THE 'BLIND' DYNAMIC ERROR CORRECTION METHOD – SIMULATION STUDY FOR THE FIRST-ORDER MEASUREMENT CHANNEL

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Abstract: Paper presents introductory results of simulations for a selected method of dynamical error correction without prior knowledge of properties of measurement channel. This task can be accomplished using a measurement system having two twin channels which measure the same input value. This correction method can be names - the "blind" method. In presented researches the measurement channel was modeled as inertial first order dynamic object. The results of the study presented in the paper confirmed the possibility of application of the continuous dynamic systems computer simulation as a research method for determining the parameters of the practical realization of the 'blind' dynamic error correction method. The results presented do not allow us to determine finally these parameters; they give, however, clear hints for further search, which will be directed to determine the effectiveness of this dynamic error correction method.

Keywords: Simulation, Dynamical Error Correction

1. INTRODUCTION

The 'blind' dynamic error correction method for a measurement consists in such an (optimal) selection of corrector parameters that the difference between the results of performance of both measurement channels (paths) with series correctors be zero. Both measurement channel shall have the same character of their dynamics (the order of mathematical model) but different parameters (e.g., time constants) [1]. A schematic diagram of a 'blind' dynamic error correction system is presented in Fig. 1. The system consist of two measurement channels, each of them has the same A/D converter at the output. The converters are connected in series to the signal processor where corrector functions are realized according to the 'blind' correction method.

The basic problem in practical application of the 'blind' correction method is ensuring high accuracy of computing in real time. One of the assessment methods for practical application of such a dynamic correction methods is carrying out model simulation study.

In the paper, the results of simulation study on the 'blind' measurement dynamic error correction method are presented.

The following assumptions have been made:

- The measurement channels tested are described by the first-order transmittance model;
- The A/D converter is modeled as the quantization operation (parameter – word length);
- The signal processor is modeled as an algorithm realized by the operations of the applied simulation language;
- The classical differentiation method is uses in the corrector algorithm;
- The measured signal is sinusoidal, 50 Hz, with interferences;
- The GODYS PC simulation language [2] is used in the study.

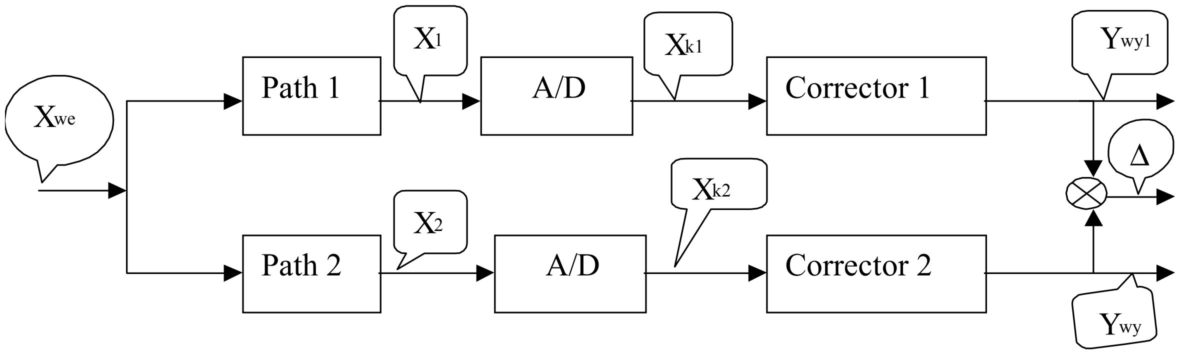

Fig. 1. Schematic diagram of the 'blind' dynamic error correction system

Basic goals of the simulation study made were as follows:
- Selecting numerical methods used in digital correctors;
- Selecting the quality criterion index used for the optimal selection of corrector parameters;
- Selecting a method of optimal selection of corrector parameters,

all based on the selection of: sampling frequency, A/D converter word length and the interference parameters of the measured signal.

2. SIMULATION OF THE 'BLIND' DYNAMIC ERROR CORRECTION SYSTEM

Measurement channels were modeled as the first-order transmittance.

$$\frac{X_1(s)}{X_{we}(s)} = \frac{1}{1+T_1 s} \qquad \frac{X_2(s)}{X_{we}(s)} = \frac{1}{1+T_2 s} \tag{1}$$

where: T_1 = 4.4 [ms], T_2 = 2.2 [ms]

A/D converters were modeled as the operation of quantization.

$$X_{k1} = q \cdot \mathrm{Entier}\left[\frac{X_1 + \frac{q}{2}}{q}\right] \qquad X_{k2} = q \cdot \mathrm{Entier}\left[\frac{X_2 + \frac{q}{2}}{q}\right] \tag{2}$$

where: q = 2.4414062 E-4 ,(word length 13 bit for range [-1,1])

Correctors were modeled as the operation of differentiation:

$$\frac{Y_{wy1}(s)}{X_{k1}(s)} = 1 + T_3 s \qquad \frac{Y_{wy2}(s)}{X_{k2}(s)} = 1 + T_4 s \tag{3}$$

where: T_3 = ALFA*T_1 i T_4 = BETA*T_2 ,ALFA i BETA - coefficients

The study on the determination of the accuracy of the classical differentiation operation represented by DERIVT in the GODYS PC language was carried out first. The sinusoidal input signal of frequency F_s=50 Hz was subsequently quantized and differentiated; the calculated errors were referred to the result of the ideal differentiation (the cosine function). Sampling (of frequency F_p) was simulated by the simulation step. Errors were calculated for one period of the investigated run. These errors were: BRS – accumulated error (the integral of the absolute value of error), BRDW – relative dynamic error, BRSK – the absolute value of the mean error per one step, BRM – maximum error. Based on the obtained results it can be concluded that all relationships between the calculated errors and the F_p/F_s ratio exhibit

minimum, although not at the same point. Moreover, it was found that the higher sampled frequency, the stronger influence of the word on the differentiation error.
The investigations did not point unequivocally at the unique sampling frequency (i.e., more adequate, the ratio $F_{p.}/F_s$). However, it was possible to state that the quantization and differentiation error did not exceed 1% over a wide range of the ratio $F_{p.}/F_s$.
In order to select one sampling frequency for the study of the 'blind' correction, simulation study were carried out to determine the relationship of three ideal 'blind' correction quality criterion indices and the ratio $F_{p.}/F_s$. Performance of both measurement channels and in-series connected ideal correctors was simulated. Ideal dynamic error correction means adopting the ALFA and BETA coefficients equal unity. The calculation of the correction quality index was based on the difference in the results of the performance of both channels (error Δ in Fig.1) in subsequent simulation steps. The calculated correction quality indices were: BKS – accumulated error (the integral of the absolute value of error), BKKW – square error (the integral of the squared error), BKMA – maximum error [3]. The values of all criteria reached their minimum for the ratio $F_{p.}/F_s$ equal 40. This number results from the favorable accumulation in the both channels of the errors of quantization, integration, differentiation and again integration. Simulations were made for various A/D converter word lengths from 10 to 16 bits, and always the minimum occurred although the longer the word the higher the
ratio $F_{p.}/F_s$ for the minimum (Fig.2). The fixed-step numerical integration methods were used in the study made, and all produced similar results with accuracy better than 1%.

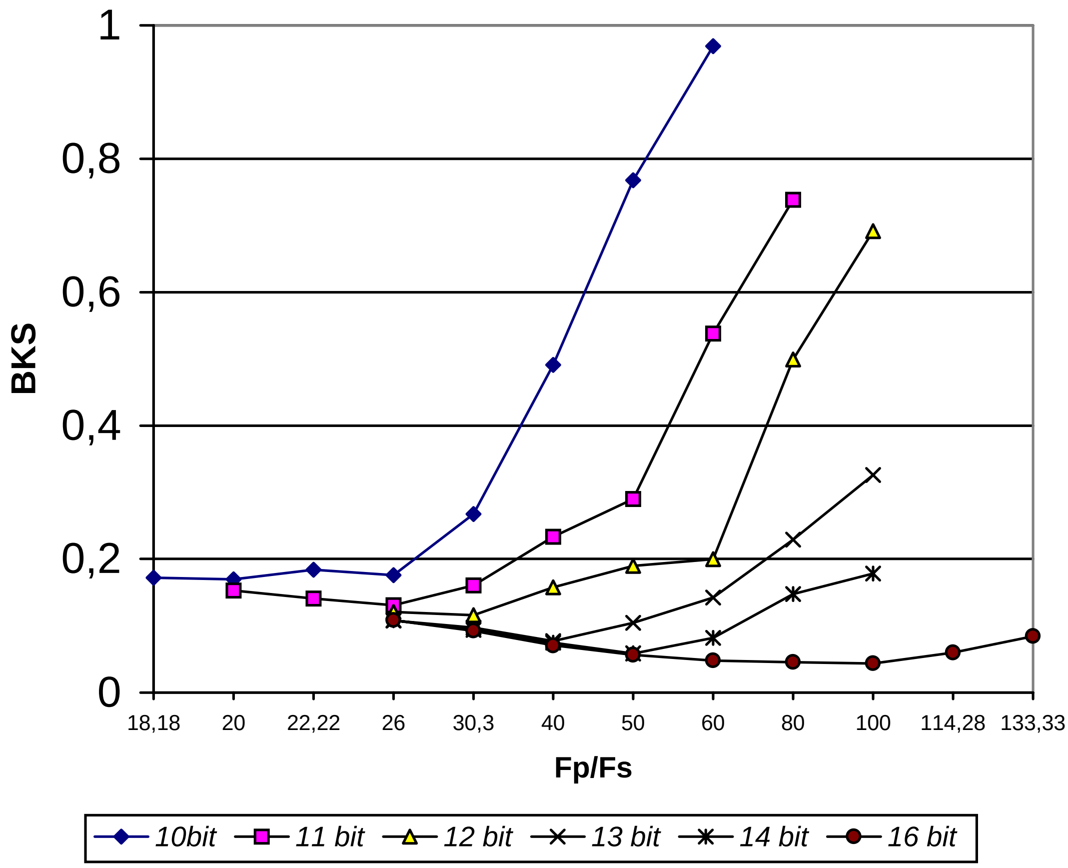

Fig.2 Correction quality index BKS in function of ratio F_p/F_s for various A/D converter word lengths .

Next series of simulation research on the ‘blind’ dynamic correction was aimed at the determination of the sensibility of the previously used quality criteria indices to the “off-tuning” of correctors by changing the ALFA and BETA coefficients. The simulations were carried out for the ratio $F_{p.}/F_s = 40$; a simulation interval included three periods of the input signal, and the errors were calculated for one full (third) period, which allowed to avoid start-up errors. Based on the obtained results it can be stated that all criteria show similar sensibility (variation by one order) to the assumed values of corrector parameters. The highest sensibility showed successively the BKS, BKKW and BKMA criteria.

Full simulation study of the ‘blind’ dynamic correction included adding an algorithm of the optimum selection of corrector parameters to the two measurement channels. For simplicity the values of the ALFA and BETA coefficients were optimized. BSK and BKKW were used as the quality criteria. The simulations were carried out for a sinusoidal input signal with a possibility of adding interferences. The simulations were carried out using the RKG numerical integration method with the step adequate for the predetermined ratio $F_{p.}/F_s = 40$. Three optimization methods, available in the GODYS PC language, were employed: DSC (Davies, Swann, Campey), MC (Monte Carlo) and SHORT (uniform interval contracting). The simulated duration included three periods of input signal, and the optimization took place in the third period.

Many simulation runs were carried out where the following was also changed:

- six starting points of optimization,
- three variability ranges of corrector coefficients,
- the level of disturbance of the input signal by the third harmonic (from 5% to 30%),
- the level of disturbance which consisted in cutting the sinusoid (from 5% to 50%),
- the A/D converter word (from 8 to 16 bits).

The quality of corrector parameter selection was determined in the sense of the mean squared error. Based on the obtained results the following conclusions can be made:

- The MC method gives the best results for both correction quality criterion indices irrespectively of the starting point. The method is up to five times slower than the others.
- The DSC method has substantially shorter calculation time but the selection errors are in average three times larger independently of the starting point. Smaller errors were obtained for the accumulated index (BKS).
- The SHORT method was totally disqualified because of its large errors.
- The result of optimization by the MC method weakly depends on the applied A/D converter word length. For example, the result does not change in the interval of 11-16 bits for BKKW and in the interval of 12-16 bits for BKS.
- The optimization by the DSC method depends on the applied length of A/D converter word and gives minimum values of BKS for 12 bits, and of BKKW for 13 bits,
- Interfering the third harmonic up to 25% does not influence the results for the MC optimization method.
- Interfering by the third harmonic always adversely influences the results for the DSC optimization method.
- Contracting the variability interval always improved the results for MC and changed not much for DSC.
- Expanding the variability interval deteriorated a bit the results for MC and slightly improved them for DSC.
- Cutting the sinusoid down even to the 50% -level did not change the final results obtained with the MC method.

3. FINAL CONCLUSIONS

The results of the study presented in the paper confirmed the possibility of application of the continuous dynamic systems computer simulation as a research method for determining the parameters of the practical realization of the 'blind' dynamic error correction method. The results presented do not allow us to determine finally these parameters; they give, however, clear hints for further search. Further studies will be directed towards the verification of other numerical methods for the operation of differentiation and parametric optimization. Also, other simulation languages will be comparatively used.

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