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Dynamic Properties of Radioelectronic Elements in the Form of Piezoceramic Cylinders with Internal Screens

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Analytical relations describing the electric fields of a radio-electronic element made in the form of a piezoceramic cylindrical shell with an internal acoustic screen and an elastic medium in the cavity between them are obtained by the method of coupled fields in multiply connected regions. A comparative analysis of the results of a numerical experiment carried out according to the frequency characteristics of the electric current of the element excitation, depending on the parameters of the design of constituents of the element, made it possible to establish a number of subtle effects in the formation of fields that are important for matching the element with the electronic generator that excites it. Possible ways to control the dynamic properties of the electric field of the transducer are determined for different compositions of the piezoceramic material of its shell and different distances between the screen and the shell. The ways of controlling the properties of the electric field of the transducer are determined, which include changes in the composition of the piezoceramic material of its shell, the dimensions of the inner screen and the distance between the screen and the shell. The results obtained make it possible to support the requirements for generator devices to ensure the energy efficiency of the corresponding radiating paths.

Keywords: Dynamic properties, Electric field, Cylindrical piezoceramic signal transducer, Internal acoustic screen.

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1. INTRODUCTION

Piezoceramic electrical signal transducers are complex elements of electronic engineering and are characterized by two related functions – energy conversion and its formation in the surrounding spaces. In this case, the process of energy conversion is determined by the connectivity of the electric, mechanical, and acoustic fields involved in it. The process of energy formation is characterized by the interaction of the elements of a radio-electronic device along the acoustic field, due to the repeated reflection of the emitted and scattered sound waves on the elements of the device. Any changes in the design of a radio electronic device associated with the construction of its oscillatory system, both in the electrical and mechanical parts, fundamentally affect the properties of the physical fields of the device. A clear demonstration of this influence is the results of studies presented in [1-14]. In [1], the influence of a piezoceramic transducer on the electric field and its dynamic properties is studied by placing a flat acoustically soft screen of finite dimensions near it along the diametral plane. The study of the interaction of acoustic and mechanical fields in radioelectronic elements in the form of cylindrical piezoceramic transducers with internal acoustic screens and its influence on dynamic properties is the subject of [2]. The same studies were carried out in [3-7] for the cases of resonant-type piezoceramic transducers, including those placed inside the matching layers. At the same time, in all the above works, radioelectronic elements in the form of single bodies were studied. In systems of such bodies, it is also necessary to take into account the interaction between bodies in the acoustic field, due to the multiple scattering of radiated and reflected sound waves. An example of such an account is given in [8]. The studies presented in the works [1-8] are performed for the cases of representation of radio-electronic elements in the form of distributed mechanical oscillatory systems. For comparison, in [9-12] the results of studies performed by the method of equivalent electromechanical circuits, which was developed for radio-electronic elements in their model representation in the form of oscillatory systems with lumped parameters, are analyzed. An analysis of known works [1-12] shows that a number of them [1-8] are made taking into account the interconnection of electric, mechanical and acoustic fields during energy conversion in radio-electronic devices of the type under consideration. At the same time, the interaction of the device elements in the acoustic field was taken into account only in [1, 2, 8], and the analytical relationships for the electric fields and calculations for them are given only in studies [1, 8]. Thus, today there are no data on the analytical ratios and quantitative values of the parameters of electric fields and the dynamic properties of electronic devices with internal acoustic screens.

Modern echolocation devices are characterized by a

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drift to the low-frequency region, which, in the absence of the possibility of increasing the dimensions of their antenna systems, is associated with the need to search for new approaches to their technical implementation. One of such approaches, relevant for solving the problem of constructing low-frequency devices, is the transfer of external screens into the internal cavity of cylindrical piezoceramic transducers [2]. It is the possibility of reducing the dimensions of radio electronic devices with this approach that determines the relevance of research on this important topic for practice [12].

The objectives of this work are: 1 – obtaining analytical relationships and 2 – numerical study on their basis of the frequency and dynamic properties of electric fields of cylindrical piezoceramic radioelectronic elements with internal screens. This will make it possible to reasonably form the requirements for generator devices to ensure the energy efficiency of the radiating paths of the corresponding echolocation devices.

2. RESEARCH METHOD

Let us define the electric field of the radio-electronic element in the form shown in **Ошибка! Источник ссылки не найден.**.

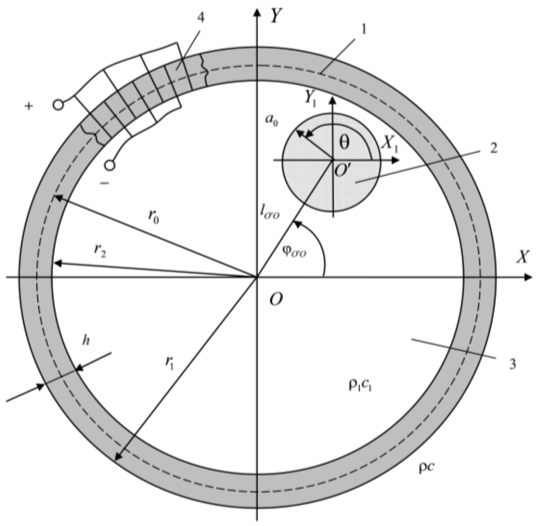

Fig. 1 – Normal section of a cylindrical transducer with an internal screen and the introduced coordinate systems

The element is made up of a piezoceramic shell 1, an acoustic screen 2 and an elastic medium 3. A cylindrical piezoceramic shell 1 with an average radius r_0, thickness h has circular polarization and consists of N piezoceramic prisms 4 rigidly glued together, electrically connected in parallel. An electric voltage $\psi_S = \psi_0 e^{-i\omega t}$ with a frequency ω is applied to the prism electrodes. The selected method of electrical excitation of an element allows "pumping" electrical energy into it only at the zero mode of its mechanical vibrations [1, 2, 12].

The acoustically soft screen 2 is made in the form of a circular cylinder with a radius a_0. Its longitudinal axis is parallel to the longitudinal axis of the shell 1 and is offset relative to it by a distance $l_{O'O}$. The elastic medium 3, which fills the space between the shell 1 and the screen 2, has a density ρ_1 and the speed of sound c_1. The radio-electronic element itself, which plays the role of a sound radiator, is located in an elastic medium with parameters ρ and c. The general and local systems of Cartesian and circular cylindrical coordinates required for solving the problem are shown in Fig. 1.

From physical considerations [1, 2, 12], it is clear that the process of operation of the considered radio-electronic element is characterized by three types of connections:

- the connection of electrical, mechanical, and acoustic fields in the process of energy conversion by a piezoceramic shell;
- the coupling of the piezoceramic shell and the screen along the acoustic field during the formation of this field inside the element due to the multiple exchange of radiated and reflected sound waves between the shell and the screen;
- the connection between the processes of transformation and formation of energy in the internal volume of the element.

It is these physical concepts that underlie the hypothesis that is the basis of this work.

Mathematically, these connections are taken into account when determining electric fields by jointly solving a system of differential equations, including: equations of forced electrostatics for piezoceramics:

$$\vec{E} = -grad\psi;\ div\vec{D} = 0; \qquad (1)$$

equations of motion for a thin piezoceramic shell with circular polarization in displacements:

$$\begin{gathered}(1+\beta)\frac{\partial^2 U}{\partial\varphi^2} + \frac{\partial W}{\partial\varphi} - \beta\frac{\partial^3 W}{\partial\varphi^3} = \alpha\gamma\frac{\partial^2 U}{\partial t^2};\\ -\frac{\partial U}{\partial\varphi} + \beta\left(\frac{\partial^3 U}{\partial\varphi^3} - \frac{\partial^4 W}{\partial\varphi^4}\right) - \\ -W + \frac{e_{33}}{C_{33}^E} r_0 E_\varphi + \frac{\alpha}{h} q_r = \alpha\gamma\frac{\partial^2 W}{\partial t^2};\end{gathered} \qquad (2)$$

the Helmholtz equation describing the motion of media inside and outside the radioelectronic element:

$$\Delta\Phi_j + k_j^2\Phi_j = 0\,. \qquad (3)$$

Here $\vec{E}$ and $\vec{D}$ – the vectors of the intensity and induction of the element's electric field; Δ – the Laplace operator; Φ_j – potential of the velocity of the acoustic field of the element inside $\Phi = \Phi_1$ and outside $\Phi_j = \Phi$ it; k_j – wave numbers of media inside $k = k_1$ and outside $k_j = k$; U and W – the circumferential and radial components of the vector of displacements of the points of the middle surface of the element shell; $\beta = h^2 \Big/ 12 r_0^2 \left(1 + e_{33}^2 \Big/ C_{33}^E \varepsilon_{33}^S\right)$; $\alpha = r_0^2 \Big/ C_{33}^E$; q_r – external radiation load of the element; C_{33}^E, ε_{33}^S, e_{33}, γ – the modulus of elasticity at zero electrical intensity, dielectric constant at zero deformation, piezo constant and density of the material of the piezoceramic shell, respectively.

Acoustic boundary conditions include Sommerfeld conditions and screen surface conditions in the inner region of the element as:

$$\Phi_1(a,\theta)=0, \quad a=a_0,\ 0\le\theta\le 2\pi; \tag{4}$$

where Φ_1 – the acoustic field in the inner area of the element, represented in local cylindrical coordinates associated with the screen.

Electric boundary conditions consist in setting of the electric field intensity in the piezoceramic shell of the following element in the form:

$$E_\varphi=-\frac{\psi_0 N}{2\pi r_0}. \tag{5}$$

In the calculation model of a radio-electronic device (**Ошибка! Источник ссылки не найден.**), it is assumed that the lengths of the shell and shield are infinite. This assumption is valid provided that the indicated lengths exceed 5-7 diameters of the considered cylinders [2, 8].

3. DERIVATION OF CALCULATED RATIOS

To solve the problem, we divide the entire multiply connected region of existence of the physical fields of the element under consideration into a number of partial regions. On the common boundaries of these areas, the natural conditions for conjugation of acoustic and mechanical fields must be fulfil:

$$\begin{gathered}-\frac{\partial\Phi_1}{\partial r}=\frac{\partial W}{\partial t},\ 0\le|\varphi|\le\pi,\ r=r_2=r_0-\frac{h}{2};\\ -\frac{\partial\Phi}{\partial r}=\frac{\partial W}{\partial t},\ 0\le|\varphi|\le\pi,\ r=r_1=r_0+\frac{h}{2};\\ \sigma_r=q_r=-\left(\rho\frac{\partial\Phi}{\partial t}-\rho_1\frac{\partial\Phi_1}{\partial t}\right),\ 0\le|\varphi|\le\pi;\end{gathered} \tag{6}$$

where σ_r – the normal component of the mechanical stress tensor in the piezoceramic element.

As far as the element under consideration is a mechanical oscillatory system distributed in space, the dimensions of which are comparable to the length of the working wave, we represent its mechanical and acoustic fields by expansions in series in angular and wave functions of a circular cylinder:

$$\begin{gathered}U=\sum_n U_n e^{in\varphi},\ W=\sum_n W_n e^{in\varphi};\\ \Phi(r,\varphi)=\sum_n A_n H_n^{(1)}(kr)e^{in\varphi};\\ \Phi_1(a,\theta)=\sum_m\left[C_m J_m(k_1a)+D_m N(k_1a)\right]e^{in\theta}.\end{gathered} \tag{7}$$

Equations (6) and (7) for Φ and Φ_1 are presented in different coordinate systems. The transfer of coordinate systems is carried out on the basis of addition theorems for cylindrical wave functions [2]:

$$\begin{gathered}J_m(k_1a)e^{im\Theta}=\sum_n J_{m-n}(k_1 l_{O'O})e^{i(m-n)\varphi_{O'O}}J_n(k_1r)e^{in\varphi},\\ N_m(k_1a)e^{im\Theta}=\sum_n J_{m-n}(k_1 l_{O'O})e^{i(m-n)\varphi_{O'O}}N_n(k_1r)e^{in\varphi};\end{gathered} \tag{8}$$

where $l_{O'O}$ and $\varphi_{O'O}$ – the polar coordinates of the origin O of the coordinate system in the coordinates of the system with the origin O'.

Algebraization of systems of functional equations (1)-(4) and (6), taking into account relations (5), (7), (8), and the properties of completeness and orthogonality of systems of angular functions, makes it possible to obtain an infinite system of linear functions for determining unknown expansion coefficients (7) algebraic equations of the form:

$$\begin{gathered}A_n=ic\frac{W_n}{H_n^{(1)\prime}(kr_1)},\ ic_1W_n=\sum_m C_m J_{m-n}(k_1 l_{O'O})\Delta_{mn}(k_1r)e^{i(m-n)\varphi_{O'O}};\\ R_\upsilon W_\upsilon+\frac{\alpha}{h}i\omega\left[\rho A_\upsilon H_\upsilon^{(1)}(kr)-\rho_1\sum_m C_m J_{m-\upsilon}(k_1 l_{O'O})e^{i(m-\upsilon)\varphi_{O'O}}\Delta'_{m\upsilon}(k_1r)\right]=\frac{e_{33}}{C_{33}^E}\frac{\psi_0 N}{4\pi^2}Q_\upsilon;\\ n=-\infty,0,\infty;\quad \upsilon=-\infty,0,\infty;\end{gathered} \tag{9}$$

where

$$\Delta_{mn}=J_n(k_1r)-\left(\frac{J_m(k_1a_0)}{N_m(k_1a_0)}\right)N_n(k_1r);$$

$$Q_\upsilon=\int_0^{2\pi}e^{-i\upsilon\varphi}=\begin{cases}2\pi\ if\ \upsilon=0;\\ 0\ if\ \upsilon\neq 0;\end{cases}$$

the prime means the derivative of the function; relations for R_υ are given in [1, 12].

The results of solving this system are used to obtain quantitative data on the electric fields of radioelectronic elements of the type under consideration.

In this case, the expressions for the total electric current I in the external excitation circuit of the element per unit of its length takes the form:

$$I=S_{el}\sum_{j=1}^{N}\frac{\partial D_\varphi^{(j)}}{\partial t};$$

where S_{el} – the area of the electrode applied to the lateral surface of the prism of the piezoceramic shell; $D_\varphi^{(j)}$ – the electric induction of the j-th prism.

Taking into account the well-known [1, 2, 12] expressions for the radial, axial and circumferential components of the electric induction at circular polarization of the piezoceramic shell, the total current in the circuit of its excitation is determined by the expression:

$$I=-i\omega S_{el}\left\{-\varepsilon_{33}^{S}\frac{\psi_0 N^2}{2\pi r_0}+\frac{e_{33}}{r_0}\sum_{j=1}^{N}\left[\sum_n inU_n e^{in\frac{2\pi j}{N}}+\sum_n W_n e^{in\frac{2\pi j}{N}}\right]\right\}. \quad (10)$$

Analysis of this expression shows that the total current has two components – capacitive and dynamic. The capacitive component is described by the first term of expression (10) and corresponds to the excitation current of a kind of piezoceramic capacitor. The appearance of the dynamic component described by the second term is due to the effect of electrostriction of the piezoceramic shell of the element. Presence of this effect that is the reason for the complex relationship between the electronic and mechanical processes that occur in the shell during the operation of the element. In this case, the decisive influence on the mechanical processes in the shell is exerted by the acoustic field formed in the inner cavity of the piezoceramic shell [2].

4. RESEARCH RESULTS

From the analysis of the physical model of the considered radioelectronic element, it follows that the properties of its electric field depend on:

- the size and composition of the material of its piezoceramic shell;
- the dimensions of the acoustic screen and the extent of its distance from the center of the shell;
- physical properties of the medium that fills the inner cavity of the shell;
- operating frequency range of the element.

In this case, the operational control of the parameters of the electric field of such a radioelectronic element can be carried out by changing either the dimensions of the acoustic screen, or the degree of its removal from the center of the shell. Technical ways to implement such control of the dynamic properties of the considered radio-electronic element are presented in [14].

Let's restrict ourselves to considering the frequency dependences of the amplitudes of the electric current of the excitation of the element depending on the size of the screen, the distance between the shell and the screen, and the composition of the piezoceramic of the shell. The calculations were carried out for an element with the following parameters: piezoceramic of compositions PZT-19 (zirconate-titanate-lead) ($\gamma = 7740\ \text{kg/m}^3$; $e_{33} = 28,272\ \text{C/m}^2$; $\varepsilon_{33}^{S} = 82,67\cdot10^{-10}$ F/m; $C_{33}^{E} = 9,3\cdot10^{10}\ \text{N/m}^2$) and TBK-3 (titanate-barium) ($\gamma = 5400\ \text{kg/m}^3$; $e_{33} = 18,51\ \text{C/m}^2$; $\varepsilon_{33}^{S} = 91,07\cdot10^{-10}$ F/m; $C_{33}^{E} = 10,8\cdot10^{10}\ \text{N/m}^2$); $r_0 = 0,068$ m; $h = 0,008$ m; $N = 48$; $\rho c = \rho_1 c_1 = 1,5\cdot10^6\ \text{kg/m}^3$; $a_0 = 0,2\,r_0$; $0,5\,r_0$; $0,9\,r_0$; $l_{O'O} = 0;\ 2a_0;\ r_2 - a_0 - 0,003$ m; $\psi_0 = 200$ V.

In calculations, the infinite system of algebraic equations (9) was solved by the reduction method [1,2,8]. The number of terms taken into account in expressions (7), (8), and (10) was taken equal to $n = \pm 50$ to ensure the convergence of the boundary conditions with an error of no more than 5%.

Calculation results of capacitive I^c, dynamic I^d and total I^t electric currents of an element depending on the size of the screen for $a_0 = 0,2\,r_0$; $0,5\,r_0$; $0,9\,r_0$ and compositions of piezoelectric ceramics PZT-19 and TBK-3 are shown in **Fig. 2** and **Fig. 3** for the case when $l_{O'O} = r_2 - a_0 - 0,003$ m. The same calculations of the frequency dependences of the electric currents of the element with a change in distance $l_{O'O} = 2a_0$; $l_{O'O} = 0$ for values $a_0 = 0,2\,r_0$ and piezoceramics of compositions PZT-19 and TBK-3 are shown in **Fig. 4**.

Analysis of the curves in **Fig. 2** and **Fig. 3** allows us to set the following. As expected, the frequency dependences of the amplitudes of the capacitive current vary linearly with frequency, do not depend on the presence of an acoustic screen in the composition of the radio-electronic element and its dimensions, and are close in values to each other for the considered compositions of piezoceramics. The latter is explained by the fact that these compositions differ little from each other in the values of the dielectric constant ε_{33}^{S} of piezoceramic materials.

The frequency dependences of the amplitudes of the dynamic current are distinguished by a completely different character of behavior. These dependences are multi-resonance curves. The number of resonant current surges, their amplitudes, frequency extent, and distribution over frequency ranges are determined by the size of the screens and the compositions of the applied piezoceramic materials. With large screens (**Fig. 2** c, **Fig. 3** c), the multi-resonant dynamic current curve of the element is converted into a single-resonance one with a frequency f_0 equal to the frequency of the mechanical resonance of the piezoceramic shell of the element in vacuum. With small screen sizes (**Fig. 2** a, **Fig. 3** a), the entire frequency range under consideration can be conditionally divided into three regions — pre-resonant ($f < 0,8\,f_0$), resonant ($0,8 < f < 1,4\,f_0$) and post-resonant ($f > 1,4\,f_0$).

A feature of the frequency characteristics of dynamic currents at small screen sizes (**Fig. 2** a, **Fig. 3** a) is the appearance of a significant number of narrow-band resonant current surges in the pre-resonance region. In this case, their amplitudes are either comparable or significantly exceed the amplitudes of the current in the resonant region of the element, and the choice of the composition of the piezoceramics has a great influence (**Fig. 2** a, **Fig. 3** a) both on the amplitudes of the resonance surges and on their number. In particular, the piezoelectric ceramics of the TBK-3 composition are significantly inferior in terms of energy conversion efficiency to the composition of PZT-19. At the same time, in the post-resonant region, an element with a piezoceramic shell made from the composition TBK-3 (Fig. 3 a) is characterized by a significantly larger number of resonance peaks than that with the composition of PZT-19 (**Fig. 2** a).

The transition to radio electronic elements with medium-sized screens significantly changes the frequency properties of their excitation current (**Fig. 2** b, **Fig. 3**b). In the pre-resonant region, the surges of current amplitudes completely disappear for all the considered compositions of piezoelectric ceramics, and their number in the resonant and post-resonant regions increases.

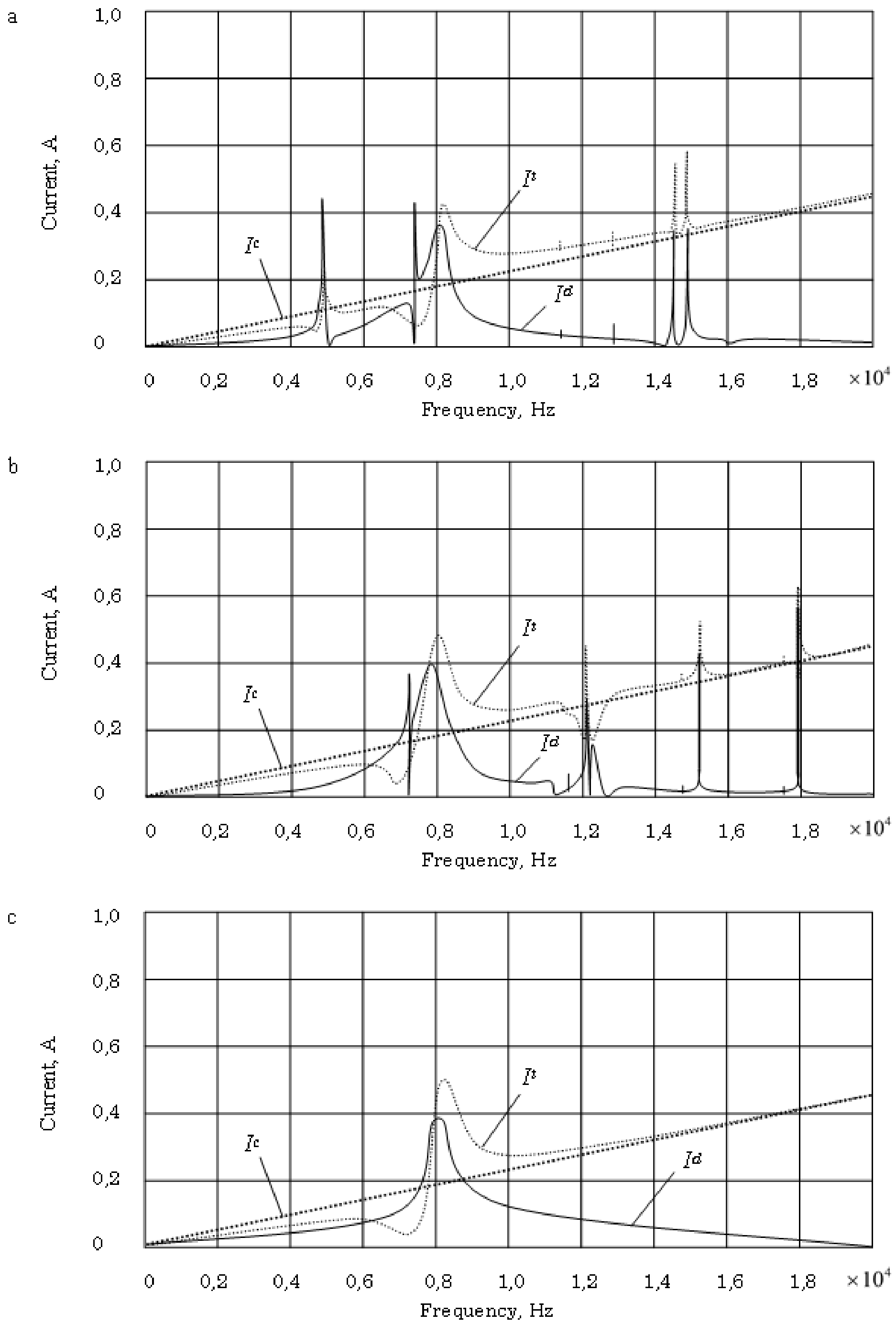

Fig. 2 – Frequency dependences of the amplitudes of the capacitive I^c, dynamic I^d components and total I^t current of the element with the screen size $a_0 = 0,2\, r_0$ (a); $0,5\, r_0$ (b); $0,9\, r_0$ (c) the composition of piezoelectric ceramics PZT-19; asterisk – experimental data

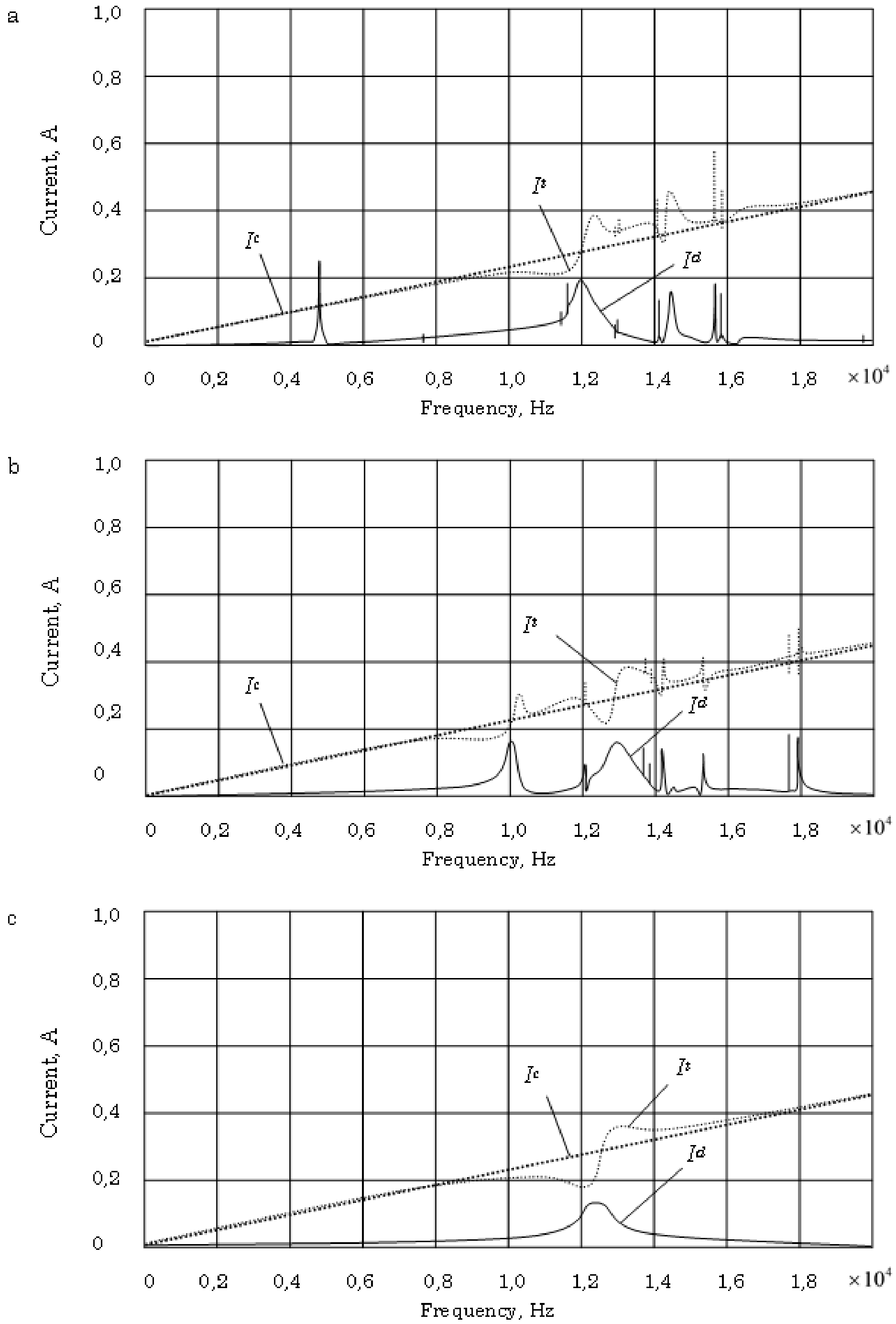

Fig. 3 – Frequency dependences of the amplitudes of the capacitive I^c, dynamic I^d components and total I^t current of the element with the screen size $a_0 = 0,2\,r_0$ (a); $0,5\,r_0$ (b); $0,9\,r_0$ (c) the composition of piezoceramics TBK-3

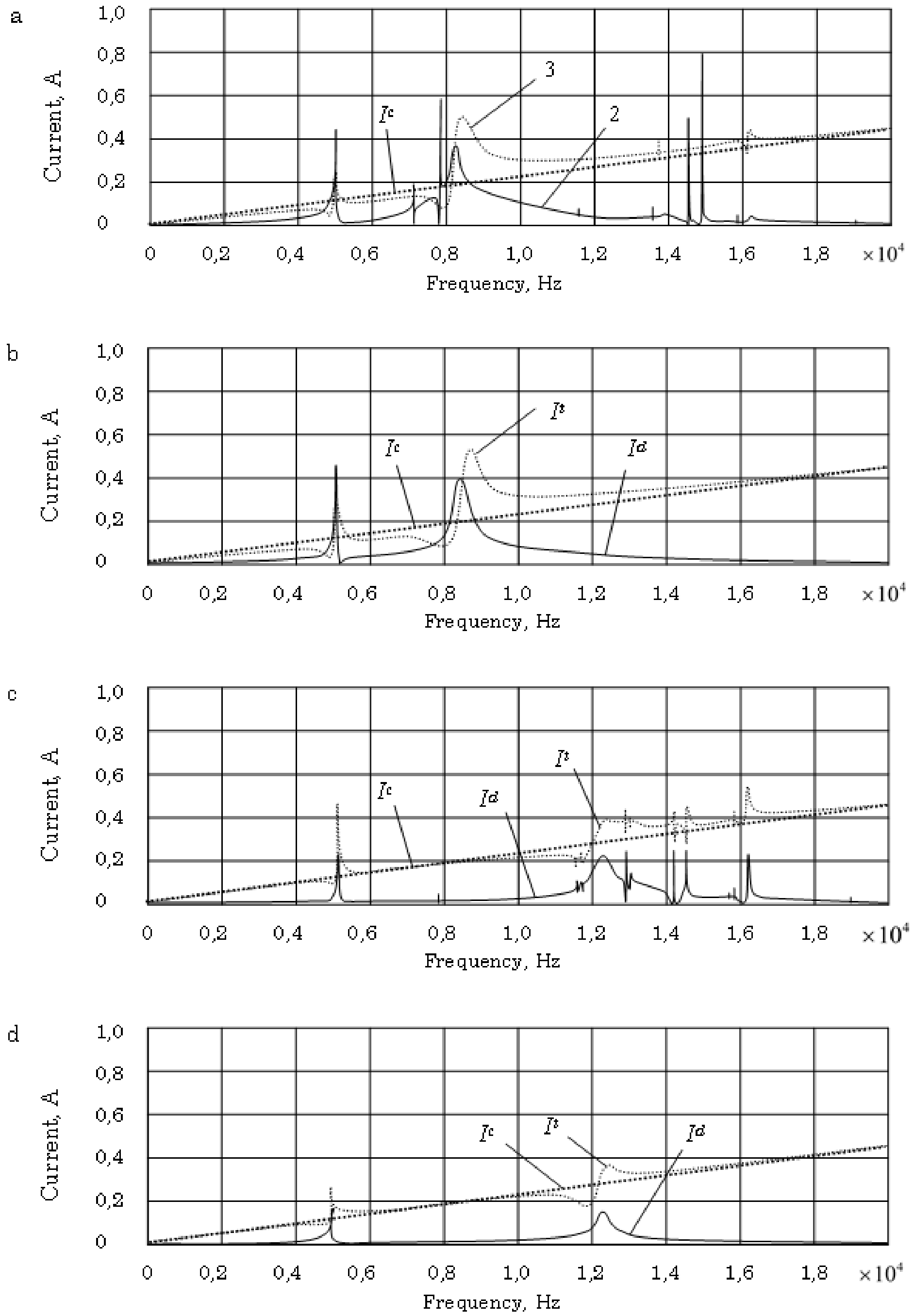

Fig. 4 – Frequency dependences of the amplitudes of the capacitive I^c, dynamic I^d and total I^t element currents at the value $l_{O'O} = 2a_0$ (a, c); $l_{O'O} = 0$ (b, d) and the composition of piezoelectric ceramics PZT-19 (a, b) and TBK-3 (c, d)

Let us consider how the frequency characteristics of the excitation current of the element under consideration change when the distance $l_{O'O}$ between the shell and the screen changes and the screen dimensions remain unchanged. Analysis of the curves in **Fig. 4** and comparing them with the curves in **Fig. 2** a, **Fig. 3** a shows that a decrease in the value $l_{O'O}$ is accompanied not only by a decrease in the amplitudes of resonant surges of the dynamic current, but also by the appearance of new surges with the coaxial placement of the piezoceramic shell and screen (**Fig. 4** b, **Fig. 4** d).

In general, the above results indicate that in the investigated frequency range of the electronic element, the total excitation current, with the exception of individual frequency sections, is controlled by the capacitive component of the current.

In order to confirm the conformity of the assumptions made in solving the problem under consideration and performing numerical calculations with real elements, experimental studies of the magnitude of the electric current in the external circuit of a cylindrical piezoceramic transducer with an internal screen were carried out.

The experimental transducer (Fig. 5) is a cylinder with an outer diameter of 148 mm and a height of 550 mm, made of piezoelectric ceramics of composition PZT-19. In its inner cavity, filled with an electrically insulating liquid, there is a cylindrical screen with an external diameter of 115 mm made of acoustically soft rubber class 10087. The piezoceramic shell with an average radius of 68 mm and a thickness of 8 mm is formed of 48 prisms and is excited by an electric voltage of 200 V. The measurements were carried out under the conditions set forth in work [12]. The number of independent realizations was 7, which ensured the root-mean-square error in measuring the frequency dependences of the current amplitudes not worse than 0.27 at a confidence level of 0.95. The results of measurements at frequencies of 6000 Hz, 8000 Hz and 10000 Hz are shown by asterisks in Fig. 2 c and indicate the agreement between the calculated and experimental data.

Fig. 5 – An experimental sample of the transducer

The physical explanation of the results obtained is of natural interest. As already noted, with radially symmetric electrical excitation of the piezoceramic shell, energy is "pumped" into the element only at one – zero mode of its mechanical vibrations.

In the presence of radial symmetry in the construction of the element, there is only one natural resonance in it, which is equal to the intrinsic resonance f_0 of its piezoceramic shell in vacuum. This situation occurs with a large internal screen (**Fig. 2** c, **Fig. 3** c).

The misalignment of the shell and the screen violates the radial symmetry of the element construction, which results in a loss of symmetry of a acoustic loading of the piezoceramic shell. The latter is due to the difference in wave paths traversed by repeatedly radiated and reflected sound waves between different parts of the surface of the shell and the screen and the occurrence of several resonant phenomena in this case [2]. In a cylindrical piezoceramic shell with a broken symmetry of acoustic loading, both the subsequent zero modes of its mechanical vibrations and resonant vibrations of the zero mode appear, associated with the appearance of standing waves between individual sections of the surfaces of the shell and the screen. And since the energy of the electric field in the element is converted into the energy of the mechanical field only at the zero mode of its mechanical vibrations and in this field is redistributed between all modes of vibration of the shell, any changes in the energy of the zero mode are reflected in the electric field of the element under consideration. This is exactly what the presented results demonstrate.

CONCLUSION

The method of coupled fields in multiply connected regions is used to obtain analytical relations for a quantitative assessment of the parameters of the electric fields of a radioelectronic element made in the form of an electric signal transducer formed from a piezoceramic shell, an internal acoustic screen, and an elastic medium in the cavity between the shell and the screen.

By means of a numerical analysis of the properties of the electric field of the transducer, it was established that the electric current of its excitation contains two components – capacitive and dynamic. Capacitive current describes the properties of the electric field of the transducer as a piezoelectric lossy capacitor. The dynamic current is the result of the electrostrictive property of the piezoceramic transducer shell.

For different frequency ranges, the electrical properties of the transducer and possible operational ways to control the dynamic properties in these ranges have been determined. The control elements for the properties of the electric field of the transducer with the selected composition of the piezoceramic material of its shell include the dimensions of the inner screen and the distance between the screen and the shell. The frequency regions of the predominant influence of each of these elements have been determined.

The results obtained make it possible to perform a dynamical rational coordination of the electrical signal transducer of the type under consideration with the electronic generator that excites it.

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Динамічні властивості радіоелектронних елементів у формі п'єзокерамічних циліндрів із внутрішніми екранами

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Методом зв'язаних полів у багатозв'язкових областях отримані аналітичні співвідношення, що описують електричні поля радіоелектронного елемента, виконаного у вигляді п'єзокерамічної циліндричної оболонки з внутрішнім акустичним екраном та пружного середовища в порожнині між ними. Порівняльний аналіз результатів чисельного експерименту, виконаного за частотними характеристиками електричного струму збудження елемента в залежності від параметрів конструктивного виконання складових елемента, дозволив встановити ряд тонких ефектів у формуванні полів, важливих для узгодження елемента з електронним генератором, який його збуджує. Визначено можливі шляхи керування динамічними властивостями електричного поля перетворювача для різних складів п'єзокерамічного матеріалу його оболонки та різних відстаней між екраном та оболонкою. Отримані результати дозволяють обґрунтовано формувати вимоги до генераторних пристроїв для забезпечення енергетичної ефективності відповідних випромінюючих трактів.

Ключові слова: Динамічні властивості, Електричне поле, Циліндричний п'єзокерамічний перетворювач сигналу, Внутрішній акустичний екран.