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A METHOD OF EXPANSION IN BASIC FUNCTIONS AT DETERMINING THE HEAT EXCHANGE BETWEEN A QUARTZ RESONATOR AND THE ENVIRONMENT

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The paper describes a new method of expansion in basic functions for determination of thermodynamic processes in a quartz-crystal resonator equipped with crystal holders. Based on the solution obtained, the physical nature of thermal resonance in a quartz resonator is explained, and the role of the crystal holders in this process is discussed.

The present-day generators of stable frequency and primary standards of frequency include, as their main part, a reference quartz-crystal oscillator, whose characteristics dictate stability of the frequency reproduction by this standard. Thermodynamic effects in quartz resonators (QR) make a noticeable contribution into resulting instability of such generators. Thus, the problem has arisen as to comprehend the physical processes in QR operating in a nonstationary temperature field of the environment.

The results of simulation of temperature impact on a quartz plate without electrodes described in [1] are applicable in some way to quartz resonators of the BVA type [2]. Here we may neglect the temperature effect of the quartz holders playing also the role of current-bearing elements. Since the quartz holders are major components taking part in the heat exchange between the quartz plate and the environment, the problem of temperature distribution inside the piezoelectric crystal plate volume hardly could be resolved without considering the effect of these holders.

The most appropriate method of treatment of the problem about thermal conductance in the “quartz plate — quartz holder” system is decomposition of the whole domain under investigation into subdomains. The solutions will be sought for each subdomain separately, followed by sewing them together at interfaces [3, 4].

This problem is handy for treatment as a problem of mathematical physics without initial conditions [5]. Here we assume that the environmental temperature, acting on the outer face plane of the crystal holder protruding from the quartz resonator envelope, represents a harmonic function $\exp(j\omega t)$. Remember that the quartz holder is a long thin rod. Provided the heat emission through its side surface is insignificant, the heat transfer equation, describing the distribution of temperature T_{qh} inside the quartz holder, can be regarded as single-dimensional with respect to the coordinate directed along the rod. Moreover, the thickness H of the quartz plate is much less than its radial dimension. Thus we may neglect the variations of temperature T_{qp} along the quartz plate thickness and reduce the heat-transfer equation to a two-dimensional one, with representing it in the polar coordinate system. In this case the problem can be represented by the following system of equations in terms of T_{qp} and T_{qh}:

REFERENCES

1. Yu. I. Yevdokimenko and Yu. S. Shimalii, Akusticheskii Zhurnal, Vol. 38, Issue 2, p. 283, 1992.

2. R. J. Besson, J. J. Boy, and F. Deyzac, Acceleration sensitivity of BVA resonators, Proc. 50th IEEE AFCS, pp. 457–463, 1996.

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

4. V. P. Shestopalov, L. N. Litvinenko, S. A. Masalov et al., Wave Diffraction of Lattices [in Russian], Izd-vo Kharkovskogo Universiteta, 1973.

5. A. N. Tikhonov and A. A. Samarskii, Mathematical Physics Equations [in Russian], Nauka, Moscow, 1977.

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