International Journal of Engineering & Technology, 7 (3.36) (2018) 10-12

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Swiftlet Vocalization in Echolocation

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Abstract

The most interesting feature of swiftlet vocalizations is many of its species utilize a sonar-like system to navigate in the darkness of their nesting caves. This way of navigation called echolocation, where the birds produce click-like sound of which the returned echo provides information about the bird's speed and position relative to an object. In this paper, echo clicks were investigated from the sound recorded in a birdhouse. Fast Fourier Transform and Spectrogram were computed using MATLAB to each click pair for five consecutive pairs. Spectrogram analysis of the echolocation click pairs revealed maximum frequency where higher energy peaks occur is between 5.513 kHz to 6.801 kHz for the first click and between 6.202 to 8.613 kHz for the second click. As the conclusion, with the analysis conducted on the signals provides the potential to study the echolocation behavior of swiftlet in more details.

Keywords: *click; echo; echolocation; sound; swiftlet*

1. Introduction

The vocalizations of swiftlets are particularly fascinating due to the ability of some species to echolocate. To date, oilbird is the only other bird discovered to echolocate [1]. Some animals have evolved echolocation in the environment where vision is ineffective. The most sophisticated echolocation focused on biosonar systems found in bats and odontocetes (dolphin and toothed whale). However, these animals use higher ultrasonic frequencies (>20 kHz) for echolocation which is above human hearing range. The study on swiftlet untapped potential can contribute to the research on echolocation using sound audible to human.

Swiftlets are small insectivorous birds, categorized under Apodidae family which breed throughout Southeast Asia and South Pacific. There are 24 species of swiftlets recorded in the world and they are divided into four genera namely *Aerodramus* (echolocating swiftlets), *Hydrochous*, *Schoutedenapus* and *Collocalia* (Non-echolocating swiftlets)[2]. Echolocation sound of swiftlets are typically uniform clicks, usually a double click, but sometimes swiftlets can also emit single click. Two species from *Aerodramus* are found producing different echolocation pulses with single click namely *Aerodramus maximus* and *Aerodramus sawtelli* [2,3]. Double click consists of two broadband pulse, separated by a short silent interval.

To understand the adaptations for echolocation in birds, it is necessary to investigate echo clicks in a more detailed manner. Sound recording is the method used to study the vocalization produced by swiftlets. Sound recordings have multiple applications not only in taxonomic research: they reveal the structure of sounds, and facilitate their description and comparison between different populations and species, while playback experiments can test reactions of birds to answer questions about song function, or to identify and draw out hidden birds for identification in faunal surveys as well as identifying individual birds. This study reported the echolocative clicks occurring in a sound recorded in a successful swiftlet birdhouse.

The analysis based on time and frequency domain of the echo clicks are presented. The minimum and maximum frequencies of each clicks, the duration of each clicks and the interval between the two clicks are presented using spectrogram.

2. Literature review

2.1. Normal Echolocative clicks

Most studies described the echolocation as double clicks design which each clicks is separated by a silent interval [4]. An example of clicks emitted by several freshly captured intact swiftlets while hovering in the flight chamber is shown in Figure 1. The first four clicks (Figure 1 a-d) indicate the range of variability present in the clicks emitted by an individual bird during a single recording session. The remaining four clicks (Figure 1 e-h) are single examples from four other swiftlets and give some indication of the extent of interindividual variation. Each of these examples consist of two successive clicks, referred to as a double click, having a broad frequency spectrum and separated by a silent period, the intraclick interval, lasting roughly 25 ms. Most of the frequency lies between 2 and 8 kHz. It is clear from Figure 1 that there are variations in the intraclick interval, even for an individual bird; typical values range from about 18 to 25 ms. The low amplitude oscillation, visible in some of the recordings (e.g., Figure 1c and d), which starts about 4 or 5 ms after each click is probably an echo.

The first member of the double click is usually at a lower amplitude and of shorter duration than the second member. The first click may consist of as little as one cycle (e.g., Figure 1g), but usually contains several cycles. An unusual variant having a long duration is illustrated in Figure 1a. Occasionally only one member of the double click is detectable, even under good recording conditions at a short range. Sometimes, on the other hand, both members of the double click are about equal in amplitude (Figure 1c and d) and rarely the first click is much more intense then the second.

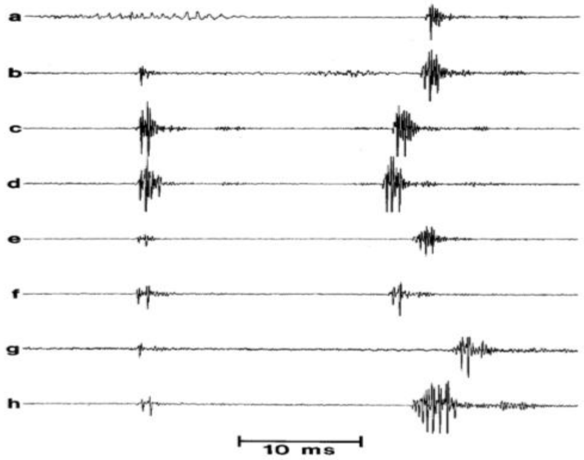

Fig. 1: Clicks emitted by intact swiftlets while hovering in front of a microphone in a dark chamber [5].

3. Methodology

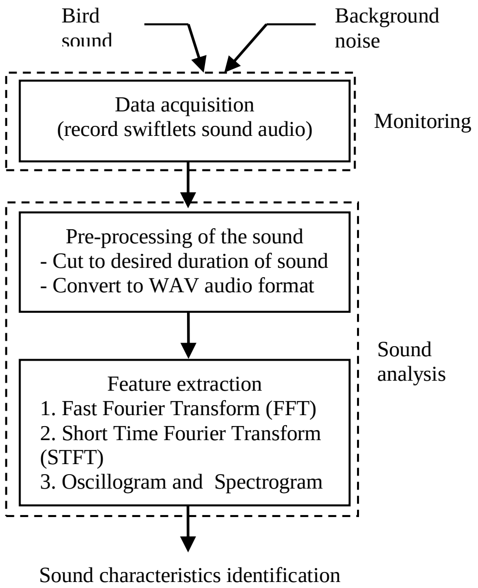

Fig. 2: Flow for analysis of sound characteristics

The swiftlet sound characteristic identification process was divided into two: monitoring and sound analysis. Data acquisition was conducted by visiting to swiftlet bird house. An external voice consists of the voice of the head of the swiftlet's population was placed outside of the swiftlet bird house. The external voice played will call and attract swiftlets to enter the bird house.
A sound recording were then obtained from swiftlets who successfully entered the bird house. Recordings were sampled using a sampling rate of 44.1 kHz. Spectrogram were produced on a PC using MATLAB software. The echolocation appeared in the sound recording were identified by plotting the sound wave in time domain. After the double clicks have been identified, spectrogram are used to investigate it's characteristics. The minimum and maximum frequency, the duration of each clicks and the interval between the two clicks were measured The analysis were made from a sound recorded in a successful birdhouse. Figure 2 shows the flow process for analysis of swiftlet sound characteristics.
Fast Fourier Transform (FFT) is a suitable algorithm when applying the analysis of swiftlet sound since the signal is in a time domain. Due to the difficulties in identifying the frequency in a time domain, FFT will translate it into frequency domain. Spectrogram was used to visualize the sound which help to give a clear overview of a signal.

4. Results and Discussions

Figure 3 shows the production of echolocation by swiftlet. Figure 3(A) is the time waveform of the double clicks echolocation, Figure 3(B) is the single-sided FFT and Figure 3(C) is the spectrogram respectively. As can be seen from Figure 3(A), the first member of double click is usually at a lower amplitude and a shorter duration compared than the second member. The first click may consist of as little as one cycle but usually contains several cycles. The first click happen when the syringeal valve vibrates as it narrows the syringeallumen before closing it completely. The silent interval between the first and second clicks is when the valves are completely closed. The silent interval occur in the range of 11 ms to 14 ms. After a short silent interval, the valve start begins to open, allowing airflow to vibrate then producing the second click [6].

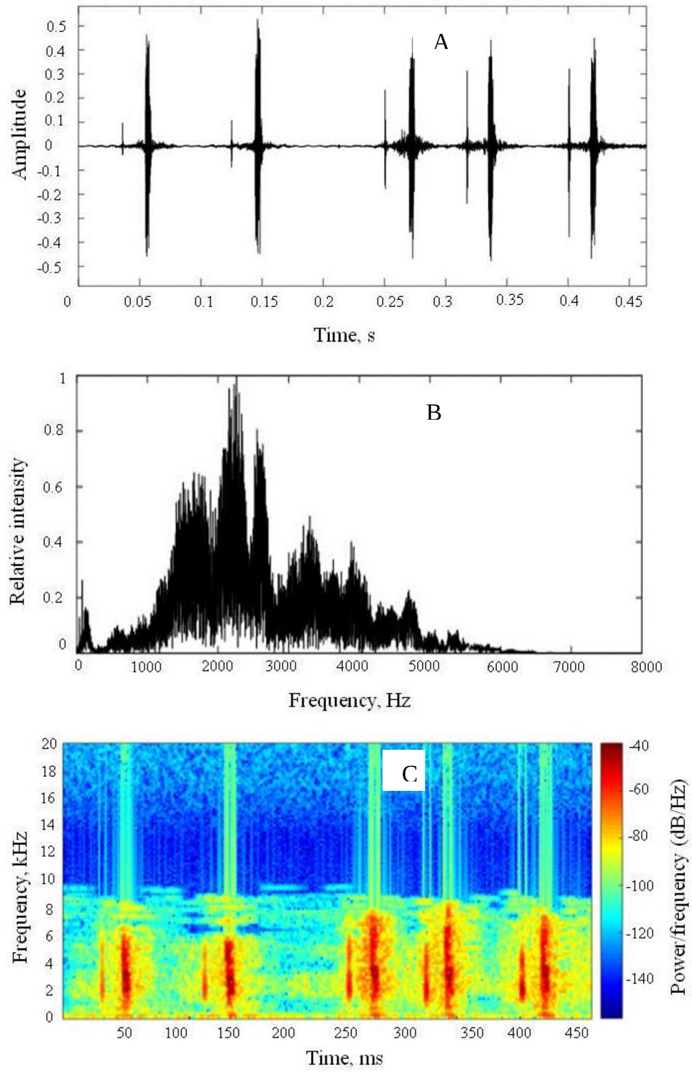

Fig. 3: Production of echolocation by swiftlet; (A) Time waveform of double click echolocation, (B) Single-sided Fast Fourier transform, (C) Spectrogram

Figure 3(B) presents the FFT of the echolocation for a five successful pair. Variable peaks can be observed between 1 kHz to 5 kHz, both within and between the clicks. Low-frequency peaks were seen in 0.1 kHz to 1 kHz and between 5 kHz to 6 kHz, but these are unlikely to be the echolocation process, but may due to the background noise during recording. Figure 3 (C) illustrates the spectrogram of five successful click pairs where the magnitude can be seen between -70 dB to -40 dB.

Figure 4 shows the example of double clicks occurring from five consecutive click pairs. Figure 4(A) is the time waveform of the clicks while Figure 4(B) is the clicks spectrogram. The time domain audio signal of swiftlet sound define as *A(t)* as illustrated in Figure 4(A), is decomposed into a two dimensional time-frequency spectrogram S (Figure 4(B)). This involves separating *A* into a set of overlapping frames {F_0, F_1,......}. Each frame F_t corresponds to a set of values {*A(t), A(t+1), ...A(t+n-1)*} where *n* is the number of samples in each frame. For each frame, F_t , a short-time fourier transform is applied to generate coefficient of { $f_0(t)$, $f_1(t)$, ...$f_{n/2}(t)$}. The spectrogram *S* as shown in Figure 4(B) composed of magnitude of the coefficient of each frame. It could be seen that the double clicks recorded make up a frequency range of 1.2 to 6.8 kHz for the first click and frequency range of 0.5 to 6.9 kHz for the second clicks. The silent interval measured is 13.06 ms.

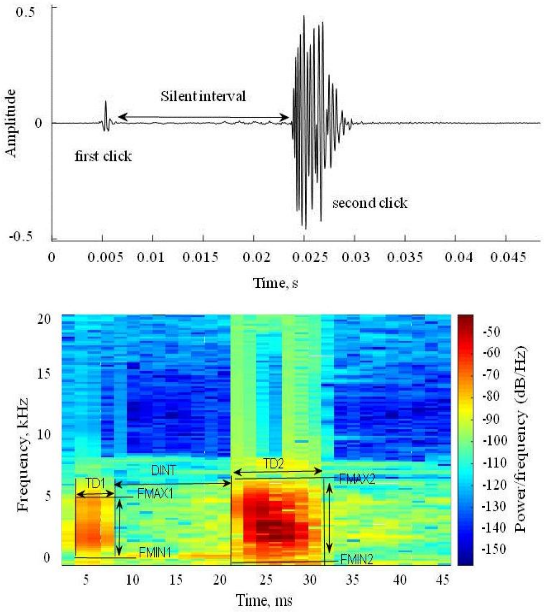

Fig. 4: Echo click, consisting of two subclicks (first click and second click) with measurement.

The following echo-click characters were measured: minimum and maximum frequencies of the first and second subclick (FMIN1, FMAX1, FMIN2 and FMAX2), duration of both subclicks (TD1 and TD2) and duration of silent interval between two subclick (DINT). Summary of the measured echo-click characteristics are tabulated in Table 1. The minimum frequency (FMIN1) for first click is between 0.6891 to 1.378 kHz while for second click, minimum frequency (FMIN2) is between 0.345 to 0.518 kHz. The maximum frequency (FMAX1) for first click is between 5.513 kHz to 6.801 kHz while for second click, the maximum frequency (FMAX2) is between 6.202 to 8.613 kHz. These results supported the results obtained by Nematollahi et.al [7] with frequency range of 1 kHz to 16 kHz.

The time duration (TD1) for first click is in the range of 4.35 to 5.81 ms while the time duration (TD2) for second click is in the range of 10.16 to 13.10 ms. The silent interval between the two click is measured in the range of 11.60 to 14.51 ms.

Table 1: Echo-clicks characters

No	FMIN1 (kHz)	FMAX 1(kHz)	FMIN 2(kHz)	FMAX 2(kHz)	TD1 (ms)	DINT (ms)	TD2 (ms)
1	1.206	6.801	0.518	6.891	4.35	13.06	10.16
2	1.378	5.513	0.345	6.202	5.81	14.51	10.16
3	1.206	6.202	0.345	8.095	5.79	11.60	13.10
4	0.689	5.685	0.345	8.613	5.80	11.61	10.16
5	1.034	5.685	0.345	7.580	5.81	11.61	10.16

Figure 5 illustrates the maximum frequency for both click, first and second clicks. Despite the variability in maximum frequency for both click components, the first click maximum frequency is more consistent compared for the second click. The first click maximum frequency occur in a range between 5.5 to 6.8 kHz compared to 6.2 to 8.6 kHz for maximum frequency of the second click.

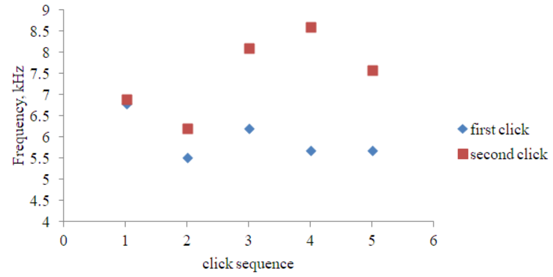

Fig. 5: Maximum frequency for first and second click

5. Conclusion

This study advocates the suitability of the technique to extract information of the swiftlet vocalization. An echo-click characteristics were studied by investigating their minimum and maximum frequency, duration for both click as well as silent interval between clicks. five consecutive clicks were identified from the sound recorded. Fast Fourier Transform (FFT) and spectrogram were computed for each component in a click pair and for the five successive pair. The highest maximum frequency measured is 6.801 kHz for the first click and 8.613 kHz for the second click. First click shows a more consistent maximum frequency distribution compared to the second click. This study highlighted the importance of sound analysis in order to determine the frequency of sound produced by swiftlet sound. The feature discovered from this study help the bird house operator determine the best sound to attract swiftlet to the bird house.

Acknowledgement

The authors would like to thank the Universiti Teknologi Malaysia (UTM) and Ministry of Education (MoE) Malaysia for financial support through Fundamental Research Grant Scheme (FRGS) with Vote No.4F821.

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