Statistics of underwater acoustic signals scattered by the rough water surface covered with a layer of oil substances*

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Waving surface
Statistical distribution
Oil film

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Abstract

Statistical distributions of amplitude of an acoustic signal scattered at a rough water surface covered with various layers of oil substances of various physical properties were examined under laboratory conditions. Statistical parameters describing the distributions were presented in the form of two-dimensional dependences on velocity of an air stream in the measuring tunnel and a thickness of the oil film. The relationship between the values of statistical parameters and molecular weight of a fraction, as well as a thickness of the layer of oil substance covering the surface was empirically estimated for a wide range of air stream velocities.

1. Introduction

Growing pollution of oceanic waters, particularly coastal zones, becomes a very important problem. Crude oil spills in coastal zones adjacent to human settlements are one of the most dangerous. Numerous services and organisations look for remote systems of identification and control of ecological condition of seas as the first step in checking and removal of this kind of pollution. However, no systems have yet been proposed meeting simultaneously several requirements, *viz*:

(i) operation under all possible weather conditions,

(ii) independence of the day/night cycle,

(iii) unequivocal assignment of the physico-chemical character of a pollutant.

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The third requirement concerns the ability of discrimination between crude patch oil and other spills of organic substances of anthropogenic or biogenic origin (Hühnerfuss *et al*, 1986, 1986a). The proposed acoustic method is capable of meeting the second and third requirement at limited state of sea. Patch oil strongly influence the field of surface wind waves, gas exchange, and a number of other physical parameters of the process of interaction of sea and atmosphere (Hühnerfuss and Garrett, 1981a). In modern oceanography the studies on variability of wind waves appearing at the surface are closely related to the problem of remote sensing of oceanic processes. Optical methods utilizing various spectrum ranges (Ermakov and Pelinovsky, 1984; Ermakov *et al*, 1986; Hühnerfuss *et al*, 1986), lidars (Hühnerfuss *et al*, 1986a) or microwave radars (Hühnerfuss *et al*, 1981, 1983, 1983a; Hühnerfuss and Garrett, 1981a) have been used for these purposes. Also satellite systems are recently used (Gairola and Pandey, 1986; Pandey *et al*, 1986; Sarkar and Kumar, 1986). The author attempts for some years to apply for this purpose the method of ultrasound beam scattered at a rough surface (Pogorzelski, 1985). So far, the method allowed the determination of the effect of the presence of an oil film at the surface of water on propagation conditions of capillary surface waves (Pogorzelski *et al*, 1984, 1986). Recently it was used for the determination of the relationship between surface changes and characteristics of a scattered signal with respect to surface waves induced by an air stream in a laboratory water–air tunnel. The paper aims at presentation of the method, already mentioned (Pogorzelski *et al*, 1986a) based on statistical analysis of an acoustic signal scattered at rough surface of water. An air stream generates surface wind waves forming a surface with randomly distributed irregularities. An acoustic signal scattered at the surface is also of statistical character which can be quantitatively described by statistical moments of signal amplitude distribution (Brzozowska, 1977). A systematic change in roughness of the surface, resulting for example from the presence of an oil substance film, reveals itself in changes in the values of statistical parameters as compared to the surface of pure water (Pogorzelski, 1986; Pogorzelski *et al*, 1986a). In the author's opinion the presented considerations can be useful for creation of a remote, contactless method of evaluation of the state of pollution of natural waters with oil-origin substances, based on a similar principle, yet built in the form of a free-floating, automatic measuring buoy.

2. Apparatus

An air–water tunnel of the dimensions: length 0.53 m, width 0.23 m, and height 0.09 m (from water surface to the upper deck plate) constitutes a main element of the apparatus presented in Figure 1. Depth of water in the tunnel is equal to 0.35 m. A stream of air is generated by two fans, which allows forming

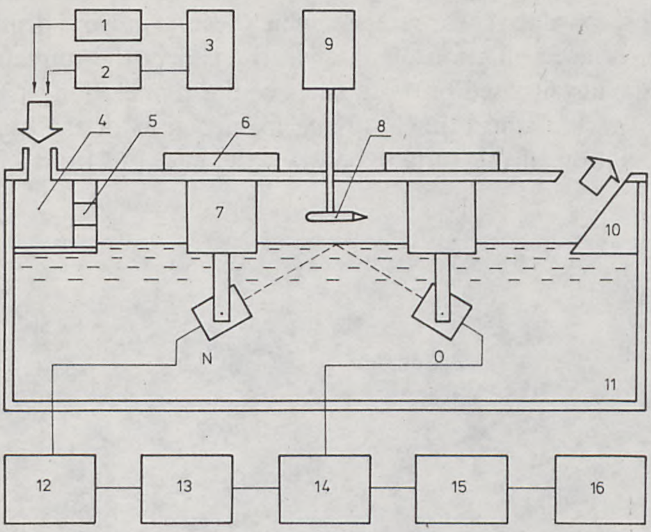

Fig. 1. Block diagram of the apparatus
Denotations: 1, 2 – fans, 3 – autotransformer, 4 – inlet nozzle, 5 – air stream guide vanes, 6 – elements retaining and controlling the position of transducers, 7 – shields, 8 – anemometer pressure probe, 9 – Prandtl's tube liquid-column gauge, 10 – inclined end of the tunnel, 11 – water container, 12 – ultrasonic transmitter, 13 – oscilloscope, 14 – ultrasonic receiver, 15 – envelope detector, 16 – statistical distribution analyser. Ultrasonic transducers: N – transmitting, O – receiving

the characteristics of the stream, and introduced it to the tunnel through a nozzle equipped with guide vanes. A supply system allows smooth adjustment of the air stream up to 15 ms^{-1}. Velocity measurement was accomplished by means of a pressure probe – Prandtl's tube situated at half height of the tunnel directly above the point of ultrasound beam scattering. The opposite bank of the tunnel is inclined at an angle $\beta = 40°$ with respect to water surface, which singificantly reduces the effect of reflected waves. Reflection coefficient ε of a surface wave reflected from a limiting bank, defined as a ratio of the amplitude of the reflected wave a_r to the amplitude of the incident wave a_i, depends on depth of water, height and length of a wave, as well as slope and porosity of the bank absorbing waves. The value of ε can be estimated on the basis of an approximate dependence (Miche, 1951):

$$\varepsilon = \frac{(2\beta/\pi)^{0.5}(sin^2\beta/\pi)}{a_i k_i}, \tag{1}$$

where $k_i = \frac{2\pi}{\lambda_i}$ is an angular wave number of incident surface wave of a length λ_i. The estimated value of ε is equal to *ca* 0.15 (for $a_i = 0.05$ m and the shortest waves in the tunnel) which agrees with observations of other scientists (Bole and Hsu, 1969).

An air steam induces at the surface shear stresses, which results in wind drift and an unfavourable effect of accumulation of water at the end of the tunnel. Figure 2 presents special shields situated on both sides of the tunnel along its entire length. They screen part of the tunnel surface from action of the air stream and allow free circulation of the surface between the end and front of

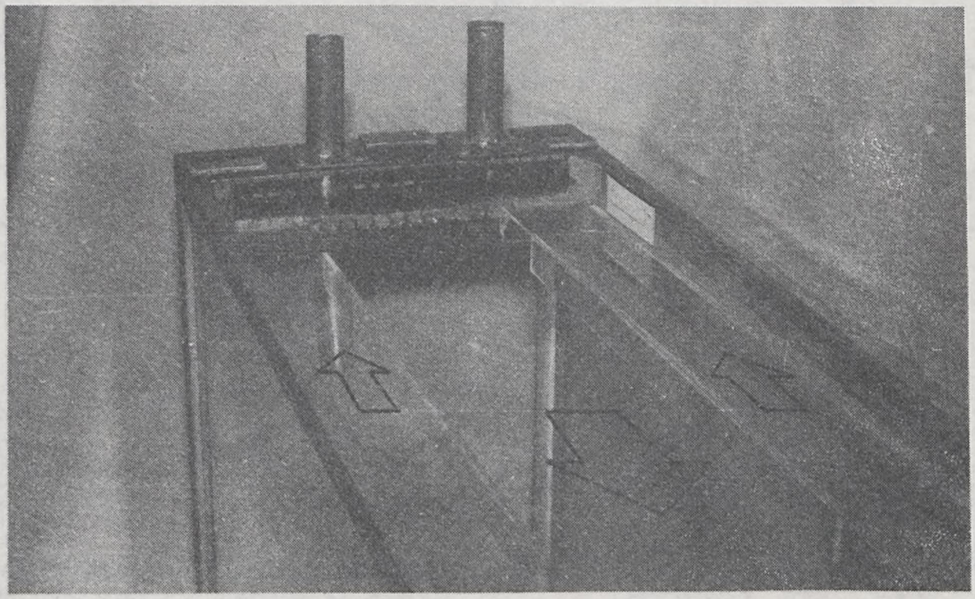

Fig. 2. Details of design of the measuring tunnel
Arrows indicate direction of wind drift of free water surface and surface hidden behind the shields

the tunnel (drift direction is indicated by arrows). Visual observation of displacement of dust particles at the surface confirmed the dependence of drift u_d on air stream velocity in the tunnel U in the following form: $u_d = (0.02-0.03)\ U$. Such a dependence was observed by numerous scientists (Hühnerfuss *et al*, 1976; Papadimitrakis, 1986). Application of shields also allows to obtain an oil layer of uniform thickness along the entire length of the tunnel without the necessity of cumbersome pumping of oil (Hühnerfuss *et al*, 1976). Hence, the conditions created for generation of wind waves and spreading of oil films are close to natural.

An acoustic channel (Fig. 1) consists of a pulse operating ultrasonic transmitter, which forms series of pulses lasting few μs of rectangular envelope, filled with sine waves of 10 MHz frequency repeated with a frequency of 3 kHz. A transmitting quartz transducer (Fig. 3) connected to the transmitter is situated below water surface at the depth of *ca* 0.05 m and the incident angle of the beam θ_1 is equal to 58°. The signal is received after scattering by an

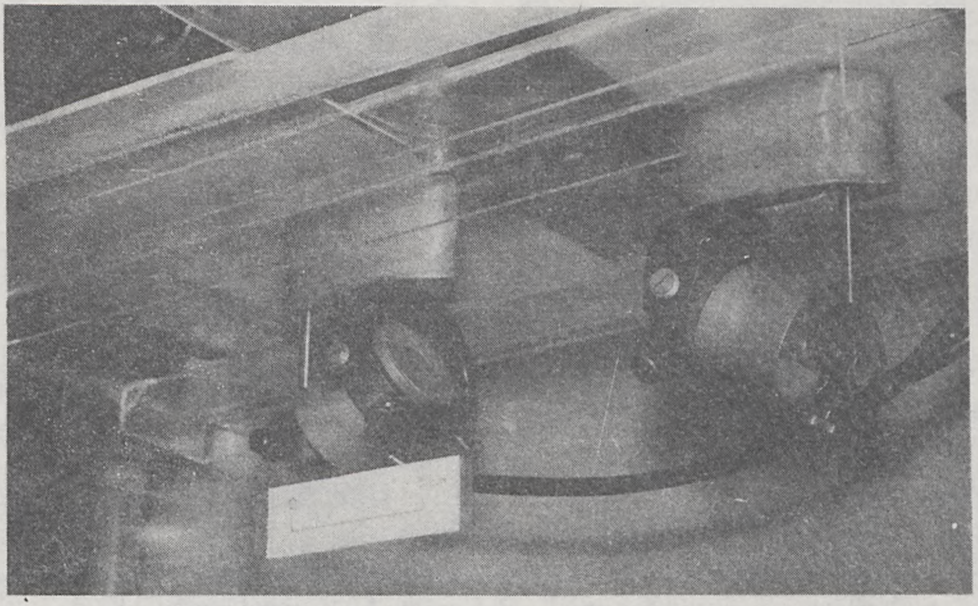

Fig. 3. Ultrasonic transducers of the acoustic channel of the measuring system
Elements retaining and controlling the position of transducers are hidden behind sectional covers, which reduces sources of turbulence in the tunnel

identical receiving transducer in the direction of mirror reflection ($\theta_1 = \theta_2$). The signal is subsequently amplified and statistical analysis is performed using Statistical Distribution Analyzer (Type 4420, Brüel and Kjaer) after signal envelope detection.

3. Conditions and methodics of experiment

Small dimensions of the tunnel cause that mainly capillary waves of high frequency are generated. Such waves occur under natural conditions on the tilted faces of long gravity waves. Changes in surface properties of water, due for example to the presence of an oil film, determine the conditions of propagation of short gravity waves and capillary ripples (Ermakov and Pelinovsky, 1984; Ermakov *et al*, 1986; Hühnerfuss *et al*, 1976, 1981). The later are characterized by particular shape (Crapper, 1957), *ie* they have a large slope and a small amplitude (Cox, 1958; Schooley, 1958). The most suitable acoustic system for investigations of scattering on this kind of rough surface consists of a transducer of narrow directional pattern, irradiating a small area of the surface and creating the conditions of scattering on so-called high frequencies, *ie* at large values of the Rayleigh's parameter $R_a \gg 1$ ($R_a = 2k_1 \zeta cos\theta_1$; $k_1 = 2\pi/\lambda_1$ – angular wave number; λ_1 – length of acoustic wave; ξ – height of surface irregularities (Tolstoy and Clay, 1966)). Waves of the height equal to few mm were observed in the tunnel, which in the case of the applied acoustic system results in values of Rayleigh's parameters of the order of 100.

An acoustic wave scattering function is defined in the Clay and Medwin notation (1977), in the following form:

$$S_{hf} = \frac{R^2 I_s}{I_0 A}, \tag{2}$$

where:
I_s, I_0 – intensity of scattered and incident acoustic waves, respectively,
R – distance between the transducer and the center of scattering surface,
A – area of scattering element.
In the case of scattering of signals of very high frequency $R_a \gg 1$ the scattered field is incoherent. The scattering function S_{hf} at high frequencies does not depend on frequency of waves, mean height of surface waves and correlation radius of irregularities. It depends solely on the mean square slope of irregularities (Tolstoy and Clay, 1966), which makes such a system particularly suitable for investigations on previously described surfaces. The value of the R_a parameter also determines statistics of the scattered signal. At small values of $R_a (R_a \ll 1)$ functions of statistical distribution of amplitudes have the form of Gaussian distribution, at large values of $R_a (R_a \gg 1)$ of Rayleigh's distribution, and at intermediate values – of generalized Rayleigh's-Rice's distributions, gamma distributions, three-parameter lognormal distributions, *etc* (Brekhovsky, 1974; Clay *et al*, 1973; Fortuin, 1970; Horton, 1972). Expansion of the Gaussian distribution in a Gram's-Charlie's series taking into account statistical moments up to the fourth one (Brzozowska, 1977) constitutes a good approximation of experimental distributions. The function of polynomial distribution has the following form (Cramer, 1946):

$$P(X_a) = P_n(X_a)\left[1 + \frac{A_1}{6} H_3(t) + \frac{A_2}{24} H_4(t) + \ldots\right], \tag{3}$$

where:
$P_n(X_a)$ – Gaussian distribution,
X_a, $\bar{X}_a$ – momentary and mean amplitude of signal, respectively,
σ – standard deviation,
$t = (X_a - \bar{X}_a)/\sigma$ – normalized random variable,
$H_3(t) = t^3 - 3t$ and $H_4(t) = t^4 - 6t^2 + 3$ – Hermite's polynomials,
$A_2 = (\mu_4/\sigma^4) - 3$ – coefficient of flattening of the distribution,
$A_1 = \mu_3/\sigma^3$ – coefficient of asymmetry of the distribution,
μ_3, μ_4 – third and fourth central moments of the statistical distribution, respectively.

The A_1 and A_2 parameters, describing deviations of experimental distribution from the Gaussian distribution, were chosen for further discussion together with the normalized mean amplitude $\bar{X}_a/X_{a0}$ (normalization to the value corresponding to reflection from a flat surface $U = 0$) and fluctuation coefficient $\eta = \sigma/\bar{X}_a$.

The system of statistical analysis of a signal measured the amplitude every 0.1 s and the distribution function was determined on the basis of 1800 counts which ensures sufficiently high accuracy of the distribution reproduction. Linear dimensions of the irradiated part of the surface in the direction of the axis connecting the transducers $2X$ and perpendicular direction $2Y$ can be calculated from the following dependences (Tolstoy and Clay, 1966):

$$X = R\Delta\Phi/\cos\theta_1, \qquad Y = R\Delta\Phi, \tag{4}$$

where $\Delta\Phi$ is half-width of the angular directional pattern of the transducer (rad).

In the case of the applied system ($\Delta\Phi = 0.043$ rad, $R = 0.073$ m) these values are equal to $2X = 0.013$ m and $2Y = 0.006$ m. The area of the irradiated region of elliptic shape (for a system of circular cross-section of the directional pattern) is equal to $A = \pi XY = 0.645 \cdot 10^{-4}$ m. The value of $2X$ is comparable to the length of surface wave of 30 Hz frequency at the surface of clean water (0.012 m). Since the scattered signal is averaged over the entire element of the area A, the dynamics of the recorded signal and sensitivity of the system to surface roughness changes decrease with an increase of surface wave frequency (decrease of its length).

The properties of the applied acoustic system allow recording surface waves of 30 Hz and smaller frequency with maximum dynamics. The measuring tunnel was filled with distilled water a few days before the measurements, which allowed elimination of air bubbles and stabilization of temperature. The surface was covered with layers of oil-derivative substances of strongly differentiated properties (Table 1). The following substances were chosen for the inves-

Table 1. Selected physical properties of oil substances used for investigations (at temperature of 292K and pressure of 101.325 Pa) (Pogorzelski, 1985).

Substance	Density $[\cdot 10^3\,\mathrm{kgm}^{-3}]$	Viscosity $[\cdot 10^{-3}\,\mathrm{Pa\cdot s}]$	Surface tension $[\cdot 10^{-3}\,\mathrm{Nm}^{-1}]$
Ethyl gasoline 78	0.724	0.676	20.30
Kerosene	0.761	1.64	21.80
Diesel oil	0.847	3.54	30.61
Extra 15 oil	0.854	11.94	35.72
Marinoll 111 oil	0.853	82.06	36.85
Water	0.998	1.04	72.75

tigations: ethyl gasoline 78, diesel oil, light engine oil *Extra 15* and heavy gear oil *Marinoll 111*. The substances were dissolved in ethyl eter and subsequently a defined quantity of the solution was spread over the surface, thus forming an uniform layer of the thickness h_w ranging from 0.002 to $0.4 \cdot 10^{-2}$ m. The upper limit of the investigated thickness range corresponds to a so-called equilibrium thickness, *ie* thickness of a patch of oil substance after a sufficiently long time after introduction onto the surface (Pogorzelski, 1985). The thickness of the oil film was measured using an ultrasonic defectoscope (Type 510, Unipan), the ultrasonic probe of which was situated in the tunnel perpendicularly to water surface at a few cm depth. The determination was carried out under waveless conditions on the basis of the view on the defectoscope screen, which presented two distinctly separated echoes corresponding to reflection of the beam from two interfacial surfaces of the water/oil and oil/ air layer system. The velocity of the stream of air in the tunnel U was changed in the range $0-15\ ms^{-1}$, and no breaking of waves or formation of foam was observed, which confirms both theoretical predictions (Phillips and Banner, 1974) and experimental results (Hansen and Svendsen, 1970) concerning various designs of water–air tunnels. The performed measurements allowed preparation of two-dimensional dependences of statistical parameters of a random variable distribution on air stream velocity and layer thickness for all the investigated oil substances (Pogorzelski, 1985). Data obtained for clean surface were adopted as a reference in further part of discussion of results.

4. Discussion of results

Figure 4 presents exemplary probability distributions $P(t)$ of amplitudes of the acoustic signal scattered at rough surface of: a) clean water, b) water covered with a diesel oil film of 0.01 thickness, obtained at an air stream velocity equal to $3.5\ m \cdot s^{-1}$. In order to facilitate the comparison between the experimental distribution (solid line) and assumed Gaussian distribution (broken line) of experimentally obtained values of $\bar{X}_a$ and σ, the distributions are presented as functions of the normalized random variable t. The distribution in the case of clean surface (Fig. 4A) reveals left-hand asymmetry (negative values of A_1) and flattening (negative values of A_2) compared to the Gaussian distribution. The shape of the received distribution corresponds well to distributions obtained by other scientists at large values of R_a (Brekhovsky, 1974; Brzozowska, 1977; Clay *et al*, 1973). The presence of an oil film (Fig. 4B) does not affect a mean amplitude of the signal and fluctuation coefficient, but it deepens the left-hand asymmetry and flattening of the distribution compared to clean surface (absolute values of A_1 and A_2 are almost two times higher).

Figures 5–8 illustrate dependences of statistical parameters of signal amplitude distribution on h_w and U only for diesel oil film. A mean normalized amplitude is presented in Figure 5. The character of variability of the curves as a function of U is similar for all the investigated thicknesses of films, although the decay rate is distinctly differentiated. Within the range of the values of U up to $2.8-3\ ms^{-1}$ a very fast decrease occurs and subsequently it becomes much slower with a tendency to reach a constant value. The increase in film thickness results in a further decrease of the slope of surface waves generated in the tunnel which is evidenced by an increase of the mean amplitude of signal.

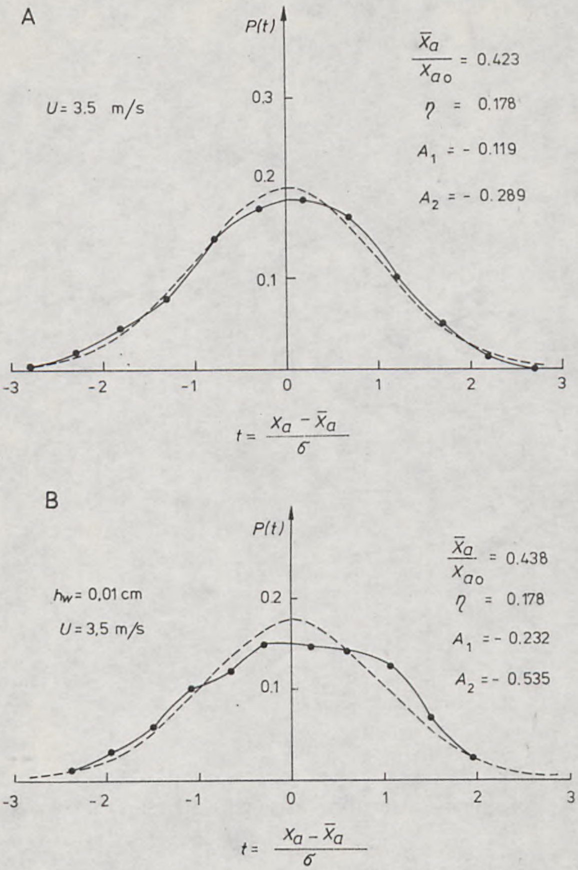

Fig. 4. Probability distributions $P(t)$ of amplitudes of the acoustic signal scattered on a rough surface
A – clean water, B – water covered with a layer of diesel oil of 0.01 cm thickness, at the velocity of air stream equal to 3.5 ms^{-1}; broken line means the theoretical Gaussian distribution (experimental values of $\bar{X}_a$ and σ), solid line means the experimental distribution

Quantitative evaluation of the decrease of the $\bar{X}_a/X_{a0}$ value as a function of U is easier after introduction of the γ function exponent assuming exponential decay in the form:

$$\frac{\bar{X}_a}{X_{a0}} = \exp(-\gamma U). \tag{5}$$

Table 2 lists the values of γ, averaged for the entire range of U for all the examined oil substances and several chosen thicknesses of films. The character of changes of γ with film thickness allows distinguishing two groups of substances. The first one includes light fractions: ethyl gasoline 78 and kerosene, the second – the remaining oil-derivative substances. In the case of

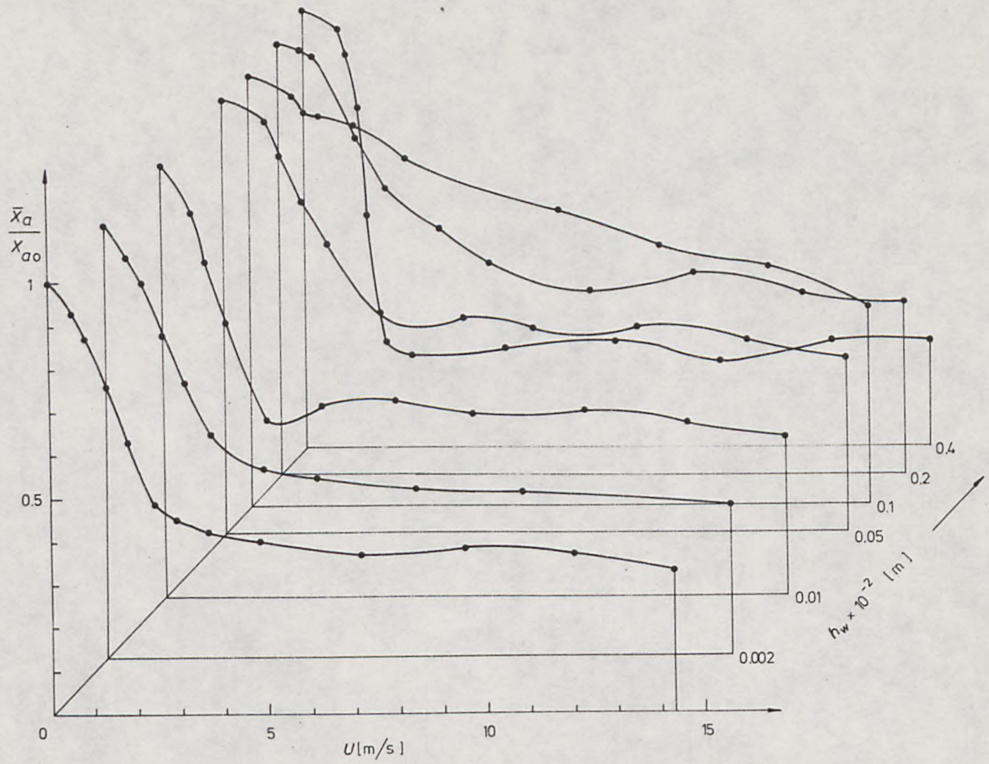

Fig. 5. Mean normalized amplitude $\bar{X}_a/X_{a0}$ of signal scattered on a rough water surface covered with a layer of diesel oil *vs* h_w and U

Table 2. Exponent of the decay function γ of the $\bar{X}_a/X_{a0} = f(U)$ dependence for the investigated oil substances and various film thicknesses

Substance	$h_w [\cdot 10^{-2}$ m]						
	0	0.002	0.01	0.05	0.1	0.2	0.4
Water	0.149	–	–	–	–	–	–
Ethyl gasoline 78	0.149	0.182	0.205	0.199	0.157	0.184	0.167
Kerosene	0.149	0.170	0.193	0.194	0.163	0.182	0.157
Diesel oil	0.149	0.145	0.155	0.107	0.057	0.109	0.105
Extra 15 oil	0.149	0.127	0.111	0.143	0.106	0.044	0.054
Marinoll 111 oil	0.149	0.090	0.051	0.062	0.048	0.071	0.064

substances from the first group the γ values are larger than for a clean surface, which is probably related to higher susceptibility to deformation of water surface covered with light oil fractions. These substances are characterized by surface tension, density and viscosity much smaller than water (Table 1), hence they suppress the generated surface waves and change the conditions of their generation to a smaller extent. Substances from the second group are characterized by smaller values of γ compared to clean surface which results mainly from their large ability to attenuate waves due to high viscosity (see Table 1, compare Pogorzelski *et al*, 1986). Moreover, γ values distinctly depend on weight of oil substance fraction (at constant h_w). The increase in molecular weight is accompanied by a decrease of γ (Table 2).

Figure 6 presents the coefficient of fluctuations η as a function of h_w and U.

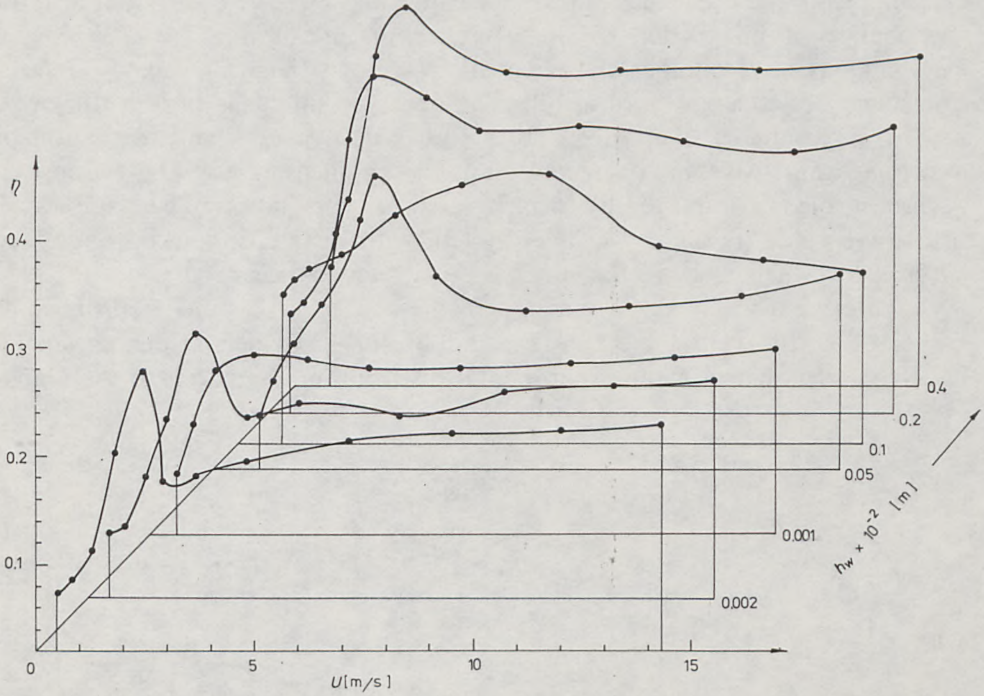

Fig. 6. Fluctuation coefficient η of amplitude of signal scattered on a rough water surface covered with a layer of diesel oil *vs* h_w and U

The values of η rapidly increase within the range of small values of U reaching a relative maximum (at $U = 2.4\ \mathrm{ms}^{-1}$ in the case of clean surface) which corresponds in the case of few film thicknesses to the inflexion point of the curves illustrated in Figure 5. The observed similarity can prove qualitatively different kind of interaction between an air stream and a layer system. The papers by Hogan (1984, 1985, 1986) predict quite particular forms of wave motion in the case of waves of large amplitude from the capillary–gravity range and allow the development of capillary plate waves (Lamb's waves) on thin layers of a liquid. A layer of insoluble oil on water surface constitutes a similar system from a physical point of view. During investigations on damping of capillary waves on water covered with layers of various oil-origin substances (Pogorzelski *et al*, 1986) the author observed occurrence of relative maximum in the dependence of wave attenuation coefficient on the thickness of a layer, which is very characteristic of a phenomenon of formation of Lamb-plate waves in solid bodies. Verification of this hypothesis requires further investigations. The values of η increase with an increase of the thickness of a layer (at $U = const$), which is related to the specific character of scattering of an ultrasound beam on the rough surface of a layer system. The value of acoustic signal depends in this case not only on the change in wave phase resulting from the existence of surface irregularities ($= 2k_1 \xi \cos\theta_1$), but also on the change of phase due to the presence of an oil film ($= 2k_2 h_w cos\theta'_1$, k_2 = angular wave number of an acoustic wave of λ_2 length in oil, λ'_1 – refraction angle of acoustic waves in oil). The observed influence of film thickness on the η parameter results from both these effects and from attenuation of a propagating wave in a strongly suppressing medium (of high viscosity). A certain role is also played by effects related to propagation of acoustic waves in a wave-guide formed by a layer system with distinctly marked boundary surface, at which a step change in acoustic impedance occurs.

Figure 7 presents the asymmetry coefficient A_1 *vs* h_w and U. For small values of U the values of A_1 are equal to *ca* -1 which evidences strong left-hand asymmetry of the experimental distribution compared to the Gaus-

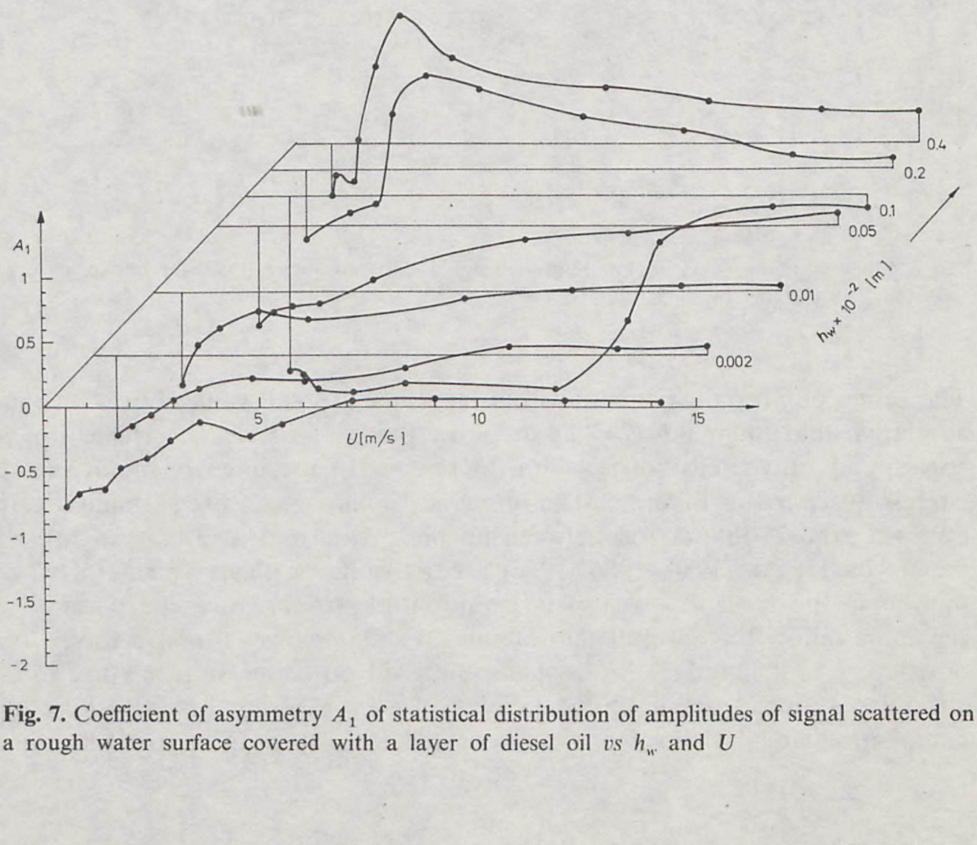

Fig. 7. Coefficient of asymmetry A_1 of statistical distribution of amplitudes of signal scattered on a rough water surface covered with a layer of diesel oil *vs* h_w and U

sian distribution, to which experimental values of $\bar{X}_a$ and σ were introduced. With an increase of U the distribution becomes more symmetrical and the values of A_1 increase approaching zero. Velocity U at which the distribution is symmetrical depends in an irregular manner on thickness of a layer. An increase in film thickness (at constant U) results in the distribution becoming more symmetrical.

Figure 8 illustrates the dependence of the coefficient of flattening of

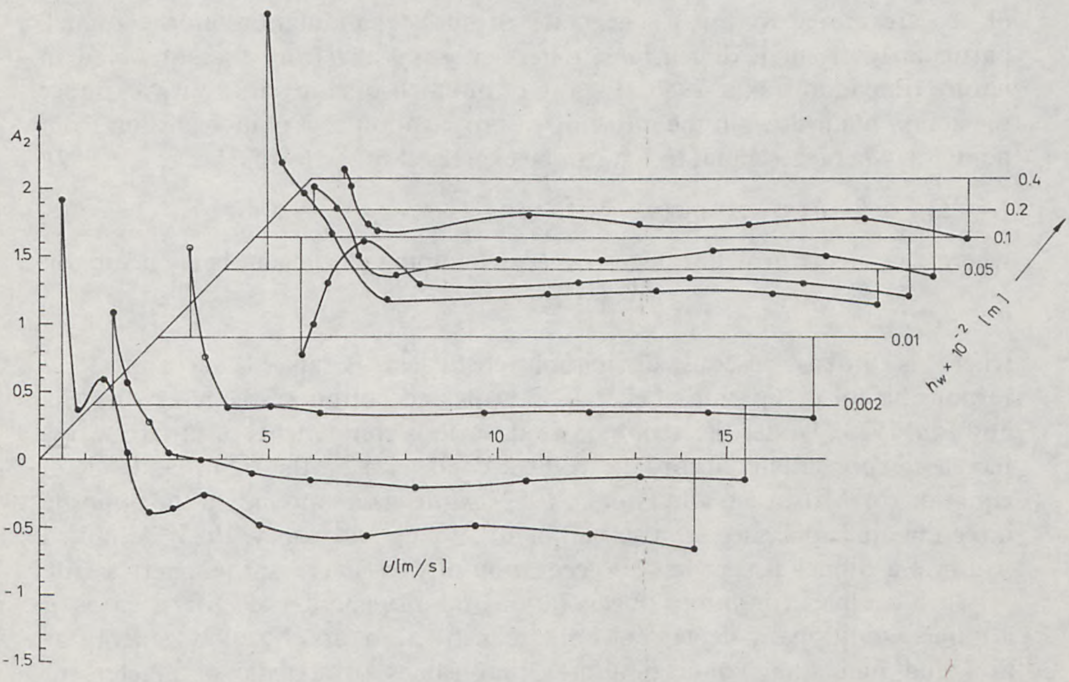

Fig. 8. Coefficient of flattening A_2 of statistical distribution of amplitudes of signal scattered on a rough water surface covered with a layer of diesel oil *vs* h_w and U

distribution A_2 on h_w and U. General character of the curves is similar for all film thicknesses. Within the range of small U the values of A_2 are positive and equal to $0.3-1$, which proves sharpening of the distribution compared to a hypothetical Gaussian distribution. The increase of U is accompanied by a decrease of A_2 reaching zero for certain values of U distinctly dependent on film thickness. This velocity is much smaller for surfaces covered with oil films (by a factor of *ca* 1.5) compared to clean surface. Further increase of U results in increasing flattening of distribution (negative values of A_2). The effect of film thickness (at constant U) on A_2 depends on the selected range of U. For intermediate velocities ($U = 5-10$ ms^{-1}) the increase in film thickness results in further flattening of the distribution, while for $U > 10\ \mathrm{ms}^{-1}$ the effect is reversed and the values of A_2 (absolute values) are closer to zero.

Previously obtained results concerning the influence of the kind of oil substance on statistical parameters of the distribution (Pogorzelski, 1985, 1989) indicate that light oil fractions deepen left-hand asymmetry within the range of $U < 5\ \mathrm{ms}^{-1}$ and right-hand asymmetry for $U > 5\,\mathrm{ms}^{-1}$ compared to the reference distribution. Heavy fractions cause symmetrization of the distribution within the entire range of U. The presence of light oil fraction results in flattening, while heavy ones – in symmetrization of the distribution (the values of A_2 are closer to zero). The state of surface undulation in the tunnel, particularly of small dimensions, differs substantially from that observed in nature (Papadimitrakis, 1986). Energy of monochromatic surface wave, under the action of air flow, in the direction of propagation at a point x distant from point x_0, where it is equal to E_0, can be expressed in the form (Hsu *et al*, 1982):

$$E = E_0 \exp[-\delta(x-x_0)+\alpha(x-x_0)], \tag{6}$$

where α is energy growth rate, δ is energy damping coefficient, being a sum of:

$$\delta = \delta_s + \delta_b, \tag{7}$$

where is Stokes' viscous dissipation coefficient (Craik, 1982) and δ_b is responsible for dissipation of energy on walls and bottom of the reservoir (Mei and Liu, 1973). Under the action of wind, various components of surface waves increase exponentially according to the second term on the right-hand side of equation (6) (Mitsuyasu and Honda, 1982), while waves moving in the opposite direction are suppressed by a stream of air (Young and Sobey, 1985). A limited width of a tunnel also promotes generation of waves across it (Garrett, 1970).

Such complex conditions of generation and propagation of surface waves in a tunnel, additionally dependent on its construction, do not allow generalization and functional connection of actual values of statistic parameters of distribution of signal amplitude with surface changes related to the presence of oil pollutants, as well as transfer of the obtained results to situation found in nature.

5. Conclusions

An acoustic system consisting of a transducer of narrow directional pattern, creating the conditions of scattering at high frequencies, allowed establishing the occurrence of surface changes of a rough water surface due to the presence of layers of various oil-derivative substances. Occurrence of changes can be established on a basis of corresponding changes in the statistics of a scattered acoustic signal compared to scattering on a clean surface. Changes in values of statistical parameters of a signal amplitude distribution are related to molecular weight of a fraction and thickness of a layer of oil substance.

Changes in values of the parameters on the order of several dozen per cent were observed in the case of mean amplitude and coefficient of its fluctuation, while in the case of the remaining parameters the changes reach even an order of magnitude. Analysis of statistical properties of the acoustic field scattered at a rough surface can be a suggestion of a new, contactless method of remote sensing of surface pollution of natural waters with oil substances.

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