Chapter 10 RNP AR APCH

10.1 General

RNP AR APCH operations permit additional safety and efficiency to be achieved by the capability of advanced navigation equipment, aircraft systems and procedures design.

A large number of RNP AR approach and departure procedures have been developed by the industry, commonly sponsored by airlines and designed using commercially developed design criteria. These operations have been approved in a number of States following evaluation on a case-by-case basis, normally for a specific aircraft type and individual operator.

The RNP AR APCH navigation specification has been developed to provide ICAO guidance for similar RNP approach procedures that can be applied generally and to a range of qualified aircraft types.

Procedure design criteria have now been published in ICAO Doc 9905 RNP AR Procedure Design Manual.

10.2 Authorisation Required

All operations involve some form of authorisation, either specific or implied, and consequently questions are often raised with regard to the use of the term authorisation required in the context of RNP AR APCH operations.

Early development work on RNP approach procedures was carried out in the United States. Under the US Federal Aviation Regulations, all instrument approach procedures that are in the public domain are developed under FAR Part 97. Where approach procedures (for whatever reason) do not comply with FAR Part 97, the FAA can approve an operation (for a specific operator) as a Special Airworthiness and Aircrew Authorisation Required (SAAAR) procedure.

Accordingly as at the time (1995) the initial work on RNP approach development was undertaken there was no provision in FAR Part 97 for this type of operation, the FAA approved RNP approach operations as procedures with SAAAR.

Subsequently the FAA developed procedure design rules (FAA Order 8260.52) and airworthiness and operational rules (FAA AC90-101) to support FAA Part 97 RNP SAAAR operations, referred to Public RNP SAAAR.

In 2005, when the then Obstacle Clearance Panel (now Instrument Flight Procedures Panel) in ICAO decided to harmonise ICAO procedure design rules with FAA Order 8260.52, it was recognised that there was no equivalent process in ICAO which related to non-conforming or *Special* procedures. Consequently it was decided to abbreviate the term to Authorisation Required or AR for ICAO application.

The implication (whether SAAAR or AR) is that improvements in operational safety and efficiency gained by the utilisation of the capability of advanced navigation capability are matched by an appropriate level of detailed evaluation of aircraft, operations and procedure design.

AR therefore requires the State to conduct a full evaluation of all aspects of the operation before issuing an approval and that only qualified operators are permitted to conduct RNP operations which are identified as *Authorisation Required*.

10.3 Characteristics

The are a number of characteristics of RNP AR APCH operations that combine to improve the capability of this type of operation, including;

- support for RNP less than 0.3 (RNP 0.1 is the lowest currently available)
- obstacle clearance lateral tolerance 2 x RNP
- final approach vertical obstacle clearance provided by a vertical error budget
- radius to fix (RF) legs enabling circular flight paths to be flown

It should be noted that while RNP AR APCH procedures support low RNP types, that this is only one characteristic and that many RNP AR APCH operations do not require RNP less than 0.3. An RNP 0.3 RNP AR APCH operation should not be confused with an RNP APCH which also uses RNP 0.3 capability.

10.4 Procedure Design

RNP AR APCH procedures are designed in accordance with ICAO Doc 9905 *REQUIRED NAVIGATION PERFORMANCE AUTHORIZATION REQUIRED (RNP AR) PROCEDURE DESIGN MANUAL*.

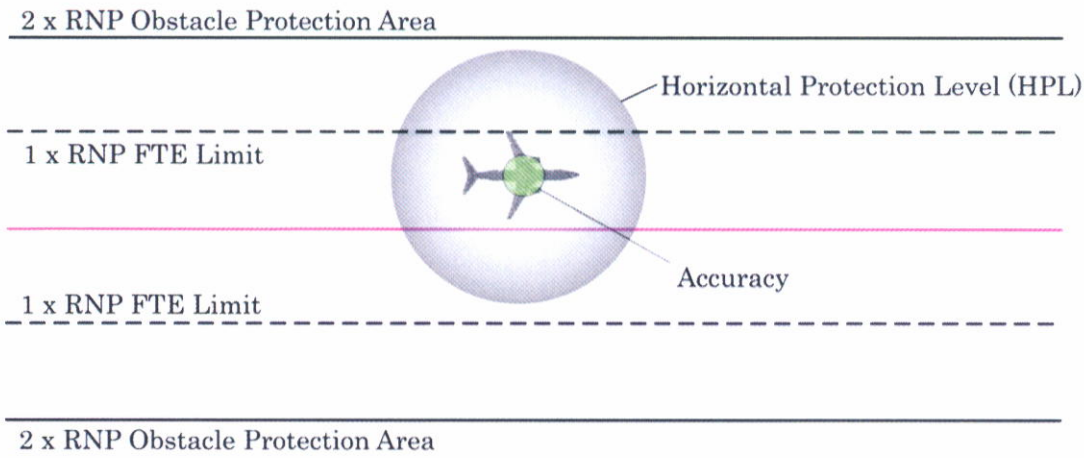


Figure 10.1: RNP AR APCH Obstacle Protection

It is advisable that inspectors are familiar with the basic principles of RNP AR APCH procedure design as AR operations are dependent upon the proper integration of aircraft capability, operating procedures and procedure design.

The design criteria for RNP AR APCH procedures has been derived from operational experience in a number of States which have generally been applied to individual operators, specific aircraft types, and industry developed design criteria. The ICAO RNP AR Procedure Design Manual provides guidance to States on the early implementation of generic RNP AR approach procedures that can be applied to any appropriately capable aircraft and qualified operating crew.

The applicability of the design criteria to a broad range of capable aircraft does result in some operational limitations, particularly in areas of difficult terrain. In order to achieve a satisfactory operational outcome it may be necessary in such cases to approve variations to the design based on specific operational mitigations.

The RNP AR Procedure Design Manual makes reference to such circumstances as follows:

> 1.1.2.5 The design criteria in this manual are applicable to a range of aircraft types and cannot therefore, take into account the full capability of some aircraft types. Consequently procedures designed in accordance with this manual will provide an acceptable operational solution in many but not all circumstances. Where an operationally acceptable solution is not available through the application of the criteria in this manual, development of detailed procedures may be needed to satisfy local conditions. Alternative design solutions may be derived which specify aircraft type or specific performance parameters, special operating conditions or limitations, crew training, operational evaluation or other requirements that can be demonstrated to provide an equivalent level of safety. Such solutions are not the subject of this manual and will require case-by-case flight operational safety assessments and operational approval.

10.5 Operational Approval

RNP AR APCH procedures depend upon the integration of aircraft, operations and procedure design to deliver a safe and efficient outcome. Conventional navigation systems which have been in common usage for many years depend on aircraft equipment & avionics, operating procedures and procedure design that have benefited from many years of common usage and we are generally

able to consider each element in isolation. For example ILS receivers are manufactured by many different companies, the operation and crew interface is standard, and a pilot qualified to fly ILS can do so on any aircraft with minimum of cross-training. ILS operating procedures are common and it is not necessary to apply different procedures for differing aircraft or avionics. Similarly the procedure designer develops ILS approaches without reference to specific avionics capabilities or operating procedures. All of these aspects are common, well understood, and standardised throughout the industry.

The same cannot be said of RNP AR APCH operations. In most cases, aircraft avionics were installed before the concept of RNP approaches was developed and equipment has been adapted to provide RNP AR APCH capability. Consequently there is no common standard yet available for RNP AR APCH avionics, cockpit displays, alerting and other functions. In some cases modification of upgrade of aircraft systems may be available, in other cases evaluation may be required for systems which cannot be upgraded.

Operating procedures also need to be matched to the aircraft, avionics, cockpit displays, etc., and will vary considerably between aircraft types, models and configurations. Both operating procedures and aircraft equipment/capability need to be evaluated against the basis upon which RNP AR APCH procedures are designed, and therefore consideration of the basic procedure design principles needs to be included in the operational approval process.

10.6 Evaluation Team

For many States, the first RNP AR APCH operational approval will be a new experience for both the operator and the regulator. Most regulatory authorities are structured to manage conventional operations and there are established procedures for approving operations. It is not uncommon for various departments (both in the airline and regulator) to carry out their work independently and there may be infrequent need to consult with technical experts in other fields of expertise.

It is recommended that a team approach is used in the conduct of an RNP AR APCH evaluation, and that cross-discipline dialogue and consultation is encouraged. As the first such operational experience will be a learning experience for all concerned it can be very useful to involve all parties, including the applicant, in a consultative approach to the approval process.

A project lead should be appointed to co-ordinate the combined efforts of the project team. As the outcome is an *operational* approval the project lead should be a person experienced in flight operations assisted by experts in other specialist fields as required. The project lead and other participants on the team should be encouraged to learn as much as possible about areas outside their immediate

area of expertise. An vital part of a successful approval process is the synergy between all aspects of the operation that leads to a successful safety outcome.

10.7 Operator's Application

An important contributor to a successful RNP AR APCH implementation project is a well developed and comprehensive application. However it needs to be realised that the operator is likely to be inexperienced in this type of operation and will be developing their knowledge and expertise during the authorisation process, so some allowance will need to be made. The applicant should be encouraged to present as clearly as possible the details of how the operation is to be conducted, and be prepared to discuss the proposal with the regulator so that a satisfactory outcome is achieved. The regulator should also recognise that it may be difficult in the early stages for the applicant to clearly identify the requirements for approval and that the regulator may also have some similar difficulty in understanding the requirements.

It needs to be recognised that while the assistance of a competent operational approvals consultant can be very helpful, at the end of the operational approval process both the applicant and the approving authority need to ensure that they have comprehensive understanding of all aspects of the operation. Leaving it to a consultant to prepare a conforming application, and then just "ticking the boxes" does little to validate the Authorisation Required process.

10.8 Aircraft Eligibility

As the airworthiness requirements for RNP AR APCH operations are relatively recent (e.g. FAA AC 90-101 published December 2005) few aircraft have yet to be specifically approved for RNP AR APCH operations. Commonly the eligibility for an aircraft to conduct RNP AR APCH operations needs to be established during the operational approval process.

Some AFMs will contain a statement of RNP capability (AR may not be mentioned) which may have been approved or accepted by the regulatory authority in the State of manufacture however such statements need to be considered against the circumstances existing at the time of manufacture. Most RNP capability statements were made at a time when there was no international guidance and the basis for the capability statements are commonly developed by the manufacturer, and were accepted by the regulatory authority at the time as being reasonable, but of no specific relevance to operations being conducted at that time in history.

Some manufacturers have applied for "RNP AR APCH approval" by their respective aviation authority, and where such documentation is available, the issue of aircraft eligibility is very much simpler to determine.

However there remain a significant number of aircraft that are RNP AR APCH capable but which do not have an RNP AR APCH airworthiness approval that is consistent with the requirements of the PBN Manual RNP AR APCH navigation specification. The reasons are varied, and may include a lack of operator demand leading the manufacturer to apply for approval, a disagreement between the manufacturer and approving authority, an inability to meet one or more specific requirements, or a lack of supporting data.

The absence of an RNP AR APCH airworthiness approval does not mean that the aircraft is not suitable for RNP AR APCH operations, but that this capability has not been demonstrated against available airworthiness guidelines. In many cases an operational procedure or mitigation is required to overcome the inability to obtain an airworthiness approval. In fact many operational approvals have been issued for aircraft that do not have an RNP AR APCH airworthiness approval.

Where the eligibility needs to be established by operational approval, the normal process is to obtain supporting data from the aircraft manufacturer. Leading manufacturers are increasingly coming under pressure from customers to provide support for RNP AR operations and the amount and detail for information available is increasing steadily.

States with limited resources may be able to request advice and assistance from States that have previously issued operational approvals in respect of specific aircraft. Care should be taken to identify the specific basis of such approvals as there are many variations in aircraft equipment, software, displays, options, and other relevant features that vary between aircraft of the same type and model.

10.9 Flight Technical Error

The manufacturer will normally use flight technical error data obtained during flight trials to establish the RNP capability depending upon the phase of flight and the method of control. Typically the lowest FTE and therefore the lowest RNP is obtained with auto-pilot coupled, however other values may be applicable to the use of flight director or map mode.

If there is any concern over the FTE data, then the operator can be required to gather additional in-service data. This can be achieved during initial operations, which should be limited to a conservative RNP (e.g. RNP 0.3). FTE data can be captured via on-board engineering monitoring systems or the Quick Access Recorder (QAR). The standard deviation of FTE observed can then be used to calculate the RNP capability based on the formula in Part 1 of this handbook.

Despite the values used for FTE, a further consideration is the monitoring of FTE performance in flight. To illustrate this point, an aircraft may demonstrate very low FTE values and therefore the calculated RNP capability could be low, but no

cockpit display is available to permit the monitoring of this performance in real time. The aircraft, while able to meet RNP performance requirements would not qualify for RNP AR APCH because it could not meet the requirement for on board performance and monitoring of the FTE. As the standard of cockpit display varies, and the ability for the flight crew to monitor FTE also varies, this has a bearing on the RNP capability.

The PBN Manual RNP AR APCH navigation specification states:

> 6.3.3.3.1.3. a) *Continuous display of deviation*. The navigation system must provide the capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft, the aircraft position relative to the RNP defined path (both lateral and vertical deviation). The display must allow the pilot to readily distinguish if the cross-track deviation exceeds the navigation accuracy (or a smaller value) or if the vertical deviation exceeds 22 m (75 ft) (or a smaller value). It is recommended that an appropriately scaled non-numeric deviation display (i.e. lateral deviation indicator and vertical deviation indicator) be located in the pilot's primary optimum field of view.
>
> 6.3.3.3.1.3 m) *Display of deviation*. The navigation system must provide a numeric display of the vertical deviation with a resolution of 3m (10ft) or less, and lateral deviation with a resolution of .01NM or less;

The preferred standard of display of lateral FTE is therefore:

A lateral deviation indicator; and

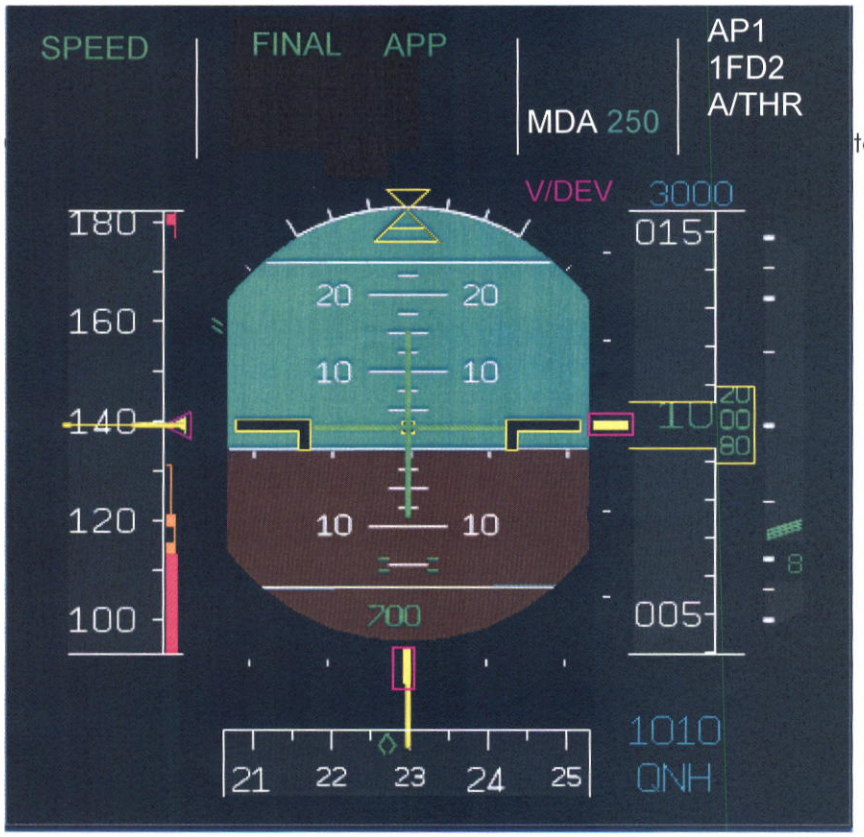
A numeric display of .01NM

However in many cases, particularly for older aircraft, this level of display is not available. The question then arises as to the eligibility and if so the RNP capability.

The purpose of the lateral display of deviation is (as stated above) to "*allow the pilot to readily distinguish if the cross-track deviation exceeds the navigation accuracy (or a similar value).*"

Where the specified standard of display is not provided, an operational evaluation needs to be conducted to determine if the display of information is adequate to support RNP AR APCH operations. The evaluation may determine, for example, that cross-track deviations of 0.3NM can be adequately monitored, but that less than that value the displays are considered inadequate. An operational approval might be given in these circumstances for RNP AR APCH operations limited to not less than RNP 0.3.

Figure 1 tors



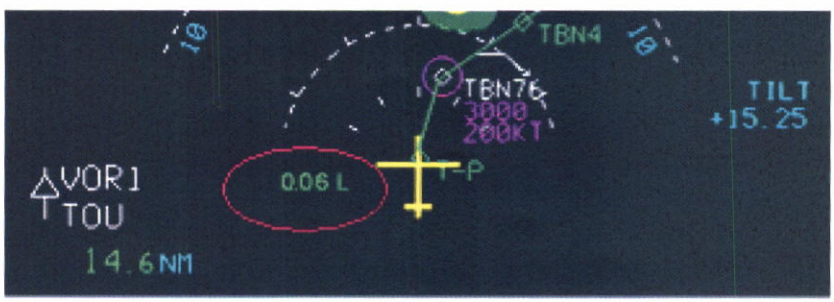


Figure 10.2: Lateral deviation displayed on a navigation (map) display

10.10 Demonstration of Path Steering Performance

The PBN manual includes a requirement that path steering performance (i.e. FTE) is evaluated under a number of conditions, including non-normal conditions.

It should be noted that differences exists amongst regulatory authorities on the means of assessment of the management of FTE in non-normal conditions. European authorities take the view that the aircraft system should be capable of managing non-normal events, while the FAA considers that operational mitigations are acceptable.

The method(s) is used to demonstrate FTE performance must be taken into account when evaluating crew procedures.

10.11 Navigation System Monitoring and Alerting

In order to qualify for RNP operations of any kind the navigation system must incorporate a system to monitor the performance of the navigation system and provide an alert to the flight crew when the system no longer meets the specified performance requirements.

Two elements of navigation system performance are normally monitored, accuracy and integrity.

Depending upon the manufacturer the parameters used and the alerting levels will vary, however the method used is not normally an issue with regard to aircraft eligibility, although there can be implications in operating procedures. Information should be obtained on the parameters that are monitored, the relevant alert limits and the method of annunciation of the alert.

Navigation system accuracy is commonly represented by Horizontal Figure of Merit (HFOM) or Estimated Position Error (EPE). These parameters represent an estimate of the position solution assuming that the satellite system is operating within its specific performance. An alert is normally generated when HFOM or EPE equals or exceeds a limit, normally 1 x RNP.

Integrity is commonly monitored by Horizontal Protection Level (HPL), sometimes called Horizontal Integrity Limit (HIL). An alert is provided when HPL equals of exceeds a limit relative to the selected RNP.

In at least one case the manufacturer derives a value for accuracy as a function of HPL. As both accuracy and integrity are dependent upon the same satellite constellation there is a relationship between derived parameters such as HFOM, EPE and HPL (HIL). Although each of these parameters measures different performance characteristics, each can be shown to be a function of another, within specified bounds.

Normally NSE integrity is monitored, but some systems monitor both accuracy and integrity and separate alerting limits are set for each parameter. In some (less common) cases HFOM is used and there may be no alert directly related to integrity. Such cases warrant further examination to ensure that integrity is adequately monitored and it may be necessary to implement supplementary procedures (e.g. ground monitoring) to ensure that integrity is available for all operations.

10.12 GNSS latent failure protection

GNSS systems must provide protection from latent GPS satellite failure. Protection is provided by an integrity monitoring system and the principles of integrity monitoring are discussed elsewhere in this handbook.

For RNP AR APCH operations the PBN Manual includes a requirement that when HIL = HAL that the probability that the aircraft remains within the obstacle clearance volume used to evaluate the procedure must be greater than 95 percent (both laterally and vertically). (Para 6.3.3.2.2 (b)). Normally the manufacturer will provide documentation that this condition is met.

An alternative means of compliance provided in the note attached to this paragraph is available if the HIL is less than 2 x RNP less 95% FTE.

It may be helpful to consider a typical case based upon the simple (alternative) case. The typical 95% FTE for a modern aircraft with AP engaged is of the order of .07NM/95%. To meet the alternative means of compliance HIL should not exceed 2 x RNP - .07NM. For the limiting case (currently) where RNP = 0.10NM, the maximum HIL is:

(2 x 0.10) - .07 = 0.13NM.

In most cases, HAL ≤ 1 x RNP and therefore this condition is met.

10.13 Operating Procedures

In recent years most manufacturers have developed recommendations for RNP AR APCH operating procedures. Although the manufacturer recommendations should be followed, the operational approval should include an independent evaluation of the operators' proposed procedures. RNP AR APCH operating procedures should be consistent with the operator's normal procedures where possible in order to minimise any human factors elements associated with the introduction of RNP AR APCH operations.

Vectoring. A procedure may be intercepted at a position inside the IAF but no later than the VIP when vectored by ATS. Descent on an approach procedure below the minimum vectoring altitude is not permitted until the aircraft is established within the vertical and lateral tolerances of the procedure and the appropriate navigation mode(s) is engaged.

10.14 RNP Availability Prediction.

As the current GPS constellation is unable to provide 100% availability of RNP at all levels of service, there a periods, depending upon a number of factors, when an RNP approach cannot be conducted. Consequently a prediction of availability is conducted to enable the flight crew and dispatchers (where applicable) to take

into consideration the level of RNP capability that can be expected at any particular location.

Commonly, even for low RNP levels, the periods when an RNP service is unavailable are short, and a delay in departure or en-route, is often sufficient to schedule an arrival when the service is predicted to be available.

An operation is not available, or should be discontinued when an alert is displayed to the flight crew. Consequently availability is determined by the means used to generate an alert, which as discussed previously, varies between aircraft. In order to be most accurate and effective a prediction of availability needs to be based on the same parameters that are used in the particular aircraft systems, rather than a general prediction of a parameter such as HPL.

The operator needs to make arrangements for prediction service to be available that replicates the monitoring system on the aircraft. Prediction services are readily available from a number of commercial sources. The prediction should be based on the latest satellite health data, which is readily available, and take into account other factors such as high terrain. On board prediction programs are generally unsatisfactory in that they are unable to take account of satellite NOTAMS and terrain masking.

While satellite prediction services are normally accurate and reliable it should be noted that an unpredicted unavailability can occur at any time. However safety is not compromised (provided adequate fuel reserves are carried) and on-board monitoring assures that the crew will be alerted and the approach can be discounted, delayed or an alternative approach conducted.

ZULSARR: Predicted EPE values for (A319) from
Fri 30-Mar-2007 1700Z to Sat 31-Mar-2007 0600Z
RNP 0.15 available 1700Z to 0600Z
RNP 0.20 available 1700Z to 0600Z
RNP 0.30 available 1700Z to 0600Z

ZULSDEP: Predicted EPE values for (A319) from
Fri 30-Mar-2007 1700Z to Sat 31-Mar-2007 0600Z
RNP 0.15 available 1700Z to 0600Z
RNP 0.20 available 1700Z to 0600Z

RNP 0.30 available 1700Z to 0600Z

Figure 10.3: Example of an RNP availability forecast

Note: In Figure 10.3 EPE values are relevant to RNP for the A319

10.15 Radio updating.

The operational approval needs to consider the method used to determine the computed aircraft position.