GUIDANCE MATERIAL
ON APPLICATION
OF THE RADIO NAVIGATION AIDS
STANDARDS

State Civil Aviation Agency of the Republic of Azerbaijan

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GUIDANCE MATERIAL ON APPLICATION OF THE RADIO NAVIGATION AIDS STANDARDS

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0.3. DISTRIBUTION CONTROL

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0.4. RECORD OF AMENDMENTS AND REVISIONS

Edition/ Revision №:	Date of Edition/ Revision:	Inserted by:	Para/ Page	Effective date:
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Edition: - *Release of a document having incorporated all previous revisions until the current version. New edition of a document will not show revised text in blue color. Current edition of a document shown on each page in footer.*

Revision: *- A change made to a part of document, where it is reflected with blue text or accompanied with a vertical line on right side of a document. Basic information on revisions (number and date) given in the List of effective Pages and indicated in header of affected page and in context itself.*

0.5. ABBREVIATION

Refer to Azerbaijan Aviation Rules – Radio Navigation Aids.

0.6. TERMS SHALL, SHOULD, MAY

The following terms shall have the meaning outlined below:

“Shall” - An action verb in the imperative sense means that the application of a rule or procedure or provision is mandatory.

“Should” - Means that the application of a procedure or provision is recommended.

“May” - Means that the application of a procedure or provision is optional.

0.7. ADMINISTRATION AND CONTROL

This document is published as a book on A4-sized sheets. The PDF files will be locked and signed to prevent changes.

This document is regularly revised and amended. All personnel must be familiarized with all revisions done.

This document will be Amended and Revised in accordance with requirements of “Documentation and Control” procedure.

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1. INTRODUCTION

1.1. This document is intended to provide guidance material on application of the radio-navigation aids standards based on the AAR-Radio Navigation Aids (hereafter AAR-RNAV Aids).

1.2. 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 prefix "indicated". Such usages are intended to convey the following meanings:*

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
Indicated course line. The locus of points in any horizontal plane at which the receiver indicator deflection is zero. ***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. ***Localizer course bend.*** A course bend is an aberration of the localizer course line with respect to its nominal position.	***ILS glide path bend.*** An ILS glide path bend is an aberration of the ILS glide path with respect to its nominal position.

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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 of the AAR-RNAV Aids have operational objectives as defined by Category I, II or III operations.

2.1.2. *Capabilities.* 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.

2.1.2.1. Equipage for additional objectives. 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.

2.1.2.2. Advanced operations. 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 of the AAR-RNAV Aids and extends down to the runway.

2.1.2.3. ILS classification system. 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 of the AAR-RNAV Aids. These additional capabilities can be exploited in order to permit operational use according to 2.1.2.1 and 2.1.2.2 to be approved down to and below the values stated in the operational objectives described in 2.1.1.

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

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 2.1.5 and Figure 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.*

2.1.3. *Course bends.* Localizer course bends should be evaluated in terms of the course structure specified in Chapter 3, 3.1.3.4 of the AAR-RNAV Aids. With regard to landing and roll-out 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 Facility Performance 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 Facility Performance 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 (Facility Performance Category II facilities) or Point D (Facility Performance 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 of the AAR-RNAV Aids, 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.*

2.1.4. *ILS glide path bends.* Bends should be evaluated in terms of the ILS glide path structure specified in Chapter 3, 3.1.5.4 of the AAR-RNAV Aids. With regard to Facility Performance Category I, 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 Facility Performance Categories II and III, 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).

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, 3.1.5.4 of the AAR-RNAV Aids, 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.*

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

— Figure 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 Facility Performance Categories I, II and III ILS.

— 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 1 for the region being evaluated. Figure 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:

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

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).

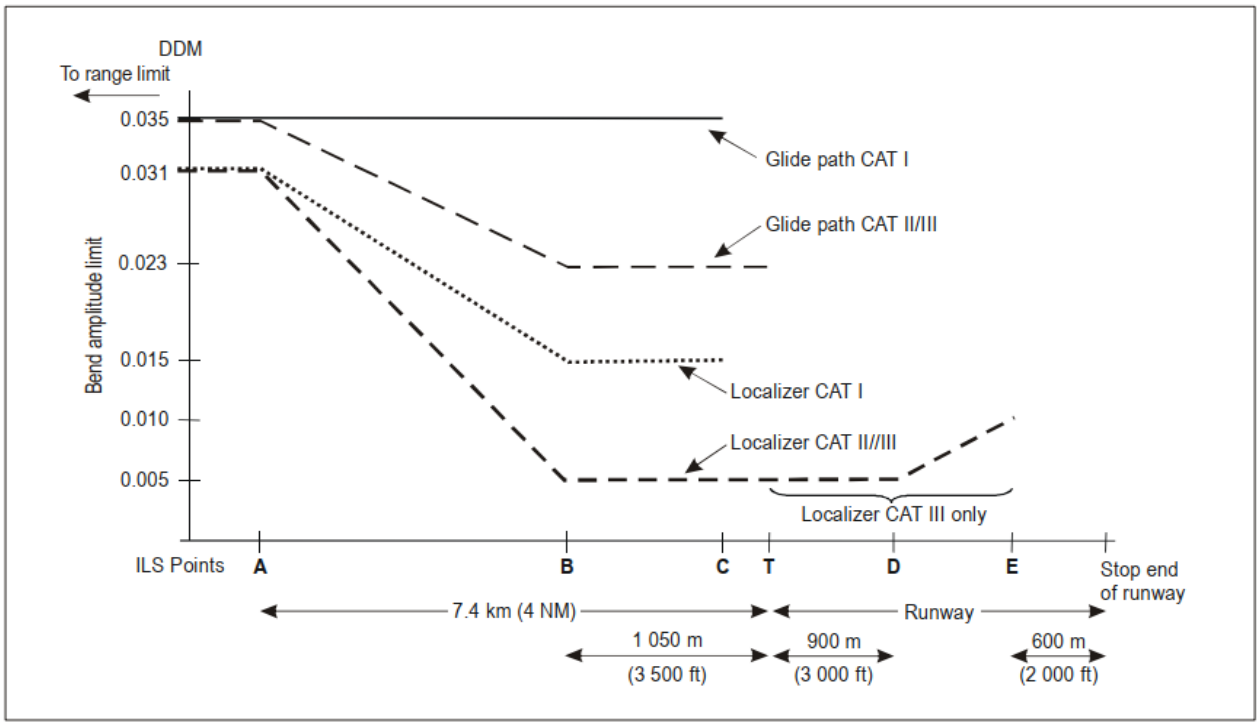


Figure 1. Localizer course and glide path bend amplitude limits

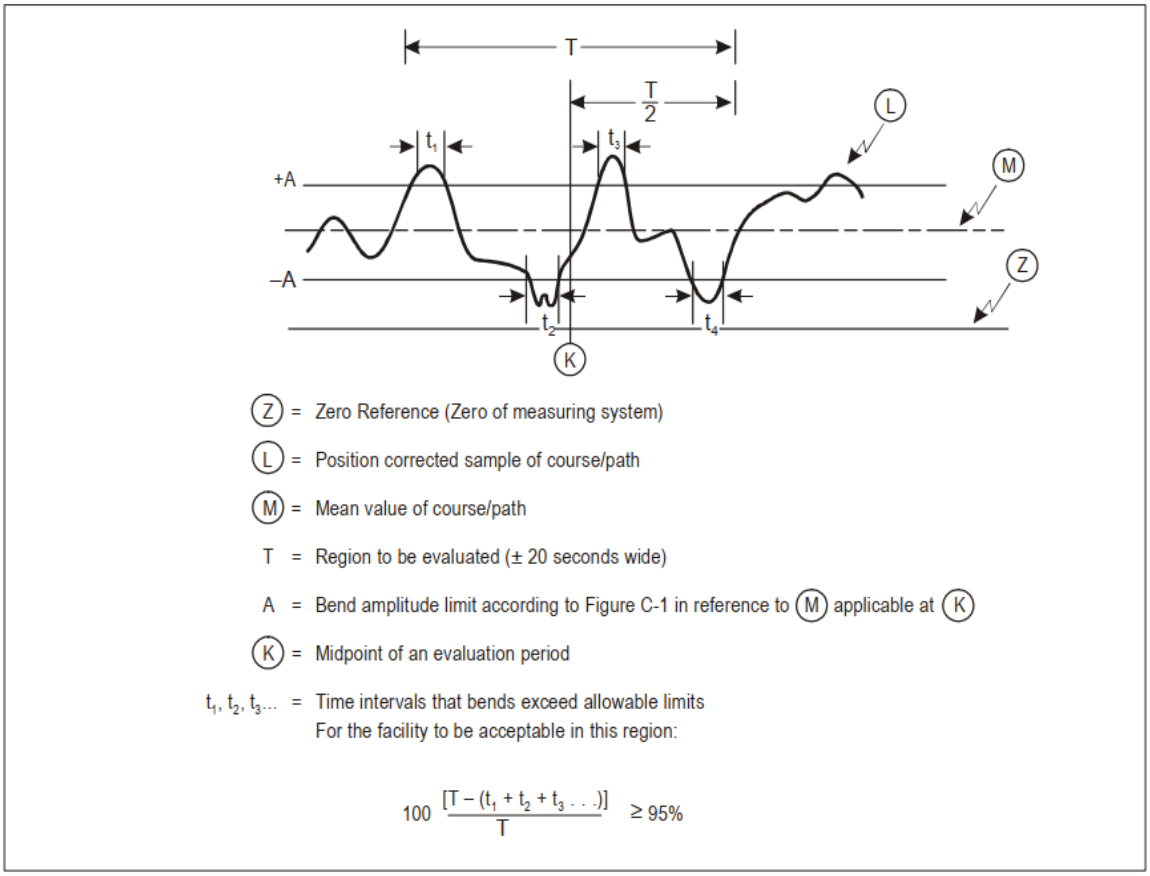


Figure 2. Evaluation of course/path bend amplitude

2.1.6. *Measurements filter.* 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 low-pass filter corner frequency (radians per second) for the receiver DDM output circuits and associated recording equipment of *V*/92.6, where *V* is the velocity in km/h of the aircraft or ground vehicle as appropriate.

2.1.7. *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 of the AAR-RNAV Aids, i.e. well within the monitor limit, can readily be achieved.

2.1.7.1. The choice of monitor limits is based on judgement, backed by 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 dayto-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 of the AAR-RNAV Aids. 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.

2.1.7.2. 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 of the AAR-RNAV Aids.

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 and birds;

   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).

2.1.7.3. 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.

2.1.8. *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 and 3.1.2.7.1 of the AAR-RNAV Aids specify the conditions under which radiation by localizers not in operational use may be permitted.

2.1.9. *ILS multipath interference*

Note 1: *This guidance material reflects how new larger aeroplanes (NLA) may impact the size of the ILS critical and sensitive areas. It also documents established engineering practices for determining critical and sensitive area dimensions, outlines the associated operational trade-offs, and presents indicative examples of the resulting sizes of the areas. In practice, however, the size of critical and sensitive areas at an aerodrome may need to be determined by specific assessments at that aerodrome.*

Note 2: *This guidance material is not intended to create a need to review established critical and sensitive area dimensions which have been demonstrated to be satisfactory at a particular aerodrome, unless the operational environment has evolved significantly (such as through the introduction of NLA operations at the aerodrome or the construction of new buildings) or the ILS installation has been changed in a way that may affect the dimensions of the areas.*

2.1.9.1. ILS environmental effects. Large reflecting objects within the ILS coverage volume, whether fixed objects or vehicles, including aircraft, can potentially cause degradation of the signal-in-space, through signal blockage and/or multipath interference, with the consequence that the signal-in-space tolerances defined in Chapter 3, 3.1 of the AAR-RNAV Aids may be exceeded. The amount of degradation is a function of the location, size and orientation of the reflecting surfaces, and of the ILS antenna characteristics. The objective of identifying critical and sensitive areas (see 2.1.9.2) and associated management procedures is to prevent such degradation and ensure that aircraft using the ILS can rely on the signal-in-space meeting the requirements of Chapter 3, 3.1 of the AAR-RNAV Aids.

2.1.9.2. ILS critical and sensitive areas. States differ in the way they choose to identify ILS protection areas. Practicesalso differ in how vehicle movement restrictions are managed. One method is to identify critical areas and sensitive areas as follows:

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 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: *In some States, the term "critical area" is used to describe an area that combines the critical and sensitive areas identified in this guidance material. In cases where the critical area overlaps operational areas, specific operational management procedures are required to ensure protection of aircraft using the ILS for intercept and final approach guidance.*

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.*

2.1.9.3. 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.

2.1.9.3.1 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.

2.1.9.3.2 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.

2.1.9.3.3 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.

2.1.9.4. Technical determination of critical and sensitive area dimensions. Critical and sensitive areas are normally calculated in the planning stage, prior to ILS installation, using computer simulation. A similar process is used when there are changes to the installation or to the environment. When using computer simulations, it is necessary to allocate the protection of individual parts of the

approach to either the critical or sensitive area. It is desirable to ensure that the combined critical and sensitive areas protect the entire approach. However, this may not be possible in all cases. Furthermore, if the logic described in 2.1.9.3 is used, this may lead to restrictively large critical areas. Some States have found that a reasonable compromise can be achieved using a different logic, whereby the critical area protects the segment from the edge of coverage down to 2 NM from the runway threshold, while the sensitive area protects the approach from 2 NM down to the runway. In this case, a sensitive area for Category I operations will exist and may require operational mitigation. Depending on the operational environment (such as timing between leading aircraft on runway roll-out and trailing aircraft on final approach), no particular measures may be needed. There may not necessarily be a direct link between the approach allocation used in simulations to determine critical and sensitive areas, and their operational management. It is a State's responsibility to define the relevant areas. If different disturbance acceptance criteria or different flight segment protections are to be applied, they must be validated through a safety analysis. The safety analysis must take all relevant factors into account, including the aerodrome configuration, traffic density and any operational issues or capacity restrictions.

2.1.9.5. Factors impacting the sizes of critical and sensitive areas. Localizer and glide path antennas with optimized radiation patterns, especially when combined with two-frequency transmitters, can be very effective in reducing the potential for signal disturbance and hence the sizes of the critical and sensitive areas. Other factors affecting the sizes of the areas include the category of approach and landing operation to be supported, the amount of static disturbance, locations, sizes and orientations of aircraft and other vehicles (particularly of their vertical surfaces), runway and taxiway layout, and antenna locations. In particular, the maximum heights of vertical aircraft tail surfaces likely to be encountered must be established, together with all possible orientations at a given location, which may include non-parallel or non-perpendicular orientations with respect to the runway. While critical and sensitive areas are evaluated in a two-dimensional (horizontal) context, protection should actually be extended to volumes, as departing aircraft and/or manoeuvring helicopters/aircraft can also cause disturbances to the ILS signals. The vertical profiles of the protection volumes depend on the vertical patterns of the transmitting arrays.

2.1.9.6. Allocation of multipath error budget. It is convenient to consider disturbances caused by mobile objects such as aircraft and other vehicles separately from the static disturbances caused by fixed objects such as buildings and terrain. Once the static multipath is known, the remainder can be allocated to dynamic disturbances. If measurements indicate that the real static multipath is significantly different from that assumed in the simulations, the allocation may need to be revised. In most cases, the root sum $^{\text{square}}$ combination of the disturbances due to fixed and mobile objects gives a more statistically valid representation of the total disturbance than an algebraic sum. For example, a limit of plus or minus 5μA for localizer course structure would be respected with plus or minus 3μA of disturbance due to static objects and an allowance of plus or minus 4μA for dynamic objects:

$$5\mu A = \sqrt{(3\mu A^2 + 4\mu A^2)}$$

2.1.9.7. Site study and computer simulations. Normally, a site specific study is conducted for a particular airport installation. The study will take into account different assumptions for the static multipath environment, airport topography, types and

effective heights of ILS arrays, and orientations of manoeuvring aircraft, such as runway crossings, 180° turns at threshold or holding orientations other than parallel or perpendicular. Simulation models 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. Air navigation service providers (ANSPs) will need to ensure that simulation models used have been validated by direct comparison with ground and flight measurements for a variety of specific situations and environments, and that the subsequent application of such models is conducted by personnel with appropriate engineering knowledge and judgement to take into account the assumptions and limitations of applying such models to specific multipath environments.

2.1.9.8. Changes in airport environment. Should major changes in the airport environment cause an increase in the static disturbances of the localizer and/or glide path, the sizes of the critical and sensitive areas may need to be redefined, with potential impact on airport efficiency or capacity. This is particularly significant when considering the location, size and orientation of proposed new buildings within or outside the airport boundary. It is recommended that suitable safeguarding criteria be employed to protect the ILS operations.

Note: *Example guidance can be found in ICAO EUR DOC 015 "European Guidance Material on Managing Building Restricted Areas".*

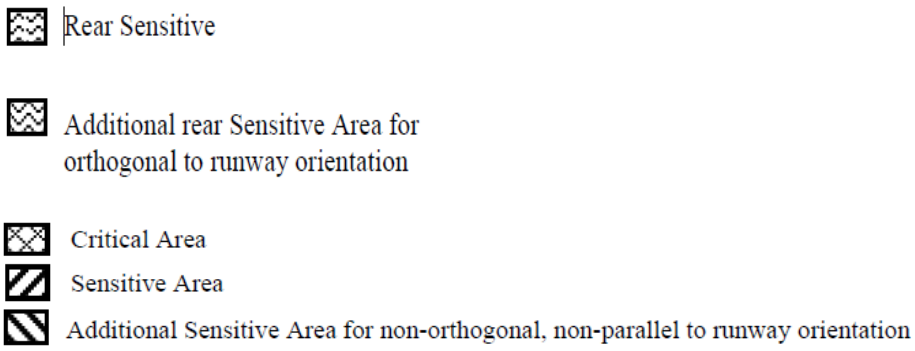
2.1.9.9. Typical examples of critical and sensitive areas. Figures 3 and 4 (including associated Tables 1, 2A and 2 B)) show examples of critical and sensitive areas for the different categories of operations and for defferent clases of vehicle/aircraft heights and several localizer and glide path antenna types. The calculation of these examples has been done with a simulation model using an exact method of resolution of ILS propagation equations applied to a 3D model of corresponding aircraft. The dimensions are based on assumptions of flat terrain, 3.0° glide path, allocations of 60 per cent of applicable tolerances for static multipath and 80 per cent for dynamic multipath, an approaching aircraft at 105 knots, i.e. with a 2.1 rad/s low-pass filter and an omnidirectional receiving antenna pattern. The examples consider typical orientations of reflecting surfaces of taxiing, holding and manoeuvring aircraft/large ground vehicles. The tail heights for the ground vehicles/small aircraft, medium, large and very large aircraft categories correspond to AAR- Aerodrome Standards reference code letters A, B/C, D/E and F, respectively, as detailed within FAA Advisory Circular 150/5300-13. In case of uncertainty about which category an aircraft belongs to for the purposes of critical and sensitive areas assessment, the tail height is the determining feature.

2.1.9.9.1 Purpose and correct application of typical examples. Since it will be rare that an actual installation fits exactly the assumptions used in these examples, adaptation to local conditions will be required. The examples serve to provide a rough order of magnitude indication of critical and sensitive area sizes, depending on how much local conditions differ from assumptions used in these examples. The example tables may also be used to assess the tools used in simulations, using the listed assumptions. In many installations, airports have established critical and sensitive areas which are different from those listed in these examples, through a combination of further technical optimizations, operational mitigations, experience, and safety assessments applicable to the

particular operational environment. In the case of new airport construction projects, potential conflicts of the example areas provided here with planned operational uses should lead to further evaluations, and may lead to implementing more advanced ILS antenna systems, for example wider aperture localizer antennas, including advanced designs such as very large aperture arrays. The typical examples provided here do not take such specific optimized systems into account. The tables differ slightly between the localizer and the glide path in terms of how different aircraft orientations are considered. These details are explained in the notes to Tables1 (note 9), 2A and 2B (note 8). In accordance with these notes, in some glide path cases the half-wingspan of aircraft needs to be added to ensure that no portion of the aircraft enters the critical or sensitive areas.

2.1.9.9.2 Limits of multipath assumptions used in example simulations. The allocation of 60 per cent for static and 80 per cent for dynamic multipath used in 2.1.9.6 represents a conservative approach which is suitable in locations where both types of multipath coincide. A different allocation may be appropriate for the glide path, especially in the case of flat terrain, as in that case the static multipath will be very small. In locations where static and dynamic multipath do not coincide, due to the specific layout of the airport, the full tolerance can be consumed by the dynamic multipath. A simulation tool able to model the complete environment (static and dynamic reflection sources) and to compute the combined effect may avoid having to apply the root sum square approximation. This may lead to an optimization of the critical and/or sensitive area dimensions.

2.1.9.9.3 Flight segment protection allocations used in example simulations. The examples given in Figure 3 for the localizer use a 2 NM transition point as described in 2.1.9.4. The examples given in Figure 4 for the glide path use a 0.6 NM transition point (corresponding to the Category I decision height). Depending on local operations, other transition points may be more suitable.



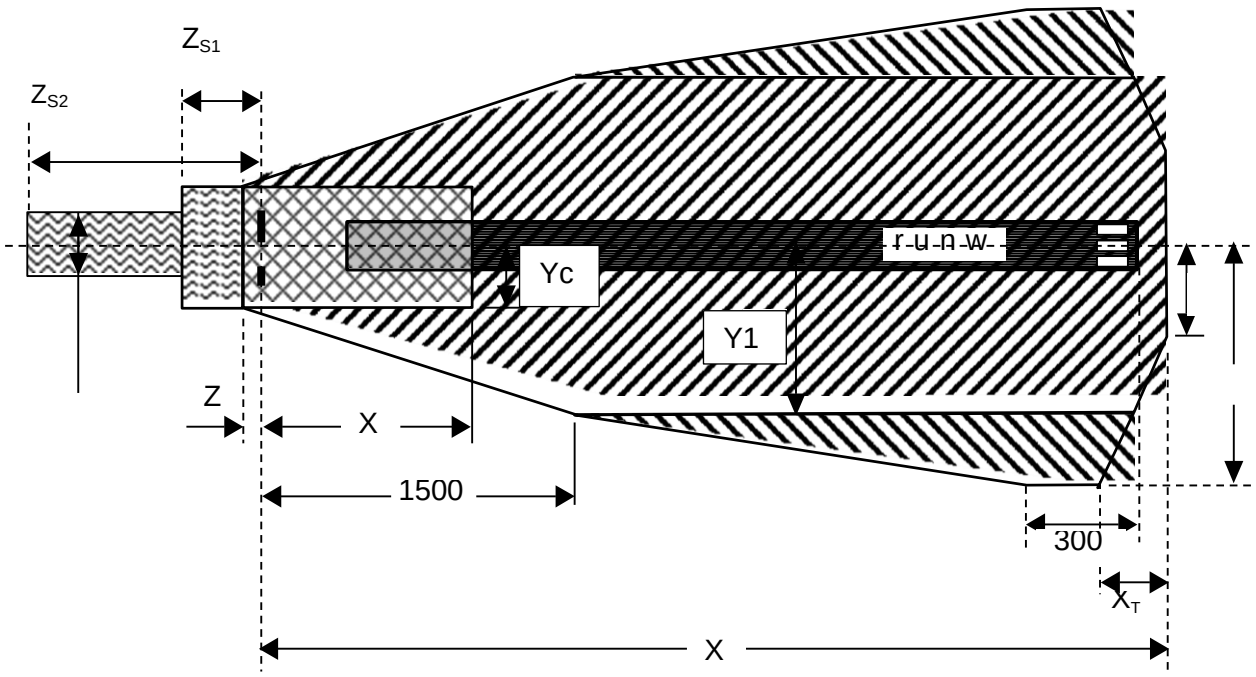


Figure 3. Example of localizer critical and sensitive area dimensions (values in associated Table 1)

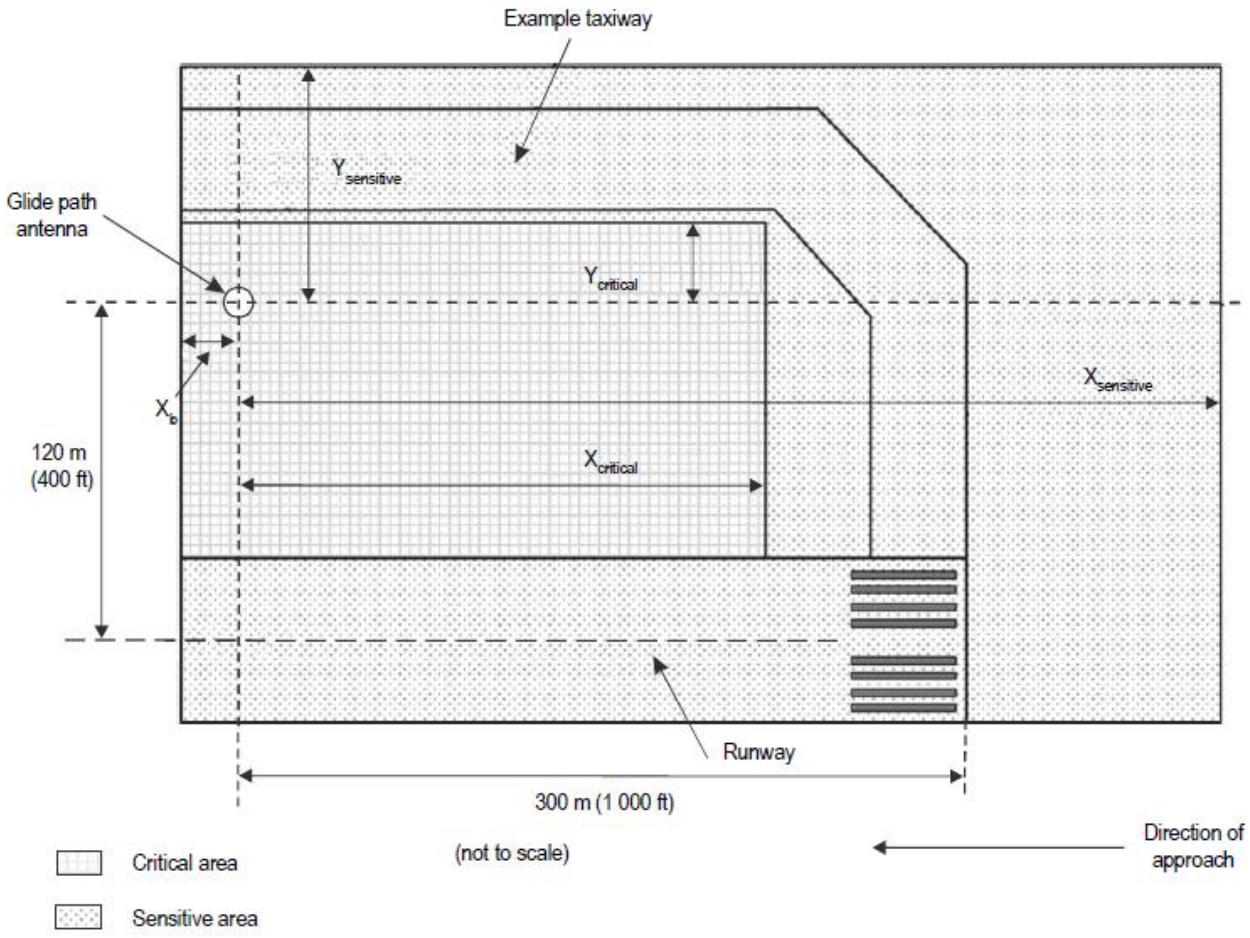


Figure 4. Example of glide path critical and sensitive areas dimension variations (values in assossiated Table 2)

Table 1. Typical localizer critical and sensitive area sizes

Aircraft / vehicle height	**H ≤ 6 m (see Note 1) Ground vehicle**			**6 m < H ≤ 14 m Medium aircraft**			**14 m < H ≤ 20 m Large aircraft**		**20 m < H ≤ 25 m Very large aircraft**	
Antenna aperture (see Note 3)	Small	Medium	Large	Small	Medium	Large	Medium	Large	Medium	Large
Critical area CAT I **XC**	180 m	65 m	45 m	360 m	200 m	150 m	500 m	410 m	660 m	580 m
ZC	10 m	10 m	10 m	35 m	35 m	35 m	50 m	50 m	60 m	60 m
(see Note 10) **YC**	50 m	15 m	20 m	110 m	25 m	25 m	50 m	30 m	55 m	40 m
Sensitive area CAT I **XS**	200 m	No sensitive area		500 m	No sensitive area		No sensitive area		1 300 m	1 100 m
Y1	40 m			90 m					90 m	50 m
Y2	40 m			90 m					90 m	50 m
ZS1	15 m			35 m					60 m	60 m
(see Note 7) **ZS2**	15 m			35 m					60 m	60 m

Aircraft/vehicle height	**H ≤ 6 m *(see Note1)* Ground vehicle**		**6 m < H ≤ 14 m Medium aircraft**		**14 m < H ≤ 20m Large aircraft**		**20 m < H ≤ 25m Very large aircraft**	
Antenna aperture (see Note 3)	Medium	Large	Medium	Large	Medium	Large	Medium	Large
Critical area CAT II **X_C**	75 m	55 m	200 m	200 m	500 m	475 m	750 m	675 m
Z_C	10 m	10 m	35 m	35 m	50 m	50 m	60 m	60 m
(see Note 10) **Y_C**	15 m	20 m	25 m	25 m	50 m	30 m	70 m	50 m
Sensitive area CAT II **X_S**	75 m	No senstive area	500 m	No sensitive area	2 100 m	1 400 m	Localizer to threshold distance	Localizer to threshold distance
Y_1	15 m		50 m		125 m ×K	60 m× K	180 m ×K	100 m ×K
Y_2	15 m		50 m		125 m ×K	60 m× K	180 m× K	125 m× K
Z_{S1}	15 m	15 m	35 m	35 m	60 m	60 m	70 m	70 m
(see Note 7) **Z_{S2}**	15 m	15 m	45 m	45 m	160 m	160 m	250 m	250 m

Aircraft/vehicle height	**H ≤ 6 m *(see Note 1)* Ground vehicle**		**6 m < H ≤ 14 m Medium aircraft**		**14 m < H ≤ 20 m Large aircraft**		**20 m < H ≤ 25 m Very large aircraft**	
Antenna aperture	Medium	Large	Medium	Large	Medium	Large	Medium	Large
Critical area CAT III	75 m	55 m	200 m	200 m	500 m	475 m	750 m	675 m
Z_C	10 m	10 m	35 m	35 m	50 m	50 m	60 m	60 m
(see Note 10) **Y_C**	15 m	20 m	25 m	25 m	50 m	30 m	70 m	50 m
Sensitive area CAT III **X_S**	100 m	No sensitive area	900 m	No sensitive area	3 100 m	3 100 m	Localizer to Threshold distance	Localizer to Threshold distance
Y_1	15 m		50 m		140 m	120 m	180 m ×K	150 m ×K
Y_2	15 m		50 m		160 m	120 m	260 m ×K	180 m ×K
Z_{S1}	15 m	15 m	35 m	35 m	60 m	60 m	70 m	70 m
(see Note 7) **Z_{S2}**	15 m	15 m	45 m	45 m	160 m	160 m	250 m	250 m

Notes:

1. *For vehicles smaller than 2.5 m in height, ZC = 3 m, assuming a 23 dB front/back ratio for the transmitting antenna for both course and clearance signals.*

2. *For systems with near-field monitor antennas, vehicles must not enter between the monitor antennas and the transmitting antenna.*

3. *Small aperture: 11 elements or less. Medium aperture: 12 to 15 elements. Large aperture: 16 elements or more. Simulations have been conducted using a commonly installed 12 element system for the medium and a commonly installed 20 element system for the large aperture cases. It is assumed that Category II/III operations are not conducted on runways equipped with small aperture localizers, and that aircraft as large as a 747 are not operating on such runways.*

4. *For localizer arrays with very low height, additional critical area will be needed due to the greater attenuation of the direct signal at low vertical angles.*

5. *A specific study for a particular airport, considering realistic orientations, static multipath environment, and airport topography and type of ILS antennas, may define different critical areas.*

6 K=√ loc to threshold distance／3 300m

7. *The rear dimensions for sensitive areas may be changed based on specific study results considering fielded antenna pattern characteristics. A directional array with a 23 dB front/back ratio is assumed for course and clearance signals.*

8. *Single aircraft taxiing or holding parallel to the runway does not generate out-of-tolerance signals.*

9. *Boundaries for critical areas or rear sensitive areas apply to the entire longitudinal axis (both tail and fuselage) of the interfering aircraft. Boundaries for sensitive areas apply only to the tail of the interfering aircraft.*

10. *The critical area semi-width, Yc, should exceed the actual physical dimension of the localizer antenna array by at least 10 m laterally (on both sides) in its portion between the localizer antenna array and the stop end of the runway.*

Table 2A. Example of glide path critical and sensitive area dimensions for parallel and perpendicular orientations

Aircraft/vehicle height	**Ground vehicle**		**Medium aircraft**		**Large aircraft**		**Very large aircraft**	
	H ≤ 6 m		**6 m < H ≤ 14m**		**14 m < H ≤ 20m**		**20 m < H ≤ 25 m**	
Glide path type	M-array	Null-ref	M-array	Null-ref	M-array	Null-ref	M-array	Null-ref
CAT I critical								
X	299 m	191 m	329 m	829 m	467 m	**1 117 m**	610 m	1 360 m
Y	29 m	29 m	**20 m**	**20 m**	**22 m**	**22 m**	**15 m**	**15 m**
CAT I sensitive								
X	299 m	399 m	**279 m**	**529 m**	**417 m**	717 m	**510 m**	760 m
Y	29 m	**15 m**	**20 m**	**20 m**	**22 m**	**16 m**	**15 m**	**15 m**
CAT II/III critical								
X	299 m	449 m	**329 m**	829 m	567 m	1 267 m	**660 m**	1 410 m
Y	29 m	29 m	**20 m**	**20 m**	**22 m**	**22 m**	**15 m**	**15 m**
CAT II/III								
X	299 m	449 m	429 m	**629 m**	**517 m**	**767m**	**560 m**	1 010 m
Y	29 m	29 m	**20 m**	**20 m**	**22 m**	**22 m**	**15 m**	**15 m**

Table 2B. Example of glide path critical and sensitive area dimensions for other orientations

Aircraft/vehicle height	**Ground vehicle**		**Medium aircraft**		**Large aircraft**		**Very large aircraft**	
	H ≤ 6 m		**6 m < H ≤ 14m**		**14 m < H ≤ 20m**		**20 m < H ≤ 25 m**	
Glide path type	M-array	Null-ref	M-array	Null-ref	M-array	Null-ref	M-array	Null-ref
CAT I critical								
X	298 m	191 m	297 m	829 m	444 m	**1 167 m**	591 m	1 360 m
Y	24 m	15 m	**39 m**	**39 m**	**35 m**	**55 m**	**34 m**	**55 m**
CAT I sensitive area								
X	298 m	394 m	**297 m**	**537 m**	**444 m**	717 m	**541 m**	710 m
Y	24 m	**24 m**	**39 m**	**39 m**	**25 m**	**18 m**	**24 m**	**24 m**
CAT II/III critical area								
X	298 m	443 m	**347 m**	829 m	544 m	1 267 m	**672 m**	1 410 m
Y	24 m	25 m	**39 m**	**39 m**	**35 m**	**55 m**	**34 m**	**55 m**
CAT II/III sensitive area								
X	298 m	445 m	297 m	**829 m**	**528 m**	**817 m**	**610 m**	1 010 m
Y	24 m	24 m	**39 m**	**39 m**	**25 m**	**25 m**	**24 m**	**24 m**

Notes:

1.X_b = 50 m and applies to both critical and sensitive areas for the large and very large aircraft category only. Otherwise, X_b = 0 m.

2.The ground vehicle category also applies to small aircraft. Simulations have approximated these aircraft or large ground vehicles using a rectangular box (4 m high – 12 m long – 3 m wide). Depending on local conditions, it may be possible to reduce especially Category I critical area dimensions such that taxiing or driving on the taxiway directly in front of the glide path antenna may be allowed.

3.Separate tables (2A and 2B) are given for parallel/perpendicular and for other orientations in order to not penalize parallel taxiway operations. To derive worst-case keep-out areas, the largest number among the two tables must be used. Values in Table 2B ("other orientations") that are larger than the corresponding ones in Table 2A ("parallel and perpendicular orientations") are highlighted in bold. Perpendicular orientations covered in Table 2A include only the orientation where the nose of the aircraft is pointing towards the runway. Perpendicular orientations with the tail of the aircraft pointing towards the runway are covered in Table2B. Table 2B also considers aircraft turning towards the runway for line-up at angles of 15, 30, 45, 60 and 75 degrees. Orientations causing the largest keep-out areas (i.e. worst aircraft orientation among all orientations causing out-of-tolerance signals) have been derived based on an A380 using an M-array antenna. Since the number of simulations

required to cover all possible orientations for all categories of vehicles over a large area would be excessive, the impact of worst-case orientations on the critical and sensitive areas may need to be verified taking into account the particular taxiway layout.

4. Simulations are referenced to the glide path antenna mast using a typical perpendicular distance to the runway centre line of 120 m and a nominal parallel distance from the runway threshold of 300 m. For different antenna-to-runway offsets, the critical and sensitive areas have to be shifted accordingly.

5. The edge of the runway closer to the glide path antenna defines the inner limit of the critical area. The farther edge of the runway defines the inner limit of the sensitive area. This sensitive area limit needs to be extended by another 50 m on the opposite side of the runway (starting from the runway centre line) for the large and very large aircraft categories when using a Null-Ref antenna.

6. Depending on simulation choices (transition point), the critical area may be larger than the sensitive area and impact associated management procedures.

7. In line with the operational logic described in 2.1.9.4 (no protection of the Category I glide path is required below decision height) as well as the observation that in Tables 1, 2A and 2B, the Category I critical area is typically equal or larger than the sensitive area, protecting the Category I sensitive area may not be necessary.

8. Boundaries for critical and sensitive areas apply to the entire aircraft (entire fuselage and wings).

2.1.10. *Reducing localizer bends and areas with insufficient difference in depth of modulation (DDM)*

2.1.10.1. 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. If this is the case, it is highly preferable to use two radio frequency carriers to provide the standard coverage and signal characteristics. Additional guidance on two radio frequency carrier coverage is provided in 2.7. If standard coverage requirements still cannot be met, reducing radiation in the direction of objects and accepting an increase of the lower vertical coverage boundaries as permitted in Chapter 3, 3.1.3.3.1 of the AAR-RNAV Aids may be employed.

2.1.10.2. Reducing standard localizer coverage. When using the coverage reduction option defined in Chapter 3, 3.1.3.3.1 of the AAR-RNAV Aids, care needs to be taken to ensure that the reduced coverage volume is consistent with the minimum altitudes published for the instrument approach procedure. Additionally, normal vectoring operations should not be terminated and a clearance to intercept the localizer should not be issued until within the promulgated coverage area. This is sometimes referred to as the operational service volume.

2.1.10.2.1 Operational considerations from an air traffic management perspective. Instrument approach procedures must be designed to take into account any reduction in localizer coverage permitted by the Standard in Chapter 3, 3.1.3.3.1 of the AAR-RNAV Aids.

This can be done either by ensuring that the procedure remains within localizer coverage or by providing alternative means to navigate. Consequently, a significant portion (3.7 km (2 NM) minimum) of the initial segment must be within localizer coverage. Localizer coverage needs to be available sufficiently in advance of the area where controllers usually

give the approach or intercept clearance to permit pilots to verify the Morse code identification (IDENT).

2.1.10.2.2 Operational considerations from a pilot/aircraft perspective. For aircraft equipped with automatic flight control systems (AFCS), localizer coverage needs to be available prior to the activation of the AFCS intercept mode (manual or automatic flight) and sufficiently in advance of the area where controllers usually give the approach or intercept clearance to permit checking the IDENT signal. When flying manually or when using an AFCS, pilots normally check the IDENT of the ILS facility and then wait to arm the mode enabling localizer intercept turn initiation and capture until after receiving the approach or intercept clearance. Ideally, additional aids (if included in the approach procedure) should permit a determination of the relationship between the aircraft position and the localizer front course line by the pilot.

2.2. ILS AIRBORNE RECEIVING EQUIPMENT

2.2.1. To ensure that the required operational objectives are achieved, it is necessary for the airborne receiving equipment to meet defined performance standards.

Note: *The relevant minimum operational performance standards for ILS receivers are detailed in RTCA DO-195 (1986) and EUROCAE ED-46B (including Amendments Nos. 1 and 2) for the localizer, in RTCA DO-143 (1970) and EUROCAE 1/WG 7/70 for the marker beacon, and in RTCA DO-192 (1986) and EUROCAE ED-47B (including Amendment No. 1) for the glide path receivers.*

2.2.2. Immunity performance of ILS localizer receiving systems to interference from VHF FM broadcast signals

2.2.2.1. With reference to Note 2 of 3.1.4.2, Chapter 3 of the AAR-RNAV Aids, 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 SM.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.

Note: *ITU Recommendation ITU-R SM.1140 can be found in the Manual on Testing of Radio Navigation Aids (Doc 8071), Volume I.*

2.2.2.2. 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 of the AAR-RNAV Aids. 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

SM.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.

Note: *ITU Recommendation ITU-R SM.1009-1 can be found in Doc 8071, Volume I.*

2.2.3. Localizer and glide path antenna polarization.

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.

2.3. ALARM CONDITIONS FOR ILS AIRBORNE EQUIPMENT

2.3.1. Ideally, a receiver alarm system such as a visual 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.*

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. *Lateral placement.* 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.

2.4.2. *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.

To limit the amount of curvature, the glide path antenna should not be located at an excessive lateral distance from the runway centre line.

2.4.3. *Procedure design.* Chapter 3, 3.1.5.1 of the AAR-RNAV Aids provides Standards and Recommended Practices for the glide path angle and the height of the ILS reference datum. The longitudinal position of the glide path antenna with respect to the runway threshold is established in order to provide the selected glide path angle and desired ILS reference datum height for the precision approach procedure designed for that runway. The precision approach procedure design may be modified to meet obstacle clearance requirements or to account for technical siting constraints for the glide path antenna (for example, crossing runways or taxiways). The procedure designer will take into account the acceptable glide path angle, threshold crossing height and runway length available as they relate to the type of aircraft expected to use the precision approach procedure.

2.4.4. *Longitudinal placement.* Assuming that the reflecting surface in the beam forming area can be approximated by a planar surface with appropriate lateral and longitudinal slopes, the required longitudinal position of the glide path antenna is then a function of the ILS reference datum above the runway threshold and of the projection of the glide path reflection plane along the runway centre line . This situation is described pictorially in Figure 5. In this figure, the line OP is defined by the intersection between the glide path reflection plane and the vertical plane along the runway centre line, and point O is at the same longitudinal distance from the threshold as the glide path antenna. Depending on the height and orientation of the reflection plane, point O may be above or below the runway surface.

For a planar reflecting surface, the longitudinal position of the glide path antenna is then calculated as follows:

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

where

D = the horizontal distance between O and P (equivalent to the longitudinal distance from the glide path antenna to the runway threshold);

H = the nominal height of the ILS reference datum above the runway threshold;

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

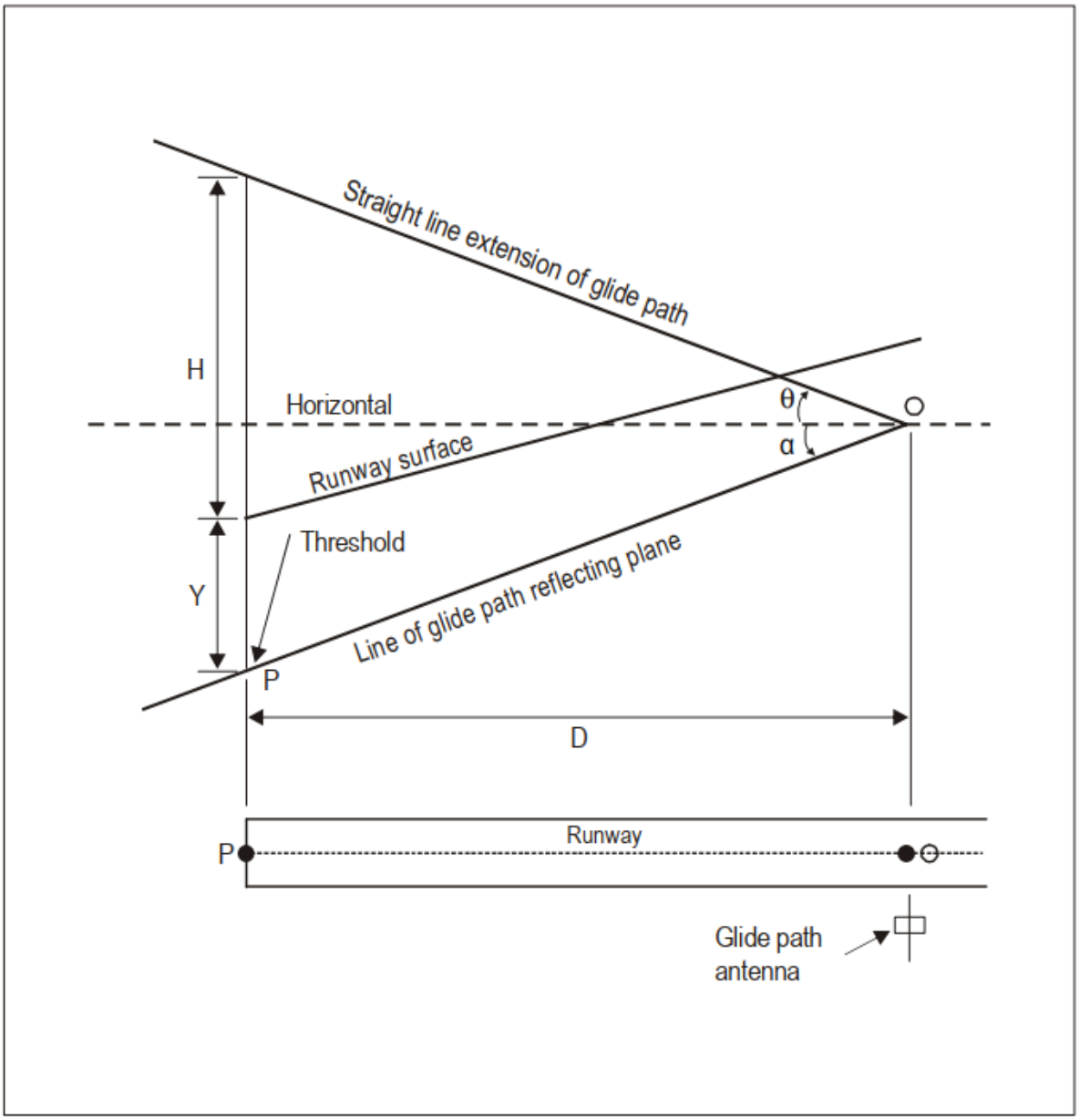


Figure 5. Glide path siting for sloping runway

θ = the nominal ILS glide path angle;

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

Note: *In the above formula α 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.*

2.4.5. The foregoing guidance material is based on the approximation of the reflecting surface by an appropriately oriented plane. Actual siting characteristics, such as significant lateral slope or an irregular rather than planar reflection surface, may require a more rigorous approach if the design goal for the height of the ILS reference datum is to be closely met. In challenging cases, mathematical modelling predictions of the effects of the siting conditions may be appropriate.

2.4.6. Typically, the glide path has some irregularities. 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.

2.4.7. 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.*

2.4.8. To reduce multipath interference to Facility Performance Category III glide paths and to reduce siting requirements and sensitive areas at these sites, it is desirable that the signals forming the horizontal radiation pattern from the Facility Performance 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.

2.4.9. Chapter 3, 3.1.5.3.1 of the AAR-RNAV Aids 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 systems will normally start the descent whenever a fly-up signal has decreased to less than about 10 microamperes.

2.4.10. 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 of the AAR-RNAV Aids, the provision of a separate clearance monitor and appropriate ground inspection and setting-up procedures.

2.4.11. 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) of the AAR-RNAV Aids 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.

2.5. DIAGRAMS

(Figures 6 to 12 illustrate certain of the Standards contained in Chapter 3 of the AAR-RNAV Aids)

For Facility Performance Categories I and II ILS the ratio should be greater than 0.903 and for Facility Performance Category III the ratio should be greater than 0.951.

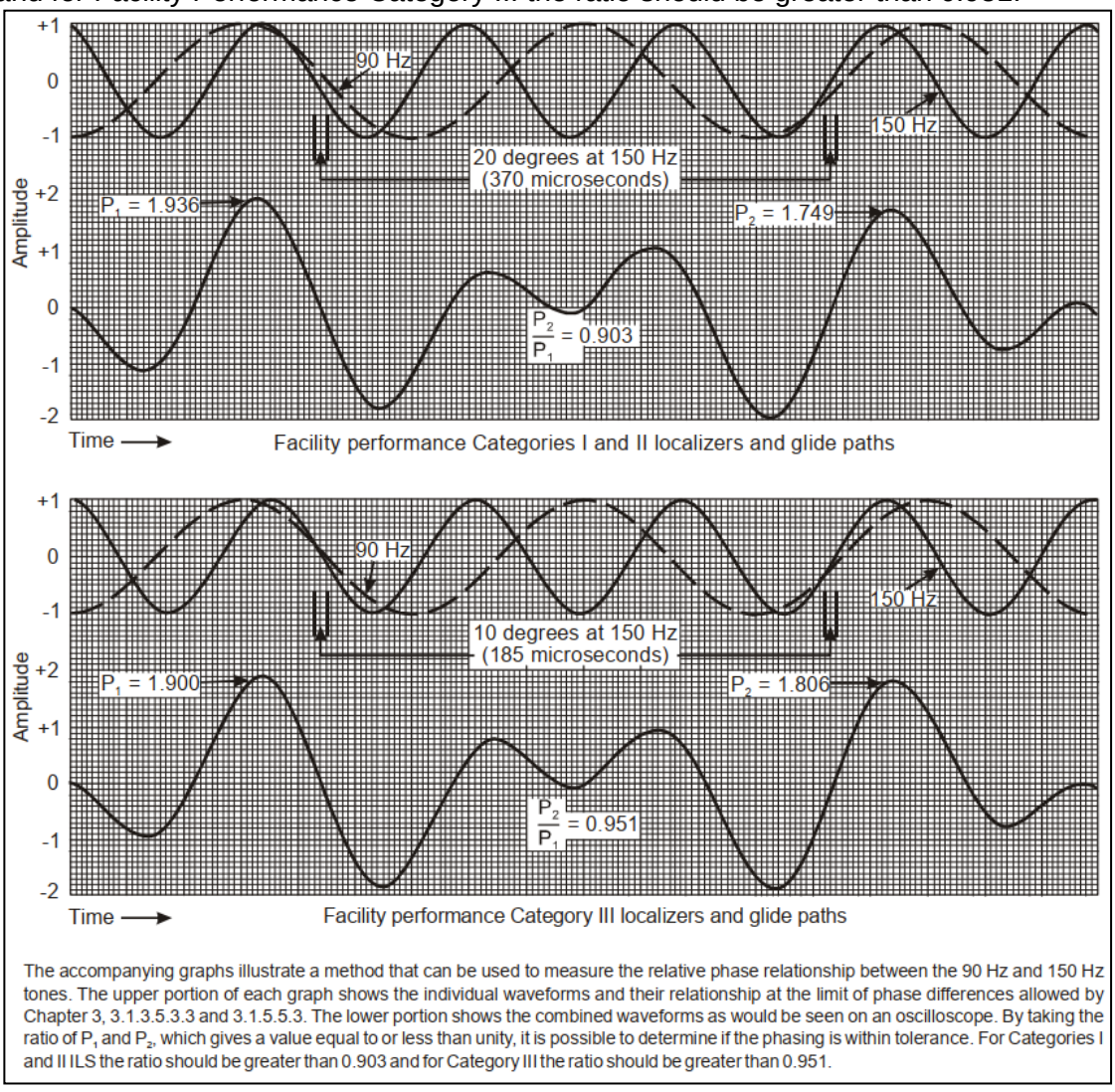


Figure 6. ILS wave forms illustrating relative audio phasing of the 90 Hz and 150 Hz tones

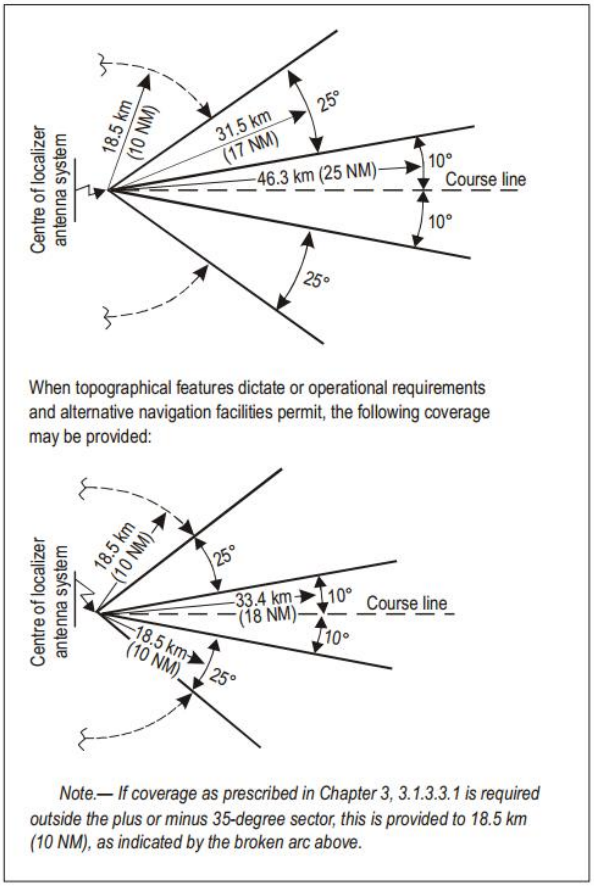


Figure 7A. Localizer coverage with respect to azimuth

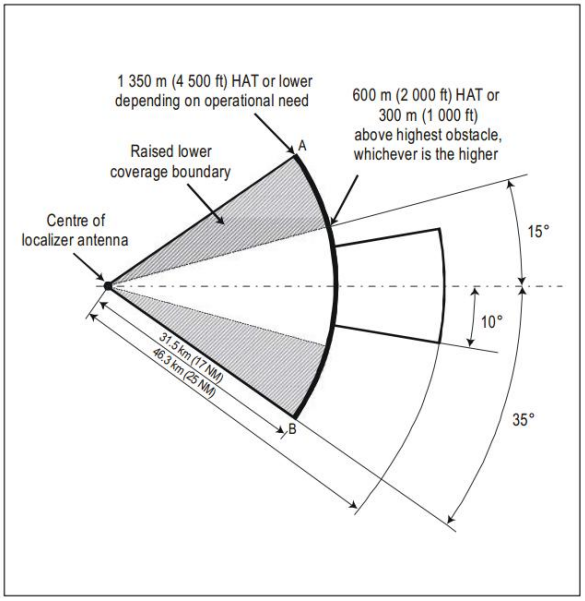


Figure 7B. Reduced localizer coverage with respect to azimuth

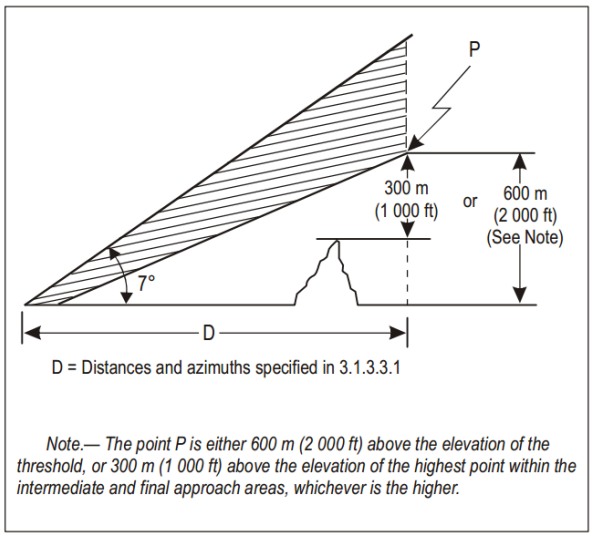


Figure 8A. Localizer coverage with respect to elevation

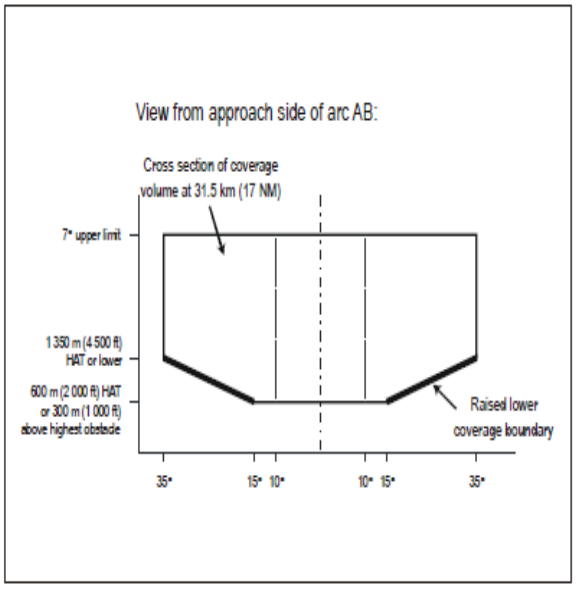


Figure 8B. Reduced localizer coverage with respect to elevation

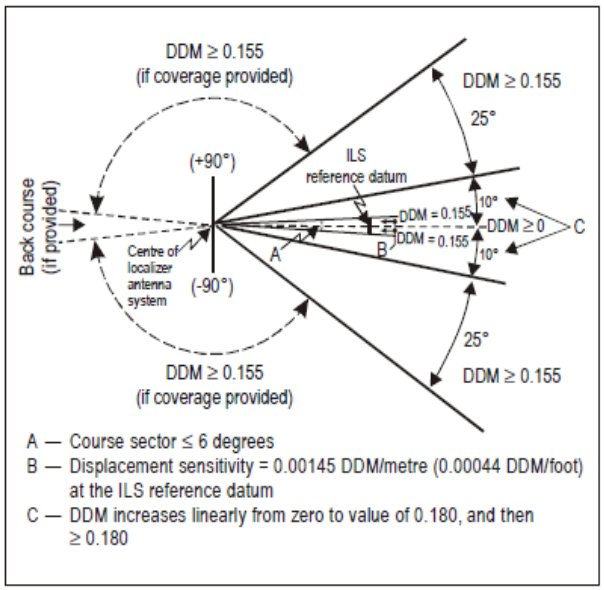


Figure 9. Diffrence in depth of the modulation and displasment sensitivity

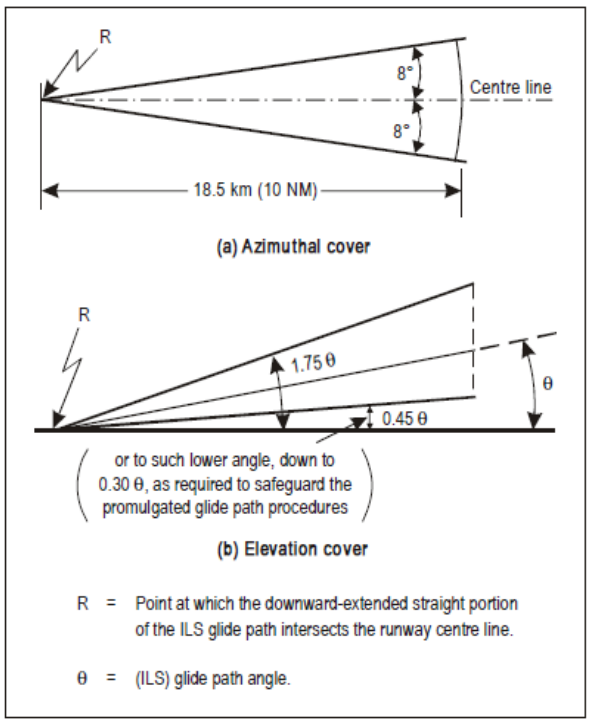


Figure 10. Glide path coverage

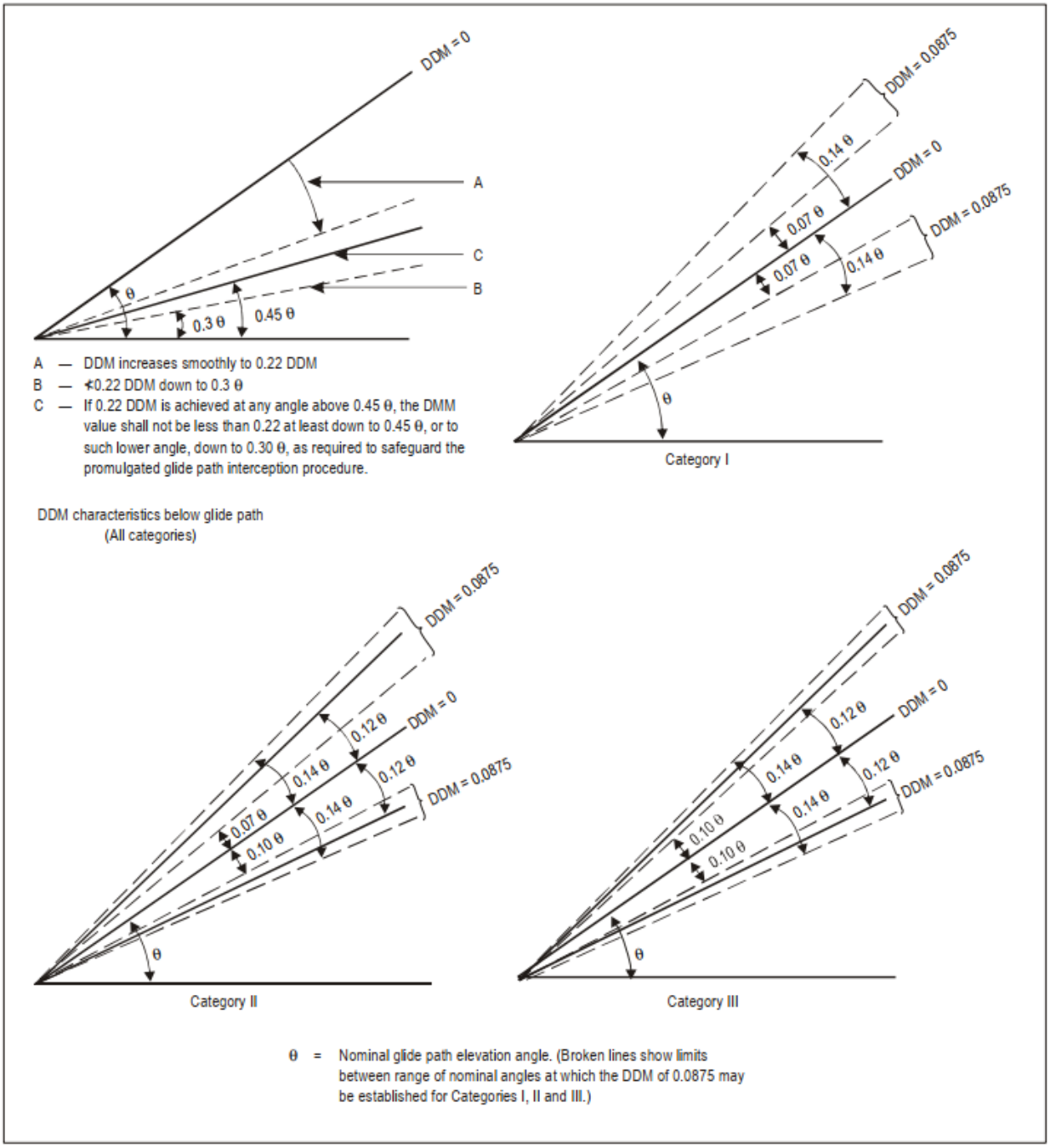


Figure 11. Glide path — difference in depth of modulation

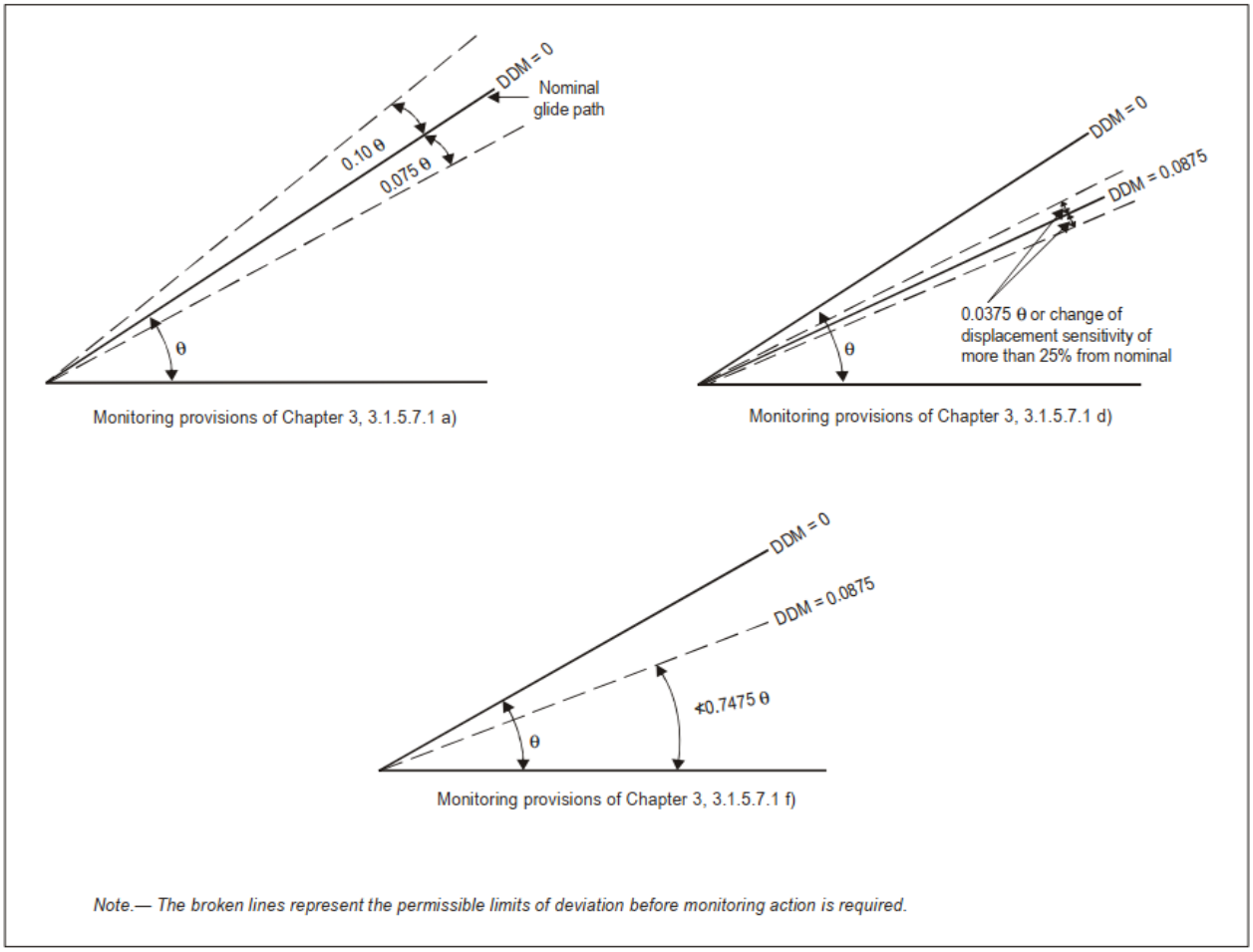


Figure 12. Glide path monitoring provisions

2.6. DEPLOYMENT OF ILS FREQUENCIES

2.6.1. In using the figures listed in Table 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 3 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.

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.

Table 3. 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 oferroneous 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.*

2.6.2.2.2 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 of the AAR-RNAV Aids, 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 separationm in 2.6.6.

Example: Referring to Chapter 3, 3.1.6.1.1 of the AAR-RNAV Aids, 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 Table3)

2.6.7. The application of the figures given in Table 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 and glide path facilities may achieve their coverage requirements by using two radiation field patterns, commonly known as the "course" and "clearance" patterns, transmitted using separate carrier frequencies spaced within the frequency channel. The course field pattern gives accurate course and displacement indications; the clearance field pattern provides displacement indications at angles beyond the limits of the course field pattern. 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.

2.7.6. *Monitoring dual frequency systems.* The dual frequency monitoring requirements in Chapter 3, 3.1.3.11.2 e) and 3.1.5.7.1 c) of the AAR-RNAV Aids specify monitor action for a power output of less than 80 per cent of normal, except that reductions can be accepted to 50 per cent of normal if certain performance requirements are met.

2.7.6.1. Monitoring the course and clearance transmitters for a 20 per cent reduction in power (approximately –1 dB) can be challenging if environmental and other effects such as large ambient temperature variations exist at the site. For example, temperature variations cause normal transmitter power output to vary and coaxial cable insertion losses to change. Even assuming no failure occurs in the transmitting system, the alarm limit occasionally may be exceeded, and this in turn may compromise continuity.

2.7.6.2. The alternative of monitoring at power reductions of up to 50 per cent appears very attractive, but must be used cautiously. Monitoring each transmitter independently at a 50 per cent reduction can allow a large change from the nominal power ratio between the two transmitters if uncorrelated failures occur.

This in turn may compromise the capture effect in the receiver, thus increasing structure errors or reducing clearance indications.

2.7.6.3. One solution is to use a monitoring scheme that limits the difference between the power output of the transmitters to approximately 1 dB (i.e. 80 per cent), while allowing both to decrease up to 3 dB (i.e. 50 per cent) if they change together. This method provides a greater tolerance for common mode effects such as cable loss changes due to temperature, and therefore increases continuity of service.

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. 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. Integrity and continuity of service are both key safety factors during the critical phase of approach and landing. 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.

2.8.1.4. The requirements for integrity and high continuity of service require highly reliable systems to minimize the probability of failure which may affect any characteristic of the total signal-in-space. It is suggested that States endeavour to achieve reliability with as large a margin as is technically and economically reasonable. 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.

2.8.2. ACHIEVEMENT AND RETENTION OF INTEGRITY 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. 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 provide fail-safe operations compliant with the Standards of Chapter 3, 3.1.3.11.4 and 3.1.5.7.4 of the AAR-RNAV Aids, and by carrying out maintenance checks on the monitor system performance at intervals which are determined by a design analysis.

2.8.2.4. A design 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) $I = 1 - P$

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

where

I = integrity

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

$M1$ = transmitter mean time between failures (MTBF)

$M2$ = 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 $T1 \geq T2$ the monitor system check may also be considered a transmitter check. In this case, therefore $T_1 = T_2$ and the formula would be:

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

2.8.2.5. 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. 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 to prevent the latter by critical and sensitive area protection are given in general terms at 2.1.9. With regard to radio interference it may be necessary to confirm periodically that the level of interference does not constitute a hazard.

2.8.2.7. 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 of the AAR-RNAV Aids. 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.

2.8.3. ACHIEVEMENT AND RETENTION OF CONTINUITY OF SERVICE LEVELS

2.8.3.1. A design analysis should be used to predict the MTBF and continuity of service of the ILS equipment. Before assignment of a level of continuity of service and introduction into Category II or III service, the mean time between outages (MTBO) of the Level 2,3or 4 ILS should be confirmed by evaluation in an operational environment. In this evaluation, an outage is defined as any unanticipated cessation of signal-in-space. This evaluation takes into account the impact of operational factors, i.e. airport environment, inclement weather conditions, power availability, quality and frequency of maintenance. MTBO is related to MTBF, but is not equivalent, as some equipment failures, such as a failure of a transmitter resulting in the immediate transfer to a standby transmitter may not necessarily result in an outage. For continuity of service Level 2, 3 or 4, the evaluation period should be sufficient to determine achievement of the required level with a high degree of confidence. One method to demonstrate that continuity standards are met is the sequential test method. If this method is used, the following considerations apply:

a) the minimum acceptable confidence level is 60 per cent. To achieve the confidence level of 60 per cent, the evaluation period has to be

longer than the required MTBO hours as stated in Table 2. Typically, these minimal evaluation periods for new and subsequent installations are for Level 2, 1 600 operating hours, for Level 3, 3 200 hours and for Level 4, 6 400 hours. To assess the seasonal influence of the environment, a minimal evaluation period of one year is typically required for a new type of installation in a particular environment. It may be possible to reduce this period in cases where the operating environment is well controlled and similar to other proven installations. 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. Once a higher confidence level is obtained for a type of installation, subsequent installation of the same type of equipment under similar operational and environmental conditions may follow shorter evaluation periods;

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.

2.8.3.2. An assigned continuity of service level 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. This weighs the MTBO for continuity of service purposes to be more relevant to the next approach, rather than computing MTBO over the lifetime of the equipment. If continuity of service deteriorates, the assigned designation should be reduced until improvements in performance can be effected.

2.8.3.3. Additional detailed guidance. Several States have published continuity of service policies and procedures. The following documents may be consulted for additional guidance and details:

a) *European Guidance Material on Continuity of Service Evaluation in Support of the Certification of ILS Ground Systems*, EUR DOC 012; and

b) *Instrument Landing System Continuity of Service Requirements and Procedures*, Order 6750.57A, United States Federal Aviation Administration.

2.8.4. 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 and 4. The localizer and glide path facilities each consist 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) confirming proper operation within the specified limits of the main transmitter and antenna system by means of majority voting among redundant monitors;

b) confirming operation of the standby equipment.

2.8.4.1. 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.

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

2.8.4.3. 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.

2.8.4.4. In the above example, the equipment would include provision to facilitate monitoring system checks at intervals specified by the manufacturer, consequent to the 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 of the AAR-RNAV Aids.

2.8.4.5. 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.

2.8.4.6. 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.

2.8.4.7. 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.

2.8.4.8. An equipment arrangement similar to that at 2.8.4, but with no transmitter redundancy, would normally be expected to achieve the objectives for continuity of service Level 2.

2.8.5. GUIDANCE RELATING TO LOCALIZER FAR FIELD MONITORS IS

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. 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 of the AAR-RNAV Aids 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 AAR-RNAV Aids. 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 AND/OR OTHER STANDARD RADIO NAVIGATION AIDS 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. If the DME associated with ILS uses a zero range offset, this facility has to be excluded from RNAV solutions.

2.11.1.1. 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.

2.11.1.2. 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.

2.11.1.3. 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.

2.11.1.4. 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.

2.11.2. In some locations, the Competent Authority may authorize the use of other means to provide fixes as detailed in the *Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS) (Doc 8168), such as NDB, VOR or GNSS. This may be useful in particular in locations where aircraft user equipage with DME is low, or if the DME is out of service.

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 of the AAR-RNAV Aids;

b) the extent of compliance with the provisions in Chapter 3, 3.1.3.4 and 3.1.5.4 of the AAR-RNAV Aids, 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.

2.14. 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 of the AAR-RNAV Aids.

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 of the AAR-RNAV Aids.

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

2.14.3. The ILS glide path 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 of the AAR-RNAV Aids.

b) A, B, C or T: this character defines the ILS points to which the glide path structure conforms to the path structure given at Chapter 3, 3.1.5.4.2 of the AAR-RNAV Aids, except the letter T, which designates the runway threshold. The points are defined in Chapter 3, 3.1.1 of the AAR-RNAV Aids.

c) 1, 2, 3 or 4: this number indicates the level of integrity and continuity of service of the glide path as defined in Chapter 3, 3.1.5.8 of the AAR-RNAV Aids and summarized in Table 2.

2.14.4. Examples

2.14.4.1. As an example, a Facility Performance Category II — localizerILS which meets the localizer course structure criteria appropriate to a Facility Performance Category III —localizerILS 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.

2.14.4.2. As an example, a Facility Performance Category I — glide path which meets the glide path structure criteria appropriate to a Facility Performance Category III — glide path down to ILS point “T” and conforms to the integrity and continuity of service objectives of Level 3 would be described as class I/T/3.

2.14.5. 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.

Table 4. 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	$1–4\times10^{-6}$ 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	$1–2\times10^{-6}$ 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.*

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.*

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3. MATERIAL CONCERNING VOR/DVOR

3.1. GUIDANCE RELATING TO VOR/DVOR EQUIVALENT ISOTROPICALLY RADIATED POWER (EIRP) AND COVERAGE

Note: *Unless specifically mentioned, all guidance material provided below applies to VOR and DVOR signals.*

3.1.1. The field strength specified at Chapter 3, 3.3.4.2 of the AAR-RNAV Aids, 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 dB
Power required at antenna	–110 dBW

The power required of minus 110 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. The necessary EIRP to achieve a field strength of 90 microvolts per metre (minus 107 dBW/m^2) is given in Figure 13. The field strength is directly proportional to the antenna elevation pattern. The actual radiation patterns of the antennas depend on a number of factors such as height of the antenna phase centre above ground level (AGL), surface roughness, terrain form and conductivity of ground and counterpoise. However, to account for lowest EIRP in notches between the lobes of the real elevation antenna pattern, a conservative value has been provided. Whenever more precise system data are available, a more precise estimation of range is permissible. Further guidance may be found in the *Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies (Doc 9718)*.

3.2. GUIDANCE IN RESPECT OF SITING OF VOR

3.2.1. VOR is susceptible to multipath interference from surrounding terrain, buildings, trees and power lines. The effect of this should therefore be considered when selecting a site for a new facility, and when considering the acceptability of proposed developments in the vicinity of established sites. Doppler VOR is more resistant to

multipath interference than conventional VOR and may be used to provide acceptable performance on more challenging multipath sites.

Note: *Guidance on siting of VOR is given in documents EUROCAE ED-52 (including Amendment No.1), United States Federal Aviation Administration Order 6820.10 and ICAO EUR DOC 015 (First Edition).*

3.2.2. The impact of wind farm developments on VOR is an increasing problem in many States due to the growth of interest in alternative energy sources. The impact of wind farms on VOR is difficult to assess for several reasons, including:

a) the cumulative effect of a group of turbines may be unacceptable even though the effect of each of the turbines may be acceptable individually;

b) worst-case errors may be experienced when the turbine blades are stationary (due to either high or low wind speeds). The actual error is a function of the orientation of the turbine and position of the turbine blades when stationary;

c) worst-case errors are likely to be experienced at the limit of coverage and at low elevation angles; and

d) it is unlikely that the worst-case errors can be confirmed by flight inspections due to the factors listed above.

3.2.3. Computer simulations can be used to assess the effect of wind farms on VOR using worst-case assumptions, as outlined above.

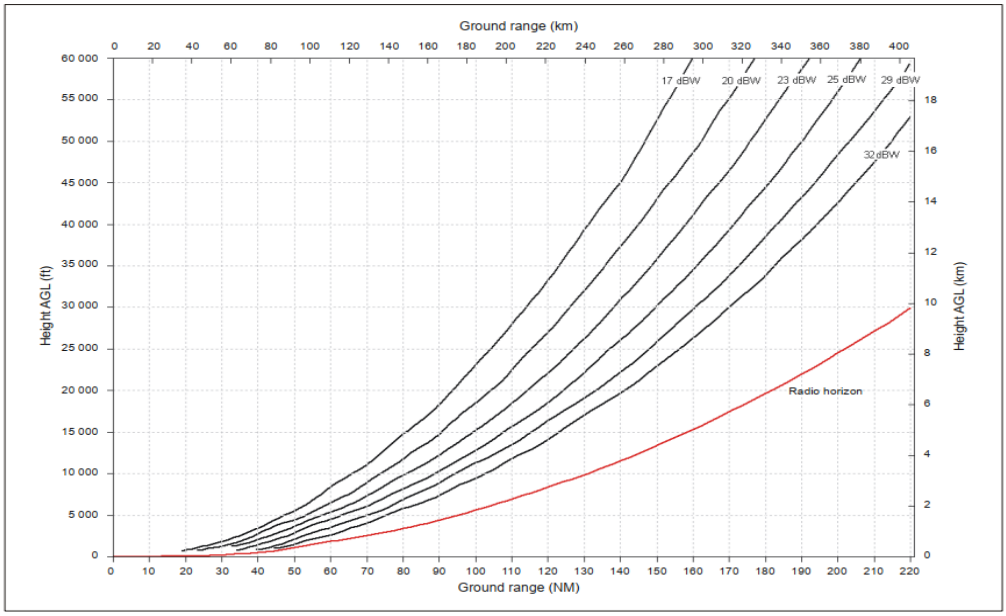


Figure 13. Necessary EIRP to achieve a field strength of 90 microvolts per metre (–107 dBW/m^2) as a function of height above and distance from the VOR/DVOR

Note 1: *The curves are based on the IF-77 propagation model with a 4/3 Earth radius which has been confirmed by measurements.*

Note 2: *The guidance provided assumes that the VOR/DVOR counterpoise height above ground level (AGL) that defines the antenna pattern is at 3 m (10 ft) AGL over flat terrain. Terrain shielding will reduce the achievable range.*

Note 3: *The transmitted power required to achieve an EIRP value as shown depends upon transmitting antenna gain and cable losses. As an example, an EIRP of 25 dBW can be achieved by a VOR with an output power of 100 W, a cable loss of 1 dB and an antenna gain of 6 dBi.*

3.3. [RESERVED]

3.4. CRITERIA FOR GEOGRAPHICAL SEPARATION OF VOR TYPE FACILITIES

3.4.1. In using the figures listed in Table 3, it must be noted that these are derived from the agreed formulae in respect of specific altitudes. In application of the figures, regional meetings would only afford protection to the extent of the operationally required altitude and distance and, by use of the formulae, criteria can be calculated for any distance or altitude.

3.4.2. The figures listed are calculated on the assumption that the effective adjacent channel rejection of the airborne receiver is better than 60 dB down at the next assignable channel.

3.4.3. The calculations are based on the assumption that the protection against interference afforded to the wanted signal from the unwanted signal is 20 dB, corresponding to a bearing error of less than 1 degree due to the unwanted signal.

3.4.4. It is recognized that, in the case of adjacent channel operation, there is a small region in the vicinity of a VOR facility, in which interference may be caused to an aircraft using another VOR facility. However, the width of this region is so small that the duration of the interference would be negligible and, in any case, it is probable that the aircraft would change its usage from one facility to the other.

3.4.5. The agreed formulae for calculating the geographical separations are as follows (nautical miles may be substituted for kilometres):

A — *minimum geographical separation (co-channel):*

either $2\,D_1 + \frac{20 - K}{S}$ km

where $D_1 > D_1 + \frac{K}{S}$

or $2D_2 + \frac{20 + K}{S} km$

where $D_1 < D_2 + \frac{K}{S}$

B — *geographical separation (adjacent channel):*

collocation case

$< \frac{40 - K}{S}$

non-collocated case

$> 2D_1 - \frac{40 + K}{S} km$

where $D_1 > D_2 + \frac{K}{S}$

or $2D_2 - \frac{40-K}{S} km$

where $D_1 < D_2 + \frac{K}{S}$

C — *geographical separation (adjacent channel)*

(receivers designed for 100 kHz channel spacing in a 50 kHz channel spacing environment)

If receivers having an effective adjacent channel rejection of no better than 26 dB are used (e.g. a 100 kHz receiver used in a 50 kHz environment), a figure of 6 should be substituted for the figure of 40 in the above adjacent channel formulae. In this instance, the geographical collocation formula should not be used as the protection afforded may be marginal.

This leads to the following formula:

$> 2D_1 + \frac{6+K}{S} km$ where $D_1 > D_2 + \frac{K}{S}$

or $2D_2 - \frac{6-K}{S} km$ where $D_1 < D_2 + \frac{K}{S}$

Table 5. Values of geographical separation distances for co-channel operation

Altitude m (ft)	S dB/km (NM)	VOR facilities of equal effective radiated power		VOR facilities which differ in effective radiated power by 6 dB				VOR facilities which differ in effective radiated power by 12 dB			
		Minimum geo--graphical separation between facilities is $2D_1 + \frac{20}{S}$ *if* $D_1 > D_2$ *or* $2D_2 + \frac{20}{S}$ *if* $D_2 > D_1$		Minimum geographical separation between facilities is $2D_1 + \frac{20-K}{S}$ *if* $D_1 > D_2 + \frac{K}{S}$ or $2D_2 + \frac{20+K}{S}$ *if* $D_1 < D_2 + \frac{K}{S}$				Minimum geographical separation between facilities is $2D_1 + \frac{20-K}{S}$ *if* $D_1 > D_2 + \frac{K}{S}$ or $2D_2 + \frac{20+K}{S}$ *if* $D_1 < D_2 + \frac{K}{S}$			
		K dB	20/S	K dB	K/S	2-K/S	(20+K)/S	KdB	K/S	(20-K)/S	(20+K)/S
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1 200 (4 000)	0.32 (0.60)	0	61 (33)	6	19 (10)	43 (23)	80 (43)	12	37 (20)	24 (13)	98 (53)
3 000 (10 000)	0.23 (0.43)	0	87 (47)	6	26 (14)	61 (33)	113 (61)	12	52 (28)	35 (19)	137 (74)
4 500 (15 000)	0.18 (0.34)	0	109 (59)	6	33 (18)	76 (41)	143 (77)	12	67 (36)	44 (24)	174 (94)
6 000 (20 000)	0.15 (0.29)	0	128 (69)	6	39 (21)	89 (48)	167 (90)	12	78 (42)	52 (28)	206 (110)
7 500 (25 000)	0.13 (0.25)	0	148 (80)	6	44 (24)	104 (56)	193 (104)	12	89 (48)	59 (32)	237 (128)
9 000 (30 000)	0.12 (0.23)	0	161 (87)	6	48 (26)	113 (61)	209 (113)	12	96 (52)	65 (35)	258 (139)
12 000 (40 000)	0.10 (0.19)	0	195 (105)	6	59 (32)	135 (73)	254 (137)	12	119 (64)	78 (42)	311 (168)
18 000 (60 000)	0.09 (0.17)	0	219 (118)	6	65 (35)	154 (83)	284 (153)	12	130 (70)	87 (47)	348 (188)

Note: *S, K and the sign of K are defined in 3.4.5.*

In the above formulae:

D1, D2=service distances required of the two facilities (km).

K = the ratio (dB) by which the effective radiated power of the facility providing D_1 coverage exceeds that of the facility providing D_2 coverage.

Note: *If the facility providing D_2 is of higher effective radiated power, then "K" will have a negative value.*

S = slope of the curve showing field strength against distance for constant altitude (dB/km).

3.4.6. The figures listed in Table 5 are based on providing an environment within which the airborne receivers can operate correctly.

3.4.6.1. In order to protect VOR 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.

3.4.6.2. In order to protect VOR 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.

3.4.7. Use of the figures given in 3.4.6 or other figures appropriate to other service distances and altitudes implies recognition of the basic assumptions made in this substitution of an approximate method of calculating separation, and the application of the figures will only be correct within the limitations set by those assumptions. The assumptions include that the change of field strength with distance (Factor "S") at various altitudes of reception is only valid for angles of elevation at the VOR of up to

about 5 degrees, but above the radio line of sight. 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.

3.4.8. The deployment of 50 kHz channel spacing requires conformity with Chapter 3, 3.3.2.2 and 3.3.5.7 and Chapter 4, 4.2.4 of the AAR-RNAV Aids. Where, due to special circumstances it is essential during the initial conversion period from 100 kHz channel spacing to 50 kHz channel spacing to take account of nearby VOR facilities that do not conform with Chapter 3, 3.3.2.2 and 3.3.5.7 and Chapter 4, 4.2.4 of the AAR-RNAV Aids, greater geographical separation between these and the new facilities utilizing 50 kHz channel spacing will be required to ensure a bearing error of less than one degree due to the unwanted signal. On the assumption that the sideband levels of the 9 960 Hz harmonic of the radiated signal of such facilities do not exceed the following levels:

9 960 Hz 0 dB reference

2nd harmonic –20 dB

3rd harmonic –30 dB

4th harmonic and above –40 dB

the separation formulae at 3.4.5 should be applied as follows:

a) where only receivers designed for 50 kHz channel spacing need to be protected, the value of 40 should be replaced by 20 in the formula at B — non-collocated case;

b) where it is necessary to protect receivers designed for 100 kHz channel spacing, the co-channel formula at A — co- channel case, should be applied for the range of altitudes for which protection is required.

3.4.9. When DME/N facilities and VOR facilities are intended to operate in association with each other, as outlined in Chapter 3, 3.5.3.3.4 of the AAR-RNAV Aids, and have a common service volume, both the co-channel and adjacent channel geographical separation distances required by the DME are satisfied by the separation distances of the VOR as computed in this section, provided the distance between VOR and DME does not exceed 600 m (2 000 ft). A potential interference situation may also occur with the implementation of DME “Y” channels since interference between two DME ground stations spaced 63 MHz apart could occur when transmitting and receiving on the same frequency (e.g. transmissions from channel 17 Y could interfere with reception on channels 80 X and 80 Y). To obviate any ground receiver desensitization due to this interference, a minimum ground separation distance of 18.5 km (10 NM) between facilities is necessary.

3.5. CRITERIA FOR GEOGRAPHICAL SEPARATION OF VOR/ILS FACILITIES

3.5.1. In using the figures of 3.5.3.1 and 3.5.3.2, it is to be borne in mind that the following assumptions have been made:

a) that the localizer receiver characteristic is as shown in 2.6.2, and the VOR receiver characteristic as shown in 3.4.2;

b) that the protection ratio for the ILS system and the VOR system is 20 dB as in 2.6.4 and 3.4.3, respectively;

c) that the protection point for ILS is at a service distance of 46.25 km (25 NM) measured along the line of use, and at an altitude of 1 900 m (6 250 ft).

Note: *With the advent of highly directional ILS localizer antenna arrays, the most critical protection point will not be along the extended runway centre line. Directive antennas result in critical protection points at maximum distance, either plus or minus 10 degrees or plus or minus 35 degrees off the runway centre line. Protection of these points should be examined during the frequency assignment process.*

3.5.2. Although international VOR and ILS facilities will not appear on the same frequency, it may occur that an international VOR facility may share temporarily the same frequency as, and on a comparable basis with, a national ILS facility. For this reason, guidance is given as to the geographical separation required not only for a VOR and an ILS facility separated by 50 kHz or 100 kHz, but also for co-channel usage.

3.5.3. Because of the differing characteristics of use of the two equipments, the criteria for minimum geographical separation of VOR/ILS to avoid harmful interference are stated separately for each facility where relevant.

3.5.3.1. Co-channel case

a) Protection of the ILS system requires that a VOR having an ERP of 17 dBW (50 W) be at least 148 km (80 NM) from the ILS protection point.

b) On the assumption that a VOR having an ERP of 17 dBW (50 W) is to be protected to a service distance of 46.25 km (25 NM) and an altitude of 3 000 m (10 000 ft), protection of the VOR system requires that the ILS be at least 148 km (80 NM) from the VOR.

c) If protection of the VOR is required to, say, 92.5 km (50 NM) and 6 000 m (20 000 ft), the ILS is to be at least 250 km (135 NM) from the VOR.

3.5.3.2. Adjacent channel case. Protection of the VOR system is effectively obtained without geographical separation of the facilities. However, in the case of:

a) a localizer receiver designed for 100 kHz channel spacing and used in an area where navaid assignments are spaced at 100 kHz, the protection of the ILS system requires that a VOR having an ERP of 17 dBW (50 W) be at least 9.3 km (5 NM) from the ILS protection point;

b) a localizer receiver designed for 100 kHz channel spacing and used in an area where assignments are spaced at 50 kHz, the protection of the ILS system requires that a VOR having an ERP of 17 dBW (50 W) be at least 79.6 km (43 NM) from the ILS protection point.

3.5.4. Use of the figures given in 3.5.3 or other figures appropriate to other service distances and altitudes implies recognition of the basic assumptions made in this substitution of an approximate method of calculating separation, and the application of the figures will only be correct within the limitations set by those assumptions. 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.

3.5.5. Protection of the ILS system from VOR interference is necessary where a VOR facility is located near an ILS approach path. In such circumstances, to avoid

disturbance of the ILS receiver output due to possible cross modulation effects, suitable frequency separation between the ILS and VOR channel frequencies should be used. The frequency separation will be dependent upon the ratio of the VOR and ILS field densities, and the characteristics of the airborne installation.

3.6. RECEIVING FUNCTION

3.6.1. *Sensitivity.* After due allowance has been made for aircraft feeder mismatch, attenuation loss and antenna polar diagram variation, the sensitivity of the receiving function should be such as to provide on a high percentage of occasions the accuracy of output specified in 3.6.2, with a signal having a field strength of 90 microvolts per metre or minus 107 dBW/m^2.

3.6.2. *Accuracy.* The error contribution of the airborne installation should not exceed plus or minus 3 degrees with a 95 per cent probability.

Note 1: *The assessment of the error contribution of the receiver will need to take account of:*

1) *the tolerance of the modulation components of the ground VOR facility as defined in Chapter 3, 3.3.5 of the AAR-RNAV Aids;*
2) *variation in signal level and carrier frequency of the ground VOR facility;*
3) *the effects of unwanted VOR and ILS signals.*

Note 2: *The airborne VOR installation is not considered to include any special elements which may be provided for the processing of VOR information in the aircraft and which may introduce errors of their own (e.g. radio magnetic indicator (RMI).).*

3.6.3. *Flag alarm operation.* Ideally, the flag alarm 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 might be satisfied is specified below.

3.6.3.1. The flag alarm movement is actuated by the sum of two currents, which are derived from the 30 Hz, and 9 960 Hz elements of the VOR bearing component signal and, therefore, the removal of these elements from the radiated carrier results in the appearance of the flags. Since the VOR ground monitor interrupts the bearing components when any unacceptable condition prevails on the ground, there will be an immediate indication within an aircraft when the system is unusable.

3.6.3.2. The flag alarm movement current is also dependent upon the AGC characteristics of the airborne equipment and any subsequent gain following the receiver's second detector. Thus, if with a correctly adjusted airborne receiver the flag is just out of view when receiving a VOR signal conforming to the modulation characteristics specified in Chapter 3, 3.3.5 of the AAR-RNAV Aids, the flags will again become visible in the event of a decrease in the receiver's overall gain characteristics.

Note: *Certain types of receivers employ warning indications other than mechanical flags to perform the functions described here.*

3.6.4. VOR receiver susceptibility to VOR and localizer signals

3.6.4.1. 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 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.*

3.6.5. Immunity performance of VOR receiving systems to interference from VHF FM broadcast signals

3.6.5.1. With reference to Chapter 3, 3.3.8 of the AAR-RNAV Aids, the immunity performance defined therein 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. Additional information can be found in ITU Recommendation ITU-R SM.1140, *Test procedures for measuring aeronautical 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*.

Note: *Receiver test procedures are also given in the VOR receiver MOPS (RTCA DO-196, and EUROCAE ED-22B).*

3.6.5.2. Commonly agreed formulae should be used to assess potential incompatibilities to receivers meeting the general interference immunity criteria specified in Chapter 3, 3.3.8 of the AAR-RNAV Aids. 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*.

3.7. VOR SYSTEM ACCURACY

3.7.1. *Purpose.* The following guidance material is intended to assist in the use of VOR systems. It is not intended to represent lateral separation standards or minimum obstacle clearances, although it may of course provide a starting point in their determination. The setting of separation standards or minimum obstacle clearances will necessarily take account of many factors not covered by the following material.

3.7.1.1. There is, however, a need to indicate a system use accuracy figure for the guidance of States planning VOR systems.

3.7.2. *Explanation of terms.* The following terms are used with the meanings indicated:

a) *VOR radial signal error.* The difference between the nominal magnetic bearing to a point of measurement from the VOR ground station and the bearing indicated by the VOR signal at that same point. The VOR radial signal error is made up of certain stable elements, such as course displacement error and most site and terrain effect errors, and certain random variable errors. The VOR radial signal error is associated with the ground station only and excludes other error factors, such as airborne equipment errors and pilotage element.

b) *VOR radial variability error.* That part of the VOR radial signal error which can be expected to vary about the essentially constant remainder. The radial variability error is the sum of the variable errors.

c) *VOR radial displacement error.* That part of the VOR radial signal error which is stable and may be considered as fixed for long periods of time.

d) *VOR airborne equipment error.* That error attributable to the inability of the equipment in the aircraft to translate correctly the bearing information contained in the radial signal. This error includes the contributions of the airborne receiver and the instrumentation used to present the information to the pilot.

e) *VOR aggregate error.* The difference between the magnetic bearing to a point of measurement from the VOR ground station and the bearing indicated by airborne VOR equipment of stated accuracy. More simply put, this is the error in the information presented to the pilot, taking into account not only the ground station and propagation path errors, but also the error contributed by the airborne VOR receiver and its instrumentation. The entire VOR radial signal error, both fixed and variable, is used.

f) *VOR pilotage element.* The error in the use of VOR navigation attributable to the fact that the pilot cannot or does not keep the aircraft precisely at the centre of the VOR radial or bearing indicated by the equipment.

g) *VOR system use error.* The square root of the sum of the squares (RSS) of VOR aggregate error and the pilotage element. This combination may be used to determine the probability of an aircraft remaining within specified limits when using VOR.

3.7.3. *Calculation of VOR system use accuracy*

3.7.3.1. The VOR system use accuracy is derived by considering the following error elements:

a) *VOR radial signal error* (Eg). This element consists of the radial displacement error and the radial variability error. It is determined by considering such factors as fixed radial displacement, monitoring, polarization effects, terrain effects and environment changes.

b) *VOR airborne equipment error* (Ea). This element embraces all factors in the airborne VOR system which introduces errors (errors resulting from the use of compass information in some VOR displays are not included).

c) *VOR pilotage element (Ep)*. The value taken for this element is that used in PANS-OPS (Doc 8168) for pilot tolerance.

Note: *A measurement error also exists, but in a generalized discussion of errors may be considered to be absorbed in the other error values.*

3.7.3.2. Since the errors in a), b), and c), when considered on a system basis (not any one radial) are independent variables, they may be combined on a root-sum-square method (RSS) when the same probability level is given to each element. For the purpose of this material, each element is considered to have a 95 per cent probability.

Therefore, the following formulae are derived:

VOR aggregate error = $\sqrt{Eg^2 + Ea^2}$

VOR system use error = $\sqrt{Eg^2 + Ea^2 + Ep^2}$

3.7.3.3. The following examples will derive only the VOR system use error but calculations can also be made to determine VOR aggregate error, if desired. By use of these formulae, the impact on the system of improvement or degradation of one of more error elements can be assessed.

Note: *All figures for VOR radial signal error are related to radials for which no restrictions are published.*

3.7.3.4. Subject to the qualifications indicated in 3.7.1, it is considered that a VOR system use accuracy of plus or minus 5 degrees on a 95 per cent probability basis is a suitable figure for use by States planning the application of the VOR system (see, however, 3.7.3.5). This figure corresponds to the following component errors:

VOR radial signal error:

plus or minus 3° (95 per cent probability), a value readily achieved in practice.

VOR airborne equipment error:

plus or minus 3° (95 per cent probability), system characteristics value (see 3.6.2).

VOR pilotage element:

plus or minus 2.5° (95 per cent probability), in accordance with PANS-OPS (see also 3.7.3.8).

3.7.3.5. While the figure of plus or minus 5 degrees on a 95 per cent probability basis is a useful figure based on broad practical experience and used by many States, it must be noted that this figure may be achieved only if the error elements which make it up remain within certain tolerances. It is clear that, if the errors attributable to the VOR system elements are larger than the amounts noted, the resulting VOR system use error will also be larger. Conversely, where any or all of the VOR system error elements are smaller than those used in the above computation, the resulting VOR system use error will also be smaller.

3.7.3.6. The following examples, also derived from practical experience, provide additional planning guidance for States:

A.— *VOR radial signal error:*

plus or minus 3.5° (95 per cent probability), used by some States as the total ground system error.

VOR airborne equipment error:

plus or minus 4.2° (95 per cent probability), recognized in some States as the minimum performance figure for some classes of operations.

VOR pilotage element:

plus or minus 2.5° (95 per cent probability), in accordance with PANS-OPS (see also 3.7.3.8).

Calculated VOR system use accuracy:

plus or minus 6° (95 per cent probability).

B. — *VOR radial signal error:*

plus or minus 1.7° (95 per cent probability), based on extensive flight measurements conducted in one State on a large number of VORs.

VOR airborne equipment error:

plus or minus 2.7° (95 per cent probability), achieved in many airline operations.

VOR pilotage element:

plus or minus 2.5° (95 per cent probability), in accordance with PANS-OPS (see also 3.7.3.8).

Calculated VOR system use accuracy:

plus or minus 4° (95 per cent probability).

3.7.3.7. More realistic application of the VOR system may be achieved by assessing the errors as they actually exist in particular circumstances, rather than by using all-embracing generalizations which may give unduly optimistic or pessimistic results. In individual applications, it may be possible to utilize a system use accuracy value less than plus or minus 5 degrees if one or more of the error elements are smaller than the values used to compute the plus or minus 5 degrees. Conversely, a system use accuracy value greater than plus or minus 5 degrees will be necessary where it is known that radials are of poor quality or significant site errors exist, or for other reasons. However, in addition to this advice a warning is also essential regarding the use of lower values of individual elements in the system (for example, the radial signal error) on the assumption that an overall improvement in system accuracy will occur. There is considerable evidence that this may not be the case in some circumstances and that lower system accuracy values should not be applied without other confirmation (e.g. by radar observation) that an actual improvement in overall performance is being achieved.

3.7.3.8. It is to be noted that in angular systems such as the VOR, the pilotage element error, expressed in angular terms, will be greater as the aircraft nears the point source. Thus, while ground system and airborne error contributions, expressed in angular terms, are for all practical purposes constant at all ranges, it is necessary when considering the overall system use accuracy figures to take into account the larger pilotage element error occurring when the aircraft is near the VOR. However, these larger pilotage element errors do not result in large lateral deviations from course when near the facility.

3.8. CHANGEOVER POINTS FOR VORS

Guidance on the establishment of changeover points on ATS routes defined by VORs is contained in Annex 11, Attachment A.

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4. PRECISION APPROACH RADAR SYSTEM

Figures 14 to 18 illustrate certain of the Standards contained in Chapter 3, 3.2.

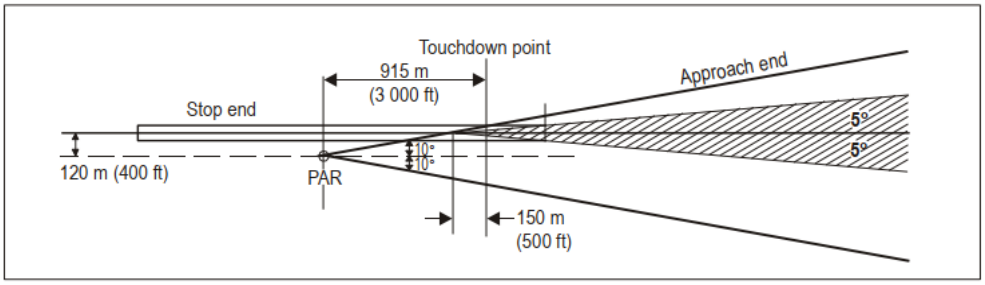


Figure 14. Minimum set-back of PAR with respect to touchdown for offset of 120 m (400 ft) when aligned to scan plus or minus 10 degrees on QDR of runway

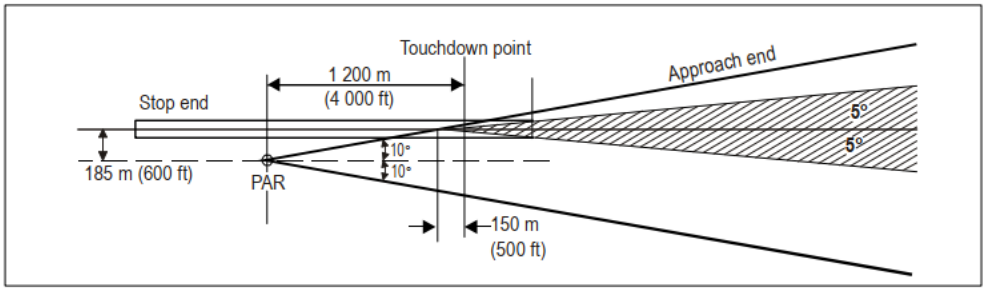


Figure 15. Minimum set-back of PAR with respect to touchdown for offset of 185 m (600 ft) when aligned to scan plus or minus 10 degrees on QDR of runway

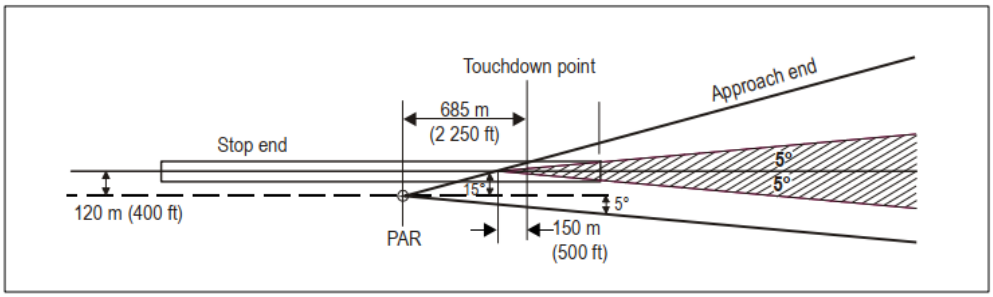


Figure 16. Minimum set-back of PAR with respect to touchdown for offset of 120 m (400 ft) when aligned to scan 5 degrees and 15 degrees on QDR of runway

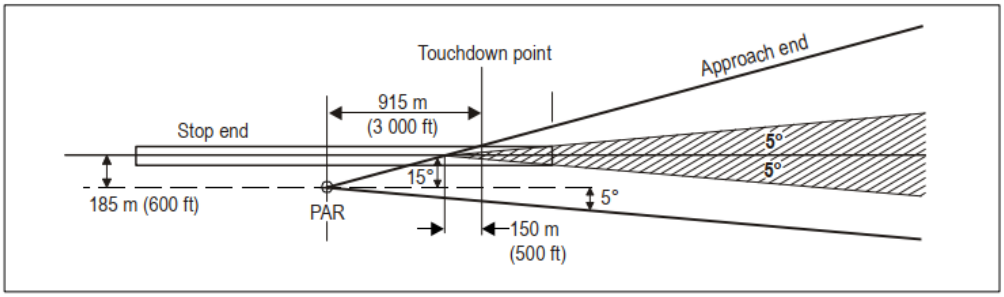


Figure 17. Minimum set-back of PAR with respect to touchdown for offset of 185 m (600 ft) when aligned to scan 5 degrees and 15 degrees on QDR of runway

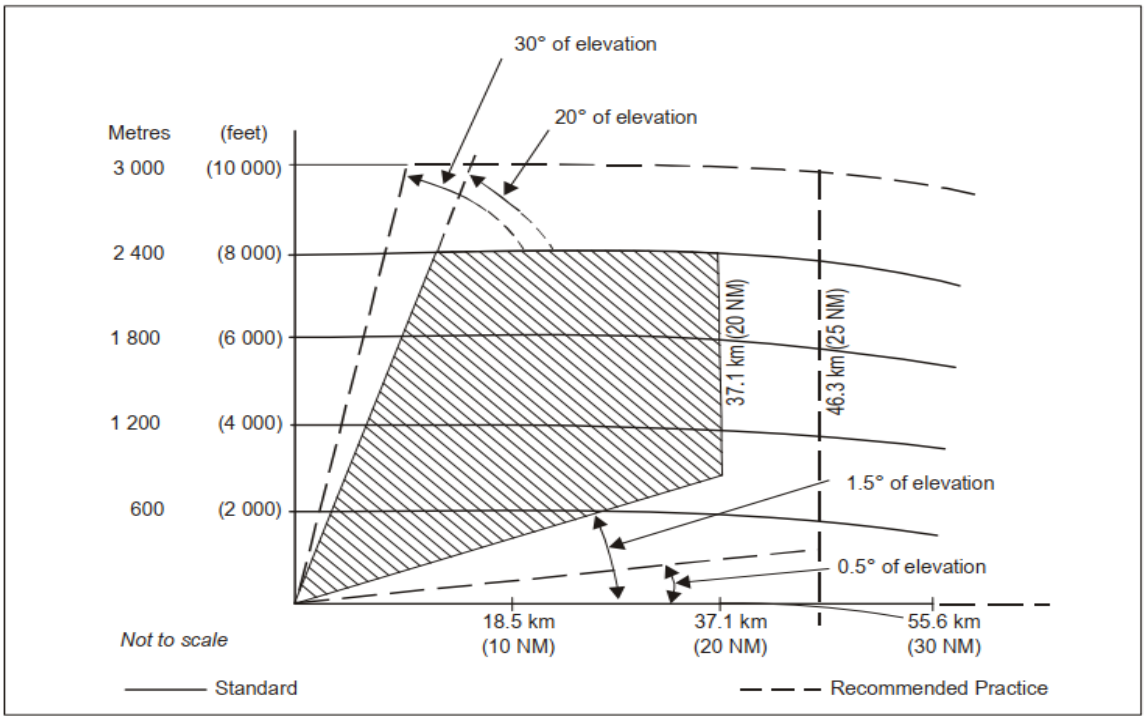


Figure18. SRE of precision approach radar system — vertical coverage on a 15 m^2 echoing area aircraft

5. SPECIFICATION FOR 75 MHZ MARKER BEACONS (EN-ROUTE)

5.1. MARKER BEACON ANTENNA ARRAYS

5.1.1. *General.* The following describes types of marker antenna arrays that are frequently used in current practice. These types are the simplest forms meeting normal requirements; in special cases, arrays having a better performance (see Note to 5.1.4) may be required.

5.1.2. Z marker beacons

a) *Radiating system.* A radiating system consisting of two horizontal dipole arrays crossed at right angles, each comprising two co-linear half-wave radiating elements with centres spaced approximately a half wavelength apart and mounted one-quarter wavelength above the counterpoise. The currents in the dipoles and their respective elements are adjusted so that:

1) the current in one set of dipole arrays relative to that in the other set is equal but differs in time phase by 90 degrees;

2) the currents in the radiating elements of a particular dipole array are equal and in time phase.

b) *Counterpoise.* A square counterpoise with minimum dimensions of 9 m × 9 m, usually elevated about 1.8 m (6 ft) above the ground and, if fabricated from wire mesh, with the dimension of the mesh not exceeding 7.5 cm × 7.5 cm.

5.1.3. Fan marker beacons for use only at low altitudes (low power fan marker beacons). A radiating system capable of providing the field strengths indicated in Chapter 3, 3.1.7.3.2 of the AAR-RNAV Aids.

5.1.4. Fan marker beacons for general use (high power fan marker beacons)

a) *Radiating system.* A radiating system consisting of four horizontal co-linear half-wave (approximate) radiating elements mounted approximately one-quarter wavelength above the counterpoise. The current in each of the antenna elements should be in phase and should have a current ratio of 1:3:3:1.

Note: *The current distribution between elements and their height above the counterpoise may be altered to provide patterns for specific operational requirements. Improved vertical patterns for certain operational needs may be achieved by adjusting the height of the dipole arrays above the counterpoise to a value of one-quarter wavelength or greater, but less than a half wavelength.*

b) Counterpoise. a rectangular counterpoise with minimum dimensions of 6 m × 12 m, usually elevated about 1.8 m (6 ft) above the ground and, if fabricated from wire mesh, with the dimension of the mesh not exceeding 7.5 cm × 7.5 cm.

5.2. IDENTIFICATION CODING FOR FAN MARKER BEACONS ASSOCIATED WITH A FOUR-COURSE RADIO RANGE

5.2.1. Fan marker beacons located on the legs of a four-course radio range do not normally require an identification signal relating to a particular geographic location, but only a signal that will indicate the leg with which they are associated.

5.2.2. In the case of a four-course radio range having not more than one marker on any leg, it is current practice to identify a marker by a single dash if on the leg bearing true north or nearest to north in a clockwise direction (east), and to identify a marker on other legs by two, three or four dashes according to whether the leg with which it is associated is the second, third or fourth leg from north in a clockwise direction. Where more than one fan marker beacon is associated with one leg of a four-course radio range, the marker nearest to the station is identified by dashes only, the next nearest by two dots preceding the dashes, and the third by three dots preceding the dashes, and so on.

Note: *In certain special circumstances, the above coding system may lead to ambiguities due to two markers associated with the legs of different but overlapping radio ranges being geographically close together. In such cases, it is desirable to use a distinctive identification coding with one of the marker beacons.*

6. MATERIAL CONCERNING NDB

6.1. GUIDANCE MATERIAL ON NDB FIELD STRENGTH REQUIREMENTS IN LATITUDES BETWEEN 30° N AND 30° S

6.1.1. In order to obtain a satisfactory service within the rated coverage of an NDB located in latitudes between 30^0 N and 30^0 S, a minimum value of field strength of 120 microvolts per metre would be required, except where practical experience in the operation of NDBs over several years has revealed that a minimum field strength of 70 microvolts per metre would be adequate to meet all the operational needs. In some specific areas, field strength values considerably in excess of 120 microvolts per metre would be required.

6.1.2. The field strength of 120 microvolts per metre is based upon practical experience to date and is a compromise between what is technically desirable and what it is economically possible to provide.

6.2. GUIDANCE MATERIAL ON MEANING AND APPLICATION OF RATED AND EFFECTIVE COVERAGE

6.2.1. Rated coverage

6.2.1.1. The rated coverage as defined in Chapter 3, 3.4.1 of the AAR-RNAV Aids, is a means of designating actual NDB performance, in a measurable way, which is dependent on the frequency, the radiated power, and the conductivity of the path between the NDB and a point on the boundary where the minimum value of field strength is specified.

6.2.1.2. The rated coverage has been found to be a useful means of facilitating regional planning and, in some instances, may be related to effective coverage.

6.2.1.3. The application of rated coverage to frequency planning is governed by the following criteria:

6.2.1.1.1 Frequencies should be deployed having regard to the rated coverage of the NDBs concerned, so that the ratio of the signal strength of any NDB at the boundary of its rated coverage to the total field strength due to co-channel stations and adjacent channel stations (with an appropriate allowance for the selectivity characteristics of a typical airborne receiver) is not less than 15 dB by day.

6.2.1.1.2 The figures set forth should be applied, as appropriate, in determining the allowance to be made for the attenuation of adjacent channel signals.

6.2.1.4. It follows from the application of rated coverage to frequency deployment planning that, unless otherwise specified, protection against harmful interference can only be ensured within the rated coverage of an NDB and, then, only if the radiated power of the NDBs is adjusted to provide within reasonably close limits the field strength required at the limit of the rated coverage. In areas where the density of NDBs is high, any NDB providing a signal at the limit of its rated coverage materially in excess of that agreed in the region concerned will give rise, in general, to harmful interference within the rated coverages of cochannel or adjacent channel NDBs in the area concerned, and will limit the number of NDBs which can be installed in the region within the available spectrum. It is important, therefore, that increases in radiated power

beyond that necessary to provide the rated coverage, particularly at night when sky wave propagation may give rise to interference over long distances, should not be made without coordination with the authorities of the other stations likely to be affected (see Chapter 3, 3.4.3).

6.2.1.5. Frequency planning is considerably facilitated if a common value of minimum field strength within the desired coverage is used.

6.2.1.6. Extensive experience has shown that in relatively low noise level areas, such as Europe, the figure of 70 microvolts per metre is satisfactory.

6.2.1.6.1 Experience has also shown that the figure of 120 microvolts per metre is generally satisfactory for higher noise level areas but will be inadequate in areas of very high noise. In such areas, the information given in 6.3 may be used for general guidance.

6.2.2. Relationship to effective coverage

6.2.2.1. Rated coverage may have a close correlation to effective coverage under the following conditions:

a) when the minimum field strength within the rated coverage is such that, for most of the time, it exceeds the field strength due to atmospheric and other noise sufficiently to ensure that the latter will not distort the information presented in the aircraft to the extent that it is unusable;

b) when the ratio of the strength of the wanted signal to that of interfering signals exceeds the minimum required value at all points within the coverage, in order to ensure that interfering signals will also not distort the information presented in the aircraft to the extent that it is unusable.

6.2.2.2. Since, normally, the lowest signal within the coverage will occur at its boundary, these conditions imply that at the boundary the field strength should be such that its ratio to atmospheric noise levels would ensure usable indications in the aircraft for most of the time and that, in respect of the boundary value, overall planning should ensure that the ratio of its value to that of interfering signals exceeds the required value for most of the time.

6.2.2.3. Although the value of 70 microvolts per metre used for frequency deployment has been found successful in Europe (i.e. north of 300 latitude) in giving coverage values which closely approximate to effective coverage most of the time, experience is too limited to prove the suitability of the 120 microvolts per metre value for general application in areas of high noise. It is to be expected that rated coverages in high noise based on a boundary value of 120 microvolts per metre will, on many occasions, be substantially greater than the effective coverage achieved. In such areas, in order to secure a better correlation between rated coverage and an average of the achieved effective coverage, it may be advisable to choose a boundary value based more closely on the proportionality of noise in that area to the noise in areas where a boundary value has been satisfactorily established (e.g. Europe), or to determine an appropriate value from a statistical examination of achieved effective coverages in respect of an NDB in the area of known performance.

6.2.2.4. It is important to appreciate, however, that minimum values of field strength based on a simple comparison of noise levels in different areas may be

insufficient, because factors such as the frequency of occurrence of noise, its character and effect on the airborne receiver and the nature of the air operation involved may all modify ratios determined in this way.

6.2.2.5. Values of diurnal and seasonal noise in various parts of the world have been published in Report 322 of the former CCIR of the ITU.

6.2.2.5.1 Correlation of these values to actual local conditions and the derivation of required signal-to-noise ratios for effective operational use of ADF equipment is not yet fully established.

6.2.3. Effective coverage

6.2.3.1. Effective coverage as defined in Chapter 3, 3.4.1 of the AAR-RNAV Aids, is the area surrounding an NDB, within which useful information to the operator concerned can be obtained at a particular time. It is, therefore, a measure of NDB performance under prevailing conditions.

6.2.3.2. The effective coverage is limited by the ratio of the strength of the steady (non-fading) signal received from the NDB to the total noise intercepted by the ADF receiver. When this ratio falls below a limiting value, useful bearings cannot be obtained. It should also be noted that the effective coverage of an NDB may in some cases be limited to the range of the usable identification signal.

6.2.3.3. The strength of signal received from the NDB is governed by:

a) the power supplied to the antenna of the NDB;

b) the radiation efficiency of the antenna, which varies according to the height of the antenna and other characteristics of the radiating system;

c) the conductivity of the path between the NDB and the receiver, which may vary considerably as between one site and another, and is always less over land than over seawater;

d) the operating radio frequency.

6.2.3.4. The noise admitted by the receiver depends on:

a) the bandwidth of the receiver;

b) the level of atmospheric noise, which varies according to the geographical area concerned, with the time of day and the season of the year, and which may reach very high levels during local thunderstorms;

c) the level of the interference produced by other radio emissions on the same or on adjacent frequencies, which is governed to a large extent by the NDB density in the area concerned and the effectiveness of regional planning;

d) the level of noise due to electrical noise in the aircraft or to industrial noise (generated by electric motors, etc.), when the coverage of the NDB extends over industrial areas.

6.2.3.4.1 It has to be noted that the effect of noise depends on characteristics of the ADF receiver and the associated equipment, and also on the nature of the noise (e.g. steady noise, impulsive noise).

6.2.3.5. A further factor which limits the effective coverage of an NDB is present at night when interaction occurs between components of the signal which are propagated respectively in the horizontal plane (ground wave propagation) and by reflection from the ionosphere (sky wave propagation). When there is interaction between these components, which arrive at the ADF receiver with a difference of phase, bearing errors are introduced (night effect).

6.2.3.6. It will thus be seen that the effective coverage of an NDB depends on so many factors, some of which are variable, that it is impossible to specify the effective coverage of an NDB in any simple manner. The effective coverage of any NDB, in fact, varies according to the time of day and the season of the year.

6.2.3.6.1 Hence any attempt to specify an effective coverage, which would be obtainable at any time throughout the day or throughout the year, would result either in a figure for coverage which would be so small (since this would be the coverage obtained under the worst conditions of atmospheric noise, etc.) as to give quite a misleading picture of the effectiveness of the NDB, or would involve such high power and costly antenna systems (to provide the required coverage under the worst conditions), that the installation of such an NDB would usually be precluded by considerations of initial and operating costs. No specific formula can be given in determining what rated coverage would be equivalent to a desired effective coverage and the relation must be assessed regionally.

6.2.3.7. Those concerned with the operational aspects of NDB coverage will normally consider requirements in terms of a desired operational coverage and, in regional planning, it will usually be necessary to interpret such requirements in terms of a rated coverage from which may be derived the essential characteristics of the NDB required and which will also define the area to be protected against harmful interference. No specific formula can be given in determining what rated coverage would be equivalent to a desired operational coverage and the relation must be assessed regionally.

6.2.3.8. Some States have recorded data on NDBs and their effective coverage; and collection of similar information would be a practical way of obtaining an assessment of effective coverage in terms of rated coverage of facilities in a given area. This information would also be useful for future regional planning. In order to reduce the number of factors involved in assessing effective coverage, it would be desirable to establish criteria for determining the limit of useful coverage in terms of the reaction of the bearing indicator. The data referred to previously, together with measurements of actual field strength within the coverage of the NDB, would also permit determination of the effectiveness of existing installations and provide a guide to improvements that may be necessary to achieve a desired effective coverage.

6.3. COVERAGE OF NDBS

6.3.1. *Introduction*

6.3.1.1. The following studies have been based on the latest propagation and noise data available to the ITU. They are included in this Attachment as general guidance in respect of NDB planning. Attention is called particularly to the assumptions made.

6.3.1.2. When applying the material, the validity of the assumptions in respect of the particular conditions under consideration should be carefully examined and, in particular, it should be noted that the assumed signal-to-noise ratios require considerable further study before they can be accepted as representative of the ratios limiting useful reception.

6.3.2. *Assumptions*

1. Operating frequency — 300 kHz.

   Reference is made, however, where appropriate, to frequencies of 200 kHz and 400 kHz.

2.

   a) Average soil conductivity: ($\sigma = 10^{-13}$ e.m.u.)

   b) Average seawater conductivity: ($\sigma = 4.10^{-11}$ e.m.u.)

3. The level of atmospheric noise (RMS) which is likely to prevail: 1) by day, 2) by night, over land masses, within the belts of latitude mentioned. [The values of expected noise have been derived from Recommendation ITU-R P.372-6 and have been taken as the average noise by day and by night during equinox periods, i.e. the values which are likely to be exceeded 20–25 per cent of the year.]

4. Input powers to the antenna of the NDB of:

   a) 5 kW
   b) 1 kW
   c) 500 W
   d) 100 W
   e) 50 W
   f) 10 W

5. The following average values of radiation efficiencies of antennas, i.e. the ratio of:

$$\left[\frac{\text{Radiated power}}{\text{Input power to antenna}}\right]$$

Input power to antenna	***Radiation efficiency of antenna***
5 kW	20% (–7 dB)
5 kW	10% (–10 dB)
1 kW	8% (–11 dB)
500 W	5% (–13 dB)
100 W	3% (–15 dB)
50 W	2% (–17 dB)
10 W	1% (–20 dB)
10 W	0.3% (–25 dB)

i) The figure for a) is included because it is possible to realize this efficiency by the use of a more elaborate antenna system than is usually employed.

ii) The figure for h) is included because many low power NDBs use very inefficient antennas.

6. An admittance band of the ADF receiver of 6 kHz.

7. Required ratios of signal-(median) to-noise (RMS) of:

a) 15 dB by day;

b) 15 dB by night.

6.3.3. *Results of studies*

A.— *Minimum field strengths required at the boundary of the rated coverage:*

Latitude	***By day for 15 dB S/N ratio***	***By night for 15 dB S/N ratio***
5°N – 5°S	320 μV/m (+50 dB)	900 μV/m (+59 dB)
5° – 15°N&S	85 μV/m (+39 dB)	700 μV/m (+57 dB)
15° – 25°N&S	40 μV/m (+32 dB)	320 μV/m (+50 dB)
25° – 35°N&S	18★μV/m (+25 dB)	120 μV/m (+42 dB)
>35°N&S	18★μV/m (+25 dB)	50 μV/m (+35 dB)

A star shown against a figure indicates that a higher value of field strength — probably 2 or 3 times the values shown (plus 6 to plus 10 dB) — may be necessary in the presence of high aircraft noise and/or industrial noise.

B .— *Coverage of NDBs (expressed in terms of the radius of a circle, in kilometres, with the NDB at the centre) which may be expected under the assumptions made:*

1) By *day*, over *land*, and for *15 dB S/N ratio* at the boundary of the coverage:

Latitude	***Input power to antenna***			
	(a) *5 kW*	*(b)* *5 kW*	*(c)* *1 kW*	*(d)* *500 W*
5°N – 5°S	320	300	170	120
5° – 15°N&S	510	470	320	250
15° – 25°N&S	>600	600	450	350
25° – 35°N&S	>600★	>600★	600★	500★
>35°N&S	>600★	>600★	>600★	500★

Latitude	*Input power to antenna*			
	(e) *100 W*	*(f)* *50 W*	*(g)* *10 W*	*(h)* *10 W*
5°N – 5°S	50	30	10	<10
5° – 15°N&S	150	90	40	10
15° – 25°N&S	220	160	70	45
25° – 35°N&S	330★	250★	130★	80★
>35°N&S	330★	250★	130★	100★

2) By *night*, over *land*, and for *15 dB S/N ratio* at the boundary of the coverage:

Latitude	*Input power to antenna*			
	(a) *5 kW*	*(b)* *5 kW*	*(c)* *1 kW*	*(d)* *500 W*
5°N – 5°S	190	150	85	50
5° – 15°N&S	210	180	110	70
15° – 25°N&S	320	300	170	120
25° – 35°N&S	390	390	280	200
>35°N&S	390	390	390	310

Latitude	*Input power to antenna*			
	(e) *100 W*	*(f)* *50 W*	*(g)* *10 W*	*(h)* *10 W*
5°N – 5°S	20	<10	<10	<10
5° – 15°N&S	25	15	<10	<10
15° – 25°N&S	50	30	10	<10
25° – 35°N&S	100	70	25	15
>35°N&S	180	120	50	30

6.3.3.1. In all of the above tables, it has to be noted that:

a) the distances are given in kilometres, in accordance with ITU practice;

b) the figures in the final columns, with the heading 10 W, are calculated on the assumption that the low power NDB uses a very inefficient antenna (see 6.3.2, assumption 5 h));

c) a star shown against a figure indicates that the coverage may be limited by aircraft and industrial noises.

6.3.3.2. It has also to be noted that:

a) if a frequency of 200 kHz were used in place of 300 kHz, this would not appreciably affect the coverage of low power short range NDBs, but the coverage of the higher power, longer range

beacons (for example, those with a range of 150 km or more) would be increased, as compared with those shown in the tables, by about 20 per cent;

b) if a frequency of 400 kHz were used in place of 300 kHz this would not appreciably affect the coverage of low power short range NDBs, but the coverage of the higher power, longer range beacons (for example, those with a range of 150 km or more) would be decreased, as compared with those shown in the tables, by about 25 per cent;

c) use of an ADF receiver with a narrower band would, other things being equal, provide wider coverage for the same radiated power of the NDB or, for the same coverage, an improved effective signal-to-noise ratio.

For example, if an admittance band of 1 kHz instead of 6 kHz were used, the coverage might be increased by as much as 30 per cent for the same radiated power or, alternatively, the effective signal-to-noise ratio might be increased by as much as 8 dB;

d) if a sector of the coverage of an NDB is over seawater, a greater coverage may be expected within that sector due to:

1) better ground wave propagation over seawater than over land;

2) the noise level, which is highest over land, often drops fairly steeply with increasing distance from the land. It might be assumed, therefore, that the distances shown in the tables could be increased by about 30 per cent by day, and by about 20 per cent by night, when the path is over seawater;

e) if, however, the beacon is sited on an island remote from land masses (for example, in mid-Pacific or mid-Atlantic, but not in the Caribbean), the coverage of the beacon is likely to be much greater, particularly in tropical latitudes, than is indicated in the tables; and in such cases figures for coverage similar to those shown for latitudes more than 35□N and S may be assumed for all latitudes, due to the much lower level of atmospheric noise which prevails in mid-ocean as compared with that experienced over, or in proximity to, land masses.

6.3.4. *Limitation of coverage of a beacon at night due to "night effect".*

a) The distances, at night, at which the ground wave and sky wave components of the received field are likely to be equal are as follows:

Frequency	***Over land***	***Over sea***
200 kHz	500 km	550 km
300 kHz	390 km	520 km
400 kHz	310 km	500 km

b) The distances, at night, at which the ground wave component of the received field is likely to exceed the sky wave component by 10 dB are as follows:

Frequency	*Over land*	*Over sea*
200 kHz	300 km	320 km
300 kHz	230 km	300 km
400 kHz	200 km	280 km

c) It is, therefore, unlikely that reliable bearings can be obtained, at night, due to interaction of the two components of the received field, at much greater distances than those shown in 6.3.4 b). These distances are independent of the power of the NDB.

d) It has to be noted, moreover, that, while with overland paths of good conductivity, night effect will only be serious at somewhat greater distances than those indicated over paths of poor conductivity, night effect may become pronounced at much shorter ranges. This will also depend to some extent upon the characteristics of the radiation system.

6.4. CONSIDERATIONS AFFECTING OPERATIONS OF NDBS

6.4.1. *Depth of modulation*

6.4.1.1. In specifying that the depth of modulation should be maintained as near to 95 per cent as is practicable, it must be noted that, at the frequencies used for NDBs, the small antennas generally in use can affect the effective modulation depth of the NDB system due to attenuation of the sidebands.

6.4.1.2. At this order of frequency, the antennas are normally only a small fraction of a wavelength long; they are therefore highly reactive and tend to have a high Q.

6.4.1.3. The effect is illustrated in Figure 19, which was compiled from measurements made by one State. The modulating frequency in these measurements was 1 020 Hz. If a lower modulating frequency were used, the effect would be less.

6.4.1.4. In order to reduce the attenuation, attempts should be made to reduce the Q of the antenna. This can be done in two ways, by increasing either its capacity or resistance.

6.4.1.5. Inserting additional resistance in an antenna wastes power, whereas increasing the capacity does not. Additionally, the effect of increasing the capacity is to reduce the voltage across the system and hence to reduce the insulation problems.

6.4.1.6. For these reasons, it is considered desirable to increase antenna capacity by the use of a top load as, for example, in the so-called umbrella top capacity.

6.4.2. *Earth systems*

Frequency planning is done on the assumption that the field strength will be maintained at the correct value. If the earth resistance is high (i.e. an insufficient earth system), not only will the radiation efficiency be low but the power radiated will be sensitive to changes in climatic conditions and other factors affecting the earth loss. In all cases, the earth system needs to be the best possible, taking into account all local circumstances.

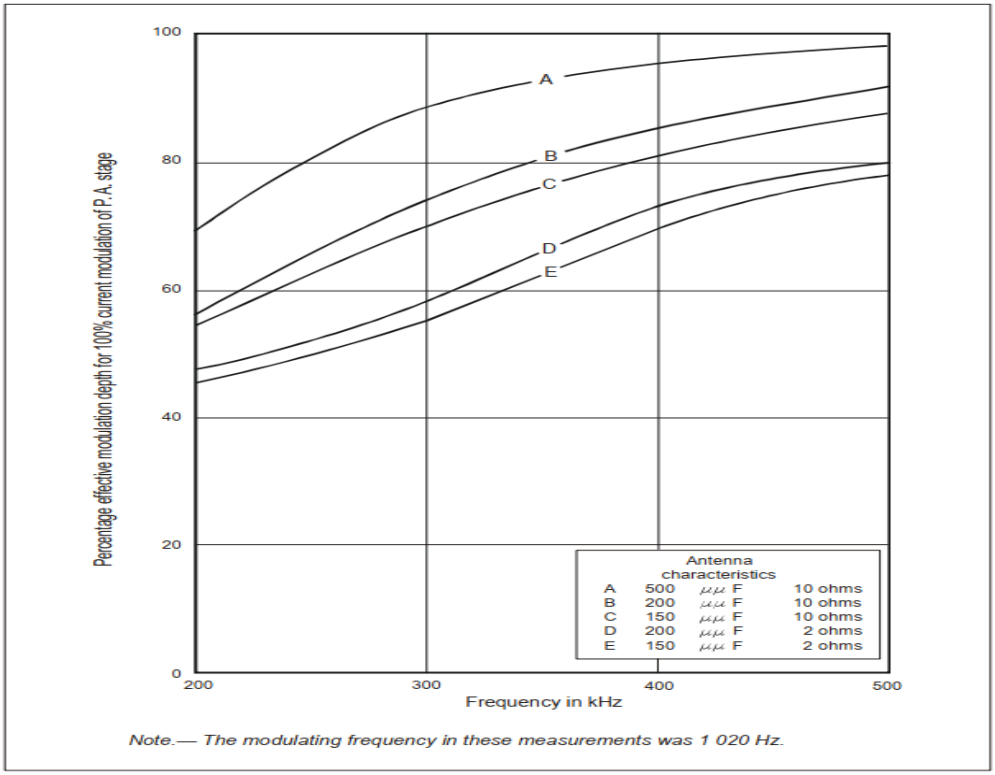


Figure 19. The effect of antenna Q on the depth of modulation of the radiated signal

6.5. CONSIDERATIONS AFFECTING THE CHOICE OF THE MODULATING FREQUENCY FOR NON/A2A NDBS

Recognition of the fact that modern narrow band ADF receivers have improved selectivity characteristics requires consideration of the fact that, in so far as attenuation of the audio sidebands by these receivers results in a reduction of the effective depth of modulation of the signal, the distance at which satisfactory identification is obtained is consequently reduced. In such circumstances, it is considered that 400 Hz would provide a better identification service than 1 020 Hz. There is some evidence, however, that under conditions of high atmospheric noise, the higher frequency of 1 020 Hz may provide a more easily readable signal.

7. MATERIAL CONCERNING DME

7.1. GUIDANCE MATERIAL CONCERNING BOTH DME/N AND DME/P

7.1.1. *System efficiency*

7.1.1.1. System efficiency is the combined effect of down-link garble, ground transponder dead time, up-link garble, and interrogator signal processor efficiency. Since each of these efficiency components are statistically independent, they can be computed individually and then combined to yield the system efficiency. The effect of a single component is defined as the percentage ratio of valid replies processed by the interrogator in response to its own interrogations assuming all other components are not present. The system efficiency is then the product of the individual components.

7.1.1.2. In computing system efficiency, the number of missing replies as well as the accuracy of the range measurement made with the received replies should be considered. Missing replies may result from signal interference due to garble or from interrogations being received at the transponder during a dead time period. Replies which contain significant errors large enough to be rejected by the interrogator signal processing also should be treated as missing replies when computing the efficiency component.

7.1.1.3. The interference rate due to garble is dependent upon the channel assignment plan, traffic loading, and the ground transponder and interrogator receiver bandwidths. Because the FA mode has a wider receiver bandwidth than the IA mode, it is more susceptible to interference. These factors were accommodated in the DME/P system definition and normally do not require special consideration by the operating authority.

7.1.2. *Down-link garble*

Down-link garble occurs when valid interrogations at the ground transponder are interfered with by coincident interrogations from other aircraft and results in loss of signal or errors in time-of-arrival measurement. This undesired air-to- ground loading is a function of the number of interrogating aircraft in the vicinity of the serving transponder and the corresponding distribution of interrogation frequencies and signal amplitudes received at the transponder.

Note: *Transponder to transponder garbling is controlled by the channel assignment authorities.*

7.1.3. *Up-link garble*

Up-link garble occurs when valid replies at the interrogator are interfered with by other transponders and results in loss of signal or errors in pulse time-of-arrival measurement. The garble can be interference from any transponder whose frequency is within the bandwidth of the interrogator, including those on the same frequency, but with different pulse coding. This undesired ground-to-air loading is a function of the number of transponders in the vicinity of the interrogator and the corresponding distribution of reply frequencies and signal amplitudes received at the interrogator.

7.1.4. *Interrogator processor efficiency*

The interrogator signal processor efficiency is the ratio of the number of replies processed by the interrogator to the number of interrogations in the absence of garble and transponder dead time effects. This efficiency depends on the reply pulse threshold level and the receiver noise level.

7.1.5. R*elationship between aircraft served and transmission rate*

7.1.5.1. Specification of the maximum transponder transmission rate establishes the maximum average transmitter power level. Chapter 3, 3.5.4.1.5.5 of the AAR-RNAV Aids recommends that the transponder have a transmission rate capability of 2 700 pulse pairs per second if 100 aircraft are to be served. This represents typical transponder loading arising from 100 aircraft. To determine the actual transmission rate capability that should be accommodated at a given facility during peak traffic conditions requires that the maximum number of interrogators be estimated. To compute the interrogation loading on the transponder, the following should be considered:

a) the number of aircraft that constitutes the peak traffic load;

b) the number of interrogators in use on each aircraft;

c) the distribution of operating modes of the interrogators in use (e.g. search, initial approach, final approach, ground test);

d) the appropriate pulse repetition frequency as given in Chapter 3, 3.5.3.4 of the AAR-RNAV Aids.

7.1.5.2. Given the interrogation loading which results from the peak traffic as well as the reply efficiency of the transponder in the presence of this load, the resulting reply rate can be computed, thereby establishing the required transmitter capability. This reply rate is the level that, when exceeded, results in a reduction in receiver sensitivity (as specified in Chapter 3, 3.5.4.2.4 of the AAR-RNAV Aids) in order to maintain the reply rate at or below this maximum level.

7.1.6. *Siting of DME associated with ILS or MLS*

7.1.6.1. The DME should, where possible, provide to the pilot an indicated zero range at touchdown in order to satisfy current operational requirements.

7.1.6.2. The optimum site for a DME transponder is dependent upon a number of technical and operational factors. DME/N may be installed with ILS where operational requirements permit. DME/P, which provides higher accuracy and coverage throughout the entire runway region, is required to support the more flexible and advanced operations that are available with MLS.

7.1.6.3. In the case of DME/N, the provision of zero range indication may be achieved by siting the transponder as close as possible to the point at which zero range indication is required. Alternatively, the transponder time delay can be adjusted to permit aircraft interrogators to indicate zero range at a specified distance from the DME antenna. When the indicated DME zero range has a reference other than the DME antenna, consideration should be given to publishing this information.

7.1.6.4. In the case of DME/P, in order to meet accuracy and coverage requirements, particularly in the runway region, it is recommended that the DME/P be sited

as closely as possible to the MLS azimuth facility, consistent with obstacle clearance criteria. For aircraft equipped with a full MLS capability, the desired zero range indication can then be obtained by utilizing MLS basic data. Note that the DME/P transponder time delay must not be adjusted for this purpose.

7.1.6.5. It is desirable that all users obtain indicated zero range at touchdown irrespective of the airborne equipment fitted. This would necessitate location of the DME/P abeam the runway at the touchdown point. In this case accuracy requirements for DME/P would not be met on the runway. It must be noted that MLS Basic Data Word 3 only permits the coding of DME/P coordinates within certain limits.

7.1.6.6. If an MLS/DME/P and an ILS/DME/N serve the same runway, an aircraft equipped with a minimum MLS capability can have a zero range indication at the MLS approach azimuth site when operating on MLS and a zero range indication at the touchdown point when operating on ILS. As this is considered to be operationally unacceptable, specifically from an ATC point of view, and if ILS/MLS/DME frequency tripling to prevent the relocation of the DME/N is not possible, the implementation of DME/P is to be postponed until the DME/N is withdrawn.

7.1.6.7. The nominal location of the zero range indication provided by a DME/N interrogator needs to be published.

7.1.6.8. In considering DME sites, it is also necessary to take into account technical factors such as runway length, profile, local terrain and transponder antenna height to assure adequate signal levels in the vicinity of the threshold and along the runway, and also to assure the required coverage volume (circular or sector). Care is also to be taken that where distance information is required in the runway region, the selected site is not likely to cause the interrogator to lose track due to excessive rate of change of velocity (i.e. the lateral offset of the DME antenna must be chosen with care).

7.1.7. *Geographical separation criteria*

7.1.7.1. In order to allow consideration of actual antenna designs, equipment characteristics, and service volumes, the signal ratios needed to assure interference-free operation of the various facilities operating on DME channels are provided in 7.1.8 and 7.1.9. Given these ratios, the geographical separations of facilities may be readily evaluated by accounting for power losses over the propagation paths.

7.1.8. *Desired to undesired (D/U) signal ratios at the airborne receiver*

7.1.8.1. Table 6 indicates the necessary D/U signal ratios needed to protect the desired transponder reply signal at an airborne receiver from the various co-frequency/adjacent frequency, same code/different code, undesired transponder reply signal combinations that may exist. The prerequisite for any calculation using the provided ratios is that the required minimum power density of the desired DME is met throughout the operationally published coverage volume. For initial assignments, the D/U ratios necessary to protect airborne equipment with 6-microsecond decoder rejection should be used. In making an assignment, each facility must be treated as the desired source with the other acting as the undesired. If both satisfy their unique D/U requirement, then the channel assignment may be made.

7.1.8.2. Accordingly, DME channel assignments depend upon the following:

a) *For co-channel assignments:* This condition occurs when both the desired and undesired signals operate on a channel (W, X, Y or Z) that is co-frequency, same code. The D/U signal ratio should be at least 8 dB throughout the service volume.

b) *For co-frequency, different code assignments:* This condition occurs when one facility operates on an X channel with the other on a W channel. A similar Y channel and a Z channel combination also applies.

c) *For first adjacent frequency, same code assignments:* This condition occurs when both the desired and undesired facilities are of W, X, Y or Z type.

d) *For first adjacent frequency, different code assignments:* This condition occurs when one facility operates on an X channel with the other on a W channel, but with a frequency offset of 1 MHz between transponder reply frequencies. A similar Y channel and a Z channel combination also applies.

e) *For second adjacent frequency, same or different code assignments:* The second adjacent *frequency* combinations generally need not be frequency protected. However, special attention should be given to Note 4 of Table 4, especially if the undesired facility is a DME/P transponder.

Table 6. Protection ratio D/U (dB)

Type of assignment	A	B
Co-frequency:		
Same pulse code	8	8
Different pulse code	8	–42
First adjacent frequency:		
Same pulse code	–(Pu – 1)	–42
Different pulse code	–(Pu + 7)	–75
Second adjacent frequency:		
Same pulse code	–(Pu + 19)	–75
Different pulse code	–(Pu + 27)	–75

Note 1: *The D/U ratios in column A protect those DME/N interrogators operating on X or Y channels. Column A applies to decoder rejection of 6 microseconds.*

Note 2: *The D/U ratios in column B protect those DME/N or DME/P interrogators utilizing discrimination in conformance with 3.5.5.3.4.2 and 3.5.5.3.4.3 of Chapter 3 of the AAR-RNAV Aids and providing a decoder rejection conforming to 3.5.5.3.5 of Chapter 3 of the AAR-RNAV Aids.*

Note 3: *P_U is the peak effective radiated power of the undesired signal in dBW.*

Note 4: *The frequency protection requirement is dependent upon the antenna patterns of the desired and undesired facility and the EIRP of the undesired facility.*

Note 5: *In assessing adjacent channel protection, the magnitude of D/U ratio in column A should not exceed the magnitude of the value in column B.*

7.1.9. *Special considerations for DME Y and Z channel assignments*

The channel assignment plan for DME is such that the transponder reply frequency for each Y or Z channel is the same as the interrogation frequency of another DME channel. Where the reply frequency of one DME matches the interrogation frequency of a second DME, the two transponders should be separated by a distance greater than the radio horizon distance between them. The radio horizon distance is calculated taking into account the elevations of the two transponder antennas.

7.1.10. *Special considerations for DME/P associated with ILS*

7.1.10.1. For those runways where it is intended to install DME associated with ILS and where early MLS/RNAV operations are planned, installation of DME/P is preferred.

7.1.10.2. When it is intended to use the DME/P ranging information throughout the terminal area, interrogation pulse pairs with the correct spacing and nominal frequency must trigger the transponder if the peak power density at the trans- ponder antenna is at least minus 93 dBW/m^2. This sensitivity level is based on the values contained in Chapter 3, 3.5.4.2.3.1 of the AAR-RNAV Aids and it is applied to DME/P IA mode, where at this level DME/P IA mode is intended to comply with DME/N reply efficiency and at least DME/N accuracy.

7.1.11. *Considerations for the universal access transceiver (UAT)*

7.1.11.1. Frequency planning criteria to ensure compatibility between DME and the UAT are contained in Part II of the *Manual on the Universal Access Transceiver (UAT) (Doc 9861).*

7.2. GUIDANCE MATERIAL CONCERNING DME/N ONLY

7.2.1. *Coverage of DME/N*

7.2.1.1. Whether a particular installation can provide the required frequency, protected coverage volume can be determined by using Figure 20. The propagation loss for paths without obstructions uses the IF-77 propagation model.

7.2.1.2. Whenever a DME that provides coverage using either a directional or bi-directional DME antenna, the antenna pattern in azimuth and elevation has to be taken into account to achieve the full benefit of the reduced separation requirements outside the antennas main lobe. The actual radiation patterns of the antennas depend on a number of factors, including height of the antenna phase centre, height of the DME counterpoise above ground level (AGL), terrain surface roughness, terrain form, site elevation above mean sea level (MSL), and conductivity of ground and counterpoise. For coverage under difficult terrain and siting conditions, it may be necessary to make appropriate increases in the equivalent isotropically radiated power (EIRP). 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 EIRP. However, to account for lowest EIRP in notches between the lobes of the real elevation antenna pattern, the values in Figure 20 are recommended.

Note: *Further guidance may be found in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies (Doc 9718).*

7.2.2. *EIRP of DME/N facilities*

7.2.2.1. The power density figure prescribed in Chapter 3, 3.5.4.1.5.2 of the AAR-RNAV Aids is based on the following example:

Airborne receiver sensitivity –120 dBW

Transmission line loss, mismatch loss, antenna polar pattern variation with respect to an isotropic antenna +9 dB

Power required at antenna –111 dBW

Minus 111 dBW at the antenna corresponds to minus 89 dBW/ m^2 at the mid-band frequency.

7.2.2.2. Nominal values of the necessary EIRP to achieve a power density of minus 89 dBW/m^2 are given in Figure 20. For coverage under difficult terrain and siting conditions it may be necessary to make appropriate increases in the EIRP. Conversely, under favourable siting conditions, the stated power density may be achieved with a lower EIRP.

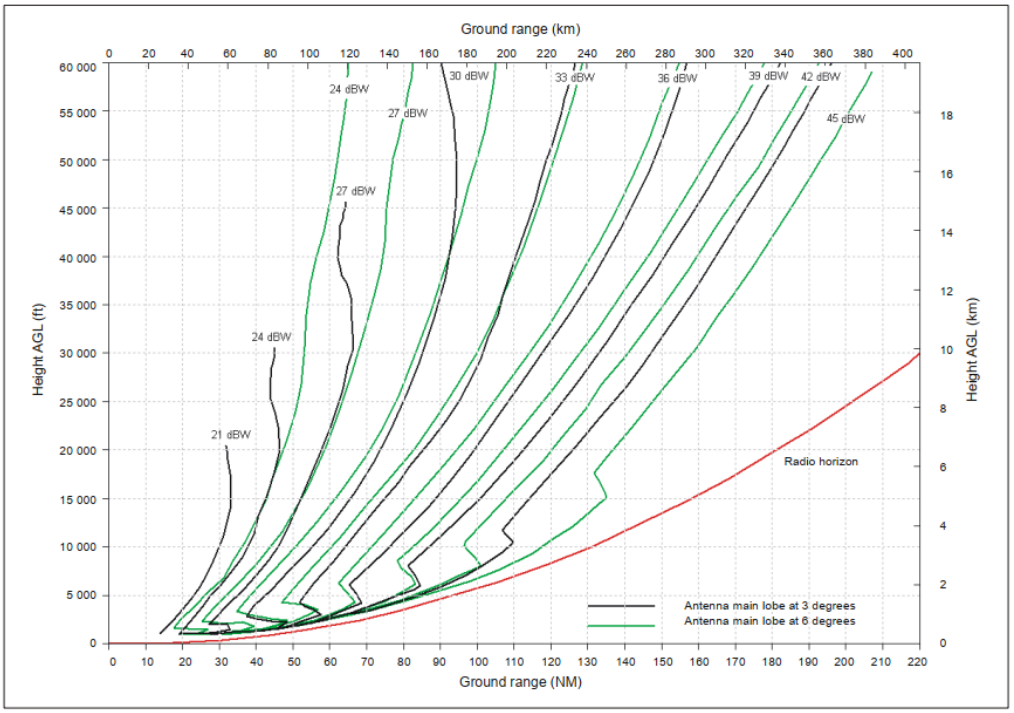


Figure 20. Necessary EIRP to achieve a power density of –89 dBW/m^2 as a function of height above and distance from the DME

Note 1: *The curves are based on the IF-77 propagation model with a 4/3 Earth radius which has been confirmed by measurements.*

Note 2: *The radio horizon in Figure 20 is for a DME antenna located 5 m (17 ft) AGL over flat terrain.Terrain shielding will reduce the achievable range.*

Note 3: *If the antenna is located significantly higher than the assumed reference antenna, the radio horizon and power density will increase.*

7.2.3. *DME-DME RNAV*

7.2.3.1. There is an increasing use of DME to support area navigation (RNAV) operations. Although the use of DME to support RNAV operations does not impose any additional technical requirements on the DME system, it does raise some additional issues compared with the traditional use of DME with VOR to support conventional operations. These are examined briefly below.

7.2.3.2. DME/DME positioning is based on the aircraft RNAV system triangulating position from multiple DME ranges from DME facility locations in the aircraft database. The resulting accuracy of the position solution depends on the range to the DMEs and their relative geometry. Some additional measures are therefore necessary to ensure that the DME infrastructure is adequate to support the RNAV operation, i.e. that sufficient DMEs are available and that their location provides adequate geometry to meet the accuracy requirements. For approach and departure procedures, it is also necessary to confirm that there is adequate signal strength and that there are no false locks or unlocks due to multipath. When ensuring there are sufficient DMEs, it is also important to identify any critical DMEs (i.e. those which must be operational for the necessary performance to be assured).

7.2.3.3. Errors in published DME facility locations will result in RNAV position errors. It is therefore important that DME positions are correctly surveyed and that adequate procedures are in place to ensure that the location data are correctly published. For DME facilities collocated with VOR, the DME position should be separately surveyed and published if the separation distance exceeds 30 m (100 ft).

7.2.3.4. When using DME to support RNAV, scanning DME aircraft receivers usually do not check the DME identification. As a consequence, removing the identification of a DME during tests and maintenance operations does not guarantee that the signals will not be used operationally. Maintenance actions that may provide misleading information should be minimized.

Note 1: *Further guidance on flight inspection of DME-DME RNAV procedures is given in Doc 8071.*

Note 2: *Further guidance on navigation infrastructure assessment to support RNAV procedures is given in EUROCONTROL-GUID-0114 (available at http://www.eurocontrol.int/eatm /public/standard_page/gr_lib.html) and on the performance-based navigation (PBN) page of the ICAO website at http://www.icao.int/pbn.*

7.3. GUIDANCE MATERIAL CONCERNING DME/P ONLY

7.3.1. *DME/P system description*

7.3.1.1. The DME/P is an integral element of the microwave landing system described in Chapter 3, 3.11 of the AAR-RNAV Aids. The DME/P signal format defines two operating modes, initial approach (IA) and final approach (FA). The IA mode is compatible and interoperable with DME/N and is designed to provide improved accuracies for the initial stages of approach and landing. The FA mode provides substantially improved accuracy in the final approach area. Both modes are combined into a single DME/P ground facility and the system characteristics are such that DME/N and DME/P functions can be combined in a single interrogator. The IA and FA modes are identified by pulse codes which are specified in Chapter 3, 3.5.4.4 of the AAR-RNAV Aids. In the MLS approach sector, the DME/P coverage is at least 41 km (22 NM) from the ground

transponder. It is intended that the interrogator does not operate in the FA mode at ranges greater than 13 km (7 NM) from the transponder site, although the transition from the IA mode may begin at 15 km (8 NM) from the transponder. These figures were selected on the assumption that the transponder is installed beyond the stop end of the runway at a distance of approximately 3 600 m (2 NM) from the threshold.

7.3.1.2. A major potential cause of accuracy degradation encountered in the final phases of the approach and landing operation is multipath (signal reflection) interference. DME/P FA mode minimizes these effects by using wideband signal processing of pulses having fast rise time leading edges, and by measuring the time of arrival at a low point on the received pulse where it has not been significantly corrupted by multipath. This is in contrast to the slower rise time pulses and higher thresholding at the 50 per cent level used in DME/N.

7.3.1.3. Because the FA mode is used at ranges less than 13 km (7 NM), the transmitter can provide an adequate signal level to meet the required accuracy without the fast rise time pulse violating the transponder pulse spectrum requirements. Use of the 50 per cent threshold and a narrow receiver bandwidth in the IA mode permits an adequate but less demanding performance to the coverage limits. The transponder determines the interrogation mode in use by the interrogation code in order to time the reply delay from the proper measurement reference. The IA mode is interoperable with DME/N permitting a DME/N interrogator to be used with a DME/P transponder to obtain at least the accuracy with a DME/N transponder. Similarly, a DME/P interrogator may be used with a DME/N transponder.

7.3.2. *DME/P system accuracy requirements*

7.3.2.1. DME/P accuracy requirements

7.3.1.1.1 When considering the DME/P accuracy requirement, the operations that can be performed in the service volume of the final approach mode tend to fall into one of two groups. This has led to two accuracy standards being defined for the final approach mode:

a) *accuracy standard 1:* this is the least demanding and is designed to cater for most CTOL operations;

b) *accuracy standard 2:* this gives improved accuracy that may be necessary for VTOL and STOL operations, CTOL flare manoeuvres using MLS flare elevation guidance and CTOL high-speed turnoffs.

7.3.1.1.2 Table 7 shows applications of DME and typical accuracy requirements. This will assist in selecting the appropriate accuracy standard to meet the operational requirement. The calculations are based on a distance of 1 768 m (5 800 ft) between the DME antenna and the runway threshold. The following paragraphs refer to Table 7.

7.3.1.1.3 It is intended that the DME/P accuracy approximately corresponds to the azimuth function PFE at a distance of 37 km (20 NM) from the MLS reference datum both along the extended runway centre line and at an azimuth angle of 40 degrees. The CMN is the linear equivalent of the plus or minus 0.1 degree CMN specified for the azimuth angle function.

7.3.1.1.4 PFE corresponds to azimuth angular error; CMN is approximately the linear equivalent of the plus or minus 0.1 degree CMN specified for the azimuth angle system.

7.3.1.1.5 The plus or minus 30 m (100 ft) PFE corresponds to a plus or minus 1.5 m (5 ft) vertical error for a 3-degree elevation angle.

7.3.1.1.6 Flare initiation begins in the vicinity of the MLS approach reference datum; MLS elevation and DME/P provide vertical guidance for automatic landing when the terrain in front of the runway threshold is uneven.

7.3.1.1.7 Sensitivity modification or autopilot gain scheduling requirements are not strongly dependent on accuracy.

Table 7.

Function	Typical distance from the threshold	PFE (95%probability)	CMN (95%probability)
Approach (7.3.2.1.3)			
— extended runway centre line	37 km (20 NM)	±250 m (±820 ft)	±68 m (±223 ft)
— at 40° azimuth	37 km (20 NM)	±375 m (±1 230 ft)	±68 m (±223 ft)
Approach (7.3.2.1.4)			
— extended runway centre line	9 km (5 NM)	±85 m (±279 ft)	±34 m (±111 ft)
— at 40° azimuth	9 km (5 NM)	±127 m (±417 ft)	±34 m (±111 ft)
Marker replacement			
— outer marker	9 km (5 NM)	±800 m (±2 625 ft)	not applicable
— middle marker	1 060 m (0.57 NM)	±400 m (±1 312 ft)	not applicable
30 m decision height determination (100 ft)	556 m (0.3 NM)	±30 m (±100 ft)	not applicable
(7.3.2.1.5)	556 m (0.3 NM)	±15 m (±50 ft)	not applicable
— 3° glide path (CTOL)			
— 6° glide path (STOL)			
Flare initiation over uneven terrain			
(7.3.2.1.6)			
— 3° glide path (CTOL)	0	±30 m (±100 ft)	±18 m (±60 ft)
— 6° glide path (STOL)	0	±12 m (±40 ft)	±12 m (±40 ft)
Sensitivity modifications (7.3.2.1.7)			
(autopilot gain scheduling)	37 km (20 NM) to 0	±250 m (±820 ft)	not applicable
Flare manoeuvre with MLS flare elevation			
(7.3.2.1.8)			
— CTOL	0	±30 m (±100 ft)	±12 m (±40 ft)
— STOL	0	±12 m (±40 ft)	±12 m (±40 ft)
Long flare alert (7.3.2.1.9)	Runway region	±30 m (±100 ft)	not applicable
CTOL high speed roll-out/turnoffs (7.3.2.1.10)	Runway region	±12 m (±40 ft)	±30 m (±100 ft)
Departure climb and missed approach	0 to 9 km (5 NM)	±100 m (±328 ft)	±68 m (±223 t)
VTOL approaches (7.3.2.1.11)	925 m (0.5 NM) to 0	±12 m (±40 ft)	±12 m (±40 ft)
Coordinate translations (7.3.2.1.12)	—	±12 m to ±30 m (±40 ft to ±100 ft)	±12 m (±40 ft)

7.3.1.1.8 It is intended that this specification applies when vertical guidance and sink rate for automatic landing are derived from the MLS flare elevation and the DME/P.

Note: *Although the standard has been developed to provide for MLS flare elevation function, this function is not implemented and is not intended for future implementation.*

7.3.1.1.9 It indicates to the pilot if the aircraft is landing beyond the touchdown region.

7.3.1.1.10 The roll-out accuracy requirement reflects system growth potential. In this application the roll-out PFE would be dictated by the possible need to optimize roll-out deceleration and turnoff so as to decrease runway utilization time.

7.3.1.1.11 It is intended to assure the pilot that the aircraft is over the landing pad before descending.

7.3.1.1.12 It may be desirable to translate the MLS coordinates from one origin to another when the antennas are not installed in accordance with Chapter 3, 3.11.5.2.6 or 3.11.5.3.5 of the AAR-RNAV Aids. The figures in the table are typical of a VTOL application; actual values will depend on the geometry of the installation.

7.3.3. *DME/P error budgets*

Example error budgets for DME/P accuracy standards 1 and 2 are shown in Table 8. If the specified error components are not individually exceeded in practice, it can be expected that the overall system performance, as specified in Chapter 3, 3.5.3.1.4 of the AAR-RNAV Aids, will be achieved. A garbling contribution to the system error is computed by taking the root sum square (RSS) of the errors obtained in the specified down-link environment with those obtained in the specified up-link environment and removing, on an RSS basis, the error obtained in a non-garbling environment.

Table 8. Example of DME/P error budget

Error source	Error component	FA mode Standard 1		FA mode Standard 2		IA mode	
		PFE m (ft)	CMN m (ft)	PFE m (ft)	CMN m (ft)	PFE m (ft)	CMN m (ft)
Instrumentation	Transponder Interrogator	±10 (±33) ±15 (±50)	±8 (±26) ±10 (±33)	±5 (±16) ±7 (±23)	±5 (±16) ±7 (±23)	±15 (±50) ±30(±100)	±10 (±33) ±15 (±50)
Site related	Down-link specular multipath Up-link specular multipath Non-specular (diffuse) multipath Garble	±10 (±33) ±10 (±33) ±3 (±10) ±6 (±20)	±8 (±26) ±8 (±26) ±3 (±10) ±6 (±20)	±3 (±10) ±3 (±10) ±3 (±10) ±6 (±20)	±3 (±10) ±3 (±10) ±3 (±10) ±6 (±20)	±37 (±121) ±37 (±121) ±3 (±10) ±6 (±20)	±20 (±66) ±20 (±66) ±3 (±10) ±6 (±20)

Note 1: *The figures for "non-specular multipath" and for "garble" are the totals of the up-link and down-link components.*

Note 2: *PFE contains both bias and time varying components. In the above table the time varying components and most site related errors are assumed to be essentially statistically independent. The bias components may not conform to any particular statistical distribution.*

In considering these error budgets, caution is to be exercised when combining the individual components in any particular mathematical manner.

Note 3: *The transmitter wave form is assumed to have a 1 200 nanosecond rise time.*

7.3.4. *System implementation*

7.3.4.1. While the DME/P may be implemented in various ways, the instrumental and propagation errors assumed are typical of those obtainable with equipment designs which provide internal time delay drift compensation and which establish timing reference points by thresholding on the leading edge of the first pulse of a pulse pair using the following techniques:

a) *IA mode.* A conventional technique which thresholds at the 50 per cent amplitude point;

b) *FA mode.* A delay-attenuate-and-compare (DAC) technique which thresholds between the 5 per cent and 30 per cent amplitude points.

7.3.4.2. Accuracy standard 1 can be achieved using a delay of 100 nanoseconds and an attenuation of 5 to 6 dB. It is also required that the threshold amplitude point of both the delayed pulse and the attenuated pulse lie within the partial rise time region.

7.3.4.3. The example above does not preclude time of arrival measurement techniques other than the DAC from being used, but it is necessary in any case that threshold measurements take place during the pulse partial rise time.

7.3.5. *DME/P interrogator signal processing*

7.3.5.1. During acquisition

a) The interrogator acquires and validates the signal within 2 seconds before transitioning to track mode even in the presence of squitter and random pulse pairs from adjacent channels, which result in a 50 per cent system efficiency.

b) After loss of the acquired signal in either the IA or FA mode, the interrogator provides a warning output within 1 second, during which time the guidance information continues to be displayed. After loss of signal, the interrogator returns to the search condition in the IA mode in order to re-establish track.

7.3.5.2. During track

When track is established, the receiver output consists of valid guidance information before removing the warning. The validation process continues to operate as long as the interrogator is in track. The interrogator remains in track as long as the system efficiency is 50 per cent or greater. While in track, the receiver provides protection against short duration, large amplitude erroneous signals.

7.3.5.3. Range date filter

The accuracy specifications in Chapter 3, 3.5.3.1.4 of the AAR-RNAV Aids, as well as the error budgets discussed in 7.3.3, assume that the higher frequency noise contributions are limited by a low pass filter with a corner frequency of qw as specified in Figure 21. Depending upon the user's application, additional filtering for noise reduction can be used provided that the induced phase delay and amplitude variation do not adversely affect the aircraft flight control system's dynamic response. The following sections recommend additional features which should be incorporated into the data filter.

7.3.5.4. Velocity memory

The data filter may require a velocity memory in order to achieve the specified accuracies in Chapter 3, 3.5.3.1.4 of the AAR-RNAV Aids with a system efficiency of 50 per cent. It should be noted that low system efficiencies can occur in the IA mode during identification transmissions.

7.3.5.5. Outlier rejection

Range estimates which are significantly different from previous filtered range estimates, because they cannot be the result of aircraft motion, should be assumed to be in error. Such data should be rejected at the input to the data filter.

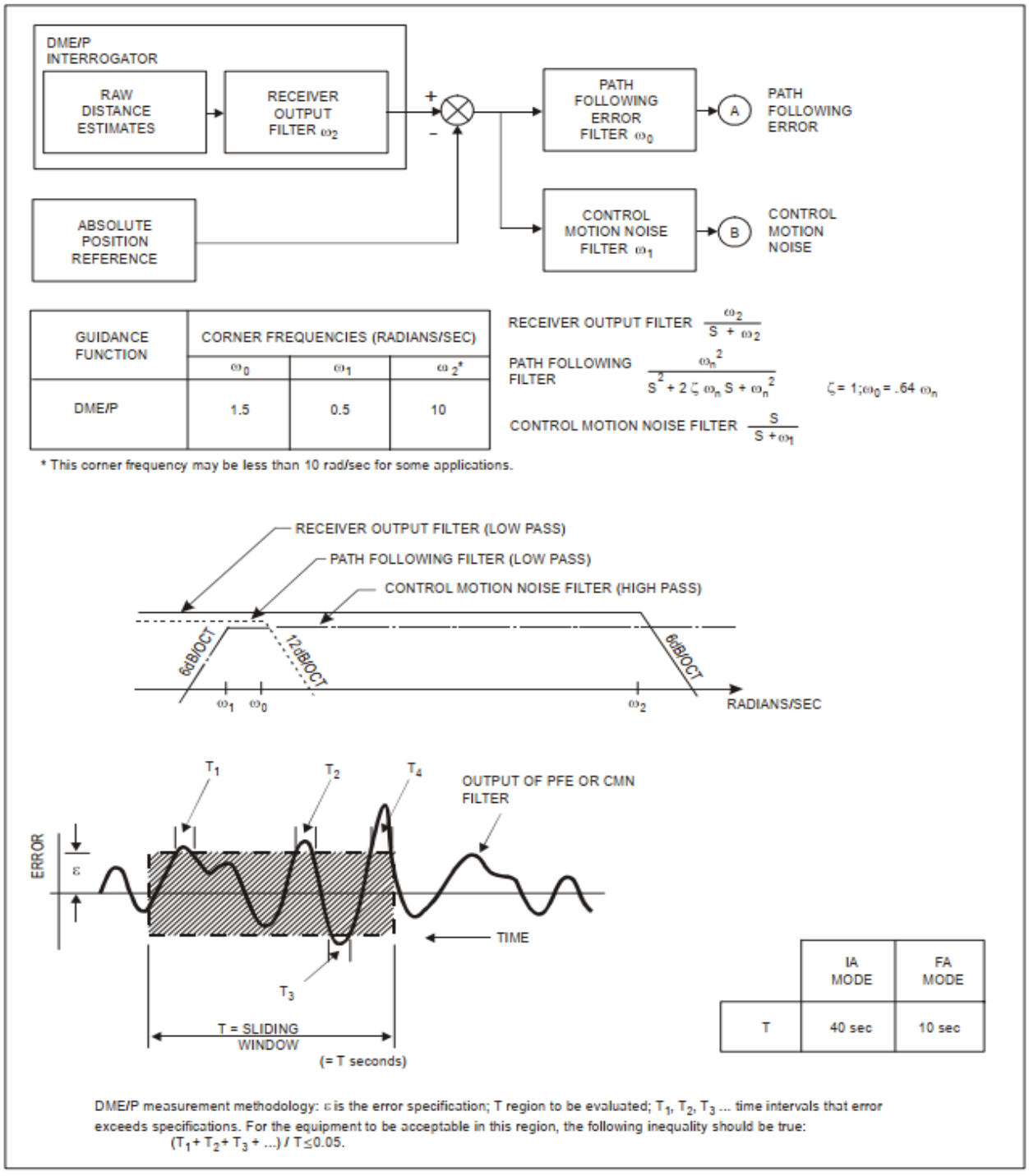
7.3.6. *DME/P error measurement methods*

7.3.6.1. System errors

7.3.3.1.1 The DME/P system accuracies are specified in Chapter 3, 3.5.4.1.4 of the AAR-RNAV Aids in terms of path following error (PFE) and control motion noise (CMN). These parameters describe the interaction of the DME/P guidance signal with the aircraft in terms directly related to aircraft position errors and flight control system design.

7.3.3.1.2 For the purposes of determining compliance with the accuracy standard, the PFE and CMN components are evaluated over any T second interval (where T = 40 seconds in the IA mode and 10 seconds in the FA mode) of the flight error record taken within the DME/P coverage limits. The 95 per cent probability requirement is interpreted to be satisfied if the PFE and CMN components do not exceed the specified error limits for a total period that is more than 5 per cent of the evaluation time interval. This is illustrated in Figure 21. To evaluate the PFE and CMN components of the DME/P guidance data, the true aircraft position, as determined by a suitable position reference, is subtracted from the guidance data to form an error signal. This error signal is then filtered by the PFE and CMN filters, where the outputs provide suitable estimates of the PFE and CMN components, respectively. These filters are defined in Figure 21.

7.3.3.1.3 These filters can be utilized to determine the transponder instrumentation error components specified in Chapter 3, 3.5.4.5.3 and 3.5.4.5.4 of the AAR-RNAV Aids. Similarly, the interrogator instrumentation error components, specified in Chapter 3, 3.5.5.4 of the AAR-RNAV Aids, can be determined.



GUIDANCE FUNCTION	CORNER FREQUENCIES (RADIANS/SEC)		
	ω_0	ω_1	ω_2*
DME/P	1.5	0.5	10

RECEIVER OUTPUT FILTER $\frac{\omega_2}{S + \omega_2}$

PATH FOLLOWING FILTER $\frac{\omega_n^2}{S^2 + 2\zeta\,\omega_n S + \omega_n^2}$ $\zeta = 1; \omega_0 = .64\ \omega_n$

CONTROL MOTION NOISE FILTER $\frac{S}{S + \omega_1}$

* This corner frequency may be less than 10 rad/sec for some applications.

	IA MODE	FA MODE
T	40 sec	10 sec

DME/P measurement methodology: ε is the error specification; T region to be evaluated; T_1, T_2, T_3 ... time intervals that error exceeds specifications. For the equipment to be acceptable in this region, the following inequality should be true:

$(T_1 + T_2 + T_3 + \ldots) / T \leq 0.05$.

Figure 21

7.3.7. *Multipath effects*

7.3.7.1. Under the multipath conditions likely to exist, the accuracy specifications of the DME/P assume that the performance is not degraded beyond a certain limit and that this degradation is equally applied to both interrogator and transponder receiver.

7.3.7.2. To ensure that the equipment is working according to the specifications, the following should apply to FA mode operation of the system:

a) if a signal of sufficient power to make thermal noise contributions insignificant is applied to the receivers, a second signal delayed between 0 and 350 nanoseconds with respect to the first, with an amplitude 3 dB or more below the first and with a scalloping frequency between 0.05 and 200 Hz should not produce errors in the receiver output of more than plus or minus 100 nanoseconds (15 m);

b) for delays more than 350 nanoseconds the error contribution will be reduced considerably. A typical value will be plus or minus 7 nanoseconds (1 m).

7.3.7.3. The airborne DME antenna should be located so as to preclude antenna gain reductions in the forward direction with the aircraft in the landing configuration. Any such antenna gain reductions could enhance the multipath error component when the aircraft is on approach and landing phases when highest DME accuracies are required.

7.3.8. *DME/P power budget*

7.3.8.1. Tables 9 and 10 are an example of CTOL air-to-ground and ground-to-air power budgets. The permitted peak ERP value is based on a pulse shape which meets the spectral constraints in Chapter 3, 3.5.4.1.3 e) of the AAR-RNAV Aids.

Table 9. CTOL ground-to-air power budget

Power budget items	41km (22 NM)	13km (7 NM)	Ref.datum	Roll-out
Peak effective radiated power, dBm	55	55	55	55
Ground multipath loss, dB	–5	–3	–4	–17
Antenna pattern loss, dB	–4	–2	–5	–5
Path loss, dB	–125	–115	–107	–103
Monitor loss, dB	–1	–1	–1	–1
Polarization and rain loss, dB	–1	–1	0	0
Received signal at aircraft, dBm Power density at aircraft, dBW/m^2	–81 –89	–67 –75	–62 –70	–71 –79
Aircraft antenna gain, dB	0	0	0	0
Aircraft cable loss, dB	–4	–4	–4	–4
Received signal at interrogator, dBm	–85	–71	–66	–75
Receiver noise video, dBm (Noise factor (NF) = 9 dB)				
IF BW: 3.5 MHz		-103	-103	-103
IF BW: 0.8 MHz	-109			
Signal-to-noise ratio (video), dB	24	32	37	28

Table 10. CTOL air-to-ground power budget

Power budget items	41km (22 NM)	13km (7 NM)	Ref. datum	Roll-out
Interrogator transmitter power, dBm	57	57	57	57
Aircraft antenna gain, dB	0	0	0	0
Aircraft cable loss, dB	–4	–4	–4	–4
Peak effective radiated power, dBm	53	53	53	53
Ground multipath loss, dB	–5	–3	–4	–17
Path loss, dB	–125	–115	–107	–103
Polarization and rain loss, dB	–1	–1	0	0
Received signal at transponder antenna, dBm	–78	–66	–58	–67
Ground antenna gain, dB	8	8	8	8
Pattern loss, dB	–4	–2	–5	–5
Cable loss, dB	–3	–3	–3	–3
Received signal at transponder, dBm	–77	–63	–58	–67
Receiver noise video, dBm				
(Noise factor (NF) = 9 dB)				
IF BW: 3.5 MHz		-106	-106	-106
IF BW: 0.8 MHz	-112			
Signal-to-noise ratio (video), dB	35	43	48	39

7.3.8.2. In the power budget calculations, it is assumed that the aircraft antenna is not shielded by the aircraft structure including the landing gear when extended.

7.3.8.3. The video power signal-to-noise ratio is related to the IF power signal-to-noise ratio in the following manner:

$$\text{S/N (video)} = \text{S/N (IF)} + 10 \log \frac{\text{IF noise bandwidth}}{\text{video noise bandwidth}}$$

Note 1: *The distances are measured from the transponder antenna.*

Note 2: *Frequency dependent parameters were calculated for 1 088 MHz.*

7.3.9. *DME/P monitor time delay measurement*

The required time delay measurement can be accomplished by measuring the output of a PFE filter and making a control decision within 1 second. However, since the transponder PFE is a slowly varying error component, an equivalent measurement is to average the unfiltered time delay samples for 1 second.

8. MATERIAL CONCERNING POWER SUPPLY SWITCH-OVER TIMES

8.1. POWER SUPPLY SWITCH-OVER TIMES FOR GROUND-BASED RADIO AIDS USED IN THE VICINITY OF AERODROMES

The power supply switch-over times for radio navigation aids and ground elements of communications systems are dependent on the type of runway and aircraft operations to be supported. Table 11 indicates representative switch-over times which may be met by power supply systems currently available.

Table11. Power supply switch-over times for ground-based radio aids used at aerodromes

Type of runway	Aids requiring power	Maximum switch - overtimes (seconds)
Instrument approach	SRE	15
	VOR	15
	NDB	15
	D/F facility	15
Precision approach, Category I	ILS localizer	10
	ILS glide path	10
	ILS middle marker	10
	ILS outer marker	10
	PAR	10
Precision approach, Category II	ILS localizer	0
	ILS glide path	0
	ILS inner marker	1
	ILS middle marker	1
	ILS outer marker	10
Precision approach, Category III	(same as Category II)	

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