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# CHARACTERISTICS IMPROVEMENT OF THE PIEZOELECTRIC ELECTRO-ACOUSTIC TRANSDUCERS WITH ADDITIONAL CONTOURS

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***Abstract.*** *The article describes a method of decreasing the resonance frequency and increasing sound pressure of piezoelectric electroacoustic transducers by means of additional units. The decreasing of the resonance frequency and increasing the sound pressure level can increase the range of the transducers. Increased bandwidth enables transducers to improve the parameters of underwater communication. To improve the characteristics of transducers used additional electrical circuits. The amplitude-frequency responses of piezoelectric electroacoustic transducers with one, two and three circuits are presented. For correction amplitude-frequency responses of transducers used additional capacitors and resistors.*

***Keywords:*** *piezoelectric transducer, oscillatory circuit, amplitude-frequency response, sound pressure.*

# УЛУЧШЕНИЕ ХАРАКТЕРИСТИК ПЬЕЗОЭЛЕКТРИЧЕСКИХ ЭЛЕКТРОАКУСТИЧЕСКИХ ПРЕОБРАЗОВАТЕЛЕЙ С ПОМОЩЬЮ ДОБАВОЧНЫХ КОНТУРОВ

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***Анотація.*** *У статті описано метод зниження резонансної частоти та підвищення рівня звукового тиску п'єзоелектричних електроакустичних перетворювачів за допомогою додаткових систем. Для покращення характеристик перетворювачів застосовано додаткові електричні коливальні контури. Приведені амплітудно-частотні характеристики п'єзоелектричних електроакустичних перетворювачів з одним, двома та трьома контурами. Для коректування амплітудно-частотних характеристик таких перетворювачів використані додаткові конденсатори та резистори.*

***Ключові слова:*** *п'єзоелектричний перетворювач, коливальний контур, амплітудно-частотна характеристика, звуковий тиск.*

Devices reformative an electric signal in acoustic name electro-acoustic transducers (EAT) [1,2]. Piezoelectric transducers most often use as EAT [3,4].

Piezoelectric transducers used widely in electroacoustics, hydroacoustics, to ultrasonic (US), the medical, measuring techniques, in scanning probe microscopy, piezoengines, in other areas of a science and techniques [1-4].

Piezoelectric transducers occupy a special place in hydroacoustics, being, in essence, with eyes and ears of the surface and underwater ships [5].

Methods of synthesis of piezoelectric transducers are described in works [6, 7]. These methods allow to create transducers with necessary characteristics.

Special interest is represented the technology of accidental elements as in this case change of characteristics of the transducer is carried out at the expense of external chains for a piezoelement among the described technologies.

The essence of this technology consists that additional electric and mechanical elements which change characteristics of the transducer attach to a piezoelement [6, 7].

Resonant frequency $f_{p,}$ level of created sound pressure $P_{sound}$ and width of a strip of working frequencies (pass-band) $\Delta f$ are important characteristics EAT.

Decrease in resonant frequency and increase of level of sound pressure allows to increase range of action of transducers. Expansion of a pass-band of converters allows to improve parameters of underwater communication [3, 4].

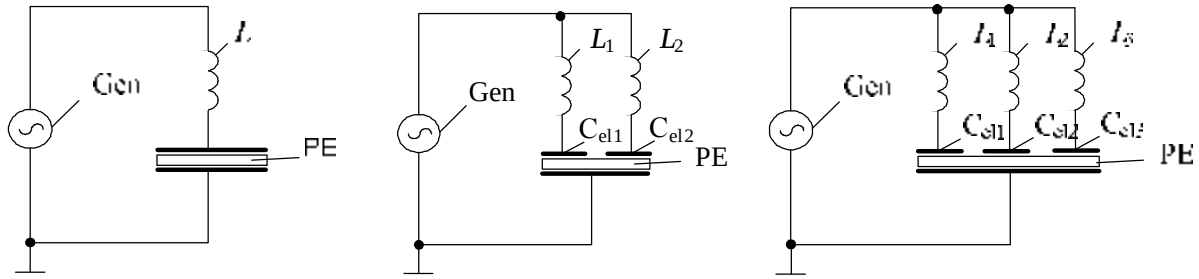
Improvement of these characteristics piezoelectric electro-acoustic transducers is **the purpose** of the given work.

Authors offered to attach to piezoelement of transducer additional oscillatory systems – electric, mechanical, electromechanical and acoustic for achievement of this purpose.

We will consider case in the given work when to a piezoelement attach additional electric oscillatory a contour [9-12].

Schemes of some variants of transducers with additional electric contours are shown on Fig. 1.

Additional contour in this case are created by means of additional inductances *L* and interelectrode capacities of a piezoelement – one (Fig. 1, a) or several (Fig. 1, b, c).




a) b) c)

**Fig. 1. – Schemes of PEAT with additional oscillatory contours**

The shown schemes do not settle possible variants of schemes of such devices certainly.

Probably some variants at realisation of the schemes represented on Fig. 1.

Electrodes on a piezoelement can be divided into parts with the identical area or different (i.e. with identical capacity or different) first of all. To inductance can be equal each other or are not equal accordingly. At last, it is possible to pick up inductance and interelectrode capacities so that resonant frequencies of contours were equal or differed from each other.

As is known [1, 2], the piezoelement represents the electromechanical oscillatory system, the equivalent electric scheme which is represented on Fig. 2 [3,4].

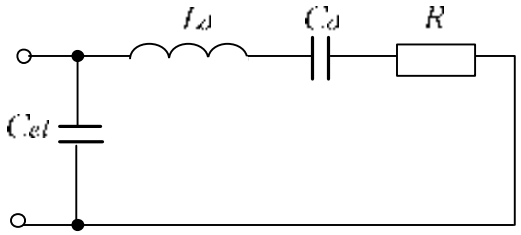



**Fig. 2. – Equivalent electric scheme of a piezoelement**

$C_{el}$ – capacity between piezoelement electrodes, $L_д$, $C_д$, $R$ – dynamic inductance and capacity and active losses in a piezoelement on this scheme.

If to attach to an input of a piezoelement inductance $L_{ad}$, this inductance and capacity between electrodes $C_{el}$ have formed the consecutive oscillatory contour $L_{ad}C_{el}$, which resonant frequency can be defined under the known formula (Fig. 3) [6, 7].

$$f_{ad} = \frac{1}{2p\sqrt{L_{ad}C_{el}}} \tag{1}$$

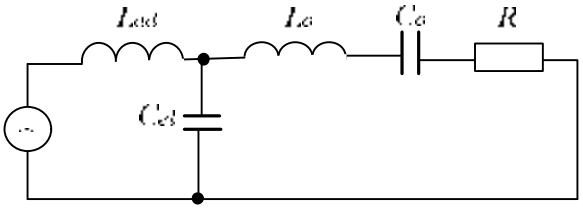



**Fig. 3. – Equivalent scheme of a piezoelement with additional inductance**

Resonant frequency a piezoelement

$$f_{PE} = \frac{1}{2p\sqrt{L_{\partial}C_{\partial}}} \tag{2}$$

Besides, there is a resonance on frequency

$$f = \frac{1}{2p\sqrt{(L_{ad} + L_{\partial})C_{\partial}}} \tag{3}$$

Depending on sizes $C_{el}$ and $L_{ad}$ three cases are possible:

$$\begin{aligned} f_{ad} &= f_{PE}; \\ f_{ad} &< f_{PE}; \\ f_{ad} &> f_{PE}. \end{aligned} \tag{4}$$

Here we will consider a case, when $f_{ad} = f_{PE}$.

If to a piezoelement to attach the second contour, such system, as is known, is called as the connected oscillatory contour [8].

Let's consider the elementary case when the contour attached to a piezoelement, has the same parameters, as a piezoelement, i.e. resonant frequencies, good quality and amount off-resonance these contours are equal:

$$\begin{aligned} w_{p1} &= w_{p2} = w_p; \\ Q_1 &= Q_2 = Q; \\ x_1 &= x_2 = x, \end{aligned} \tag{5}$$

where $x = \frac{x}{r}$,

$x$ – jet resistance;

$r$ – active resistance of a contour.

Dependence of relative conductivity $Y_{12} / Y_{12\max}$ from relative amount off-resonance $x$ and various values of the factor of communication of contours $A$ looks like for this case [8]:

$$\frac{Y_{12}}{Y_{12\max}} = \frac{2A}{\sqrt{(1 + A^2 - x^2)^2 + 4x^2}} \tag{6}$$

Dependence of relative conductivity of connected identical contours $Y_{12}/Y_{12\max}$ from generalised amount off-resonance $\xi$ for different values of the factor of communication of contours $A$ is shown on Fig. 4:

$$A = \frac{x_c}{\sqrt{r_1 r_2}} \tag{7}$$

where $x_c$ – jet resistance of communication;

$r_1$, $r_2$ – active resistance of the first and second contours accordingly [8]:

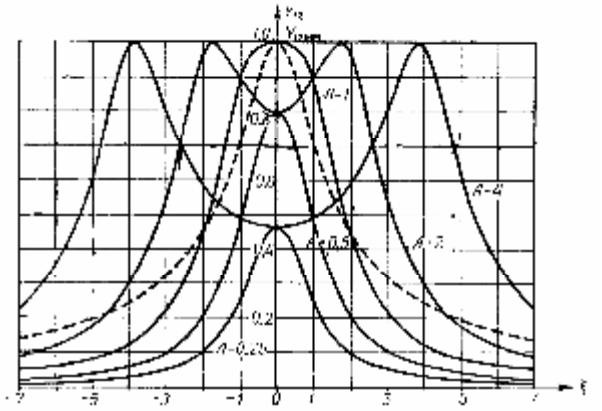


**Fig. 4. – Family of the resonant curve two connected identical contours**

Maintenance of a condition (5) is inconvenient, since demands application of coils of inductance of high good quality in practice. Occurrence of additional resonances according to a condition (3) should be besides, specified.

In case of application of two and three additional oscillatory contours the picture of fluctuations even more becomes complicated. Usually one oscillatory contour is adjusted on frequency of electromechanical fluctuations of a piezoelement (expression (2)), that provides increase of level of sound pressure on this frequency.

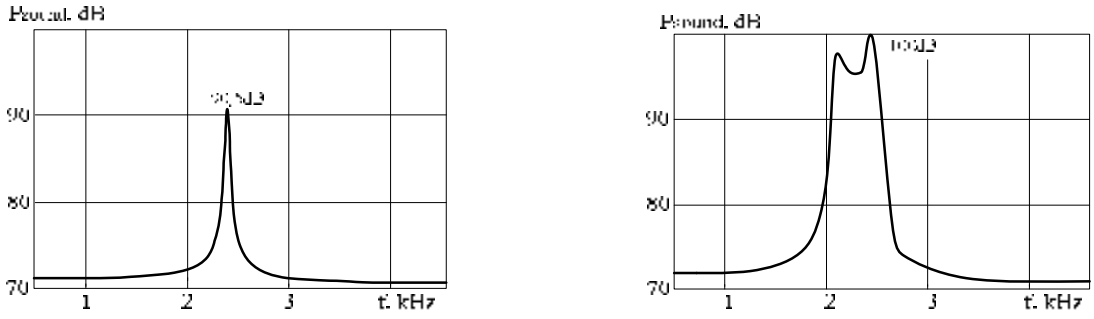
The second and third contour adjust on lower frequencies that provides pass-band expansion.

Analytical expressions for calculation of the peak-frequency characteristic (AFC) such oscillatory systems are absent, therefore definition AFC we will spend experimentally.

The electro-acoustic converter on a basis биморфного an element from converter ЗП-19 of manufacture of Open Society "Aurora" (Volgograd) was for this purpose used.

Bimorph element consists of a plate from a steel 40X in diameter 32 and thickness of 0,15 mm. To a plate it is pasted epoxy compound piezoelement Ø23 and thickness of 0,2 mm. The is fixed in the case from shock-resistant polystyrene. On an input of the piezoelectric transducer (PT) pressure from generator G3-109 moved.

AFC the transducer on sound pressure on the basis of it биморфного an element and биморфного an element with one additional contour are shown on Fig. 5.

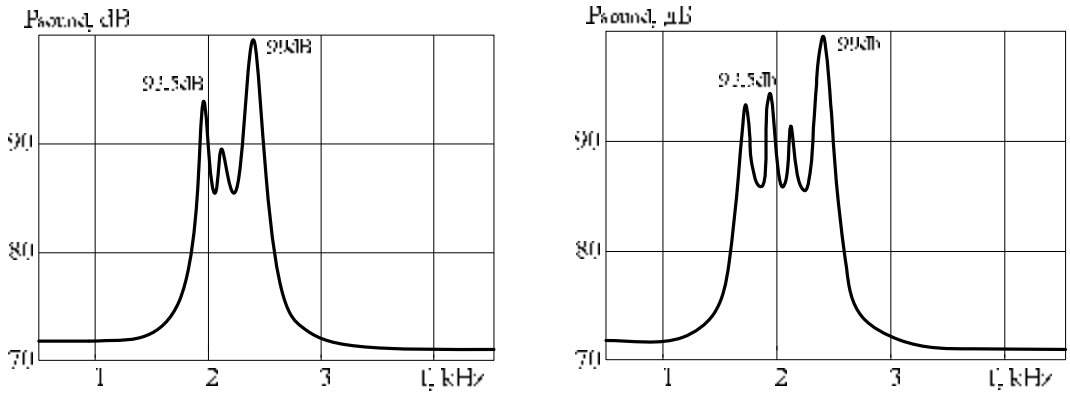



*a)* *b)*

**Fig. 5. – AFC of transducer and transducer Without an additional contour (a*)* and with a contour (b*)***

Apparently from Fig. 5, application of an additional contour has allowed to raise level of sound pressure and to expand a strip of frequencies.

AFC of the same transducer with two and three additional contours it is shown on Fig. 6.

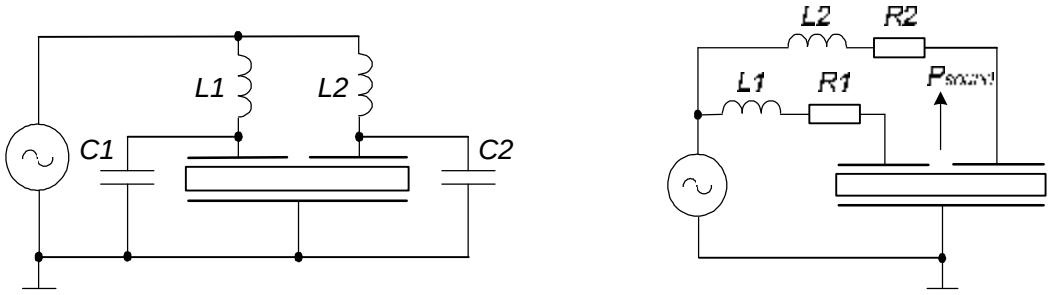



*a)* *b)*

**Fig. 6. – AFC of transducers with two (a) and three (b) additional contours**

Apparently from Fig. 6, application of two and three additional oscillatory contours allows to expand width of a strip of frequencies even more.

For updating AfC in the converter by in parallel entrance electrode condensers (Fig. 7, a) can be connected and is consecutive with additional inductance – resistors (Fig. 7, b).




a) b)

**Fig. 7. – Schemes of transducers with additional condensers (a) and resistors (b)**

**Conclusions:**

1. Additional electric oscillatory contours can be used for improvement of characteristics of piezoelectric electro-acoustic transducers.
2. Additional condensers and resistors can be used for updating AFC of such transducers.

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