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SINGLE LATERAL CHANNEL VELOCITY INFORMATION-AIDED INERTIAL NAVIGATION SYSTEM

SANU VIENKANĀLA AR ĀTRUMA INFORMĀCIJU KORIĢĒJAMA INERCIĀLA NAVIGĀCIJAS SISTĒMA

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Keywords: inertial navigation, single-channel, lateral channel, aided, correction, accuracy analysis, error model, error propagation,

Abstract: ***Inertial Navigation System (INS) block diagram analysis results show that it is possible to create single-channel Inertial Navigation System (1INS) using only one channel from conventional full-channel system - lateral, longitudinal or vertical channel respectively. In the full-channel variant of INS there is a crosslink between channels and for this reason the additional external flying vehicle flight parameter sources are needed for channel crosslink compensation. In the 1INS without these additional sources system error increases significantly in comparison with full-channel INS variant. 1INS model is offered in this work (lateral channel is used). Simulations results of this system error model are presented. Different variants of system correction using external velocity information source are offered (velocity-aided 1INS). Different models of 1INS with correction are offered, and also error model with different correction variant and its combinations simulation results are presented in this work. Obtained simulation results shows that there is significant accuracy increase of 1INS when using offered correction methods.***

Inertial Navigation System (INS) operation is based on integration of acceleration signal. Gimbaled INS consists of gyro orienting unit which stabilize platform in given direction relative to the Earth surface, two integrators and two correctors. Accelerometer corrector transform accelerometer output signal into relative acceleration information signal. Gyro orienting unit corrector compute gyro orienting unit control signal. As a result INS algorithm can be given as:

$$S_i(t) = S_{i_0} + \int_0^t U_i(t)\cdot dt,$$

$$U_i(t) = U_{i_0} + \int_0^t a_{relat_i}(t)\cdot dt,$$

$$a_{relat_i}(t) = a_{acc_i}(t) - a_{corr}(U_i, U_j, \phi),$$

$$\Omega_{Ej}(t) = f(U_i, U_j, \phi, \psi) \qquad (1)$$

Single-channel Inertial Navigation System (1INS) form only one velocity feedback loop and additional information from other sources are entered into a system at a different points of this loop. This type of INS structure characteristic property is minimal count of hidden loops.

INS accuracy depends on its block diagram formation. System structure defines paths on which sensor errors being transformed into system's errors. System's error values as well as shape of error growth with time is mostly depends of system structure. It is necessary to analyze system error genesis to perform choice of the best 1INS variant.

Single-channel INS error model simulations has shown that it has high level of system errors. Velocity error ΔU increase in time and reached 75 km/h after 5 hours simulation time. In that case position error was 105 km after 5 hours simulation time.

To reduce 1INS errors special correction circuit was introduced, which operating principle is based on correction method which was developed in Aviation Institute of Riga Technical University. Single – channel aided INS block diagram is shown on Fig. 1.

INS artificial correction circuit consists of system's artificial corrector and on-board velocity signal source. As shown on Fig. 1. There is an additional feedback loop, called artificial correction loop, which enclose velocity and acceleration integrators.

The next step will be the analysis of 1INS with velocity correction loop error propagation with time, when primary sensor errors exists (gyro drift WE = 0.1 [deg/h]; gyro angular error α_E =0.2 [deg]; accelerometer error Δa_a = 0.01 [m/s^2])

Using velocity correction loop which encloses only one integrator (velocity integrator) it is possible to decrease 1INS error. If, for example, correction gain coefficient (Ka) is equal to 0.001, then (Fig. 2.) velocity error will decreases approximately 8 times in comparison with 1INS without correction loop, but using this type of correction (short velocity correction loop) it is not possible to decrease position error ΔS.

It is possible to expand artificial velocity correction loop. If we consider the case when artificial correction loop encloses two integrators (velocity and gyro integrators), as

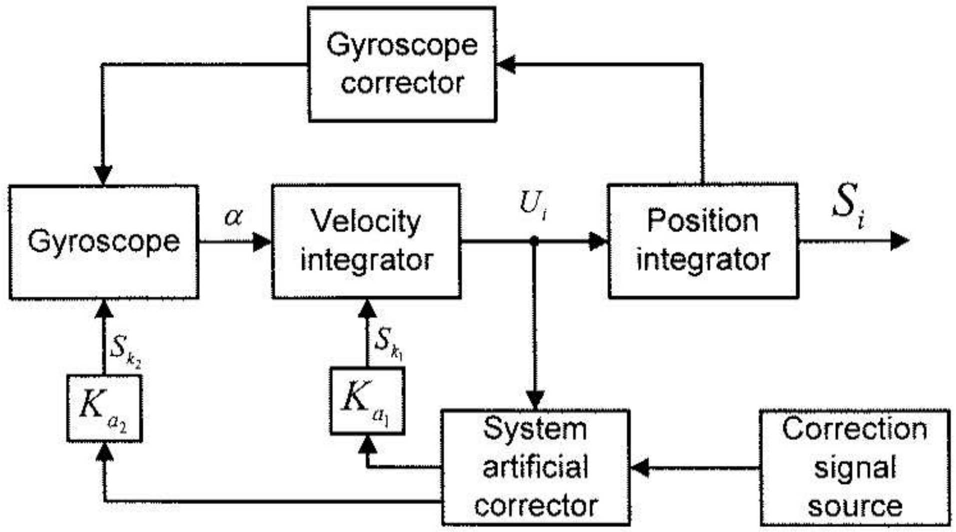

Fig.1. Single – channel aided inertial navigation system block diagram

shown on Fig. 1. (aided 1INS with long correction loop) and analyze system error propagation with time which is shown on Fig.3. we will see oscillating nature error curves.

Performed simulations have shown that using long velocity correction loop it is possible to decrease single-channel INS errors. If long velocity correction loop gain coefficient (Ka) is equal to 0.0000001, then position error ΔS maximum value will be 15 [km]. That means that long velocity correction loop improve performance of single-channel INS. In the single-channel INS with long correction loop velocity error doesn't increase with time continuously.

If this occurs, then INS has stable maximum level of position error, but correction doesn't give significant decrease of velocity error. Velocity error are decreased from 75 km/h to 40 km/h in comparison with system without correction.

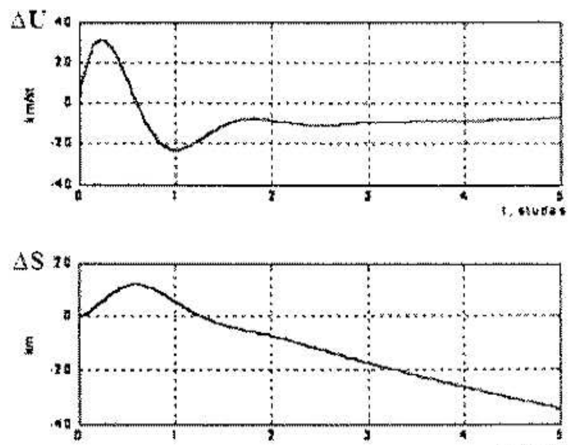

Fig. 2. System error propagation with time using short velocity correction loop

If we consider system with both correction loops whose operates simultaneously (both short and long velocity correction loops). The short correction loop encloses only one integrator and the long correction loop encloses both integrators.

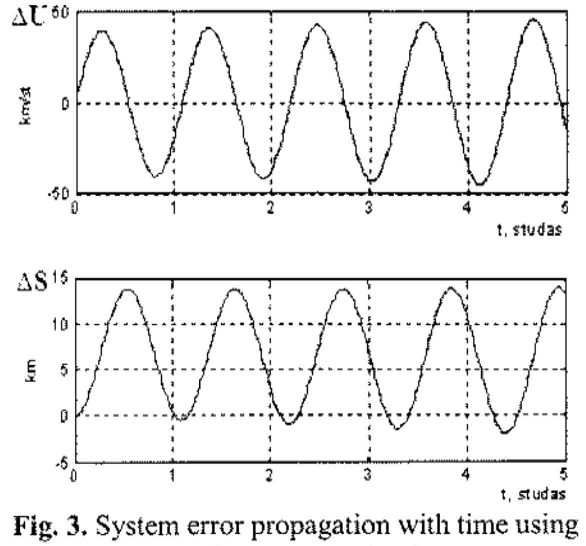

Fig. 3. System error propagation with time using long velocity correction loop

Single-channel INS with two correction loops error value and its propagation with time are depends on each loop gain coefficient value ratio (Ka_1 and Ka_2 ratio).

Operation of two correction loops improves 1INS error transient process in comparison with 1INS without correction. If, for example, $Ka_1 = 0.01$, and $Ka_2 = 5 \cdot 10^{-8}$ (Fig. 4.), then velocity and position errors doesn't increase with time. Velocity error value tends to zero and lateral channel position error value tends to value of 10 km. Error curve has a periodic process shape.

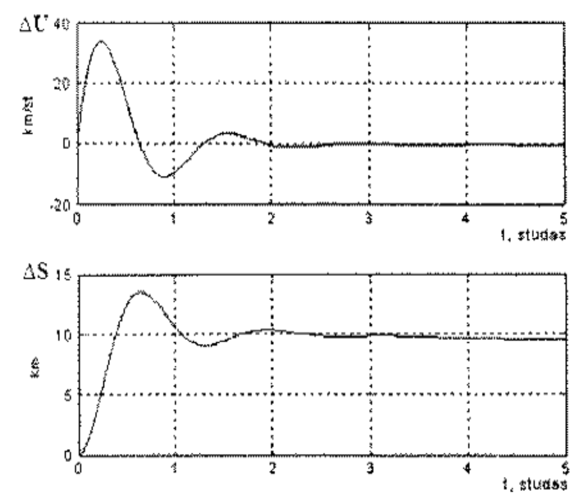

Fig. 4. System error propagation with time. Both correction loops operates simultaneously

Then, by using developed correction it is possible to increase significantly 1INS performance. Velocity correction using two correction loops when accordingly one and both integrators are enclosed simultaneously by correction loop results in velocity and position error stabilization on definite level. This is characteristic property of velocity-aided 1INS with correction loops.

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P.Trifonovs –Bogdanovs, D.Fetisovs, T. Trifonova – Bogdanova. Sanu vienkanāla ar ātruma informāciju koriģējama inerciāla navigācijas sistēma

Inerciālā navigācijas sistēmās (INS)struktursh̄emu analīzes rezultāti rada uz vienkanāla inerciālās navigācijas sistēmas (1INS) izveidošanas iespēju, izmantojot tikai vienu kanālu, attiecīgi - sānkanālu, garēnkanālu vai vertikālo kanālu. Pilnkanālā varianta sistēmai ir šķērssaites starp kanālu galvēniem ķēdēm, un tāpēc vienkanāla varianta gadījumā ir nepieciešama papildus informācija par gaisa kuģa kustību (ātrumu, paātrinājumu, ceļu, leņķiskiem ātrumiem un leņķisko stāvokli). Bez ārējiem informācijas avotiem sistēmas kļūda krietni pieaug, salīdzinājumā ar sistēmas pilnkanālā variantu. Darba tiks piedāvāts vienkanāla navigācijas sistēmas modelis (izmantots sānu kanāls). Doti 1INS kļūdu modeļa modelēšanas rezultāti. Tiks piedāvāti atšķirīgie sistēmas korekcijas varianti, izmantojot ārējo informācijas avotu par gaisa kuģu kustības ātrumu. Aplūkoti un nomodelēti vienkanāla sistēmas kļūdu modeļi ar dažādu variantu ievēstam korekcijām un to kombinācijām, ka arī doti rezultāti, iegūti modelēšanas gaitā. Iegūti modelēšanas rezultāti rada uz ievērojamu 1INS precizitāšu raksturojumu uzlabojumu.

P.Trifonovs –Bogdanovs, D.Fetisovs, T. Trifonova – Bogdanova. Одноканальная инерциальная навигационная система бокового канала с коррекцией по информации о скорости.

Результаты анализа структурных схем инерциальных навигационных систем (ИНС) указывают на возможность создания одноканальной инерциальной навигационной системы(1ИНС), используя лишь боковой, продольный или вертикальный каналы. В полноканальном варианте, система имеет перекрестные связи между главными цепями каналов, поэтому при одноканальном варианте необходимы дополнительные источники нформации о движении воздушного судна. Без внешних источников информации погрешность системы значительно увеличивается по сравнению с полноканальным вариантом. В работе предложена модель одноканальной инерциальной навигационной системы (используется боковой канал). Приведены результаты моделирования модели погрешностей 1ИНС. Предложены различные варианты коррекции системы, используя внешний источник информации о скорости движения. Рассмотрены и смоделированы модели погрешностей одноканальной системы с введеными различными вариантами коррекций и их комбинации, а также представлены полученый результаты моделирования. Полученые результаты моделирования указывают на значительное увеличение точностных показателей 1ИНС.