International Civil Aviation Organization
CAR/SAM Regional Planning and Implementation Group (GREPECAS)
First Meeting of the Communications, Navigation and Surveillance/Air Traffic Management Subgroup (CNS/ATM/SG/1)
(Lima, Peru, 15 to 19 March 2010)

Agenda Item 4: **Review to pending matters of the ATM/CNS/SG, ATM/COMM, CNS/COMM and respective Task Forces, for consideration in the CNS/ATM Subgroup work programme**

Analysis of DME/DME Navigation Infrastructure in support of PBN

(Presented by Spain)

SUMMARY

The use of DME/DME to support RNAV operations has a direct impact on the size of the ground infrastructure of such systems, which is based on the precision that must be achieved and the geometric elements required for achieving it.

References:

- ICAO Doc 7300/8;
- ICAO Annex 11 (RNP Routes, Annex B);
- ICAO Performance-based Navigation (PBN) Manual (Doc 9613);
- JAA TGL 10 Section 4c; and
- NSP Navigation Infrastructure Assessment in Support of PBN.

ICAO Strategic Objectives:	*A - Safety* *D - Efficiency*

1. Introduction

1.1 PBN implementation entails an analysis of the ground radio aid infrastructure, mainly DMEs, which will have a significant impact on State plans for the deployment of such radio aids and the corresponding investment plans. This working paper presents some considerations to be taken into account and analyses possible alternatives in this regard.

2. Discussion

2.1 RNAV procedures should permit the use of GNSS; however, since some aircraft lack GNSS capabilities, or the GNSS system can fail, it is necessary to have an alternate infrastructure based on DME/DME or DME/DME/INS.

2.2 Since the GNSS in its basic forms (GPS, ABAS and RAIM) is available worldwide, no concrete infrastructure is needed. However, it should be noted that, since the responsibility for the provision of the GNSS-based service falls upon the State responsible for the airspace, air navigation service providers must ensure that the level and quality of the service, as well as the level of interference, are appropriate for the service, according to the planned or authorised procedures. This can be achieved in several ways, *e.g.*, taking measures against interference on board and/or on the ground (see ICAO Doc 9846, GNSS Manual, Doc 8071 and Annex 10), or through GPS augmentations, such as SBAS or GBAS.

2.3 Furthermore, the ground aid network can support RNAV operations based on an appropriate deployment of DME stations, covering the DOC (Designated Operational Coverage) area, which is the term that defines the coverage boundaries of a navigation aid. In this sense, it should be noted that, given the implementation of the set of DMEs set to be used by the FMS for RNAV, the DME facility shall not be used if located at a distance of more than 160 NM or less than 3 NM, irrespective of the published DOC. Likewise, if the elevation between the station and the aircraft exceeds 40 degrees, it shall also be excluded. These conditioning elements have a direct impact on the precision obtained in a DME/DME operation, and when sizing the DME network for RNAV in support of PBN implementation.

2.4 Obviously, these aspects have an impact on DME/DME coverage and precision. When determining precision, it should be noted that, while the precision of one DME may be consistent with that specified in ICAO Annex 10, when we speak of the precision obtained from the use of two or more DMEs, geometric aspects must be taken into account, according to that stated above. In this respect, the overall precision of the system for RNAV-1 (total system error, TSE) must be equal or less than +/-1 NM, 95% of the time of the flight. This includes the navigation error (NSE), the position estimation error (PEE), as well as the flight technical error (FTE). The PEE is made up by the signal-in-space error and the on-board receiver error.

2.5 The first level of position precision is between the FTE and the NSE, which, in the case of RNAV-1, is 0.5 NM (95%) for FTE, a value recommended when using the flight director or the automatic pilot, although attainable in manual flight. Since the FTE and the NSE are treated as independent errors, the FTE provides a maximum allowed NSE of ± 0.866 NM (95%), obtained from the root sum square formula. These errors will be treated as circular errors, and no errors will be assigned along longitudinal or transverse paths.

2.6 When analysing DME/DME precision, the NSE can be divided into two parts: one resulting from the on-board equipment (interrogator) and the other from the ground equipment (transponder), including signal-in-space propagation effects. Since a minimum of two DMEs with an acceptable geometry and adequate range (160 NM – 3 NM) is required for RNAV, the following formula will be used to determine precision (PBN manual):

$$2\sigma_{DME/DME} \leq 2\,\frac{\sqrt{\left(\sigma^2_{1,air} + \sigma^2_{1,SIS}\right) + \left(\sigma^2_{2,air} + \sigma^2_{2,SIS}\right)}}{\sin(\alpha)}$$

where:

σ_{SIS} = 0.05 NM

σ_{air} is maximum (0.085 NM, 0.125 % of distance)

α must be between 30º and 150º

2.7 This formula is used for determining whether a given pair of DMEs can support a given procedure, evaluating the two $2\sigma_{DME/DME}$ against a maximum NSE of 0.866 NM.

2.8 With the above data, we can analyse the infrastructure required to support a given RNAV procedure, based on the use of DME/DME. To this end, it is advisable to use SW tools to expedite calculations, and take into account all variables and the combination of stations. The process to be followed can be divided into six steps:

a) Obtaining the required data.
b) Identifying individual DME stations that can be used.
c) Defining the DME pairs to be used.

d) Identifying specific elements.
e) Preparing and conducting the flight inspection.
f) Completing the implementation studies.

2.9 In order to determine what DME can be used, a terrain modelling tool should be used to see if the DME will be in line of sight of each point within the service volume of a given procedure, so that it can be used by an FMS (range less than 160 NM and greater than 3 NM with an angle of less than 40 degrees). Once the list of DMEs is available, ILS-coupled or co-channel DMEs must be discarded.

2.10 From the resulting list of DMEs, pairs will be sought, based on the definition of all possible combinations within the service volume of a given procedure. For each possible combination of DME pairs, we must determine if angle requirements (within 30 to 150 degrees) are met. Next, for each pair thus obtained, the resulting NSE must be calculated, making sure it meets the precision requirement: ± 0.866 NM (95%).

2.11 Based on this analysis, the number of new DMEs to be used can be determined, taking into account a new parameter, which is up to what flight level will DME/DME coverage be provided. The cost of implementing the new facilities and maintaining the resulting network will be determined through a cost-benefit analysis.

2.12 These activities include a parallel analysis of RNAV implementation using GNSS, with a view to rationalising costs and optimising the infrastructure serving the airspace.

3. Suggested action

3.1 The Meeting is invited to:

a) take note of the information contained in this working paper;

b) define the action required to assess DME coverage of the States, and determine the number of new facilities required for the implementation of RNAV procedures;

c) conduct the corresponding cost-benefit analyses; and

d) analyse GNSS alternatives.

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