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ABOUT COMPLEX INTELLIGENT TECHNOLOGIES FOR TECHNO-ECOLOGICAL EVENTS CONTROL IN THE WATER AREA

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Розглядаються аспекти, що стосуються вирішення важливого завдання створення комплексних інтелектуальних технологій підтримки прийняття рішень для ідентифікації виникаючої техно-екологічної події (ТЕП) та оптимального вибору послідовності доступних заходів зі скорочення життєвого циклу даного ТЕП в акваторії з метою мінімізації матеріальних збитків (створення системи «УПРАВЛІННЯ_ТЕП»). В Інституті кібернетики імені В.М. Глушкова НАНУ сумісно з Концерном «BaltRobotics» (Україна – Польща), НТУУ «КПІ ім. Ігоря Сікорського» проводяться вивчення питання можливості теоретичної розробки, дослідження та практичної реалізації методів і засобів, що складають інформаційну технологію дослідницького проектування (інформаційне, математичне, алгоритмічне, програмне, технічне, організаційне забезпечення) інтелектуалізованих роботів, призначених для розвідки і нейтралізації небезпечних ТЕП у ряді середовищ. Для завдання класифікації хвиль отримано і вирішено математичні моделі поширення, як хвиль, що біжать, так і стоять, в акваторії моря. Розроблено структуру сховища інформації ситуаційного центру. Для створення бази даних інформаційного сховища ситуаційного центру було проведено класифікацію хвиль та відповідне математичне та комп'ютерне моделювання. Розглянуто детермінований процес поширення звуку в плоскому хвилеводі в однорідному режимі. Вирішено спеціальні крайові завдання та завдання Коші для двовимірного хвильового рівняння, і, відповідно, для рівняння Гельмгольця. В аналітичному замкнутому вигляді отримані розрахункові формули для звукового тиску і відповідно до його швидкостей. У загальному випадку за методикою робіт Білоносова, Овсієнка, Лі, Зінченка, Ногіна обчислено у вигляді рядів Фур'є дотичну і нормальну компоненти вектору швидкості і гідродинамічний потенціал.

Ключові слова: акваторія, техно-екологічна подія, класифікація хвиль, інформаційне сховище, математичне моделювання.

Aspects of the important task solution of creating complex intelligent decision-making support technologies for the identification of techno-ecological event (TEE) and the optimal selection of the sequence of available measures to reduce the life cycle of this TEE in the water area in order to minimize material losses are considered ("CONTROL_TEE" system). In the V.M. Glushkov Institute of Cybernetics of NAS of Ukraine, Concern "BaltRobotics" (Ukraine-Poland), NTU of Ukraine "Igor Sikorsky KPI" study of the possibility of theoretical development, research and practical implementation of methods and tools that make up the information technology of research design (informational, mathematical, algorithmic, software, technical, organizational support) of robots intended for reconnaissance and neutralization of TEE in a number of environment. For the classifying waves, mathematical models of the propagation of both running and standing waves in the sea area were obtained and solved. The structure of the information storage of the situation center has been developed. In order to create a database wave classification and mathematical and computer modeling were carried out. The deterministic process of sound propagation in a flat waveguide in the homogeneous mode is considered. Special boundary value problems and Cauchy problems are solved for the two-dimensional wave equation and, accordingly, for the Helmholtz equation. Calculation formulas for sound pressure and corresponding to its velocities are obtained in an analytical closed form. In the general case, the tangent and normal components of the velocity vector and the hydrodynamic potential are calculated in the form of Fourier series by the methodology of the works of Bilonosov, Ovsienko, Li, Zinchenko, Zinchenko, Nogin.

Keywords: water area, techno-ecologicalevent, wave classification, information storage, mathematical modeling.

Introduction

The paper examines aspects relevant to solving the important task of creating complex intelligent decision-making support technologies for identifying an emerging techno-ecological event (TEE) and optimally choosing a sequence of available measures to reduce the life cycle of a given TEE in the water area in order to minimize material damage (creation of an intelligent system "CONTROL_TEE") [1-6].

For the problem of wave classification, mathematical models of propagation of both traveling and standing waves in the sea are obtained and solved.

The structure of the information storage of the situational center has been developed [1].

A deterministic process of sound propagation in a plane wave guide in a uniform regime is considered.

Formulation of the problem

In the V.M. Glushkov Institute of Cybernetics of NAS of Ukraine, Concern "BaltRobotics" (Ukraine-Poland), NTU of Ukraine "Igor Sikorsky KPI" study of the possibility of theoretical development, research and practical implementation of methods and tools that make up the information technology of research design for reconnaissance and neutralization of TEE in a number of environment.

Suggested Solution

Aspects of the important task solution of creating complex intelligent decision-making support technologies for the identification of techno-ecological event (TEE) and the optimal selection of the sequence of available measures to reduce the life cycle of this TEE in the water area in order to minimize material losses are considered ("CONTROL_ TEE" system) of intellectualized robots intended.

Statement of the research problem

The informational, mathematical, algorithmic, software, technical, organizational support is considered. The structure of the information storage of the situation center has been developed. In order to create a database wave classification and mathematical and computer modeling were carried out. The deterministic process of sound propagation in a flat waveguide in the homogeneous mode is considered.

Proposed components of mathematical and software for intelligent monitoring and control systems for TEE

For the classifying waves, mathematical models of the propagation of both running and standing waves in the sea area were obtained and solved.

Special boundary value problems and the Cauchy problem for the two-dimensional wave equation and, accordingly, for the Helmholtz equation are solved. As a result, calculation formulas for the sound pressure *P(x,z,t)* and, accordingly, its velocities $V_x = \frac{1}{i\omega\rho}\frac{\partial P}{\partial x}$, $V_z = \frac{1}{i\omega\rho}\frac{\partial P}{\partial z}$ are obtained in an analytical closed form.

A qualitative analysis and numerical computer solutions are carried out.

Under the sound, in the modern sense of this term, we mean arbitrary vibrations of a liquid or air in the frequency range of 15 Hz - 15 kHz. Note that oscillations with a frequency lower than 15 Hz are called infrasonic, and higher than 15 kHz are called ultrasonic.

In accordance with [7, 8], based on the Euler and continuity equations for the sound pressure in a plane waveguide (Fig. 1), the sound pressure has the form

$$P(x,z,t) = e^{-i\omega t}P(x,z), \tag{1}$$

where the complex amplitude *P(x,z)* satisfies the Helmholtz equation

$$\frac{\partial^2 P}{\partial x^2} + \frac{\partial^2 P}{\partial z^2} + k^2 P = 0 \tag{2}$$

where k – wave number, $k = \frac{\omega}{c}$, c – constant sound speed.

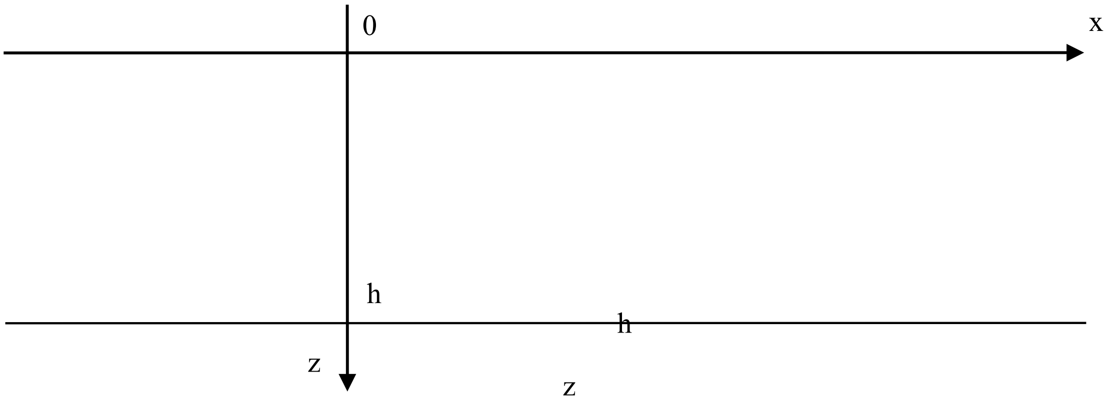


Fig. 1. Planar waveguide.

The general solution of the Helmholtz equation satisfies the boundary conditions on a rigid surface (i.e. here the vertical component of the velocity $V_z = 0$ by $z = 0$ and $z = h$). As a result, we obtain the Neumann boundary conditions:

$$\left.\frac{\partial P}{\partial x}\right|_{z=0} = \left.\frac{\partial P}{\partial x}\right|_{z=h} = 0 \tag{3}$$

In accordance with the methodology of works [1, 4] by the Fourier method, the solution of the boundary value problem (2), (3) with the help of the auxiliary Sturm-Liouville problem for an orthogonal system of functions was obtained in the form of a special series of the form:

$$P(x,z,t) = e^{-i\omega t}\sum_{m=0}^{\infty}\cos\frac{\pi mz}{h}e^{-k_x x}, \tag{4}$$

where

$$k_x^2 = k^2 - \frac{\pi^2 m^2}{h^2}. \tag{5}$$

Atlow frequencies, only the first summand ($m = 0$) describes the traveling wave, because now $k_x \equiv k^2 = \frac{\omega}{c}$.

In our case, in the range of "ordinary frequencies", when $m \in N$, $k_x > k$, we get purely imaginary values [9, 10]:

$$k_x = \pm i\frac{\omega}{c}\sqrt{\frac{\pi^2 m^2}{k^2 h^2} - 1}. \tag{6}$$

Thus, the terms of the series, starting from the second, represent waves whose amplitudes decrease quite rapidly as the distance to the point source increases.

Finally, when the condition $\frac{\pi^2 c^2}{\omega^2 h^2} = 1 \Rightarrow k = \frac{\pi}{h}$ is satisfied, then k_x is a real value and the first normal wave appears.

Thus, waves with numbers satisfying the condition are propagating $N = \left[\frac{\omega h}{\pi c}\right]$, where parentheses [ ] – the whole part of number.

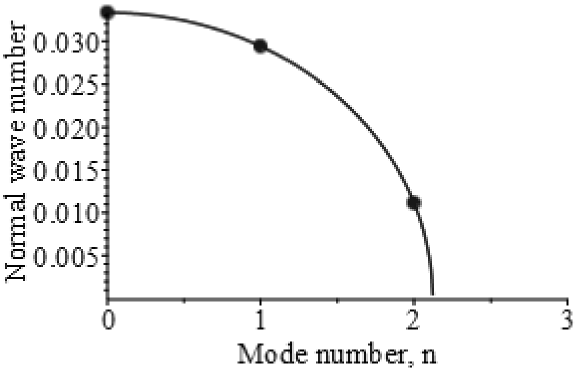


Fig. 2. Wave numbers of normal waves.

Taking into account expressions (4) and (6) for the "frozen" time, we obtain an expression for acoustic pressure in the form:

$$P(x,z) = \sum_{m=0}^{N}\cos\left(\frac{\pi mz}{h}\right)e^{-ik_x^m x},$$

where k_x^m – wave number of m-th mode.

The initial condition of the boundary value problem (wave profile) has the following form fig. 3.

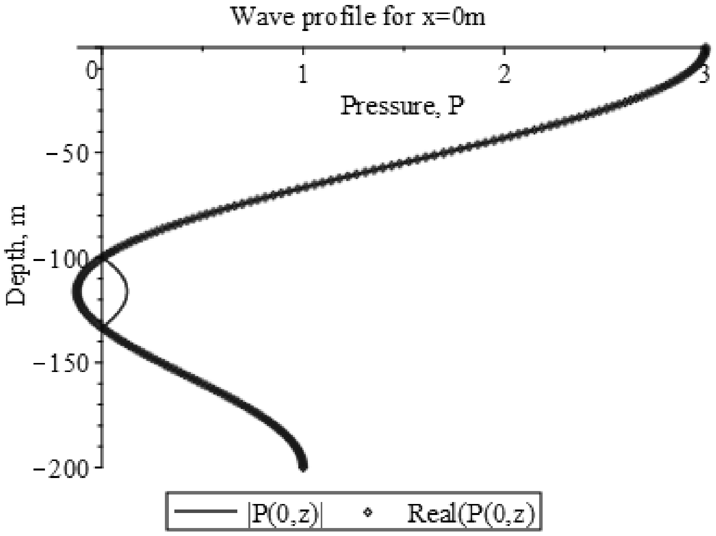


Fig. 3. Wave Profile.

For the model case, the following pressure distribution in a planar waterway is obtained (modulus and real part).

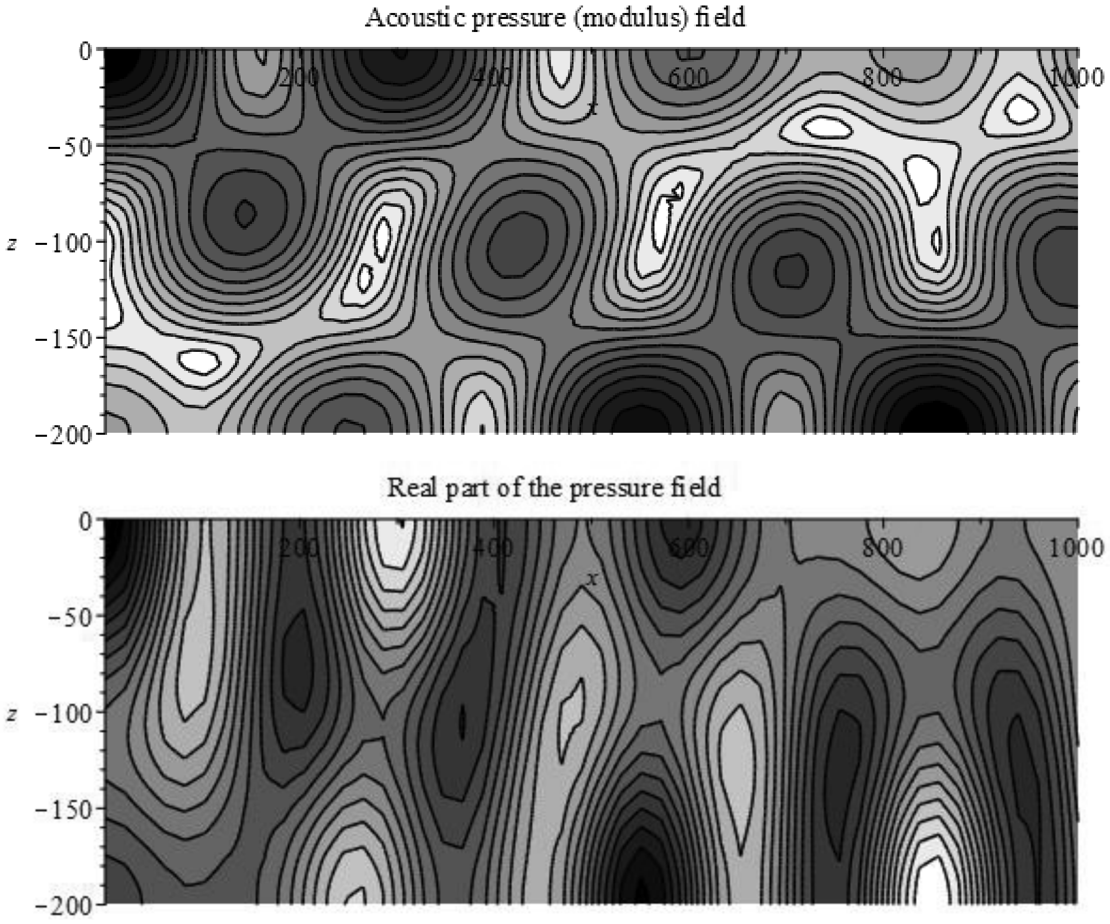
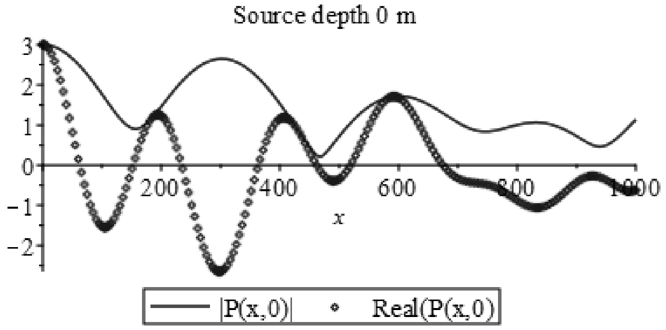


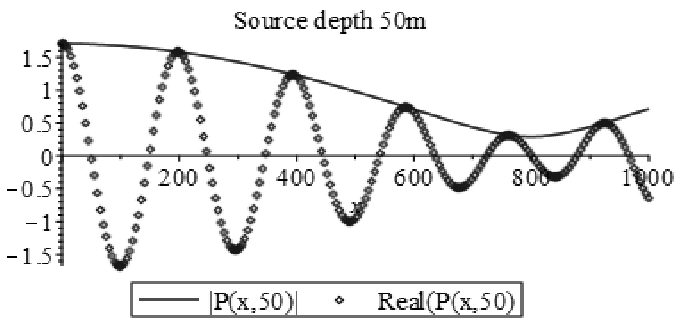
Fig. 4. Modulus and real part of the pressure field.

We use horizontal sections of the obtained fields to study hydroacoustic signals.

In particular, the frequency $\omega_1 = \frac{c}{2h}$ is called the transverse resonance frequency of the waveguide.

Now the width of the waveguide is $\frac{1}{2}\lambda_1$ (wavelength $\lambda_1 = \frac{c}{\omega_1}$).





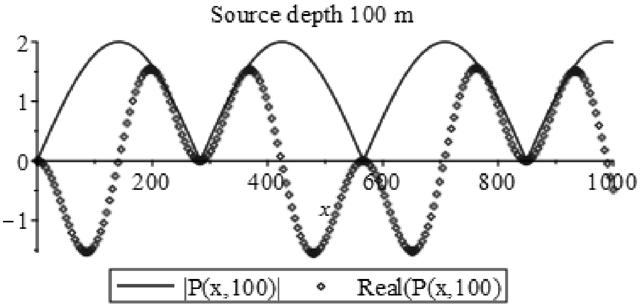


Fig. 5. Horizontal sections of the field at different depths.

In the case of low frequencies, which is very important for practice, below the frequency of the transverse resonance, in our case, in the presence of non-zero boundary conditions, the attenuation of the amplitudes, with an increase in “x”, passes so quickly that we can take [9]:

$$P = A_0 \cos\left(\frac{\omega}{c}x + \varphi_0\right), \tag{7}$$

where A_0, φ_0 determined by the properties of the radiation source. Then $V_z \equiv 0$,

$$V_x = -\frac{A_0\omega}{c}\frac{1}{i\omega\rho}\sin\left(\frac{\omega}{c}x + \varphi_0\right). \tag{8}$$

Remark. Under zero boundary conditions, the nature of oscillations in the waveguide may differ significantly from that considered above. In this case, the number and location of the field maxima will depend in another way on the superposition of the propagating waves. To do this, we solve a boundary-value problem for the Helmholtz equation with initial conditions under which the pressure profile is represented as a parabola.

Boundary conditions on the walls of the waveguide $P\Big|_{z=0} = P\Big|_{z=h} = 0.$

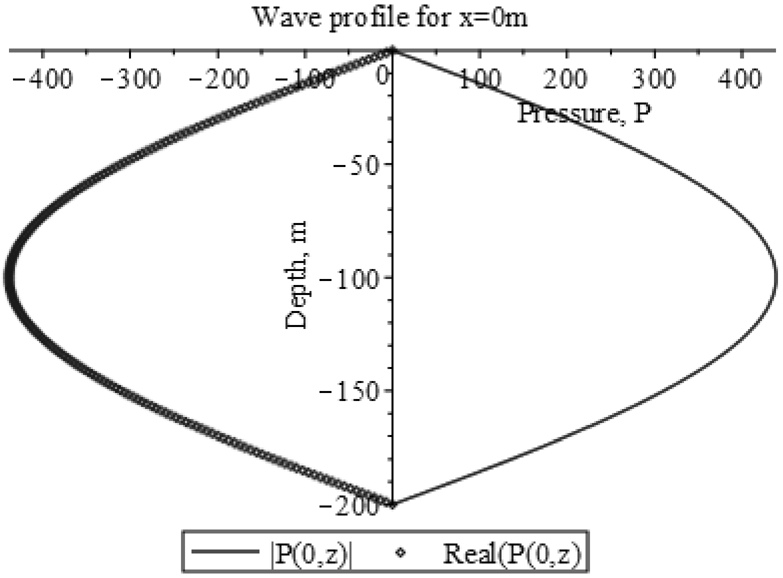


Fig. 6. Modulus and real part of parabolic wave profile.

The analytical expression for calculating the acoustic pressure field is obtained in the form

$$P(x,z,t) = \frac{8\rho c}{\pi^3}\left[\cos(\omega t) - i\sin(\omega t)\right]\sum_{k=0}^{N}\frac{\sin\left(\frac{\pi(2k+1)}{h}z\right)}{\sqrt{1-\frac{[\pi c(2k+1)]^2}{(\omega h)^2}}}\cdot\frac{1}{(2k+1)^3}\cdot e^{-\frac{\sqrt{[\pi c(2k+1)]^2-(\omega h)^2}}{c(2k+1)}x}, \tag{9}$$

where ρ – water density.

A detailed examination of the behavior of the profile of the real part of the pressure shows that in some areas the initial parabolic wave becomes almost flat or changes its sign several times depending on the depth (Fig. 9).

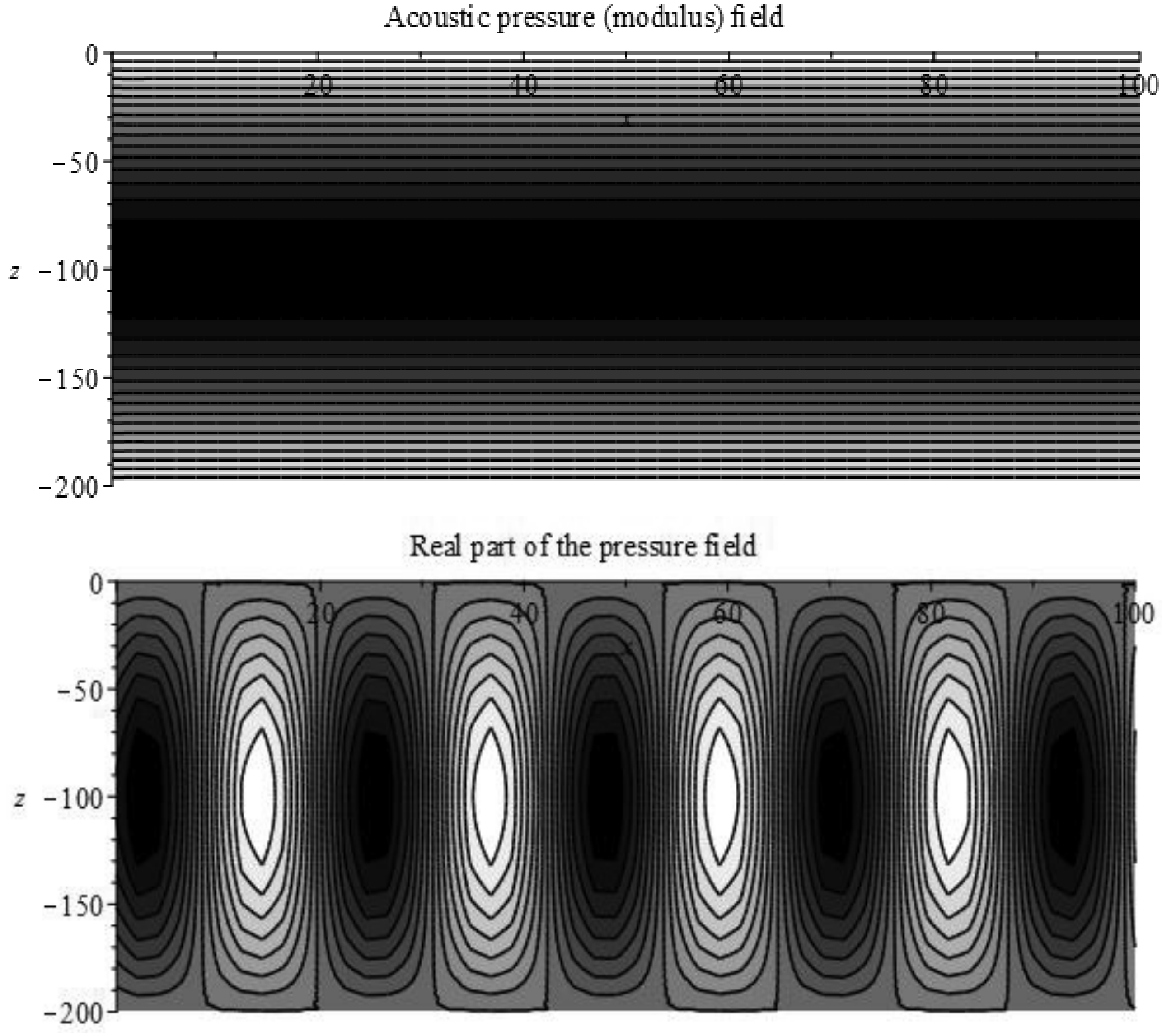


Fig. 7. Modulus and real part of the parabolic wave pressure field.

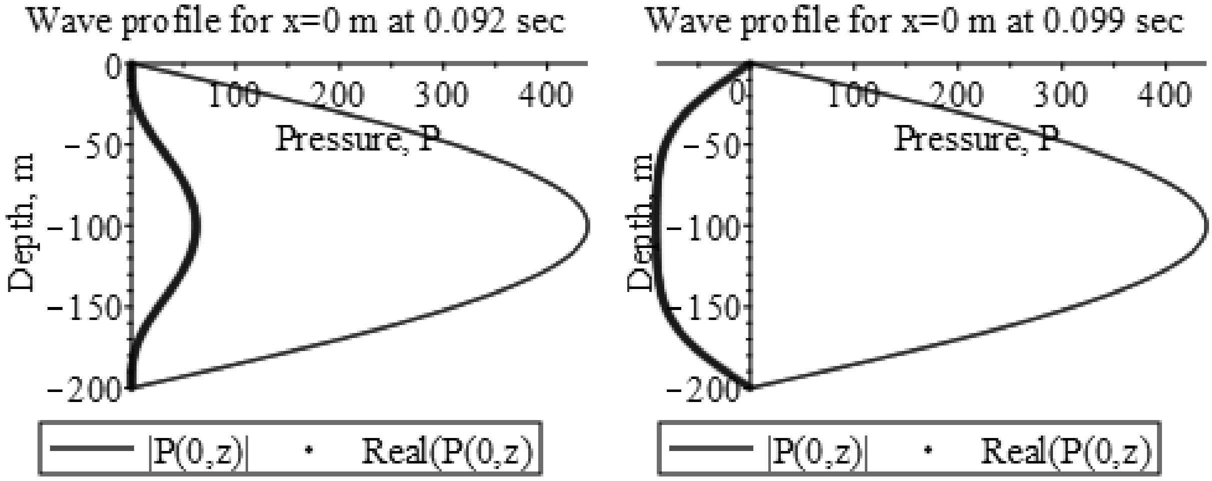


Fig. 8. Wave profiles at different times.

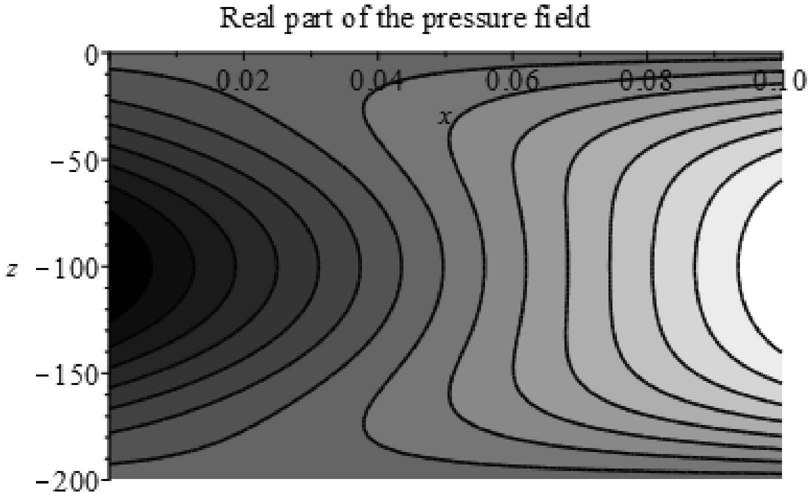


Fig. 9. Feature of parabolic wave propagation.

Conclusions

The paper shows that analytical solutions of the Helmholtz equation for a plane waveguide can be obtained not only as a sum of normal waves, but also as special series that take into account the characteristics of the radiation source. To develop a database of the situational center information storage waves were classified and the corresponding mathematical and computer modeling was carried out.

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техно-екологічними подіями в акваторії

Прізвища та ініціали авторів і назва доповіді англійською мовою:
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About complex intelligent technologies for techno-ecological
events control in the water area

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