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NAFASS: Discrete spectroscopy of random signals

R.R. Nigmatullin [a,*], S.I. Osokin [a,*], V.A. Toboev [b]

[a] Institute of Physics, Kazan (Volga Region) Federal University, Kremlevskaya str.18, Kazan, Tatarstan 420008, Russia

[b] Department of Mathematics, Chuvash State University, Moskovskiy pr.,15, Cheboksary 428015, Russia

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ABSTRACT

In this paper we suggest a new discrete spectroscopy for analysis of random signals and fluctuations. This discrete spectroscopy is based on successful solution of the modified Prony's problem for the strongly-correlated random sequences. As opposed to the general Prony's problem where the set of frequencies is supposed to be unknown in the new approach suggested the distribution of the unknown frequencies can be found for the strongly-correlated random sequences. Preliminary information about the frequency distribution facilitates the calculations and attaches an additional stability in the presence of a noise. This spectroscopy uses only the informative-significant frequency band that helps to fit the given signal with high accuracy. It means that any random signal measured in *t*-domain can be "read" in terms of its amplitude-frequency response (AFR) *without* model assumptions related to the behavior of this signal in the frequency region. The method overcomes some essential drawbacks of the conventional Prony's method and can be determined as the non-orthogonal amplitude frequency analysis of the smoothed sequences (NAFASS). In this paper we outline the basic principles of the NAFASS procedure and show its high potential possibilities based on analysis of some actual NIR data. The AFR obtained serves as a specific fingerprint and contains all necessary information which is sufficient for calibration and classification of the informative-significant band frequencies that the complex or nanoscopic system studied might have.

1. Formulation of the problem

In spite of the essential progress of the Fourier and wavelet analysis [1–14] the treatment and subsequent fit of an arbitrary random sequence containing a set of unknown multi-frequency periodical functions is far from its satisfaction. For any researcher it is necessary to fit a segment of the given random sampling (or signal) by a finite number of frequencies with amplitudes that contain significant information about the periodical processes involved in its behavior. For example, in Fig. 1 we show a typical example of such kind containing a sufficient large number of the measured points ($N > 1500$). For this part of the random sequence it would be very important to find the desired fitting function, including only the informative-significant band of frequencies and amplitudes that can fit this segment with high accuracy. The first attempt of such kind was undertaken by Prony in 1795. During long period this method was essentially modified [15–30] but in nowadays many researchers admit that this method is *not* numerically stable for large number of measured points and to presence of a random component defined usually as "a noise". In order to overcome these drawbacks and increase the possibilities of the fitting of any random sequences one can try to achieve *preliminary* information about the frequency distribution ω_k ($k = 0, 1, \ldots, K-1$) over the numbers of modes *k*. If this information can be found

Abbreviations: ACF, autocorrelation function; AFR, amplitude–frequency response; ECs, the Eigen-Coordinate method; FM, fluctuation metrology; LLSM, the linear least-square method; LPSCV, the linear principle of the strongly correlated variables; NAFASS, non-orthogonal amplitude–frequency analysis of the smoothed sequences; NIR, near infra-red; PEN, pseudo-ergodic noise; POLS, procedure of the optimal linear smoothing.

* Corresponding authors.

E-mail address: nigmat@knet.ru (R.R. Nigmatullin).

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