FUNCTIONAL TESTING OF ANGLE-DATA TRANSMITTERS OF THE LIMITED ROTATION ANGLE

B. M. KHARCHYSHYN, M. V. KHAi, P. A. BOLKOT

The aim is to develop the method of defining the angle-data transmitters’ nonlinearity of output characteristics of the limited rotation angle, and the method of confirmation the feasibility of creating them on base of the n-bit goniometric system. Practical value. An example of digital signal processing is provided. Originality. We proposed to build a calibration curve across the even points and compare its values in the odd points of the experiment.

Keywords: inductive angle-data transmitter, limited rotation angle, transversal magnetic system, nonlinearity of the output characteristic, calibration curve, measure of code inaccuracy.

The general requirement for the $E_{s1}(\alpha)$ and $E_{s2}(\alpha)$ is the following: they both should be line-symmetrical with respect to the vertical axis and the straight line $E_{av}$.

Fig. 1 – The form of functional dependencies $E_s(\alpha)$ and $E_s(\alpha)$

In addition, dependences of the signals’ amplitude on the angle should be directly proportional. Otherwise, the value of the angle $\alpha$ should be determined by the function inverse to the $E(\alpha)$ function, using programmable logic integrated circuits [2, 3].

Formulation of the problem. In practice, because of the technological specifics of manufacturing angle transmitters in general and the magnetic ferrite, in particular, it is impossible to achieve the abovementioned properties of the outputs. Therefore, there is a need to assess their deviation from the ideal condition. This investigation is dedicated to creating the methods of testing the nonlinearity of the amplitude’s dependence of the output signals on the angle, and checking the feasibility of implementing angle transmitter based n-bit goniometric system. Of course, when it comes to acceptance testing that each angle transmitter sample undergoes, this testing should not be too expensive. On the other hand, when producing
the single sets of angle-data transmitters, it is inappropriate to create expensive testing facilities. Therefore, there is one more limitation of using analog-digital converters, of course, except for the high voltage voltmeter (type B7-28 or multimeter Protek 608).

**Research objective** in this article is the output characteristic of angle-data transmitters of the limited rotation angle with the transversal magnetic system.

**Presenting the main material.**

To carry out the necessary testing, a full-range of rotation angles \( \alpha_{\text{oper}} \in (\text{arcmin}) \), expressed in arcminute, should be divided into \( m \) (recommended as odd) parts of the extreme points \( i = 0 ... m \). When using the goniometric device, we set the appropriate angular position that corresponds with each point in the range, \( \alpha_i \), and determine the value of output voltage amplitude of the angle-data transmitter’s signal windings \( U_{1i} \) and \( U_{2i} \).

After the experimental part, we should process the numerical data.

For each point in range of rotation \( \alpha_i \) the value of numerical angle’s code is defined as follows \( A_i = \text{round}(\alpha_i / c) \), where \( c = \alpha_{\text{oper}} \cdot 2^{-n} \) — \( n \)-bit code discrete value of the goniometric system.

The value of the digital code of angle transmitters \( D_i \) [relat.units] at the \( \alpha_i \) points

\[
D_i = \frac{U_{1i} - U_{2i}}{U_{1i} + U_{2i}} \cdot \frac{U_{10} - U_{20}}{U_{10} + U_{20}}
\]

(3).

The value of the digital code of the angle transmitter in discretes

\[
d_i = \text{round} \left( \frac{D_i}{D_m} \cdot A_m \right)
\]

(4).

A calibration curve \( T_i \) is obtained by assigning the real (specified) angle \( A_i \) values, to the code of the angle-data transmitter \( d_i \) in discretes for the even experiment points. The equation of a calibration curve as the dependence of actual angle on the actual code value in discretes is defined as cubic spline interpolation.

To determine the measure of inaccuracy of the code nonlinearity, a regression line as the regression curve of the first order was created

\[
PR_i = \text{round} \left( \text{interp} \left( S, X, Y, X_i \right) \right),
\]

(5)

where \( X \rightarrow A_i \), \( Y \rightarrow d_i \); \( S = \text{spline} \left( Z, V \right) \); and \( X = \text{regress} \left( X, Y, 1 \right) \).

Nonlinearity error \( \Delta \% \) is defined as the difference between the relative magnitude of the angle-data transmitter and regressive dependence values

\[
\Delta \% = \frac{d_i - \text{PR}_i}{d_i} \cdot 100\%.
\]

(6)

Goniometric system’s measure of code inaccuracy in discrete system

\[
\Delta_i = T_i - A_i
\]

(7)

reaches its maximum in odd points and decreases up to zero as we approach the even ones. Obviously, to reduce the measure of code inaccuracy, for building the calibration curve as many points of the experiment as possible should be used.

**Example of a use case** of such method is implemented in the Matlab package for testing the angle-data transmitter 1ДУ60 with the working angular range of 60°. It was developed at Special Design Bureau of Electromechanical Systems of the Lviv Polytechnic National University for usage in 14-bit goniometric system depicted below.

The results of experimental values are recorded in the table 1.

The value of the digital code angle \( A_i \) is defined as \( A_i = \text{round}(\alpha_i / c) \),

where \( c = \alpha_{\text{oper}} \cdot 2^{-14} = 36002^{14} = 0.219726562 \) — the discrete value of the 14-bit code goniometric system, is expressed in arcminutes (arcmin).

The value of the angle-data transmitter’s digital code \( D_i \) [arb. unit] is defined as follows (3).

The value of the digital code angle-data transmitter in discretes \( d_i \) is defined as follows

\[
d_i = \text{round} \left( \frac{D_i}{D_m} \cdot A_m \right).
\]

The value of a calibration curve code \( T_i \) [in discretes] is defined as \( T_i = \text{round} \left( \text{interp} \left( S, X, Y, d_i \right) \right) \)

where \( X \rightarrow A_i \), \( Y \rightarrow d_i \); \( S = \text{spline} \left( Z, V \right) \); and \( Z_i = A_i \) (even), \( V_i = d_i \) (even).

The equation of the regression straight line is defined as follows (5).

Nonlinearity error \( \Delta \% \) is defined by (6) at the \( m=37 \).

Dependence of codes of the angle-data transmitters \( d_i \) and its regression line on the codes of the predefined corners \( A_i \) is depicted in the Figure 2. And, the non-linearity of this dependence is expressed in percentage in Figure 3.
Table 1 – The results of experimental values

<table>
<thead>
<tr>
<th>Reference number ( i )</th>
<th>The value of the specified angles ( \alpha_i ) (arcmin)</th>
<th>The voltage of the 1\textsuperscript{st} signal winding ( U_1 ) (V)</th>
<th>The voltage of the 2\textsuperscript{nd} signal winding ( U_2 ) (V)</th>
<th>Digital code of the specified angles ( A_i ) (discr.)</th>
<th>Digital code of the angle-data transmitter ( D_i ) (relat.units)</th>
<th>Digital code of the angle-data transmitter ( d_i ) (discr.)</th>
<th>Calculated values of the calibration curve ( T_i ) (discr.)</th>
<th>The measure of code inaccuracy ( \Delta_i ) (discr.)</th>
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</table>

Therefore, the nonlinearity of the source angle in the operating range of angles does not exceed 0.6%. The measure of code inaccuracy in the operating system’s goniometric range of angles is less than 5 discrete that the angular dimension is equal to 1.32 arcmin.

![Fig. 3 – Nonlinearity of angle’s code dependence on the specified angle](image_url)

![Fig. 4 – The dependence of the angle-data transmitter’s code measure of inaccuracy on the code of the specified angle values](image_url)
Conclusions. Therefore, the proposed method of testing does not require huge financial expenses in terms of resources and the time spent. Besides, it is sufficient for establishing the basic functional parameters of angle-data transmitters of limited rotation angle of the transversal magnetic system and can be used for developing specifications.

References


References (transliterated)


Bibliographic descriptions


About the Authors

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