EXPERIMENTAL INVESTIGATION OF THE SOUND MULTIPOLE SOURCE'S PARAMETERS USING SPACE INTENSITY SENSOR[1)]

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The aim of this paper is to present the energetic description of the sound field and first results of the experimental investigation using the space intensity sensor. We offer the multi-elements acoustic sensor that gives the opportunity to find the source's parameters (distance between the observer and the source, direction to the source, power of radiation, its multipole type). It is very important for diagnoses of natural sources and technique. The method of intensity sensor calibration which allows to correct amplitude and phase inaccuracy while computer treatment is proposed. The results of the measurements of the sound multipole source's parameters are presented. The test's experimental data correspond well to the real controlled parameters. So, the principles that were the base of all calculations in this situation are proved to work well. This fact is witness of using the receiving system and the procedure of computer treatment of received information.

I. INTRODUCTION

Recently due to modern equipment, methods of sound field investigation, based on the determination of acoustic field's energetic parameters, has spread widely [1–3]. On the one hand, the information of the field's energetic structure has fundamental character, on the other hand, it is very important for diagnoses of natural noise sources and technic.

The investigation of the complicated wave field energetic structure is a new area in air- and hydroacoustics. It is called sound intensity method. With modern equipment not only sound pressure, but the spatial distribution of energetic field characteristics may be measured. This possibility is based on the exploitation of the multichannel systems for informational treatment, which we shall discuss later. The cases, when the radiated wave field is the result of the wave system interference, are to be of most importance.

These problems are connected with the acoustic diagnosis of technical objects and natural sound sources, or with the development of sound absorption methods, or with the determination of sound characteristics.

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II. THEORETICAL CONSIDERATION

The sound intensity method is based on several physical preconditions [4].

The noise acoustic field is known to be described by statistical methods using the corresponding moments of the occasional field quantities. Let us suppose that the process we shall regard is established. Then the main characteristic to be measured is the paired correlation function, with which the spectral densities of the acoustic fields energetic characteristics, for example, densities of potential Π and kinetic energy K, energy flow density vector $\boldsymbol{S}$, are connected.

The wave field energetic structure can be characterized entirely by the moving liquids energy-momentum 4-tensor. That is why the quantities Π, K, S role is so fundamental.

The classical approach gives the basic magnitudes of these tensor components:

$$\begin{aligned} \tau_{oo} &= \tau^{oo} = \frac{\rho_o v^2}{2} + \frac{p^2}{2\rho_o c^2} = K + \Pi, \\ \tau_{\alpha\beta} &= \tau^{\alpha\beta} = \rho_o v_\alpha v_\beta = T_{\alpha\beta}, \\ \tau^{o\alpha} &= -\tau_{o\alpha} \sim \rho v^\alpha. \end{aligned} \tag{1}$$

These quantities determine the acoustic noise field thin energetic structure entirely. Here the components $\tau_{o\alpha}$ are proportional to the momentum flow density vectors components ρv_α. The acoustic energy flow density is determined by $S^\alpha = \rho v^\alpha \sim c^2 \tau^{o\alpha}$. Here c is sound velocity, ρ_o is nonperturbed substance density. For a synonymous characterizing of the investigated wave field it is necessary to know the quantities Π, K, $\boldsymbol{S}$, $T_{\alpha\beta}$, as they determine the spectral densities of the corresponding energetic characteristics. That is the basis of the sound intensity method, because these quantities may be determined experimentally and include the information about amplitude and phase of wave field characteristics.

Finally, let us stress that the significant part of noise investigating results relates to the far sound field. Pressure level is a good description of it. In the region, where sound pressure and vibration velocity in a sampling point have phase coincidence, there the main energetic characteristics may be determined by measuring the pressure level under the certain direction to the source. In the close field the situation becomes essentially complicated, because of the interference effects. These effects appear due to the defined phase correlations and geometrical sources distribution influence to the field structure features. Therefore, to describe the close area sound field completely, one has to determine the acoustic pressure level, as well as the other field characteristics. It means that except Π, we should know the level of $K, \boldsymbol{S}, T_{\alpha\beta}$.

According to the determination, $\boldsymbol{S}(\omega)$ is the intensity noise field's spectral density vector and it may be written as $p(\omega)v^*(\omega)$, where the asterisk is the sign of complex conjugation. Such presentation is not occasional. Since vector's components are obviously related to amplitude and phase of the pressure's and velocity's

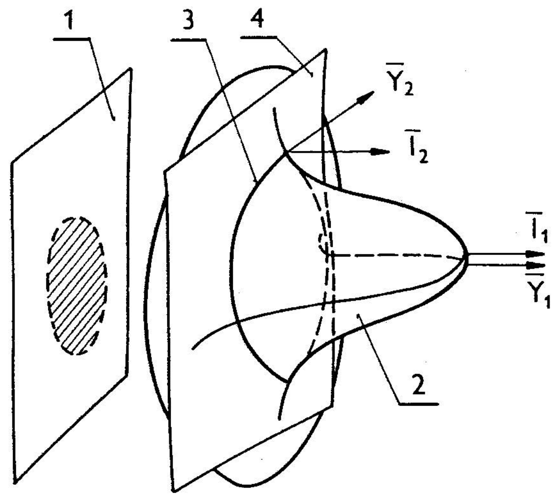

Fig. 1. The structure with rot $\boldsymbol{I} = 0$ is formed near the axialsymmetrical radiator: 1 – the plane of the radiator; 2 – the surface of $|p|$ = Const; 3 – the line of rot $\boldsymbol{I}$ = Const; 4 – the surface of constant phase.

Fourier-components, so their assignment can simply determine the field. The physical sense of real (active) and imaginary (reactive) $\boldsymbol{S}$-vector's components is quite obvious: $\boldsymbol{I} = \mathrm{Re}\,\boldsymbol{S}(\omega)$ characterizes the process of acoustic energy propagation in medium and is normal to the sound wave constant phase surface; $\boldsymbol{Y} = \mathrm{Im}\,\boldsymbol{S}(\omega)$, that includes the information about the potential energy field's spatial density distribution, i.e. the sound pressure level, is normal to the equal level surface of the acoustic pressure. Hence there appears an interesting property which can be easily realized in a close wave area: the wave field is able to create the vortex-type structures in the spatial domains, where $\boldsymbol{I}$ and $\boldsymbol{Y}$ vectors are noncolinear (fig. 1.).

The simple analysis shows that the vectors components satisfy the following equations:

$$\begin{aligned} \mathrm{div}\,\boldsymbol{I} &= SW^{(i)}\delta(\boldsymbol{x} - \boldsymbol{x}_i), \\ \mathrm{rot}\,\boldsymbol{I} &= 2\omega[\boldsymbol{I}, \boldsymbol{Y}]/c^2\Pi, \\ \mathrm{div}\,\boldsymbol{Y} &= \omega(K - \Pi), \\ \mathrm{rot}\,\boldsymbol{Y} &= 0. \end{aligned} \tag{2}$$

Here, the sound sources, characterized by the power $W^{(i)}$, as well as the absorbers, are supposed to be localized in the spatial regions, which are small in comparison with the characteristic spatial scale of the wave process. So they can be spatially localized by a delta-functional approach.

The equations (2) show that the combined measuring of both active and reactive components of the acoustic energy's flow density vector permits effective detection of the acoustic sources.

III. ENERGETIC STRUCTURE OF ACOUSTIC FIELD NEAR SOURCES

We investigate the space distribution of the energy characteristics near the multipole sources, as well as we illustrate a number of typical examples of the connection of these characteristics with actual parameters of the sources [5].

As we have mentioned before, the complex structure of near source field allows to use the vector of energy density flow: $\boldsymbol{S} = \boldsymbol{S}(\omega) = p(\omega)\boldsymbol{v}^*(\omega) = \boldsymbol{I} + \mathrm{i}\boldsymbol{Y}$.

Let the motion of the medium near the compact source be singularly described by the velocity potential. In accordance with the cause principle, the sound source forms in the medium a separate spherical wave of the velocity potential, and, consequently, the pressure since the potential satisfies the wave equation. Having this circumstance in mind, it is not difficult to show that there exists the correlation between the radial velocity and the pressure

$$v(r,t) = \frac{p(r,t)}{\rho c} + \frac{1}{\rho r}\int_{-\infty}^{t} dt'\, p(r,t'), \tag{3}$$

where: ρ is the density of air, v is the velocity of sound, r is the distance between point of source and point of observation.

In eq. (3) the first member is the wave components, and decreasing in accordance with the condition of radiation and equal to the power flow of energy radiated from the source.

In eq. (3) the second sum describes the hydrodynamics motion of the medium, not connected with the wave process of energy transference, and the decreasing is comparable to r^2. It describes a "fur-coat" round the source. To be sure of this, one should put $c \to \infty$ in eq. (3) (i.e. hydrodynamics approximation). In this approximation, the second member in eq. (3) is non-zero, unlike the first one.

By using the Fourier-transformation of eq. (3), the Fourier components of velocity and pressure are connected by

$$v(r,t) = \frac{1}{\rho c} p(r,t)\left[1 + \frac{1}{kr}\right], \tag{4}$$

where: $k = \omega/c$ is the wave number. Equation (3) shows the physical meaning of the phase mismatch between the Fourier components of velocity and pressure. The phase mismatch also shows that there also exists a non-wave component of the medium motion near the source, which is not connected with energy radiation.

Having considered the p–$\boldsymbol{v}$ connection, following from the linear equations of hydrodynamics, the $\boldsymbol{S}$ – vector can be presented in the form: $\boldsymbol{S} = \frac{\mathrm{i}}{\rho\omega} p\,\mathrm{grad}\,p^*$.

Omitting the calculations we shall demonstrate the final result. For the multipole source of noise, it yields:

$$\boldsymbol{S} = \frac{\mathrm{i}k^2|M_{Lm}|^2}{\rho\omega[(2L+1)!!]^2}\left\{h_L^{(1)}(kr)Y_{Lm}(\boldsymbol{n})\mathrm{grad}\,(h_L^{(2)}(kr)Y_{Lm}^*(\boldsymbol{n}))\right\}. \qquad (5)$$

Here $h_L^{(1,2)}(kr)$ is Hankel's function of orders one and two, $Y_{Lm}(\boldsymbol{n})$ are spherical functions, $\boldsymbol{n} = \boldsymbol{x}/r$ is unit-vector, M_{Lm} - the debit of source.

For the aim of this work the eq. (5) is fundamental.

Let us use the convenient form of the grad-operator: i.e. grad $= \boldsymbol{e}_r\partial_r - \mathrm{i}[\boldsymbol{x}, \hat{L}]/r^2$. The operator of momentum of the motion quantity $\hat{L} = -\mathrm{i}[\boldsymbol{x}, \mathrm{grad}]$ affects only the angle variables.

The radial component of vector $\boldsymbol{S}$, according to eq. (5), can be expressed in the form:

$$S_{(r)} = (\boldsymbol{e}_r \cdot \boldsymbol{S}) = \frac{\mathrm{i}k^3|M_{Lm}|^2|Y_{Lm}|^2}{\rho\omega[(2L+1)!!]^2}D_L(kr). \qquad (6)$$

Here was used the approximation, obtained from the formula:

$$D_L(z) = h_L^{(1)}\partial_z h_L^{(2)} = \frac{1}{2}\partial_z(j_L^2 + n_L^2) - \frac{\mathrm{i}}{z^2} \qquad (7)$$

(j_L, n_L — Bessel's and Neimann's spherical functions). The expression is correct for any meaning of the argument $z = kr$.

Now we shall calculate the component $\boldsymbol{S}$, which is orthogonal to the vector $\boldsymbol{x}$. Everywhere we suppose summing by the repeated index from 1 to 3.

The second sum of the grad-operator is convenient to write in components: $-\mathrm{i}\varepsilon_{\alpha\beta\gamma}r_\beta\hat{L}_\gamma r^{-2}$, where $\varepsilon_{\alpha\beta\gamma}$ is the unit of the antisymmetric tensor of the third degree. The complex fundamental 3-vectors e_μ, which give definite advantage in the calculation with the spherical functions, are connecteded with the Cartesian coordinate unit vectors by:

$$e_0 = e_z; \qquad e_1 = -(e_x + \mathrm{i}e_y)/\sqrt{2}; \qquad e_{-1} = (e_x - \mathrm{i}e_y)/\sqrt{2};$$

under the conditions: $e_\mu \cdot e_{\mu'} = \delta_{\mu\mu'}$; $\mu = 0, -1$.

Taking into account these conditions, the relation is written:

$$\hat{L}_\mu Y_{Lm} = (-1)^\mu\sqrt{L(L+1)}(L,\, 1,\, m+\mu,\, -\mu lL,\, m)Y_{L\,m+\mu}. \qquad (8)$$

Here $(L_1,\, L_2,\, m_1,\, m_2 lL\, m)$ are the vector addition coefficients or the Clebshe-Gordan coefficients. Taking into consideration $Y_{Lm}^* = (-1)^m Y_{L,-m}$ and the properties of symmetry for the Clebshe-Gordan coefficients, the expression (8) can be simplified.

Then, in view of the general expression for the $\boldsymbol{S}$-vector (5), as stated above, expressing the angle variable grad-operator, and also that can be given in the form

$r_\beta = \sqrt{4\pi/3}rY_{1\beta}$, the tangential components of vector $\boldsymbol{S}$ can be obtained in the following form:

$$S_{(tr)} = k^2(-1)^{m+\mu}\sqrt{\frac{4\pi}{3}}|M_{Lm}|^2|h_L^{(1)}(kr)|^2\rho\omega r\times$$
$$\times\, \varepsilon_{\alpha\beta\gamma}\frac{\sqrt{L(L+1)}Y_{1m}Y_{1\beta}Y_{L,-m+\mu}}{\rho\omega r[(2L+1)!!]^2}(l,\, 1,\, m,\, -\mu,\, \mu lL,\, m). \qquad (9)$$

In this formula we suppose summing by repeated indexes. The relations (6), (9) present precise expressions for the $\boldsymbol{S}$-vector components from the multipole source of order L.

In spite of a seldom appearance they are highly informative.

It is not difficult to see that energy flow vector components can generally contain both real and imaginary parts. Their physical meaning was discussed earlier.

The analysis of the expressions (6), (9) shows that they contain the amount of information sufficient to determine the coordinates and the orientation of the multipole sound source in space. First of all it is possible to solve this problem, because the real $\boldsymbol{I}$ and imaginary $\boldsymbol{Y}$ parts of the $\boldsymbol{S}$-vector are not collinear in any point of space observation. For example, in the spherical system of coordinates for the dipole sound source the parts are defined by:

$$\boldsymbol{I} = \boldsymbol{e}_r\left\{\frac{M^2k^2\cos^2\vartheta}{16\pi^2\rho\omega r^2}\right\};$$
$$\boldsymbol{Y} = \boldsymbol{e}_r\left\{\frac{M^2}{16\pi^2\rho\omega}\left(\frac{k^2}{r^3} + \frac{2}{r^5}\right)\cos^2\vartheta\right\} + \qquad (10)$$
$$+\, \boldsymbol{e}_\vartheta\left\{\frac{M^2}{16\pi^2\rho\omega}\left(\frac{1}{r^2} + \frac{k^2}{r^3}\right)\sin\vartheta\cos\vartheta\right\};$$

where $M = Ad$, d — is the distance between the point sources of the same productivity A. The non-triviality of this type of source sound-field structure results the non-equality of rot $\boldsymbol{I}$ to zero:

$$\mathrm{Curl}\,\boldsymbol{I} = \boldsymbol{e}_\varphi\frac{M^2k^2}{16\pi^2\rho\omega r^2}\sin 2\vartheta. \qquad (11)$$

It is important to note that in such sound fields the motion of medium particles is realized by ellipse trajectory and, in other words, the velocity vector in the field presentation rotates along the ellipse plane.

It is easy to see from the equations (10), (11) that by measuring the dipole source's sound field vectorial energy characteristics magnitude and direction, one can obtain the source location in full volume. In particular, to solve this problem we can use calculation formulae determined by

$$\frac{(\boldsymbol{Y}\cdot\boldsymbol{e}_\vartheta)}{|\mathrm{Curl}\,\boldsymbol{I}|} = \frac{1+(kr)^2}{2k(kr)^2}; \quad W = \frac{4\pi}{3}\frac{|\boldsymbol{I}|}{\cos^2\vartheta}; \quad \frac{|\boldsymbol{I}|}{|\mathrm{Curl}\,\boldsymbol{I}|} = \frac{1}{2}r|\mathrm{ctg}\vartheta|, \qquad (12)$$

where W is the power of a dipole source. The direction to the dipole source is defined by the direction of the $\boldsymbol{I}$-vector, the plane, in which the source is oriented in the plane of $(\boldsymbol{I}, \boldsymbol{Y})$-vectors, the distance r and the angle ϑ of the dipole's axis to the direction $\boldsymbol{I}$-vector can be found from equation (12).

An interesting supplement of the conducted general consideration is the possibility to determine the type of the source due to measuring of vectorial energy characteristics. To make the essence of the question clear, let us consider the case $z = kr < 1$. From the exact presentation (7) we can find:

$$\frac{1}{2}\partial_z |h_L^{(1)}|^2 \cong -\left\{\frac{(L+1)[(2L+1)!!]^2}{z^{2L+3}}\right\}. \tag{13}$$

Then from (6) we obtain the expression for the radial component of intensity:

$$S_{(r)} = \frac{k^3 |M_{Lm}|^2 |Y_{Lm}|^2}{\rho\omega[(2L+1)!!]^2}\left\{\frac{1}{z^2} - i\frac{(L+1)[(2L+1)!!]^2}{z^{2L+3}}\right\}. \tag{14}$$

Further it is not difficult to see that by the frequency dependence of the function

$$\Xi(\omega) = \frac{|\mathrm{Re}\, S_{(r)}(z)|}{|\mathrm{Im}\, S_{(r)}(z)|} \tag{15}$$

useful information can be acquired about the order of multipole of the source. Indeed we obtain

$$\frac{\Xi(\omega_1)}{\Xi(\omega_2)} = \left(\frac{\omega_1}{\omega_2}\right)^{2L+1}. \tag{16}$$

Here L is the multipole order ($L = 0$ — monopole source, $L = 1$ — dipole source).

It should be noted that this relation is applicable in the range of low frequencies.

IV. METHOD OF CALCULATION

We offer the multi-elements acoustic intensity sensor that gives the opportunity to determine all three complex components of the $\boldsymbol{S}$-vector. Hence it is possible to find the source's parameters we are interested in (distance between the observer and the source, direction to the source, power of its radiation), and its multipole type.

The acoustic intensity sensor consists of four isotropic microphones situated in the tops of the tetrahedron. The results of the measuring are calculated to the centre of sphere, describing the tetrahedron.

The characteristic (directivity pattern) of the sensor was proved to be isotropic in space. It means that it has no influence what direction we choose, the sensor determines the quantity and direction of the complex $\boldsymbol{S}$ - vector's components equally well (fig. 2).

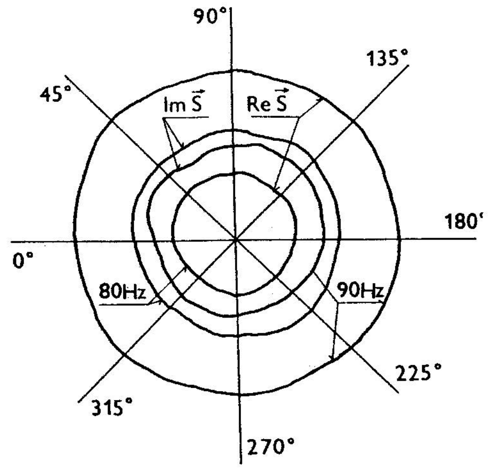

Fig. 2. Directivity pattern of the sensor.

Let the characteristic acoustic wave length fulfill the condition $\varepsilon = kl \ll 1$ ($l = \max r_n$ — system size). For the fourmicrophones system this presentation can be written down in the form of the matrix:

$$\hat{p}_m = \alpha_{mj}\hat{P}_{oj}, \qquad \hat{P}_{oj} = \alpha_{jm}^{-1}\hat{P}_m, \qquad \hat{P}_{oj}^T = |P(r_0), \partial_x P(r_0), \partial_y(r_0), \partial_z(r_0)|, \tag{17}$$

where P_m is sound pressure measured by the microphone number m, α_{ij} — coefficient that depends upon the geometry of the system.

The matrix system (17) yields the quantity of Fourier-components of the sound pressure and the projections of the oscillating velocity on the coordinating axis in the point of observation. Now it can be written down in this way:

$$\begin{aligned} P(r_o) &= \frac{1}{4}(P_1 + P_2 + P_3 + P_4) \\ U_x(r_o) &= \frac{1}{\rho\omega}\partial_x P(r_o) = \frac{1}{\rho\omega\sqrt{2}d}(-P_1 + P_2 - P_3 + P_4) \\ U_y(r_o) &= \frac{1}{\rho\omega}\partial_y P(r_o)\frac{1}{\rho\omega\sqrt{2}d}(-P_1 + P_2 + P_3 - P_4) \\ U_z(r_o) &= \frac{1}{\rho\omega}\partial_z P(r_o) = \frac{1}{\rho\omega\sqrt{2}d}(-P_1 - P_2 + P_3 + P_4). \end{aligned} \tag{18}$$

Here the d is distance between the microphones.

Having the sound pressure level determined, one can obtain quantities and direction in space of the vectors $\mathrm{Re}\,\boldsymbol{S}$ and $\mathrm{Im}\,\boldsymbol{S}$. It is possible to do it with the help of the corresponding algorithms [5].

The knowledge of the pointed energetic characteristics of the field affords the location of the source. The distance — r; the angles of the orientation — Θ, φ; the power of radiation — W; the multipole type may be determined (12), (15), (16).

V. MEASURING COMPLEX

In order to register the energetic parameters of the acoustic field and to determine the sources parameters, the measuring complex that includes the multi-elements intensity sensor and the computer was assembled.

Preliminary measurements have been carried out by using the emitters of the monopole and the dipole type in the anechoic chamber of the Department of Acoustics at the Moscow State University.

The sound source has been situated in the centre of the anechoic chamber. The receiving system was put at some distance from the source. The acoustic signals from the source were received by four identical microphones of the sensor. Electric signals are proportional to the acoustic characteristics of the field - pressure and signal phase. Numerical magnitudes of these electric signals were given in the computer to calculate energetic parameters of the field and the source characteristics.

VI. METHOD OF CALIBRATION

It has to be noted that for intensity measurements extraordinary exact requirements on the exploited equipment are applied. That is the reason of high attention to the calibration method.

While measuring the equipments characteristics — amplitude and phase — were controlled. Calibration of the tracts of the measuring complex and the receiving system has been done and immediately, the important role of the amplitude and the phase inaccuracy of the receiving system microphones was cleared. This led to the necessity of their most exact correlation. Preliminary microphones calibration was carried out by pistonphone of "Bruel & Kjer". Nevertheless, because of the limited calibration precision, there exists some amplitude and phase inaccuracy that is not admissible. Thus extra exact requirements on amplitude and phase correlation of microphones are necessary.

To compensate microphones inaccuracy, we created the computer program for the calculation of the amplitude and the phase corrections γ_n which should be added to each microphone on each frequency. This approach is based on the fact that while turning the receiving system - intensity sensor - around one of the axes (the centre of coordinates is in the centre of the tetrahedron), the $\boldsymbol{S}$-vector components theoretically are harmonic functions of angle turning. The obtained data were compared with the ideal ones. The expression, allowing to calculate corrections γ_n:

$$C^{-1}_{nm}\langle y_m\rangle = \langle p_n\rangle(1+\gamma_n). \qquad (19)$$

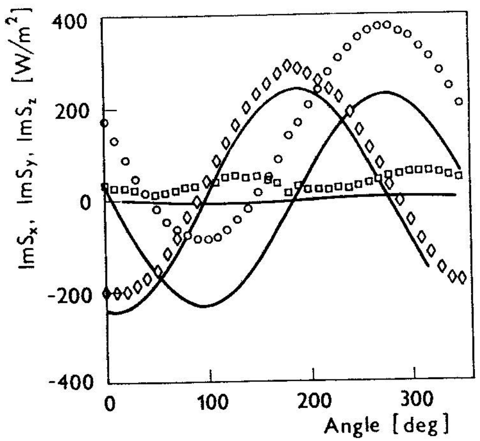

Fig. 3. Imaginary parts of $\boldsymbol{S}$-vector components.

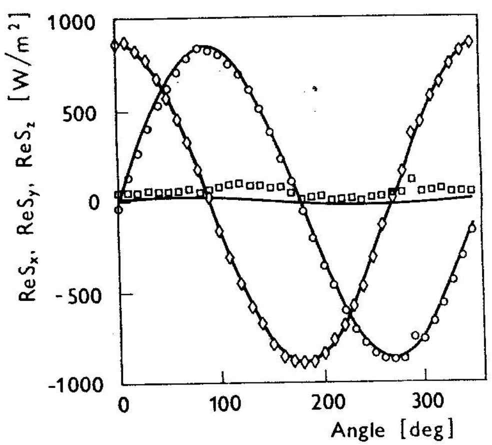

Fig. 4. Real parts of $\boldsymbol{S}$-vector components.

Here C_{nm} — matrix, depending on the system geometry, y_n — ideal data, p_n — measured pressure, γ_n — amplitude and phase microphones corrections.

For example, fig. 3 presents imaginary (Im$\boldsymbol{S}$) parts and fig. 4 presents real (Re $\boldsymbol{S}$) parts of $\boldsymbol{S}$- vector components, obtained by the intensity sensor turning around the z-axis, without and with amplitude and phase corrections (○ — x-component Im $\boldsymbol{S}$ and Re $\boldsymbol{S}$, ◊ — y-component, □ — z-component). The line is the computer treatment result including by (19) amplitude and phase corrections.

The suggested method of amplitude and phase correction seems to be sufficiently reliable and gives the opportunity to improve significantly the source parameters determination precision.

Ideally, in an anechoic chamber free field conditions are to be created. For us, the regions of low frequencies have been of the greatest interest, but in these regions the chamber does not realize its function. Unfortunately, the effects that concern, for example, the reflection of the radiated waves from the chamber walls appeared to be essential, and so on. This made us taking into account these undesirable factors and their influence on calibration and the system action.

Before using the sensor it was necessary to evaluate the chamber quality, it means its ability to imitate the free field. We tested the law of the pressure level falling in the field of the monopole type source. Declination of the pressure amplitude reverse proportionality to distance between the centre of the radiating source and the point of observation has been determined. These evaluations afforded to choose the suitable frequency range with minimum distortion of the sound field structure.

On the other hand it was found that the test had to be carried out on just short enough distances from the sound source, because there the direct wave contribution exceeds significantly corresponding the reflected wave field contribution. To evaluate the distortion contribution, it was found that just near the receiving system the field distortion was determined by the factor:

$$F = 1 + ikre^{i2ka}\left(z_k^{-1} - 1 - (ka)^{-1}\right)\left(e^{ik\eta}\right) \tag{20}$$

where r is distance between the source and the receiving system, a is the characteristic chamber's size, $r \ll a$, $kr < 1$, z_k is the wall impedance.

The second sum in (20) describes the wave distortion because of the chamber walls; the expression in brackets means the form-factor of the chamber configuration, which is described by η — quantity. Taking into account the diffraction corrections and corresponding experimental investigations, the range of distance to measure was chosen.

VII. RESULTS

After the preliminary analysis had been done, the series of measurements were carried out (fig. 5,6). In fig. 5 points correspond to experimental quantities of multipole types ($L = 0$ — monopole, $L = 1$ — dipole), in fig. 6 — distance and in fig. 7 — direction to the source. Everything was obtained for different frequencies.

VIII. CONCLUSION

The test experimental data correspond well to the real controlled parameters. Thus the principles that were the base of all calculations in this situation have proved to work well. This fact is witness of using the receiving system and the procedure of computer treatment of the received information.

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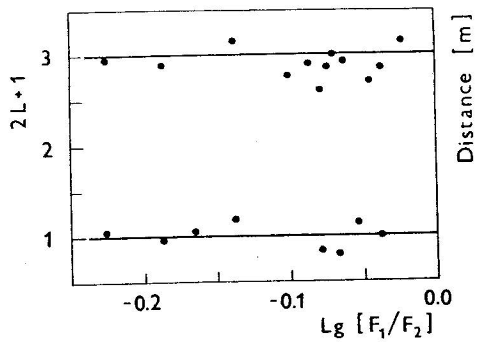

Fig. 5. Determination of the source multipole type.

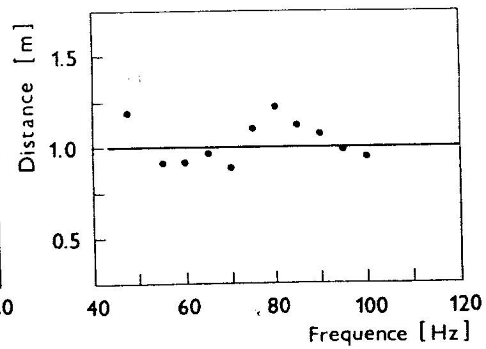

Fig. 6. Determination of distance to the source.

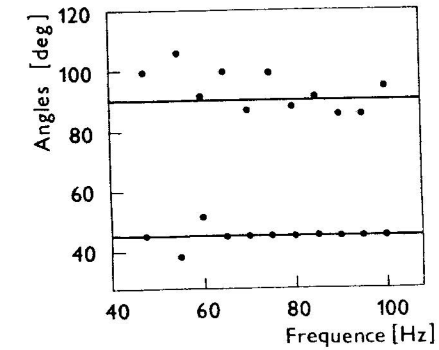

Fig. 7. Determination of direction to the source.

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ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ ПАРАМЕТРОВ МУЛТИПОЛЬНОГО ИСТОЧНИКА ЗВУКА С ПРИМЕНЕНИЕМ ДАТЧИКОВ ПРОСТРАНСТВЕННОЙ ИНТЕНСИВНОСТИ

В работе приведено энергетическое описание звукового поля и первые результаты исследований с применением датчиков пространственной чувствительности. Показан мултиэлементный акустический датчик, позволяющий определять параметры источника (расстояние от источника, направление в котором находится источник, его мощность, излучение и мултипольность). Датчик оказывается полезным при диагностике естественных источников. Показан способ правильной калибровки датчика с исправлением амплитудных и фазовых неточностей с применением компютера. Даются также результаты измерений параметров мултипольных источников, которые хорошо согласуются с реальными. Поскольку, принципы работы, полученные на основании расчетов хорошо себя зарекомендовали, датчики можно применить в интелигентной системе приема информации на основе компютера.