**V.V.Kazakov**

# ON PARTICULARITIES OF CHOICE OF ULTRASONIC TRANSDUCERS FEATURES AT AIR LOCATION

Institute of Applied Physics of RAS
46, Ul'ynov Str., GSP-120, Nizhny Novgorod, 603950, Russia,
Tel.: (7-8312) 164986; Fax: (7-8312) 363792
E-mail: kazak@appl.sci-nnov.ru

*Analysis of features of ultrasonic transducers for air location carry out. Special emphasis was attend for development of transducers, working at radial modes of fluctuations, used for making the ultrasonic phase vibrodisplacement meters. Brought main characteristic of such type transducers. Shown dependency of sensitivity of measurements from the choice of frequency of location and distinctive size of transducer.*

For location at air the most broad using have found transducers on the base of piezoceramic PZT-19. Herewith general trend of their use was concluded in following: on frequencies above several hundreds kilohertz were used converter fluctuations on the thickness, on frequencies in hundreds a kilohertz - thickness, radial, or combined thickness and radial modes of fluctuations, on frequencies in groups of ten a kilohertz - made on their base bimorph converters or converters of Lanjeven's type.

Progress in the development of ultrasonic converters happened in last years and to a considerable extent new technologies and piezomaterials, has brought to creation of broadband, high sensitivity, well acoustic impedance matching with the air of transducers of capacitive type [1,2], converters PVDF (polyvinylidene fluoride) on the base of piezopolymer films [3,4] and agreeing layers on the base of polymers, having porous microspheres or cells, occupying near 70% from the volume used compound, or glass fiber [5,6]. If un matching transducers have losses (at location in mode "on passing") at a rate of - 60 ÷ -70 dB, the acoustic impedance matching reduces them before -30 ÷ -40 dB [7-9]. Main features of transducers are provided in the table [9].

***Table.*** Comparative features of ultrasonic transducers

| | Type of transducers | | | |
|---|---|---|---|---|
| Parameter | Capacitive | Piezoceramic (with matching layer) | Composite (kit of layers) | PVDF |
| Sensitivity on acceptance, mV/Pa | 2 | 1 | 0,1 | 0,4 |
| Sensitivity on radiat., mV/Pa | 0,2 | 1 | 0,3 | 0,1 |
| Frequency range, kHz | 200 | 500 | 500 | 200 |
| Freq. band, % | 30 | 2 | 30 | 30 |
| Temperatures (max), deg | 80 | > 100 | > 100 | 80 |
| Stability to environment | low | high | high | low |
| Stability | middle | low | middle | high |

From tables follows that capacitive converters - broadband (band of acceptance and radiating within the range of 250 ÷ 900 kHz); converters with matching layer - the most sensitive, but have a narrow passband; converters on the base PVDF have high sensitivity, broadband, but either as capacitive have less stable features and temperature of use before 80°C.

Part of transducers is released serial by companies: Murata (Japan), Pepperl+Fuchs (USA), STS Electronics Ltd (Bulgaria)). They basically oriented for deciding the problems of ranging and positioning and used converters of bimorph type on frequency 40 kHz. Using the converters of such type presents the

greater requirements to conditions of the measurements, as far as ultrasonic wave of such frequency fades weakly and on small distances of location possible reflection from closely set objects. High frequency transducers, for instance company Murata, have too much ( 20 % for 400 kHz) dispersion on resonance frequency that requires their preliminary selection, so as its frequency has complied with the frequency used quartz generator.

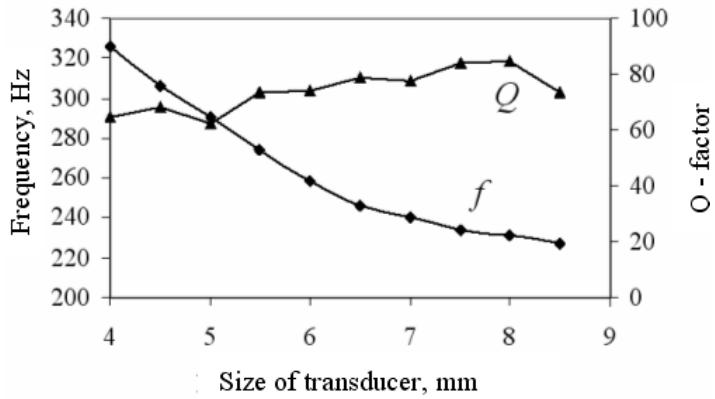


***Fig.1.*** Changing a frequency (f) and Q-factor (Q) from size of converters.

Thereby, problem of making the ultrasonic sensors, distinguishing ease of manufacturing of fabrication on fixed radiating frequencies, as before stays actual and in this connection the significant interest have work, in which are researched radial fluctuations of piezoelectric cell. For instance, for increasing efficiency of radiating are used heavy-wall piezoelectric cell, beside which attitude of diameter to the thickness forms an order of units and more, powerfully showing multimodal fluctuations [10, 11]. In particular, at the attitude of diameter to the thickness equal 1,33 occurs a tight binding between first radial and thickness modes [12]. In work [13] is noted that grading of lateral surface defines spectral composition of radial modes: fabrication of converters with protuberant verges brings about increasing a frequency, but concave galley proofs reduce a fluctuation frequency. Analysis of literature has shown that problem of making the high-performance ultrasonic transducers, distinguishing simplicity and ease of manufacturing of fabrication on fixed frequencies of radiating possible to decide using piezoceramic cell of PZT-19, at excitement them on radial modes of fluctuations.

For developed schemes of ultrasonic phase meters of vibrodisplacements [14,15], using continuous mode of radiating an ultrasonic wave, were designed transducers, in which as radiating and receiving converters were used square (or rectangular) plates, having width d = 5 ÷ 10 mm and thickness 2 ÷ 4 mm. The plates are acoustic unlaced and change in general body under corner to one another. Changing corner of installing the converters and their sizes, get necessary their spatial characteristics depending on requirements of deciding problem.

On fig.1 brought typical dependencies of resonance frequency and Q-factor for made converters by the thickness 4 mm from PZT-19. Active resistance of converters on radiating frequency within the range of frequencies 220 ÷ 320 kHz was enlarged with 160 Ohm before 480 Ohm, but passband - from 1,3 kHz till 2,5 kHz. For the comparison: converters from PZT-23, sizes 6,5 x 6,6 x 6 mm on thickness mode of fluctuations had Q-factor within the range 330 ÷ 500, passband 0,2 ÷ 0,25 kHz and resistance 90 ÷ 120 Ohm. From brought data follows that using the converters on radial modes of fluctuations allows to decide the problem of stabilization of radiating frequency by selecting their sizes. Except this, turns out to be possible to make radiating and taking converters on the different resonance frequency for the reason additional expansions of band of acceptance and increasing sensitivity, as this is done, for instance, at the production of converters of company Murata type MA40B8R and MA40B8S, MA40E7R and MA40E7S for 40 kHz.

As it was noted earlier, radiating and receiving converters in the sensor have the position under corner to its axis (refer to fig.2). This corner is chosen depending on average distance $R_0$ to the reflect surface, since in this case ultrasonic beam mirror gets on the receiving converter. However at the analysis of such scheme of measurements of little attention given to a study dependencies of accuracy of installing a corner on changing a signal amplitude of received wave. At the choice of sizes of receiving converter.

having distinctive size $d_2$ it is necessary to take a possibility of changing a corner of falling into account. Also it is necessary to take into account the chosen value $R_0$ at the fabrication of transducer, so and its change at carrying out of measurements because the average distance up to the surface is distinguished from $R_0$.

Define a changing a signal amplitude on output the receiving converter by the size $d_2$, to which falls a plane wave of frequency $f$ and corner of falling changes comparatively installed corner $\beta$ on the value $\Delta\beta$ (refer to fig.2). For this purpose to break the length of converter $d_2$ on elementary areas by the width $\Delta d_i$ each.

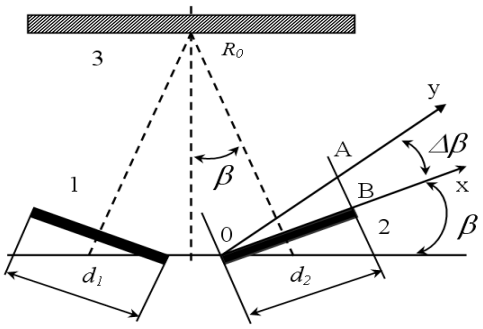


***Fig.2.*** Scheme of location of converters, where 1, 2 – received and transmitted converters, 3 - reflecting surface

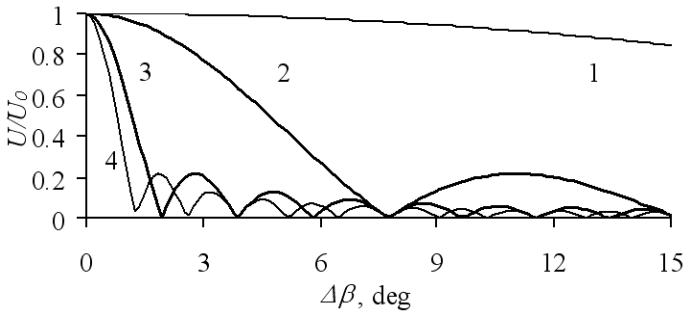


***Fig.3.*** Relative changing a signal amplitude of received wave depending on changing its corner of falling for the converter by the size 10 mms and frequencies: 1- 40 kHz, 2 - 250 kHz, 3 - 1 MHz, 4 - 1,5 MHz

From the triangle OAB will find a changing a phase incursion on each area $\Delta d_i = U_0 \cos[\omega t - k\, n\, \Delta d_i \tan(\Delta\beta)]$. Will be to define an average value of changing a signal by the amplitude $U_0$ for the whole length when parameter $\omega t$ is changing. As result to get the changing the signal on received converter equal $U(\Delta\beta,t) = U_0 \cos[\omega t - \left(\sum_{i=0}^{i=n} kn\Delta d_i \tan(\Delta\beta)\right)/n]$, at the passing through it the plane waves, and will build a normalize changing its amplitude $U(\Delta\beta)/U(\Delta\beta)_{\Delta\beta=0}$ , depending on positive values of changing a corner of fall $\Delta\beta$.

On fig.3 brought results of the calculation for different values of frequencies under the fixed size of converter $d_2$ = 10 mm, but on fig.4a,b - for fixed frequencies 250 kHz and 1 MHz and sizes of converters from 3 mm till 15 mm.

From obtained dependencies is seen that size of converter by the qualitative image influences on amplitude received wave. Reduction of frequency under fixed size of converter does the dependency from the corner more smooth, receiver all more becomes monopoly, particularly for frequencies below 40 kHz. For frequencies of order hundred kilohertz ÷ units a megahertz the dependency from the mistake of determination of corner becomes essential. Moreover, exist corners under which separate forming falling waves completely compensate each other. This effect was observed by the author experimentally for location of distance by the frequency 1,2 MHz and using a converter with the distinctive size 1 sm. From fig.4a follows that for the frequency 250 kHz taking converter must possible have smaller sizes that dependency from changing the falling wave corner was possible less, in particular, for $d_2$ = 10 mm inaccuracy in installing a corner must not exceed 3,5°, but for $d_2$ = 3 mm - ± 11°.

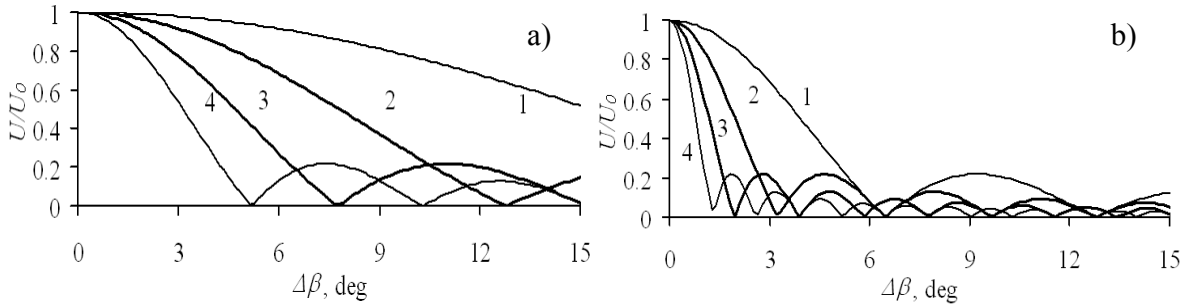


***Fig.4.*** Relative changing a signal amplitude of received wave depending on corner of falling for frequency - 250 kHz (a) and 1 MHz (b) and sizes of converters: 1- 3 mm, 2 - 6 mm, 3 - 10 mm, 4 - 15 mm

Thereby shown that radiating converter must possible have a big sizes for radiating a plane wave, but receiver must be point, though this and regard it to reducing sensitivity of measurements to the account of reducing its area.

## REFERENCES


1. D.W. Schindel, D.A. Hutchins, W.A. Grandia Capacitive and piezoelectric air-coupled transducers for resonant ultrasonic inspection // Ultrasonics. — 1996. — V.34. — P.621-627.
2. L-F. Ge Electrostatic airborne ultrasonic transducers: modeling and characterization // IEEE Transactions on ultrasonics, ferroelectrics and frequency control. — 1999. — V.46, — № 5. — P.1120-1127.
3. L. Capineri, A. Fiorillo, L. Masotti, S. Rocchi Piezo-polymer transducers for ultrasonic imaging in air // IEEE Transactions on ultrasonics, ferroelectrics and frequency control. —1997. — V.44, —№ 1.—P.36-43.
4. M. Toda, S. Tosima Theory of curved, clamped, piezoelectric film, air-borne transducers // IEEE Transactions on ultrasonics, ferroelectrics and frequency control. — 2000. — V.47, — № 6. — P.1421-1431.
5. T. Yano, M. Tone, A. Fukumoto Range finding and surface characterization using high-frequency air transducers // IEEE Transactions on ultrasonics, ferroelectrics and frequency control. — 1987. — V.34, — № 2. — P.232-236.
6. R. Coates, R.F. Mathams Design of matching networks for transducers // Ultrasonics. — 1988. —V.26. —P.59-64.
7. A.Gachagan, G. Hayward, S.P. Kelly, W. Galbraith Characterization of air-coupled transducers // IEEE Transactions on ultrasonics, ferroelectrics and frequency control. — 1996. — V.43, — № 4. — P.678-689.
8. T.E. Gomez Acoustic impedance matching of piezoelectric transducers to the air // IEEE Trans. Ultrason., Ferroelectr. and Freq. Contr. — 2004. — V.51, — № 5. — P.624-633.
9. W.Manthey, N.Kroemer, V.Magori Ultrasonic transducers and transducer arrays for application in air // Meas. Sci. Technol. — 1992. — № 3. — P.249-261.
10. V. Domarkas, A. Petrauskas Piezoelectric converter with the transformation of type of fluctuations // Tr. VUZov. Lit. SSR. Ser. Ultrasound. – Vilnius: Mocsclas. —1975. —№ 7. —P.127-131.
11. S.I. Sayuskas, A.P. Maschonis, V.S. Zvanorus Ultrasonic transducer // Pat. № 1241126 SSSR. — 1986. — B. of Inv. № 24.
12. R.-I. Kazysh Experimental study of pulsed mode ultrasonic waveguide transducers // Tr. VUZov. Lit. SSR. Ser. Ultrasound. – Vilnius: Mocsclas.—1975. — № 7. — P.97-104.
13. S. Sayauskas, V.Zvanorus Investigation of multimode disc converters // Tr. VUZov. Lit. SSR. Ser. Ultrasound. – Vilnius: Mocsclas.. — 1986. — № 18. — P.65-70.
14. V.V. Kazakov Ultrasonic phase meters of vibrodisplacements // Vibroacoustic fields of complex objects and their diagnostics. Gorky: IAP USSR. — 1989, — P. 178-190.
15. V.V. Kazakov Measurement of vibration field by ultrasonic phase vibrodisplacement meters // In Proceed. XV session RAS. Acoustical measurements. – M.: GEOS. — 2004. — P.17-21.