2P6-4

Analysis of pulses constituting sperm whale vocalizations

マッコウクジラ鳴音構成パルスの解析

Ryoichi lwase [1†]([1]JAMSTEC)
岩瀬良一 [1†]([1] 海洋研究開発機構)

1. Introduction

Sperm whales usually vocalize impulsive regular sound called “click” whose duration is less than 50 ms and whose time interval (inter-click interval, ICI) is about 0.5 s to 2 s[1,2]. The click is composed of several sound pulses. This structure depends on the sound production mechanism of the sperm whale. The initial sound pulse generated at the front of the head reflects between air sacs at the anterior and posterior end of the spermaceti organ which fills the head that makes up approximately 1/3 of the whale’s total body length, resulting in the multi-pulsed structure of the click[3]. Consequently, the time between the pulses (inter-pulse interval, IPI) within the click is the indicator of the length of the head and also the body length of the sperm whale. However, according to this sound production mechanism, the observed waveform of the click might differ depending on the relative orientaion of the whale and the receiver[3,4]. Specifically, when the receiver is located on-axis of the whale body, the observed waveform contains distinct and regular IPIs. On the other hand, when the receiver is located off-axis, the IPI might not be distinguished from the observed waveform.

Meanwhile, the sperm whale vocalizations have been detected at the multidisciplinary cabled observatory off Hatsushima Island in Sagami Bay[5] (hereafter “off Hatsushima Island observatory”), which is comprised of several kinds of sensors including a bottom-mounted single hydrophone (ITC-1010A). In this study. through the analysis of the sound pulses of the sperm whale click observed at the off Hatsushima Island observatory, the IPI and the associated conditions were investigated.

2. Observation Data

In this study, since the receiver, i.e., the hydrophone of the off Hatsushima Island observatory, is located on the seafloor, a simple condition of on-axis is the case that the sperm whale is descending or ascending just above the observatory. One such case was observed on July 11th 2003. 1.5 s and 30 ms paste-up waveforms observed at that time are shown in **Fig. 1** and **Fig. 2**, respectively. In Fig. 1, the envelopes of the waveforms are drawn in log scale. In Fig. 2 the waveforms just around the click are drawn. In both Figs. the origin of horizontal axis (relative time in second) is set to the observed time of the maximum peak of the pulse within the click. Distinct later arrival signals of sea surface reflection are recognized in Fig.1 and regularly spaced pulses can be recognized in Fig. 2, which indicate that the sperm whale was descending just above the observatory.

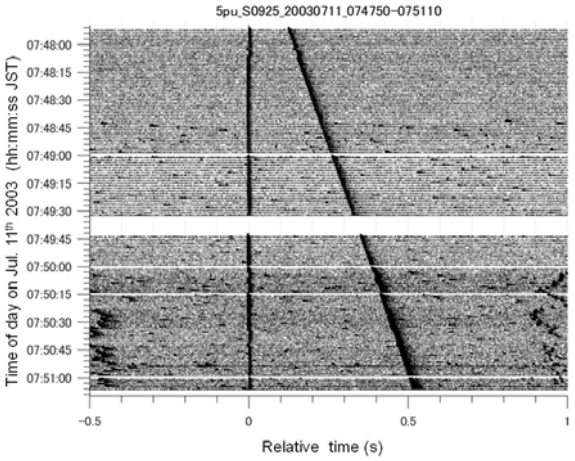

Fig. 1 1.5 s paste-up waveforms observed from 07:47 to 07:51 JST on Jul. 11th 2003.

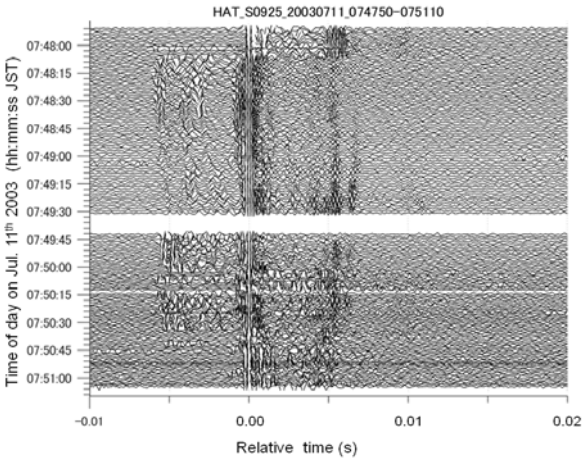

Fig. 2 30 ms paste-up waveforms observed from 07:47 to 07:51 JST on Jul. 11th 2003.

In **Fig. 3** and **Fig. 4,** 1.5 s and 30 ms paste-up waveforms observed on January 4th 2002 are shown. In this case, the distinct later arrival signals in Fig. 3 but no regularly spaced pulses in Fig. 4

can be recognized, which would indicate the moderate ascent of the sperm whale apart from the observatory.

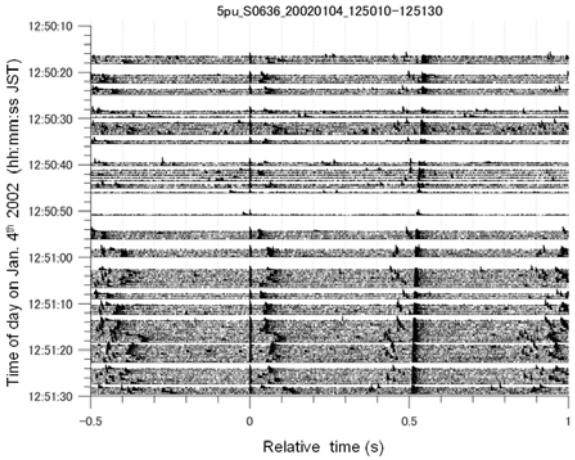

Fig. 3 1.5 s paste-up waveforms observed from 12:50 to 12:51 JST on Jan. 4th 2002.

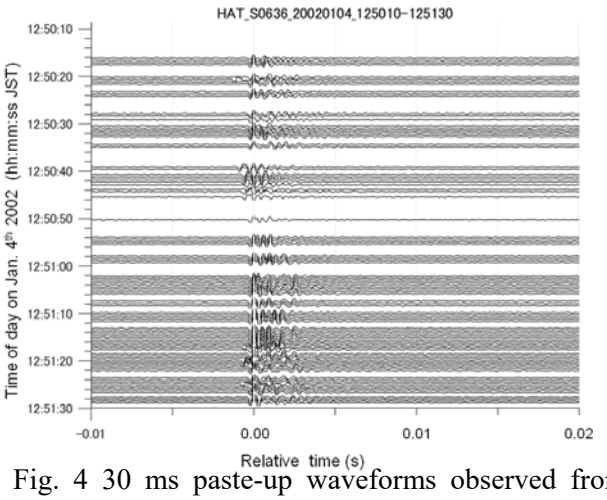

Fig. 4 30 ms paste-up waveforms observed from 12:50 to 12:51 JST on Jan. 4th 2002.

3. Measuring IPI

In the previous studies, several methods of measuring IPI from click waveform of the sperm whale were proposed. In Ref.4, IPIs were derived by using cepstral averages for clicks, which might be applicable for clicks from unknown aspect. **Fig. 5** and **Fig. 6** are the cepstral averages for clicks in Fig. 2 and Fig. 4, respectively. Judging from Fig.2, peaks larger than 10 ms indicate another reflection. In Fig.5, a peak is recognized when the quefrency is 5 ms, which means the IPI is 5 ms. On the other hand, no peak corresponding to IPI exists in Fig. 6.

Besides those cases, the distinct IPIs were recognized in some “creaks” observed on January 4th 2002, which are another kind of sperm whale vocalization with shorter ICI. Fig. 7 is the cepstral averages for the creak at 12:43 JST, which indicates that IPI is also 5 ms. According to Ref. 6, IPI 5 ms corresponds to the body length of 12 m.

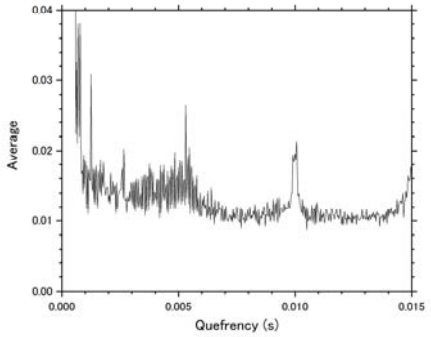

Fig. 5 Cepstral averages for the clicks in Fig. 2.

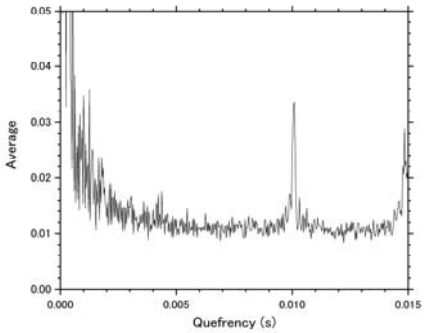

Fig. 6 Cepstral averages for the clicks in Fig. 4.

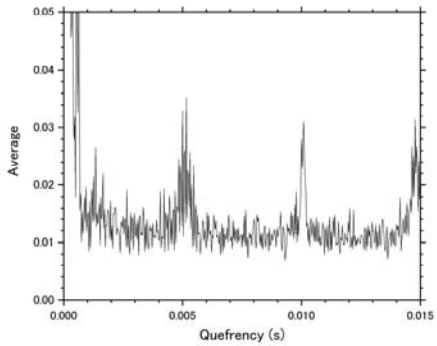

Fig. 7 Cepstral averages for the creak observed from 12:43:57 to 12:43:58 JST on Jan. 4th 2002..

4. Concluding remarks

Based on the analysis of the pulses within the sperm whale clicks and creaks, IPIs could be derived corresponding to the body length of 12 m.

References

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