UNDERTONES AND TUNING FORKS

Rozhan Asadi, Farzanegan 4 High school, Tehran, Iran , hana.r.asadi@gmail.com

ARTICLE INFO

Participated in ICYS 2019, Malaysia

Accepted in country selection by Ariaian Young

Innovative Minds Institute , AYIMI

http://www.ayimi.org ,info@ayimi.org

ABSTRACT

Undertone frequencies can only be generated in special and strange situations. This paper investigates if creating an undertone frequency using a tuning fork is possible. The research presented in this paper explores under what circumstances and with what objects undertone can be made using tuning fork.

1 Introduction

Sound is a mechanical disturbance from a state of equilibrium that propagates through an elastic material medium. One can describe tone as a sound that can be recognized by its regularity of vibration. A sound that has only one frequency although its intensity may vary is a “simple tone”. A “complex tone” consists of two or more simple tones. The fundamental tone of an object is its lowest natural frequency. Let's consider a mechanical system, a spring which is fixed at one end and has a mass attached to the other end. The natural frequency depends on two system properties: mass and stiffness. The natural frequency is radians per second is measured as ω_n, (Eq. 1).

$$\omega_n = \sqrt{\frac{k}{m}} \tag{1}$$

where, k is stiffness of the spring, and m denotes mass. We write the natural frequency in *Hz* (Eq. 2).

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \tag{2}$$

where , f_n denotes natural frequency in Hertz, K is the stiffness of spring, and m the mass.

The frequency of the first mode is called the “fundamental frequency”. Harmonic series is simply a positive integer multiplied by the frequency of a vibrating object. “Overtone” is a term used to refer to any resonate frequency above the fundamental frequency. Any sound-producing source such as a violin string could oscillate as many different larger segments, multiples of the string – one at a time. It is as though the strings were infinitely multipliable with equal parts of itself: two doubles, three triples, four quadruples and so on. These harmonics are called undertones or subharmonics. Acoustically, the undertone series is like a mirror image of the overtone series; its opposite in every way [1]. Undertone frequencies can only be created in special and strange situations.

A tuning fork is an acoustic resonator in the form of a two-pronged fork with the prongs formed from a U-shaped bar of elastic metal. It resonates at a specific constant pitch when set vibrating by striking it against a surface or with an object, and it emits a pure musical tone once the high overtones fade out [2].

In tuning fork's fundamental vibrating mode, the two prongs vibrate 180 degrees out-of-phase with respect to one another.

To analyze the behavior, we simulated vibrating fork's prongs using COMSOL which shows the simulation of vibration and displacement of the tuning fork prongs (Fig. 1)[3].

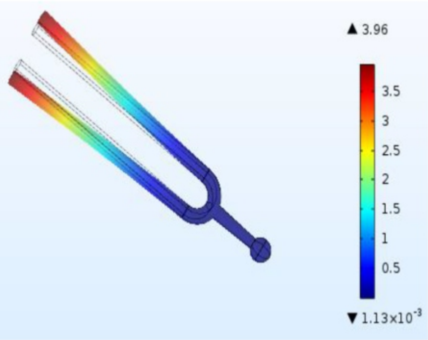


Fig 1: Simulation of vibration and displacement of a turning fork's prongs

A tuning fork has numerous natural frequencies. Many of the frequencies are excited when the tuning fork is struck by an object. But the higher frequencies quickly die [4]. In this research we are going to examine if we can succeed in making undertone frequencies with tuning fork and how this can be achieved and what are the required circumstances.

A tuning fork along can only make overtones. Therefore, it is important to find an object to help us.

2 Experiments

In our experiments, the initial hypothesis was using sheets of materials to create the tone. The sound of a tuning fork with a fundamental frequency of 440 Hz was recorded to determine the accuracy of the tools that we are using in these experiments.

The sound was analyzed in MATLAB. The fundamental frequency in our tuning fork was 440 Hz (Fig. 2).

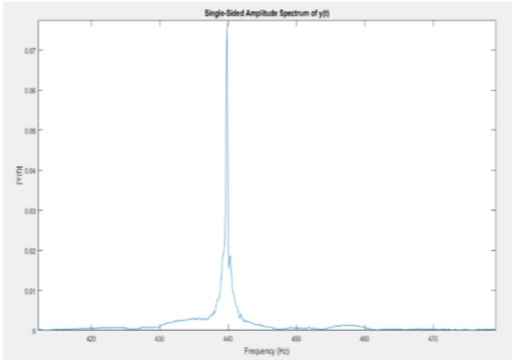


Fig. 2: Single sided amplitude spectrum, sound was analyzed in MATLAB and the fundamental frequency was 440 Hz

Next, three different materials of sheets; paper sheet, aluminum sheet and plastic sheet in deferent sizes were tested. We clamped the sheets to a stand and let them be connected weakly to the head of tuning fork's prong.

In experimenting with aluminum sheets and plastic sheets, we did not reach to spectacular results. However, while experimenting with paper sheets, in some parts some undertones were successfully made.

As it can be seen in Figure (3), the frequency 220 Hz is the first undertone of tuning fork's frequency which was made.

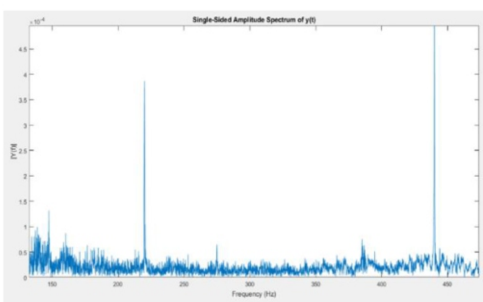


Fig. 3: Frequency plot for the experiment with the paper sheet

As it was mentioned before, the paper is connected weakly in only some parts. In this way, we were able to produce the undertone sound using the paper. Figure (4) illustrates the experiment setup.

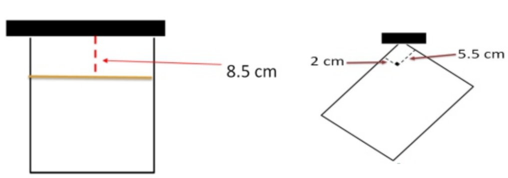


Fig. 4: Experiment setup indicating where undertone was made (top) A5 paper, and (bottom) A4 paper.

The points where the undertone was made in an A5 paper were on a line 8.5 cm away from its width where it was clipped. When A4 paper was clipped from a corner, the point was on the opposite corner of a rectangle with 2 cm width and 5.5 cm length. When the experiments were carried out in the setup of connecting the papers on these points weakly to a prong, not only an undertone was detected on the record results but also a harmonic series of the undertone frequency was created too (Fig. 5).

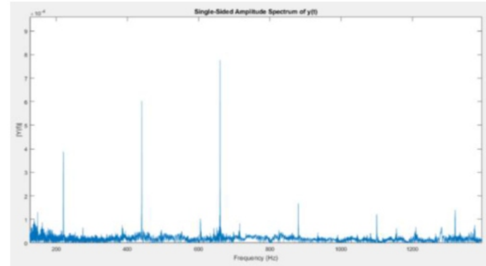
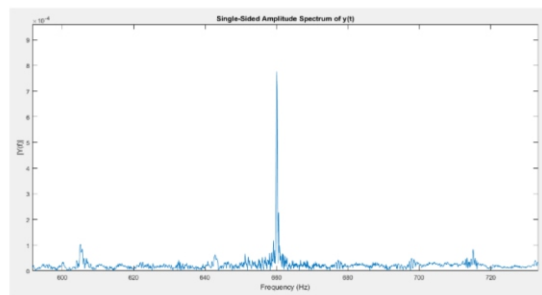
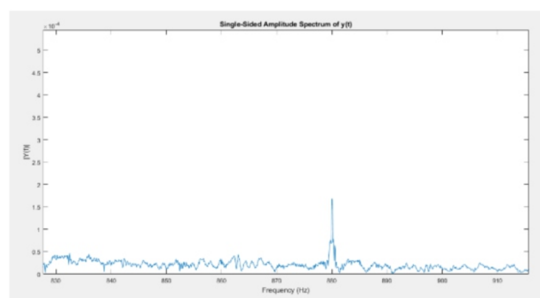


Fig. 5: Frequency plot showing the harmonic series of the undertone in experiment with paper connected in specific points

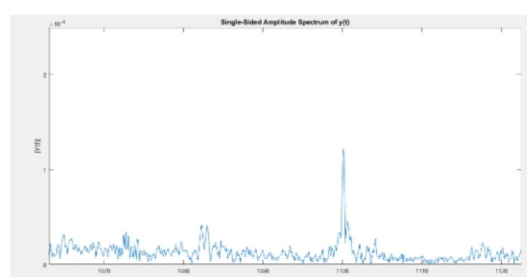
As shown earlier, the undertone that we got from our tuning fork was 220 Hz. The frequencies 660 Hz, 880Hz and 1100 Hz, can be overtones of 220 Hz. The 440 Hz, the fundamental frequency of the tuning fork, can be the overtone of 220 Hz too (Fig. 6).



(a)



(b)



(c)

Fig. 6: Frequency plot, a) 660 Hz, b) 880 Hz, c) 1100 Hz as the overtone of 220 Hz

3 Results

In our experiments, we got the undertone sound . However, the question about the reason behind the creation of this undertone has remained unanswered. This section addresses this question.

When the prong starts vibrating, it hits the paper, which causes the paper to vibrate. The paper starts to move back and forth on a very small scale. If the prong goes back and forth two times while the paper goes back and forth one time and they hit each other, then the sound wave made from this hit will have a frequency half of the fundamental frequency of the tuning fork. In other words, if the speed of the paper sheet becomes half of the prongs speed, an undertone with frequency half of the fundamental frequency will be made.

Next, we examine why this phenomenon only happens when we connect them in these points. Paper has different vibrating modes, depending on where, how, and with what force is hit. Whether the paper is clamped or not, and the place of the clamp are important factors since they affect the vibration. When the paper is connected weakly to the prong from those points and hit the prong there, it vibrates in a way that its speed is half of the prong's speed. So the undertone will be made.

4 Conclusion

This paper presents research investigating a physical phenomenon. We explored different conditions to create undertone using a tuning fork. The results show that with a paper sheet and a tuning fork, one can create a special situation where an undertone sounds with half of the tuning fork's natural frequency, can be heard. Our investigation shows that not only a tuning fork can create an undertone, but also we can have harmonic of the created undertone. This undertone sound can only be made when we connect the paper weakly to one of the prongs from several specific points.

References

[1] Irvine, T, (2001), "Tuning fork sound and vibration by Tom Irvine". tutorial material.

[2] Constantinsen, B., (2015), "The physics of sound", research report.

[3] Feldmann, H. (1997). "History of the tuning fork I: Invention of the tuning fork", Laryngorhinootologie.76(2):116-22.

[4] Research materials from www.acs.psu.edu.

[5] Halliday, D, Resnick,R and Walker, J, (2013), "Fundamentals of physics", 10th edition.

[6] Knapman, Herbert (1904), "An Experiment Illustrating Harmonic Undertones." Proceedings of the Royal Society of London, vol. 74, , pp. 118–120. JSTOR, www.jstor.org/stable/116664.

[7] Thomas R D, Russell, D A, and Brown, D E, (1992), "On the acoustics of tuning forks." American journal of physics 60, 1992 (7) 620-626.