NEW NUMERICAL METHOD OF SIMULATION ANALYSIS OF TRANSIENTS IN RADIO ENGINEERING DISTRIBUTED PARAMETERS

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ABSTRACT

The new numerical method of simulation analysis of transients in radio technical chains with distributed parameters without taking losses into account in a circuit is offered. The new simple recurrence relations easily displayed on a computer have been obtained.

Keywords: numerical method, simulation analysis , technical chains

I.INTRODUCTION

Radio technical circuits, basically belong to the class of distributed networks (antennas, feeder lines, waveguides) [1, 3] and at signaling through them, inevitably there are time-varying processes in which under their effect signals transmitted to a customer are subject to significant divergence. Therefore, at present the important problem which is of interest to communication engineering is estimation of impulse signals' distortions arising during transmission, with the purpose of proper sampling of the detecting device parameters for obtaining desirable waveform.

In this connection, the study of the time-varying processes arising in radio technical distributed parameters, is of great scientific and practical significance.

However, computational methods of transients in radio
technical distributed networks, in the scientific literature haven't been worked out enough, causing a lot of difficulties both [1- 3] at their design and operation.

Now in requirements of a widespread computerization into practice of engineering design, rapt notice is paid to the matters of developing the numerical methods for simulation analysis of transients .

The transients which occur in radio technical chains with distributed parameters, are represented with differential equations in partial derivatives, generally, of hyperbolic type (wave and telegraph equations) [1- 3].

Now one of the new effective numerical methods for simulation analysis of transients in entities with distributed parameters, is the numerical method [1-3] based on use of a discrete analog of an integral equation of convolution.

Advantage of the above method is that it enables allows to determine the dynamic processes arising in entities with distributed parameters, without transition to the domain of sampled transforms [1-3], and also to realize transition from Laplace transform of required functions the domain of original functions without finding of radicals of a characteristic equation, that considerably simplifies mathematical calculations and improves accuracy of calculations.

The presented properties of the approach [1-3] essentially widen a circle of practical problems being under solution.

In the given paper, for the first time in the scientific literature, the problems concerning the further development and generalization of papers [1-3], for development of a new numerical method of simulation analysis of transients in radio technical distributed parameters without taking losses in a link into account are considered.

Let's consider the process of switching on of the loaded technical distributed parameter with the active resistance R_2 at the end, to a source of the random voltage $U_0(t)$ through the lumped resistance R_1 and inductance L.

The transients which occur in radio technical chains distributed parameters without ignoring losses in a link are presented with wave equations:

$$-\frac{\partial U}{\partial x} = L\frac{\partial i}{\partial t},$$

$$-\frac{\partial i}{\partial x} = C\frac{\partial U}{\partial t},$$

$$0 \le x \le l \qquad (1)$$

where $U = U(x, t)$ - voltage; $i = i(x, t)$ - current; L, C - inductance and capacity between a wire and the ground, attributed to a unity of chain length; l - chain length.

The initial conditions are zero:

$$U(x,t)_{t=0} = 0,\ i(x,t)_{t=0} = 0$$

The boundary conditions are presented as:

$$U(x,t)\ x=0 = U_н(t),\ i_к(t) = \frac{U_k(t)}{R_2}$$

where $U_к(t) = U(l,t)$, $i_к(t) = i(l,t)$.

The singularity of solving the set task is that in under boundary conditions the value of function $U_н(t)$ in the beginning of solving this problem is unknown. The function value is determined during solution of the problem.

According to the new approach in offered [2,3] during solution of the set task, at the first stage it is necessary to obtain the Laplacian transform for functions $U(x,t)$, $i(x,t)$.

In this connection, under given initial and boundary conditions, from solution of a system of equations (1) we shall obtain the following expression for the pointed functions in the operator form:

$$U(x,s) = \frac{Sh\gamma(l-x) + \frac{R_2}{\rho}Ch\gamma(l-x)}{Sh\gamma l + \frac{R_2}{\rho}Ch\gamma l}U_н(s), \quad (2)$$

$$i(x,s) = \frac{1}{\rho}\frac{Ch\gamma(l-x) + \frac{R_2}{\rho}Sh\gamma(l-x)}{Sh\gamma l + \frac{R_2}{\rho}Ch\gamma l}U_н(s), \quad (3)$$

where $\gamma = \frac{s}{\upsilon}$ - wave propagation factor; $\rho = \sqrt{\frac{L}{C}}$ - wave impedance of a circuit;

$U(x,s)$, $i(x,s)$, $U_н(t)$ - the Laplacian transform of functions $U(x,t)$, $i(x,t)$, $U_н(t)$; s - an operator of the Laplace transformation; υ - a wave propagation velocity.

The second stage in solution of the given problem is connected with carrying out transitions from images (2), (3) to the domain of original functions.

In this connection, expressions (2), (3) can be presented in the form of:

$$U(\delta,s)\left[\frac{1}{s} - e^{\varphi}k_1(s)\right] = \left[k_2(s) - e^{\varphi}k_3(s)\right]U_н(s) \quad (4)$$

$$i(\delta,s)\left[\frac{1}{s} - e^{\varphi}k_1(s)\right] = \frac{1}{\rho}\left[k_2(s) + e^{\varphi}k_3(s)\right]U_н(s), \quad (5)$$

Where

$$k_1(s) = \frac{1}{s}e^{-\frac{2l}{\upsilon}s},\ k_2(s) = \frac{1}{s}e^{-\frac{2l\delta}{\upsilon}s},$$

$$k_3(s) = \frac{1}{s}e^{-\frac{2l(1-\delta)}{\upsilon}s},\ e^{\varphi} = \frac{\rho-\mu}{\rho+\mu},$$

$$\delta = \frac{x}{2l}$$

In an idle mode of operation of a chain, $e^{\varphi} = -1$, and under short chain condition $e^{\varphi} = 1$.

On the basis of convolution theorem, transferring from equations (4), (5) concerning transforms, to the equations concerning original functions, we shall obtain:

$$\int_0^e U(t-\theta,\delta)1(\theta)d\theta - e^{\varphi}\int_{\frac{2l}{\upsilon}}^t U(t-\theta,\delta)k_1(\theta)d\theta =$$

$$= \int_{\frac{2l\delta}{\upsilon}}^t U_H(t-\theta)k_2(\theta)d\theta - e^{\varphi}\int_{\frac{2l}{\upsilon}(1-\delta)}^t U_H(t-\theta)k_3(\theta)d\theta, \quad (6)$$

$$\int_0^t i(t-\theta,\delta)1(\theta)d\theta - e^{\varphi}\int_{\frac{2l}{\upsilon}}^t i(t-\theta,\delta)k_1(\theta)d\theta =$$

$$= \frac{1}{\rho}\int_{\frac{2l\delta}{\upsilon}}^t U_H(t-\theta)k_2(\theta)d\theta + \frac{1}{\rho}\int_{\frac{2l}{\upsilon}(1-\delta)}^t U_H(t-\theta)k_3(\theta)d\theta \quad (7)$$

Integral equations (6), (7) can be solved numerically if to substitute integrals for sums.

In this connection, according to [2-3], using connection between the continuous time t and discrete n in the form of $t = nT/\lambda$ (where - λ is any integer; n = 0, 1, 2 …), we make a discrete sampling of integral equations (6), (7) for sampled interval T/λ, substituting operation of continuous integration for summation, using a rectangular formula.

For this instead of (6) and (7) following recurrence relations ratios for trellis functions $U[n,d]$, $i[n,d]$ have been obtained.

$$U\left[n,\delta\right]=$$
$$\left(\sum_{m=\lambda\delta}^{n}1\left[m-\lambda\delta\right]-e^{\varphi}\sum_{m=\lambda(1-\delta)}^{n}1\left[m-\lambda\left(1-\delta\right)\right]\right)$$
$$\cdot U_{H}\left[n-m\right]+$$
$$+e^{\varphi}\sum_{m=\lambda}^{n}1\left[m-\lambda\right]U\left[n-m,\delta\right]-\sum_{m=0}^{n-1}1\left[n-m\right]U\left[m,\delta\right] \quad (8)$$

$$i[n,\delta]=\frac{1}{\rho}$$
$$\left(\sum_{m=\lambda\delta}^{n}1[m-\lambda\delta]+e^{\varphi}\sum_{m=\lambda(1-\delta)}^{n}1[m-\lambda(1-\delta)]\right)$$
$$\cdot U_{H}[n-m]+$$

$$+e^{\varphi}\sum_{m=\lambda}^{n}1\left[m-\lambda\right]i\left[n-m,\delta\right]-\sum_{m=0}^{n-1}1\left[n-m\right]i\left[m,\delta\right], \quad (9)$$

The error in estimations is related to value λ. The more the sampled number λ is, the less is the difference between the characteristics of the continuous function and the respective characteristics of the trellis ones.

The recurrence relations obtained in (8), (9) determine voltage and current variations at the arbitrary point of a technical distributed parameter at any moment and are easily realized on a computer.

The recurrence relations (8), (9) include an unknown function $U_н[n]$. Determination of its value is carried out on the following procedure.

For starting point in a radio technical distributed parameter can be presented with the following expression in the operator form:

$$i_{н}(s)=\left[U_{0}(s)-U_{н}(s)\right]K_{0}(s) \quad (10)$$

Where $K_{0}(s)=\dfrac{1}{R_{1}+L_{1}s}$

Expression (10) in the discrete form in the domain of original functions can be presented in the form of:

$$i_{н}\left[n\right]=\frac{1}{L_{1}}\cdot\frac{T}{\lambda}\left(\sum_{m=0}^{n}K_{0}\left[m\right]\left(U_{0}\left[n-m\right]-U_{H}\left[n-m\right]\right)\right)$$ Where $K_{0}\left[n\right]=e^{-\frac{R_{1}}{L_{1}}\cdot\frac{Tn}{\lambda}}$

Further for $\delta = 0$, determining from the recurrence relation (9), the expression for trellis function $i_н[n]$ and, solving jointly with expression (11), we shall obtain the following recurrence for voltage $U_н[n]$:

$$U_{н}\left[n\right]=\frac{A_{0}}{1+A_{0}}\cdot\left[U_{0}\left[n\right]\right]+$$
$$+\sum_{m=1}^{n}K_{0}\left[m\right]\left(U_{0}\left[n-m\right]-U_{H}\left[n-m\right]\right)-\frac{\rho}{1+A_{0}}\cdot B\left[n\right], \quad (11)$$

Where $B\left[n\right]=\frac{1}{\rho}\left(\sum_{m=1}^{n}1\left[m\right]+e^{\varphi}\sum_{m=\lambda}^{n}1\left[m-\lambda\right]\right)\cdot U_{H}\left[n-m\right]+$

$$+e^{\varphi}\sum_{m=\lambda}^{n}1\left[m-\lambda\right]i_{н}\left[n-m\right]-\sum_{m=0}^{n-1}1\left[n-m\right]i_{н}\left[m\right], \quad (12)$$

The offered numerical method can be widely used for design and operation of radio technical distributed parameters.

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