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Signal processing in cryogenic-optical gravimeter

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Satellite and ground gravimeters are main devices required to the study of geodynamic processes, the evolution of Earth's gravitational field and the motion of its poles, risk assessment of emergencies and other fields [1]. Among the many types of gravimeters for high sensitivity measurements of gravitational field has been developed the cryogenic-optical device [1]. The development of new signal processing methods in this gravimeter is the main objective of this report. In [1] the principle of data processing in cryogenic-optical gravimeter was described in detail, but the question of structural-parametric identification of the controlled sensor requires further consideration.

Assume that the controlled sensor describes by non-stationary bilinear system:

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} a_{11}(t) & a_{12}(t) \\ a_{21}(t) & a_{22}(t) \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} a_{11}(t)x_1(t) & a_{12}(t)x_2(t) \\ a_{21}(t)x_1(t) & a_{22}(t)x_2(t) \end{bmatrix} \begin{bmatrix} u_1(t) \\ u_2(t) \end{bmatrix}, \quad (1)$$

$$y_1 = d_0 + D_1 x(t). \quad (2)$$

Let the state of the system (1) at the initial time is unknown. The general solution of system (1) is.

$$\begin{cases} x_1(t) = C_1\lambda_1(t)e^{r_1(t)t} + C_2\lambda_2(t)e^{r_2(t)t}, \\ x_1(t) = C_1\mu_1(t)e^{r_1(t)t} + C_2\mu_2(t)e^{r_2(t)t}. \end{cases} \quad (3)$$

The following algorithm for parametric identification of the system (1) and equation (2) is proposed. There are following formulas for estimating parameters (1), (2).

$$\begin{cases} r_k(t) = 0, t = 0, k = \overline{(1..2)} \\ r_k(t) = \dfrac{1}{t} ln \dfrac{u_k^p(t)}{u_k^p(0)}, t > 0, k = \overline{(1..2)}, p = 2. \end{cases} \quad (4)$$

$$\lambda_k(t) = \frac{u_k^p(t)}{e^{r_k(t)t}} \quad (5)$$

$$\mu_k(t)=\frac{u_k^{p-1}(t)}{e^{r_k(t)t}} \tag{6}$$

Let in the system (1):

$$\begin{bmatrix} a_{11}(t)+a_{11}(t)u_1(t) & a_{12}(t)+a_{12}(t)u_2(t) \\ a_{21}(t)+a_{21}(t)u_1(t) & a_{22}(t)+a_{22}(t)u_2(t) \end{bmatrix}=\begin{bmatrix} b_{11}(t) & b_{12}(t) \\ b_{21}(t) & b_{22}(t) \end{bmatrix} \tag{7}$$

For the two states of the system (1):

$$b_{11}(t)=\frac{r_1(t)\frac{\lambda_1(t)}{\mu_1(t)}-r_2(t)\frac{\lambda_2(t)}{\mu_2(t)}}{\frac{\lambda_1(t)}{\mu_1(t)}-\frac{\lambda_2(t)}{\mu_2(t)}},$$

$$b_{12}(t)=-\frac{\lambda_1(t)}{\mu_1(t)}\frac{\left(r_1(t)\frac{\lambda_1(t)}{\mu_1(t)}-r_2(t)\frac{\lambda_2(t)}{\mu_2(t)}\right)}{\left(\frac{\lambda_1(t)}{\mu_1(t)}-\frac{\lambda_2(t)}{\mu_2(t)}\right)}+r_1(t)\frac{\lambda_1(t)}{\mu_1(t)},$$

$$b_{21}(t)=-\frac{\mu_2(t)}{\lambda_2(t)}\frac{\left(r_1(t)\frac{\mu_1(t)}{\lambda_1(t)}-r_2(t)\frac{\mu_2(t)}{\lambda_2(t)}\right)}{\left(\frac{\mu_1(t)}{\lambda_1(t)}-\frac{\mu_2(t)}{\lambda_2(t)}\right)}+r_2(t)\frac{\mu_2(t)}{\lambda_2(t)},$$

$$b_{22}(t)=\frac{\left(r_1(t)\frac{\mu_1(t)}{\lambda_1(t)}-r_2(t)\frac{\mu_2(t)}{\lambda_2(t)}\right)}{\left(\frac{\mu_1(t)}{\lambda_1(t)}-\frac{\mu_2(t)}{\lambda_2(t)}\right)}.$$

Unknown parameters $\|a_{ij}(t)\|$ are equal:

$$\begin{bmatrix} a_{11}(t) & a_{12}(t) \\ a_{21}(t) & a_{22}(t) \end{bmatrix}=\begin{bmatrix} \frac{b_{11}(t)}{1+u_1(t)} & \frac{b_{12}(t)}{1+u_2(t)} \\ \frac{b_{21}(t)}{1+u_1(t)} & \frac{b_{22}(t)}{1+u_2(t)} \end{bmatrix}$$

The algorithm of parametric identification of the bilinear system (1) and equation (2) for signal processing in cryogenic-optical gravimeter was proposed.

References

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