Vibrato and Tremolo Analysis

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Abstract

In this study, the effects of vibrato and tremolo are observed and analyzed over various instruments at different frequencies. One of the instruments analyzed was a Wurlitzer electric piano that had an electronic simulation of what was advertised as a vibrato effect. The rest of the instruments analyzed had vibrato and tremolo properties that were purely made by the user manipulating either the instrument or their embouchure. From the data collected, it was evident that string based instruments generally can display only the vibrato effect, whereas wind instruments can display both vibrato and tremolo. This was due to the nature of the sustain that all the instruments have.

Introduction

Many musical instruments have the capability of producing vibrato, tremolo, or both in order to add musicality to compositions. The main goal of this project was to analyze and compare the vibrato and tremolo of different musical instruments. While tremolo and vibrato might sound almost identical to the untrained ear, they differ on a very fundamental level. Vibrato is an effect that occurs when the value of the frequency is changed in rapid succession. Tremolo does not change frequency in rapid succession but instead changes the tone's amplitude rapidly. To simplify, vibrato is constantly changing pitch and tremolo is constantly changing its volume intensity at frequencies of their own. At a high frequency, the beats of the tones sound closer together and at lower frequencies they are further apart. Figure 1 is a visual representation of the difference between the two musical techniques.

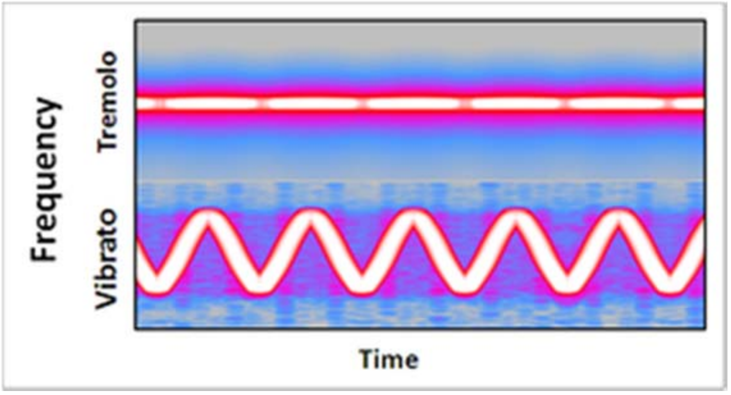

Figure 1. Vibrato and Tremolo Frequency vs. Time

([Aandroyd at English Wikipedia](#))

Methods

To carry out this study, we analyzed the vibrato and tremolo effects of six different instruments: flute, Danelectro guitar, Wurlitzer piano, Gibson G-3 bass, trombone, and tenor saxophone.

To create vibrato on a flute, the player must adjust the placement of their tongue within their mouth rapidly. To create vibrato on a Danelectro guitar, the player must bend the string rapidly above the nut of the guitar. The vibrato on the Wurlitzer piano is a consequence of special circuitry, and a dial must be turned to adjust the rate of the vibrato. Vibrato was created on the Gibson G-3 grabber bass by bending the string in the third fret of the neck rapidly. Vibrato was created on the trombone via two different methods: by adjusting the embouchure of the mouth and by moving the slide rapidly. To create vibrato on the saxophone, the player must adjust the placement of their tongue within their mouth and the placement of their jaw rapidly.

We recorded each of these instruments playing the same six notes with vibrato: E, A, D, G, B, and high E. The only exception to the notes which were recorded were those of the Gibson G-3 bass: G, C, F, and Bb. The recordings were taken on a 16-bit digital stereo recorder (Marantz PMD671).

Once we recorded all of the instruments, we ran the recordings through the MATLAB wave analysis program. We then looked at the graphs that were produced for amplitude (tremolo) and frequency (vibrato) for every note on every instrument at multiple frequencies. The wave analysis program was originally designed for steady state sounds, so there were some spikes when higher frequencies were analyzed (especially for flute), but the lower frequencies produced very good results.

Looking at the graphs that were produced for amplitude and frequency allowed us to determine which musical quality (vibrato or tremolo) had more of an effect for each instrument.

Results

The results of our experiments showed various characteristics of both vibrato and tremolo among several instruments. Over these instruments, the productions of sound varied based on the source and technique to create these two effects. In our analysis, we were not interested in the phase change of the tone from the different instruments. Instead, we concentrated on the amplitude and frequency changes because those give more information regarding the vibrato and tremolo produced by each instrument.

Danelectro Guitar

The first instrument that we looked at was a Danelectro guitar over the notes E (82.41 Hz), A (110.00 Hz), D (146.83 Hz), G (196.00 Hz), B (246.94 Hz), and High E (329.63 Hz). The 1st and 2nd harmonic frequencies, phase, and amplitudes for this guitar for the note E are shown in figure 2. The higher 3rd and 4th harmonic are shown in figure 3. In figures 2 and 3, the amplitude does not oscillate around a steady mean, rather it dies out as time goes on. Additionally, the frequency changes but only in a higher direction. The amplitude dies out and does not oscillate because it is not possible to have a steady “loudness” from a guitar. The tone is produced once by the vibration of a plucked or strummed string, which eventually dies out. The frequency increases because the technique used to obtain vibrato involved pressing the string down above the nut of the guitar. This makes the string tighter, not looser, and as a result, the pitch has an overall upward frequency shift. More properties relating to the frequency and amplitude of the guitar can also be seen in figures 4 and 5.

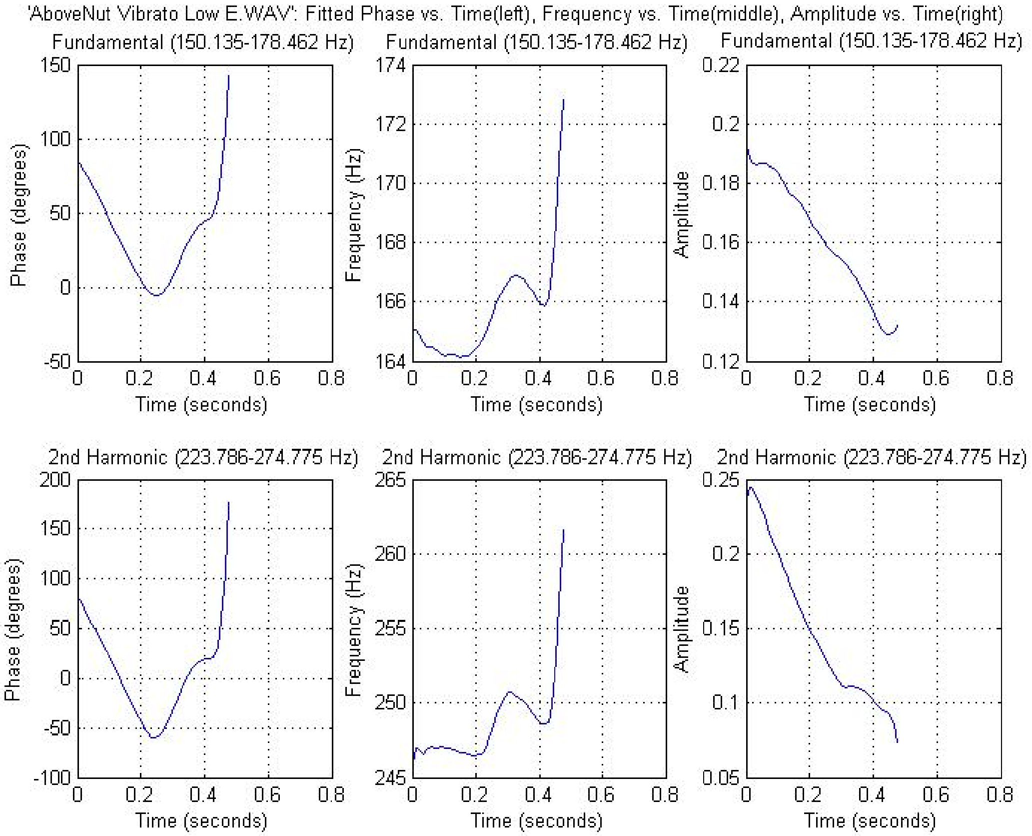

Figure 2. 1st and 2nd harmonic characteristics of the Danelectro guitar at E2

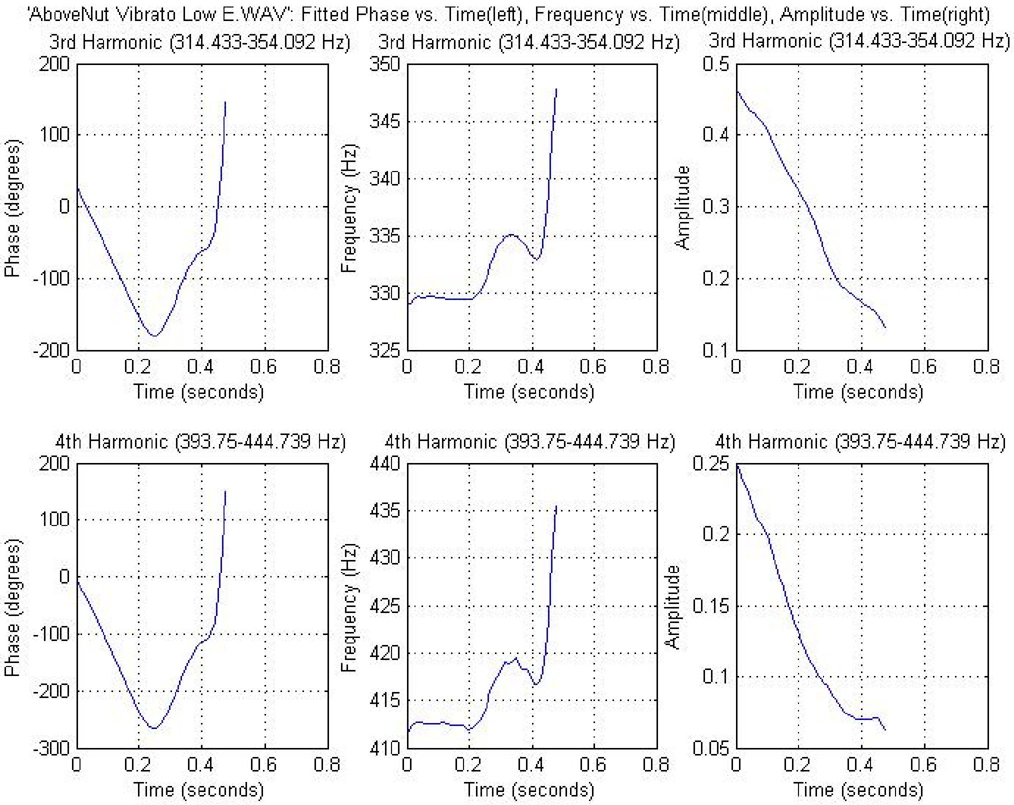

Figure 3. 3rd and 4th harmonic characteristics of the Danelectro guitar at E2

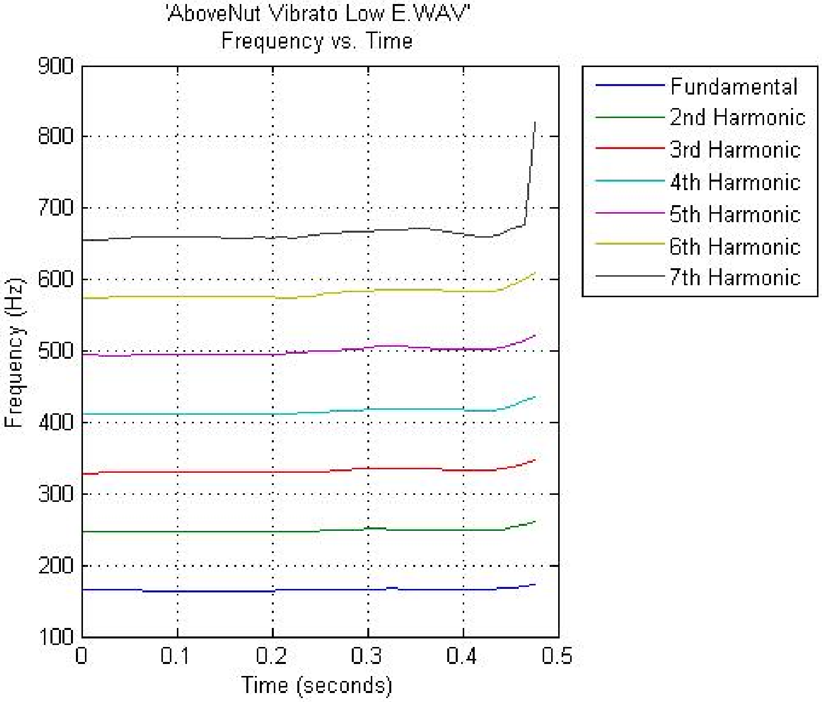

Figure 4. Low E frequency vs. time plot for the Danelectro guitar

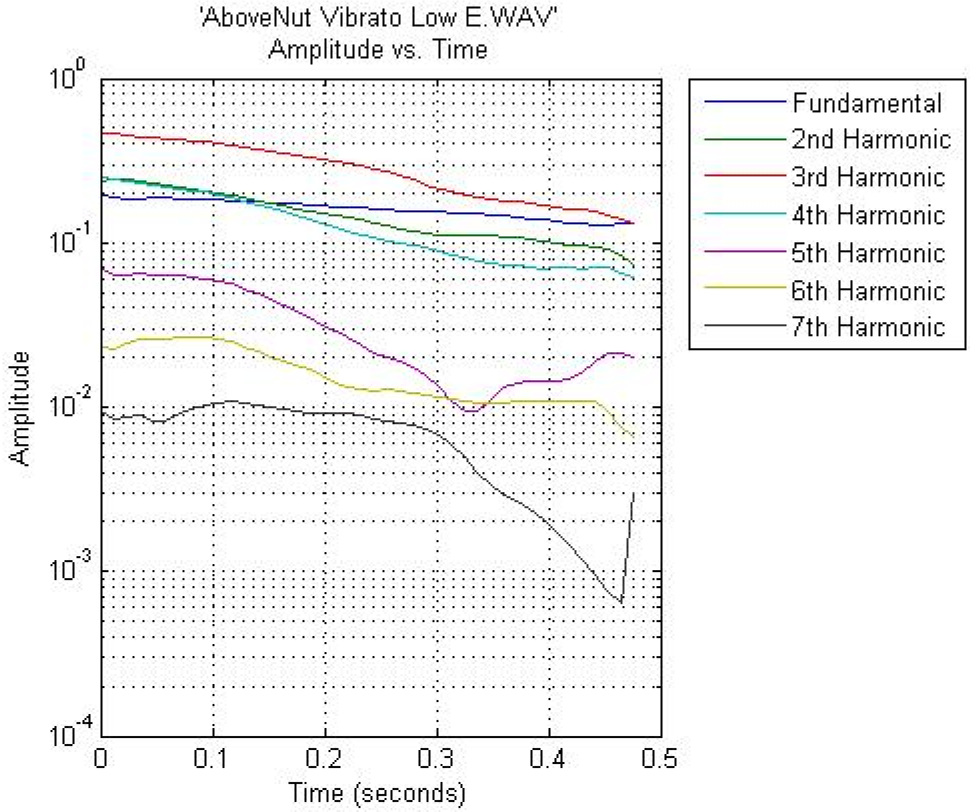

Figure 5. Low E amplitude vs. time plot for the Danelectro guitar

Wurlitzer Electric Piano

The second instrument that we looked at was a Wurlitzer piano over the same notes as the Danelectro guitar. The 1st and 2nd harmonic frequencies, phase, and amplitudes for the Wurlitzer for the note E are shown in figure 6. The higher 3rd and 4th harmonic are shown in figure 7. In figures 6 and 7, the amplitude does not oscillate around a steady volume, rather it generally dies out as time goes on. However, the frequency does oscillate around a steady state. The amplitude dies out and does not oscillate because, again, it is not possible to have a steady "loudness" from a piano. The tone is produced via an electronic circuit, which eventually dies out. The Wurlitzer has a special dial on it which is marketed as a "vibrato" dial. However, the vibrato effect produced by the Wurlitzer is much less than the tremolo effect, as evidenced by the very small range of frequencies seen in figures 6, 7, 8, and 9. This leads us to believe that the label on the Wurlitzer is false advertising. More properties relating to the frequency and amplitude of the piano can also be seen in figures 8 and 9.

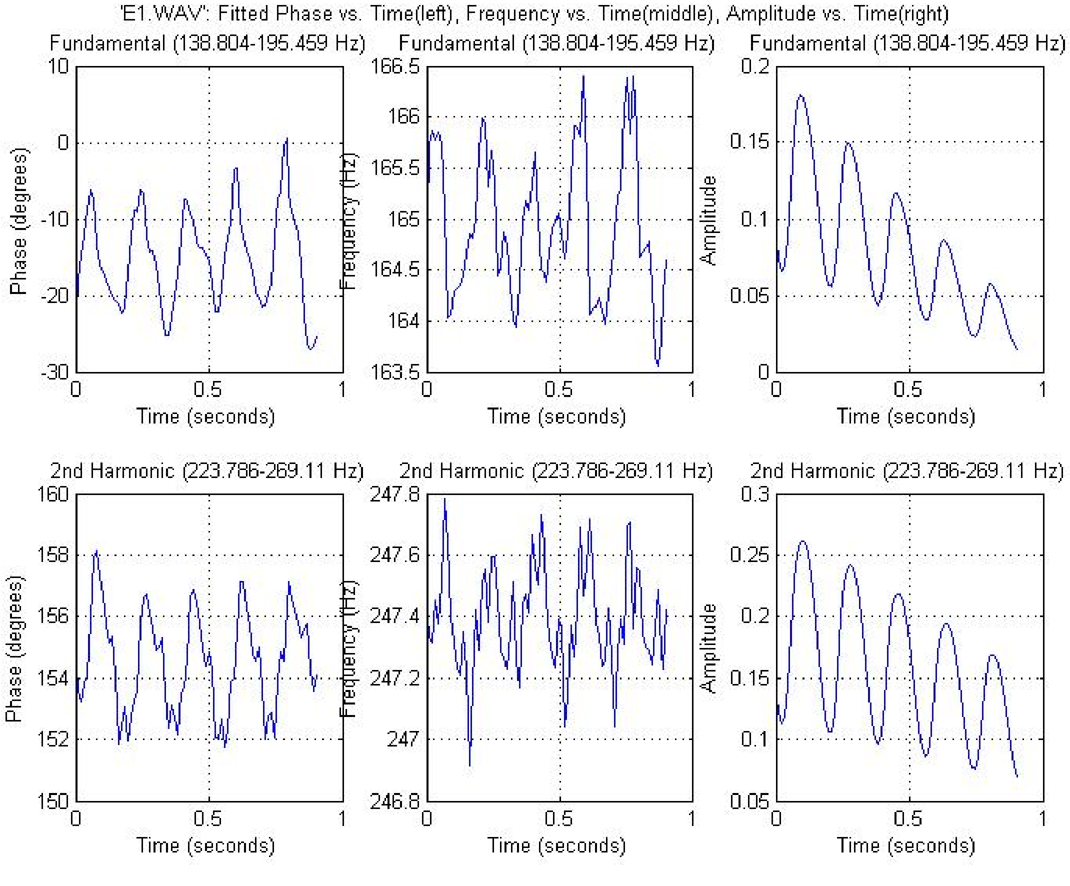

Figure 6. 1st and 2nd harmonic characteristics of the Wurlitzer piano

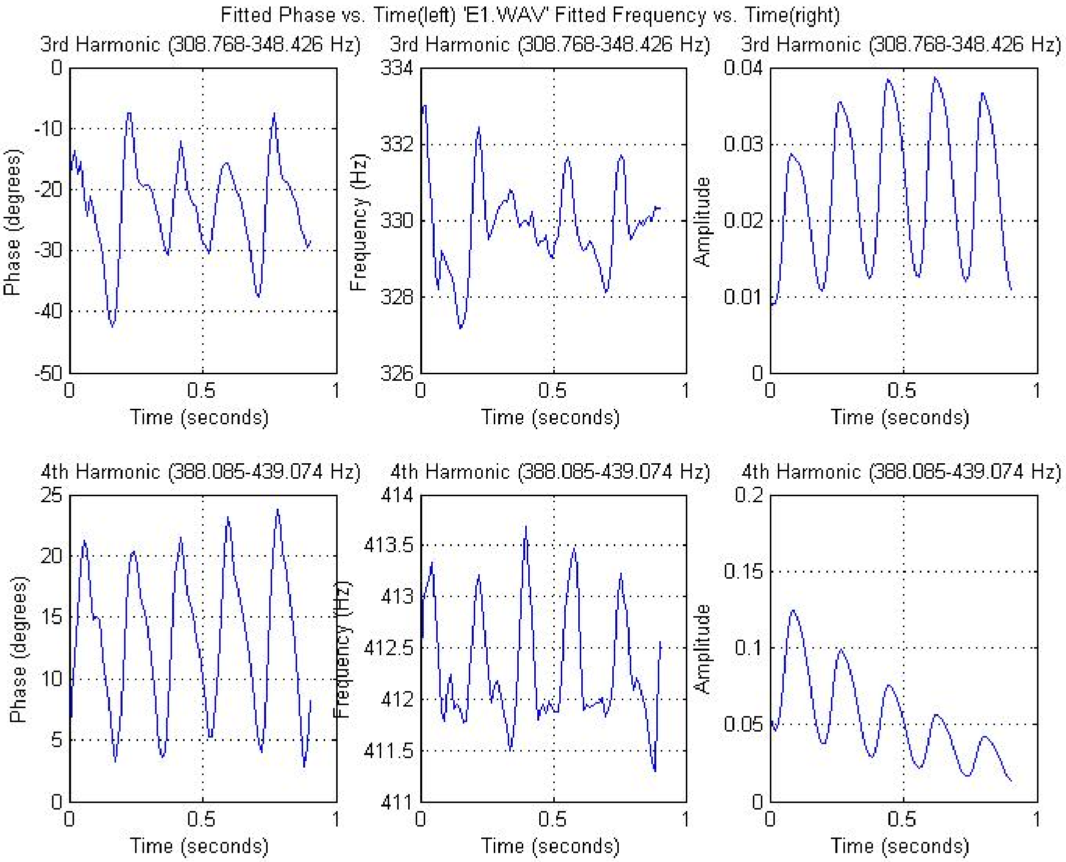

Figure 7. 3rd and 4th harmonic characteristics of the Wurlitzer piano

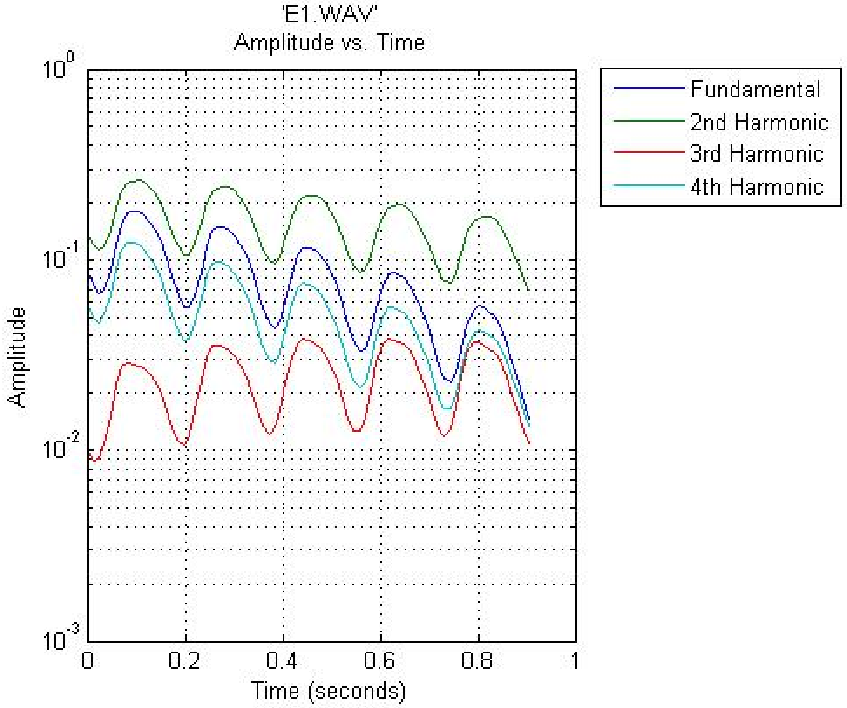

Figure 8. Low E amplitude vs. time plot for the Wurlitzer piano.

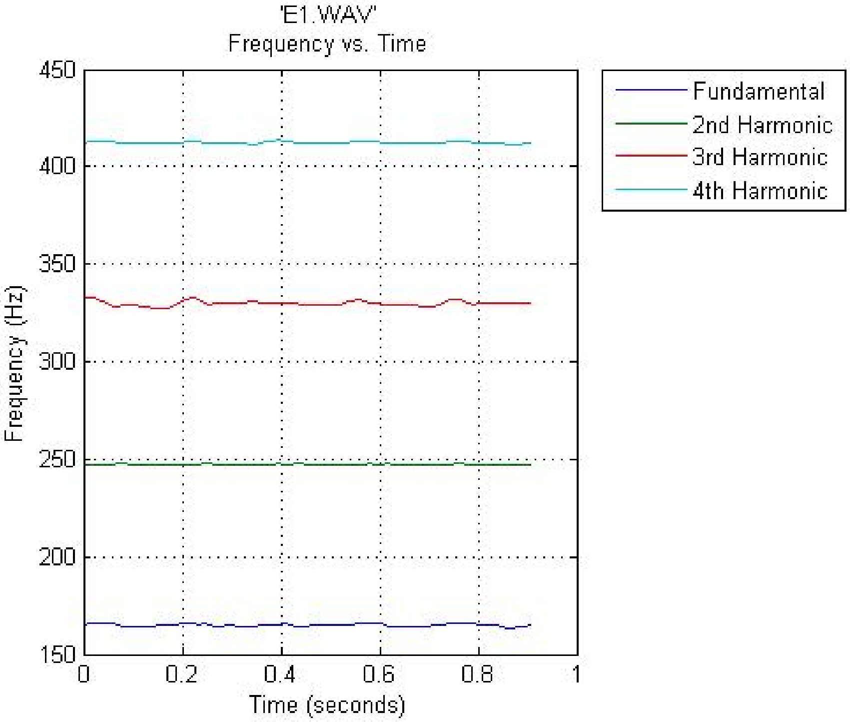

Figure 9. Low E frequency vs. time plot for the Wurlitzer piano.

Gibson G-3 Bass

The third instrument that we looked at was a Gibson G-3 bass over the notes G (49.00 Hz), C (65.41 Hz), F (87.31 Hz), and B ♭ (116.54 Hz). This is the only instrument where we did not use the same notes as we did on the guitar. This was done because the only way that we could produce vibrato on the base was by having a finger placed on the string. Because we wanted to study this instrument in its most common range, we had to choose notes that were very close to the open notes on a bass of E, A, D and G. We decided to use the 3rd fret values as a result. The 1st and 2nd harmonic frequencies, phase, and amplitudes for this bass for the note G are shown in figure 10. The higher 3rd and 4th harmonics are shown in figure 11. In figures 10 and 11, the amplitude does not oscillate around a steady mean, rather it dies out as time goes on. The frequency seems to oscillate about a steady state. The amplitude dies out and does not oscillate because it is not possible to have a steady "loudness" from a bass. The tone is produced once by the vibration of a plucked or strummed string, which eventually dies out. Overall, vibrato played a much larger role than tremolo in the wavering effect produced by the bass. More properties relating to the frequency and amplitude of the bass can also be seen in figures 12 and 13.

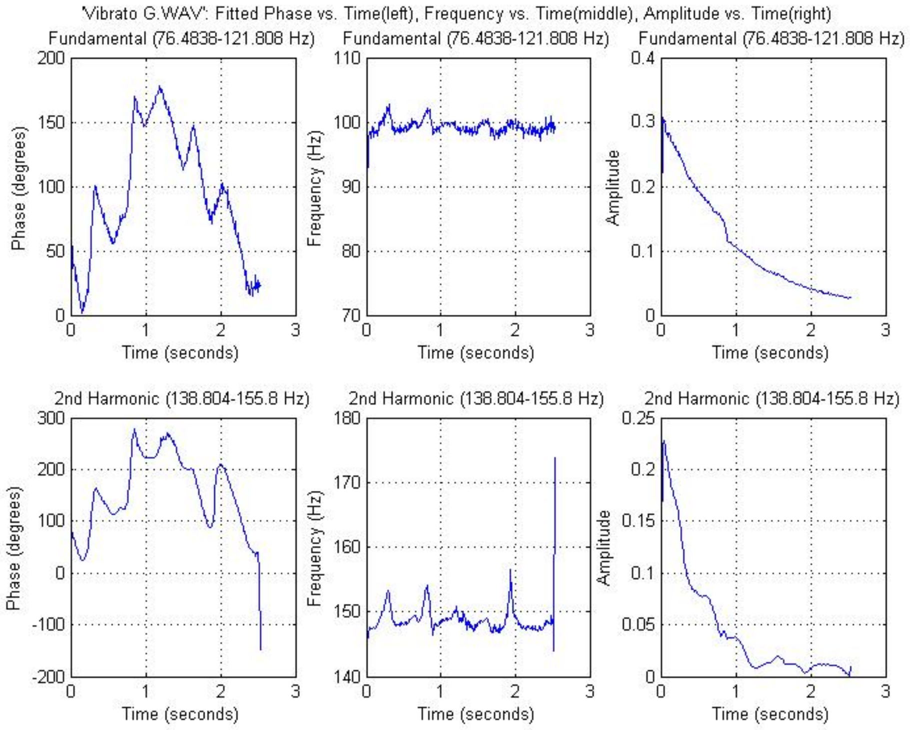

Figure 10. 1st and 2nd harmonic characteristics of the Gibson G-3 Bass

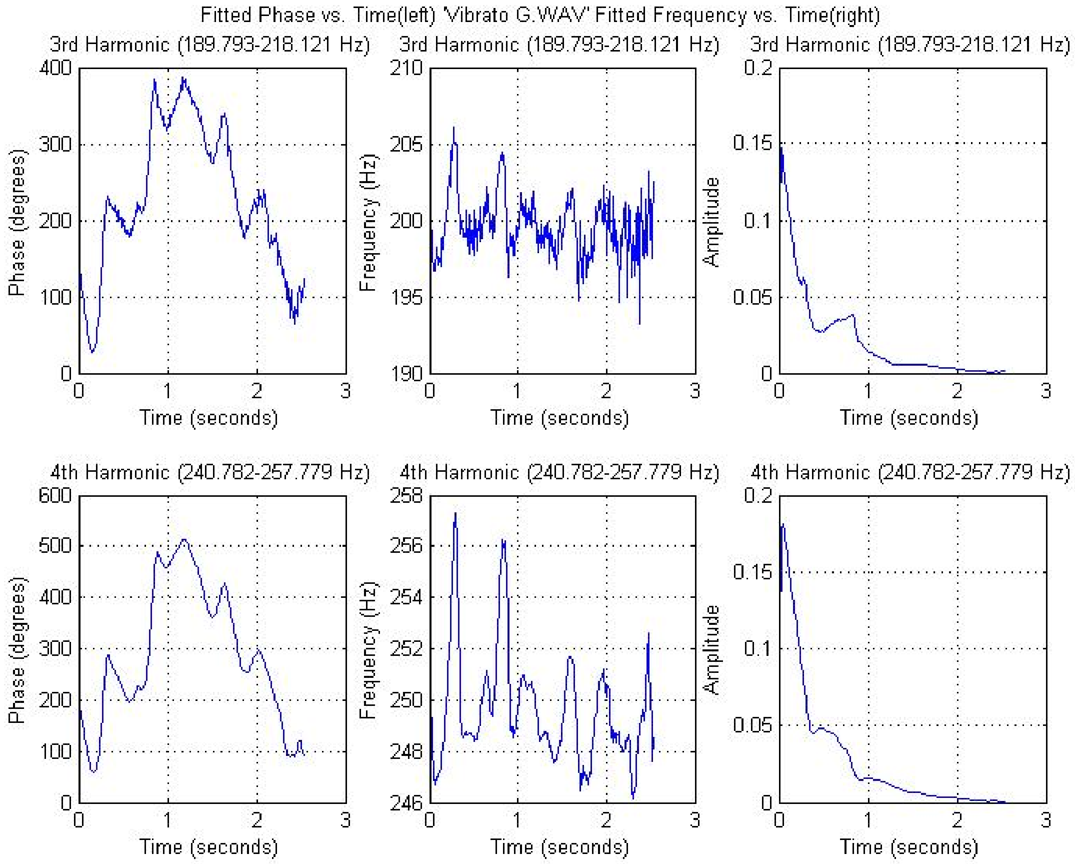

Figure 11. 3rd and 4th harmonic characteristics of the Gibson G-3 Bass

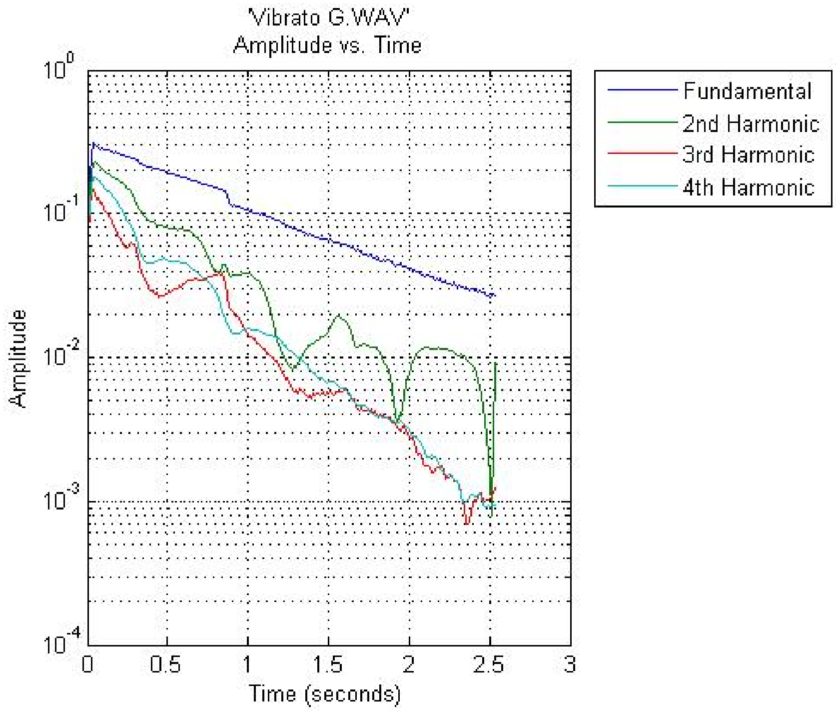

Figure 12. G amplitude vs. time plot for the Gibson G-3 Bass.

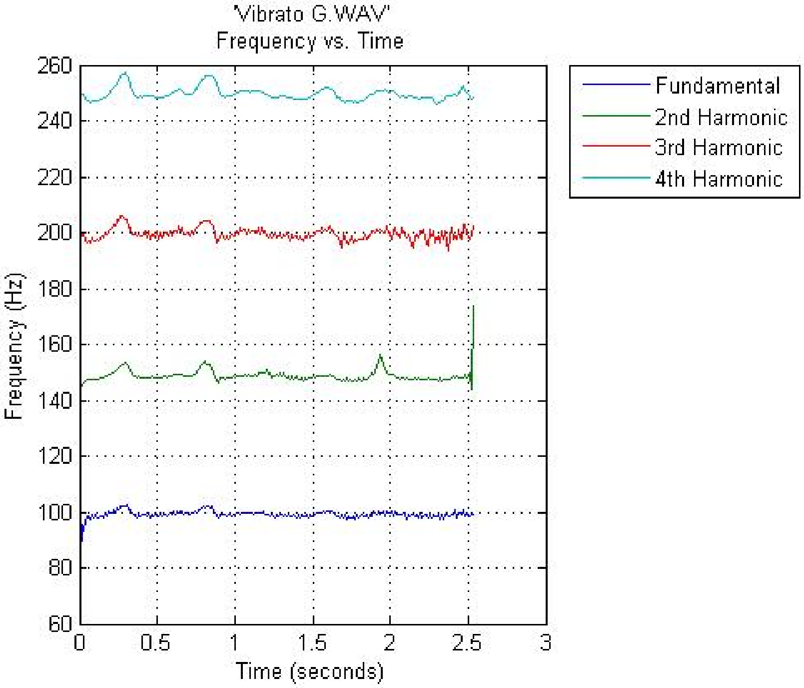

Figure 13. G frequency vs. time plot for the Gibson G-3 Bass.

Flute

The fourth instrument that we looked at was a flute over the same notes as the Danelectro guitar. The 1st and 2nd harmonic frequencies, phase, and amplitudes for the flute for the note E are shown in figure 14. The higher 3rd and 4th harmonic are shown in figure 15. In figures 14 and 15, both the amplitude and frequency are shown to oscillate about a steady sound. Creating a tone that oscillates around a steady volume and frequency is relatively easy on the flute because the sound is controlled by the player's air. Tones are much more easily sustained on woodwind and brass instruments than on plucked string instruments. Both vibrato and tremolo played equal parts producing in the wavering effect of the flute. More properties relating to the frequency and amplitude of the piano can also be seen in figures 16 and 17.

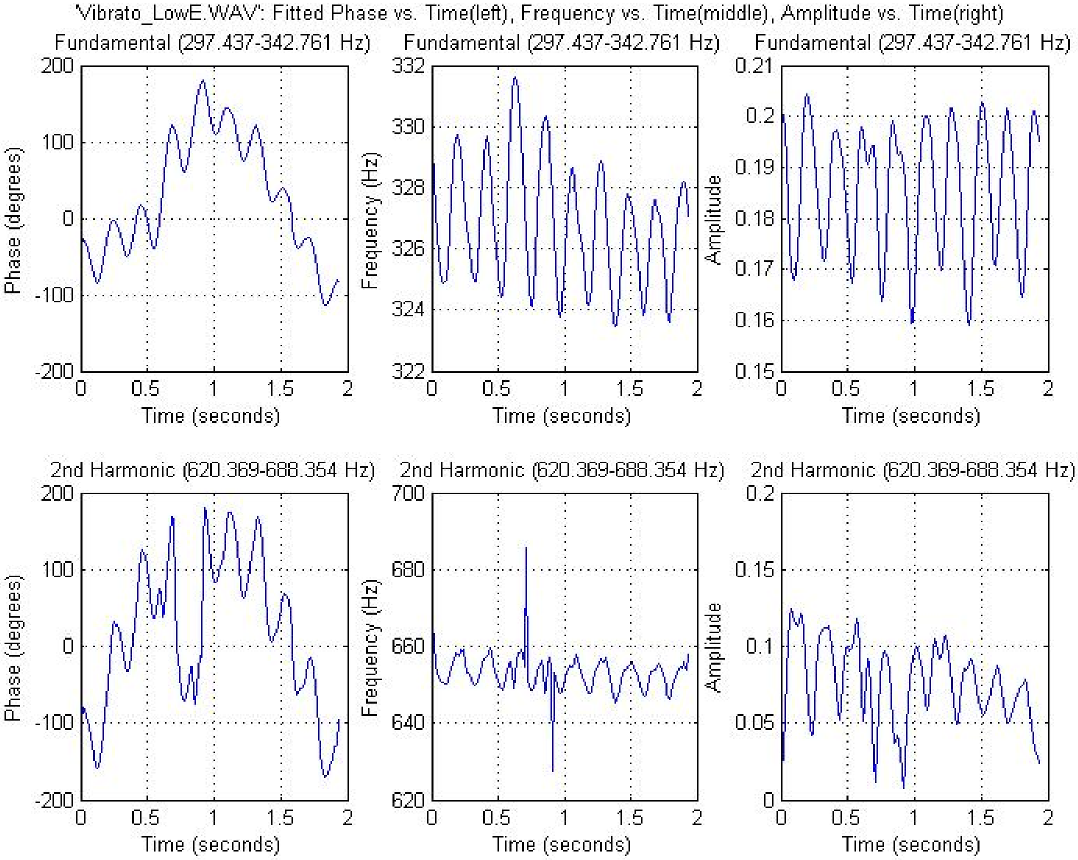

Figure 14. 1st and 2nd harmonic characteristics for the flute

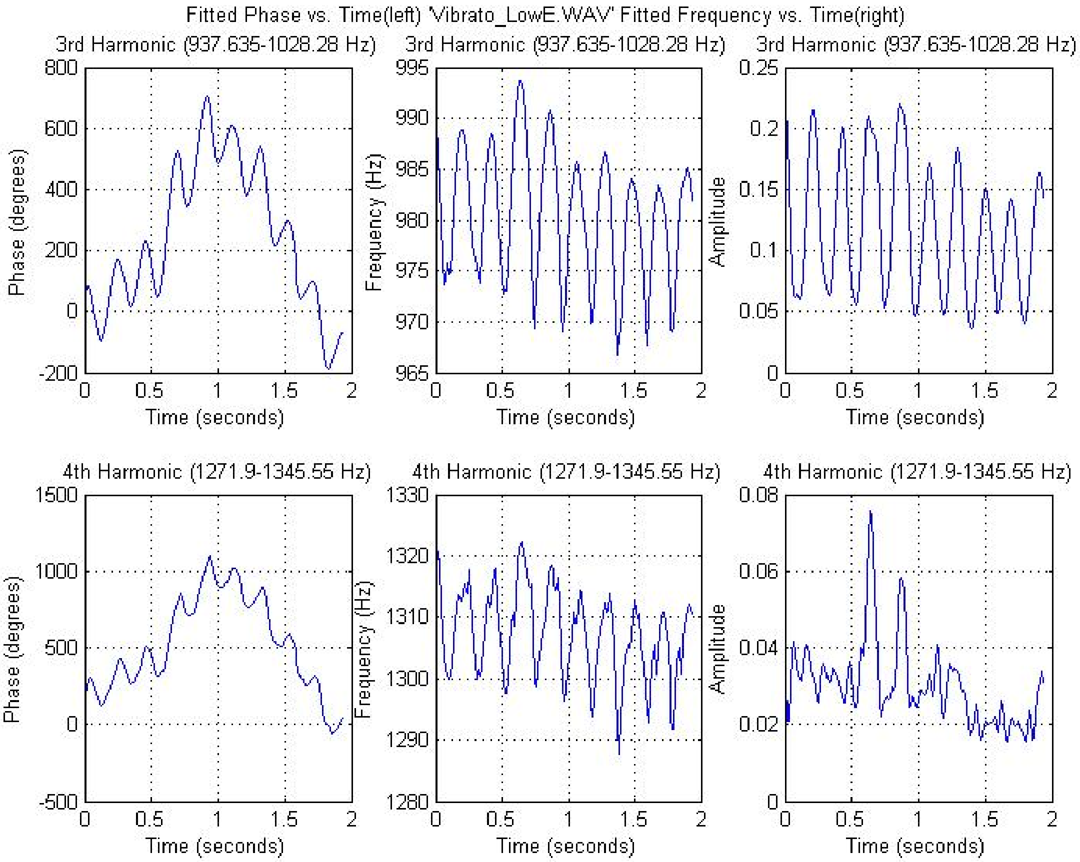

Figure 15. 3rd and 4th harmonic characteristics for the flute

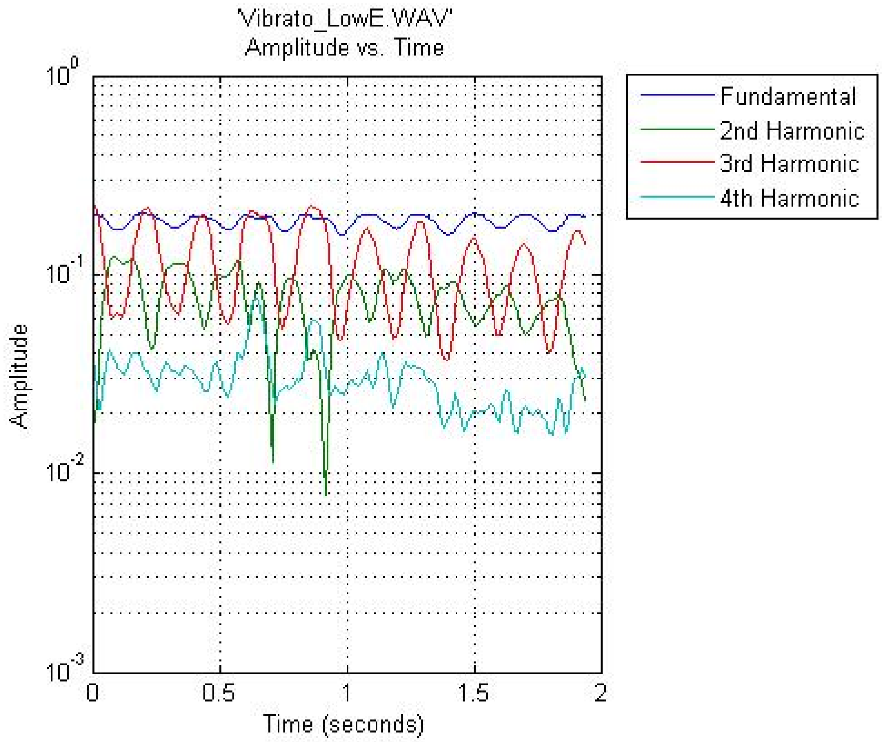

Figure 16. Low E amplitude vs. time plot for the flute

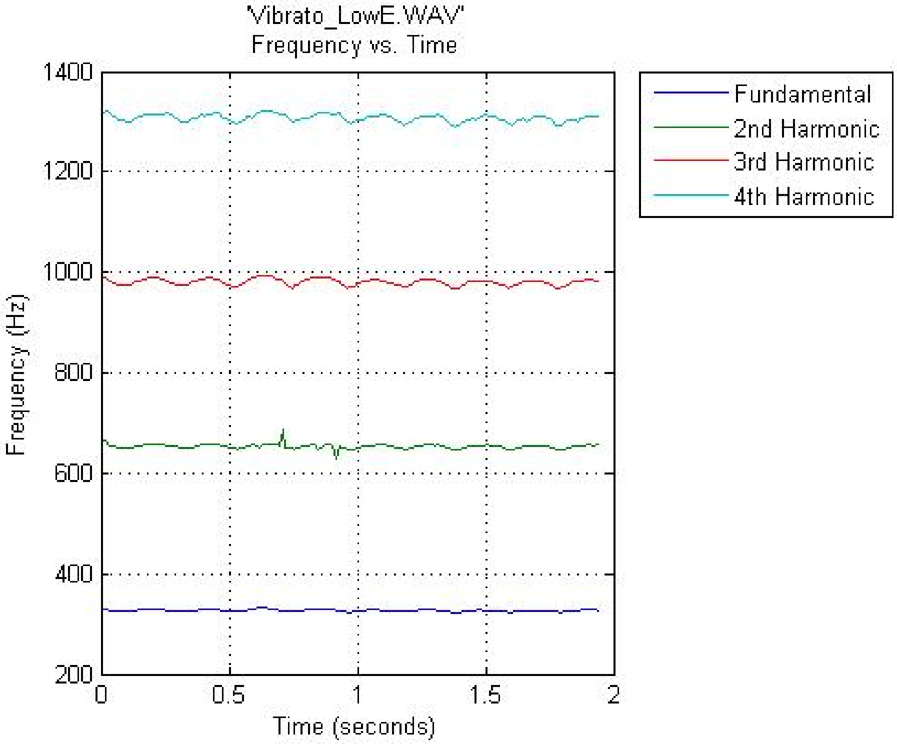

Figure 17. Low E frequency vs. time plot for the flute

Tenor Saxophone

The fifth instrument that we looked at was a tenor saxophone over the notes E (164.810), A (220.00 Hz), D (293.660 Hz), G (392.00 Hz), B (493.880 Hz), and High E (659.260 Hz). The 1st and 2nd harmonic frequencies, phase, and amplitudes for the saxophone at the note E are shown in figure 18. The higher 3rd and 4th harmonics are shown in figure 19. In figures 18 and 19, the amplitude oscillates very largely and rapidly. Additionally, the frequency oscillates around a steady tone. The amplitude changes a lot because as the player's mouth adjusts to change the pitch they can be blowing different amounts of air at different intensities to increase and decrease the volume of the tone. The tone is produced by air vibrating the reed. When there is more air at a faster speed the volume is louder. The frequency increases and decreases because lowering the jaw makes lower tones and tightening or pinching the reed makes higher tones. This makes a combination of both low and high tones. Properties relating to the frequency and amplitude of the saxophone can also be seen in figures 20 and 21.

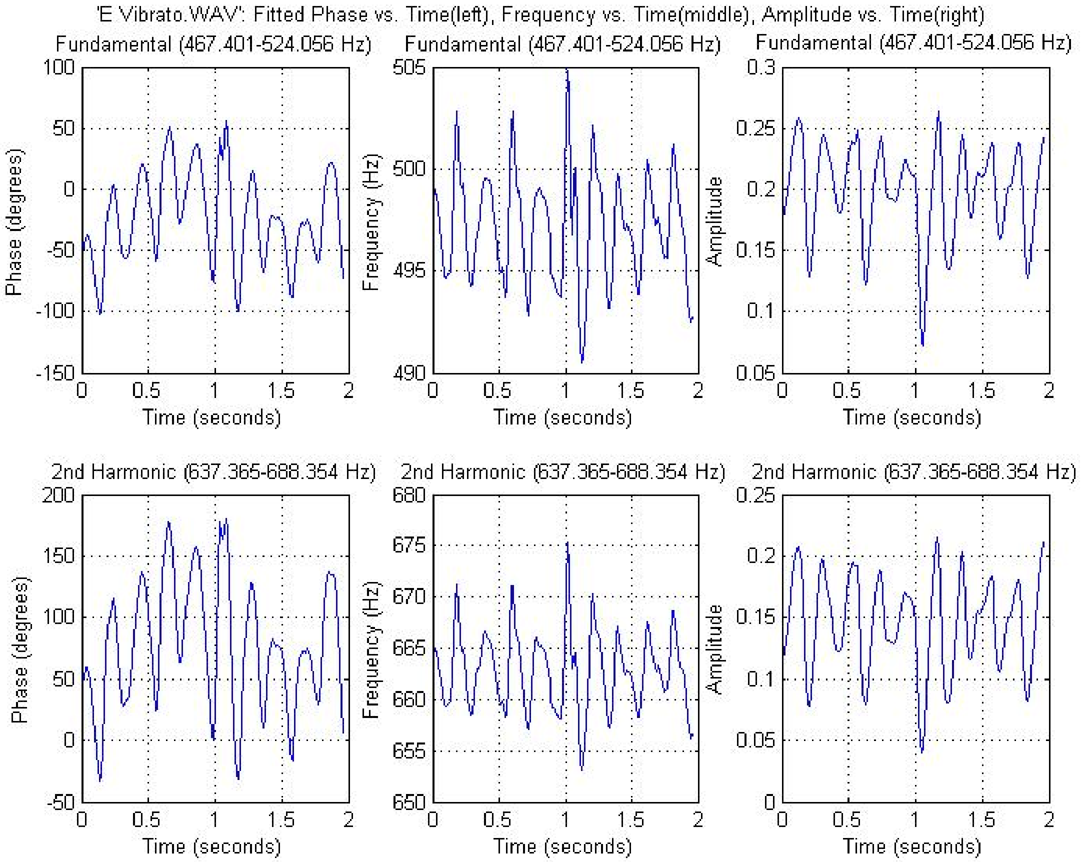

Figure 18. 1st and 2nd harmonic characteristics for the tenor saxophone

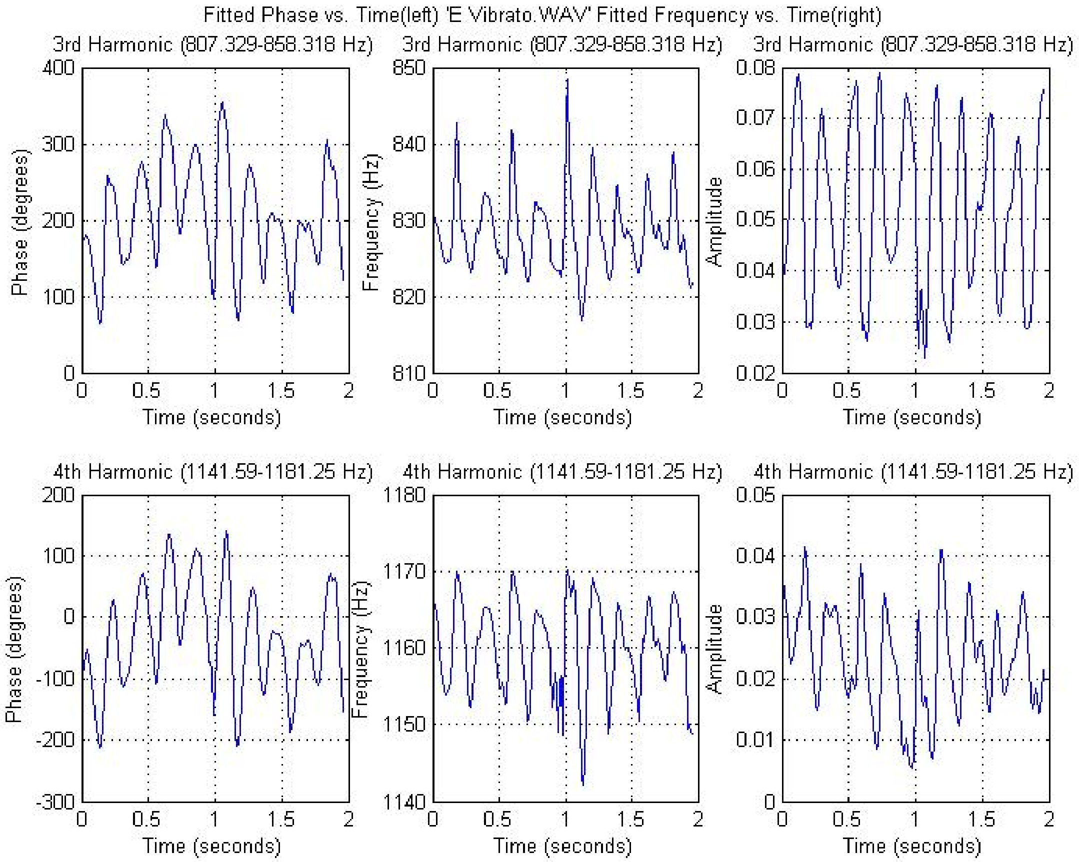

Figure 19. 3rd and 4th harmonic characteristics for the tenor saxophone

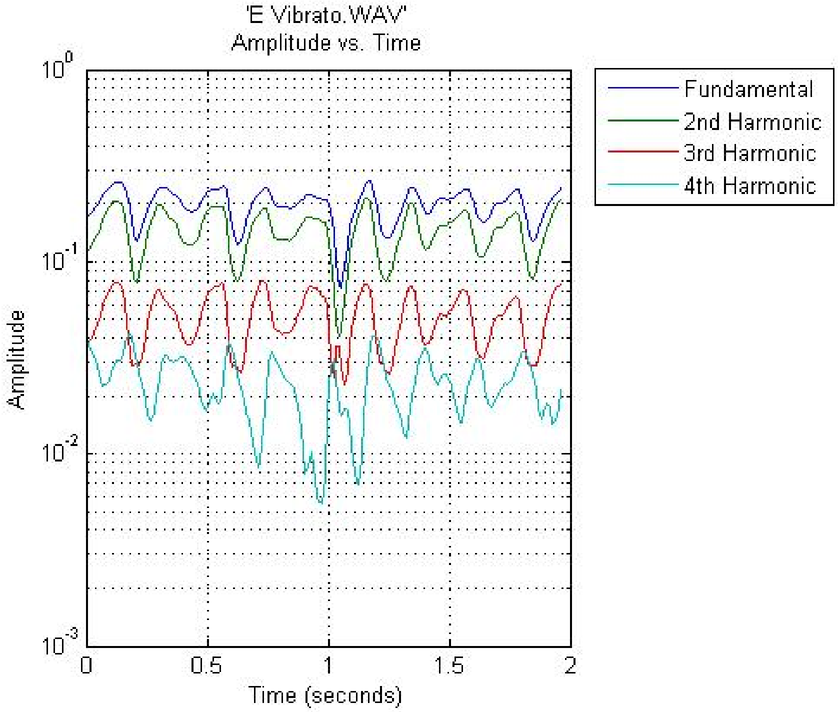

Figure 20. Low E amplitude vs. time plot for the tenor saxophone

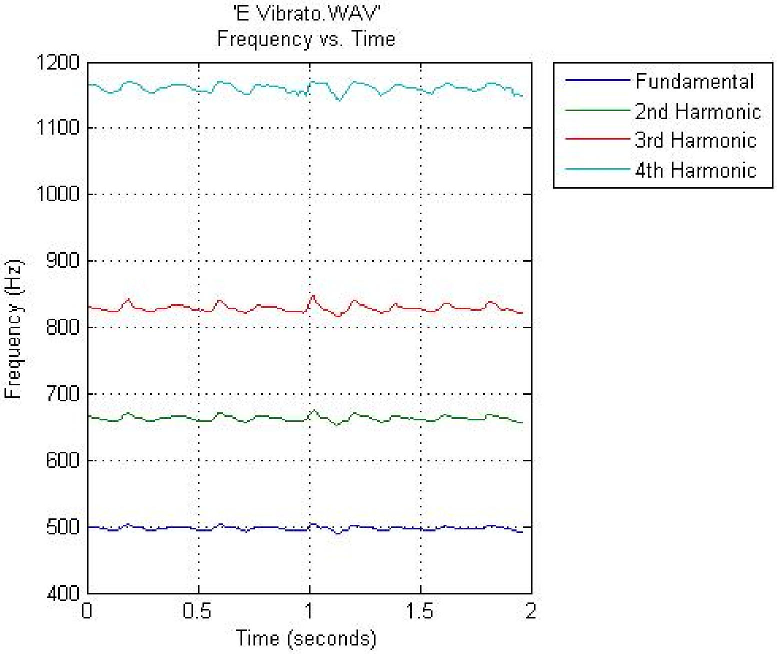

Figure 21. Low E frequency vs. time plot for the tenor saxophone

Trombone

The sixth and last instrument that we looked at was a trombone over the notes E, A, D, G, B, and high E. The 1st and 2nd harmonic frequencies, phase, and amplitudes for the trombone for the lowest note E using mouth vibrato are shown in figure 22. The higher 3rd and 4th harmonics for the lowest note E using mouth vibrato are shown in figure 23. In figures 22 and 23, the amplitude does not seem to oscillate about a steady sound. The frequency, however, does oscillate about a steady sound, but the range is not very large. While, in general, tones are much more easily sustained on woodwind and brass instruments than on plucked string instruments, lower notes are harder to sustain on wind instruments because they require more air. Both vibrato and tremolo seem to have an equal effect when the mouth is producing the wavering on the trombone. More properties relating to the frequency and amplitude of the mouth vibrato of the trombone can also be seen in figures 24 and 25.

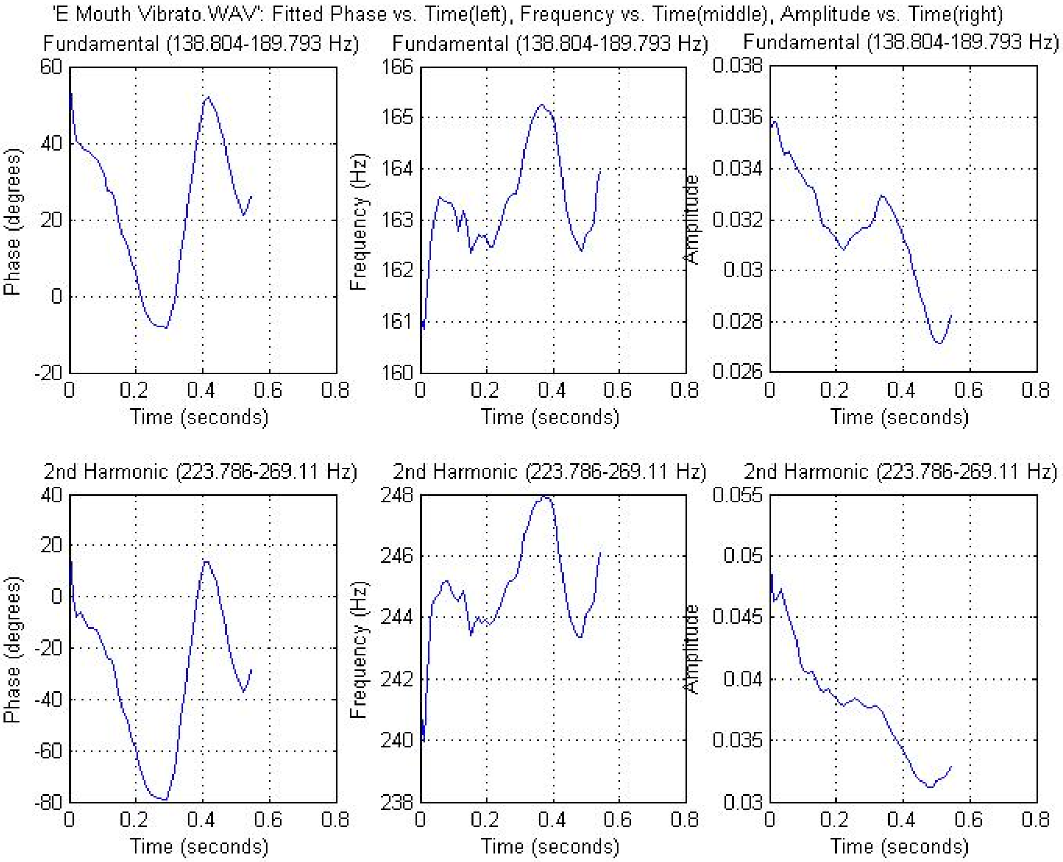

Figure 22. 1st and 2nd harmonic characteristics for trombone mouth vibrato

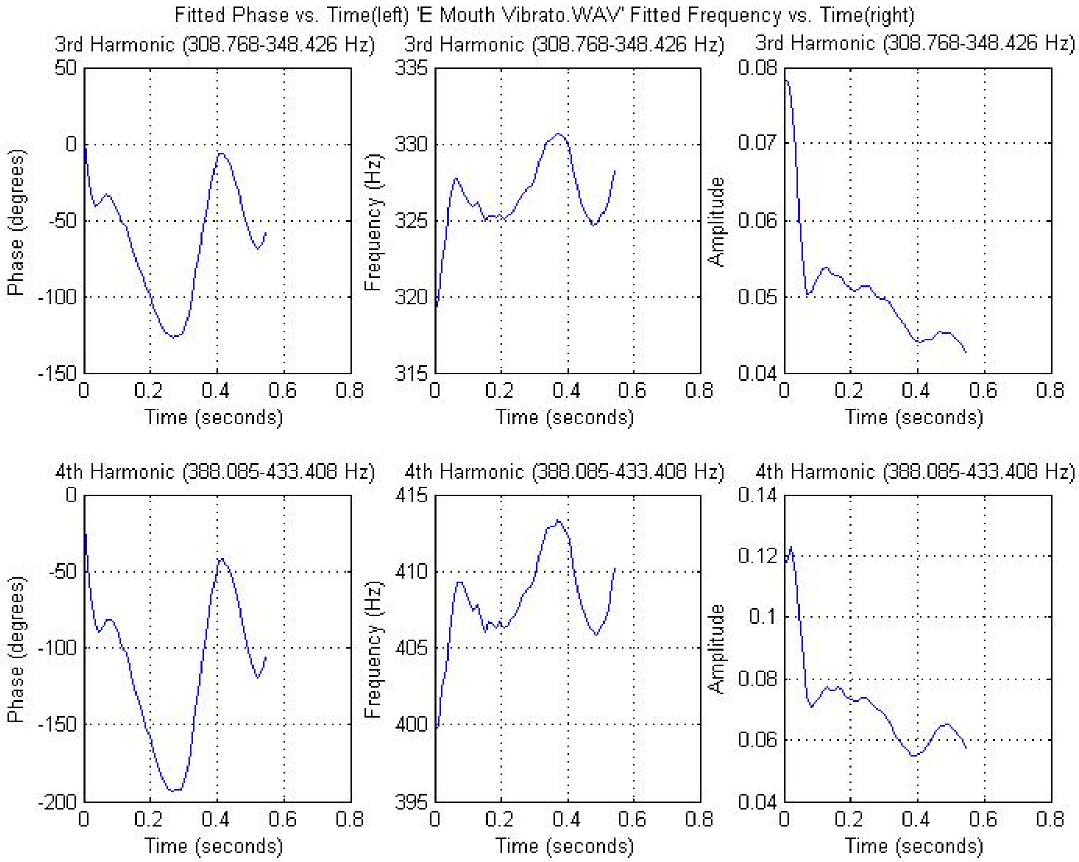

Figure 23. 3rd and 4th harmonic characteristics for trombone mouth vibrato

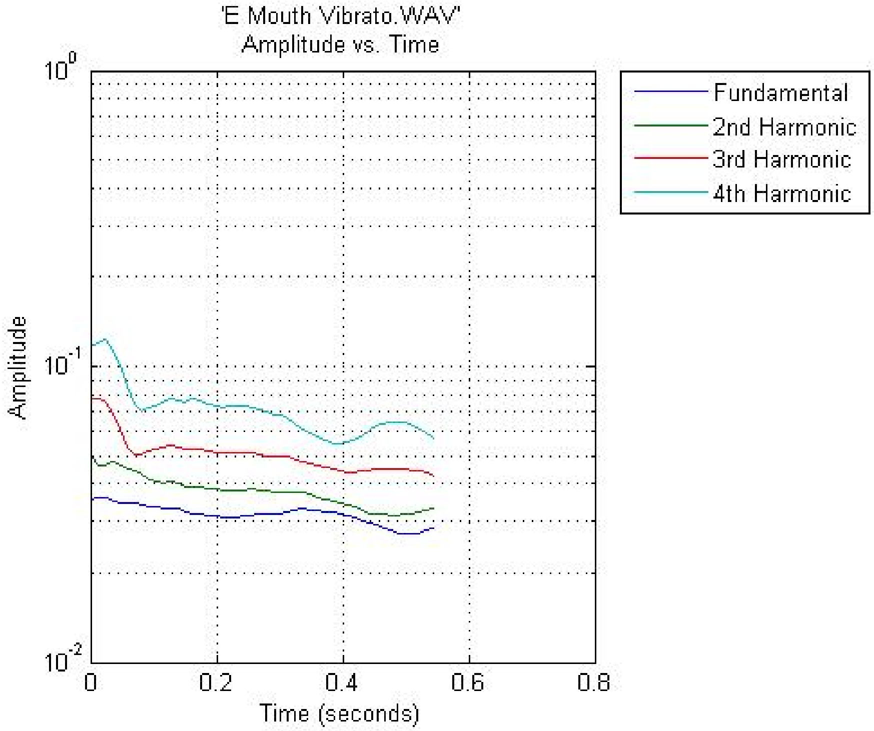

Figure 24. Low E amplitude vs. time plot for trombone mouth vibrato

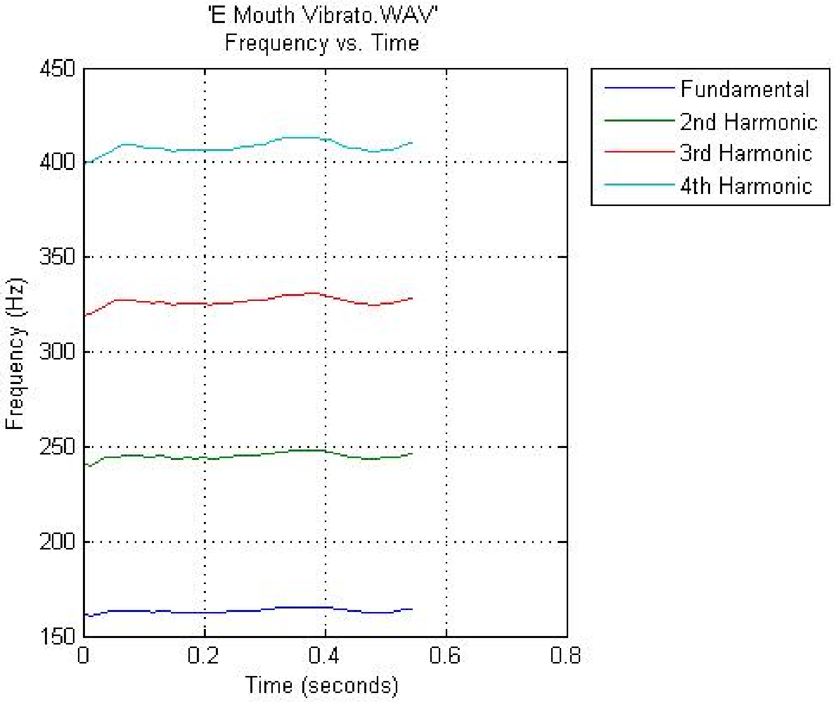

Figure 25. Low E frequency vs. time plot for trombone mouth vibrato

The 1st and 2nd harmonic frequencies, phase, and amplitudes for the trombone for the lowest note E using slide vibrato are shown in figure 26. The higher 3rd and 4th harmonics for the lowest note E using slide vibrato are shown in figure 27. In figures 26 and 27, the amplitude does not seem to oscillate about a steady sound. The frequency, however, does oscillate about a steady sound, and this time the range is much larger. This is because it is easier to alter the frequency of a trombone's sound by moving the slide. Vibrato is a much larger effect when the slide is producing the wavering. More properties relating to the frequency and amplitude of slide vibrato of the trombone can also be seen in figures 28 and 29.

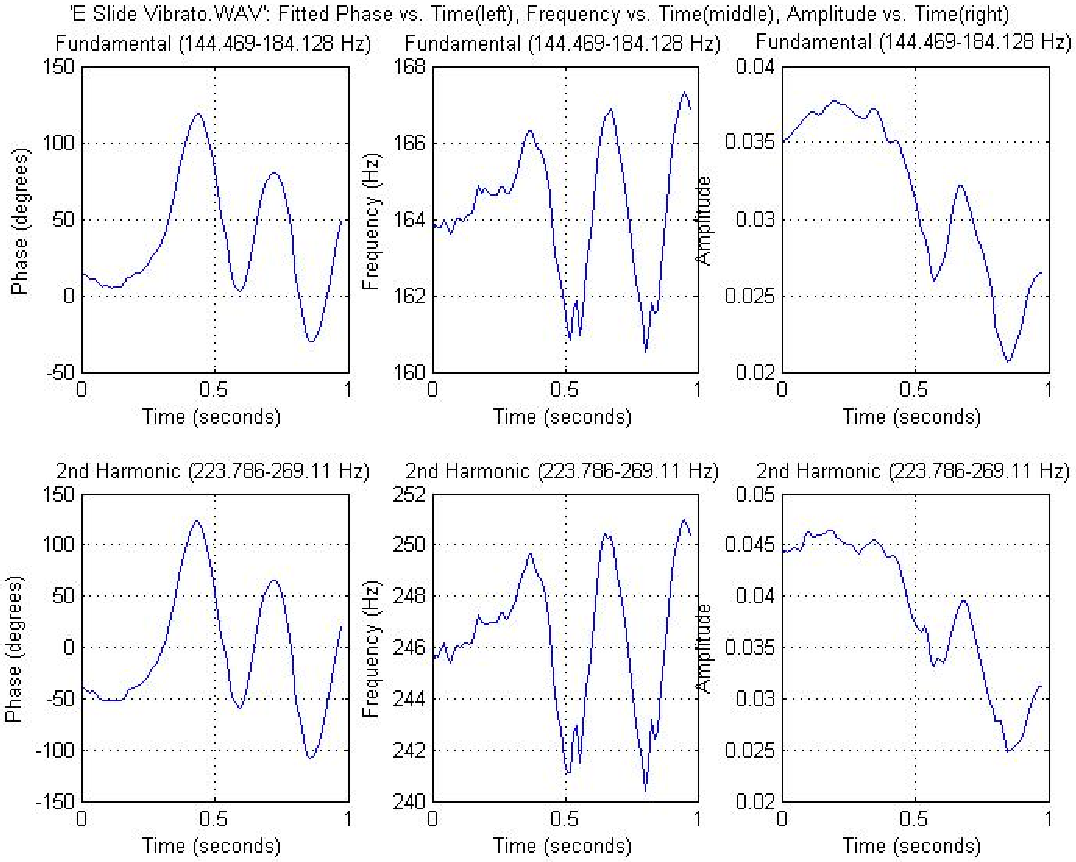

Figure 26. 1st and 2nd harmonic characteristics for trombone slide vibrato

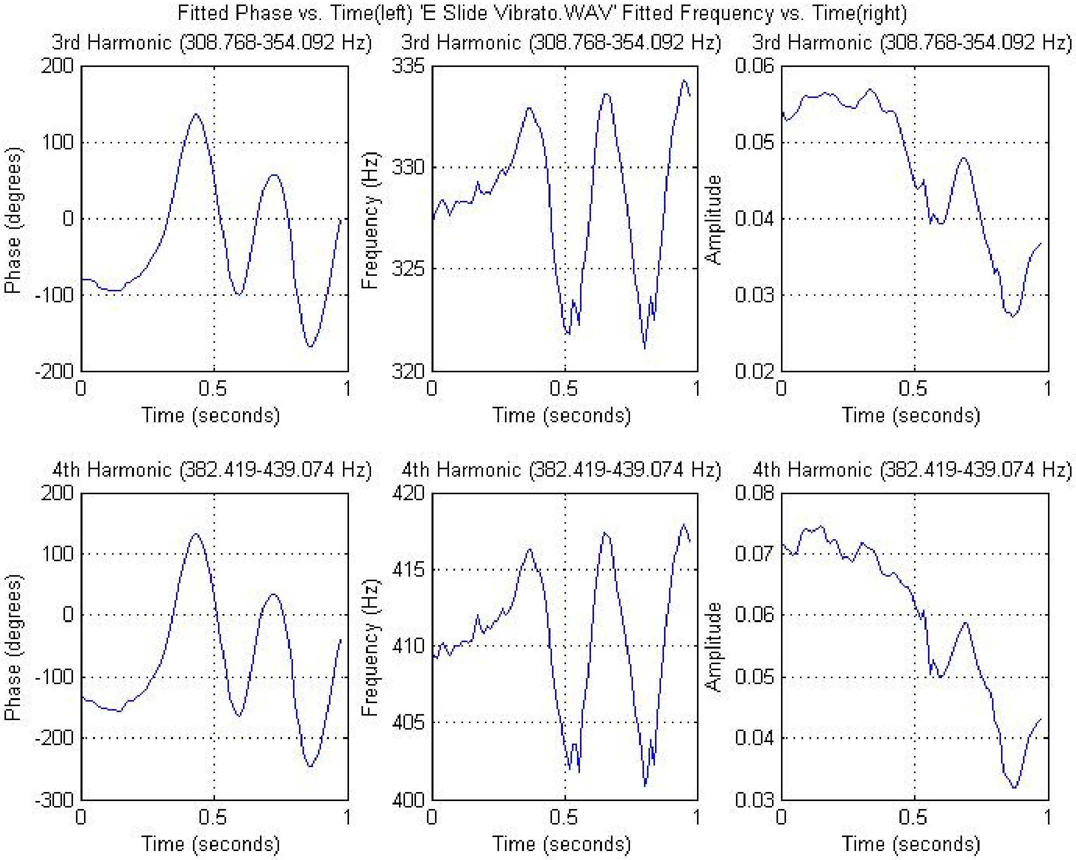

Figure 27. 3rd and 4th harmonic characteristics for trombone slide vibrato

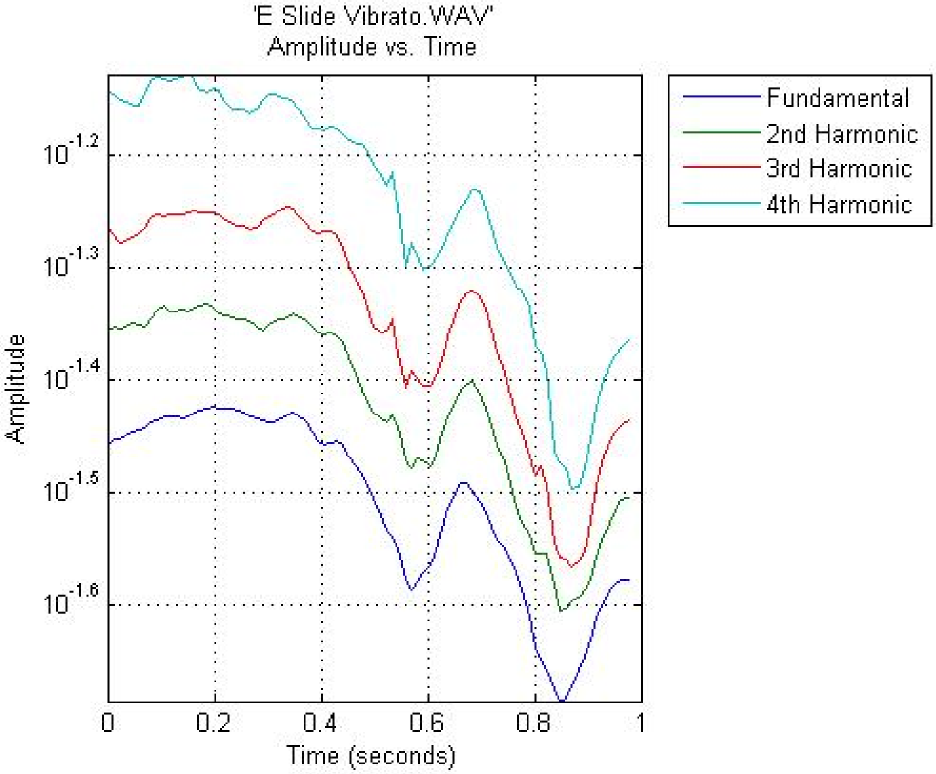

Figure 28. Low E amplitude vs. time plot for trombone slide vibrato

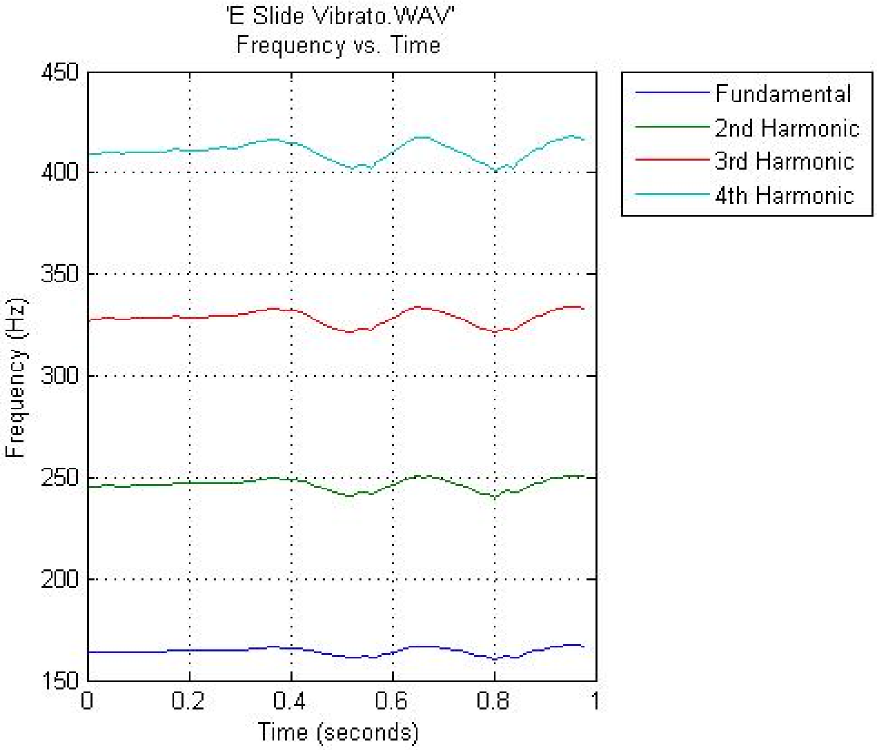

Figure 29. Low E frequency vs. time plot for trombone slide vibrato

Conclusion

There were a couple of conclusions that we came to after looking at all of these instruments under the effect of vibrato and tremolo. Overall, from our data we noticed that the wind instruments showed a lot more of a noticeable vibrato effect than the string instruments. We think that was due to the fact that wind instruments can oscillate between low and high notes instead of string instruments that can only go higher. It is a much fuller and more desirable sound when an instrument can both lower and raise the pitch because it complements the note that it is centered around and shows more range. Another very interesting result that was obtained from our data was related to the Wurlitzer electric piano. On the piano, there is a dial to control the effect of the vibrato, but we noticed that this was a bit of false advertisement. From our data we saw that there was minimal change in the frequency at all, but there was a large change in the amplitude of the tone. This results in tremolo rather than vibrato.

Although we collected a lot of data, there is still one more piece of data that we would have liked to collect. A Leslie speaker has cones that rotate at various speeds. The cones are the source of the sound. When they move, the pitch and the volume of the sound vary, creating a vibrato/tremolo effect. It provides a vibrato effect because the source is constantly moving toward and away the listener, causing a Doppler effect and therefore changing the pitch. It changes the intensity because the direction of the source of sound is always changing. It would be an interesting study to take a few instruments and study the sound to see if the Leslie creates more of a tremolo or vibrato effect. This would be done by looking at the frequency and amplitude change and see which element is more prominent in the sound. It would also be interesting to carry out this study with a percussive instrument that uses a 2-D membrane, a human voice, or a stringed instrument that has a sound that will not die out, such as a violin. Those results could give us greater insight and comparison to the instruments we already analyzed.