POLYTECH
Peter the Great St.Petersburg Polytechnic University

Available online at www.sciencedirect.com

ScienceDirect

St. Petersburg Polytechnical University Journal: Physics and Mathematics 000 (2016) 1–9

www.elsevier.com/locate/spjpm

The study of acoustic signals and the supposed spoken language of the dolphins

Vyacheslav A. Ryabov

T. I. Vyazemsky Karadag Scientific Station–Nature Reserve of RAS, 24 Nauki St., Kurortnoye, Feodosiya, 298188, Russian Federation

Available online xxx

Abstract

This paper continues studies in the problem of animal language by registering acoustic signals from two quasi-stationary Black Sea bottlenose dolphins (*Tursiops truncatus*) using a two-channel system in the frequency band up to 220 kHz with a dynamic range of 81 dB. The packs of mutually noncoherent pulses (NP) generated by the dolphins were matched to the animals. The waveforms and the spectra of these pulses changed from one pulse to another in each pack. In this connection, a suggestion was made that the set of spectral components of each pulse is a 'word' of the dolphin's spoken language and a pack of NPs is a sentence. The paper studied the NP peculiarities in the context of the characteristics of the human spoken language.

Keywords: Dolphin; Spoken language; Acoustics; Signal; Pack; Noncoherent pulse.

Introduction

Acoustic signals of toothed whales are diverse and serve as their primary means for mediating complex coordinated social behavior (foraging, defense against predators, etc.), navigation and communication among dispersed individuals, obtaining information on the environment [1]. We should specifically stress that these signals are the only source of sensory cues for the animals in poor visibility conditions.

To date, the general consensus in the scientific literature has been that the toothed whales (Odontoceti) possess a sonar. The sounding signals of the dolphin sonar are clicks lasting about 50 μs, with the maximum energy reached at frequencies around 120–130 kHz [2].

Most species of dolphins produce two types of sounds, which possibly play the role of communication signals in their social relationships. These are packs of broadband pulses and 'whistles' [3]. Several species of dolphins of the *Kogiidae*, *Physeteridae* and *Phocoenidae* families and the *Cephalorhynchinae* subfamily (Hector's dolphin) do not produce whistles and may communicate by pulsed sounds [4–6].

Pulse packs consist of a sequence of broadband pulses that are similar to echolocation clicks but unlike them have very short (0.5–10 ms) interpulse intervals [7] and significantly lower sound pressure levels (SPL) [2]. The presence and the function of these packs still remain unclear, even though the hypothesis that dolphins use them for communication has been discussed

E-mail address: ryabofff@inbox.ru.

http://dx.doi.org/10.1016/j.spjpm.2016.08.004

(Peer review under responsibility of St. Petersburg Polytechnic University).

Please cite this article as: V.A. Ryabov, The study of acoustic signals and the supposed spoken language of the dolphins, St. Petersburg Polytechnical University Journal: Physics and Mathematics (2016), http://dx.doi.org/10.1016/j.spjpm.2016.08.004

since the 1960s [6,8,9]. This hypothesis is based on the fact that the above-described signals are recorded when the dolphins are engaged in high social activity and at short distances (2–14 m) from them [1], and the interpulse intervals of these signals have a shorter processing time typical for echolocation (15–45 ms). It should be noted that the vast majority of the dolphin signals were recorded in the frequency band only up to 20 kHz (see, e.g., [8,10]), with few exceptions [6,7].

Many species of dolphins produce long frequency-modulated (FM) acoustic signals containing a large number of harmonics that occur at n-tuples of the fundamental frequency (n is an integer). Such signals have come to be called whistles because this is how humans perceive them.

The repertoire of context-specific whistles which vary according to the situation or to animal activity was studied and described almost immediately after the whistles were first recorded [11–13].

Most species of dolphins producing whistle signals are gregarious animals and live in large groups, so it was suggested that whistles play an important role in their social communication [14–16]. The manner in which such signals can be used for communications is the most common subject of discussion in the scientific literature. Recent studies have established that the fundamental frequency of the majority of whistles covers the frequency range of 2–35 kHz and up to 100 kHz for the harmonic frequencies [7,17–19]. However, both the necessity and the function of the harmonics which make up an integral part of the whistle are currently unexplained.

The signature-whistle hypothesis claiming that dolphins use these whistles to inform the community about their identity and about the location of other members of the social group [20,21] has been discussed recently and has found support in numerous papers (see, e.g., [16,22,23]).

It was also suggested that whistles have a communicative function, i.e., they are used for establishing connections, coordinating actions and maintaining cohesion in a group of animals scattered around the water area [16]. The maximum distance at which the dolphins can communicate with whistling signals was calculated based on the data on the maximum SPL of the whistle, the sensitivity of the dolphin's hearing, the level of ambient noise and sound attenuation with distance. It amounted to about 10.5 km. [24]

The material of the brief review presented above indicates the great interest of researchers in studying the acoustic signals of dolphins. At the same time, only echolocation clicks were the most extensively investigated in the frequency band up to 200 kHz, with a known position of the dolphin relative to the hydrophone. The vast majority of other types of dolphin signals were detected and described in the frequency band up to 20 kHz. Additionally, acoustic signals were recorded using equipment with insufficient dynamic range; the pulsed character of the sounds and the position of the dolphins relative to the hydrophone (the animals were swimming freely) were not taken into account. Perhaps that is why the authors of these studies failed to clearly identify which acoustic signals of the animals could be regarded as communication.

At the same time, a promising new technique for studying the functions of the acoustic signals of dolphins by registering the signals of two quasi-stationary dolphins using a two-channel recording system was described in Refs. [25–27]. This technique has allowed for the first time to ascribe each signal to a specific animal, to record the sequence for the exchange of different types of signals between the dolphins, the dynamics of the changes in the characteristic of the radiation pattern and the signal waveform, to classify and interpret the functionality of the signals in view of the theory of signals and echolocation. Dolphins signals were divided into the following classes:

a sequence of ultrashort sequence ultra-wideband coherent pulses (clicks);
packs of mutually noncoherent pulses (NP);
pack of mutually coherent pulses (CP);
packs of versatile pulses (VP);
FM-simultons with evenly distributed tones (whistles).

The results of the studies give reason to regard all acoustic signals of dolphins as sounding signals of not one sonar (as discussed earlier) but at least six different sonar types. At the same time, it was suggested in Refs. [25–27] that NPs are the signals of a highly advanced spoken language of dolphins.

The goal of this study is to reliably measure and analyze the noncoherent pulses as the most likely acoustic signals of the hypothetic spoken language of the dolphins.

Experimental subjects and procedures

The experiments were performed on two adult Black Sea bottlenose dolphins (*Tursips truncatus*), named Yasha (male) and Yana (female), in a closed concrete pool with the dimensions 27 m × 9.5 m × 4.5 m, located at the T.I. Vyazemsky Karadag Scientific Station – Nature Reserve of RAS.

Please cite this article as: V.A. Ryabov, The study of acoustic signals and the supposed spoken language of the dolphins, St. Petersburg Polytechnical University Journal: Physics and Mathematics (2016), http://dx.doi.org/10.1016/j.spjpm.2016.08.004