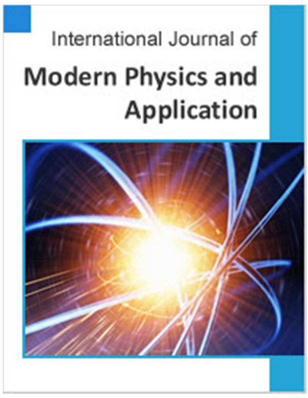
International Journal of Modern Physics and Application
2016; 3(1): 14-18
Published online February 8, 2016 (http://www.aascit.org/journal/ijmpa)
ISSN: 2375-3870

American Association for Science and Technology



Keywords
Review,
Infrasound Vibrations,
Radiators Infrasound Waves (Risw)

Received: December 9, 2015
Revised: December 26, 2015
Accepted: December 28, 2015

Infrasound: Multilateral Aspects

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Citation
Galyna I. Sokol, Valeriya D. Babenko, Vladislav Yu. Kotlov, Lizaveta V. Nikiforova. Infrasound: Multilateral Aspects. *International Journal of Modern Physics and Application.*
Vol. 3, No. 1, 2016, pp. 14-18.

Abstract
This article is a review of the scientific works on the uncharted field of acoustics: infrasound vibrations. Scientific papers published over the last 25 years are analyzed. A more complete summary of the review was published in the monograph "The features of acoustic processes in the infrasonic range of frequency," which in the bibliography of this article is 1. Therefore, in the text of this article is often put links to the source literature [see. 1].

1. Introduction

Currently a rather large amount of research conducted on the specific effect of low-frequency and infrasound waves on living organisms [1-10]. There should be noted the works on the use of infrasound (IS) for an intensification of technological processes [4, 11-13]. Analysis of the mentioned above actions is impossible without special studies that require special installations as radiators infrasound waves (RISW).

2. Problem Formulation

There are some works that present research on generating RISW by natural, industrial, and specially designed emitters. In the area of mid and high audio frequencies there are reliable methods for the generation and study of acoustic fields [see 1]. In the area of low frequencies, these methods are poorly developed and only for individual tasks. The fact that the ratio between the radius of the radiator R and the wavelength of infrasound λ (parameter kR, where k - wave number, $k = 2\pi / \lambda$, π is the number of "π") is very small, hence the active component of the acoustic power is small [4, 5]. The factor kR < 1 leads to generating of the low frequency acoustic fields in nature with high sound pressure levels (SPL) (100 dB or more) very rarely. But in industry we see SPL in infrasound waves more 100 dB very often.

3. The Purpose of Article

The purpose of this article is to provide materials about impact of the RISW on living organisms, dissemination and application of low-frequency acoustic vibrations according to RISW sources.

4. Well-Known Sources of Infrasound Waves

The conditions under which the generation of RISW occurs spontaneously in nature, industrial and transportation are discussed in [1, 2-5, 7-9]. Such sources of infrasound attracted attention because sound pressure level (SPL) in such cases is quite high. Classification of IS sources presented by E. Malyshev [2], L. Pimonov [5], A. Rimsky - Korsakov [14], V. Brienza and his co-authors [9].

E. Malyshev [2] divided sources into two types: mechanical and aerodynamic. The first type are sources with fluctuating surface. There are vibroplatforms, swaying bridges, car body and others. IS levels of such sources registered up to 124 dB. Studies have shown [1, 2, 5] that in industry and transport cars and mechanisms, with the surface of large dimensions that realize oscillation with frequency 1 - 20 Hz, are the IS sources of mechanical type. To the second type are referred suction, blowing apparatus and pipes in which gases move turbulence. V. Brienza with co-authors [9] suggested to put in classification the third type of IS source: heat ones.

In A. Rimsky – Korsakov`s work and his co-authors [14] all kinds of low-frequency underwater sound radiators are divided into two big groups: transmitters that use reversible electromechanical energy converters and radiators, in which the principle of unilateral conversion of energy (often a compressed gas or mechanical energy of rotation) into acoustic oscillations. In the same paper emitters are divided by the nature of the signal into two large groups: a continuous signal (a long, periodic) and the emitters of the pulse signal.

The analysis of generation of RISW in nature and in the industry has allowed to define the characteristics features that may be used in a special generating of RISW for research. Firstly, we consider the features of the propagation of low-frequency waves in the air and in aqueous medium.

5. The Peculiarities of Infrasonic Waves Expansion

Adiabatic character of RISW spreading in the air is proved in the dissertation by E. Malyshev [2]. For small amplitudes spreading of RISW is considered in the linear approximation.

L. Pimonov [5] results in mathematical expressions for the calculation of displacement, velocity and acceleration of oscillating only in the case when the RISW is flat. The [5] shows graphs with the calculated values of the velocity of sound in various environments, the wavelength dependence of the frequency, magnitude relations between the values of the sound pressure in microbars, and the values of SPL in dB. Attenuation of IS in the atmosphere is little, due to the proportional of coefficient of attenuation to square of the frequency. Sometimes RISW is called "acoustic neutrino." RISW energy absorption with 0.1 Hz in the lower atmosphere is 2 • 10 - 9 dB / km. [5]. The problem of the use of RISW to transmit energy over long distances is studied. However, in [5] shows the mathematical expressions for determining the SPL for the propagation of waves in a medium with a more complex shape of the front and high amplitude sound pressure level (170 dB) when distributing RISW should be considered in the nonlinear formulation.

The theory of propagation of RISW in layered media is developed [see. 1] (Lavrent'ev, V.E. Zuev, H.G. Leventhall, W.L. Donn, D. Rind, R.K Cook).

Development of asymptotic methods for calculating infrasonic fields in layered nonuniform mediums is made by G. Alekseev [15].

Nonlinear RISW in the presence of wind in the atmosphere are described by D. Blokhintsev, D. Benney, K. Davis [see. 1].

Evaluation of power of IS, the side emitted into the atmosphere while the Earth vibrating candling spent Y. Zaslavsky [see. 1].

Y. Birfeldom, A. Tarantseva, S. Soroka shown [see. 1, 16] that the RISW have a significant impact on the ionosphere. Previously considered a source of perturbation, solar flares, it is now proved that it is possible disturbances of ionosphere by infrasound from earthquakes and volcanic eruptions with the birth of magnetic storms.

When passing IS into the Earth's atmosphere in the presence of variable density height there is the generating of the acoustic - gravitational waves [see. 1].

Distribution characteristics of RISW in an aqueous medium: in the fresh water, in the sea, in the deep ocean, in the shallow water off the coast are determined higher than the air; medium density, the presence of heterogeneities in the northern latitudes because of the presence of ice, changing the shape of the wave front during its transition from the deep part to the coastal shallows, the presence of underwater sound channel.

6. Infrasound`s Radiators

Structural design of RISW radiators appeared recently. In the 30 - s of the 20 th century RISW emitters were a non-directional low power sources, such as the radiator - a rotor (prof. Myasnikov and prof. Shuleikin) [see. 1].

Guidelines for designing generators RISW is the work of prof. A. V. Rimsky - Korsakov and others [14]. It presented the theory of the radiation of low frequency sound with the influence of the boundaries of the medium, are the main types of elementary emitters and their specifications, formulas for calculating the equivalent weight and flexibilities oscillatory systems at low frequencies.

Generators infrasound waves represented by L. Pimonov [5] E.N Malysheva [2], in the materials of colloquium on infrasound (France, 1973) [4], in the works of V. Gavro [3].

Designed by E.N. Malyshev RISW radiators constructions are closed chamber with dimensions: length - 6,4 m, diameter - 1.3m. Excitation of oscillations accomplished by the piston, which is a link of crank - rod mechanism, sirens drive with a mouthpiece, an electrodynamic loudspeaker. SPL reaches up to 190 dB. Generators used for studies on the IS impact of the frequencies below 3 Hz on a living organism.

For emitters, operating in an open space, the far-field characteristics are provided when the distance r from the emitting surface exceeds the wavelength λ emitted by acoustic waves. The above approach is limited notion of "low" and "high" frequency that does not give a specific idea of kR the area occupied by RISW with high sound pressure levels.

The practical implementation of generating of RISW with flat wave front for working in an infinite medium is almost impossible, as the size (diameter) of the radiating element of the generator must be more than the length of the generated wave. For frequencies of infrasound range this size should be between 340 m (1 Hz) to 17 m (for 20 Hz). Type of emitter in this case may be the pistons of circular or square shape, strip, flat plates [see. 1].

Plane waves may be implemented as running and standing while sound propagation in tubes. In cases of low frequencies the reflection from the open end of the tube is strongly dependent on model: the tube can be viewed without a flange, a tube with a flange, a tube with an endless flange. There are data on the use of IS generators out of based on organ pipes [2 - 6]. The frequency of infrasound generated by the pipe organ and depends on its structural layout and length. Infrasound device [see. 1], established in 1978 at the Leningrad Philharmonic, had a tube length of 17 m and generate a frequency of 11 Hz RISW. Generators based on organ pipes are presented in V. Gavro [1, 3]. RISW with rate 7 Hz is got by exciting of 24 - meter tube speaker. In order to generate high IS with high level of sound pressure the pipe organ with square section was powered by whistle Levavassor with additional resonant cavity. The cavity is another organ pipe resonates at 1/4 λ. With adjustment telescopic pipe V. Gavro developed a "whistle-gun".

IS with frequency of 3.5 Hz was obtained by excitation of an organ pipe by pistonphone. Generation of WPI in the pipes is possible when their thermal excitation [1, 4, 5] (see. N. Belyaev, N. Belik and A. Polshin. Monography "Thermoacoustic fluctuations of gas-liquid flows in complex power pipelines").

Of interest is the generator of Helmholtz as resonator type. Some method of construction of a low-frequency acoustic radiator with water-filled tubes was described by V. Glazanov and V. Mikhailov [see. 1].

Generator of spherical RISW with high efficiency (30%) is the sirens. But they require significant costs of gas. (see V. Gavro [3]). Setting of the speaker gave a significant increase in the acoustic power. RISW generators in kind of whistles are presented by the Soviet copyright certificates and foreign patents [see. 1].

Infrasound generator type police whistle (see. V. Gavro [3]) had a concrete case with a diameter of 3.5m and generated infrasound from a frequency of 7 Hz. The intensity level was 160 dB.

Radiation of sound by system of vortex rings represented by A. Gurzhiy and V. Myeleshko [see. 1].

In the oceanographic and seismic studies are used pulse emitters [14]. This is explosive, electric discharge, pneumatic, gas explosion, piston diesel radiators.

In [5] calculated spectra for ten different wave forms containing infrasonic components. Generating of RISW is possible by moving shock waves in acoustics. It is shown that from explosions and shock waves propagating from the bodies and moving at high speeds, the largest spectral density falls on infrasound`s frequencies. Electric and explosive discharges [see. 1] do not allow precise control of the energy density and of the frequency. Generation of RISW in the electrically conductive medium is considered in [17].

Directional radiation of RISW by using multiple sources is suggested by L. Pimonov [5]. The best focus is achieved when placing the sources at a distance of half a wavelength. It is concluded that the modern level of technical development has not yet allowed to build a giant infrasound antenna. Diameter of radiator in the antenna`s array 10 * 10 is 165 m. Underwater low-frequency transducers to monitor the ocean and seafloor presented by scientists led by prof. A. V. Rimsky - Korsakov, by «Reytheon» [see. 1], O. Levushkin and Penkin S. [cm. 1].

Radiators of discrete frequencies created on the base of the interaction of the jet with a wedge, are described in works of V. Kondratieff [see. 1].

If low-frequency transducer is a speaker, then to increase returns and eliminate the phenomenon of "short-circuit" or "acoustic shadow". In this case radiator is supplied by large screen. The providing the analysis of the characteristics of low-frequency electro-emitters [14] showed that the radiators of this type are effective only in the vicinity of mechanics and acoustic resonance. For radiator of low-frequency resistance of radiation has inertial character. Therefore, to create an effective electrodynamics' transducer is possible by increasing the activity of the radiation resistance and the active component of the acoustic power by the use of the horn. Schematic diagrams of acoustic emitters of electrodynamics' type are widely used at audio frequencies in broadcasting, applicable to the construction of low-frequency sound emitters [18 - 20]. In detail the role of mouthpiece in generating RISW by generators of membrane and piston type presented in [18 - 27]. In broadcasting the length of the horn is usually chosen so that the frequency characteristic of the emissivity of the dimensionless active impedance component in the throat, in the operating frequency range of the speaker was smooth. The infrasonic frequencies such horn must have a length of several tens of meters [5]. Therefore the choice of the length of the horn is an urgent task. It is solved in [21, 23, 24] based on the works of L. Gutin [see. 1], where is represented the theory of wave propagation in a finite length of the horns. The mouth`s model serves the piston diaphragm radiating by one side in an infinite medium. The new result in [21, 23, 24] was the mathematical description of wave propagation in the horn of finite length cathenoid form. On the basis of mathematical apparatus and experiments studied resonance phenomena in the throat and are defined for a particular form of the horn and the length of the frequency at which the radiation coefficient reaches a maximum, and therefore the maximum acoustic power of generator. a The schematic diagram of the transmitter low-frequency oscillations in the implementation of the horn throat spectral components of the noise based on the interaction of the jet with a wedge in [20] is suggested. The design of the horn involves changing its length so that the frequency at which the radiation coefficient reaches a maximum matches with the frequency of one of the spectral components of the generated noise. This ensures the maximum meaning of acoustic power of transducer.

If the generating acoustic vibrations of high power their is the nonlinear effects occur. This effect is in the horns. If we have the propagation of waves of finite (big) amplitude in horn is generated the second harmonic. This effect for horns of exponential, cathenoid and conical forms were studied in [22, 25-27]. Here are proposed and defended by new inventions the new way to quench the nonlinear effects. In the horn are using of higher harmonics and concepts of sound generator resonators - absorbers. We get the describing equations of the propagation of the velocity analog of the second harmonic and the sound pressure in its horns of cathenoid and conic shapes. Exact solutions of the equations are found analytically. It helps to simulate mathematically the physical process of growth and decay of the second harmonic as it propagates along the horn from the throat to the mouth. The calculations showed that for the same operating frequencies and with the same particle displacement in the throat of the horn maximum amplitude meaning of the second harmonic in the horn of cathenoid form is in 1.25 times higher than in the horn form of an exponential form. We get the analytical expressions for determining coordinate cross-section of the conical horns, exponential and cathenoid forms where the second harmonic of sound pressure reaches its maximum. The second harmonic in the horn of cathenoid form quickly reaches its maximum value of 1.4 times. We derive expressions that define the factors of the nonlinear distortion to the horns of the three forms.

7. Conclusions

1. The analysis of methods and devices for the generation of infrasound waves are shown in the thesis. We can make the conclusion that there is indication of the limited number of methods of generating a low-frequency acoustic oscillation. The classification of already developed devices is provided in the work. The factor $kR < 1$ radiating elements required to solve the problem of creating new generators of low-frequency acoustic fields. Experimental studies are not in confined spaces and in open spaces.

2. The problem of the generation of low-frequency acoustic waves with high levels of sound pressure in the air by the generator of a mechanical type is solved. The physical principles of maximum radiated power through the creation of resonance phenomena in the horn of finite length are laid. The mathematical apparatus and the method of calculation of the characteristics of the emission coefficient for the mouthpiece of cathenoid form are developed. The calculation results are confirmed by experimental studies.

3. The cases of the appearance of nonlinear effects in the horns in the emission and spread of low-frequency waves of large amplitude are studied.

In connection with the implementation in industrial and transport of new machinery and large capacity mechanisms and facilities it is important to conduct further analysis of low-frequency acoustic fields, especially in wind power.

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