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Calculation of the Original of Response of Multiinput Nonlinear Wireless Devices Using the Volterra Series

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Abstract—A computing method has been proposed for calculating the original of response under the action of complex signals of multiinput nonlinear devices by using the tool of Volterra functional series. This method is based on the technique of determining Volterra kernels by differentiation of the system of harmonic balance equations and the procedure of transition to a single variable in the domain of transforms. A response in the time domain can be obtained by using the one-dimensional Laplace transform in the form of function of circuit parameters and input actions where the characteristics of nonlinear elements are approximated by an arbitrary analytic function. This study includes an example of computing the original of response of a nonlinear circuit with two inputs.

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The problem of analysis of the complex signals (i.e., multifrequency signals with aliquant and incommensurable frequencies) passing through nonlinear frequency selective wireless devices (WD) can be fairly effectively solved by applying the tool of Volterra functional series (VFS). In this case, similar to methods of the linear circuit theory the VFS methods imply two approaches to simulation of nonlinear WD for calculating the original of response. The first approach is based on the time domain analysis only and extends the pulsed functions method using the known convolution integral to the case of nonlinear circuits. The second approach implies the analysis in the domain of transforms and the subsequent transition to the time domain using the inverse Laplace transform.

An expression for the response in the VFS form of the nonlinear radio circuit (NRC) with three inputs (Fig. 1) was presented in paper [1].

If NRC has time-constant parameters, the time domain response of such circuit can be obtained in the form:

$$y(t)=\int_{-\infty}^{\infty} h_1(u_1)x^{(1)}(t-u_1)\mathrm{d}u_1+\int_{-\infty}^{\infty} h_1(v_1)x^{(2)}(t-v_1)\mathrm{d}v_1+\int_{-\infty}^{\infty} h_1(w_1)x^{(3)}$$

$$\times(t-w_1)\mathrm{d}w_1+\int_{-\infty}^{\infty}\!\!\int h_{1;1}(u_1;v_1)x^{(1)}(t-u_1)x^{(2)}(t-v_1)\mathrm{d}u_1\mathrm{d}v_1+\int_{-\infty}^{\infty}\!\!\int h_{1;1}(u_1;w_1)$$

$$\times x^{(1)}(t-u_1)x^{(3)}(t-w_1)\mathrm{d}u_1\mathrm{d}w_1+\int_{-\infty}^{\infty}\!\!\int h_{1;1}(v_1;w_1)x^{(2)}(t-v_1)x^{(3)}(t-w_1)\mathrm{d}v_1\mathrm{d}w_1$$

$$+\int\int_{-\infty}^{\infty}\!\!\int h_{1;1;1}(u_1;v_1;w_1)x^{(1)}(t-u_1)x^{(2)}(t-v_1)x^{(3)}(t-w_1)\mathrm{d}u_1\mathrm{d}v_1\mathrm{d}w_1+\ldots, \qquad (1)$$

where $h_1(*)$ are Volterra kernels of the first order or pulse-response characteristics determined in terms of each of the inputs; $h_{1;1}(*)$, $h_{1;1;1}(*)$ are Volterra kernels of the second and third orders determined in terms of