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NOISE MEASUREMENT AT THE ENTRANCE OF PORT CONSTANTA WITH ITS ASSOCIATED IMPACT ON ACOUSTIC EMISSION FROM SPECIES OF DOLPHINS (TURSIOSPS TRUNCATUS)

Vergil CHITAC [1]
Mihail PRICOP [2]
Tiberiu PAZARA [3]
Dinu ATODIRESEI [4]
Florin GHEORGHE [5]
Codruta PRICOP [6]
[1] Professor Ph.D., Naval Architecture Department, “Mircea cel Batran” Naval Academy, Constanta
[2] Associate Professor Ph.D., Naval Architecture Department, “Mircea cel Batran” Naval Academy, Constanta
[3] Lecturer Ph.D., Naval Architecture Department, “Mircea cel Batran” Naval Academy, Constanta
[4] Naval Architecture Department, “Mircea cel Batran” Naval Academy, Constanta
[5] Naval Architecture Department, “Mircea cel Batran” Naval Academy, Constanta
[6] Associate Professor Ph.D., Department of Naval Electrotechnics, Constanta Maritime University

***Abstract**: For the dolphins, sound emitting and hearing capabilities are very important tools for all activities associated with their behaviour and habits in underwater life. The measurements took place at the entrance of port Constanta, where is an intense naval activity. The recordings were analized using FFT (Fast Fourier Transform), STFT (Short-Time Fourier Transform) and DWT (Discrete Wavelet Transform). FFT and STFT are usually used for the analysis of the noise. DWT was used to determine the energy distribution of the signal in time and frequency. The classification of sound signals emitted by the dolphin group from NW Black Sea area, using the above mentioned methods is necessary in order to determine group’s functionality and social relevance in the initial groups’ geographic area. In the end, conclusions are made about the noise produced by the ships and about the acoustic parameters of the sounds emitted by the dolphins.*
***Keywords:** underwater noise, ship, Tursiosps truncatus, FFT, STFT, DWT*

1. INTRODUCTION

This study describes the available information on the audiograms and hearing sensitivity of these species and gives a review of the impacts that anthropogenic sounds can have on cetaceans. In the Black Sea there are three species of cetaceans; bottlenose dolphin *Tursiops truncatus*, common dolphin *Delphinus delphis* and harbour porpoise *Phocoena phocoena* [1]. These are all of the order Odontoceti (toothed whales). All three species represent subspecies endemic to the Black Sea due to morphological differences and genetic differentiation from populations in other areas [1;2]. three species are currently considered endangered [1].

The dolphins are emitting three different types of sounds (low frequency sounds for orientation during deep sea movements, high frequency sounds used for food detection and detailed examination of different objects, and whistle like sounds emitted for communication). The dolphin’s sound perception capability is very wide, starting from very low frequency values up to values of 170 – 220 KHz.

The approximate frequency range of bottlenose dolphin whistles is 5 to 15 kHz. The broadband sonar clicks emitted by dolphins are thought to be exclusively used for echolocation (range for echolocation clicks is 0.25 to 220 kHz) and broadband burst pulse sounds are a general classification given to such sounds as barks, mews, chirps, and pops [5].

It is confirmed that solitary bottlenose dolphins are not producing social signals, and also it was observed a proportional relation between group size and the production of social signals, particularly during feeding or socializing, confirming that dolphin social signals are used for communicative and social purposes. According to other significant carried studies, from the selected 220 acoustic recordings, 7713 separate vocalizations were categorized aurally and visually into three structural categories “tonal” (3503 vocalizations), “short burst pulsed vocalizations” (1748 vocalizations), and “long burst of pulses” (2462 vocalizations). Within these three classes, there were transcribed 14 different signal types based in part on previously reported vocalizations and partly on novel interpretation (Figure 1) [4].

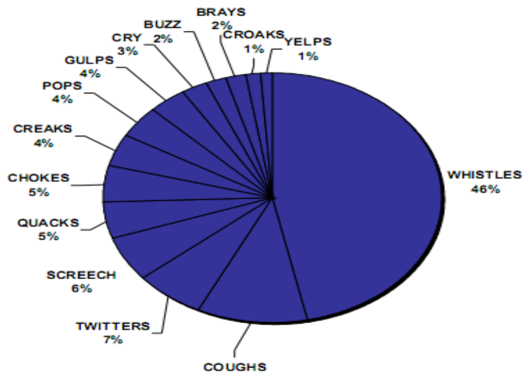


Fig. 1 Proportions of social signals recorded in various contexts during focal group sampling by López and Shirai, 2009[4]

Signature whistle parameters may vary by age, sex and context. Young dolphins (both male and female) have higher signature whistle rates than adults, but whistle rate decreases more quickly with age for males than females. Adult dolphins produce more loops per whistle than infants and sub-adults, therefore we can conclude that certain parameters of signature whistles (e.g., frequency, number of loops and duration of loops) appeared to be closely related to the level of arousal of an individual dolphin; however, these differences were not consistent across individuals [3].

Despite of a large variety of studies carried out for sounds emitted by the bottlenose dolphins, we have summary data about the main characteristics of these sounds, very important for the study of species behavior in natural conditions from the Black Sea NW underwater habitats.

The signals in oceanography are complex and contain a lot of information. The underwater signals can be considered to comprise sounds - acoustic events of interest superimposed on background underwater sound environment. For this kind of signals, the low-frequency content is the most important because gives the signal identity. On the other hand, the high - frequency components of the signal gives its nuance and unique characteristics.

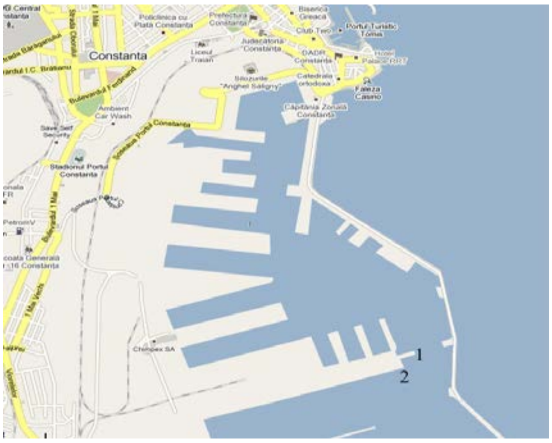
For these reasons, a signal decomposition method to extract the low - frequency and high - frequency of the underwater signal can be very efficiently exploited to extract different features of the highly non - stationary underwater signal.

The time - frequency signal processing technique used in order to achieve our goals is the wavelet technique, more precisely Discrete Wavelet Decomposition.

2. METHOD

The measurements were carried out on May 24nd 2010 with a boat from the Naval Academy, in Constanta Port area at 1,5 miles from port entrance. At the anchorage point water depth is 28m. In the area was spotted a bottlenose dolphin (*Tursiops truncatus*) group with 5 adults and 1 juvenile. The water temperature was at that moment 15°C at the surface, and the sea state was 2 degrees Beaufort scale.

The vessel traffic in the area was pretty intense during the measurements. Measurements were made early in the morning of May 24th, between 6.50 AM and 9.00 AM. The weather was calm, very little winds, air temperature – 19 ^{0}C, water temperature – 15 ^{0}C and there were very small waves (sea level 0-1). Two measuring points were chosen: first one was near Red Lighthouse (Fig. 3.10 3.10 point n^{o}1) and the second was near the ore terminal (Fig. 3.10 3.10 point n^{0}2).



Map of Constanta North Port:
1 – first place used for measurements (north port entrance);
2 – second place used for measurements (bulk pier);
Fig. 2 Measurements locations

One hydrophone type 8104 was used and it was connected to a Machine Diagnostics Toolbox 9727, both manufactured by Bruel & Kjaer. For recording and processing it was used the software PULSE 12 also from Bruel & Kjaer (FFT-Fig. 3.25-3.27, Appendix 4, 5).

The noise sources encountered during these measurements may be broadly categorized into two main types:

- sources of roughly constant level which represent the background noise;
- sources that appear for a short period of time representing the noise from the ships.

2.1. Time-Frequency Analysis. Short Time Fourier Transform (STFT) Spectrogram

One of the most important method for the time-frequency spectral analysis is time - varying spectrum, a technique that represents a signal's power spectrum changing over time. Adapted for spectral analysis of non stationary signals, time - frequency representation of signals based by Short Time Fourier Transform, seems to offers a good choice to describe the evolution of frequency content in time.

The Short Time Fourier Transform of a signal s(t) is defined as follows:

(1) $$STFT(f,\sigma) = \int_{-\infty}^{+\infty} s(\tau)\gamma(\tau - t)e^{-j2\pi f\tau}d\tau$$

where $\gamma(t)$, so called the window function (i.e. window Hamming function).

The length of the windows function $\gamma(t)$ is a very important parameter for STFT spectrogram.

The time – dependent spectrogram, a quadratic transform, called Short Time Fourier Transform STFT - spectrogram, is defined [6] as follows:

(2) $$P(t,f)=\left|\int_{-\infty}^{\infty} s(\tau)\gamma(\tau-t)e^{-j2\pi f\tau}d\tau\right|^2$$

where $P(t,f)$ is Power Spectral Density (PSD).

The Short Time Fourier Transform STFT –spectrogram computes PSD, which measures power per unit of frequency and has power/frequency units.

PSD can be expressed in logarithmic values:

(3) $$[P]_{dB}=10\lg|P(t,f)|$$

This spectrogram is the magnitude of PSD represented in time - frequency plane, in coloured logarithmic scale.

2.2. Discrete Wavelet Transform

The wavelet signal analysis based by Discrete Wavelet Transform (DWT) [7], [10] is a time/frequency method that decompose signal in low frequency and high-frequency components.

Signal decomposition through Discrete Wavelet Transform can be efficiently realized by means of a pair of low - pass and high - pass wavelet filter, denoted as h(k) and $g(k)=(-1)^k h(1-k)$, respectively [8].

These filters, also known as Quadrature Mirror Filters (QMF), are constructed from the selected mother wavelet $\psi(t)$ and its corresponding scaling function $\phi(t)$, expressed as:

(4) $$\begin{cases}\phi(t)=\sqrt{2}\sum_k h(k)\phi(2t-k)\\ \psi(t)=\sqrt{2}\sum_k g(k)\psi(2t-k)\end{cases}$$

Using the wavelet filters, the analysed signal is decomposed into a set of low and high - frequency components:

(5) $$\begin{cases}a_{j,k}=\sum_m h(2k-m)a_{m,j-1}\\ d_{j,k}=\sum_m g(2k-m)a_{m,j-1}\end{cases}$$

In equation (5), $a_{j,k}$ is the approximation coefficient, which represents the low - frequency component of the signal, and $d_{j,k}$ is the detail coefficient, which corresponds to the high - frequency component. The approximate and detail coefficients at wavelet scale 2^j (with j denoting the level) are obtained by convolving the approximate coefficients at the previous level (j-1) with the low - pass and high - pass filter coefficients, respectively.

In this paper we use also The Discrete Meyer Wavelet for underwater signal analysis because this wavelet has a shape suited for this kind of signal. The recorded signal was decomposed with Discrete Transform at 5 level of decomposition. For Meyer Wavelet and scaling function are defined in frequency domain, starting with an auxiliary function [9].

3. RESULTS

The values determined for Sound Pressure Level on 24th of May 2010 is presented at Fig. 3

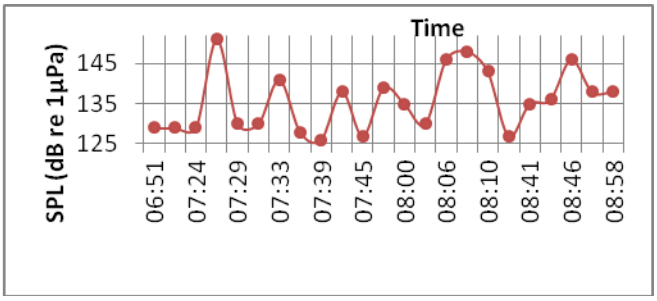


Fig 3 Values determined for Sound Pressure Level on 24th of May 2010

For sounds signal from dolphins, at the results analysis, it appeared that the FFT diagram doesn’t describe accurately the time – frequency variation, especially for transient signals.

Because the dolphins sound signals are mostly transient signals, we will use from this point short time Fourier transform spectrogram and discrete wavelet transform.

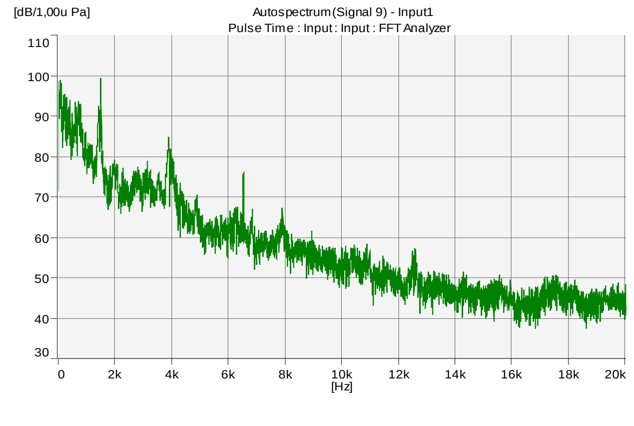


Fig. 3.a. - The FFT diagram for bottlenose dolphins’ twitter sound signal

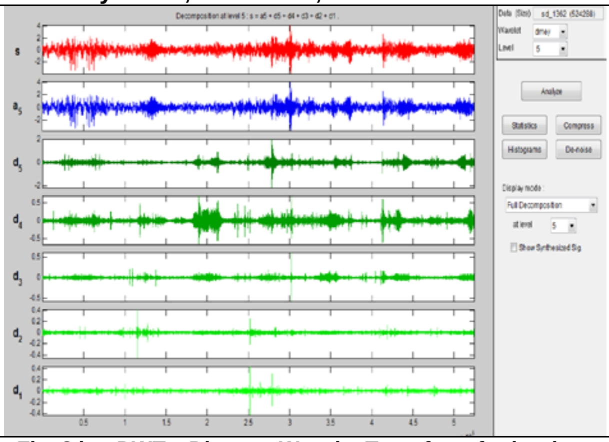


Fig. 3.b. - DWT – Discrete Wavelet Transform for bottlenose dolphins’ twitter sound signal

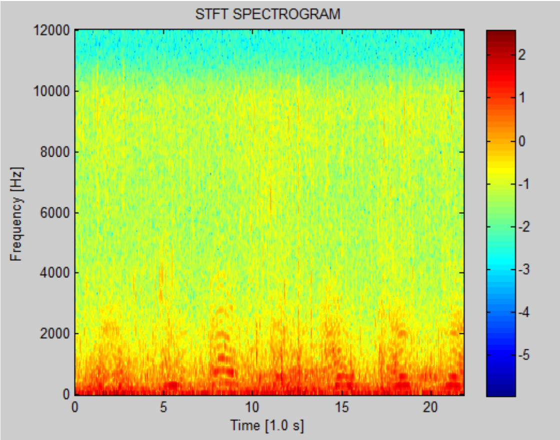


Fig. 3.c - STFT - The spectrogram for bottlenose dolphins’ twitter sound signal

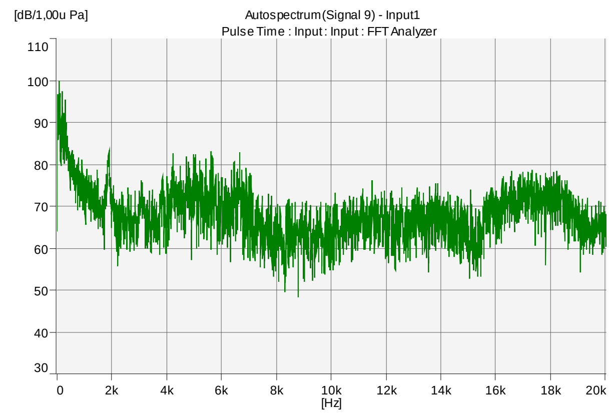


Fig. 4.a. - The FFT diagram for bottlenose dolphins’ short burst pulse sound signal

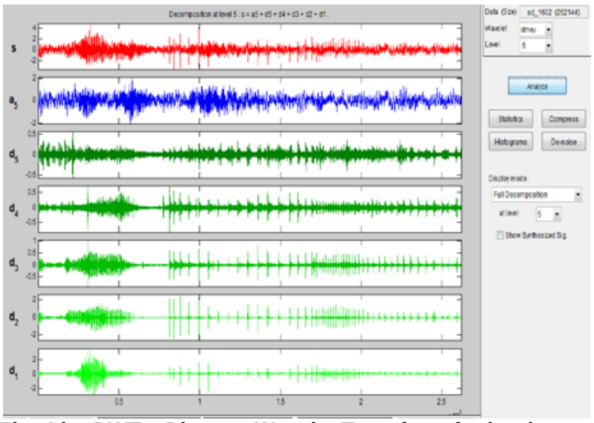


Fig. 4.b - DWT – Discrete Wavelet Transform for bottlenose dolphins’ short burst pulse sound signal

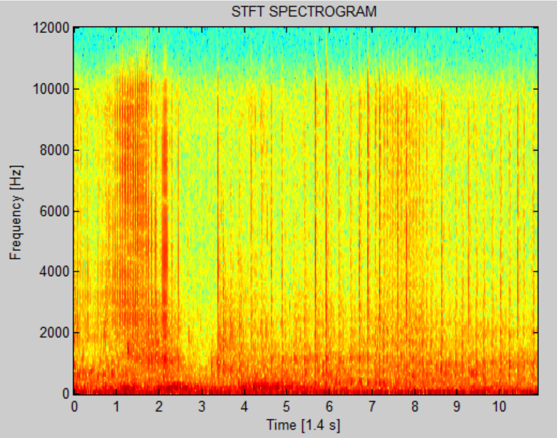


Fig. 4.c. - STFT - The spectrogram for bottlenose dolphins’ short burst pulse sound signal

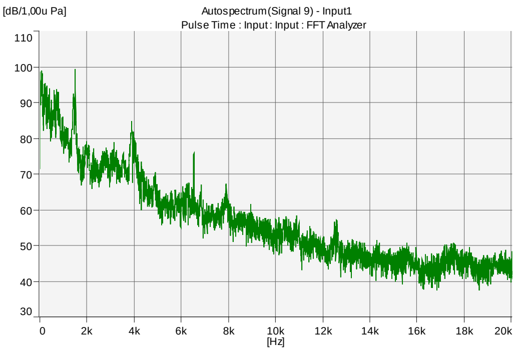


Figure 5.a - The FFT diagram for bottlenose dolphins’whistle

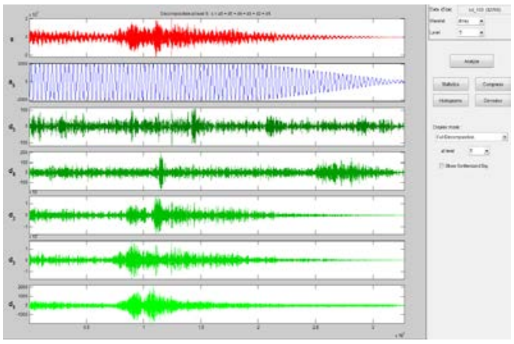


Fig. 5.b - DWT – Discrete Wavelet Transform for bottlenose dolphins’whistle

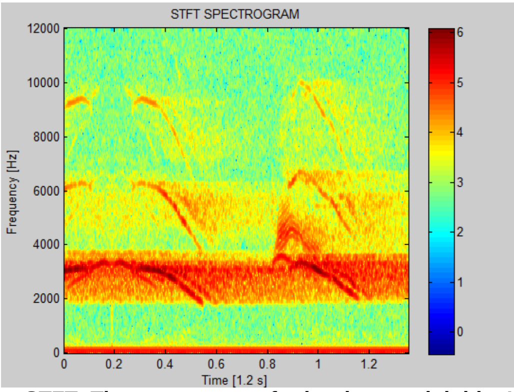


Fig. 5.c. - STFT- The spectrogram for bottlenose dolphins’ whistle

The recorded signal blocks were decomposed with MATLAB - Wavelet toolbox through Discrete Meyer Wavelet Transform at 5 level decomposition. The Discrete Wavelet transform split the frequency band of the signal into disjunct frequency subbands as related in Table 1.

Table 1. Discrete Wavelet Transform (DWT) and splitting of the frequency band for the recorded signal

Signal	Band: [0; 25 600 Hz]	
1st level Discrete Wavelet Decomposition	Approximation a1: [0 ; 25 600 Hz]	Details d1: [0; 25600 Hz]
2nd level Discrete Wavelet Decomposition	Approximation a2: [0; 12800 Hz]	Details d2: [12800 Hz; 25600 Hz]
3rd level Discrete Wavelet Decomposition	Approximation a3: [0; 6400 Hz]	Details d3: [6400; 12800 Hz]
4th level Discrete Wavelet Decomposition	Approximation a4: [0 ; 3200 Hz]	Details d4: [3200; 6400 Hz]
5th level Discrete Wavelet Decomposition	Approximation a5: [0 ; 1600 Hz]	Details d5: [1600; 3200 Hz]

DWT underwater signal decomposition calculates the DWT coefficients. These DWT coefficients provide a compact representation that shows the energy distribution of the signal in time and frequency.

In order to compress the underwater signal (to reduce the dimensionality of the extracted feature vectors associated to DWT signal decomposition) statistics over the set of the discrete wavelet decomposition can be used.

For extracting features in order to characterise the underwater signal we can use:

- the mean of the absolute value of the coefficients in each subband. These features provide information about the frequency distribution of the audio signal;
- the standard deviation of the coefficients in each subband. These features provide information about the amount of change of the frequency distribution;
- the ratios of the mean values between adjacent subbands. These features also provide information about the frequency distribution.

4. CONCLUSIONS

The classification of sound signals emitted by the bottlenose dolphin group from NW Black Sea area, using the above mentioned methods is necessary in order to determine group's functionality and social relevance in the initial groups' geographic area; also, it will help to create a database with the acoustic signatures of dolphins from the Black Sea. The database will be used to identify the specie of the dolphin from various groups monitored in the Black Sea.

The length of the window function $\gamma(t)$ can be adequate choose in order to obtain the time and frequency desired resolution (long time duration window lead to good frequency resolution and poor time resolution and viceversa). This is so called the window effect.

The main advantages of the STFT - spectrogram consist in the fact that these kind of representations create a correct distribution of energy in the time frequency plane an are simple and easily implemented.

Since the backscattering in oceanography is a non-stationary process, the simultaneous time - frequency localization characteristics are considerably important. The two dimensional space described by time and frequency is called phase space.

Wavelet - based techniques used in underwater signal processing leads to an optimum time - frequency localization and characterization of salient signal features as transient or isolated components.

Burst pulses are probably signals intended to be heard by nearby animal and are predominantly ultrasonic signals. By producing whistles at higher frequencies, dolphins improve their S/N ratio and may thus increase the range or ''active space''

The realized study upon the sound signals emitted by the targeted dolphin group, creates a starting point for further more accurate studies, in order to achieve more information for each individual, the signal segregation becomes mandatory, either in captivity conditions or in open sea, more precisely in a strictly delimited area.

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