies to the peak frequency or phase deviation as measured with the 90 Hz tone filter specified in 2.15.4.

Note 2.— This column applies to the peak frequency or phase deviation as measured with the 150 Hz tone filter specified in 2.15.4.

Note 3.— This column applies to the difference in peak frequency deviation between the separate measurements of the undesired 90 Hz FM (or equivalent PM) and the 150 Hz FM (or equivalent PM) obtained with the filters specified in the table in 2.15.4. The equivalent deviation for 90 Hz and 150 Hz measured PM values is calculated by multiplying each peak PM measurement in radians by its corresponding modulating frequency in Hz.

3. Material concerning VOR

3.1 Guidance relating to VOR effective radiated power (ERP) and coverage

3.1.1 The field strength specified at Chapter 3, 3.3.4.2, is based on the following consideration:

Airborne receiver sensitivity	–117 dBW
Transmission line loss, mismatch loss, antenna polar pattern variation with respect to an isotropic antenna	+7 dBW
Power required at antenna	–110 dBW

The power required of minus 100 dBW is obtained at 118 MHz with a power density of minus 107 dBW/m^2; minus 107 dBW/m^2 is equivalent to 90 microvolts per metre, i.e. plus 39 dB referenced to 1 microvolt per metre.

Note.— The power density for the case of an isotropic antenna may be computed in the following manner:

$$P_d = P_a - 10 \log \frac{\lambda^2}{4\pi}$$

where

P_d = power density in dBW/m^2;

P_a = power at receiving point in dBW;

λ = wavelength in metres.

3.1.2 Nominal values of the necessary ERP to achieve a field strength of 90 microvolts per metre (minus 107 dBW/m^2) are given at Figure C-13. For coverage under difficult terrain and siting conditions, it may be necessary to make appropriate increases in the effective radiated power. Conversely, practical experience has shown that under favourable siting conditions, and under the less pessimistic conditions often found in actual service, satisfactory system operation is achieved with a lower ERP.