Interpolation method modification for nonlinear objects identification using Volterra model in a frequency domain

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INTERPOLATION METHOD MODIFICATION FOR NONLINEAR OBJECTS IDENTIFICATION USING VOLTERRA MODEL IN A FREQUENCY DOMAIN

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Abstract — The accuracy of the modified interpolation method of nonlinear dynamical systems identification based on the Volterra model in the frequency domain is studied. The polyharmonic signals with reduced amplitudes are used as the test ones. The model is built as first, second and third order amplitude–frequency and phase–frequency characteristics. The comparison of obtained characteristics with previous works is given.

УСОВЕРШЕНСТВОВАНННЫЙ ИНТЕРПОЛЯЦИОННЫЙ МЕТОД ИДЕНТИФИКАЦИИ НЕЛИНЕЙНЫХ ОБЪЕКТОВ С ИСПОЛЬЗОВАНИЕМ МОДЕЛИ ВОЛЬТЕРРА В ЧАСТОТНОЙ ОБЛАСТИ

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Аннотация — В работе исследуется точность усовершенствованного интерполяционного метода идентификации нелинейных динамических объектов с использованием модели Вольтерра в частотной области. Данный метод заключается в n–кратном дифференцировании откликов идентифицируемой нелинейной системы по значению параметра–амплитуды тестовых полигармонических сигналов. Во время исследований используются уменьшенные значения амплитуд. Для построения информационной модели нелинейной системы в виде АЧХ и ФЧХ первого, второго и третьего порядков используется разработанный программный комплекс идентификации.

I. Introduction

It is necessary to consider technical conditions of the communication channels (CC) operation for effective data transfer. Changes in environmental conditions cause reducing the transmission data rate: in the digital CC – up to a full stop of the transmission, in analog CC – to the noise and distortion of the transmitted signals. The new methods and supporting toolkit are developed to automate the measurement of parameters and taking into account the characteristics of the CC. This toolkit allows obtaining the informational and mathematical model of such nonlinear dynamic object, as the CC [1], i.e. solving the identification problem.

Modern continuous CC's are nonlinear stochastic inertial systems. The model in the form of integro–power Volterra series used to identify them [2—5].

Building a model of nonlinear dynamic system in the form of a Volterra series is in the choice of the test actions form. Also it uses the developed algorithm that allows determining the Volterra kernels and their Fourier–images for the measured responses (multidimensional amplitude–frequency characteristics (AFC) and phase–frequency characteristics (PFC)) to simulate the CC in the time or frequency domain, respectively [6].

II. Main Part

The interpolation method of nonlinear dynamical objects identification was studied in [7].

The main purpose was to identify the multifrequency performances characterizing nonlinear and dynamical properties of nonlinear test object. Volterra model in the form of the second order polynomial is used. Thus, test object properties are characterized by transfer functions of $W_1(j\omega_1)$, $W_2(j\omega_1,j\omega_2)$, $W_3(j\omega_1,j\omega_2,j\omega_3)$ — by Fourier–images of weight functions $w_1(t)$, $w_2(t_1, t_2)$, $w_3(t_1, t_2, t_3)$.

The weighted sum is formed from received signals – responses of each group. As a result the partial components of CC responses $y_1(t)$, $y_2(t)$ and $y_3(t)$ are obtained. For each partial component of response the Fourier transform (the FFT is used) is calculated, and from received spectrum only informative harmonics (which amplitudes represent values of required characteristics of the first, second and third orders AFC) are taken.

The first order AFC $|W_1(j\omega_1)|$ and PFC $\arg W_1(j\omega_1)$, where $\omega_1=\omega$ are obtained by extracting the harmonics with frequency f from the spectrum of the CC partial response $y_1(t)$ to the test signal $x(t)=A/2(\cos\omega t)$.

The second order AFC $|W_2(j\omega_1,j\omega_2)|$ and PFC $\arg W_2(j\omega_1,j\omega_2)$, where $\omega_1=\omega$ and $\omega_2=\omega_1+\Omega_1$, were received by extracting the harmonics with summary frequency $\omega_1+\omega_2$ from the spectrum of the CC partial response $y_2(t)$ to the test signal $x(t)=(A/2)(\cos\omega_1 t+\cos\omega_2 t)$.

The third order AFC $|W_3(j\omega_1,j\omega_2,j\omega_3)|$ and PFC $\arg W_3(j\omega_1,j\omega_2,j\omega_3)$, where $\omega_1=\omega$, $\omega_2=\omega_1+\Omega_1$, $\omega_3=\omega_2+\Omega_2$ were received by extracting the harmonics with summary frequency $\omega_1+\omega_2+\omega_3$ from the spectrum of the CC partial response $y_2(t)$ to the test signal $x(t)=(A/2)(\cos\omega_1 t+\cos\omega_2 t+\cos\omega_3 t)$.

As compared to experiments studied in [7] the amplitudes of the current experiments were reduced in 10 times. This reduces the standard deviation of some result characteristics because of reducing the impact of the nonlinear part of the characteristics.

Numerical values of identification accuracy using interpolation method with reduced amplitudes of the test signals for the test object are represented in table 1.

The results (first, second and third order AFC and PFC) which had been received after procedure of identification are represented in fig. 1—3 (number of experiments for the model N=6).

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Table 1. Numerical values of identification accuracy using modified interpolation method

Табл. 1. Числовые значения точности идентификации для усовершенствованного интерполяционного метода

Kernel order, *k*	Experiments quantity, *N*	AFC relative error, %	PFC relative error, %
1	2	2.9968	2.8330
	4	1.0806	2.0936
	6	0.8137	1.8203
2	2	47.995	84.5081
	4	4.4374	7.2064
	6	16.6681	4.1836
3	4	4.0957	2.1917
	6	3.8830	2.1396

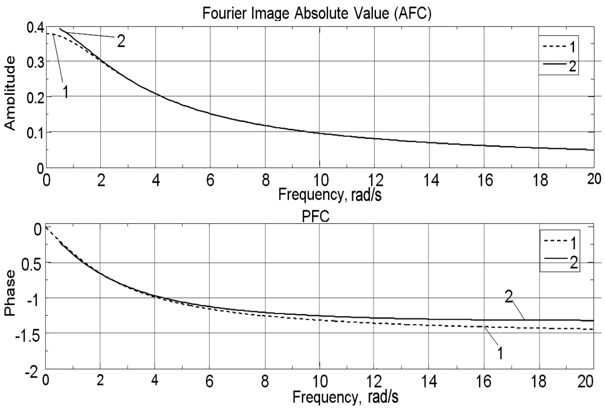

Fig. 1. The first order AFC and PFC of the test object: analytically calculated values (1), section estimation values with number of experiments for the model N=6 (2).

Рис. 1. АЧХ и ФЧХ первого порядка для тестового объекта: значения, рассчитанные по аналитическим выражениям (1), значения оценки диагонального сечения для модели с количеством экспериментов N=6 (2)

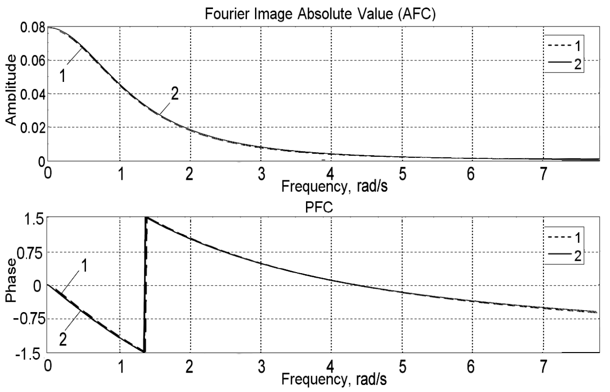

Fig. 2. The second order AFC and PFC of the test object: analytically calculated values (1), subdiagonal cross–section values with number of experiments for the model N=4 (2), Ω_1=0,01 rad/s.

Рис. 2. АЧХ и ФЧХ второго порядка для тестового объекта: значения, рассчитанные по аналитическим выражениям (1), значения для поддиагонального сечения для модели с количеством экспериментов N=4 (2)

IV. Conclusion

The method based on Volterra model using polyharmonic test signals for identification nonlinear dynamical systems was analyzed. New values of test signals amplitudes were tested and model were validated using the test object. The excellent accuracy level for the obtained model is achieved both in linear and nonlinear models. Given values are greatly raising the accuracy of identification in compare to method described in [8]. The identification accuracy of nonlinear part for the test object has grown 1.5–2 times while the standard deviation in the best cases is no more than 3–4%.

In the further researches it is necessary to study the noise immunity of frequency characteristics using the method being studied.

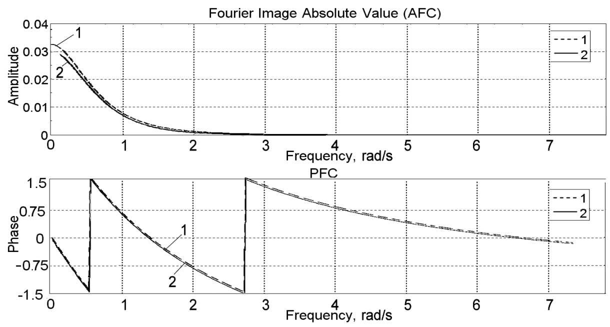

Fig. 3.The third order AFC and PFC of the test object: analytically calculated values (1), subdiagonal cross-section values with number of experiments for the model N=6 (2), Ω_1=0.01 rad/s, Ω_2=0.1 rad/s.

Рис. 3. АЧХ и ФЧХ третьего порядка для тестового объекта: значения, рассчитанные по аналитическим выражениям (1), значения для поддиагонального сечения для модели с N=6 (2)

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