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Highly Uncomfortable Mosquito Signal Based on Subjective Evaluation

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ABSTRACT

In recent years, the mosquito signal has been increasinegly used as a method of dispersing noisy groups of young people from public spaces. The mosquito signal is a high-frequency signal—around 17 kHz—that is audible to young people but not to older adults. A recent study on an acoustic system using the mosquito signal indicated that it was able to disperse young people gathered at a park in Japan in around three minutes, which clearly shows that the mosquito signal is both effective and useful. In our study, we have attempted to design a highly uncomfortable mosquito signal for the dispersal of human noise sources. We focused on three kinds of signals: sine signals, environmental signals, and signals based on the auditory sense. First, we designed the sine signals. We used a highly pure sine wave because conventional reports have suggested that highly uncomfortable signals tend to hold a sharper attenuation from the main peak in frequency. Next, we designed the environmental signals. We used a combination of three different signals: a motor noise to simulate a cleaner, a crying noise to simulate an infant, and a scrub noise to simulate foamed styrol. We then convoluted a high-pass filter to these signals. Finally, we designed the signals based on the auditory sense. We used the same three signals asine the previous design but shifted from a lower frequency (1–5 kHz) to a higher frequency band, because humans tend to mainly hear the signal transmitted on 1–5 kHz. We used the mean opinion score (MOS) to conduct a subjective evaluation. Results demonstrated that the new mosquito signals were more uncomfortable than the conventional ones, and that the pure sine mosquito signal at 15 kHz was the most uncomfortable of the proposed signal sine future work, we intend to design an even more uncomfortable mosquito signal based on complex sine waves. We will also focus on controlling the signal's output area to reduce the negative effects on local citizens and animals.

INTRODUCTION

In recent year, the mosquito signal is focused to repulse the louder young people. The mosquito signal is proposed on Britain and there is high-frequency signal around 17 kHz. For example, when the mosquito signal is installed experimentally on the park in Japan, the louder young people disappears around three minutes. Thus, the mosquito signal is confirmed to be useful. In this paper, we aim to repulse louder young people by using concept of the mosquito signal. Therefore, we design the high discomfort mosquito signal that is higher than the conventional mosquito signal based on study of uncomfortable signal. There are (1) the mosquito sine signal, (2) the mosquito environmental signal and (3) the mosquito signal by using auditory sense. They sharply attenuate from main peak as uncomfortable signal characteristics. Therefore, the mosquito sine signal is designed by single frequency. There are motor noise of cleaner, infant cry and scrub coolite noise as uncomfortable signal. Therefore, the mosquito environment signal is designed to attenuate energy of low frequency. Human mainly hears some of frequency bands between 1 kHz and 5 kHz as auditory sense. That is, there is uncomfortable signal feature. Therefore, the mosquito signal by using auditory sense is designed to shift low frequency characteristics in high-frequency. The designed mosquito signal is evaluated by subjective evaluation based on Mean-Opinion-Score (MOS). We confirm to be useful by calculating average and standard deviation of discomfort value for the designed mosquito signal. As a result, the mosquito sine signal of 15 kHz is the highest of all designed mosquito signals. In addition, uncomfortable signal has characteristics at low frequency between 1 kHz and 5 kHz.

A STUDY OF HIGHLY UNCOMFORTABLE SIGNAL

Study of highly uncomfortable signal for young people is necessary to repulse them. Therefore, we studied highly uncomfortable feeling young people and frequency characteristics of highly uncomfortable signal.

Highly Uncomfortable Signal

Dr. Trevor Cox, Dr. Kuwano et al. and Dr. Hiramatsu et al. have already studied about highly uncomfortable signal [1] [2] [3]. Dr. Trevor Cox experimented to decide uncomfortable signal from prepared 34 signals for 1.1 million people around the world. As a result, he reported that uncomfortable signal is different by the individual. Dr. Kuwano et al. experimented to evaluate relation between uncomfortable signal and sound pressure from speech signal, acoustic signal, environment signal and artificial signal. As a result, he reported that acoustic signal is not always proportional to sound pressure than other signals [2]. Dr. Hiramatsu et al. experimented to evaluate relation between comfortable signal and uncomfortable signal from 59 different kinds of environmental signals and artificial signals. As a result, he reported that sound pressure is no correlation between comfortable signal and

uncomfortable signal [3]. Therefore, we design highly uncomfortable mosquito signal by using sine wave, cleaner noise, styrol noise, crying noise, white noise and pink noise as sound source. Then, we experiment that sound pressure is constant.

Frequency Characteristics of Highly Uncomfortable Signal

Frequency analysis is necessary to decide characteristics of uncomfortable signal [4]. In general, frequency analysis is used by First Fourier Transform (FFT). FFT can analyze difference of each single frequency. At first, Dr. Nomura et al. analyzed spectrum form of uncomfortable signal. As a result, he reported that uncomfortable signal has frequency characteristics that have sharply irregular spectrum form than comfortable signal [4]. In addition, uncomfortable signal has frequency characteristics that attenuate gradually from main peak and are constant around high-frequency band (12 kHz – 20 kHz) [4]. Therefore, we design highly uncomfortable signal based on auditory sense. Then, we focus spectrum form of highly uncomfortable signal.

MOSQUITO SIGNAL DESIGN

The mosquito signal is a high-frequency signal—around 17 kHz—that is audible to young people but not to older adults. In our study, we have attempted to design a highly uncomfortable mosquito signal for the dispersal of louder young people. We design some of mosquito signals that young people feel uncomfortable. Except, we design mosquito signal around audibility (15 kHz – 17 kHz) based on preparatory experiment. In addition, artificial signals of white noise and pink noise are lower uncomfortable feeling than other signals. Therefore, in this paper, we design some mosquito signals that use sine wave and environmental signal. We focus on three kinds of mosquito signals: sine signals, environmental signals, and signals based on the auditory sense.

The Sine Wave Mosquito Signal

At first, we experiment to estimate the uncomfortable feeling of each single frequency based on a study of highly uncomfortable signal. Therefore, we design some of sine wave mosquito signals as shown in Fig. 1. Solid line is the 13 kHz sine wave mosquito signal, dashed line is the 15 kHz sine wave mosquito signal, chained line is the 17 kHz sine wave mosquito signal and dotted line is the 19 kHz sine wave mosquito signal.

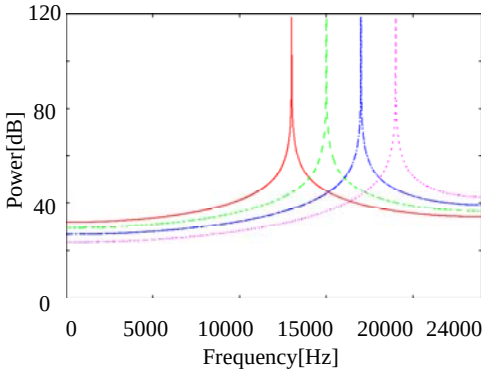
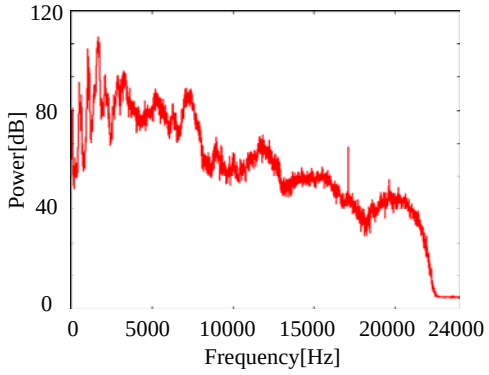


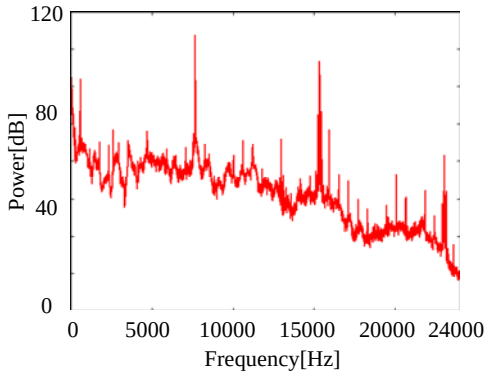
Figure 1. The sine wave mosquito spectrum

The Environmental Mosquito Signal

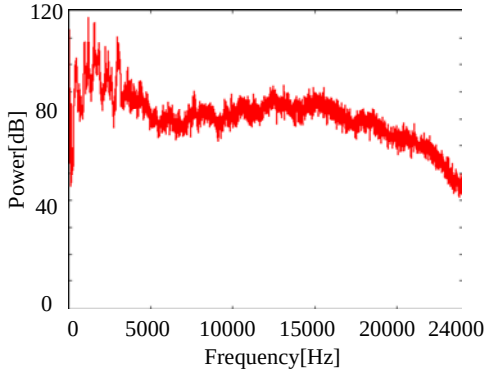
Next, we experiment to estimate the uncomfortable feeling of each environmental signals and artificial signals for young people based on a study of highly uncomfortable signal. Therefore, we design some of environmental mosquito signals and artificial mosquito signals by using three kinds of environmental signals and two kinds of artificial signals as shown in Figs. 2 and 3. Figure 2 shows three kinds of the environmental spectrums: (a) crying noise, (b) cleaner noise and (c) styrol noise. and Figure 3 shows two kinds of the artificial signals: (a) white noise and (b) pink noise. We used a combination of three different signals that are a motor noise to simulate a cleaner, a crying noise to simulate an infant, and a scrub noise to simulate foamed styrol as environment signal. The environmental mosquito signal and the artificial mosquito signal are designed by convoluted a high pass filter and each signal.



(a) Crying noise



(b) Cleaner noise



(c) Styrol noise

Figure 2. The environmental spectrums

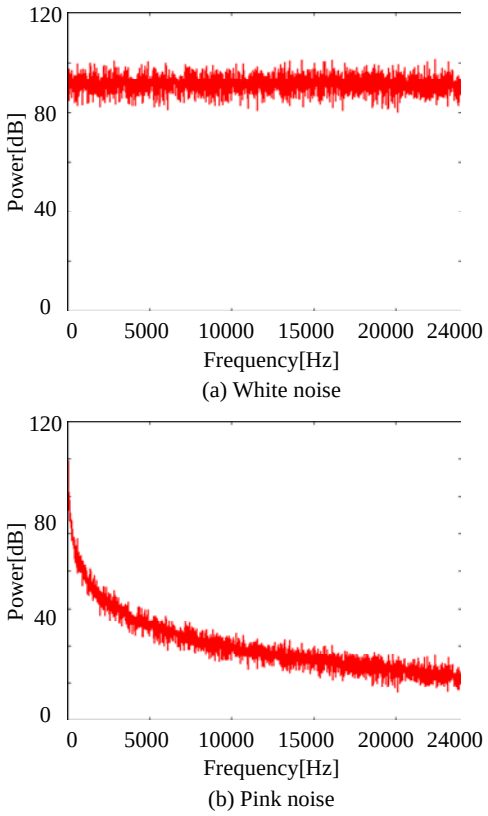


Figure 3. The artificial spectrums

The Mosquito Signal Based on Auditory Sense

At last, we design the signals based on the auditory sense. We design the highly uncomfortable mosquito signals that shift from a lower frequency (1 kHz – 5 kHz) to a higher frequency band, because human tend to mainly hear the signal transmitted on 1 kHz – 5 kHz[5]. In addition, designed steps are configurated by following equations. $X(\omega)$ shows sound source, $HPF(\omega)$ shows high pass filter, α shows cut-off frequency, ω shows angular frequency, $Y_1(\omega)$ shows sound source, $Y_2(\omega)$ shows to convolute sound source and high pass filter and $Y_3(\omega)$ shows designed signal based on auditory sense.

$$Y_1(\omega) = X(\omega), \tag{1}$$

$$Y_2(\omega) = X(\omega)HPF(\omega), \tag{2}$$

$$Y_3(\omega) = \begin{cases} Y_1(\omega-\alpha) & (\omega > \alpha) \\ Y_2(\omega) & (\omega \le \alpha). \end{cases} \tag{3}$$

SUBJECTIVE EVALUATION BY USING MEAN OPINION SCORE (MOS)

In this paper, we experiment to analyze uncomfortable feeling for young people by using Mean-Opinion-Score (MOS). MOS is one of subjective evaluation and evaluated to use five grade evaluations: excellent, good, normal, poor and bad. Then, we evaluate uncomfortable feeling of each designed mosquito signals by calculating average and standard deviation from MOS.

Table 1. Preparatory experiment of result

Sine	M	M	M	F	F	F	F	F
13kHz	3	2	3	3	3	3	2	2
15kHz	2	2	1	2	3	2	2	1
17kHz	2	2	1	2	1	1	1	1
19kHz	1	1	1	1	1	1	1	1

Table 2. Preparatory experiment of result

	Sine wave	White noise	Pink noise	Cry-ing noise	Clean er noise	Styrol noise
50dB	6	3	4	4	5	6
60dB	6	3	3	3	5	5
70dB	6	4	3	5	6	8
80dB	6	7	5	7	6	7

Experiment Condition

Subjects are three females and seven males who have normal hearing ability and average age is 23 years old. Then, used signal and frequency band are decided by preparatory experiment. Table 1 shows preparatory experiment of result and we experiment by using sine wave. “F” means female, “M” means male, grade 1 of score can be possible audition, grade 2 of score is difficult audition, grade 3 of score can not be possible audition and average age is 41 years old. All of the subjects answer that sine wave of 13 kHz can hear possible and sine wave of 19 kHz can not hear. Then, we decide to use signals of 13 kHz and 15 kHz. Table 2 shows preparatpry experiment of result. Numeric character shows number of answer. All of the subjects answer that sine wave is the most uncomfortable signal of all signals. However white noise and pink noise of artificial signal and crying noise of environmental signal are lower uncomfortable feeling than other signals. Then, we decide to use three kinds of signals: sine wave, cleaner noise and styrol noise.

Results

Tables 3 and 4 show average and standard deviation of uncomfortable feeling designed mosquito signal with 15 kHz and 17 kHz. As a result, the sine wave mosquito signal of 15 kHz is the highest uncomfortable signal of all designed mosquito signals because the sine wave mosquito signal of 15 kHz is the lowest average and standard deviation of uncomfortable feeling with designed mosquito signals. That is, we could confirm that the sine wave mosquito signal of 15 kHz is the most uncomfortable signal of all signals. The styrol mosquito signal based on auditory sense is reducer average and standard deviation of uncomfortable feeling designed mosquito signal than the environmental mosquito signal. That is, we can confirm that the mosquito signal based on auditory sense advances uncomfortable feeling. However, average and standard deviation of the cleaner mosquito signals hardly change based on auditory sense.

Table 3. Average and standard deviation of uncomfortable feeling designed mosquito signal (15 kHz)

15kHz	The sine wave mosquito signal	The styrol mosquito signal		The cleaner mosquito signal	
	(1)	(2)	(3)	(2)	(3)
Average	1.9	3.0	2.2	1.5	1.7
Standard deviation	0.49	3.00	1.16	0.45	0.89

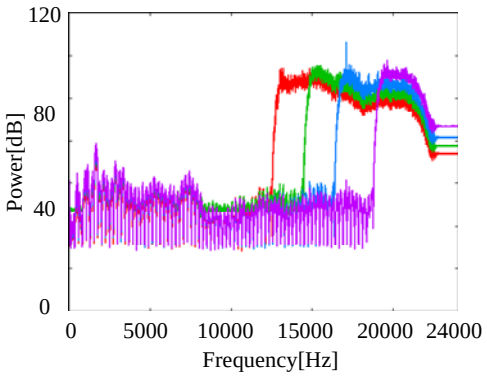
*(1) shows the sine wave mosquito signal.
*(2) shows the mosquito signal by processed high pass filter.
*(3) shows the mosquito signal based on auditory sense.

Table 4. Average and standard deviation of uncomfortable feeling designed mosquito signal (17 kHz)

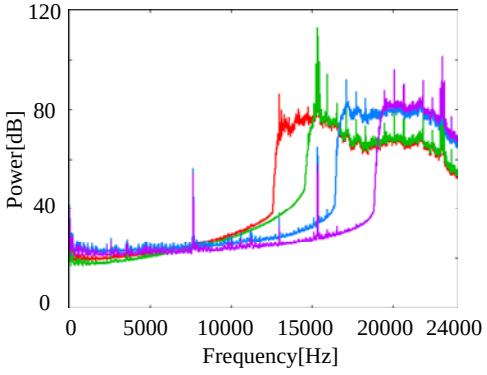
17kHz	The sine wave mosquito signal	The styrol mosquito signal		The cleaner mosquito signal	
	(1)	(2)	(3)	(2)	(3)
Average	3.0	4.2	3.9	2.7	2.4
Standard deviation	1.40	1.16	0.49	1.21	1.69

Discussions

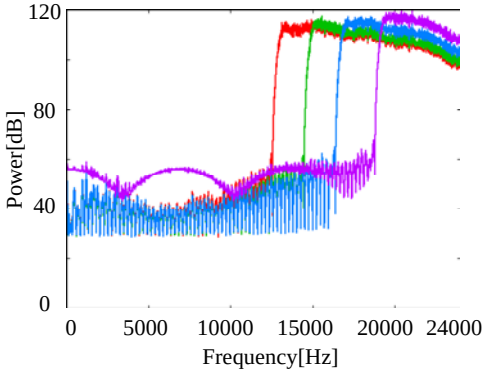
Figures 4 and 5 show the spectrum of environmental mosquito signals and the spectrum of mosquito signals based on auditory sense. Then, Fig. 4 shows three kinds of the environmental signals: (a) the crying mosquito signal, (b) the cleaner mosquito signal and (c) the styrol mosquito signal and Figure 5 shows two kinds of the mosquito signals based on auditory sense: (a) the cleaner mosquito signal based on auditory sense and (b) the styrol mosquito signal based on auditory sense. To shift from a lower frequency (1–5 kHz) to a higher frequency band advances uncomfortable feeling. Therefore, characteristics of uncomfortable feeling signal exist lower frequency band. Then, the environmental mosquito signal as stationary signal has high mutual relation. Therefore, uncomfortable feeling is concerned individually.



(a) The crying mosquito signal

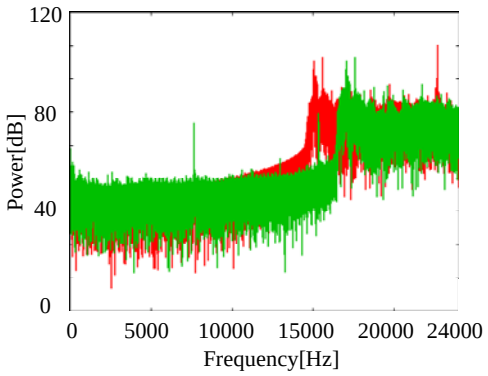


(b) The cleaner mosquito signal

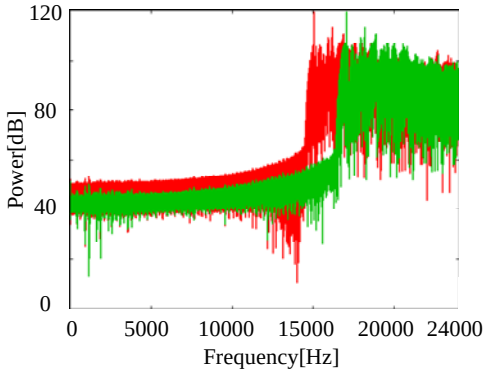


(c) The styrol mosquito signal

Figure 4. The spectrum of environmental mosquito signals



(a)The cleaner mosquito signal based on auditory sense



(b)The styrol mosquito signal based on auditory sense

Figure 5. The mosquito signal based on auditory sense

CONCLUSIONS

In this paper, we design some of signals to repulse young people based on a study of highly uncomfortable signal. We focused on three kinds of mosquito signals that are sine wave signal, environmental signal, and signal based on the auditory sense. First, we designed the sine signal. Next, we designed the environmental signal. We used a combination of three different signals. We then convoluted a high-pass filter to these signals. Finally, we designed the signals based on the auditory sense. We used the same three signals asine the previous design but shifted from a lower frequency (1–5 kHz) to a higher frequency band, because humans tend to mainly hear the signal transmitted on 1–5 kHz. We used the MOS to conduct subjective evaluation. As a result, the sine wave mosquito signal of 15 kHz is the highest uncomfortable signal of all designed mosquito signals because the sine wave mosquito signal of 15 kHz is the lowest average and standard deviation of uncomfortable feeling of designed mosquito signals. That is, we can confirm that the sine wave mosquito signal of 15 kHz signal has high uncomfortable feeling. And we also can confirm that the mosquito signal based on auditory sense advances uncomfortable feeling. In the future work, we intend to design an even more uncomfortable mosquito signal based on complex sine waves. We will also focus on controlling the signal's output area to reduce the negative effects on local citizens and animals.

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