



NAMIBIAN CIVIL AVIATION AUTHORITY

Advisory Pamphlet (AP)

ANSSO-ATS-AP172/06

**GUIDANCE ON ESTABLISHING OF ATS ROUTES DEFINED BY
VOR**

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GUIDANCE ON ESTABLISHING OF ATS ROUTES DEFINED BY VOR

1. PURPOSE

This Advisory Pamphlet (AP) provides guidance to ATS providers when establishing ATS routes defined by VOR to meet the requirements of the NAMCARs, Part 172 and the associated technical standards.

2. BACKGROUND

- (a) The NAM-CARs Parts 172 requires ATS providers to ensure that they comply with the prescribed standards when establishing ATS routes.
- (b) The NAM-CARs Parts 172 also requires ATS providers to ensure that they comply with the prescribed standards when establishing and identifying change-over points on ATS route segments
- (c) NAM-CATS Part 172 requires that when ATS routes are established, a protected airspace along each ATS route and a safe spacing between adjacent ATS routes be provided.
- (d) NAM-CATS Part 172 further requires ATS providers to define and publish change-over points on ATS route segments defined by reference to very high frequency omnidirectional radio ranges (VOR) where this will assist accurate navigation along the route segments.
- (e) Below are the extracts from the Civil Aviation Regulations Part 172 – Air traffic services provider, to which this Advisory Pamphlet apply.

3. EXTRACTS FROM NAM-CARS, PART 172 – AIR TRAFFIC SERVICES

172.03.13 Establishment and identification of air traffic service routes

- (1) The establishment and identification of air traffic service routes in Namibia shall be as prescribed in Document NAM-CATS-ATS.

172.03.14 Establishment of change-over points

- (1) The requirements for establishment of change-over points on air traffic service route segments in Namibia shall be as prescribed in NAM-CATS - ATS.

4. EXTRACTS FROM NAM-CATS, PART 172 – AIR TRAFFIC SERVICES

172.03.13 ESTABLISHMENT AND IDENTIFICATION OF AIR TRAFFIC SERVICES ROUTES

1. Establishment of air traffic services routes

- 1.1 When ATS routes are established, a protected airspace along each ATS route and a safe spacing between adjacent ATS routes shall be provided.
- 1.2 When warranted by density, complexity or nature of the traffic, special routes shall be established for use by low-level traffic, including helicopters operating to and from helidecks on the high seas. When determining the lateral spacing between such routes, account shall be taken of the navigational means available and the navigation equipment carried on board helicopters.
- 1.3 ATS routes must be identified by designators.
- 1.4 Designators for ATS routes other than standard departure and arrival routes must be selected in accordance with the principles set forth in Appendix 1 to this NAM-CATS-ATS.
- 1.5 Standard departure and arrival routes and associated procedures must be identified in accordance with the principles set forth in Appendix 3 of the NAM-CATS-ATS.

172.03.14 ESTABLISHMENT OF CHANGE-OVER POINTS

- 1.1 An ATS provider must define and publish change-over points on ATS route segments defined by reference to very high frequency omnidirectional radio ranges where this will assist accurate navigation along the route segments. The establishment of change-over points must be limited to route segments of 110 km (60 NM) or more, except where the complexity of ATS routes, the density of navigation aids or other technical and operational reasons warrant the establishment of change-over points on shorter route segments.
- 1.2 Unless otherwise established in relation to the performance of the navigation aids or frequency protection criteria, the change-over point on a route segment shall be the mid-point between the facilities in the case of a straight route segment or the intersection of radials in the case of a route segment which changes direction between the facilities.
- 1.3 When establishing points for changeover from one VOR to another for primary navigational guidance on VOR-defined ATS routes, the ATS provider must consider the following:
 - (a) the establishment of change-over points must be made on the basis of performance of the VOR stations concerned, including an evaluation of the interference protection criteria. The process should be verified by flight checking;
 - (a) where frequency protection is critical, flight inspection must be undertaken at the highest altitudes to which the facility is protected.

GUIDANCE ON ESTABLISHING ATS ROUTES DEFINED BY VOR

1. Introduction

- 1.1 NAMCAR Part 172 and the associated technical standards requires an ATS provider to establish air traffic service routes and ensure that a protected airspace along each route and a safe spacing between adjacent routes are provided. In addition, the ATS provider is required to define and publish change-over points on ATS route segments defined by reference to very high frequency omnidirectional radio ranges (VOR) where this will assist accurate navigation along the route segments.
- 1.2 This Advisory pamphlet (AP) provides information and guidance to the ATS providers to ensure that when ATS routes defined by VORs are established, the protected airspace along each route and the spacing between adjacent routes meet the requirements of the regulations. In addition, the AP provides information and guidance to the ATS providers to ensure that change-over points along route segments are established on the basis of performance of the VOR stations concerned and are defined, and published in accordance with the prescribed standards.
- 1.3 This guidance is based on the results of comprehensive studies carried out in Europe in 1972 and the United States in 1978, which were in general agreement. Details of the European studies can be found in ICAO Circular 120 — *Methodology for the Derivation of Separation Minima Applied to the Spacing between Parallel Tracks in ATS Route Structures*.
- 1.4 In applying the guidance material in Sections 3 and 4 of this AP, it should be recognized that the data on which it is based are generally representative of navigation using VOR meeting the full requirements of Doc 8071 — *Manual on Testing of Radio Navigation Aids*, Volume I. Any additional factors, such as those due to particular operational requirements, frequency of aircraft passings or information available regarding the actual track-keeping performance of aircraft within a given portion of airspace should be taken into account.

- 1.5 Attention of ATS providers is drawn to the basic assumptions given in paragraph 4.2 and to the fact that the values given in paragraph 4.1 represent a conservative approach. Before applying these values, ATS providers should take into account any practical experience gained in the airspace under consideration, as well as the possibility of achieving improvements in the overall navigation performance of aircraft.
- 1.6 The ATS provider should as much as possible, coordinate with ICAO when establishing ATS routes in accordance with the guidance provided in this AP.

2. Determination of VOR system performance values

- 2.1 Due to the large variability of the values which are likely to be associated with each of the factors that make up the total VOR system, and the limitation of presently available methods to measure all these effects individually with the required precision, an assessment of the total system error is necessary for determining the VOR system performance. The guidance in Sections 3 and 4 of this AP should be applied only after study of ICAO Circular 120 referred to in paragraph 1.3 especially with respect to the environmental conditions.
- 2.1 Overall VOR system accuracy shall be in accordance with the specifications prescribed in NAMCAR Part 171.

3. Determination of protected airspace along VOR-defined routes

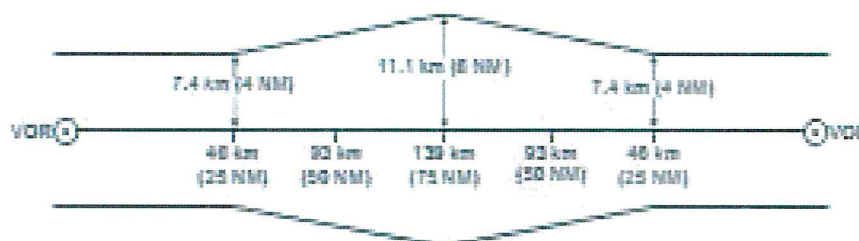
Note. The ATS provider is requested to note that:

- a) the material contained in this section has not been derived by means of the collision-risk/target level of safety method.*
- b) the use of the word "containment" as used in this section is intended to indicate that the protected airspace provided will contain the traffic for 95 per cent of the total flying time (i.e. accumulated over all aircraft) for which the traffic operates along the route in question. Where, for example 95 per cent containment is provided, it is implicit*

that for 5 per cent of the total flying time, traffic will be outside the protected airspace. It is not possible to quantify the maximum distance which such traffic is likely to deviate beyond the protected airspace.

- 3.1 For VOR-defined routes where radar or ADS-B is not used to assist aircraft in remaining within the protected airspace, the following guidance is provided. However, when the lateral deviations of aircraft are being controlled with the aid of radar or ADS-B monitoring, the size of the protected airspace required may be reduced, as indicated by practical experience gained in the airspace under consideration.
- 3.2 As a minimum, protection against activity in airspace adjacent to the routes should provide 95 per cent containment.
- 3.3 The work described in Circular 120 indicates that a VOR system performance based on the probability of 95 per cent containment would require the following protected airspace around the centre line of the route to allow for possible deviations:
- VOR routes with 93 km (50 NM) or less between VORs: ± 7.4 km (4 NM);
 - VOR routes with up to 278 km (150 NM) between VORs: ± 7.4 km (4 NM) up to 46 km (25 NM) from the VOR then expanding protected airspace up to ± 11.1 km (6 NM) at 139 km (75 NM) from the VOR.

Figure 1



- 3.4 If the appropriate ATS authority considers that a better protection is required, e.g. because of the proximity of prohibited, restricted or danger areas, climb or descent paths of military aircraft, etc., it may decide that a higher level of

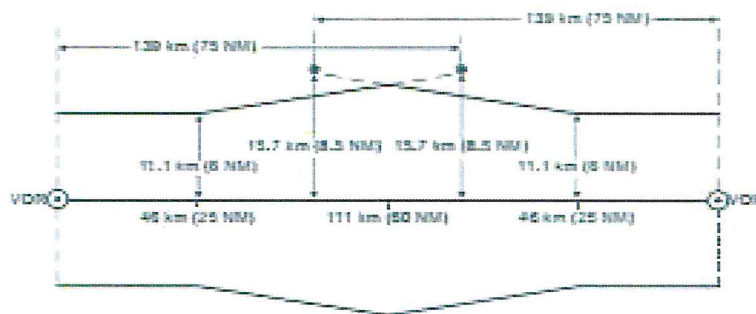
containment should be provided. For delineating the protected airspace the following values should then be used:

- for segments with 93 km (50 NM) or less between VORs, use the values in line A of the table below;
- for segments with more than 93 km (50 NM) and less than 278 km (150 NM) between the VORs use the values as shown in line A up to 46 km (25 NM), then expand linearly to the value shown in line B at 139 km(75 NM) from the VOR as shown in the Table below:

		Percentage containment					
		95	96	97	98	99	99.5
A (km)		±7.4	±7.4	±8.3	±9.3	±10.2	±11.1
NM		±4.0	±4.0	±4.5	±5.0	±5.5	±6.0
B (km)		±11.1	±11.1	±12.0	±12.0	±13.0	±15.7
NM		±6.0	±6.0	±6.5	±6.5	±7.0	±8.5

For example, the protected area for a route of 222 km (120 NM) between VORs and for which 99.5 per cent containment is required should have the following shape:

Figure 2

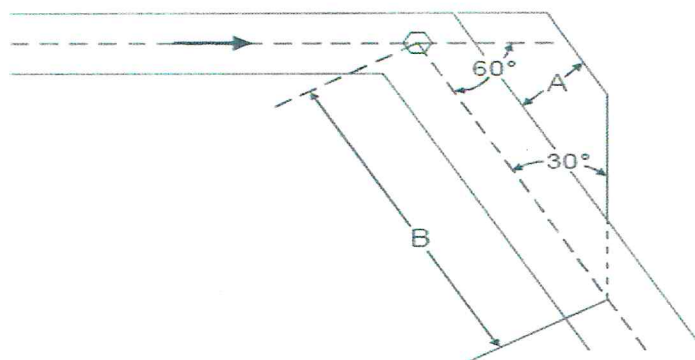


3.5 If two segments of a VOR-defined ATS route intersect at an angle of more than 25 degrees, additional protected airspace should be provided on the outside of the turn and also on the inside of the turn as necessary. This additional space is to act as a buffer for increased lateral displacement of aircraft, observed in practice, during changes of direction exceeding 25

degrees. The amount of airspace added varies with the angle of intersection. The greater the angle, the greater the additional airspace to be used. Guidance is provided for protected airspace required at turns of no more than 90 degrees. For the exceptional circumstances which require an ATS route with a turn of more than 90 degrees, States should ensure that adequate protected airspace is provided on both the inside and outside of such turns.

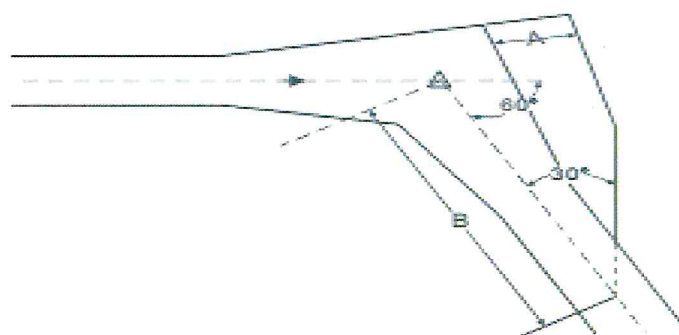
- 3.6 The following examples have been synthesized from the practices of two States which use templates to facilitate the diagramming of airspace for planning purposes. Design of the turning area templates took into account factors such as aircraft speed, bank angle in turns, probable wind velocity, position errors, pilot delays and an intercept angle of at least 30 degrees to achieve the new track, and provides at least 95 per cent containment.
- 3.7 A template was used to establish the additional airspace required on the outside of turns to contain aircraft executing turns of 30, 45, 60, 75 and 90 degrees. The simplified figures below represent the outer limits of this airspace with the fairing curves removed to allow easy construction. In each case, the additional airspace is shown for aircraft flying in the direction of the large arrow. Where routes are used in both directions, the same additional airspace should be provided on the other outside boundary.
- 3.8 Figure 3 illustrates the application of two segments intersecting at a VOR, at an angle of 60 degrees.

Figure 3



3.9 Figure 4 illustrates the application for two segments meeting at a VOR intersection at an angle of 60 degrees beyond the point where boundary splay is required in order to comply with 3.3 and Figure 1.

Figure 4



- 3.10 The following table outlines the distances to be used in sample cases when providing additional protected airspace for route segments at and below FL 450, intersecting at a VOR or meeting at a VOR intersection not more than 139 km (75 NM) from each VOR.

Note. — Refer to Figures 3 and 4.

Angle of intersection	30°	40°	60°	75°	90°
VOR					
*Distance "A" (km)	5	9	13	17	21
(NM)	3	5	7	9	11
*Distance "A" (km)	46	62	73	86	92
(NM)	25	34	40	46	50
Intersection					
*Distance "A" (km)	7	11	17	23	29
(NM)	4	6	9	13	16
*Distance "A" (km)	66	76	88	103	111
(NM)	36	41	48	56	60

*Distance are rounded up to the next whole kilometre/nautical mile.

Note. For behaviour of aircraft at turns, see Circular 120, 4.4.

- 3.11 Figure 5 illustrates a method to construct the required additional protected airspace on the inside of turns for turns of 90 degrees or less:

Locate a point on the airway centre line, equal to the radius of turn plus the along-track tolerance prior to the nominal turning point.

From this point, drop a perpendicular line to intersect the edge of the airway on the inside of the turn.

From this point on the inner edge of the airway, construct a line to intersect the airway centre line beyond the turn at an angle of half of the angle of turn.

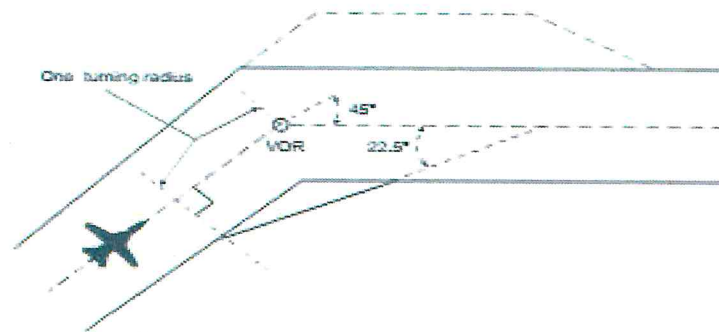
The resulting triangle on the inside of the turn depicts the additional airspace which should be protected for the change of direction. For

any turn of 90 degrees or less, the extra space on the inside will serve for aircraft approaching the turn from either direction.

Note 1. Criteria for the calculation of the along-track tolerance are contained in PANS-OPS (Doc 8168), Volume II.

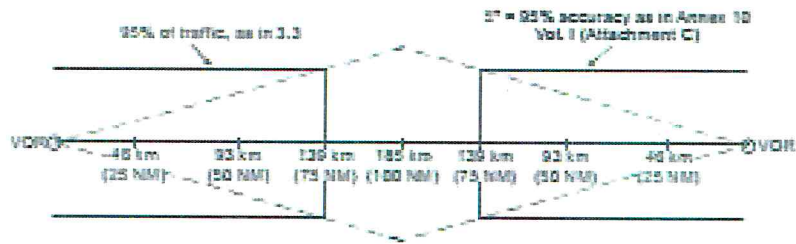
Note 2. Guidance on the calculation of radius of turn is provided in Section 7.

Figure 5



- 3.12 For turns at VOR intersections, the principles of construction for extra airspace on the inside of a turn as described in 3.11 can be applied. Depending on the distance of the intersection from one or both VORs, one or both airways may have a splay at the intersection. Depending upon the situation, the extra airspace may be inside, partially inside, or outside of the 95 per cent containment. If the route is used in both directions, the construction should be completed separately for each direction.
- 3.13 Measured data for routes longer than 278 km (150 NM) between VORs are not yet available. To determine protected airspace beyond 139 km (75 NM) from the VOR, the use of an angular value of the order of 5 degrees as representing the probable system performance would appear satisfactory. The following figure illustrates this application.

Figure 6

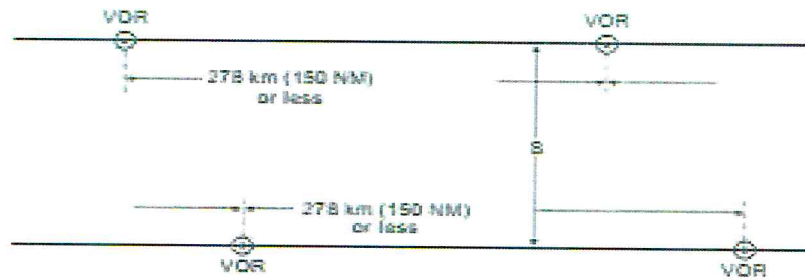


4. Spacing of parallel routes defined by VORs

Note. The guidance in this section has been derived from measured data using the collision-risk/target level of safety method.

- 4.1 The collision risk calculation, performed with the data of the European study mentioned in 1.3 indicates that, in the type of environment investigated, the distance between route centre lines (S in Figure 7) for distances between VORs of 278 km (150 NM) or less should normally be a minimum of:
- 33.3 km (18 NM) for parallel routes where the aircraft on the routes fly in opposite direction; and
 - 30.6 km (16.5 NM) for parallel routes where the aircraft on the two routes fly in the same direction.

Figure 7



Note. Two route segments are considered parallel when:

- a) they have about the same orientation, i.e. the angular difference does not exceed 10 degrees;
- b) they are not intersecting, i.e. another form of separation must exist at a defined distance from the intersection;
- c) traffic on each route is independent of traffic on the other route, i.e. it does not lead to restrictions on the other route

4.2 This spacing of parallel routes assumes:

- a) aircraft may either during climb or descent or during level flight be at the same flight levels on the two routes;
- b) traffic densities of 25 000 to 50 000 flights per busy two-month period;
- c) VOR transmissions which are regularly flight checked in accordance with Doc 8071 — *Manual on Testing of Radio Navigation Aids, Volume I*, and have been found to be satisfactory in accordance with the procedures in that document for navigational purposes on the defined routes; and
- d) no real-time radar or ADS-B monitoring or control of the lateral deviations is exercised.

4.3 Preliminary work indicates that, in the circumstances described in a) to c) below, it may be possible to reduce the minimum distance between routes. However, the figures given have not been precisely calculated and in each case a detailed study of the particular circumstances is essential:

- a) if the aircraft on adjacent routes are not assigned the same flight levels, the distance between the routes may be reduced; the magnitude of the reduction will depend on the vertical separation between aircraft on the adjacent tracks and on the percentage of

climbing and descending traffic, but is not likely to be more than 5.6 km (3 NM);

- b) if the traffic characteristics differ significantly from those contained in Circular 120, the minima contained in 4.1 may require adjustment. For example, for traffic densities of about 10 000 flights per busy two-month period, a reduction of 900 to 1 850 m (0.5 to 1.0 NM) may be possible;
- c) the relative locations of the VORs defining the two tracks and the distance between the VORs will have an effect on the spacing, but this has not been quantified.

4.4 Application of radar or ADS-B monitoring and control of the lateral deviations of the aircraft may have a large effect on the minimum allowable distance between routes. Studies on the effect of radar monitoring indicate that:

- a) further work is necessary before a fully satisfactory mathematical model can be developed;
- b) any reduction of separation is closely related to:
 - (i) traffic (volume, characteristics);
 - (ii) coverage and data processing, availability of an automatic alarm;
 - (iii) monitoring continuity;
 - (iv) sector workload; and
 - (v) radiotelephony quality.

4.4.1 According to these studies and taking into account the experience some States have accumulated over many years with parallel route systems under continuous radar control, it can be expected that a reduction to the order of 15 to 18.5 km (8 to 10 NM), but most probably not less than 13 km (7 NM), may be possible as long as radar monitoring workload is not increased substantially by that reduction. Actual operations of such systems using reduced lateral spacing have shown that:

- a) it is very important to define and publish change-over points (see also 6);
 - b) large turns should be avoided when possible; and
 - c) where large turns cannot be avoided, required turn profiles should be defined for turns larger than 20 degrees.
- 4.4.2 Even where the probability of total radar or ADS-B failure is very small, procedures to cover that case should be considered

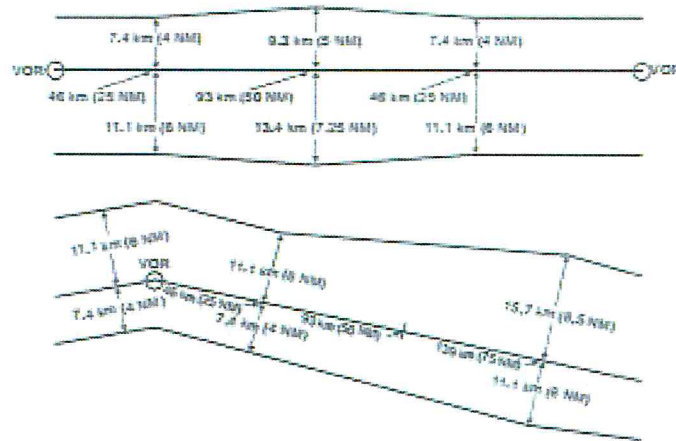
5. Spacing of adjacent VOR-defined routes that are not parallel

Note 1. The material of this section is intended to provide guidance for situations where non-intersecting VOR-defined routes are adjacent and have an angular difference exceeding 10 degrees.

Note 2. The material of this section has not been derived by means of the collision-risk/target level of safety method.

- 5.1 For adjacent non-intersecting VOR-defined routes that are not parallel, the collision-risk/target level of safety method is not, at its present state of development, fully appropriate. For this reason use should be made of the material in 3.
- 5.2 The protected airspace between such routes should not be less than that which will provide, without overlap, the 99.5 per cent containment values given in the table in paragraph 3.4 (see example in Figure 8).
- 5.3 Where there is an angular difference of more than 25 degrees between route segments, additional protected airspace, as indicated in 3.5 to 3.10, should be provided.

Figure 8



6. Change-over points for VORs

6.1 When considering the establishment of points for changeover from one VOR to another for primary navigational guidance on VOR-defined ATS routes, States should bear in mind that:

- a) the establishment of change-over points should be made on the basis of performance of the VOR stations concerned, including an evaluation of the interference protection criteria. The process should be verified by flight checking (see the *Manual on Testing of Radio Navigation Aids* (Doc 8071), Volume I);
- b) where frequency protection is critical, flight inspection should be undertaken at the highest altitudes to which the facility is protected.

6.2 Nothing in 6.1 should be interpreted as placing a restriction on the service ranges of VOR installations meeting the specifications in NAMCAR Part 171.

7. Calculation of radius of turn

7.1 The method used to calculate turn radii and the turn radii indicated below are applicable to aircraft performing a constant radius turn. The material has been derived from the turn performance criteria developed for RNP 1 ATS routes and can be used in the construction of the required additional

- 7.4 By calculation, the radius of turn of an aircraft flying at 1 400 km/h (750 kt) ground speed, with a bank angle of 20 degrees, is 22.51 NM (41.69 km). For purposes of expediency, this has been reduced to 22.5 NM (41.6 km). Following the same logic for the lower airspace, it is considered that up to FL 200 (6 100 m) the maximum figures to be encountered are a true airspeed of 740 km/h (400 kt), with a tailwind of 370 km/h (200 kt). Keeping the maximum bank angle of 20 degrees, and following the same formula, the turn would be defined along a radius of 14.45 NM (26.76 km). For expediency, this figure may be rounded up to 15 NM (27.8 km).
- 7.5 Given the above, the most logical break point between the two ground speed conditions is between FL 190 (5 800 m) and FL 200 (6 100 m). In order to encompass the range of turn anticipation algorithms used in current flight management systems (FMS) under all foreseeable conditions, the turn radius at FL 200 and above should be defined as 22.5 NM (41.6 km) and at FL 190 and below as 15 NM (27.8 km).