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Frequency symbolic models of linear parametric circuits

Abstract. *The methods of constructing symbolic models of linear parametric circuits in frequency domain are considered. The models introduce the systems of linear algebraic equations and are formed on the basis of nodal solution. It is considered that the circuit contains only one parametric element which is replaced with additional signal source or by frequency model of parametric element or controlled source of current.*

Keywords: *linear parametric circuits, symbolic analysis, frequency symbolic models.*

Introduction

Expression 1 deals with frequency symbolic method of analysis of linear parametric circuits that is based on differential equation which connects input and output signals

$$(1)\quad \begin{aligned} & a_n(t)y^{(n)} + a_{n-1}(t)y^{(n-1)} + \ldots + a_1(t)y = \\ & b_m(t)x^{(m)} + b_{m-1}(t)x^{(m-1)} + \ldots + b_1(t)x \end{aligned}$$

(y – output and x – input signals; $a_i(t)$, $b_j(t)$ – known functions of time t), approximation of parametric transfer function $W(s,t)$ in the form of truncated Fourier series (suppose it has k harmonic components), which connects input $x(s)$ and output $y(s,t)$ signals of the given circuit in frequency domain.

$$(2)\qquad y(s,t) = W(s,t)\cdot x(s),$$

where $s = j\omega$ is complex variable. It is considered that in the circuit there is one parametric element and its parameter changes periodically with frequency Ω. The method is symbolic as the parameters of the circuit can be set by symbols.

In the given article frequency symbolic model of the parametric circuit on the basis of frequency symbolic method is formed as a whole which represents the system of linear algebraic equations done by nodal solution and allows further analysis of the circuit to be done in frequency domain.

This article contains three of such models and they differ by the way of modelling parametric element: A) model with additional independent source of signal; B) model with frequency symbolic model of parametric element; C) model with controlled source.

Technique

The suggested frequency symbolic models are the following.

A. The model of the circuit with additional independent source of signal.

Let us suppose that according to frequency symbolic method the parametric transfer function $\mathrm{A}(s,t)$ from input current that goes through parametric element $i_{par}(s,t)$ is determined:

$$(3)\qquad i_{par}(s,t) = \mathrm{A}(s,t)\cdot i_1(s).$$

According to the replacement theory expression (3) is considered to be the source of current with the help of which the parametric element of the circuit can be replaced. In this case the parametric circuit becomes the circuit with constant parameters and additional independent source of signal. Its frequency symbolic model is the following:

$$(4)\qquad Y(s_\Omega)\cdot U(s_\Omega,t) = I(s,t)$$

and contains two complex variables: s and s_Ω. The variable s is in expressions (3) of the constant term vector $I(s,t)$ and due to presence of harmonic components with frequency $(\omega \pm i\Omega)$ and $i = 0,1,\ldots,k$ in expression (3), variable s_Ω shows the necessity of substitution of appropriate variable $s_\Omega = j(\omega \pm i\Omega)$ when identifying the unknown quantity from vector $U(s_\Omega,t)$.

B. Model of the circuit with frequency symbolic model of parametric element.

Let us suppose that according to frequency symbolic method two parametric tranfer functions are determined. One of them is function of transfering $\mathrm{A}(s,t)$ from input current $i_1(s)$ to the current of parametric element $i_{par}(s,t)$ from expression (3) and the other is the function of transfering $Z(s,t)$ from input current $i_1(s)$ to current on parametric element $u_{par}(s,t)$:

$$(5)\qquad u_{par}(s,t) = Z(s,t)\cdot i_1(s).$$

The relation of these functions

$$(6)\quad i_{par}(s,t)/u_{par}(s,t) = \mathrm{A}(s,t)/Z(s,t) = S_{par}(s,t)$$

determines the frequency symbolic model of parametric element that enters the matrix of circuit conductance as a whole according to usual rules.

C. Model of the circuit with controlled source.

It is similar to model (B) but expression (5) determines current not on the parametric element but, for example, on the resistor connected in consecutive order with the source of incoming current. In this case expression (6) is treated as controlled source of current that is controlled with such current. Such chosen controlling current leads to disappearing of denominator in expression (6).

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