The Correct Explanation for the Working of the Straw Oboe

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Abstract

A straw oboe is constructed by cutting one end of the drinking straw into a wedge shape. We got intrigued when we saw the demonstration of how the straw oboe produces sounds of higher frequency when it is cut into smaller lengths. The standard explanation is that the drinking straw has an air column which is open at both ends, and so when the flaps vibrate, they set up stationary sound waves in the air column (open at both ends) which have resonant frequencies based on the length of the straw.

However, when we measured the sound frequencies produced by the straw and compared it with the expected resonant frequencies, we found them to be 15 times lower!

This set us thinking and we then conducted a thorough investigation by taking 5 trials for each length and measured the first four harmonic frequencies (using the 'plot spectrum' feature of AUDACITY software to analyse the sound clips recorded using an iphone) for 26 different lengths of the straw. The data provides comprehensive proof that the current accepted belief is wrong. We found the sound frequencies to be around 15 times lower than the corresponding resonant frequencies. This can be understood by considering the sound to be produced by the vibration of the flaps in the wedge directly. The flaps vibrate at around 15 times lower frequency than the corresponding resonant frequency for the length of the straw. This 'correction factor' of 15 is expected to depend on the material properties of the flap like the size, shape and stiffness of the flap which we plan to confirm in our next investigation.

Introduction

Our research question is: **How does the frequency of sound produced by a 'straw oboe' depend on the length of the straw?**

The current theory found in textbooks and internet sources [1,2,3,4,5] state that the frequency of sound produced by the vibrating straw should match with the resonant frequencies possible for stationary waves that can be set up in an air column of length equal to that of the straw, which is open at both ends.

But our preliminary investigation showed a huge difference between the measured frequency and the frequency predicted by current theory. So we wanted to establish a new and correct model to predict the frequencies of sound emitted by the straw oboe for different lengths.

We plan to establish this by collecting accurate data (by measuring the sound frequency 5 times for each length) over a wide range of the independent variable (26 different lengths of the straw). We expect to find a difference between the expected and measured frequencies and hope to construct a model which will enable us to predict the correct frequencies.

Methods and Materials

Two drinking straws were joined together by sliding one straw by a few millimetres inside the other straw and cellotaping the joint so that it won't slip. Thus a straw of length 53.0 cm was obtained. A triangular wedge-shaped cut was made on one end using a scissor.

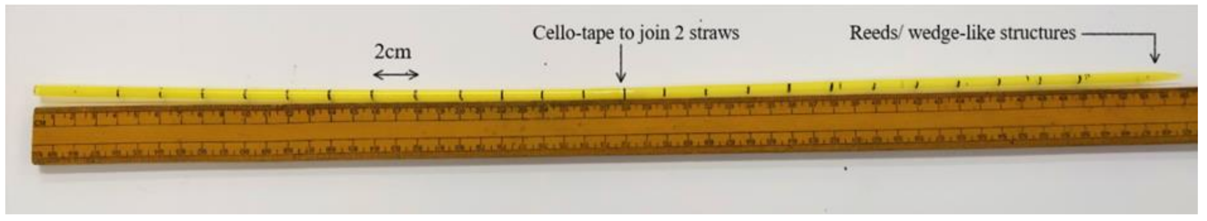

Figure 1. The straw used in the investigation

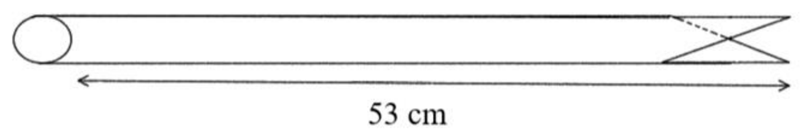

Figure 2. One end of the straw cut into a wedge shape to make it a straw oboe

In a quiet room, air was blown through the wedge-shaped end by gently holding that end between the lips, and the sound produced was recorded using the sound recorder in the iphone. The sound was recorded 4 more times. This was repeated for different lengths of the straw obtained by cutting the straw in steps of 2cm.

The sound clips were then opened in AUDACITY software and the first four harmonic frequencies were noted as shown in Figure 3.

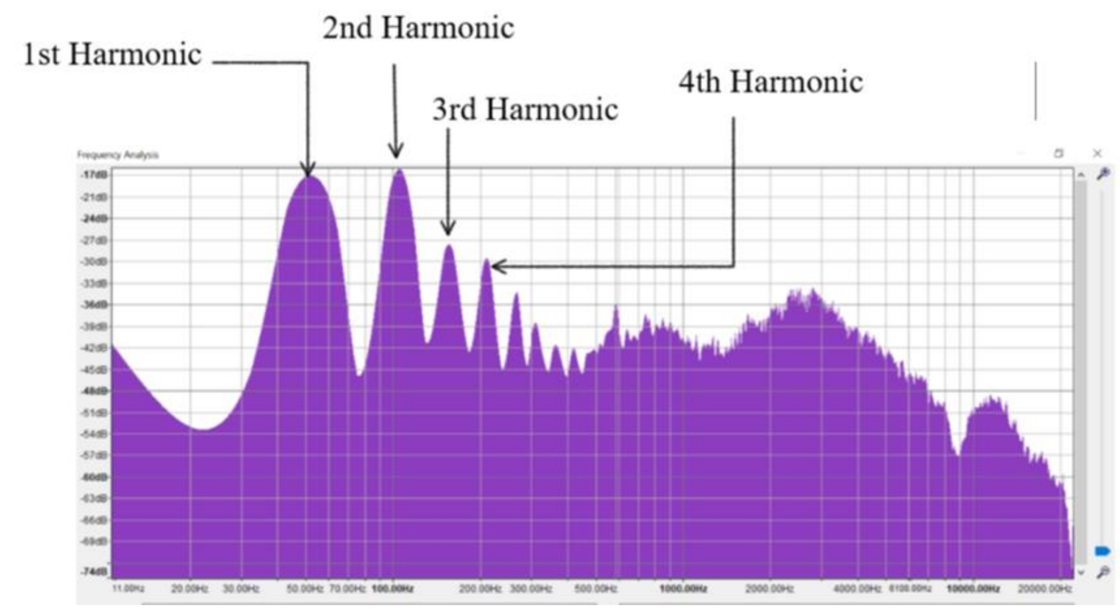

Figure 3. Frequency Plot Spectrum in Audacity software

Results and Discussion

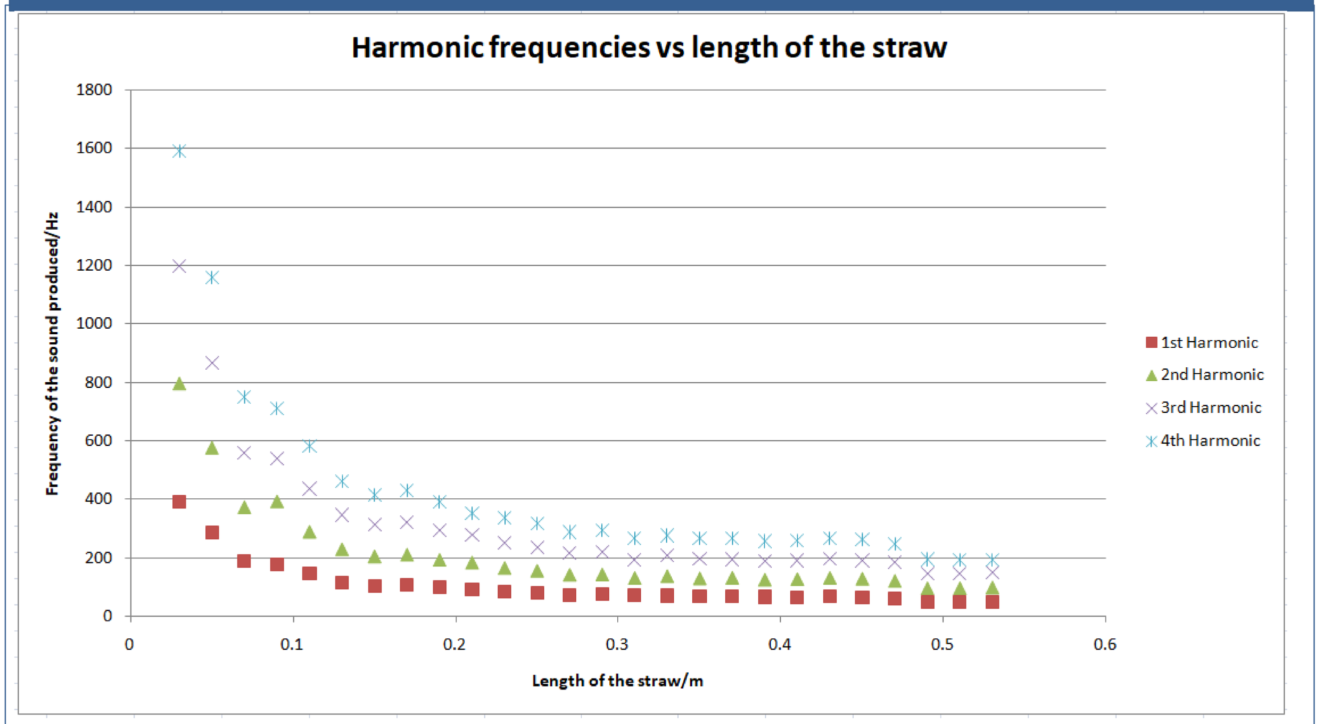

Figure 4. The graph of mean harmonic frequency vs length of the straw shows an increase in frequency with decrease in length of the straw for all harmonic frequencies as expected.

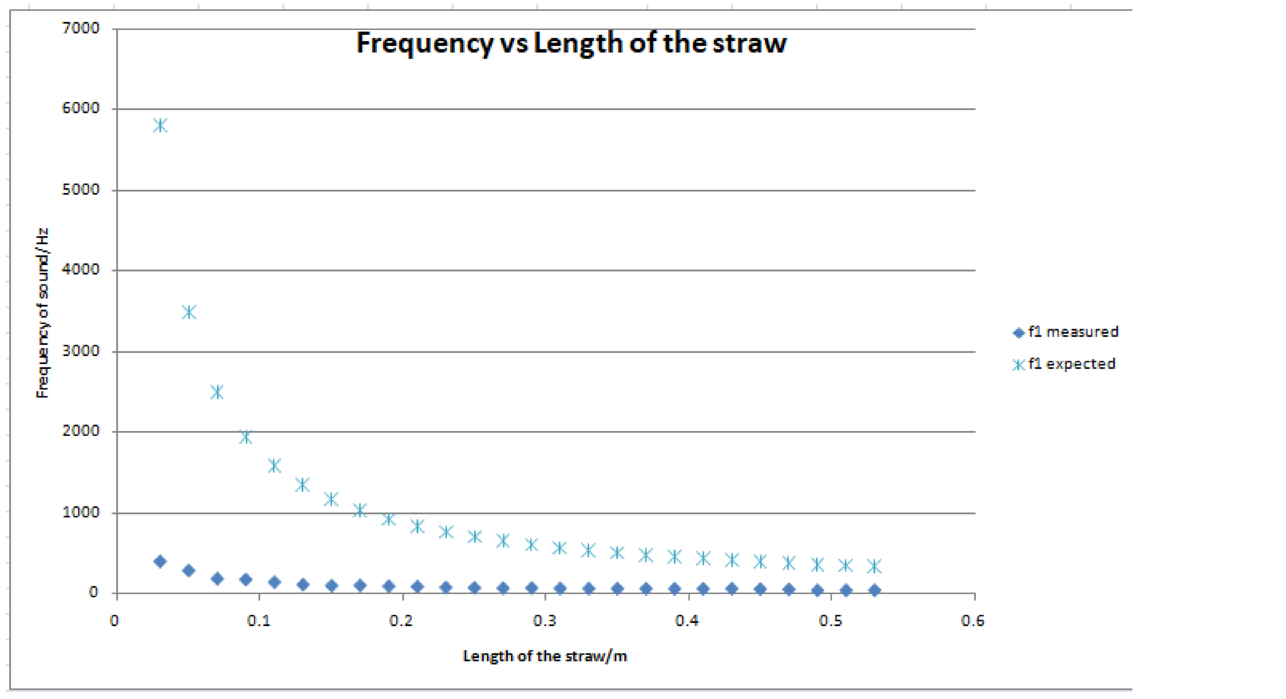

Figure 5. When the expected 1st harmonic frequency calculated by taking the speed of sound in air to be 349 m/s (because room temperature during the experiment was 30° C) was compared with the measured 1st harmonic frequency, the measured values turned out to be around 15 times lesser. This relationship was found to be true for all the higher harmonics as well.

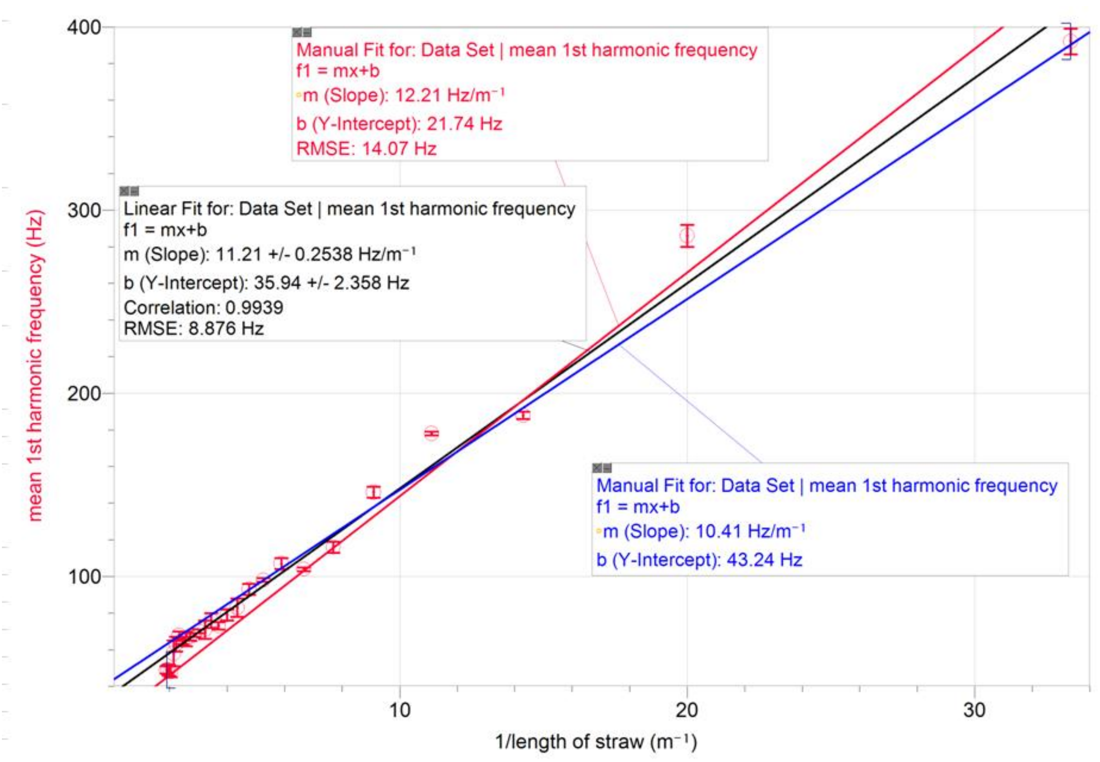

Figure 6. The slope of the linear fit for the first harmonic was estimated to be 11.2 Hz.m with an uncertainty of 0.9, suggesting the velocity of sound to be 22.4 m/s which is not possible, thus proving that the sound being heard was not the stationary waves that were set up in the air column inside the straw.

To predict the correct frequencies, our model suggests that the measured sound is produced by the vibrating flaps which vibrate at around 15 times lower frequency than the stationary sound wave set up in the air column. So we introduced a correction factor ***m = 15*** to compute the predicted measured frequency f_1 from the stationary wave frequency f_2 using the relation $f_1 = \frac{f_2}{m} = \left(\frac{v}{2m}\right) \times \frac{1}{L}$

Thus, slope of the f_1 vs (1/L) graph should equal v/(2m), which gives m=v/(2*slope)= 15.6 for speed of sound v=349 m/s. On using this correction factor all the predicted frequencies match very closely with the measured frequencies for all the harmonics.

Conclusions

The sound produced by blowing through the straw oboe matches the frequency of the vibrating flaps and not the stationary wave vibrations inside the straw. The sound produced by the stationary wave is too weak to be heard and recorded separately. The frequency at which the reeds vibrate is exactly an integer factor lower than the frequency of the stationary wave setup inside the air column.

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