Resonance and Harmonic Analysis of Double Bass and Bass Guitar

Physics of Music Final Project

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5/11/12

Abstract

During the semester I completed projects for two similar instruments, the double bass and a solid body bass guitar. First, I investigated the harmonic content for both instruments with different variables. Second, I did resonance mapping of the instruments at a variety of different locations to establish where there were strong resonances. I compared the resonance mapping and harmonic analysis of the two instruments as well as with other bass guitars of the same and different make that were done by previous students.

Instrument Background

The bass guitar and double bass provide an interesting pair for sound analysis. First of all, they represent the lowest-pitched commonly used string instruments. The four strings of the bass guitar and string bass are tuned the same, to (from lowest to highest) E1, A1, D2, and G2, which correspond to 41.2 Hz, 55 Hz, 73.4 Hz, and 98 Hz, respectively. Oftentimes, extensions or extra strings are added to add a low B (B0) to the instrument, which is the 3rd lowest note on a piano at 30.9 Hz. The highest note for the bass guitar or double bass is typically considered G4 at 392 Hz. The double bass is the only string instrument in the standard symphony orchestra that is tuned to perfect fourths instead of perfect fifths. The string bass can be played either with a bow or plucked, while the bass guitar is usually plucked, slapped, or picked. The typical double bass stands about six feet tall with no endpin, while the bass guitar is about four feet.

Harmonic Analysis

The first step of the experimentation was to analyze the harmonic content of both the bass guitar and the string bass. Seven notes were recorded for each instrument, open E, A, D, and G, as well as a closed A (A2), closed G (G1) and harmonic G (G3). For the double bass, notes were recorded played both with a bow and plucked. For the bass guitar, the seven notes were recorded using different pickup configurations. The bass guitar I tested is a 2006 Music Man Sterling Limited Edition with 2 humbucker pickups. The recordings were made using all the pickups, just the neck pickups, and just the bridge pickups. From these recordings, we were able to extrapolate the harmonic content using a matlab program. Initially, there were issues with the low frequency notes, but adjustments to the code allowed us to overcome this issue. Generally, the primary harmonics had the highest amplitude and further harmonics declined in amplitude, as seen in figure 1. However, due to the limitations of the recording equipment, for lower frequency notes the primary harmonics (which have lower frequencies than the higher harmonics) were not fully picked up, as in figure 2.

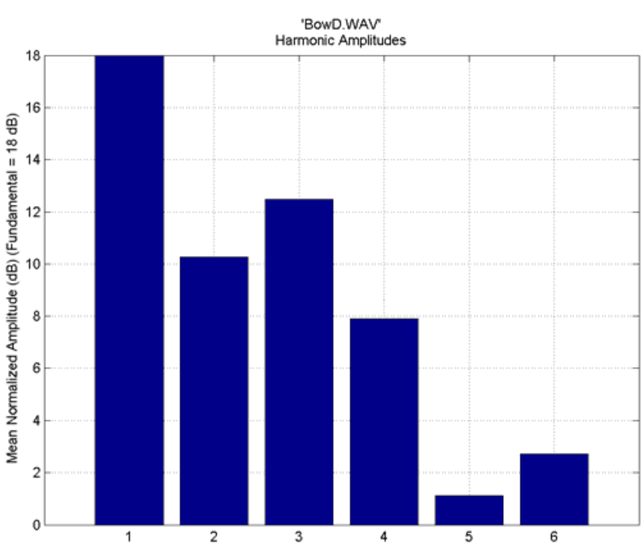

Figure 1. String Bass Bowed D mean normalized amplitude versus harmonic

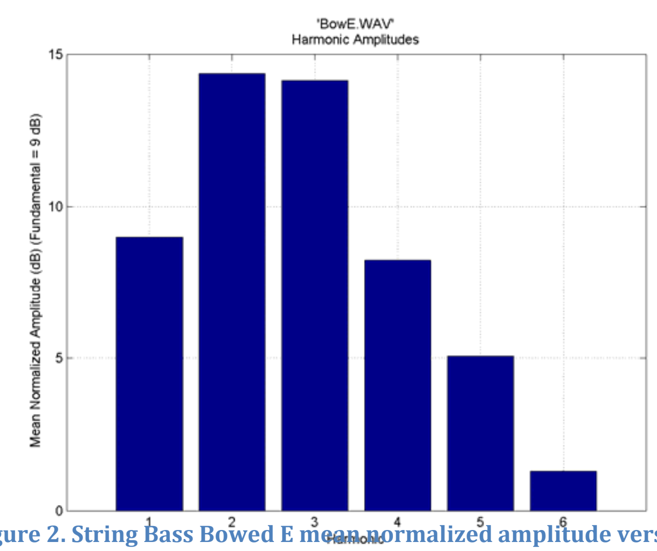

Figure 2. String Bass Bowed E mean normalized amplitude versus harmonic

One of the most useful graphs that were obtained was a frequency vs time vs log amplitude graph of the harmonics. The relative strengths and frequencies of the harmonics as well as their activity with time are shown in the graph. In figure 3, one can see a comparison of the frequency time amplitude graph for open G in with all five variables (string bass bowed and plucked, bass guitar all pickups, neck pickups, and bridge pickups).

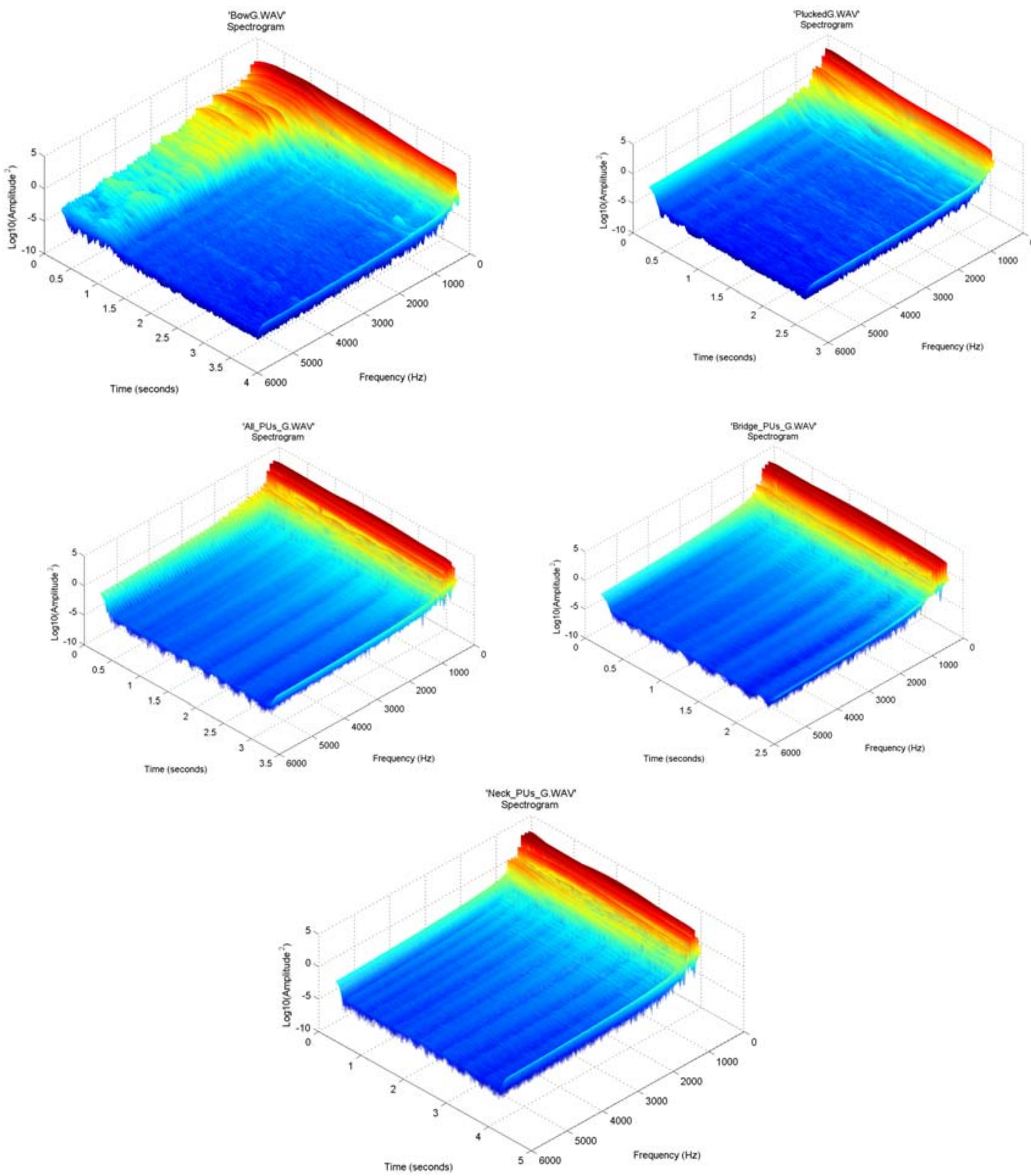

Figure 3. Log Amplitude vs Time vs Frequency Plots

Clearly, most of the harmonics for the instruments were at less than 1000 Hz. The top two graphs were those of the string bass, which had more activity than the ones of the solid body bass guitar. However, those higher harmonics died out much quicker than the 5 or 6 lowest harmonics. The decay of these harmonics was consistent between the two instruments. The richness of the harmonic content for the double bass is most likely attributed to the acoustical nature of this instrument as opposed to the solid body bass guitar.

Resonance Mapping

The second part of my project was mapping the resonances for the double bass and bass guitar. To do this, the instruments needed to be suspended by their endpin and the base of their neck as to not disturb the vibrations being run through the instruments. Figures 4 and 5 show the setup for the bass guitar and string bass, respectively. Being the first double bass to have resonance testing done in the lab, the setup needed to be adjusted to accommodate for its size. The strings of the instrument were muted so it was only the body of the instrument itself that was being tested for resonances. A voltage is then run through an electrode, which is placed at six different parts of the instrument: headstock, bridge, top front bout, top rear bout, bottom front bout, and bottom rear bout. The voltage is run through the instrument at 1-volt steps from about 10 Hz to about 1000 Hz. Higher frequencies were not needed because most of the harmonics on these instruments were at less than 500 Hz.

Figure 4. Setup for bass guitar

Figure 5. Setup for double bass

Though there were many bass guitars (including the same model) to compare resonances with, this was the first double bass to be tested in this lab, so general resonance trends could not be established for that instrument. From sending voltages through the instrument at 1 Hz steps, we could extrapolate a great deal of information, including the real and imaginary components of the strength of the resonances versus frequency as well as the phase versus frequency. The phase versus frequency was pretty chaotic; the resonance strength versus frequency was what really helped determine where the resonances of the instruments were. The absolute value of the voltage is shown in figures 6 and 7 for the double bass and bass guitar, respectively.

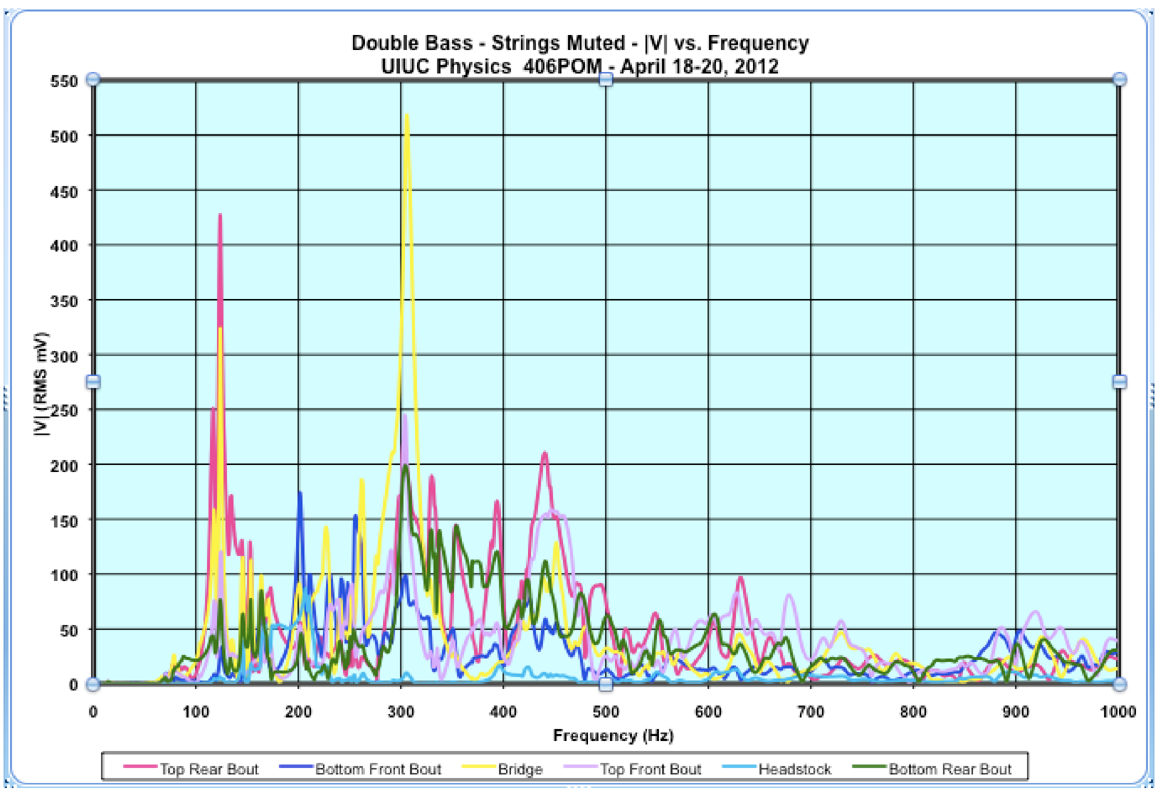

Figure 7. Resonance testing results for double bass at top rear bout, bottom front bout, bridge, top front bout, headstock, and bottom front bout

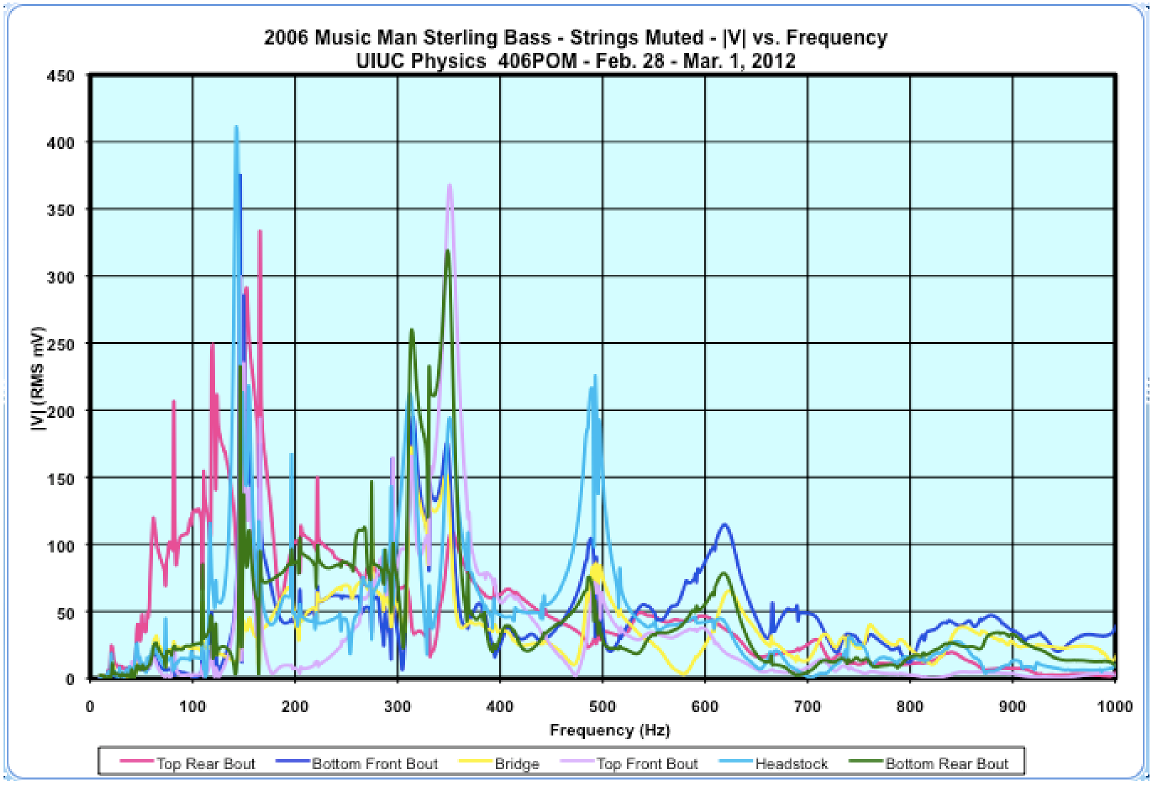

Figure 7. Resonance testing results for 2006 Music Man Sterling bass guitar

The Music Man Sterling bass guitar had four very strong resonances. The first was near 150 Hz which peaked at 410 RMS mV, the second around 350 Hz at 375 RMS mV, the third a little under 500 Hz at 225 MRS mV, and the fourth at about 625 Hz at 120 RMS mV. The strongest resonance was observed at 150 Hz on the headstock. The double bass had much more activity throughout the instrument at higher frequencies. A massive resonance was found at the bridge at 300 Hz, which was 525 RMS mV. Around 125 Hz the bridge and top rear bout also showed a strong resonance peaking at 425 RMS mV. The headstock showed very little activity because it is solid all the way through and very ornate, whereas the headstock of the bass guitar is flat.

Another interesting plot was the imaginary versus the real component. During a resonance the voltage phases through both its real and imaginary components, peaking first in the real then switching off to the imaginary. The "loops" in figures 8 and 9 show the strength of the resonance.

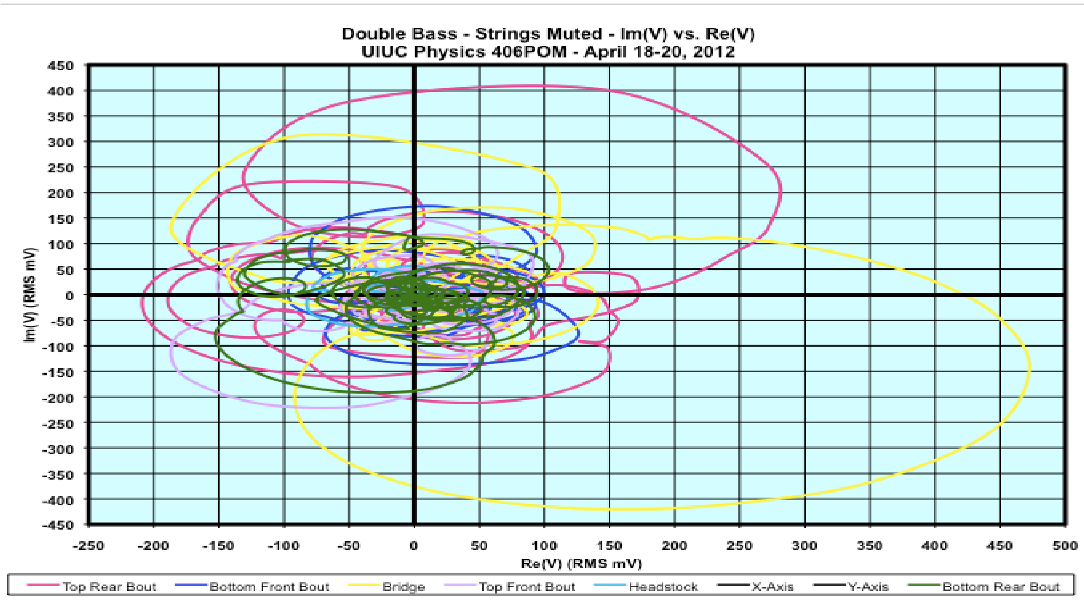

Figure 8. Real versus Imaginary for Double Bass

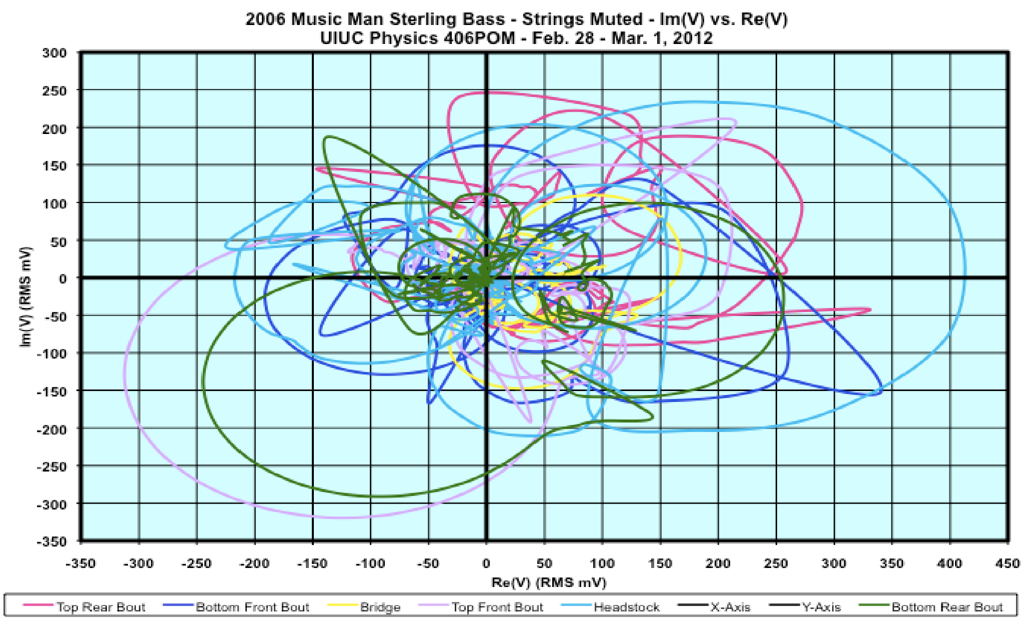

Figure 9. Real versus Imaginary for Bass Guitar

Though there was only one double bass that has been tested, a variety of bass guitars including the same model I tested have previously had resonance testing done. As expected, the bass guitars of the same model had extremely similar resonance mapping with the peaks at the same frequencies. Different basses had different resonance trends, but as with the two Music Man Sterlings basses of similar models had similar resonances. The figure below shows a comparison of resonance mapping for four different bass guitars.

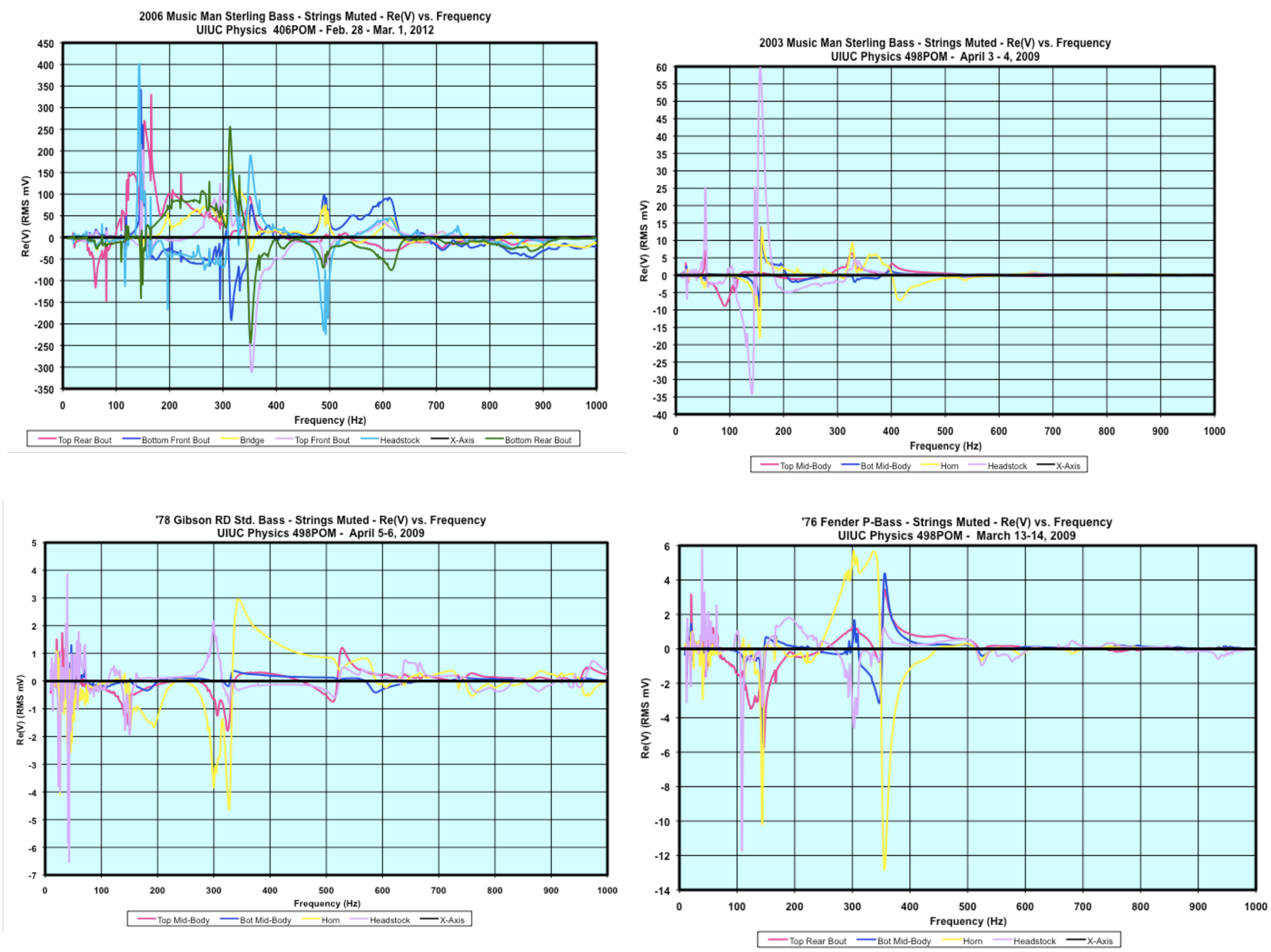

Figure 10. Sonic resonance analysis for 2006 Music Man Sterling, 2003 Music Man Sterling, 1978 Gibson RD, and 1976 Fender P bass guitars

Conclusion

Being a musician, it was very interesting to do tests on the instruments I play. I've been playing string bass for fourteen years, and have had my string bass for ten. Analyzing the harmonics and mapping the resonances showed me a side of music and physics that I would not normally see. I very much enjoyed the entire process and learned a great deal about my instruments and the physics of sound.