Inquiring activities on the acoustic phenomena at the classroom using sound card in personal computer

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Inquiring activities on the acoustic phenomena have been carried out at the classroom of an high school for highly gifted children. Instead of expensive instruments such as function generator and oscilloscope, sound card installed in the personal computer was employed for the generation and detection of sound. The stereo function of sound card offered two sound source, so that phenomena of interference and beat can be realized in the classroom. The record function of sound card offered detection of sound, so that frequency spectrum analysis of sounds from two tuning forks or sound from moving fork. Using sound card, a lot of acoustic phenomena can be demonstrated in the classroom. In addition, sound from Rijke tube, which is a typical theromacoustic phenomena, was analyzed by using sound card. Popup sound of wine bottle and breaking of wine glasses, which are related to resonance and standing wave, were also inquired. Curiosity of students was greatly increased through a series of inquiring activity with sound card, so that they were so completely absorbed in the research on acoustics.

1 Introduction

Sound as well as light are wave phenomena experienced everyday. It is taught in physics at secondary school that sound is a mechanical wave and causes a longitudinal vibration of medium. Basic properties of sound such as resonances of tubes and Doppler effect of horn sound from a moving vehicle are also taught. Even sound wave is just as important as light, experiments on sound are not provided as much as those on light. Experiments of sound are limited to the air column resonance and beat of two tuning forks because sound is invisible. The extra instruments to detect sound is required because sound is invisible. Microphone and speaker with amplifiers are basic instruments for the acoustic experiments. Expensive instruments such as function generator and oscilloscope are strongly required for the proper experiments of sound. It causes expense for instruments. In addition, have students have scruples about handling complex instruments.

Recently, the growth of electronic technique makes personal computer (PC) become common to everyone, and PC can be easily found in the physics laboratories. Sound cards are basically included in the personal computers for sound effects and multimedia. We can listen music by aid of sound cards. Microphone input is also offered to record sound. Therefore we can generate and record sound using sound cards. The frequency range of sound cards are as same as those of audible sound. Therefore, sound cards have high potential to be utilized in education of acoustics. Stereo feature of sound card enables to generate two sound source, so that sound phenomena such as beat and interference can be studied.

Young ages such as students are familiar to the computer, and they easily handle given research tool; personal computer, microphone, external speaker and software to control the system. Almost students start to handle this tool without hesitation.

Inquiry activity is also a kind of new instruction methods. As similar to International Young Physicist Tournament (IYPT) several topics were given to student. Various approaches are possible to explain the given phenomena. Sound cars in PC were used to study given problem, and precise instruments were complementally used for more quantitative explanation. Four teams of three students were typically grouped for inquiry activity. Heated discussion in a team during inquiry and debate with other team after that took place, and stimulated competition.

Choosing the problem from daily life and using personal computer invoke curiosity of students, so that they participate inquiry activity on their own initiative. They really enjoyed activities, drew qualitative explanation and made quantitative results.

In the present work, inquiring activities on the acoustic phenomena have been carried out at the classroom of an secondary school for highly gifted children. They can understand various phenomena related to the sound by visualization of waveform and frequency spectrum. Several research topics were given to the students. They tried to find suitable explanation of given phenomena. Sound cards in PC were used to find solution, however function generator and oscilloscope were complementally used for precise experiment. Typical topics for inquiring activities were as follows:

- beating of two tuning forks
- thermoacoustic phenomena with Rijke tube
- sound during pouring water into a cylinder
- sound during pop up cork stopper from wine bottle
- sound during rotating a pipe with bellows
- breaking a wine glass using sound

As results, students showed great interests in sound, and became curious. They started to study given topics by themselves, and arrived at conclusion.

2 Program for sound cards

We have two versions of sound card, 'sound 1.5' and 'sori 1.0' ('sori' is Korean word of which meaning is 'sound'), which were developed by a maker of MBL [1]. They were programmed by using LabView [2] and some advantage and disadvantage. They were freeware for teachers and students.

These program offer following features:

- Operating system: Microsoft windows
- capturing sound in time-domain waveform with 44.1 kHz sampling rate.
- frequency spectrum analysis
- store data in excel format (upto 65,536 data points) as well as their own format
- store image file
- generation of sound in stereo with independent frequency, amplitude and phase.

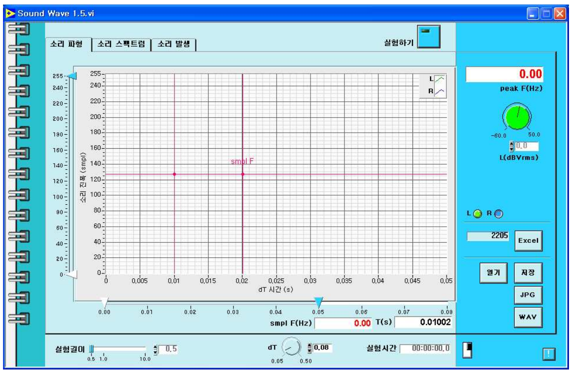


Figure 1: Typical control panel of ‘sound 1.5’ for generation of sound.

Microphone and external speaker used in the present work were ATM-520P (Audiotrak, pin mic) and BR-1000A (Britz, 60 watt rated output), respectively. Fig. 1 shows typical control panel of ‘sound 1.5’ for generation of sound.

3 Examples of applications

Several topics were carried out as inquiry activities. Students submitted reports of inquiry activities. Some of them are summarized in this paper.

3.1 Superposition and Beating

Beating is one of typical wave characteristics of wave. When two sound pressure, p_1 and p_2 with similar frequency are superposed, the resultant pressure p is given as addition of p_1 and p_2.

$$p = p_1 + p_2 = 2C \sin \frac{2\pi(f_1+f_2)t}{2} \cos \frac{2\pi(f_1-f_2)t}{2}, \quad (1)$$

where

$$p_1 = C \sin 2\pi f_1 t \text{ and } p_2 = C \sin 2\pi f_2 t$$

Eq. (1) is composed of two terms: higher frequency term, $(f_1 + f_2)/2$, and lower frequency term $|f_1 - f_2|/2$. Lower frequency term is slowly varied compared to the higher frequency, so that it can be considered as an amplitude of higher frequency component, $A(t)$ as,

$$A(t) = 2C \cos \frac{2\pi(f_1-f_2)t}{2}. \quad (2)$$

Assuming $f_1 \approx f_2 = f$, Eq. (1) becomes

$$p = A(t) \sin 2\pi f t. \quad (3)$$

Since negative value of amplitude, $A(t)$, means reverse phase, magnitude of amplitude has twice peak per one period. Beat frequency f_B is

$$f_B = |f_1 - f_2| \quad (4)$$

Two approaches to beat were used: beat of two tuning forks, and two sound sources generated by sound cards.

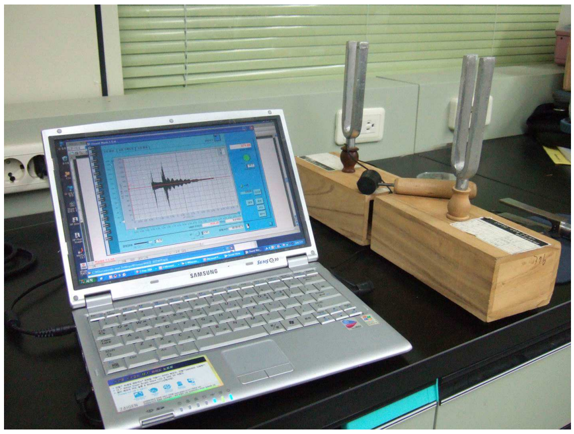
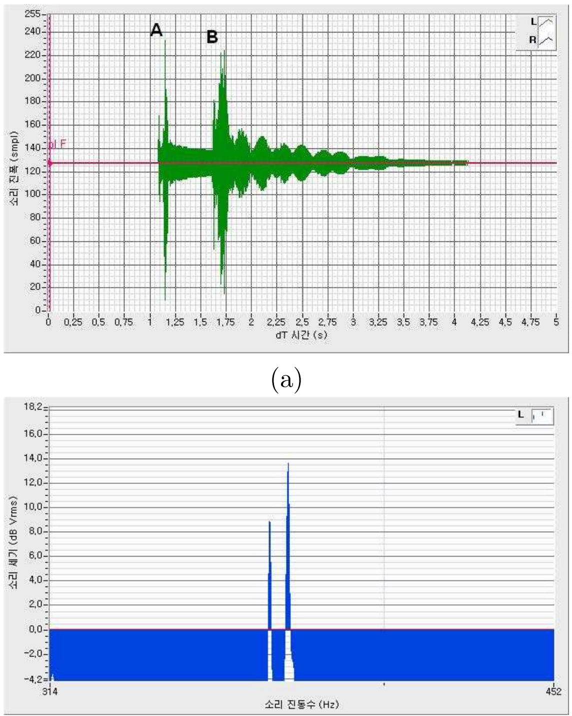


Figure 2: Experimental setup for beat of two tuning forks.



(a)

(b)

Figure 3: (a) Time domain waveform of beat of two tuning forks, and (b) Frequency spectrum of beat of two tuning forks.

Even though beat of two tuning forks can be recognized, it is hard to identify quantitative beat frequency by ear. Fig. 2 shows setup of personal computer and tuning forks in order to study quantitative beat experiment. Two tuning fork were struck one by one with time interval of 0.5 second. Waveform captured by sound card was shown in Fig. 3(a). ‘A’ and ‘B’ marked in Fig. 3(a) are time to strike tuning forks. There is no amplitude variation before second tuning fork was stuck (time interval between ‘A’ and ‘B’, Whereas amplitude variations were observed after second tuning fork was stuck. Five times beats for one second were observed. It implies that beat frequency is 5 Hz, and it is hard to count beat by ear. Frequency spectrum of Fig. 3(a) was shown in Fig. 3(b). Peak frequencies in this frequency spectrum were 368.1 Hz and 373.1 Hz, and frequency difference is 5 Hz. Therefore, the beat frequency from frequency

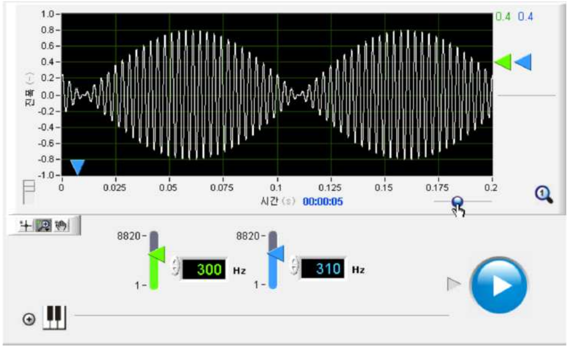


Figure 4: Superposed waveform of generated by two sound source with different frequencies; 300 Hz and 310 Hz.

spectrum shows good agreement with those from time domain waveform.

The other approach to beat is to generate two sound using stereo signals from sound card. External PC speakers were employed to amplifying sound. Fig. 4 shows typical signal of sum of right and left channel when frequencies of both channel were 300 Hz and 310 Hz. Beating signal can be clearly observed in the signal. Students separately heard sound from each channel at first, and then did mixed one from both channel by using balance control on the volume control of PC. Beat frequency was varied by changing frequencies of both channel, and it could be recognized by ear at lower beat frequency, up to 10 Hz.

Two sounds were generated with same frequency and different phase in order to study constructive and destructive interferences. However, desired results could not be obtained due to the size of speakers and separation of ears. Scanning of microphone showed not clear but feasible results due to reflections from objects such as desk and wall. Sound insulation is required to obtain reliable results.

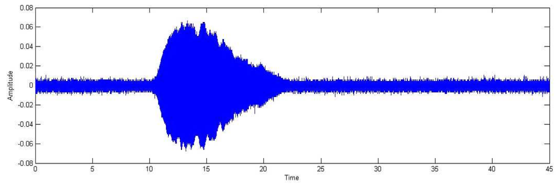
Doppler effect was also under inquiry. Tuning fork or microphone was moved by hand as fast as possible, however reliable results could not be obtained due to less changes in frequency than the resolution of frequency spectrum.

3.2 Theromacoustics - Rijke tube

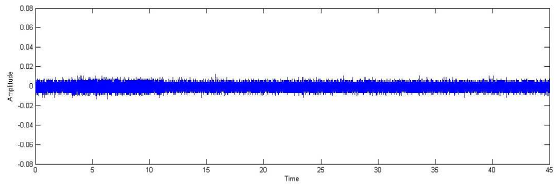
Sound generated from the thermal energy is called as thermoacoustic phenomena which is observed as a air column vibration by local heating. Loud sounds are generated by the interaction between standing wave of air column and heat transfer. Typical thermoacoustic pheonomena are Rijke vibration, Sondhauss and singing flame [3].

Rijke's tube turns heat into sound, by creating a self-amplifying standing wave. It is an interesting phenomenon and an excellent example of resonance. vibration generated when a gauze placed in a pipe with open ends is heated is typical theromacoustic phenomenon [4]. In the present work, sound generated from Rijke tube as shown in Fig. 5 were studied.

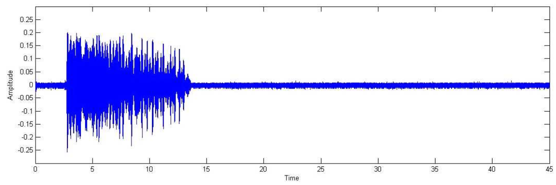
Figure 5: Rijke tube used in the present work. Length of tube was 49 cm.



(a)



(b)



(c)

Figure 6: Sounds from Rijke tube according to the location of heating gauze. (a) lower, (b) middle and (c) upper half of tube.

Sounds generated from Rijke tube according to the location of heating gauze are shown in Fig. 6. The waveforms were stored in excel format and time-frequency analysis were carried out. When a heating gauze was in lower half of tube, sound was not generated during heating, whereas loud sound was generated during cooling down as shown in Fig. 6(a). When a heating gauze was in upper half of the tube, loud sound was generated during heating, whereas no sound was generated during cooling down as shown in Fig. 6(c). When a heating gauze was middle of tube, no sound was generated neither during heating nor during cooling down as shown in Fig. 6(b).

These results agreed with Rayleigh's criterion: Sound is amplified when heat is supplied to the oscillating gas at high pressure and removed at low pressure in standing wave thermoacoustic device[5]. Self-sustained oscillation satisfies Rayleigh's criterion and by this process

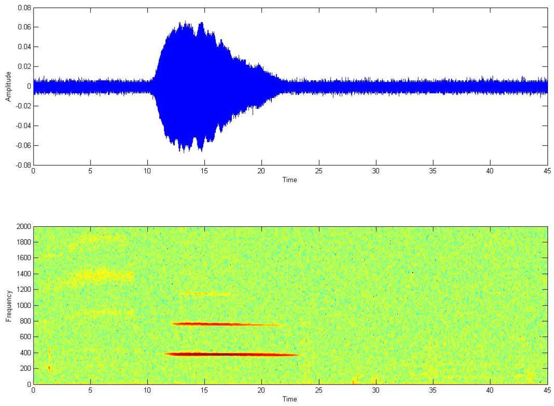


Figure 7: Time-frequency analysis of sound generated from Rijke tube with heating gauze placed at lower half.

heat is converted into acoustic power.

Result of time-frequency analysis is shown in Fig. 7 for the sound generated from Rijke tube with heating gauze at lower half of the tube. Time frequency diagram shows higher harmonics as well as fundamental resonance of Rijke tube, 400 Hz. Frequencies of higher harmonics were whole number of fundamental frequency, because Rijke tube is open tube. It is also observed that sound speed change during cooling decreased resonant frequency.

3.3 Pouring water sound

Another application involves the sound generated when water is poured into a tall cylinder[6]. The sound source is the gurgling water which is nearly white noise, containing almost all frequencies of the audible spectrum. The cylinder is a closed tube, and at any given instant of time it has resonances consisting of odd harmonics of its fundamental frequency. As water fills the cylinder, fundamental frequency and all of its odd harmonics increase in frequency because the length of the resonant air column decreases.

Fig. 8 shows time-frequency analysis of water being poured into a cylinder of 30 cm long. The individual harmonics of the resonant air column are clearly visible. The missing even harmonics of the closed tube was observed, and frequencies of the harmonics increased as the length of the air column decreased.

3.4 Cork pop-up sound

One of interesting application was the analysis of cheerful sound produced when cork stopper was removed from a wine bottle. Syringes with various diameters and lengths were employed in order to change parameters. Relationship between resonant frequency and geometry (length and diameter) of syringes were studied, and it is qualitatively found that pop-up sound is resonance of closed tube. Sudden release of pressure produces broadband sound source, resonance lasts long. It is also found that end correction is needed through quantitative analysis. Effective length of open tube was introduced [7].

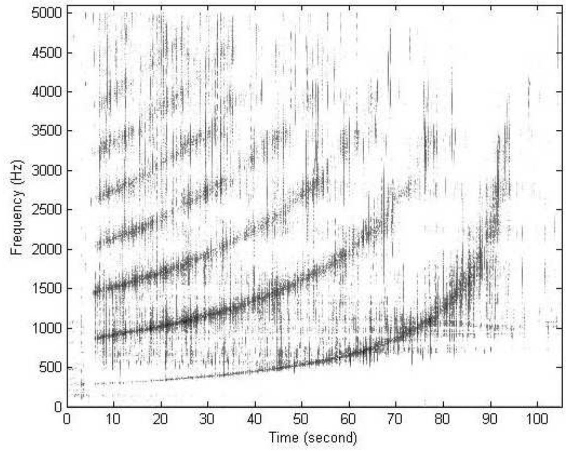


Figure 8: Time-frequency analysis of water being poured into a cylinder.

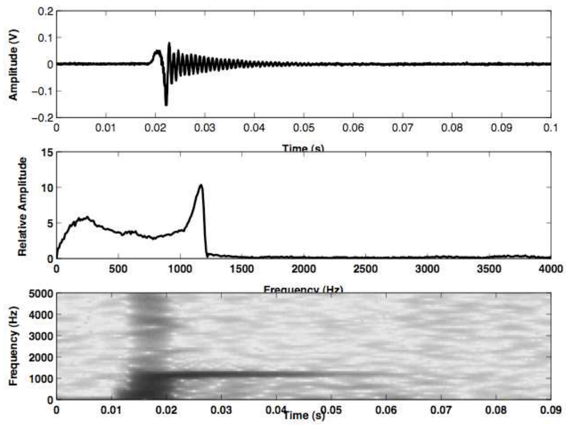


Figure 9: Sound generated by pop-up of cork stopper from wine bottle. Time domain waveform, frequency spectrum and time-frequency analysis (from top).

Fig. 9 showed pop-up sound when a cork stopper was removed from a wine bottle. Resonance signal sa well as impulse signal were observed in time domain waveform, and a clear resonant peak was in frequency spectrum. Time frequency analysis shows that impulse is a broadband signal. Length of air column in wine bottle neck was calculated from resonant frequency, 1.170 kHz. The calculated length was 7.4 cm which is slight larger than actual length, 6.5 cm. Considering diameter of bottle neck, the effective length was 7.2 cm which is close to that obtained from pop-up sound.

4 Conclusion

Inquiring activities on the acoustic phenomena have been carried out at the classroom of an high school for highly gifted children. Instead of expensive instruments such as function generator and oscilloscope, sound card installed in the personal computer was employed for the generation and detection of sound. The stereo function of sound card offered two sound source, so that phenomena of interference and beat can be realized in the classroom. The record function of sound card offered detection of sound, so that frequency spectrum analysis of sounds from two tuning forks or sound from moving fork. Using sound card, a lot of acoustic phenomena can be demonstrated in the classroom. Students showed great interests in sound, and became curious. They started to study given topics by themselves, and arrived at conclusion. They were so completely absorbed in the research on acoustics.

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