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DIFFERENTIAL MODES OF OPERATION OF SATELLITE RADIO NAVIGATION SYSTEMS

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Methods of securing high accuracy in determining navigational parameters when using the NAVSTAR and GLONASS radio navigation systems are considered.

Among the existing navigational systems the best integral characteristics may be found on satellite radio navigation systems (SRNS). Among the latter the best modern systems of common use are NAVSTAR (the U.S.A.) and GLONASS (Russia).

The quality of a navigational system may be estimated depending on how user' demands are met. Here the most rigid requirements are imposed when flying vehicles (FV), ships in ports, etc do their maneuvering. For instance, a FV approach in conformity with Category 3 is a maneuver that imposes the following demands to the navigation system: horizontal error < 4.0 m; vertical error < 0.5 m; accessibility of navigation system > 99.9998% of the whole space. Yet, the NAVSTAR and GLONASS systems show accessibility below 70%, NAVSTAR guarantees minimum error for civilian users 100 m (for civilian users of the NAVSTAR readings are made specially more rough) while GLONASS — 10–30 m (both for military and civilian users) [1, 2] which does not meet the above requirements.

Several methods can cope with these problems: simultaneous usage of both systems (the so-called combined system); differential mode of operation; the combined system and differential mode. The optimal way seems to be the use of the combined system and one variant of differential correction. In these SRNS a pseudo-range-finding method for location is used in which we may permit a shift of the on-board time scale with respect to the universal time scale by an unknown but constant (within the time of the navigational task solution) value Δt and measurement of four pseudo-ranges using one of the following alternatives: simultaneous measurements of one pseudo-range to each of four navigation satellites, or two consecutive measurements within range to two satellites, or four consecutive measurements of range to only one satellite. The coordinates x, y, z, and the on-board time Δt may be determined through solving a system of four equations written in the form:

$$R_i = [(x_i - x)^2 + (y_i - y) + (z_i - z)^2]^{1/2} + \Delta R, \ i = 1, 2, \ldots, N, \qquad (1)$$

where R_i is the pseudo-range to the ith navigational satellite; x_i, y_i, z_i are coordinates of the navigational satellite in the Cartesian system of coordinates; x, y, z are the required coordinates of the user in the Cartesian system; N is the number of navigational satellites in the working cluster; $\Delta R = c\,\Delta t + \Delta r$ is the systematic error when determining the pseudo-range; c is the speed of light in free space; and Δr is the absolute range error due to difference between c and the actual speed of the signal propagation between the navigational satellite and user.

It is for compensation of the ΔR error that the differential method of location is used in which, based on the signals from navigational satellites, the known coordinates of the control-and-correcting station (CCS) are determined, and, by comparison of known CCS coordinates and those found by means of SRNS, the differential corrections of the CCS location are calculated and then transmitted to users to determine their location. There are four different variants of using differential corrections of the navigational procedures in satellite radio navigational systems (NAVSTAR and GLONASS): correction of the location coordinates; range correction; time correction; and the use of a pseudo-satellite system.

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