# STUDY FOR REDUCING NOISE POLLUTION OF THE MARINE ENVIRONMENT BY INTRODUCING NOISE AT THE ACOUSTIC SOURCE

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*This paper presents a virtual instrument and a simulation in order to reduce the noise produced by rig tenders. Underwater noise sources cause environmental pollution, with damage to marine life habitat, their communication, disrupting the feeding area, with economic repercussions on the number of fish and the fishing activity. Measurement of sound power level of these noise sources has led to the conclusion that the highest level, according to 120 dB re 1μPa criterion was extended to 3-5 km distance from the platform. Virtual instruments were built by the phenomenon of composition leads to attenuation of sound waves in the vicinity of marine platforms. Project which measurements were made, the system of acoustic measurement / recording / transmitting, the mobile polygon, the virtual instrumentation are a personal contribution to the efforts to reduce the noise pollution of the marine environment.*

**Keywords:** underwater noise, virtual instrument, underwater loudspeaker

## 1. Introduction

### Anthropogenic noise source in the marine environment

Anthropogenic sound in the ocean is created unintentionally and randomly. Results are fluctuating noise intensities and frequencies.

Noise sources are located along the coast, throughout the ocean and in the circulated areas. Increased use of sea for commercial shipping, geophysical exploration and advanced warships led to a higher level of noise in recent passed decades. Estimates suggest that noise levels are at least 10 times higher today than they were a few decades ago.

Anthropogenic ocean noise sources become stronger, increasing the background levels and peak sound intensity levels. Sound is an extremely effective way to propagate through the ocean energy and marine mammals have evolved to exploit its potential. Many marine mammals use sound as a primary means of communication.

Sound waves reduce their intensity through the barrier water / air a thousand times. This means that we are virtually isolated from the sound of the propellers of ships, their engines, by sonar, etc. In underwater environment, the acoustic pressure produced by sound waves attenuates depending on the distance

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and the obstacles they encountered. That's why is very important to reduce the anthropogenic noise

Marine ecosystems fulfill a number of important functions: climate adjust, erosion prevention, accumulate and distribute solar energy, absorb carbon dioxide, maintain biological control [1].

The paper presents a solution to reduce the generated noise from industrial facilities in operation or under construction by introducing noise from 180 ° out of phase noise at the source location.

**Commercial ships**

In marine environment, commercial vessels have a major contribution in the low frequency (5 to 500Hz).

Distanced ships contribute to background noise on a wide scale. Traffic noise at high latitudes propagates very efficiently over long distances, as in the oceanic sound channel regions (areas of effective sound propagation) reaches the water surface [2].

In terms of sound, a ship is a radiant source with broadband spectrum and a series of discrete components caused by the operation of various equipment and mechanisms on board.

Noise transmission from the generation source can be done by air (air noise) or hull form of vibration, in which case structural noise appears.Noise and vibration sources on board the ships can be divided into two main groups:

- Main sources - which causes noise and vibration movements by acting on the hull, consisting of main engines, auxiliary engines, marine engines and action on the hull;
- Secondary sources – which receive movement from the main sources and after this they become sound source generators of their own, [3].

In terms of character movement resultant noise and vibration sources on board also can be divided into two categories namely:

Another noise source, are the industrial targets (offshore) during the construction and operational activities of their. In this category are included: wind turbines, offshore exploration and exploitation, LNG terminals (Liquid Natural Gas).

Industrial and construction activities conducted both shoreline and offshore, activities such as percussion, dredging, digging tunnels, operations / off channel of navigation, location and operation of wind farms have an important impact on the marine environment [4].

Activities related to oil and gas drilling generates noise including marine, offshore location and relocation of structures and production. Sound pressure levels associated with drilling are highest with the widest energy band (10 Hz to 10 kHz) with about 190 re 1μPa . Ship drilling noise comes from several sources:

oil rig, propellers, engines for ships maintaining station pertinent.. Placing offshore structures creates localized noise for brief periods. To transport these structures are used powerful vessels. This activity may take several weeks and may occur 8 to 10 times a year on a internationally scale.

**Natural sounds in the ocean**

Acoustic environment inside the ocean is highly variable. At a certain time and place it can be combined several sources of noise. In addition, the particular conditions of a site may influence the reception of sounds (such as water depth). Natural phenomena that contribute to the sound of the ocean environment include: wind, restlessness sea, waves, bubbles distributor, currents and turbulence, seismic activity, precipitation, icing work; marine life [5]. In the absence of anthropogenic and biological sounds, ambient noise is wind dependent and takes place over a very wide band of frequencies between 1Hz and 100kHz. At frequencies lower than 10 Hz sound generation mechanisms are dominant interactions between surface waves. In frequencies between 10Hz and 100kHz main source of noise is given by moving bubbles in the water column as individual bubbles or clouds of bubbles [6].

Rainfall is another factor that can increase the ambient noise level by more than 35dB in the frequency range from 100Hz to 20kHz [7].

Breaking the ice can produce up to 1 kHz pulse lasting one second or more. Interaction with the ocean waves can produce ice marginal between 4-12dB noise [8].

## 2. Types of sound sources

In acoustics define several types of sound sources.

***Monopol source (****point sources****)***

**Monopol source** is the simplest and most common type of sound source, can be treated as a point source. Fans, exhaust vents, speakers are just a few examples of such sources.

**Free field Sources.** If the noise source is in the open field (outside the building), then the relation between sound pressure level and sound power level is:

$$L_{p=}L_w - 20lgr - 11\ [dB] \quad (1)$$

where: $L_p$ sound pressure level [dB]; $L_w$ - sound pressure level [dB]; $r$ - source distance –receiver [m].

If the source is placed in an open field, the energy radiates uniformly in all directions, so the source is omnidirectional.

Most energy sources do not radiate uniformly in all directions, but preferentially emit a certain direction, forming angle θ about an axis of reference, so they are directional.

Corresponding acoustic field can be characterized by Dθ directivity factor of the source. Noise from plant sources are often directional.

If sources in the open field near a building sound wave sound energy and focuses only on certain directions. Sound pressure level Lp is calculated as:

$$L_p = L_w + 10\lg\left(\frac{D_\theta}{4\pi d^2}\right) + 0,5\left[dB\right] \qquad (2)$$

Where: $L_p$ is the sound pressure level in a room at a distance r from the source [dB]; $L_w$ sound power level of the source frequency [dB]; $D_\theta$ - directivity factor of the source; d- measuring the distance from the source point [m].

**Sources in reverberant field**

$$L_p = L_w + 10\lg\left(\frac{D_\theta}{4\pi d^2} + \frac{4}{R_l}\right) + 0,5\left[dB\right] \qquad (3)$$

where: $L_p$ is the sound pressure level in a room at a distance r from beacon [dB]; $L_w$ -sound power level in the frequency band of the source [dB]; $D_\theta$ -the directivity factor of the source; *d* - measuring the distance from the source point [m]; $R_l$ - constant absorption site [$m^2$].

If $\frac{D_\theta}{4\pi d^2}$ dominates, when the handset is near field and most of the sound energy is received directly from the source. If $\frac{4}{R_l}$ is dominant, the handset is reverberant field.

***Thompson and Schultz equations***

Relation (3) is used to calculate the relationship between sound pressure level and sound power indoors. There are two relationships relationship relation Thompson and Schultz, deduced experimentally used in some cases to calculate the relationship between sound pressure level and sound power.

Thompson relation:

$$L_p = L_w + 10\lg\left(\frac{D_\theta e^{-\alpha d}}{4\pi d^2} + \frac{\frac{4V}{Sd}}{\frac{4}{R_l}}\right) + 10\lg N + 0{,}5\,[dB] \quad (4)$$

where: $D_\theta$ - is the directivity factor; α - absorption coefficient of air; $d$ - source-receiver distance [m]; $R_l$ - absorption constant room; $N$ -The number of sources that can be decomposed monopoly power; $V$ - room volume [$m^3$]; $S$- The total area of the room [$m^2$] .

Schultz relation:

$$L_p = L_w - 10lgd - 5lgV - 3lgv + 10lgN + 0{,}5\ \ [dB] \quad (5)$$

Where: $d$ is distance between source and receiver [m]; $N$ - number of sources that can be decomposed monopoly power; $V$-room volume [$m^3$]; υ- octave band center frequency [Hz].

The above relationship is used monopolistic sources such as speakers or the suction. This relationship is valid for a maximum of three sources monopoly. For four or more speakers, Schultz relationship is:

$$L_p = L_{ws} - 27{,}6lgh - 5lgX - 3lgv + 1{,}3lgN + 15{,}8\ \ [dB] \quad (6)$$

where: $L_{ws}$ is the power level corresponding to a single speaker [dB]; $h$ – ceiling height[m]; $X$ - the floor area ratio between the speaker and the square served by ceiling height.

Classical equation (3) to calculate the relationship between Lp and Lw gives good results for the near field and reverberant field.

Thomson relation is classical equation as a starting point, but with modifications based on experimental measurements. Schultz is completely empirical relationship.

***Linear source located in free field***

The relation between sound pressure level and sound power level of the source is given by

$$L_p = L_w + 10lg\left(\frac{D_\theta}{\pi dL}\right) + 0{,}5\ \ [dB] \quad (7)$$

where: $D_\theta$ - directivity factor; $d$ –distance source-receiver [m] ; $L$ –source lenght [m].

***Plane source in free field***

Sound pressure level is calculated like:

$$L_p = L_w + 10lg\psi - 8 \ [dB] \quad (8)$$

If $r = \frac{b}{\pi}$ plane source behaves as a linear source located at the same distance from the receiver.
If $r = \frac{c}{\pi}$, plane source behaves as a monopole source located at the same distance from the receiver.

Relationship between sound pressure levels measured at distances r1 and r2 from source to source power W computed as follows:

I. If $0 < r_1$ and $r_2 < \frac{b}{\pi}$, then $L_p(r_1) = L_p(r_2) \ [dB]$ (9)

II. If $r_1 < \frac{b}{\pi}$ and $r_2 < \frac{a}{\pi}$, then $L_{p,2} = L_{p,1} - 10lg\frac{r_2}{r_1} \ [dB]$ (10)

III. $r_1$ and $r_2 < \frac{a}{\pi}$, then $L_{p,2} = L_{p,1} - 20lg\frac{r_2}{r_1} \ [dB]$ (11)

where: $L_{p1}$ is the measured acoustic pressure level at distance $r_1$ from source; $L_{p2}$ - is the measured acoustic pressure level at distance $r_2$ from the sound source; *b* – source width [m]; *c* –source lenght [m] [6].

## 3. Virtual instruments for noise injection

To reduce noise introduced into the environment by human activity, was proposed the insertion of an experimental context antiphase noise at the source of noise pollution.

Used for this purpose is the physical phenomenon of wave composition. When the waves come from one or more sources that interact, they will compose leading either to increase or to decrease wave energy at the point where they meet. When meeting elastic waves with the same frequency, amplitude and are in phase their energy will accumulate so that the resulting wave (compound) will have a greater amplitude. Resultant of two waves out of phase by 180 degrees (which are in antiphase) has amplitude zero energy waves will cancel each other. At phase angles between 0 and 180 degrees will produce a range of intermediate stages between full sum and total cancellation. Resulting wavefront can have different values, including zero, depending on timing sources.

Given the above I considered the introduction of noise out of phase by 180 º from the product source will result in lower sound pressure level that is emitted by the source.

For this we developed a virtual instrumentation to produce signal in antiphase with the signal acquired of the underwater noise.

We used for this purpose LabView program which is a graphical programming language for virtual instrumentation. With the help of signal conditioners for different types of sensors, LabVIEW allows the computer to measure certain physical quantities and control processes.

LabView uses virtual applications as Virtual Instruments (VI).

The components of a VI in LabVIEW are:

- Front panel - user interface;
- Block diagram - graphically source code for the operation VI;
- Icon connector pannel – for identifying and prioritizing the VI for its interconnection within another VI, through which the sub VI.

LabVIEW uses for application development, front panels intuitive symbols and block diagrams. The application software develops through hierarchical construction of virtual instruments (VIs). Virtual instrument is a graphical software package presents and acts as a tool. Common interface for interactive operations is front panel (with knobs, switches, switches, dials tools) and contains inputs, outputs, change display sizes, verifiers performing the process [9].

On the desktop front panel is placed:

- control devices - Such as buttons, keys, sliders, etc
- Display devices (signs) of various types - LEDs, scales measuring instruments, displays graphics.

**Block diagram**

Desktop of the block diagram is the graphical representation of the corresponding functions on the front panel objects and shows how moving data flow and processing operations.

**Virtual instrument "sinusoidal signal generator"**

First built virtual machine is a signal generator that generates a sinusoidal wave with a prescribed form, and also a sine wave contrafază (180 degrees out of phase as the starting point of the wave). These waves are combined in a summing VI and the resultant wave is shown in data presentation element on the front panel of the virtual instrument. The resulting signal intensity is zero.

**LabVIEW** instrument library has a sub-VI "Simulate Signal", which is a signal generator waveforms with variation defined by laws such as sinusoidal, rectangular, triangular, to sawtooth, signal ramp, pulse. This sub-VI was used to demonstrate the process of composing waves.

Block diagram of virtual instrument "sinusoidal signal generator" is shown in Fig. 1.

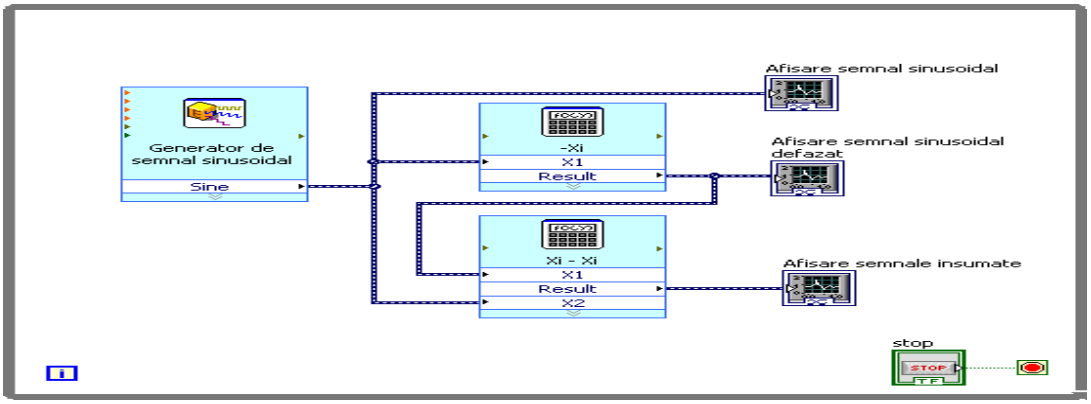


Fig. 1. Diagrama bloc a VI-ului “Generator de semnal sinusoidal”

Virtual instrument is built into a repetitive structure with termination condition (while loop). VI signal produced by the "Simulate Signal" is sent to a second sub-VI "Formula" using a computer interface to create mathematical formulas. In this sub-VI signals are added together and the resulting wave by canceling phase and antiphase signal is displayed on the front panel.

**Noise signal acquisition. Description of the experimental context.**

We build more devices that initially to test the possibility of obtaining a signal intensity zero and then the noise signals generated and achizitonate to get off or reduce them.

For radiated noise measurements were used a hydrophone array, which consists of three hydrophones placed at different depths and maintained in vertical alignment with a buoy and a ballast (Fig.3).

System is located at the measurement location and then recovered with a motor boat.

The acoustic field Measurement Mobile Polygon (Fig.2) provides the following performance parameters:

- dynamic measurement and operative analysis of the rig tender acoustic radiation values
- high reliability, embedded test, easy operation by a single operator,
- high degree of automation of measurement,
- the minimum level of the measured field: 80 dB/μPa.

Fig. 2. Measuring stand: testing procedure 1 – multichannel rack for data acquisition; 2 – reinforced laptop; 3 – signal amplifier; 4 – anechoic tank

Experimental background noise and emission acquisition in antiphase is presented in Fig. 3. In Table 1 are given the depths to which they are located hydrophones and underwater loudspeakers.

Acoustic recording system is shown schematically in Fig. 3.

The noise source upon which noise measurements were made was the research vessel "Mare Nigrum"

The experimental context has 2 major components:

- Noise source connected component that contains:
    - Noise source: research vessel "Mare Nigrum",
    - A computer working virtual instrumentation,
    - A system of three underwater sound projectors with systems of reinforcement / recovery related;

- component that records, measures and processes data related to noise reaching away from the ship (noise source). Noise acquisition system consists of:
    - three hydrophones Bruel & Kjaer 8104, 8105, 8106 in frequency response calibrated, placed at different depths, has adopted this type of array hydrophone because the noise diminishes with increasing depth and need to decide at what depth will be located projector underwaterc;
    - Data acquisition and processing system Bruel & Kjaer 3560D.
    - Software: Bruel&Kjaer Pulse 12.

The system is reinforced and stabilized by means of a submarine cable with a buoys and ballast. Movement and location of the hydrophone system is done by a speedboat where as well can be placed the acquisition system.

Recordings were made over a period between 8 and 12 hours at each site with 44.1 kHz sampling rate. Sound recorder was anchored on the seabed with concrete weights. After each deployment the recording system recovers [10].

*Tabel 1*

| Nr.crt | Object | Depth (m) |
|---|---|---|
| 1. | Float cylindrical stainless | 3 |
| 2. | upper hydrophone | 5 |
| 3. | median hydrophone | 14 |
| 4. | lower hydrophone | 22 |
| 5. | Ballast | 27 |

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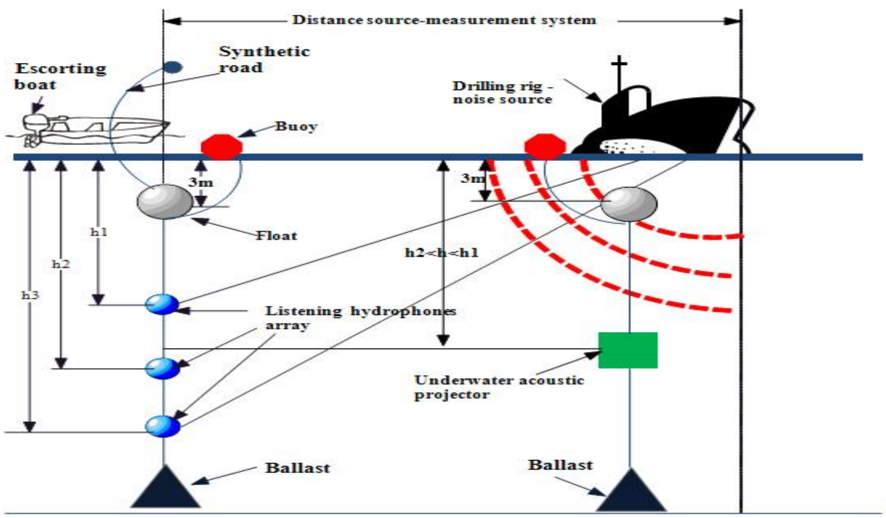



**a)**

Fig. 3 Experimental background noise acquisition

Recording was done with three hydrophones placed at different depths:

- shallow hydrophone: 5m,
- average depth hydrophone: 14m,
- deep sea hydrophone: 22m.

Measurements were taken from the boat and stored in databases.

The noise emission at 180 º out of phase consists of:

- three acoustic projectors, located near the noise source, anchored on the seafloor with a ballast and maintained at a depth h1> h> h2 with a buoy.

The proposed system should provide high reliability and a reduced rate of falls because in the event of accidental failure of the system, measurements are compromised.

For this purpose must be provided logistical base to allow:

- operation of long hydro-acoustic system;

- operational check of the operation and system parameters by providing test programs built just stating module defect;

ensuring appropriate reservations for electronic components to facilitate rapid operation of the system in case of accidental falls.

To achieve Lubell underwater transducer propose experimental context LL9642T.The Lubell LL9642T Underwater Acoustic Transducer (**Underwater LoudSpeaker)** is designed for general purpose military and scientific applications.

The LL9642T may also be used as an underwater loudspeaker when high power is required. IPA300T power amplifier is required 300W/33 ohm, 240V/50Hz, CE/RoHS.

Acquisition records for processing and storage of used software Bruel & Kjaer Pulse 12 shown in Fig. 4.

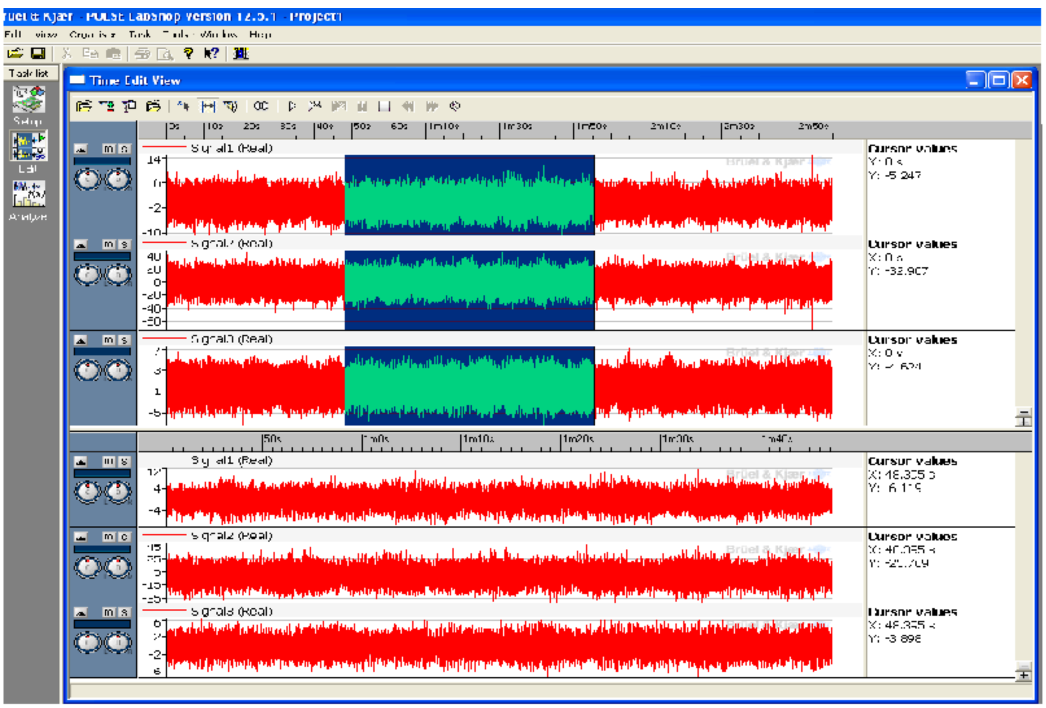



Fig.4 Software Bruel & Kjaer sound intensity measurement; Acquired the signals from the Three hydrophones

It can display and process sound signal captured from three hydrophones placed at depths presented in Table 1.
Records show that the maximum noise level is the depth to which it is placed the median hydrophone (14 m).

At this depth, the noise level is about 6-10 times stronger than that recorded by hydrophone located at 27 m.

## 4. Virtual tools for the injection of noise at source

The following describes two virtual instruments producing noise in antiphase:

- one with the signal acquired and stored;
- another one with the acquisition in real time and automatic configuration of the emitted signal.

The hydrophone system shown in Fig. 3 is to check noise reduction depending on the distance from the source. More speakers will be placed around the platform sea level power up to ensure maximum acoustic noise necessary mitigation.

### Virtual Instrument Read Sound File

The noise records were made with Bruel & Kjaer instruments, as described above, and were set in the database.

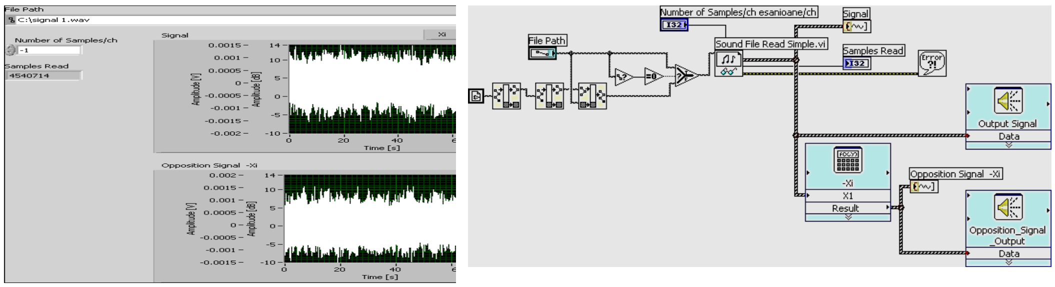
Virtual instrumentation designed uses records from database specifically designed for different types of noise sources. A recording taken from a hydrophone can be recharged in a virtual instrument and processed it (reverse phase).

Virtual instrument provides an out of phase signal which is amplified and played through speakers in the same environment and at the same location with the noise source.

In Fig. 5 is shown the front panel and block diagram of the virtual instrument.

Virtual instrument front panel contains two displayed: signal loaded from the database file and the signal out of phase.

Out of phase signal is taken IPA300T power amplifier power amplifier and played through speakers in the environment caused by the composition wave noise attenuation.




a) VI front panel “Read Sound File” b) VI block diagram “Read Sound File”

Fig. 5 Virtual instrument "Read Sound File”

The use of this type of Virtual Instruments is conditioned of the preexistence of a specialized data base for certain types of noise.

To reduce underwater noise produced by anthropogenic activities it should be introduced a legislation to provide the use of such devices in all activities with potential noise pollution.

It is also necessary, development of database access control can be used by managers such activities.

**Acquisition virtual instrument for real-time adjustable configuration**

In cases where no data are available to properly characterize the noise source has designed a virtual instrument that has the following functions:

- Signal acquisition from the noise source;
- Produces phase shift of $180^0$;
- Adds two signals (acquired at source and out of phase) and displays the result;
- Configure broadcast signal (out of phase) so that the noise level recorded by hydrophone system shown in Fig. 3, and monitoring under Directive are minimum;
- Monitoring can be made as follows:
    - by an operator remote from the source and communicating research results to the ship configuration or
    - even where it is placed aboard both computer using virtual instrumentation and computer that receives the signal acquired by remote hydrophone network.

Virtual instrument front panel of Fig. 6 contains only elements of presenting data appropriate signals such noise over the hydrophone and the result by composing with another of the same amplitude but in antiphase.

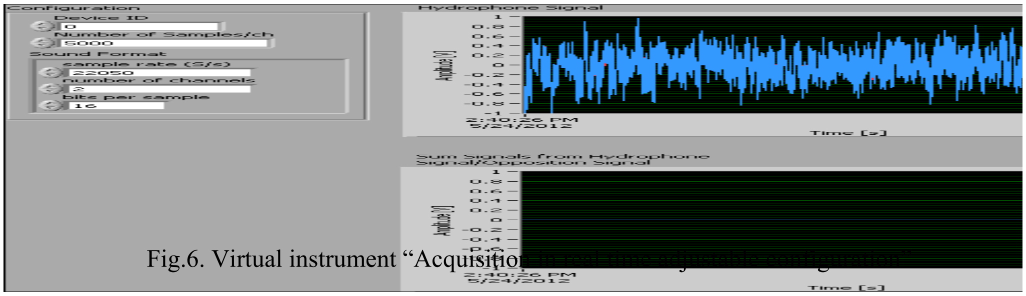



Fig.6. Virtual instrument “Acquisitio

Device’s front pannel (Fig.6) of:

- An overview of the data which is displayed in real time recorded signal,

An overview of the data where the resulting signal is displayed by summing the two signals: purchased ("Show hydrophone signal to noise") and delivered ("Show summary acquired noise signal / noise out of phase") in antiphase.

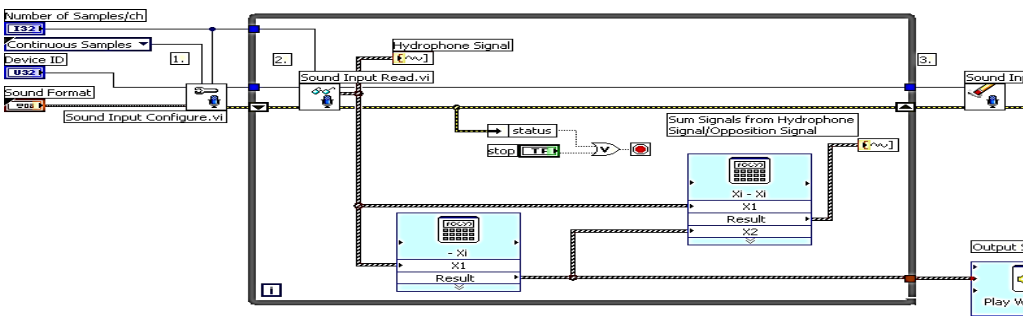



Fig.7. Virtual instrument “Acquisition in real time adjustable configuration”.
VI block diagram “real-time acquisition”

The block diagram is presented in Fig. 7. Out of phase signal is taken IPA300T power amplifier power amplifier and played through speakers in the marine environment by composition waves causing noise attenuation. Listen to underwater noise operator over the hydrophone and other acts on the level of the power amplifier up to reduce it as much as possible. Virtual instrumentation with real-time configuration is recommended for cases where there is no information about the foreseeable noise level may be issued in such activities or when performing research for the compilation of databases. The device will produce a better attenuation of underwater noise than the playback tab with real-time configuration. This virtual instrument, however, is more demanding in terms of required material base and highly qualified staff.

## 5. Conclusion

Machines were made "Virtual Instrument Sound File Read" for each of the three hydrophones acquisition, located at different depths as it may adopt a noise injection solution out of phase at all three depths where there is the necessary equipment. This tool is based on existing databases and used in contexts described the conditions under which the data were acquired.

For purposes of applied field was a virtual instrument designed for "real-time acquisition adjustable configuration". This device is used when you want to set up a database, performing measurements for research or mitigation is needed as much noise pollution by adjusting power in real time acoustic signal emitted by underwater speaker. The instrument acquires samples of noise, in a controlled and continuous emission signal and makes of phase in real time.

Virtual Instruments brings two new elements presented in noise management both through their conception and the presented experimental context:

- Practical solutions have been proposed, allowing immediate implementation of the objectives with the highest noise emission, in a first stage using existing databases;
- It was designed an experimental context that can be used for further research and for activities which are not available on database modeling scenarios appropriate to the type of activity.

The use of such devices to minimize the impact of anthropogenic activities on the marine environment should become mandatory for all sources of noise emitted during construction and operation of industrial facilities offshore.

The use of silencers specialized for commercial ships, fishing and cruise may greatly reduce the overall level of environmental noise, their contribution to overall noise budget is around 37%.

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