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PHY 406

Prof. Errede

5-11-12

# Classical Guitar Comparisons

**Objectives:**

For my project I wanted to compare and contrast the acoustical properties and the sound quality of two classical guitars in different price ranges. Also, by using everyday household items I wanted to see if I could reproduce the sound quality of the cheaper guitar to the more expensive one.

**Background History:**

The guitar has been a staple instrument in the development of music ever since it was first created in the 1500's. The very first guitars resembled something like todays ukuleles. Since then it has gone through various transformations and adaptations. The most popular style of guitar is the acoustic guitar. While that too has numerous versions, the way the sound is produced from the instrument is fairly constant. When the strings get plucked and vibrate, the vibrations travel through the saddle to the bridge, to the soundboard. The entire soundboard starts to vibrate, and the body of the guitar, which forms a hollow soundbox, amplifies the vibrations of the soundboard.

The classical guitar uses these same methods, however, there are a number of things that differentiate it from today's standard acoustic guitars. For starters, the hardware is very different. While most classical guitars still hold the same basic shape, they are in fact shorter than standard acoustic guitars in both scale length and overall length. "The modern full size classical guitar has a scale length of around 650 mm (25.6 inches), with an overall instrument length of 965–1016 mm (38-40 inches). The scale length has remained quite consistent since it was chosen by the originator of the instrument, Antonio de Torres" (Wikipedia). This length may have been chosen because it's twice the length of a violin string. Also, the strings themselves are made of nylon whereas acoustics have steel strings. This helps add to its unique sound. Another key difference is how the instrument is actually played. While acoustic guitar players normally use a pick to excite the strings, classical guitarists use all five fingers to pluck the strings with their fingernails. All of these things help distinguish the classical guitar from its steel stringed counterpart.

**Motivation:**

Growing up I have always been infatuated with guitars. I love not only the sound that they can produce, but I also respect the amount of skill it takes to play them. It's no wonder that the music I primarily listen to today is guitar oriented. Another reason why I am drawn to this instrument more than to others is because my best friend is a highly talented guitarist. He was the one that first introduced me to classical guitars. I liked them so much so that I started taking private lessons at my community college and have now been playing them for the past 2.5 years. I personally own a starter level guitar and while playing alongside my friend, I quickly noticed the sound difference between my guitar and his more expensive one. Since then I've wanted to know what causes the difference in sound quality and what might justify the price difference between most guitars (other than brand names). When this class started I saw it as a great opportunity to utilize the machines that we had in the lab to help me draw some conclusions about this matter.

**The instruments:**

Type: Lucero LC-100

Price: $100

Specs: All mahogany body with a gloss finish

Body length 39.5"

Type: Cordoba C3-M

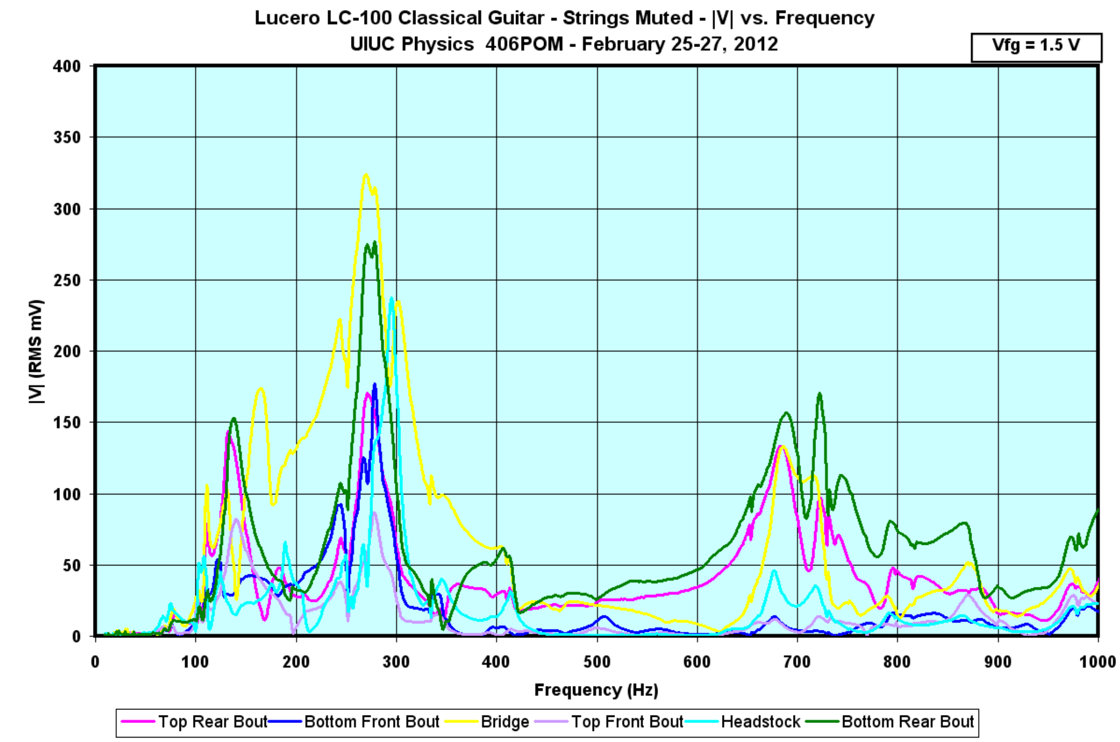
Price: $250

Specs: Top is solid Cedar while the back and sides are mahogany. It has a natural finish.

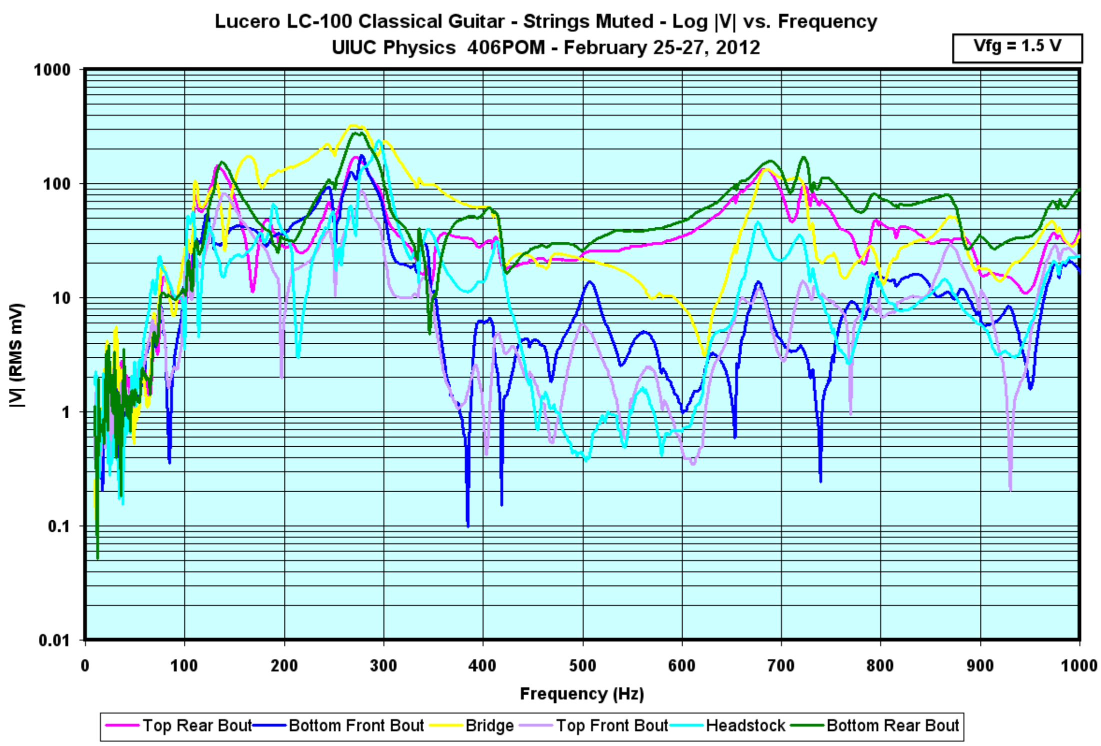
Body length 39.5"

**Testing Acoustical Properties:**

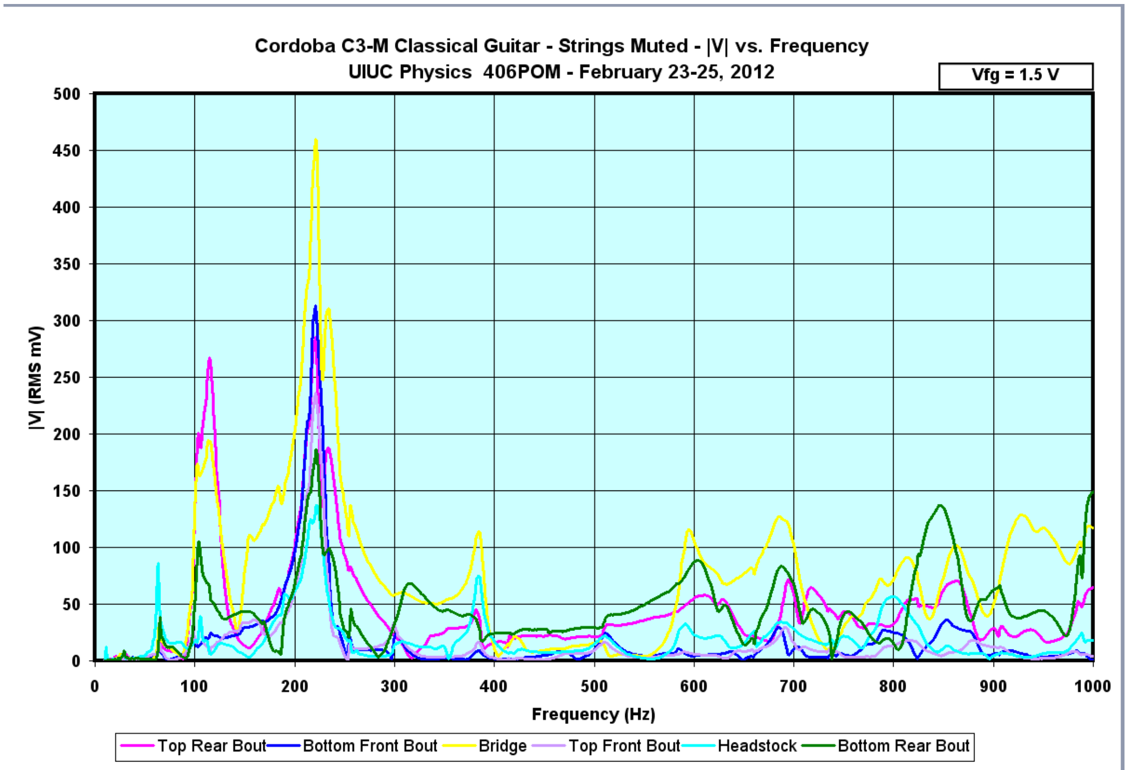
Now that I had my two guitars to compare, I first wanted to measure their mechanical resonance and compare the results. In doing so I hoped that it might shed light onto why they were sounding different. This was achieved by using two different piezoelectric elements at various positions on the body of the guitar. Prof. Errede was gracious enough to help set up the machine and run the tests for both of the guitars. The piezoelectric elements worked by having one vibrate at a certain frequency while the other receives the information and with that it calculates its resonance. Adding an AC voltage of a certain frequency is what triggers the vibrations of the piezoelectric element. The results were very interesting. For the Lucero it really only had three main resonances. The biggest occurred at about 250 Hz-275Hz and it peaked at about 325 (RMS mV). The Cordoba on the other hand had about seven distinct resonances. The highest occurring at 200Hz-250Hz, and it topped off at 460 (RMS mV). The extra resonances showed that the Cordoba really was producing a much brighter and fuller sound than what the Lucero was capable of. Also, from the second type of graph you can see that the Lucero had more anti resonances. This means it has more places where if played, it will produce a dead sound.



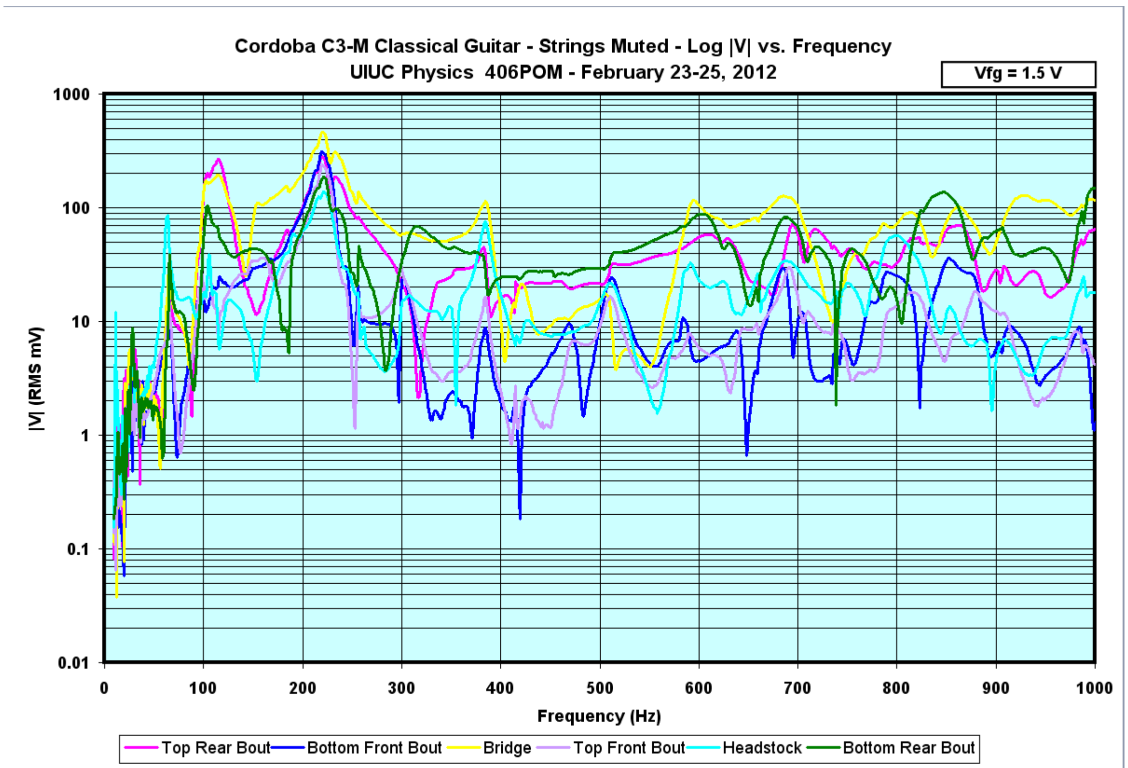

Resonances for the Lucero




Anti Resonances for the Lucero



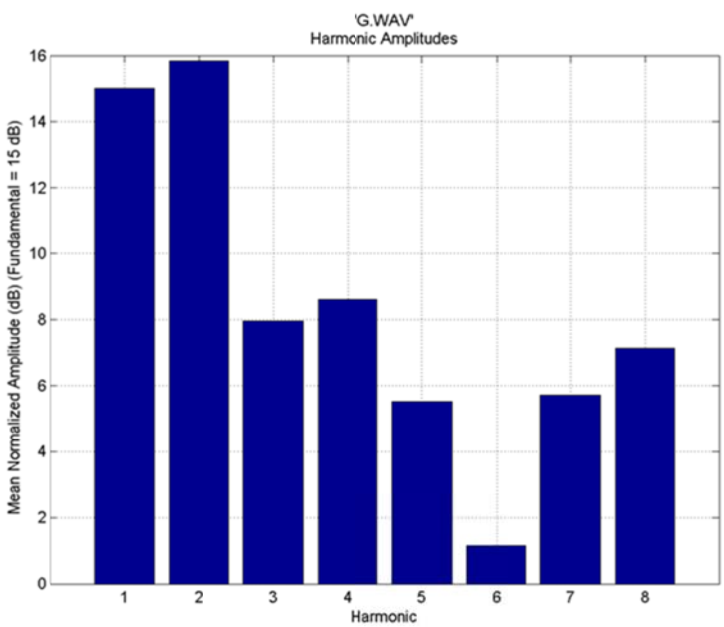

Resonance for the Cordoba



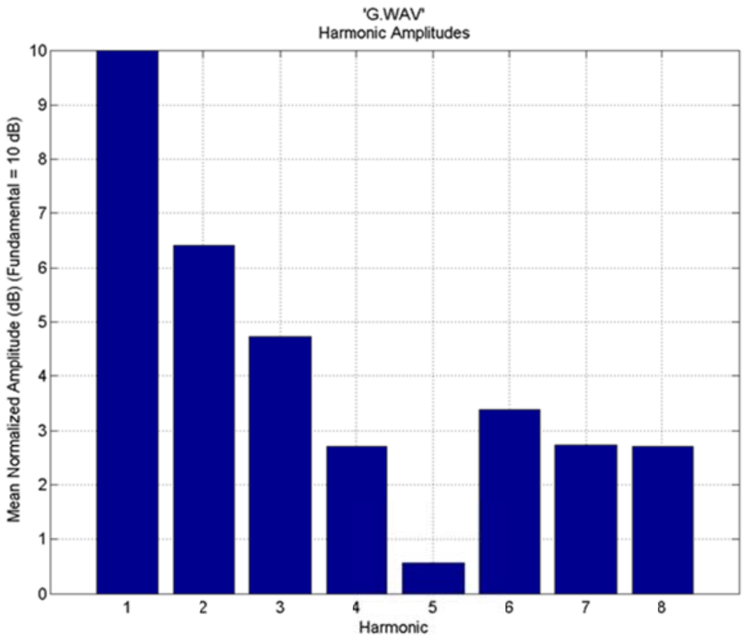

Anti Resonance for the Cordoba

**Sound recordings:**

After I finished measuring the resonance of the two guitars, I wanted to measure some sound samples and analyze them to see how their acoustical properties affected their sound output. I ended up recording the open notes from both of the guitars using a sound recorder. While doing this I made sure to strike the notes at the same location on the string as well as with the same power. This was done to help prevent any unwanted variables. After all the recordings were done I ran the files through a matlab program, and I used the graph of amplitude vs. frequency to identify the first few playable harmonics. From there I acquired several graphs illustrating values such as the amplitudes, frequencies, and relative phases of the harmonics. In the two graphs below I have it showing the amplitude vs harmonic charts of the open G string for both the Cordoba and the Lucero. I found it interesting that the first harmonic didn't have the highest amplitude for the Cordoba. However, it does show that the average amplitude over all the harmonics measured is much higher for the Cordoba. This can be correlated with the previous results that were found out during the resonance measuring. It shows how the Cordoba has a richer and fuller sound over the Lucero.




The graph for the Cordoba




The graph for the Lucero

**Testing homemade experiments:**

For most of the second half of the semester I tried to find a way to improve the sound of my Lucero guitar and try to match it to the Cordoba. I was interested in finding a cheap way to make a cheap guitar sound better. Using the information about how sound waves behave that I learned though out the course, I set off to try out my ideas.

1) The first thing that came to my mind for trying to get the Lucero to sound a little brighter, and a little more full was reducing the area of the body. I figured if the body didn't have as much open space, then the vibrations would travel quicker and the sound would come out at a faster frequency. Luckily the blinds in my room were the perfect width to cover the height of the body, and they were flexible enough to squeeze in the sound hole. All I had to do was cut it down to the size that I needed.

Also, I wanted to keep the same shape of the body inside and have it all be evenly distributed from the sides. To get that I ended up measuring out some wooden dividers and placed them evenly along the sides on the inside of the body. Tape ended up being the most effective way of holding the blind still. After countless hours and attempts later, I finally had a smaller body on my guitar. That being said, when I first played the guitar it sounded very different. It ended up sounding almost distorted. I believe it was due to the fact the there was still a gap between the actual side of the body and the newly fitted blind. So with that I went on to try something else.

2) On my second attempt I did some research and found a site that said cedar was a little denser than mahogany. Since the top of the Cordoba's body is made of cedar, I thought if I could somehow alter the top of the Lucero's body I might get some interesting results. I ended up settling with using electrical tape to do the job. I carefully taped the top of the body so that it had on an even layer of tape. I had to make a few layers because the first few didn't seem to affect the sound quality at all. After about four layers the sound started to die off a bit and it ended up losing the bright sound it had. Thankfully the Lucero has a gloss finish so removing the tape was pain free.

In the last couple of weeks I ended up trying different variations of my first attempt. I even added some sponge in-between the blind and the body, but none of it didn't really seem to help.

**Conclusions:**

I found the time spent in PHY 406 to be very rewarding and a fun experience. I was able to see graphical data that showed why my guitar didn't sound the same as the other. Also, it helped me learn much more about what's actually going on with my instrument. And in the process I've grown a new found respect for the people that created these instruments after seeing how hard it was to just modify my guitar. By the end of the class I had even more ideas for lab projects than I did in the beginning. If I could continue the course in the summer I would like to take the mechanical resonance of a cutaway guitar and compare it to a full bodied one. Overall, I had a great time with this course and I would recommend it to anyone who would like to learn more about the physics of music.

**Special Thanks:**

Prof. Errede for all the assistance in the lab

Thomas Satrom for helping me understand all the data

**Reference:**

Brain, Marshall. "How Acoustic Guitars Work." HowStuffWorks. Web. 11 May 2012. <http://entertainment.howstuffworks.com/guitar1.htm>.

"Classical Guitar." Wikipedia. Wikimedia Foundation, 05 July 2012. Web. 11 May 2012. <http://en.wikipedia.org/wiki/Classical_guitar>.