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METHOD AND RESULT OF MEASURING THE GEOMETRICAL DISPERSION IN SOUND BEAMS

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The method of measuring of the geometrical dispersion caused by the diffraction processes in sound beams is offered. The experimental installation surveyed, observed result of measuring longitudinal allocations of additional attack phase invariant the three-frequency wave and dispersion parameter of a bundle are given. Local character of a geometrical dispersion which area focused in a short-range band of a bundle, and also two various mechanisms, giving to its nonuniform allocation in space is marked. The consent of calculation and experiment is received.

In the given operation the geometrical variance is understood as the frequency dependence of phase velocity at distribution to the homogeneous dispersion-free medium quasiplane the harmonic wave, restricted in space as a bundle [1]. The viewed phenomenon is caused by a diffraction and not interlinked to change of properties of the material medium occuring under activity of a sound wave, as in case of a physical variance because of relaxation processes [2], oscillations gas bubble in a fluid, etc.

The offered method allows how to measure, and visually to observe display of a variance, using for this purpose Lissajous figures. In a basis of the offered approach use of such known effect, as infringement of phase synchronism is necessary at distribution of a multifrequency wave to medium with a variance [1]. As the variance guesses distinction of phase velocities at waves of different frequencies at distribution phase relations between the frequency builders of a wave which measuring is easier, than a finding of the diffraction attacks of phases in each of a builder will change.

For a narrow-band signal with the symmetric frequency content (ω_0, $\omega_{H,B} = \omega_0 \mp \Omega$, $\omega_0 >> \Omega$), the check of phase relations becomes simpler, as the phase structure of a signal can be described by one parameter - phase invariant β_0 (PI) which quantity for the one-dimensional wave does not depend on time and the transited distance [3, 4]

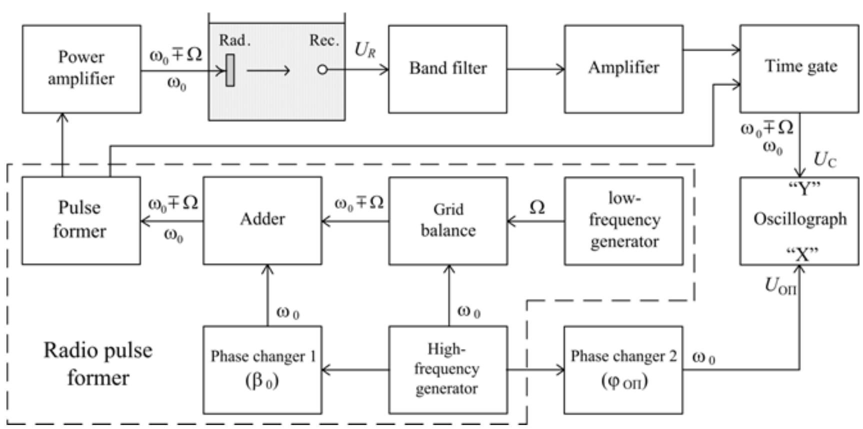
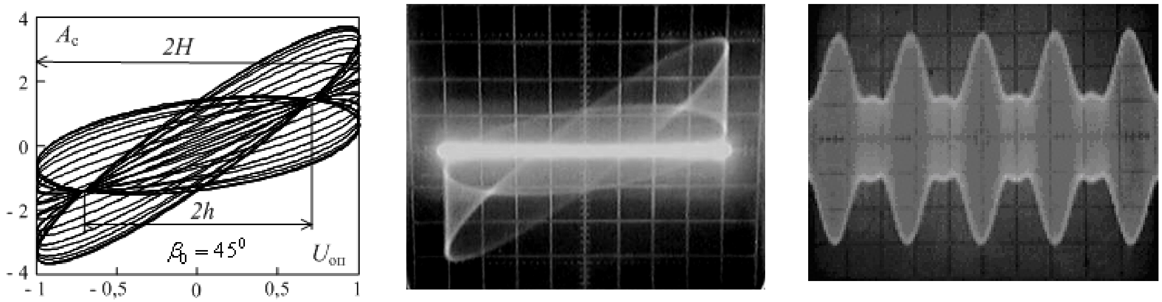


Fig. 1. Structure chart of installations

For supervision of a geometrical dispersion and measurement of spatial changes PI of a three-frequency wave experimental installation which block diagram is resulted on fig. 1 was used. The measurement technique of phase ratio in a three-frequency signal with use Lissajous figures is considered in [4]. The radiating path of installation includes the shaper of radio impulses with three-frequency filling, the amplifier of capacity and piezoelectric radiator (PR). The shaper of radio impulses will consist of the shaper of duration and frequency of following of pulses, the adder, the balancing modulator, the phase shifter 1, generators high-frequency (HF) and low-frequency (LF) of fluctuations. Initial value PI of a wave package (β_0) is set by the phase shifter 1. In structure of a reception path have come a hydrobackground (Пр.), the passive strip filter, the amplifier, the time selector of accepted pulses, an oscillograph and the phase shifter 2.

The control of the three-frequency signal accepted by a hydrobackground was carried out simultaneously under time diagrams and Lissajous figures, fig. 2. One oscillograph (on the circuit it is not shown), working in a mode of internal synchronization, displayed on the screen a time structure of a wave package $U_C(t)$, fig. 2-c. For supervision of Lissajous figures on Y - an input of other oscillograph the signal $U_C(t)$ moved, and the continuous harmonious fluctuation $U_{Oï}(t) = U_0 \cos(\omega_0 t + \varphi_{Îï})$ acting as basic, fig. 2-b was brought to $X -$ continuous harmonic oscillation was brought to an entrance $U_{Îï}(t) = U_0 \cos(\omega_0 t + \varphi_{Îï})$, which represents itself as basic



a) **b)** **c)**

Fig. 2. Designt (a) and experimental (b) Lissajous figures, the time diagram signal (c) at $\beta_0 = 45^0$ and $m = 1$; distance between a radiator and the receiver $x = 1\,m$

Extent of area Fresnel diffraction (near zone) piston radiator and his sensitivity a mode of radiation on frequency толщинного a resonance $\omega_P / 2\pi = 1300$ *кHz* have made $l_d = 56$ *mm* and $\gamma = 6800$ *Pa/V*. For registration of acoustic waves it was used cylindrical sound receiver with the sizes 3×3 *mm* which were settled down on an axis of a radiator. Experiment was carried out in a pulse mode: duration of radio impulses $\tau = 80\,us$, the period of following $T = 10\,ms$. Sizes $U = |maxU(t)|$ and m, indicated on experimental results, were measured at $\beta_0 = 0$. Measurements were carried out at $m = 1$, $\Omega/2\pi = 45$ and $90\,кHz$. The pressure of a signal on a radiator was supported equal $U = 10$ V, that there corresponds to a mode of small amplitude at which nonlinear processes in the environment are not shown yet, fig. 2-c.

Procedure of measurements of current value PI $\beta(r, x)$ in the chosen point of a field where r and x - cross and longitudinal coordinates of a sound field, began with installation by the phase shifter 2 such values of a phase $\varphi_{Îï}$ that the condition [4] satisfied

$$\varphi_{ОП} = -\beta_0 . \quad (1)$$

In this case the figure observable on an oscillograph becomes, shown on fig. 2-b. Bright засветка as a horizontal line on fig. 2-н appears owing to work of experimental installation in a pulse mode. In the central part of a figure it is observable the bright area reminding a parallelogram which big diagonal is inclined in relation to a horizontal axis, and small should be vertical, that is provided with adjustment of size $\varphi_{Îï}$. After performance of a condition (1) presence $\beta(r, x)$ is reduced to measurement of two pieces ($2h$, $2H$), fig. 2, and substitutions of their values [4] in expression:

$$\beta(r, x) = \arcsin(2h/2H).$$

Values $\beta(r,x)$ by virtue of linear character of diffraction do not depend on amplitude-phase ratio in a spectrum of an initial wave and can be measured at any values β_0. However, the preference was given $\beta_0 \cong \pm 45^0$, at which presentation and accuracy of measurements were the best. At research of a geometrical dispersion interest represent diffractive attacks PI $\Delta\beta_\partial(r,x)$. Therefore after a presence the difference between current and initial values PI, and also dispersive parameter was calculated

$$\Delta\beta_\partial(r,x) = \beta(r,x) - \beta_0\,; \quad D_\partial(\omega_0, x) = \frac{d^2 k(\omega_0, x)}{d\omega^2} \cong -\frac{1}{2}\cdot\frac{\Delta\beta_\partial(x)}{\Omega^2 x}\bigg|_{\omega_0 >> \Omega}.$$

Let's note the important advantage of a examined method is an independence of results of peak ratio in a spectrum of a three-frequency wave, i.e. from factor of modulation m and the attitude of amplitudes lateral a component of a three-frequency signal. It allows to exclude influence diffractive changes of amplitudes which size in a near zone of a beam is especially great

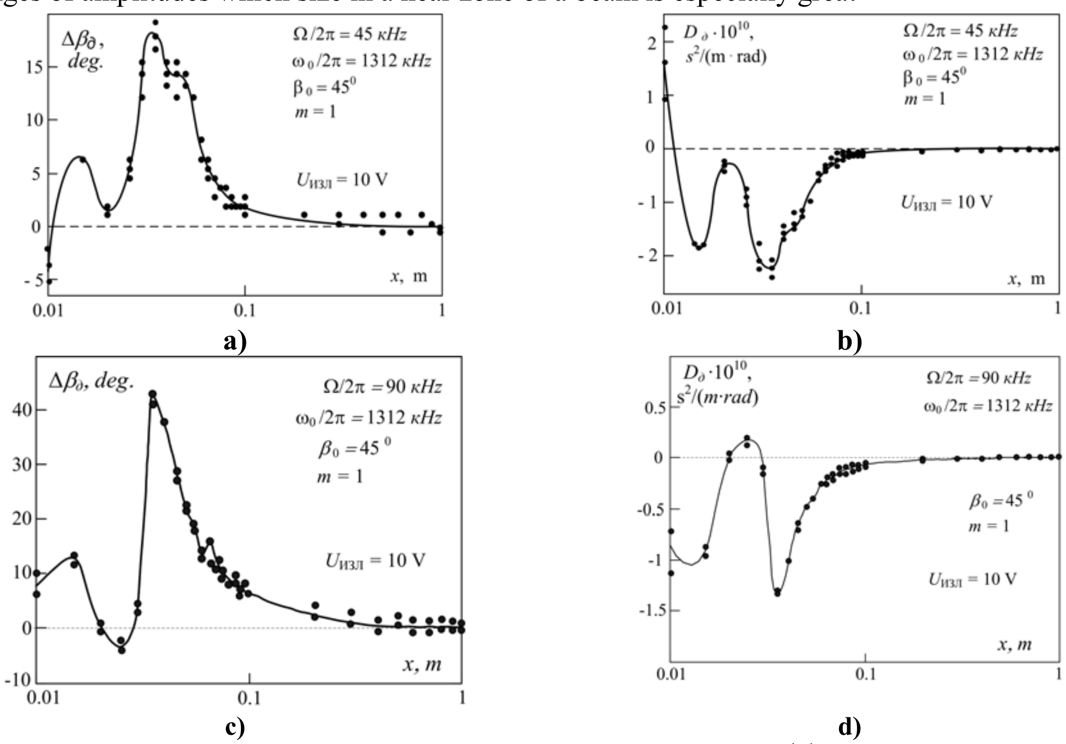


Fig. 3. Axial distributions diffractional attack PI $\Delta\beta_\partial(x)$ (a, c)
and dispersion parameter D_∂ (b, d) при $\Omega/2\pi = 45\,kHz$ и 90 kHz

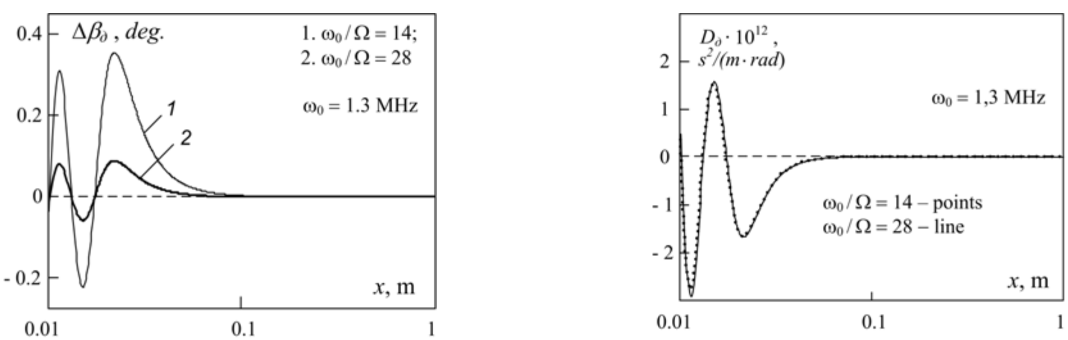
On fig. 3 axial allocations $\Delta\beta_\partial(x)$ and dispersion parameter $D_\partial(x)$ are given at various frequencies of modulation Ω. It is visible, that dispersion contortions focused mainly in a short-range band of a bundle where alongside with transformation of a wavefront the interference of contributions of the Fresnel zones located on a surface of an emitter takes place. Display of the last looks like oscillation which considerably exceed the diffraction component [3]. In a band of a spherical discrepancy of a ultrasonic field ($x > l_d$) the diffraction changes of amplitudes and phases of the different frequency a builder because of a narrow frequency band of a undular package ($\omega_0 >> \Omega$) are commensurable on quantity and do not give in change of a lateral view of a wave. On an example $\Delta\beta_\partial(x)$ also $D_\partial(x)$ it is visible, that for $x > 0{,}1$ m the variance practically misses.

Magnification of frequency Ω equivalently to expansion of a spectrum $(2\Omega/\omega_0)$, giving in amplification of the diffraction distinctions at a builder with frequencies ω_0, ω_H and ω_B. In result in terrain clearance values $\Delta\beta_\partial$ some times grow. But dynamics of dispersion parameter thus changes insignificantly, that proves to be true calculation [3]. On fig. 4 are shown $\Delta\beta_\partial(x)$ and $D_\partial(x)$ for a round bundle with sharply expressed boundary and a polynomial distribution of amplitude at a stationary value to a phase along a surface of an emitter

$$A_n(z_n=0,r_n)=\begin{cases}\dfrac{A(z_n=0,r_n)}{A(z_n=0,r_n=0)}=\dfrac{A(z_n=0,r_n)}{A_0}=\left(1-r_n^2\right)^2, & \text{при} \quad r_n\le 1;\\ 0, \quad \text{при} \quad r_n>1.\end{cases} \qquad (2)$$

where $z_n = z/l_{d0}$; $l_{d0} = \omega_0 a^2/2c_0$; $r_n = r/a$. Axial allocation of complex amplitude for given is featured by expression(α_0 – decay factor on frequency ω_0) [5] :

$$A_n(z_n,0)=\left\{1+2\cdot z_n^2\left[\cos\left(\frac{1}{z_n}\right)-1\right]+i2z_n\left[1-z_n\sin\left(\frac{1}{z_n}\right)\right]\right\}\exp(-\alpha_0 z_n l_{d0})\cdot$$



a) **b)**

Fig. 4. Axial allocations of dispersion attack PI (a) and dispersion parameter (b) in a bundle with sharply expressed boundary

The quantitative discrepancies of the experimental and design values $\Delta\beta_\partial(x)$ also $D_\partial(x)$ are investigation of discrepancy of an actual emitter to requirements (2) which by the form was closer than peak allocation to case of the piston. In operation [3] on an example gaussian and piston emitters it is shown, that transition from smooth, waning to edges, allocations of amplitude to a bundle with sharp boundaries, it is accompanied by the considerable growth oscillation on axial allocations $\Delta\beta_\partial$ and D_∂, caused by amplification of influence of Fresnel zones. Unsymmetrical concerning a horizontal axis oscillation $\Delta\beta_\partial(x)$ also $D_\partial(x)$ confirm presence in the sound beams of two mechanisms of a geometrical variance caused diffraction and interference (Fresnel zone) by the processes, to divide which within the framework of the described method it is not obviously possible.

R E F E R E N C E S

1. Vinogradova M.B., Rudenko O.V., Sukhorukov A.P.theor of waves. M.: the Science. 1979. P.384.
2. Krasilnikov V.A., Krylov V.V.introduction in physical acoustics. M.: the Science. 1984. P.400.
3. Gavriklov A.M.geometrical a variance of velocity of a sound in restricted bundles // News TSURE. Taganrog: Publishing house TRTU. 2003. № 6. P. 130-136.
4. A.M. Gavrilov, R.O. Sitnikov.use of Lissajous figures for measuring phase relations in a spectrum of the three- frequency signal // Proc. High schools. The Nor'.-Caucasian region. Engineering science, № 3, 2006.
5. Boasters H.C., Zhilejkin J.M., Zabolotskaiy E.A.nonlinear the theory of sound beams. M.: the Science. 1982. P. 176