Radioelectronics and Communications Systems
Vol. 47, No. 6, pp. 14–20, 2004

Izvestiya VUZ. Radioelektronika
Vol. 47, No. 6, pp. 21–30, 2004
UDC 537.874.72.01

EQUATIONS OF CURRENTS IN AN ELECTRIC NONLINEAR VIBRATOR EXCITED BY BIHARMONIC IDEAL EMF

B. M. Petrov

Taganrog State Radio-Engineering University, Russia

The paper describes a new mathematical model of a thin rectilinear electric vibrator driven with biharmonic ideal electromotive force. The emf is applied to a cut filled with a substance having nonlinear properties with respect to electric field. The field in the cut is investigated. Integral equations of spectral components of the vibrator current are derived. It is shown that dispersive characteristics of the vibrator are dictated by electrophysical properties of the substance in the cut, and by the vibrator's electric dimensions.

Considerable efforts are being directed at development of the theory of antennas with nonlinear load [1], where one of the main issues consists in resolving the problem of excitation of a linear electric vibrator [1–3]. However, if we deal with a nonlinear electric vibrator, various non-electrodynamic methods are used, based on replacement of the vibrator by some network with lumped parameters [4–5]. The purpose of this paper consists in derivation of the Hallen-type equation for the combinative component of the current in the vibrator's arms.

Consider the formulation of the problem in more detail. A rectilinear metal cylinder, with its radius a and length $l_1 + l_2$, is located in unlimited space filled with isotropic, homogeneous, linear medium with absolute complex permittivity $\tilde{\varepsilon}_a(\omega)$ and permeability μ_a. The cylinder has a domain V_i formed by two cross-sections $2b$ apart. The domain V_i (the cut) is filled with nonlinear (in terms of electric field), isotropic, homogeneous substance whose current-voltage characteristic (CVC) is set a priori. The z-axis of Cartesian coordinate system (CaCS) is directed along the cylinder axis, and its origin is in the center of the domain V_i. The origin of the cylindrical coordinate system (CyCS), with its components r, φ, z, is aligned with the CaCS origin. The cut is driven with an external electromagnetic field (EMF), in which the vectors of the electric and magnetic fields' intensities, at $r \geq a+0$ are as follows: $E^{\text{st}}(p,t) = 1_z E^{\text{st}}(p,t)$, $H^{\text{st}}(p,t) = 1_\varphi H^{\text{st}}(p,t)$, where 1_z, 1_φ are the unit vectors in CyCS; $p(r, \varphi, z)$ is the observation point; t is the time. Thus, we assume that at the cylinder metal ends (in the sections $S_\perp(-b)$ and $S_\perp(b)$ of the cylinder) the boundary conditions in the cut are met, while E^{st} and H^{st} are uniform over φ. Denote by $l_1 - b$, $l_2 - b$ the lengths of the vibrator's metal arms. The instantaneous value of the current in the cross-section $S_\perp(z)$ of the vibrator is denoted by $i(z, t)$.

The magnitudes of E^{st}, H^{st} result from superposition of two monochromatic fields at frequencies ω and Ω, supplemented by the "displacement field" intensity E^{st}_{00}, which is invariant with time. In this case the external field intensity can be represented in the form of a trigonometric polynomial

$$E^{\text{st}}(a+0,t) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} \dot{E}^{\text{st}}_{mn} \exp(\mathrm{i}\omega_{mn} t) = \sum\nolimits_{mn} \dot{E}^{\text{st}}_{mn}(a+0) \exp(\mathrm{i}\omega_{mn} t), \qquad (1)$$

REFERENCES

1. P. L. Kapitsa, V. A. Fok, and L. A. Vainshtein, Waves of current in a thin cylindrical conductor. Symmetric electric oscillations of an ideally conducting hollow cylinder of a finite length — in the book: L. A. Vainshtein, The Diffraction Theory [in Russian], Radio i Svyaz’, Moscow, 1995, pp. 65–125.

2. R. Mittra (editor), Computational Methods in Electrodynamics [Russian translation], Mir, Moscow, 1977.

3. S. I. Eminov, Antenny, Issue 12(67), pp. 9–10, 2002.

4. J. Francescetti and I. Pinto, Antennas with nonlinear load — in the book: Nonlinear Electromagnetic Waves [Russian translation], Mir, Moscow, pp. 223–249, 1983.

5. B. M. Petrov and D. V. Semenikhina, Elektrodinamika i Tekhnika SVCh i KVCh, Vol. 7, No. 7, pp. 52–71, 1999.

6. E. Shmutzer, Fundamental Principles of Classical Mechanics and Classical Field Theory [Russian translation], Mir, Moscow, 1976.

7. N. N. Bogolyubov and Yu. A. Mitropol’skii, Asymptotic Methods in the Theory of Nonlinear Oscillations [in Russian], Nauka, Moscow, 1974.

8. G. Ye. Pukhov, Differential Transformations of Functions and Equations [in Russian], Naukova Dumka, Kiev, 1984.

9. B. M. Levitan, Quasiperiodic Functions [in Russian], GITTL, Moscow, 1953.

10. E. Landau, Foundations of Differential and Integral Calculus [Russian translation], IIL, Moscow, 1948.

11. S. L. Sobolev, Mathematical Physics Equations [in Russian], Nauka, Moscow, 1966.

12. A. D. Polyanin and A. V. Manzhirov, Handbook of Integral Equations [in Russian], Fizmatlit, Moscow, 2003.

8 December 2003