

Spectrum Analysis Signature Whistle of Bottlenose Dolphins (*Tursiops aduncus*) at Captive, Indonesia with Yule-Walker AR and Welch Power Spectral Density Method

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Abstract

Signal and spectrum analysis signature whistle of bottlenose dolphins using Wavelab, and Raven Pro 1.5 software. Analysis spectrum of bottlenose dolphin with software analysis Raven Pro 1.5 with wave data channels 1 with sample rates is 44100 Hz, encoding data 16-bit signed, length time duration is 0,7 second, and samples of data is 32386 and have 6 pattern of signature whistle bottlenose dolphins. Analysis of power spectral density used Power Spectral Density (PSD) Yule-Walker AR and Welch Power Spectral Density of signature whistles with location of research in safari park captivity, Indonesia. The pattern seen in the sound has six patterns of range is at 100-700 ms with frequency 6-22 kHz. Interval of whistle have range in pattern 1 is 100-200 ms, pattern 2 is 200-300 ms, pattern 3 is 320-370 ms, pattern 4 is 430-550 ms, pattern 5 is 550-600 and pattern 6 is 600-650 ms. Range intensity color -47 until -48 dB, range frequency 1-8 kHz, time duration 0-500 ms. Highest intensity value of signature whistle bottlenose dolphins (*Tursiops aduncus*) is -37.71 dB in frequency 18 kHz with time duration 100 ms. Yule-Walker AR method have result in marker 1 (perpendicular line) with clay color have (x) 2728 and (y) -15.70 dB, and marker 2 with interrupted line have (x) value 5456 and (y) value -5.55 dB. Welch method have result in marker 1 (perpendicular line) with clay color have (x) 1365 and (y) -32,67 dB, and marker 2 with interrupted line have (x) value 2728 and (y) value -32.46 dB Welch power spectral density is a good method used for signal and spectrum analysis with object signature whistle of bottlenose dolphins.

Keywords: Bottlenose dolphins; Signature whistle; Yule-Walker AR; Welch; Frequency; Intensity

Introduction

Signals are important in communication systems in everyday life, signal processing, and electrical engineering is a function that "convey something of information or insight into actions and behaviors or attributes of some phenomena" [1] (Figure 1).



Figure 1: Bottlenose dolphins (*Tursiops aduncus*).

In parts of the physical world, the results indicate the quantity of variation in the form of time or variations in the shape of space, and the potential of the signal that might provide information about a physical system status, or leave a message for each observer [1,2].

In acoustics science, spectrogram is the frequency spectrum of sound was be representation in visual as a function of time or another the variable [3]. Function of the spectrum analyzer is an passive acoustic instrument which can be used to converting the sound wave from the source of the note of musical into visual display of the constituent frequency [4]. Acoustic spectrogram was be generated by the analyzer of spectrum provides in acoustic signature sound from the source by passive acoustic instrumental. In addition fundamental frequency and its signature signal to revealing, the spectrogram is also useful for temporal attack analysis, broken, defended, and deleting of the signature signal note [5]. Sound source of a signal can have many different intensity and frequencies mixed. A signature sounds is characterized by its spectrum of harmonic. In environment sound that we refer to as noise includes many different frequencies, intensity and sound press level (SPL). When the signal of sound contains a mixed of all audible from frequencies, distributed in equally over spectrum of audio, it is called to represented of white noise [3].

Individuals who have their signature whistles of dolphins acoustic environment is through the experience with them [6,7], resulting in a unique whistle contour results with a high level scale kekhasandari individual who is independent of voice features common [8]. Information on the identity of the signature whistles encoded in different frequency contour of this study to analyze the signature whistles of stereotypes [8,9] (Figure 2).

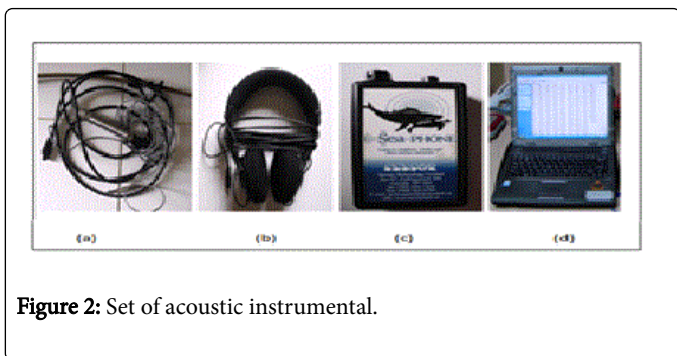


Figure 2: Set of acoustic instrumental.

They can be manufactured as a single signal, or berhubngan or interrupted with a multi-looped form and they are often also produced in a fight which contains a repetition of the type of whistle same signature [9]. Signature whistles (*Tursiops aduncus*) we have documented in captivity (the safari park, Indonesia) and free from 2 animals [10,11]. However, with the exception of marine mammals dolphins (*Tursiops* sp) Exist in the area of Shark Bay, in Australia [12], little attention has been given to the species, whether using a signature whistle. In addition, learning about the production of the results of vocalization, the process by which a whistle signature species that thrive in *T. truncatus* [7,13], and they must be assured and demonstrated in Specific species of other marine mammals [14]. Here we study the signal and spectrum analysis of the signature whistles of dolphins (*Tursiops aduncus*) and Power Spectral Density (PSD) Yule-Walker AR and Welch Power Spectrum Meeting of signature whistle in the safari park, Cisarua, Bogor, Indonesia.

Methods

Data collection and acoustic data analysis

Data were collected in captivity, Indonesia on May 2015. Passive acoustic instruments for the retrieval of data collected using this type SQ3 hydrophone with built-in preamplifier, sensivity than 165 dB return V / μ Pa, and that the frequency response of 5 Hz - 35 kHz (± 3 dB). SQ 3 recorder with software Wavelab 6 Software, and store data with a form that is WAV files with 16-bit. All acoustic wave file, aural, and spectrograms checked using software Wavelab 6 and Raven Pro software (version 1.5; Cornell Laboratory of Ornithology, NY). It can be used as a connector in combination with Hanning window function, temporal network within 0.7s with an overlap of 50% from 100%, and 22 kHz frequency resolution grid with the size of the window and the Fast Fourier Transform (FFT) size both in 2048 (depending on the level samples of sound files of dolphins diperole), produces filter 3-dB bandwidth of 22 kHz. During the recording process by using a hydrophone in the treatment of swimming events at the safari park with a pool depth of 0.5 m below the water surface. In the event the pool there are two dolphins are used as research objects. Number two dolphins have the same size, without a name or designation given.

Dolphins bottle has a length of 2.6 meters, weighs 232 kg, and the age of 14 years (dolphins are classified as adults). The treatments were given in this study is a before and after meals with dolphins object 2 bottles. Figure one set of passive acoustics (Figures 3 and 4) and Sketch in research can be seen in Figure 4.

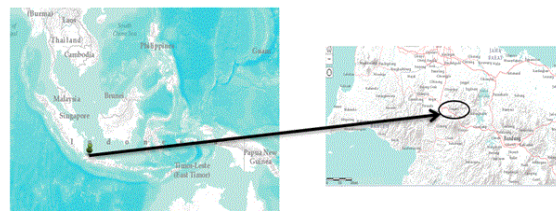


Figure 3: Map of research location (safari park, Cisarua Bogor, Indonesia).

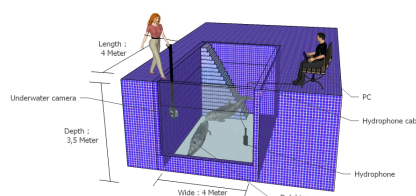


Figure 4: Sketch of experimental research of dolphins in safari park.

Recording whistle

Values in the propagation of the pressure wave away from the sound in a medium to have a component of particle velocity (v) and has a component of the pressure (p), as well as defining the product acoustic intensity (I), in equation is:

$$I = p \cdot v \quad (1)$$

V is the velocity of pressure divided by the acoustic impedance of the medium. The acoustic impedance of the media that is (p) in equation is:

$$I = p^2 / (\rho c) \quad (2)$$

In decibel, the equation is:

$$10 \log_{10} (I/I_0) \quad (3)$$

I_0 is the intensity of sound target of the sound pressure in scale is 1 mPa in seawater measured, quantify the sound pressure in equations is:

$$\text{dB re } \mu\text{Pa} = 20 \log_{10} (p/p_0) \quad (4)$$

Welch method will result in increased an estimation method consists of four steps (Welch 1967). Periodogram method used to determine the power density of the frequency components in the signal based on Fourier transform. Welch method of estimating the power spectral density with an average modified periodogram. With periodogram modifications are:

$$\hat{s}_{xx}^{(i)}(f) = \frac{T_s}{C.M} \left| \sum_{n=0}^{M-1} x_i(n) \times w(n) \times e^{-j2\pi f n} \right|^2 \quad (5)$$

where $f = fs$ is the frequency variable normalized to have a unit of cycles per sample. The scale factor T_s adjust the amount of time discrete signal spectrum to be the same as the analog signal spectrum. M is the length of the signal $x(n)$. Windowing function represented by the sample $w(n)$, and C is a normalization constant defined as:

$$\hat{s}_{xx}^w(f) = \frac{1}{L} \sum_{i=0}^{L-1} \hat{s}_{xx}^{(i)}(f) \quad (6)$$

Finally, the estimation of the power density spectrum is:

$$C = \frac{1}{M} \sum_{n=0}^{M-1} w^2(n) \quad (7)$$

Whistles are assigned to specific individuals when dolphins were alone near the hydrophone (passive acoustic instrument), near the sole (<0.5 m) from the hydrophone, or the bubble emissions showed that simultaneous and correlated with a whistle (Figure 5).

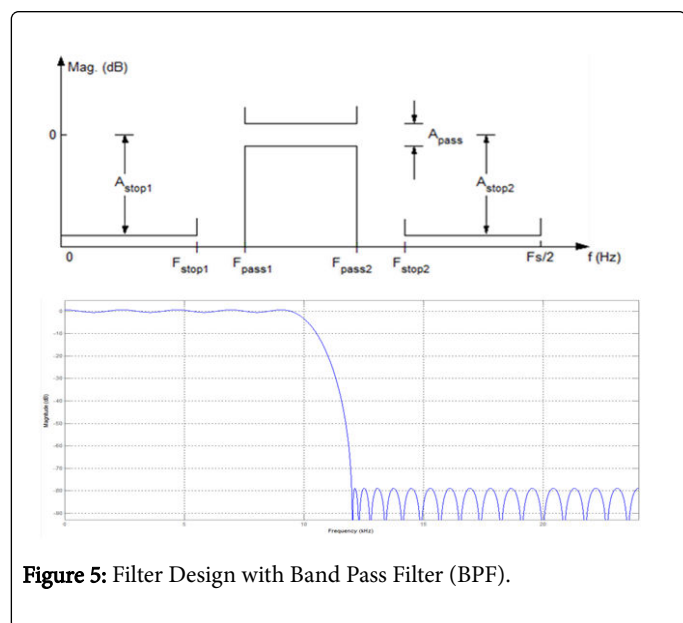


Figure 5: Filter Design with Band Pass Filter (BPF).

Although the results in the form of variable amplitude in the vocalizations of dolphins, individuals are more than 3 m of passive acoustic equipment itself to make the recording never emitted a whistle as loudly as a dolphin in 0.5 m. If a group of dolphins came to the hydrophones, the intensity of the whistle is used only to determine the individual whistle when one of the dolphins was close to the position of the hydrophone (<0.5 m) and the rest of the group was further (≥ 3 m). Filters used to design the data whistle Band Pass Filter (BPF), Band Pass Filter design can be seen in Figure 5.

Results and Discussion

This study has demonstrated signal and spectrum analysis the whistle of bottlenose dolphins (*Tursiops aduncus*), clustering spectrum and power spectral density Yule-Walker AR and Welch Power Spectral Density using signature whistles (Figure 6). While this paper aims to describe whistles sound recorded in captivity, Indonesia, and the bottlenose dolphins have trainee for behaviour in show pool. The pattern seen in the sound has six patterns of sound that is at 0-700 ms with frequency 0-2200 Hz.

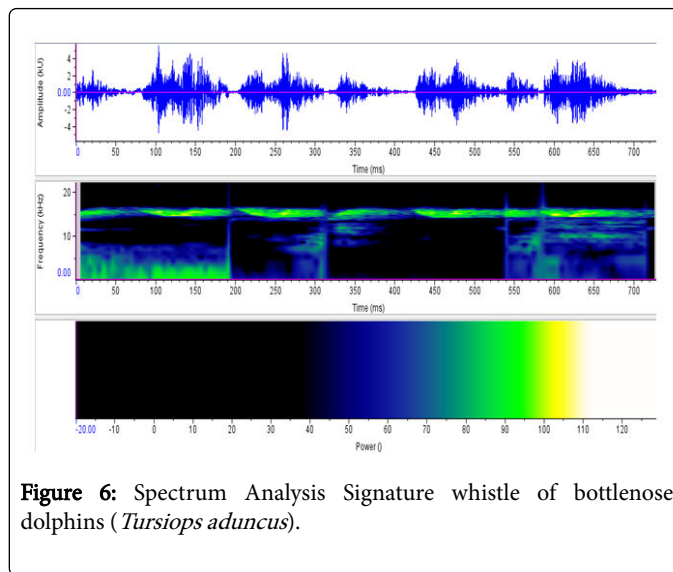


Figure 6: Spectrum Analysis Signature whistle of bottlenose dolphins (*Tursiops aduncus*).

Interval of whistle have range in pattern 1 100-200 ms, pattern 2 200-300 ms, pattern 3 320-370 ms, pattern 4 430-550 ms, pattern 5 550-600 and pattern 6 600-650 ms. This suggests a different sound patterns within a specific time range produced by bottlenose dolphins with maximum time is 100 ms with range power 80-90 kU (Figure 6), and the result is almost the same as the previous study [10,11,15,16]. The clustering of whistle have 8 pattern, the result have using Matlab R2008b with signal processing method (Figure 7), and highest magnitude value in pattern 2 with 0.9 dB. Result of intensity, frequency, and time duration in 3D can be seen in Figure 8.

Figure 6 showed the analysis spectrum of bottlenose dolphins in captive with software analysis Raven Pro 1.5 with wave data channels 1 with sample rates is 44100 Hz, encoding data 16-bit signed, length time duration 0,7 second, and samples of data is 32386 and have 6 pattern of signature whistle bottlenose dolphins.

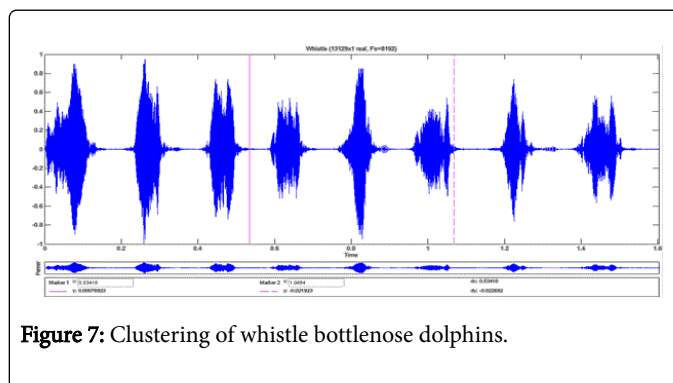


Figure 7: Clustering of whistle bottlenose dolphins.

In Figure 8 showed the 3D figure of intensity (y axes), frequency (x axes), and time duration (z axes) with range intensity color -47 until -48 dB, range frequency 1-8 kHz, time duration 0-500 ms. Highest intensity value of signature whistle bottlenose dolphins (*Tursiops aduncus*) is -37.71 dB in frequency 18 kHz with time duration 100 ms. This result showed signature whistle which really is at range frequency 5-6 kHz with highest intensity is -40 dB (Figure 8). Result of Max frequency of whistle in this research be same according in the references [10,17,18].

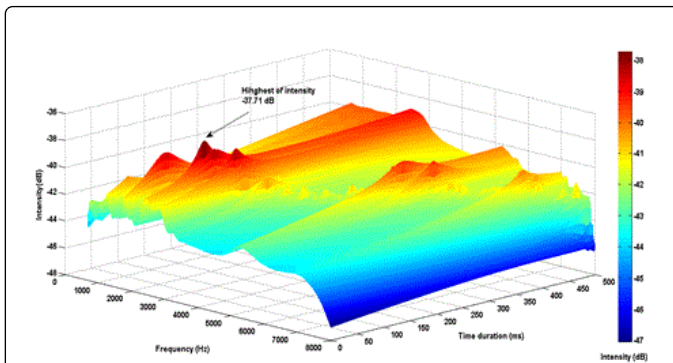


Figure 8: 3D Intensity (y), Frequency (x), and Time duration (z) of signature whistle.

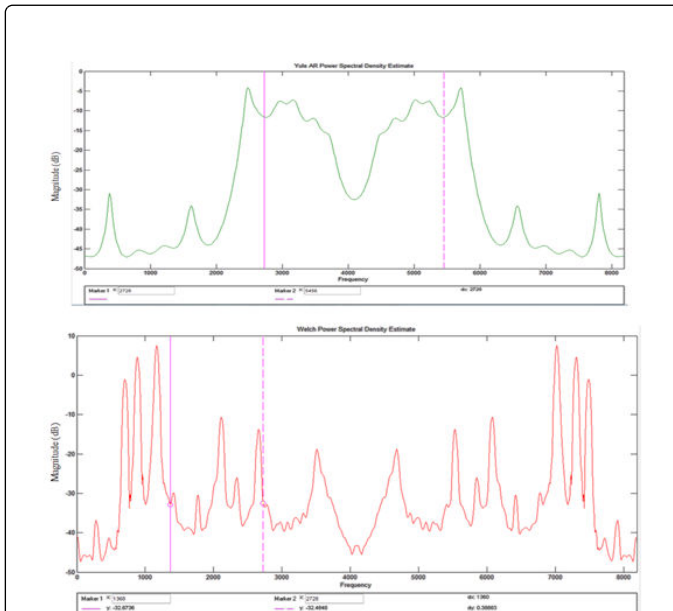


Figure 9: Power Spectral Density (PSD); a) Yule-Walker AR, and b) Welch Method of signature whistle.

A result obtained from the Figure 9 has a difference that allows the difference equations used. These results were obtained in the same voice and the same dolphins. It is apparent that the equation welch magnitude value (dB) at the highest frequency range of 500-1000 Hz and 7000 Hz -7500 with the same frequency difference is 5 kHz. Yule-Walker AR power spectral density have result in marker 1 (perpendicular line) with clay color have (x) 2728 and (y) -15.70 dB, and marker 2 with interrupted line have (x) value 5456 and (y) value -5.55 dB (Figure 9a). Welch power spectral density have result in marker 1 (perpendicular line) with clay color have (x) 1365 and (y) -32,67 dB, and marker 2 with interrupted line have (x) value 2728 and (y) value -32.46 dB (Figure 9b). The results of x (frequency) and y (intensity) values obtained by the two equations differ very significantly towards the results of the frequency and intensity are produced, how it has been described by [19,20]. Total of data can be affect to result of spectral density estimates according in reference [21]. Result of welch spectral density have a difference in frequency and

intensity with Yule-Walker AR power spectral density after described in previous studies [19,22-25].

Conclusion

Signal and spectrum analysis signature whistle of bottlenose dolphins in captivity, Indonesia have total of whistle pattern is 6, range frequency of signature whistle is 5-6 kHz with intensity -40 dB. This result have different in intensity and frequency value using software Raven Pro 1.5, Yule-Walker AR power spectral density, and welch power spectral density in signal processing method. Welch power spectral density is a good method used for signal and spectrum analysis with object signature whistle of bottlenose dolphins.

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