IMPROVING THE AIRSPACE EFFICIENCY ON BASIS OF REGIONAL NAVIGATION

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Abstract. The article presents analytical data on the zonal navigation of civil aviation aircraft. The issues of the influence of zonal navigation on the efficiency of the use of airspace are reflected.

Keywords: civil aviation, aircraft, air traffic control, air navigation, regional navigation (RNAV), GPS, GLONASS.

Introduction: Over the decades, aviation has relied heavily on ground-based beacons like VOR for route navigation. However, with the surge in air traffic, traditional beacon-dependent routes became inadequate. This spurred discussions on the necessity of arbitrary flight paths, ultimately leading to the advent of zonal navigation. Zonal navigation, facilitated by RNAV (Regional Navigation) equipment, revolutionized air navigation by enabling aircraft to fly along arbitrary trajectories without reliance on ground-based beacons. This article explores the technical aspects of RNAV equipment and its role in ensuring efficient and safe zonal navigation.

Principles and features of the use of zonal navigation

For many decades, aircraft have built their flight routes in such a way that they pass through ground-based beacons; for example, the most famous of them is VOR. The flights were carried out "to" or "from" the beacon. The on-board equipment determined the angular inclination and direction of the aircraft and indicated them on the PNP signs (CDI or HIS). This greatly facilitated the work of the pilots before maintaining the line of the set path by holding the bar in the center of the device. The information provided to the pilot at any given time about a deviation from a given trajectory is called navigation guidance. Route direction indicators and boarding patterns have become mandatory and frequently used in many countries around the world. The increase in air flow led to the fact that by the mid-80s, the airways passing through the beacons had become insufficient to provide the required air space transmittance. This led to a discussion about an arbitrary flight path in which the use of a radio beacon is not necessary.

In order to ensure safe flight along such routes and increase the throughput on board aircraft, the following was required:

1) information about the location of the aircraft.

2) Provide information about the deviation of the aircraft from the specified flight direction.

To solve the first of the problems posed, the use of two devices combined into one was started, which led to the formation of the VOR/DME radio beacon, which allowed continuous measurement of the range and bearing of aircraft. The solution to the second problem was that the aircraft had to have on-board calculators capable of continuously calculating the remaining distance and bearing. During this period, computer technology began to be used in on-board navigation systems, which turned out to be an excellent solution to this problem.

Navigation of a route that does not pass through beacons is called "zonal navigation (Figure 1), but for its implementation, it was required that the aircraft be in the range of the beacon. Later, other means began to be used to determine the location of the aircraft: satellite, difference-rangefinder, and inertial. In the future, it became necessary to be in the "zone" to determine the location; the term "zonal navigation" remained.

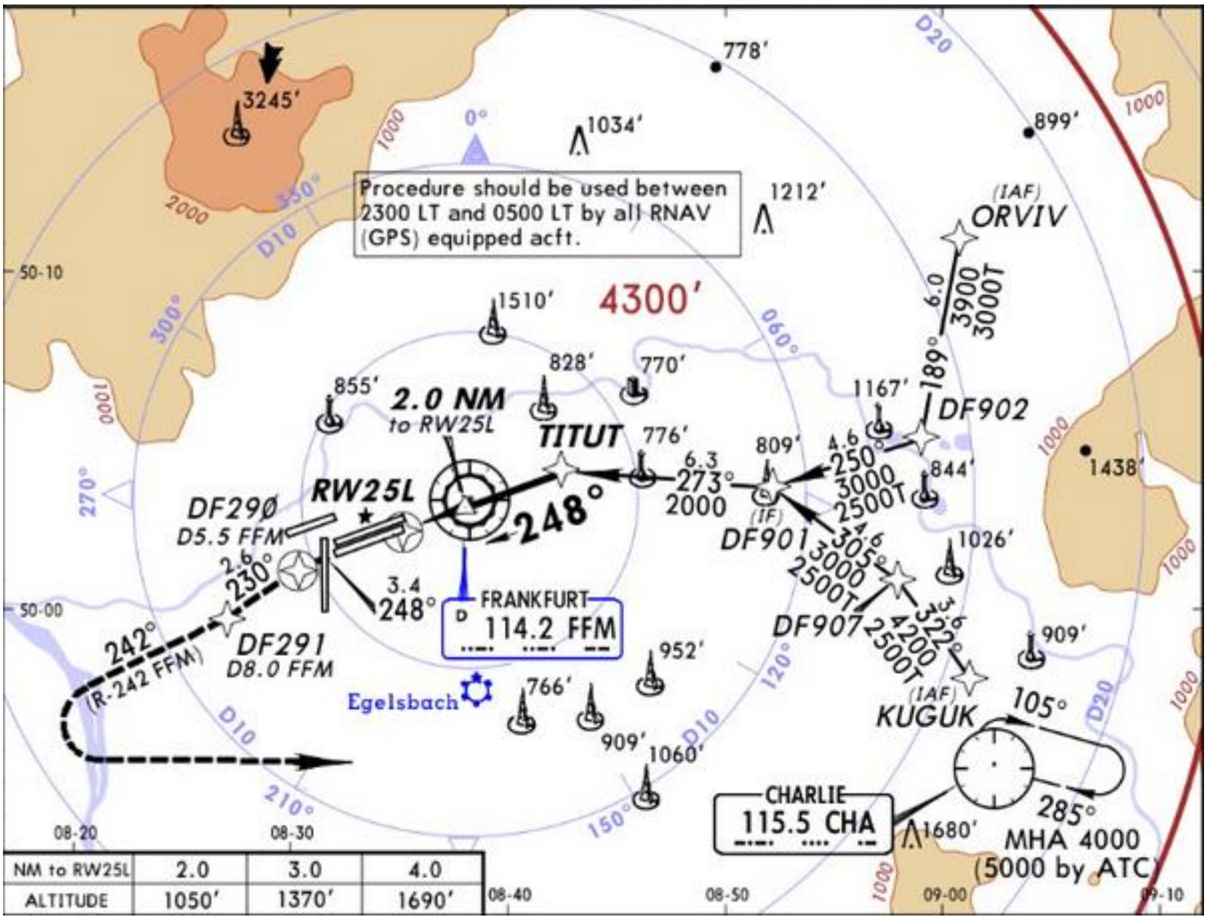

Figure 1. *RNAV approach pattern at Frankfurt Airport*

The equipment allowing the use of this type of navigation became known as "zone navigation equipment" or "RNAV equipment." The task of this equipment was to determine the location of the aircraft using several sensors, calculate the path distance, lateral deviation, and flight time, and also continuously show the deviation on a device such as a checkpoint and a PNP. Geodesic coordinates, called path points, were used to set the trajectory.

To set the flight path, you can use not only the horizontal plane but also the vertical plane to determine the flight altitude, angles, or gradients of inclination. A space-time trajectory can be used to implement a certain flight time. Zonal navigation can be divided into three types using the dimension of the space in which the flight is carried out:

- 2D-RNAV – two-dimensional RNAV - LNAV (Lateral Navigation) guidance used in the horizontal plane is carried out only by lateral evasion.
- 3D RNAV is a three-dimensional RNAV used in horizontal and vertical planes. VNAV (Vertical Navigation) guidance is performed in a vertical plane.
- 4D-RNAV – it is possible to use it in the horizontal and vertical planes to solve the problem of regulating the arrival time at the airfield at a given time. TNAV (the letter T from the word Time) - time navigation.

The solution to the problem was not only to ensure flight along arbitrary trajectories, but also that the accuracy of endurance was acceptable in this region. In air navigation, these requirements were set in the form of required navigation characteristics (RNP-Required Navigation Performance).

The introduction of zonal navigation is a difficult task, which consists not only in ensuring the possibility of flying along an arbitrary trajectory but also in ensuring high accuracy of its compliance in accordance with established requirements in a particular region. In modern air navigation, these requirements are formulated in the form of required navigation characteristics (RNP: Required Navigation Performance). Therefore, the issues of zonal navigation are closely related to the problems of RNP, and they are currently combined in one ICAO document.

The previously existing ICAO document "Guidance on Zonal Navigation" has been discontinued, and all its material has been included in the "Guidance on Required Navigation Characteristics RNP." RNP is now considered a tool for the technical and regulatory regulation of flights using RNAV.

Depending on the rigidity of the requirements for the accuracy of maintaining a given trajectory and the nature of the functional requirements for on-board equipment, various types of RNAV are widely used: B-RNAV (basic RNAV), P-RNAV (precision RNAV), and RNP-RNAV.

RNAV is considered by ICAO as the main type of navigation of the future, as it has a number of advantages over traditional navigation. It improves flight safety by increasing navigation accuracy, increasing throughput and efficiency of airspace use, making the route structure dynamic, reducing the burden on the flight crew and the dispatcher, and also reducing the number of ground navigation aids.

When using RNAV methods, mandatory conditions must be met, such as stable reception of ground or satellite signals, determination of the coordinates of the waypoints in the World Geodetic Coordinate System WGS-84 with the required accuracy, certification of equipment for en-route flight, and access by the flight crew.

Thus, the introduction of zonal navigation and the application of RNAV methods have significant potential to improve the safety and efficiency of air navigation.

Technical equipment of the regional navigation system

To ensure zonal navigation on board aircraft, it is necessary to solve a number of tasks related to determining the current location, storing information about the flight route, determining deviations from the line of a given path, and other parameters necessary for navigation. In this article, we will look at various ways to determine the location and functions of RNAV equipment.

One of the oldest methods of determining location is the VOR angle measuring system and the DME rangefinder system. This method consists of converting the bearing and range from the beacon into a linear lateral deviation from the line of a given path. The low accuracy of this method is associated with the azimuth channel of the VOR system, which limits the maximum permissible range of use of the beacon.

Another way is the LORAN-C (Figure 2) range-finding system, which has good accuracy but is subject to various interferences. The Inertial Navigation System (INS) is an autonomous location determination system based on the calculation of coordinates. The measured accelerations of the aircraft are integrated by a digital computer, which allows you to obtain the coordinates of the aircraft's location and other information necessary for navigation.

LORAN-C became one of the most common and widely used navigation systems for large areas of North America, Europe, Japan, and the entire Atlantic and Pacific. The Soviet Union operated a nearly identical system, CHAYKA.

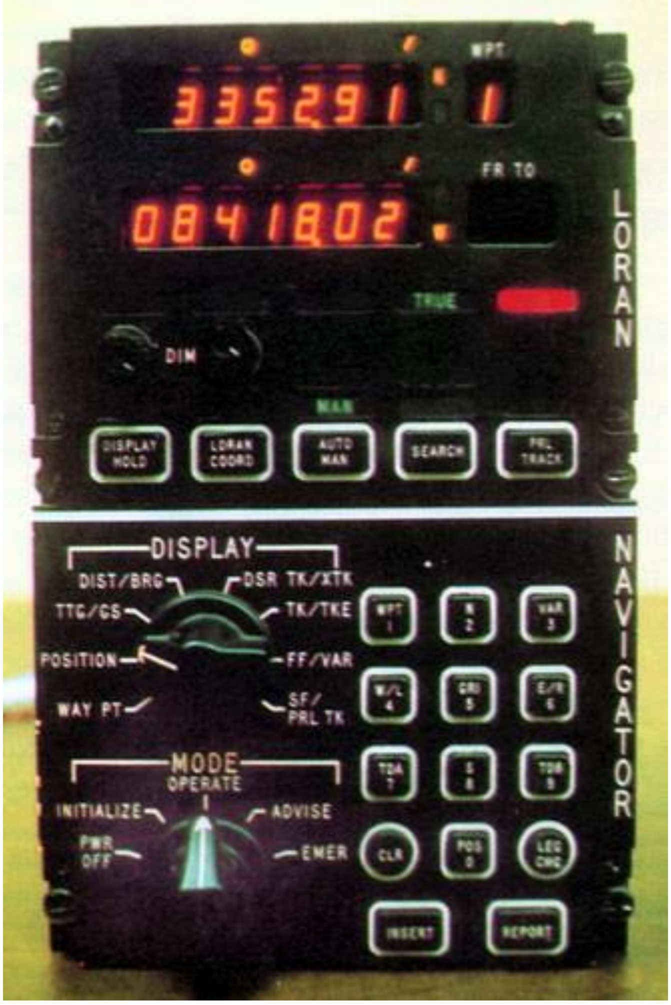

Figure 2. *On-board equipment of the LORAN-C system.*

The rangefinder coordinate determination method (DME/DME) provides a higher accuracy of location determination compared to the angle-rangefinder method. To determine the location of the aircraft, it must be simultaneously in the range of two radio beacons.

Global satellite navigation systems include the American GPS (Figure 3), Navstar, and the domestic GLONASS. GNSS provides high-precision coordinate measurement and a wide range of functions required for RNAV.

In aviation, navigation receivers are integrated into on-board air navigation support systems that provide route navigation and landing in difficult meteorological conditions. Satellite navigation is of great importance for ensuring the landing of small aircraft on unequipped airfields. GLONASS-based navigation systems also improve the safety of helicopter navigation and the navigation accuracy of unmanned aerial vehicles.

Thanks to GNSS, new and more efficient air routes are emerging. There is a tremendous saving of time and money. Aircraft, thanks to the use of satellite navigation, can fly in more favorable conditions and on more efficient routes, saving time and fuel and increasing income.

The use of satellite navigation systems during landing is almost the only way to improve the safety of aviation transport. Leading manufacturers of aviation equipment include GLONASS-based landing systems in promising aircraft navigation and landing complexes.

Figure 3. *Garmin GNS-430. One of the most common aviation GPS receivers*

To provide guidance based on information from the listed sensors, it is necessary to calculate the deviation from the specified trajectory and other parameters required for RNAV. The functions performed by RNAV equipment include indicating the coordinates of the current aircraft location, selecting or entering a flight plan, storing aeronautical data, monitoring and correcting the aircraft location displayed on the indicators, and others.

For high-traffic airspace, additional functions may be required, such as generating signals for the autopilot, displaying three-dimensional and four-dimensional location data, warning about approaching a waypoint, and others.

Conclusion: In conclusion, the integration of zonal navigation through RNAV technology marks a significant milestone in aviation history. By allowing aircraft to navigate along arbitrary trajectories with high precision and autonomy, RNAV enhances flight safety, airspace efficiency, and operational flexibility. As aviation evolves, the adoption of RNAV methods continues to demonstrate immense potential in transforming air navigation, emphasizing the importance of robust technical infrastructure and proficient crew training in realizing safer and more efficient air travel.

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