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# Numerical Analytical Simulation Technique for Nonlinear Feedback Systems

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**Abstract**—A simulation method for nonlinear inertial feedback systems has been proposed. It involves the presenting of each functional block of the system in the form of a set of nonlinear transfer functions. Nonlinear transfer functions of the system as a whole are determined by using the differential Taylor transformations.

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Functional simulation of radio engineering systems can be applied both at the initial stage of schematic design and the final stage of circuit analysis for the verification and optimization of results obtained.

For this purpose a variety of effective computer-aided tools were developed for schematic design of devices at the circuit level. The specified tools include the software package Visual System Simulator integrated into the Microwave Office System, the System View software produced by Elanix Company, the Ansoft Designer circuit simulation package, the general purpose Simulink software package intended for block simulation and integrated with the Matlab System, etc.

These application software packages make it possible to implement the main kinds of analysis of the linear and nonlinear systems composed of ideal models of functional blocks in the time and frequency domains. The tools for "real" functional simulation are developed to a considerably smaller degree. We refer here to the tools taking into rigorous account the complex nonlinearities of circuit elements of a block and the matching conditions of these blocks in the system.

Such tools can be effectively used at the final stage of development when a conclusion can be made about the degree of conformity of the system characteristics to the requirements specification on the basis of the results of schematic design stage. In addition, for solving the problems of parametric optimization and multivariate analysis it is quite expedient to obtain a mathematical model of nonlinear system on the basis of mathematical models of its component blocks.

The method of "real" functional simulation of a nonlinear inertial system in the form of cascade connection of blocks that corresponds to the specified requirements is presented in paper [1], where it is proposed to obtain nonlinear transfer functions (NTF) of the system on the basis of NTF of its component blocks using the differential Taylor transformations.

The simulation of a nonlinear system with feedbacks is also a case of practical importance. In such a case, the determination of transfer functions of linear feedback (FB) system does not pose any difficulties and has been described in many papers. However, such problem for a nonlinear system in the general case has not been yet solved.

For weakly nonlinear systems this problem can be solved by the methods based on the expansion of the system response in the Volterra series by the substitution of series into series and series inversion [2–4]. In this case, only the linear feedback is generally taken into account. Given the multifrequency input, this approach proves to be ineffective and unformalized, since it is based on analytical derivations of formulas for a specific type of connection of system blocks and is suitable for multidimensional transfer functions of the order not higher than three.

It should be noted that feedbacks (for example in nonlinear wireless systems) are used not only for frequency correction, but also for the compensation of nonlinear distortions, automatic gain control, enhancing the system stability in regard to destabilizing factors, etc. All this involves the need of calculating the nonlinearities of high order, taking into account "subtle" effects and, consequently, determining a high order NTF. The algorithm of taking into account feedbacks should be sufficiently formalizable for programming.