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STRUCTURE AND APPLICATION OF ATDP SUITE FOR ELECTRONIC SYSTEM STATES DETECTION AND EVOLUTION OPERATOR RESTORATION

I.I. Magda, A.V. Paschenko, I.M. Shapoval, V.E. Novikov*

National Science Center «Kharkov Institute of Physics & Technology»
1 Academicheskaya, Kharkov 61108, Ukraine
E-mail: imagda@online.kharkiv.com

**) Science & Technology Center of Electrophysics, NASU*
P.O. Box 8812, Kharkov 61002, Ukraine
E-mail: nve@vl.kharkov.ua

Structure and peculiarities of the Adaptive Testing Data Processing software Suite (ATDP Suite) are presented. It is applied for dynamic characteristics restoration from experimental time series of nonlinear and unstable electronic system. Basic methods realized in ATDP Suite are demonstrated. Application of ATDP Suite for electromagnetic tests of microwave receivers demonstrated the possibility to analyze and interpret the dynamic characteristics of complex nonlinear system.

1. Introduction

A method of Adaptive Testing was created and regarded as novel methodological means and software suite for analysis and estimation of generic dynamic system (DS) parameters which describe complex electronic circuits and systems. The method is based on specific condition of tests over complex DS by electric and electromagnetic ultra-short-pulses (USP) [1,2]. The conceptual interrelations of adaptive testing procedure is demonstrated by Fig. 1.

The present version of ATDP Suite deals with experience on electromagnetic USP tests performed over microwave devices [3]. It allows to obtain reliable data of the system analysis based on time series with arbitrary little amount of points (10^3-10^4), characteristic for USP interference. Below a brief description of the ATDP Suite particularities, its structure and the main methods of analysis are described.

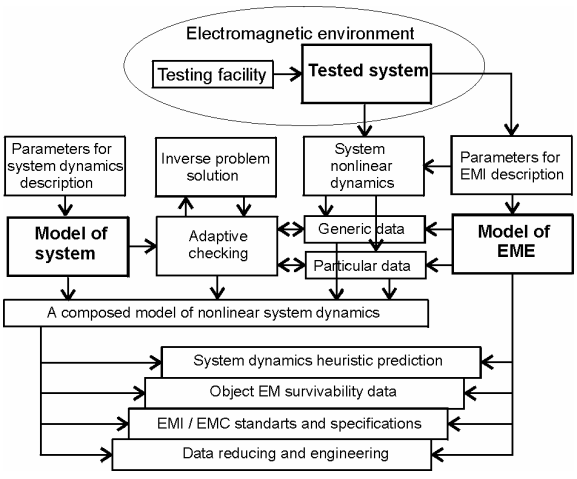

Fig. 1. *Conceptual structure of ATC*

2. ATDP Suite Structure Features

The electromagnetic USP coupling to sensitive electronic devices can produce nonlinear response very often presenting chaotic modes [3]. Such regimes are characterized by an instability regarding to initial condition perturbations, which are known as stimulus to phase trajectories chaotization. As it was shown [4], such instabilities excitation demonstrates tight correspondence between diagnostics of complex system and solving incorrect mathematical problem with the help of fractional integral-differential restoration operator. *The procedure of restoration is one of the main features of ATDP Suite.*

The DS features of importance are also the parameters of the phase trajectory statistical distributions, as well as the distances between phase trajectories of the real system and of some typical test DS (regular or chaotic). The distances are calculated basing on pseudometrics, introduced in [3] and modified with the use of a variety of probabilistic distributions. Thus, *the usage of symbolic dynamics and pseudometrics technologies is the second particularity of ATDP Suite procedure.*

As important reasons for nonlinear regimes excitation in complex electronic system an electromagnetic wave scattering on account of inter-block mismatch in broad range of USP signal frequencies and boundary conditions instability, were pointed out in [2,3]. In such a case, the DS evolution can be well described by an iterated function system (IFS) formalism. *Application of this technique to both the DS state description and the DS evolution operator determination by experimental time series is the third main feature of ATDP Suite.*

The possibility to reconstruction the system of common differential equations, describing DS state evolution is also realized in software. The evolution operator indexes are defined from the condition of minimum distance between a phase trajectory obtained from real time series, and one generated by restored evolution operator. *Reconstruction is a part of qualifying procedure, which is based upon genetic algorithm and neuron network technologies.*

An efficient reconstruction of DS state evolution results from selection the generalized characteristics (qualifiers and functionals), used for DS parameters optimization.

3. Qualifying Characteristics and Analytical Means for Description Unstable Nonlinear Systems

The basic procedures of time series processing and analysis are the following.

A signal processing procedure which proceeds observation of electronic device response to USP interference must take into account the following:

- ***strong instability of studying processes*** with characteristic minimum record time of the order of time limit, available for measuring equipment. Practically, the possibility to registrations signal-response is limited by the oscilloscope frequencies range of 3-5 GHz and the analog-to-digital converter time step – (0.3-0.5 ns).
- ***finite and very small duration of signal-response*** (10^{-7}-10^{-5} s), stipulating a comparatively small length of time series and volume of data.

Such conditions require providing definite algorithms for data processing and analysis, which takes into account instability of processes, and instant (or local on time) DS characteristics, as well as introduction the concept of the ***system state*** and, respectively, the ***dynamics of transition between states***.

Qualifying the system states must be conducted with the use of a set of qualifying parameters – ***qualifiers***, providing qualitative and quantitative description both the ***states of the system***, and the ***transitions between states***.

The main DS characteristics can be divided into two classes:

- correlation and topological characteristics of the system;
- instability characteristics of DS.

A basement to analysis for the first-class characteristics is symbolic and topological dynamics, and for the second - real-time Lyapunov index analysis. In accordance with this division, the authors had offered and applied to practice two generalized qualifier, taking into account the characteristics of the specified classes:

- ***the distance based on the probabilistic distribution of binary sequence, corresponding to experimental time series*** (distribution of Mandelbrauth-Cipff), and
- ***the distance based on the distribution function of real-time (local) Lyapunov indexes***.

These qualifiers reflect specified above particularities for complex unstable system dynamics.

The categorization procedure for states of the system is founded on comparison of given object with ***control test objects***. The control test objects must reflect the most typical characteristic of real testing objects ensemble. Such well notified and contrast on their characteristics test objects are, for instance, dynamic systems demonstrating regular and chaotic dynamics.

Test models have also form several levels. Abstract mathematical models for states of the system occupy higher levels. Specific models of different class DS (for instance, radio- or electronic device), are used at lower levels of representation, which reside the most typical states – ***regular and chaotic***.

It worth noting that mathematical technique used in ATDP Suite is principally oriented to analysis of multidimensional nonlinear DS of different types. In this case, the amount of system measured parameters does not change the character of analytical process, since the optimization technology of neuron networks and genetic algorithms are applied as efficient means for processing multivariable data.

A recovery of dynamic system operator is a goal of testing system analysis. At the condition of the analysis, which uses a technology of neuron networks, a recovering of DS operator is reduced to a problem of ***image recognition***. Thus, a greatly simple and adequate mathematical model of a system is created. Searching for DS parameters is produced so that the model-image parameters correspond the most to the parameters of real system. In this case, the states of both the model system, and the testing system correspond to all possible types of states, from regular to chaotic.

Aforementioned procedures and basic algorithms providing an adaptive testing and experimen-

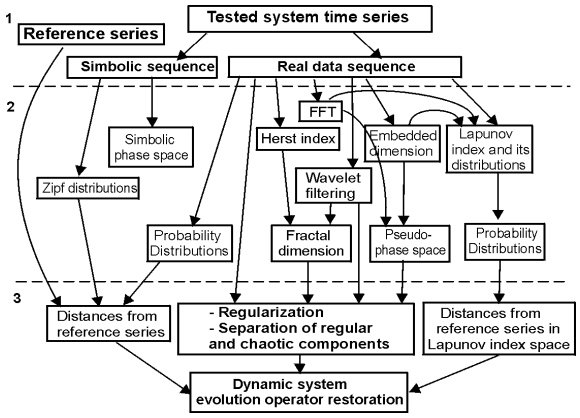

Fig. 2. *Schematics and interaction of ATDP Suite algorithms. Sections 1, 2, and 3 correspond to the ATDP Suite hierarchy – data preparation, processing and analysis*

tal data processing [3] which comprises three structural levels with their parts, are gathered in unitary ATDP Suite software, Fig. 2:

1. Preliminary experimental and test time series preparation.
2. Data processing:
   - Fourier, Gilbert and wavelet transformations;
   - probability and Zipf distributions;
   - Lapunov indexes, fractal and embedding dimensions;
3. Data analysis and qualification:
   - time series regularization;
   - evolution operator and non-linear unstable system operator restoration;
   - non-linear analysis of dynamics based on analytical models of complex system;
   - dynamic system attractor qualification.

4. An Analysis of Responses of Microwave Receiver Unit

Experimental study of non-linear system responses was provided for conditions of electromagnetic USP signals coupling to microwave receiving device. The coupling signals differed for the type (narrow-band (NB) – $\Delta f / f = 0.03$, ultra-broadband (UWB) $\Delta f / f = 0.7 \div 0.9$ and combination of these two in time) and amplitude within the limits of 70 dB [3].

Responses represented typical strongly unstable processes witnessing excitation in the system different states depending on type and hardness of interference. A goal of the study was to demonstrate the possibility to provide some canonical parameters (specific for the system of interest) for description nonlinear dynamic system and for estimation its state.

According to structure of the ATDP Suite, filtration and regularization of initial time series of system response starts the processing procedure. As an example, a wavelet transformation of the response to UWB interference is given in Fig. 3. It can be seen, that the signal consists of two (low-frequency regular and high-frequency complex-structured) components corresponding to frequency band of 0.01-2 GHz and 2-5 GHz.

The most important performances of nonlinear system are the parameters of different phase trajectory statistical distributions, and also the distance between system phase trajectories and test phase trajectories. To analyze microwave receiving device dynamics the test phase trajectories were chosen for regular signal corresponding to undisturbed process, and for the signal with maximum fractal dimension about 2 corresponding to a maximum complex signal.

The distance between experimental system response and testing time series was determined with the help of a pseudo-metrics. Fig. 4 demonstrates the time series probability distributions for combined NB-UWB USP interference.

A dynamics presentations for the local dimension for the distance between perturbed system state

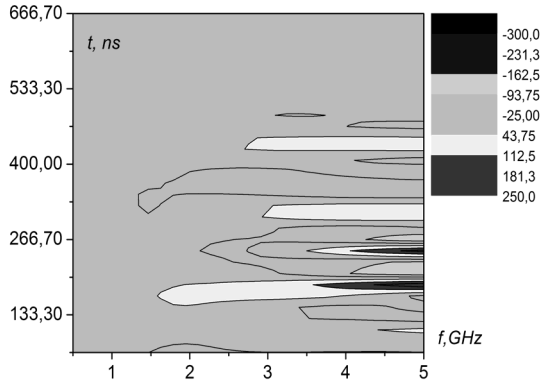

Fig. 3. *System response progressive Gauss wavelet transformation $W(t, f)$ to UWB interference, where t – the real time, and f – the frequency of a wavelet*

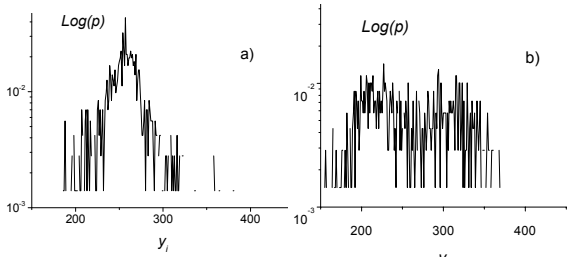

Fig. 4. *Response time series probability distribution (logarithmic coordinate) $p_y(i)$ for LB (a) and UWB (b) interference*

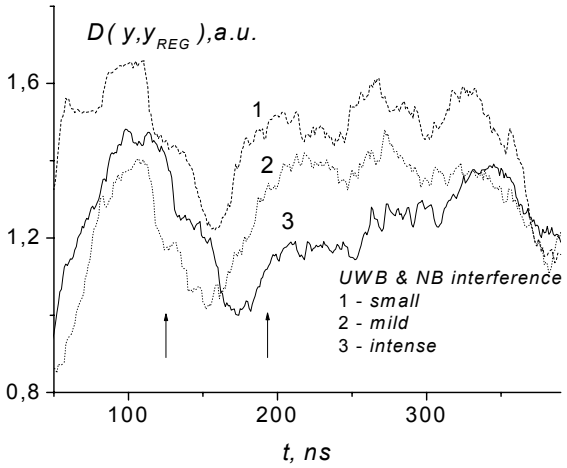

Fig. 5. *Dynamics of the distance between system state for complex interference of different strength and test regular state. Arrows indicate the area of qualitative change of system state*

and different sample test states are important for analysis of system states at different perturbations. In Fig. 5 the dynamics of such parameter for a case of regular test series is shown.

5. Conclusion

The software for Adaptive Testing and Data Processing is produced and applied to qualitative analysis of dynamics and unstable states qualification of electronic system. Features of the method, its structure and application to analysis and classification of electronic system states exposed to electromagnetic USP interference is presented.

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СТРУКТУРА И ПРИМЕНЕНИЕ ПРОГРАММНОГО ПАКЕТА ATDP ДЛЯ ОПРЕДЕЛЕНИЯ СОСТОЯНИЯ ЭЛЕКТРОННЫХ СИСТЕМ И ВОССТАНОВЛЕНИЯ ЭВОЛЮЦИОННОГО ОПЕРАТОРА

И.И. Магда, А.В. Пащенко, И.М. Шаповал, В.Е. Новиков

Представлены структура и особенности программного пакета адаптивной тестирующей обработки данных (ATDP Suite). Он применен к восстановлению динамических характеристик из экспериментальных временных рядов нелинейной и нестабильной электронной системы. Продемонстрированы основные методы, реализованные в ATDP Suite. Применение ATDP Suite для электромагнитного тестирования СВЧ приемников показало возможность анализировать и интерпретировать динамические характеристики сложной нелинейной системы.

СТРУКТУРА ТА ЗАСТОСУВАННЯ ПРОГРАМНОГО ПАКЕТА ATDP ДЛЯ ВИЗНАЧЕННЯ СТАНУ ЕЛЕКТРОННИХ СИСТЕМ ТА ВІДТВОРЕННЯ ЕВОЛЮЦІЙНОГО ОПЕРАТОРА

І.І. Магда, А.В. Пащенко, І.М. Шаповал, В.Є. Новиков

Представлено структуру та особливості програмного пакета адаптивної тестуючої обробки даних (ATDP Suite). Його застосовано для відтворення динамічних характеристик з експериментальних часових рядів нелінійної та нестабільної електронної системи. Продемонстровано основні методи, реалізовані в ATDP Suite. Застосування ATDP Suite для електромагнітного тестування НВЧ приймачів продемонструвало можливість аналізувати та інтерпретувати динамічні характеристики складної нелінійної системи.