New Trends of Using GNSS In the Area Navigation

Jozef Sabo
Technical University of Košice
Faculty of Aeronautics
Slovakia
E-mail: jozef.sabo@tuke.sk

Peter Korba
Technical University of Košice
Faculty of Aeronautics
Slovakia
E-mail: peter.korba@tuke.sk

Matej Antoško
Technical University of Košice
Faculty of Aeronautics
Slovakia
E-mail: matej.antosko@tuke.sk

UDK 656.7:629.7.05
Review
Paper accepted: 11. 3. 2014.

Summary

The article analyses new trends in aircraft control under instrument flight rules. It describes the possibilities of using conventional area navigation methods with GNSS devices in approach phase. The authors describe the actual possibilities of using GNSS, especially GPS system, during navigation. In the next part, arrival and departure RNAV routes that are actually in use are described. The article also discusses briefing and preparation for RNAV approaches and describes requirements for the aircrew.

KEY WORDS
area navigation
global navigation satellite systems
required navigation performance
instrument flight rules
GPS

INTRODUCTION

Increase of the number of movements and associated requirements for more efficient use of airspace in the 80s resulted in implementation of RNAV (Area Navigation). The area navigation allows operations of aircraft over any route which is covered with signal ground radio navigation aids or global satellite navigation systems or autonomous navigation equipment on board of airplanes and appropriate combinations.

The RNAV system enables navigation of aircraft (with the required accuracy) outside the published conventional flight paths. Onboard software automatically evaluates the aircraft position by one or more sources of navigation in order to respect the RNP Required Navigation Performance (Required Navigation Performance).

These navigation devices can be:

- VOR/DME,
- DME/DME,
- GNSS (Global Navigation Satellite System),
- INS/IRS (Inertial Navigation System / Inertial Reference System),
- FMC/FMS (Flight Management Computer / Flight Management System).

RNAV routes are defined by RNAV waypoints, which may be “fixes” for utilizing ground-based radio navigation aids or points defined by geographical coordinates. The RNAV navigation system (with an updated database) contains a set of waypoints that are published on the track (ENR) or airport (STAR, SID, APP) maps, and must also enable creation of new points using VOR / DME or geographic coordinates.

POSSIBILITIES OF AREA NAVIGATION

In general aviation, a device, for example GPS receiver, can be certified for RNAV. For larger transport aircraft the FMS (Flight Management System) is a device that allows navigation with comprehensive inputs from multiple navigation devices simultaneously. Benefits of RNAV are, for example: shorter distance and flight time, reduced costs, greater flexibility in creating flight routes and increased airspace capacity.

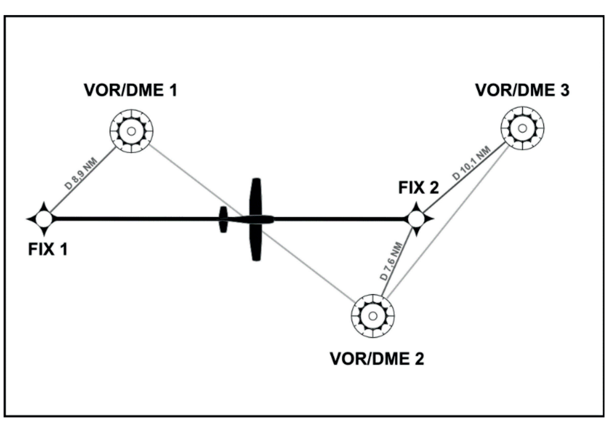

Figure 1. Advantages of RNAV en route flight

Typical RNAV systems tend to provide navigation information and services:

- An on-board indicator in the basic field of the pilot flying (PF) must be continuously available displaying position of the aircraft of the desired track (in case of a two-man crew this indication must be available also on the non-flying pilot´s panel - PNF),
- Display distance and time (ETA - Estimated Time of Arrival) for selecting waypoint,
- Insert a waypoint,
- Ground Speed,
- Display information on the HSI / CDI,
- Fault indication of the RNAV system,
- Connection to the command system (FD - Flight Director), which provides data for the autopilot,
- “Direct To” function,
- Navigation database,
- An automatic switching track section,
- See the advance curve (in the case of application of fly-by waypoints),
- Current position shown by geographical coordinates. [1]

When you view the position information from the GPS indicator

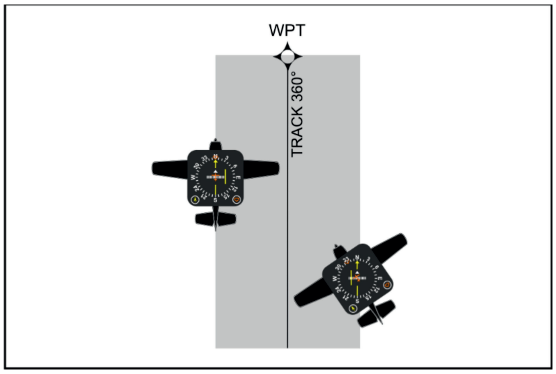

Figure 2. Deviation from the desired track is indicated as a distance

on the HSI or CDI compared to conventional satellite navigation there is a significant difference. In case of a flight to the VOR or from VOR, the system indicates deflection in degrees (2 degrees per dot). In GPS mode the deflection is based on distance.

With the gradual development of on-board navigation systems of RNAV they were divided into three levels:

- 2D RNAV – a system allowing positional navigation,
- 3D RNAV – a system allowing navigation in space (location and altitude),
- 4D RNAV – a system allowing navigation in space and time. [2]

In European airspace, two types of RNAV are defined by the standards of EASA, which differ in the value of Required Navigation Performance.

RNP is characterized by the following parameters:

- Accuracy - expressed by the maximum value (5, 1 and 0.3 NM) of an allowable measurement error of the airspace position with given navigational safety for 95 % of the total flight time. The accuracy value includes: an error signal of ground equipment, an airborne receiver error, a system error display, errors of piloting techniques (or an autopilot error of).
- Integrity - ensuring of correct information. If the navigation system is unable of correct operation, the user must provide early warning alarm.
- Continuity - the ability of navigation system to function without interruption during the intended operation.
- Readiness - the ability of navigation system to function at the beginning of intended operation.

Arrivals and Departures on RNAV Routes

Currently, almost all airports with higher traffic density have arrival and departure RNAV routes (RNAV STAR, RNAV SID). The specific requirements and their implementation can be found in the Aeronautical Information Publication (AIP) or the 10-1P section "Airport Briefing" in Jeppesen publications. Many airports require certification of aircraft in P-RNAV (RNP requirement 1).

This means that navigation systems on board of aircraft must be able to have at least 95 % of the flight time accuracy with a maximum deflection of 1 NM from the desired track. If we want to fly to the airport and aircraft is not certified to operate under RNAV, we must inform air traffic control service in the form of notes in the flight plan and, on the first radio contact, say the phrase: "Unable RNAV due to equipment". In this case, we can expect delay due to increasing traffic, and later a radar vectoring. [3][4]

Also there exists the Basic RNAV requirement (B-RNAV) which means that plane is able to have at least 95% of the flight time accuracy with maximum deflection of 3 NM from the desired track.

ARRIVAL ROUTES "RNAV TRANSITION"

TRANSITION of RNAV arrival routes are published at airports with intensive operation. These routes have waypoints that allow a gradual reduction of speed and altitudes of arriving aircraft. Sequencing of aircraft is very flexible, because air traffic controllers can send aircraft directly to whatever waypoint on this route. The pilot then follows the arrival route „TRANSITION " to the end, or, depending on the density of traffic, can expect radar vectoring to the final approach track. Arrival routes "TRANSITION" increase traffic flow and eliminate the waiting aircraft in holding patterns. [1]

GNSS (GLOBAL NAVIGATION SATELLITE SYSTEMS) AND RNAV

Scientists have been dealing with usage of satellite navigation systems since 1950s. Their main advantage is independence of the terrestrial radio navigation devices whose operation is consistent with the concept ICAO - FANS (Future Air Navigation Systems) of 1983 and gradually being reduced. GNSS allows you to specify a single location in a coordinate system within the coverage of satellites. There are currently three independent global satellite navigation systems - Russian GLONASS, the European system in development - Galileo and the U.S. NAVSTAR GPS. Since nowadays there is a vast majority of aircraft with the GPS

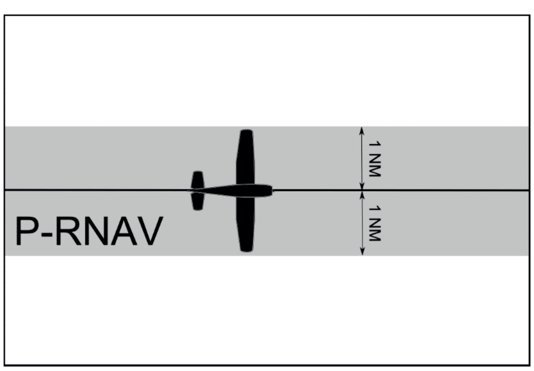

Figure 3. P-RNAV

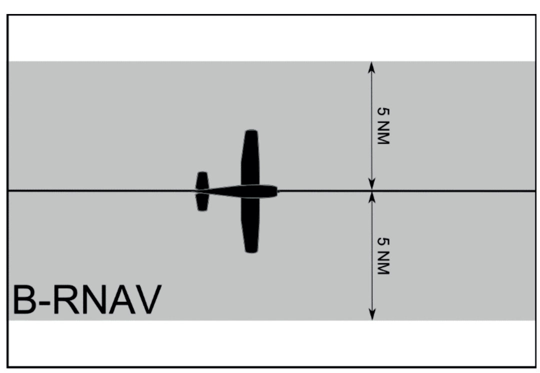

Figure 4. B-RNAV

Figure 5. Garmin GNS 430 GPS receiver

receiver installed on-board, it will be discuss more specifically in this paper. [3]

THE GPS SYSTEM IN PRACTICE

GPS navigation receivers today can be found on board of most aircraft and general aviation traffic. Pilots often use them only to monitor the position during VFR and IFR flights. For general aviation there is usually a necessity for certification of aircraft on RNAV. The Garmin GNS 430 is the most widespread receiver for general aviation aircraft.

The condition for its use in RNAV is a valid Jeppesen database. The aircraft equipped with an onboard GPS device certified for Basic RNAV provides necessary information by conventional navigational instruments, mostly displayed on HSI. If we are on the specified route or we're going to a certain point directly, output information is the same as if we were flying on radial of some VOR, either with an angle deflection or with a distance deflection from the desired track. As we switch to the "OBS" mode anywhere we can build "pseudo VOR" that imaginary point which has the characteristics of VOR. All other necessary views, as deflections from the route, the required rate, distance, estimated time to a selected point or ground speed (GS) can be found directly on the display of GPS device. From the receiver menu, the pilot selects the graphical output, which suits him the most, such as maps, what we can see in the picture below.

RNAV GNSS APPROACHES

As mentioned above, the use of satellite navigation to approach the primary system has been a part of the ICAO - FANS (Future Air Navigation System) since 1983. FANS concept assumes a gradual shutdown of conventional radio navigation aids and implementation of GNSS navigation procedures not only for en-route, but also for instrument approaches. Relatively complex regulatory basis, the different attitudes of FAA and EASA and not least delayed construction of the European GNSS Galileo has resulted in different approaches towards the implementation of RNAV / GNSS approaches. The biggest advantage of using the GNSS RNAV approach is the independence of the conventional radio navigation aids. RNAV (GNSS) approaches are the most widespread in the U.S. and Canada. At European airports, this type of approach is being gradually published instead of the NDB approaches. In Europe two types of RNAV (GNSS) approaches are now certified according to EASA AMC 20-27, namely:

- RNAV GNSS NPA approach without vertical guidance (LNAV - lateral)
- APV BARO approach also with vertical guidance (LNAV - lateral/ VNAV - vertical)

The use of the approaches depends on the aircraft navigation equipment. When we use LNAV approach, the aircraft is guided only directionally (therefore it belongs into the category of non-precision approaches). LNAV / VNAV an approach also with the vertical guidance based on the barometric altitude sensing system of altimeters and their entry into FMS (Flight Management System). This equipment is now typical in most of airliners, where navigation systems must have higher requirements. "GNSS LNAV" with a horizontal guidance (in the maps, minimums for this approach are labelled as "LNAV minimums"). Requirements for the inaccurate approach using satellite navigation meet the necessary certification and a lot of general aviation aircraft. The total horizontal error of the RNP approach must be equal to or less than +/- 1 NM for 95 % of flight time in the field of initial and middle approach and missed approach segment (RNP 1) and the system must also have the required parameters of integrity, continuity and availability.

A typical trajectory of RNAV (GNSS) approach is called "basic T". The basic shape of a "T" can be modified (for example due the surrounding mountainous terrain or airspace use), most of the initial approach routes have an angle of about 90 degrees with a final track. The flight established correctly on the final approach track is represented by the display function before f the turn, this function has the most conventional navigational devices operating in the area navigation. Basic "T" usually involves two points of the initial approach (IAF) which are located on the sides of 4-5 nm from the final approach track. The middle point of approach (IF) is located under the requirements of the regulation L 8168 dealing with the final approach track and if you make a direct (" straight -in ") approach, it is identical with the initial approach fix (IAF). The final approach point (FAF) is usually +/- 5 NM from the runway threshold. The onboard GPS indicator (HSI or CDI) usually shows a flight on route information + / -5 nm (requirements for RNP 5 of the B-RNAV) from the selected track. In the middle section, after the arrival routes and after the entry into TMA, the sensitivity of a scale on HSI or CDI increases and full deflection represents +/-1 NM (requirements for RNP 1 of the P-RNAV arrival routes). This range is still not sufficient for carrying out the approach and thus the sensitivity of +/-1

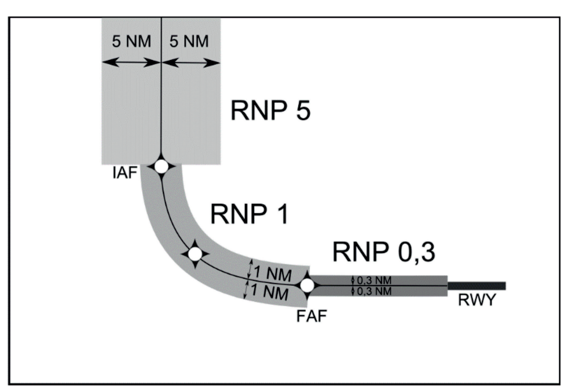

Figure 6. - RNP dependence on the approach section

NM before the FAF point changed to +/- 0.3 NM (0.3 RNP requirements for flight during the final approach segment). [6]

RNAV (GNSS) is usually published as a substitute procedure for NDB or as a new primary procedure for instrument approaches at airports where IFR operation previously could not be possible. Trajectory of approach is similar to VOR/DME and also this procedure does not require increased demands on crew activities. It is necessary to have the display position primarily in the field of pilots´ indicators of CDI, HSI or the navigation screen of EFIS.

APPROACH BRIEFING FOR RNAV (GNSS)

Preparing for the RNAV approach has its specificities and constraints with which the operator and crew must be thoroughly familiar. Before the RNAV (GNSS) flight, a pilot must ensure that he has indicated the required navigation equipment in the flight plan. The crew must also carry out the following measures:

- A map of the intended instrument approach must have the sign "RNAV (GNSS) Rwy" and crew have to verify the altitude of OCA (H) or MDA (H), and if the aircraft satisfies required criteria of the category and gradient in the missed approach procedure.
- Crew verify the validity of maps and navigation database for the expected approach, including an approach to alternate aerodrome if the alternate is required.
- Crew must also ensure that in case of restrictions in the RNP of RNAV approach, they will be able to do conventional navigation at the destination or alternate aerodrome.
- Crew must consider the valid NOTAM information, which could affect or limit the implementation of the intended approach at the destination or alternate aerodrome.
- If a missed approach is determined according to conventional radio navigation aids (NDB, VOR), aircraft must be functionally available, onboard equipment approved and ground equipment must be in operation.
- Onboard GNSS systems must ensure the integrity of 15 minutes before and 15 minutes after the time ETA (Estimated Time of Arrival), which represents the IFR arrival time to the initial approach point. If estimated unavailability of more than 5 minutes is determined in the pre-flight briefing, take-off must be an approach deferred or re-planned.
- Equipment for the approach satisfies the requirements of the MEL (Minimum Equipment List). [5]

PROCEDURES DURING THE APPROACH

The final approach track shall be established on the latest point in the final approach to avoid premature beginning of the descent outside the protection area. In addition, the crew checks the integrity of switch -board equipment to the zoom mode, which occurs 2 NM before the final approach point (not certain on-board systems with a different way to view the information). During the approach, the aircraft's position must be continuously displayed and monitored to reach the desired final approach track.

Approach must be discontinued and followed by a missed approach if:

- Malfunction of equipment RNAV
- Observed loss of system integrity (RAIM)
- Identification of the excessive flight bug. [5]

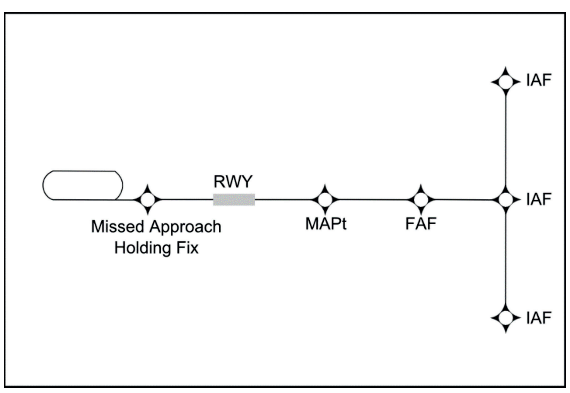

Figure 7. The basic "T" shape of approach

CONCLUSION

Introduction of flight procedures that use satellite (space) navigation, after success in the United States, Australia, Germany and other countries, is becoming the current trend in Visegrad countries. There are lots of new published RNAV (GNSS) procedures in the Czech Republic and Hungary, while in Slovakia and Poland this question is much more conservative. This article describes possibilities and advantages of using Area Navigation with GNSS during approach to the airport. The biggest advantage of RNAV approaches is low cost of construction, but also its cheap operation. RNAV procedures may be applied to airports where it has not been possible yet, either in financial aspects or in terms of technical or realization reasons. Introduction of these procedures, however, involves higher requirements for aircraft equipment but also for the aircrew.

REFERENCES

[1] SOLDÁN V. - Letové postupy a provoz letadel. Letecká informační služba ŘLP ČR, Jeneč, 2007. 1. vydání. ISBN 978-80-239-8595-5.

[2] VOSECKÝ S., KULČÁK, L., STAVOVČÍK, L. - Radionavigace (062 00). Akademické nakladatelství CERM, s.r.o., Brno 2006. ISBN 80-7204-448-6.

[3] PEČÍNKA, R. - Letecké radionavigační systémy. Radar L+K (Letectví a kosmonautika), 16/1996.

[4] ICAO Doc 9613. Manual on Required Navigation Performance (RNP). 2nd Edition, 1999. 41 p.

[5] EASA AMC 20-27. Airworthiness Approval and Operational Criteria for RNP APPROACH (RNP APCH) Operations Including APV BARO-VNAV Operations. 2009. 33 p.

[6] JAA TGL 10. Airworthiness and Operational Approval for Precision RNAV Operations in Designated European Airpsace. 2000. 29 p.

[7] CHMELÍKOVÁ K., ADAMEC V. - Response of Rescue System to anExtraordinary Event. In Proceedings of the Europan Safety and Reliability Conference, ESREL 2013, Amsterdam, The Netherlands, Taylor & Francis Group, London, p. 495-501, 2010, ISBN 978-1-138-00123-7.

[8] ORAVEC M., VARGOVA S., ŠOLC M. - Manažérstvo priemyselných havárií, 1. vyd - Košice : Technická univerzita - 2013. - 243 s.. - ISBN 978-80-553-1604-8.

[9] FABIAN, M. - Skenování a softwarová rekonstrukce nasnímaných dat, 2013. In: CAD. Vol. 23, no. 2 (2013), p. 38-41. - ISSN 1805-8418

[10] Sabová,J., Pukanská,K.: . Expansion of local geodetic point field and its quality. In: GeoScience Engineering. Vol. 58, no. 3 (2012), p. 47-51. - ISSN 1802-5420.

[11] Sabová,J., Jakub,V.: Verification of geodetic points using GPS measurements. In: Modern Management of Mine Producing, Geology and Enviromental Protection. Sofia: SGEM, 2005, p. 615-620.

[12] KOZUBA J. - Impact of human factor on likehood of aircraft accident, Proceding on the International, Katowice 2011, s. 29-36, ISBN: 978-83-927504-8-2

[13] LAZAR T., PIĽA J., KURDEL P. - Aircraft assistance systems and flight safety, 2011. In: Acta Avionica. Roč. 13, č. 21 (2011), s. 93-95. - ISSN 1335-9479