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Physics 406
Semester Project Report

Fabrication and Analysis of Two Ocarinas

Introduction:

I remember my excitement at the start of the year when we were presented with the semester project for this course. We could pick anything assuming it had to do with sound. The sheer number of projects was a little daunting and I had a little trouble choosing what I wanted to do. I wanted to come away from the class with something tangible as well as a good understanding of acoustics. What better way to accomplish both of these goals than to create my own instrument? I had a little background in music having played alto sax and clarinet in high school. This influenced me to create some sort of wind instrument. After looking online for a while I saw several builds for clay ocarinas. In the beginning I planned on making multiple ocarinas out of different materials and testing their different musical properties. However, time and money constraints prevented me from accomplishing this lofty goal. I was able to construct a couple ocarinas of different sizes to compare and contrast their harmonics and waveforms.

How it Works:

How the ocarina makes sound is actually quite interesting. The instrument itself is essentially a Helmholtz resonator. As you blow across the voicing or “labium” as it is officially called, the air from the mouthpiece is cut in half. Half of the air flow goes into the resonating chamber, half to the outside. The air going in to the chamber creates a high pressure center within the instrument. This in turn pushes air out of the chamber. After air leaves, there is a low pressure center created. The air rushes in from the outside and the process continues until you stop blowing. The vibration of the air creates an "air reed" that makes the note. The reason for why lifting fingers increases the pitch frequency is simple. Pitch of the note is related to the ratio of the surface area of the note holes to the total volume of the chamber. In essence, the entire cavity resonates and the more surface area of open holes, the higher the pitch.

Materials and Construction:

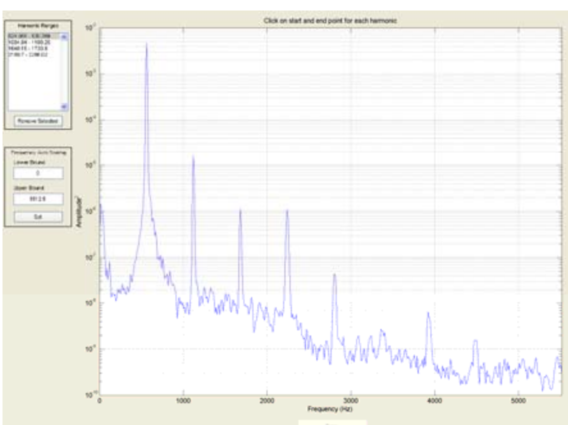
Luckily for me, all I needed to construct the ocarinas was a ten pound hunk of clay, some clay working tools, and a lot of patience. A quick trip to the arts and craft store remedied my need. Construction wasn't too difficult. I started by shaping the body into somewhat of an elongated acorn shape. After that was completed, I cut each acorn in half long ways so that I could hollow them out to make the resonance chamber of the ocarina. Next came cutting the voicing and the most aggravating part of fabrication. What makes the cutting voicing so difficult is 1) the clay is wet and malleable and 2) if the voicing isn't cut just right, sound will not be produced. This one step probably accounted for about half of the build time for the small ocarina, even more so for the larger one. After putting the halves back together and testing the sound to make sure I was satisfied, I placed my fingers on the body to find out where I should cut the note holes. I drilled holes using a regular drill bit and attached both halves of the body together using two snakes of wet clay to fasten the chamber together. I cut seven holes in the smaller ocarina (one for each note of an eight note scale minus one for the fundamental) and ten in the larger one (one for each finger). The reason I did not drill ten holes in the smaller ocarina was to minimize possible mistakes. The two thumb holes usually found on the bottom of traditional ocarinas have a tendency to mess with the voicing and in many cases cause the instrument not to function. On the small ocarina I cut six holes in the top and one thumb hole on the bottom. There were ultimately eight holes on top and two thumb holes on the bottom of the large ocarina. Once all the pilot holes were cut I could start tuning. On the small ocarina, I tuned all the notes to the C major scale which just so happened to be the fundamental of the ocarina (i.e. the sound produced when all finger holes are covered and the lowest note that can be played). The larger ocarina was tuned to an F major scale. The way tuning is accomplished is by taking a regular tuner and blowing into the ocarina to produce a sound. If the sound is too flat, all you do is cut the hole larger. If the sound is too sharp, I filled in the hole and re-cut it smaller. All that was left to do after the holes were cut was to let them dry overnight since I used air dry clay.

Complications:

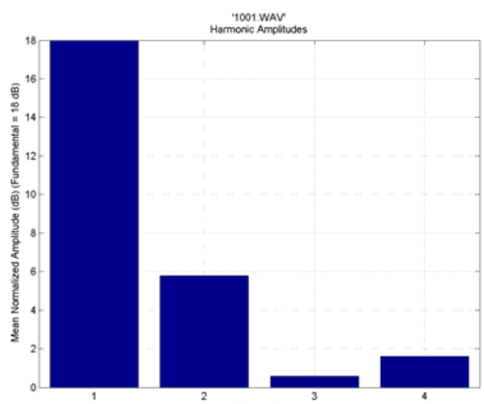
Some complications while building were as mentioned before: cutting the voicing, and the drying. Voicing was constantly an issue during production. During creation of both ocarinas, cutting the note holes moved the voicing slightly to the point where it wouldn't produce sound. Drying also caused problems in the larger ocarina. Due to the way I constructed the larger ocarina over the course of two days, the top half of the resonating chamber ended up drying faster than the bottom causing a split. Despite these couple setbacks, I managed to assemble two working ocarinas.

Waveform Analysis:

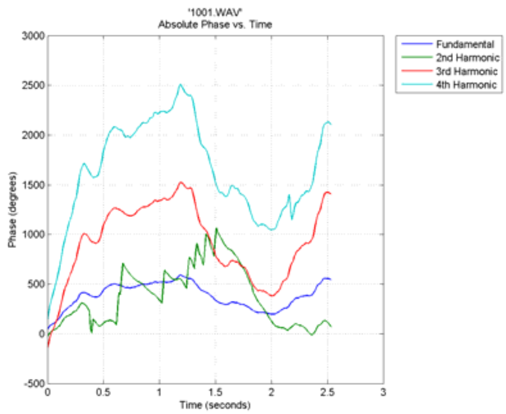
The first way I tested my ocarinas was to run their different notes through the wave form analysis program in matlab. With the help of one of the TA's, I recorded 8 notes from each ocarina in high definition and ran them through the script. Below are a few of the graphs the program produced. The rest of my data is kept in the sounds folder on the computer (didn't want to flood my report with all the graphs and information obtained). For each not I had to pick out the fundamental and a few harmonics. I let the program do the work after that. The interesting part about the data I collected was how many harmonics I was able to pick up from each note. Both ocarinas had very strong fundamentals however; the harmonics for each note were very small and almost undetectable by the program.



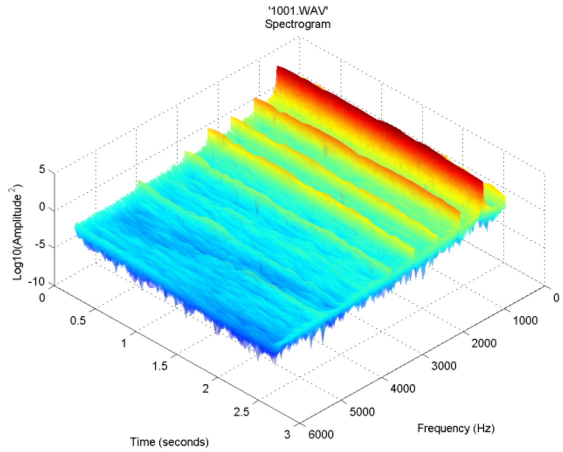
Harmonic content (small ocarina)



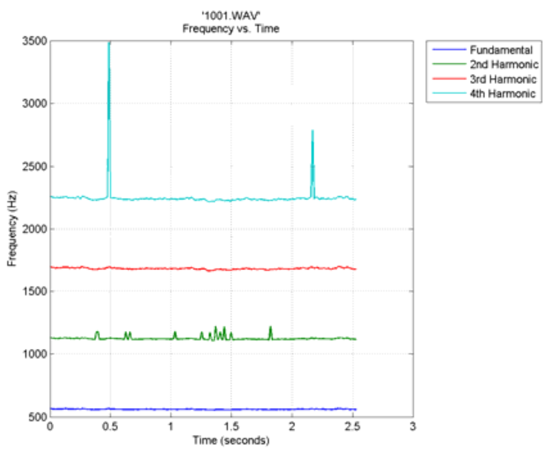
Strength of each harmonic (small ocarina)



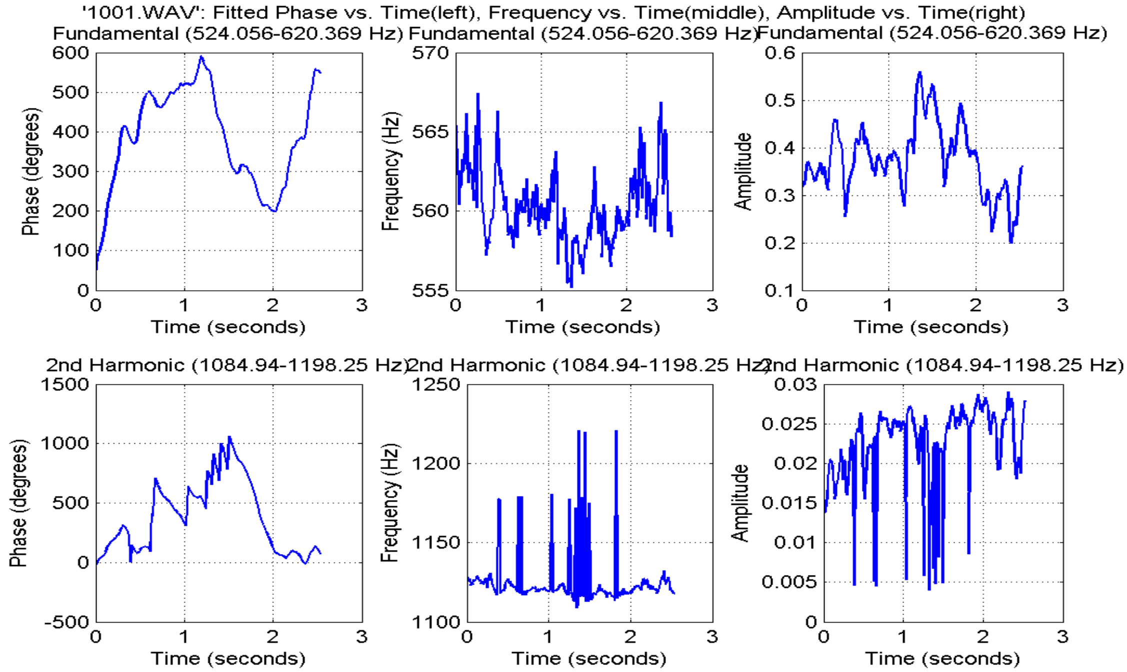
Phases of harmonics (small ocarina)



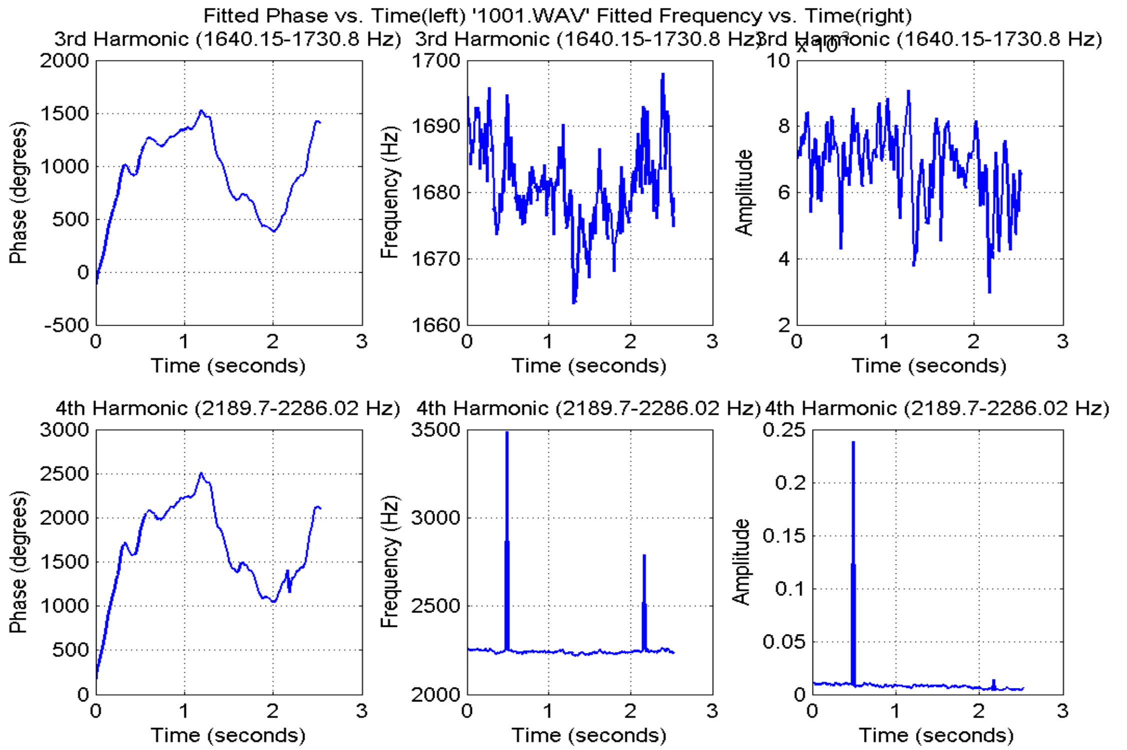
Spectogram of first note (small ocarina)



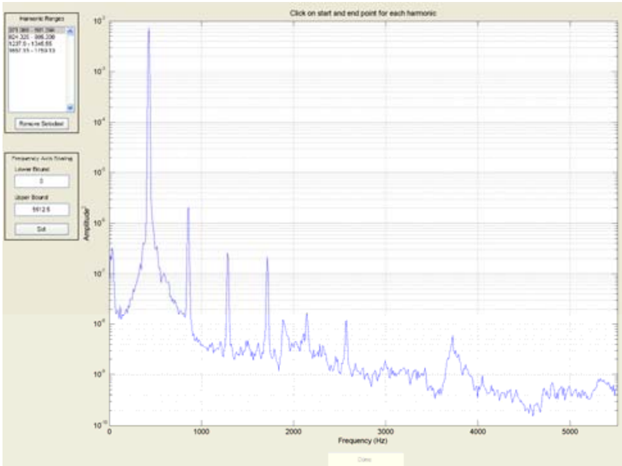
Frequencies of Harmonics (small ocarina)



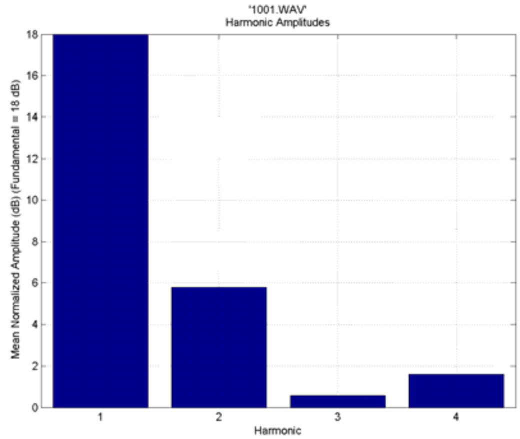
First note of small ocarina harmonic analysis (fundamental and second harmonic)



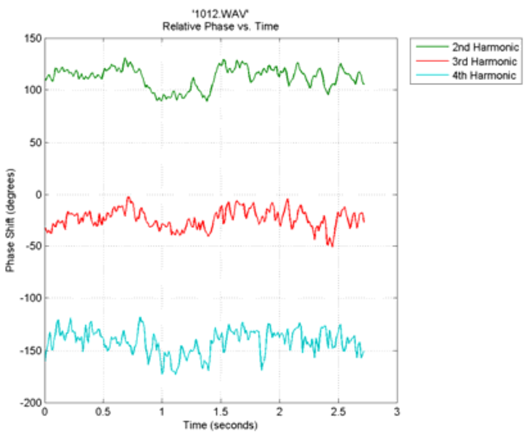
First note of the small ocarina harmonic analysis (third and fourth harmonic)



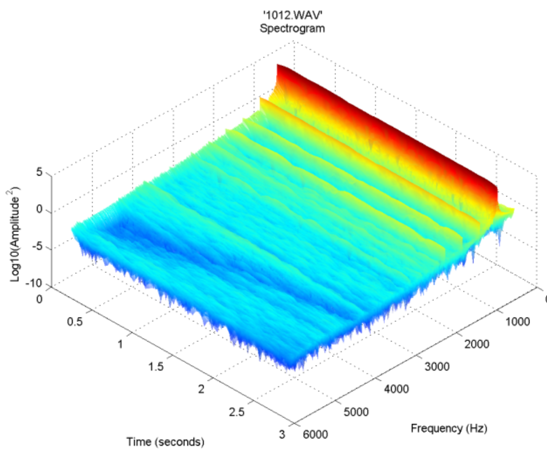
Harmonic Content (large ocarina)



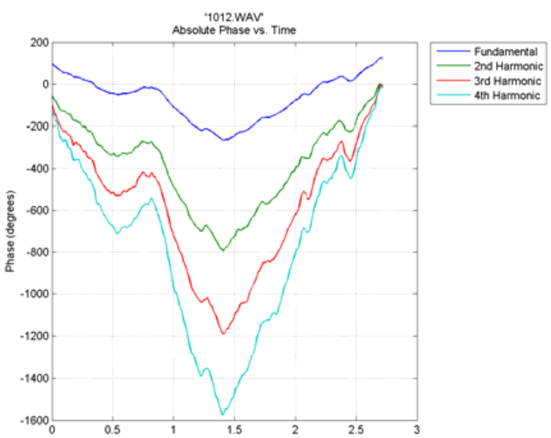
Strength of each harmonic (large ocarina)



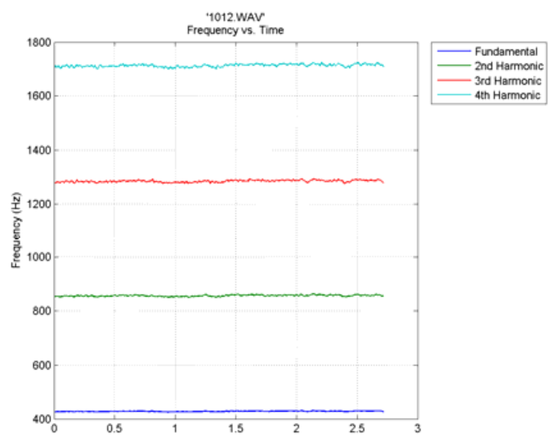
Relative phases (large ocarina



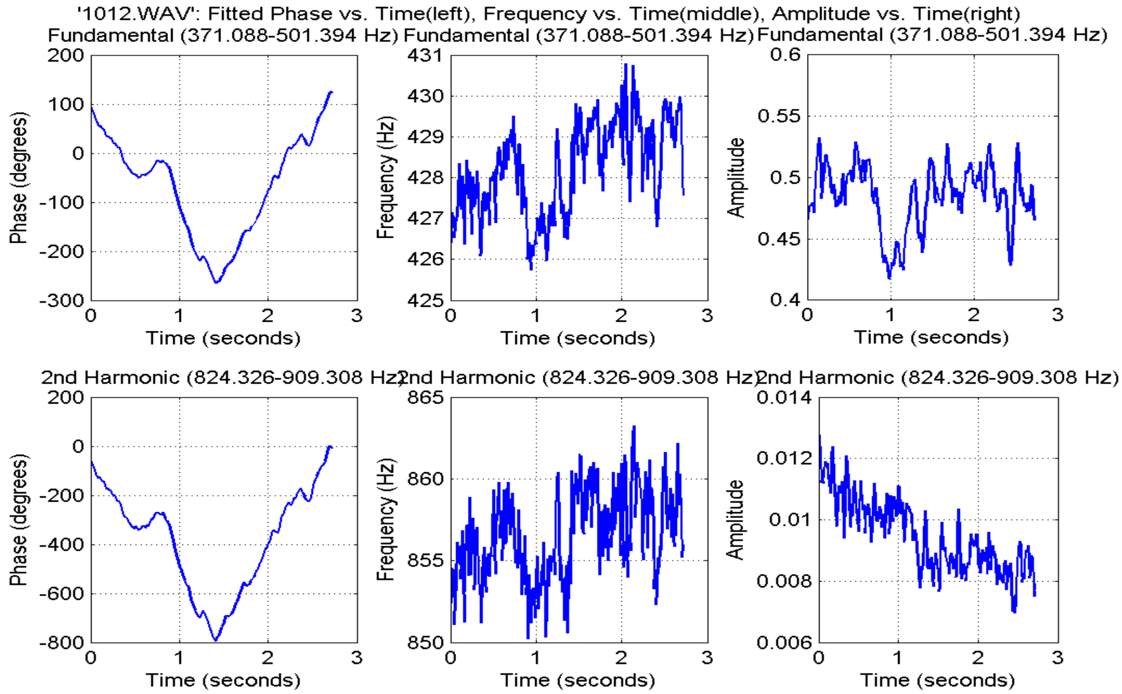
Spectograph (large ocarina)



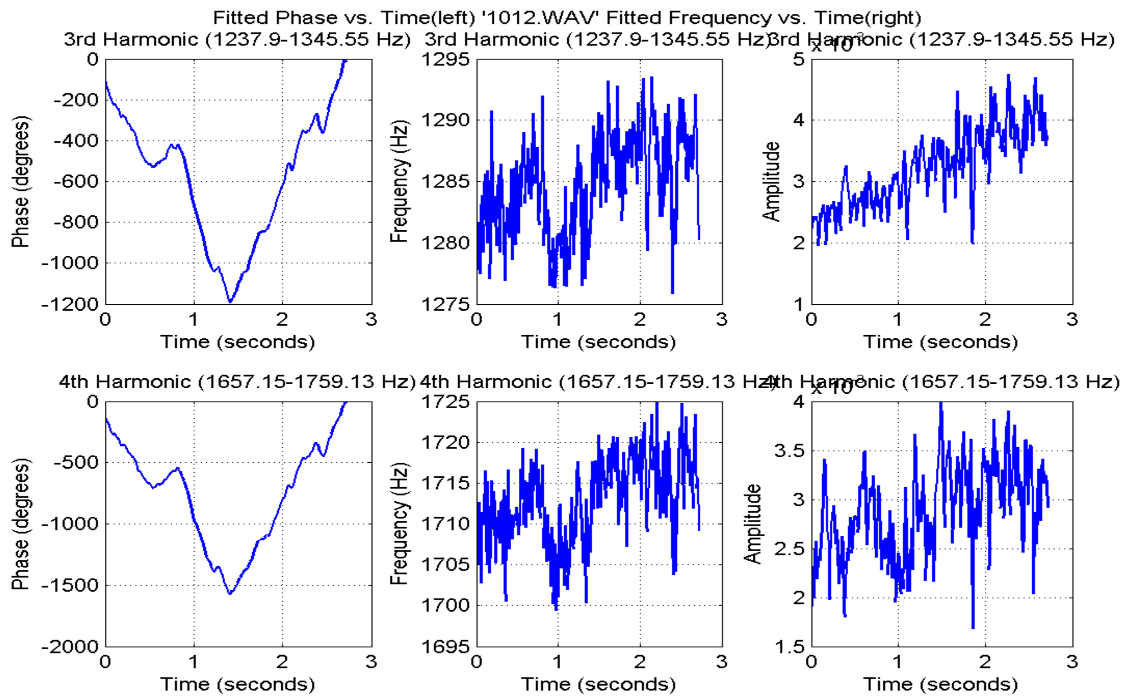
Phases of harmonics (large ocarina)



Frequencies of harmonics (large ocarina)



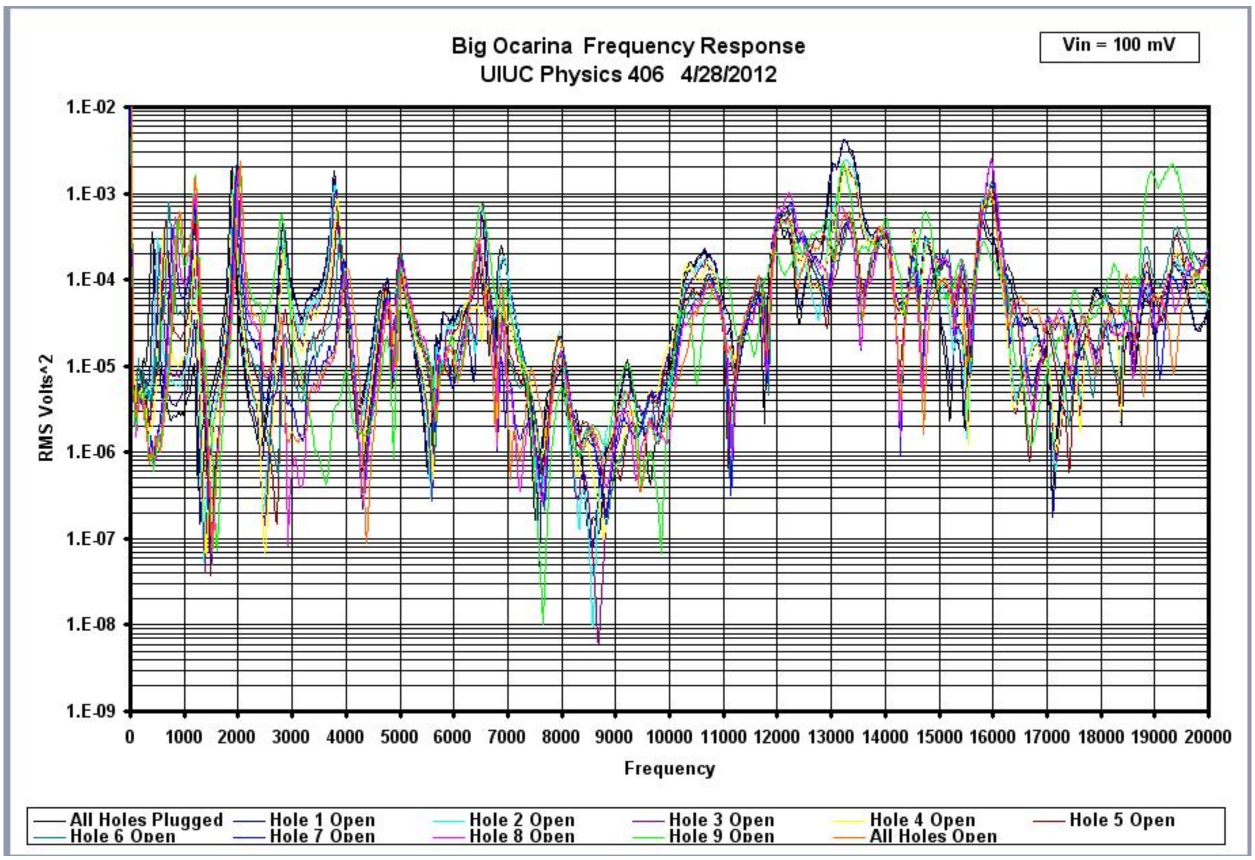
First note of the large ocarina harmonic analysis (fundamental and second harmonic)



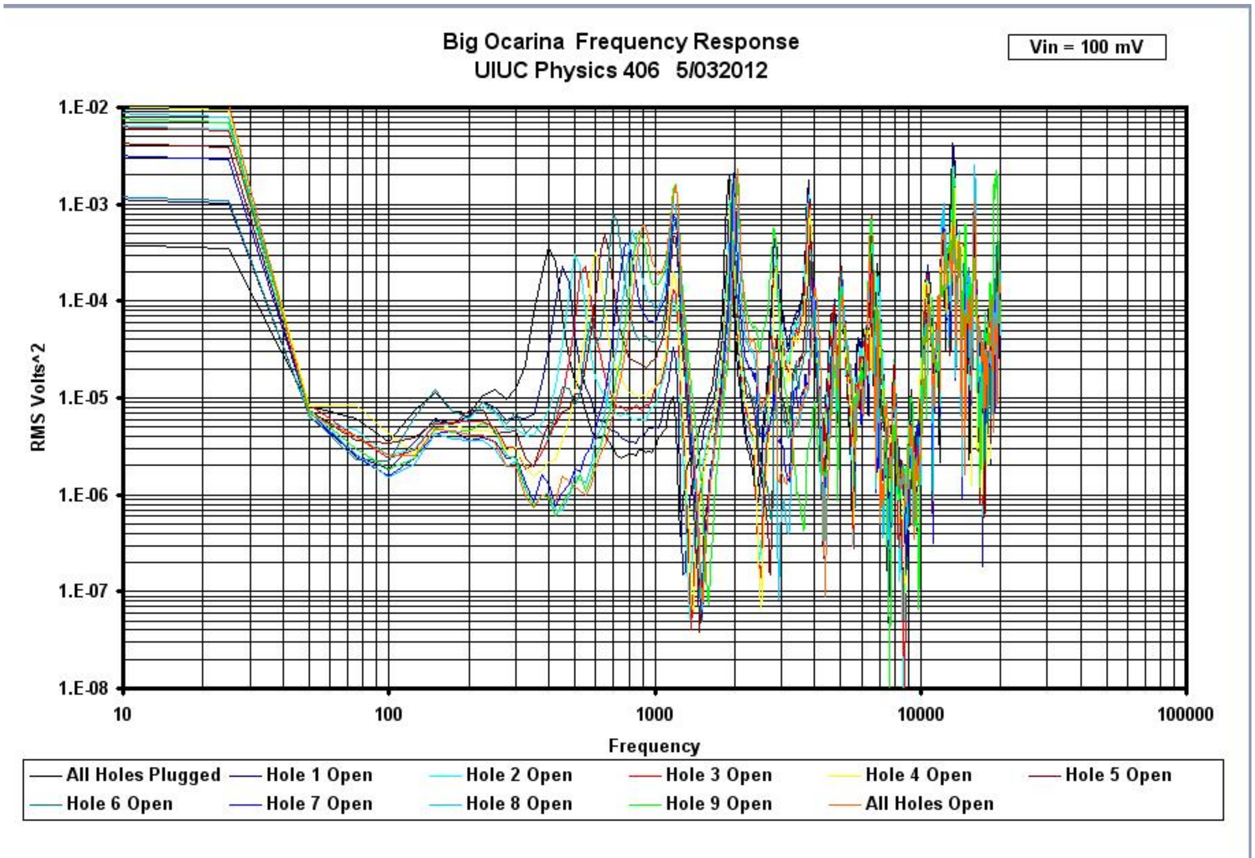
First note of the large ocarina harmonic analysis (third and fourth harmonic)

Large Ocarina Frequency response:

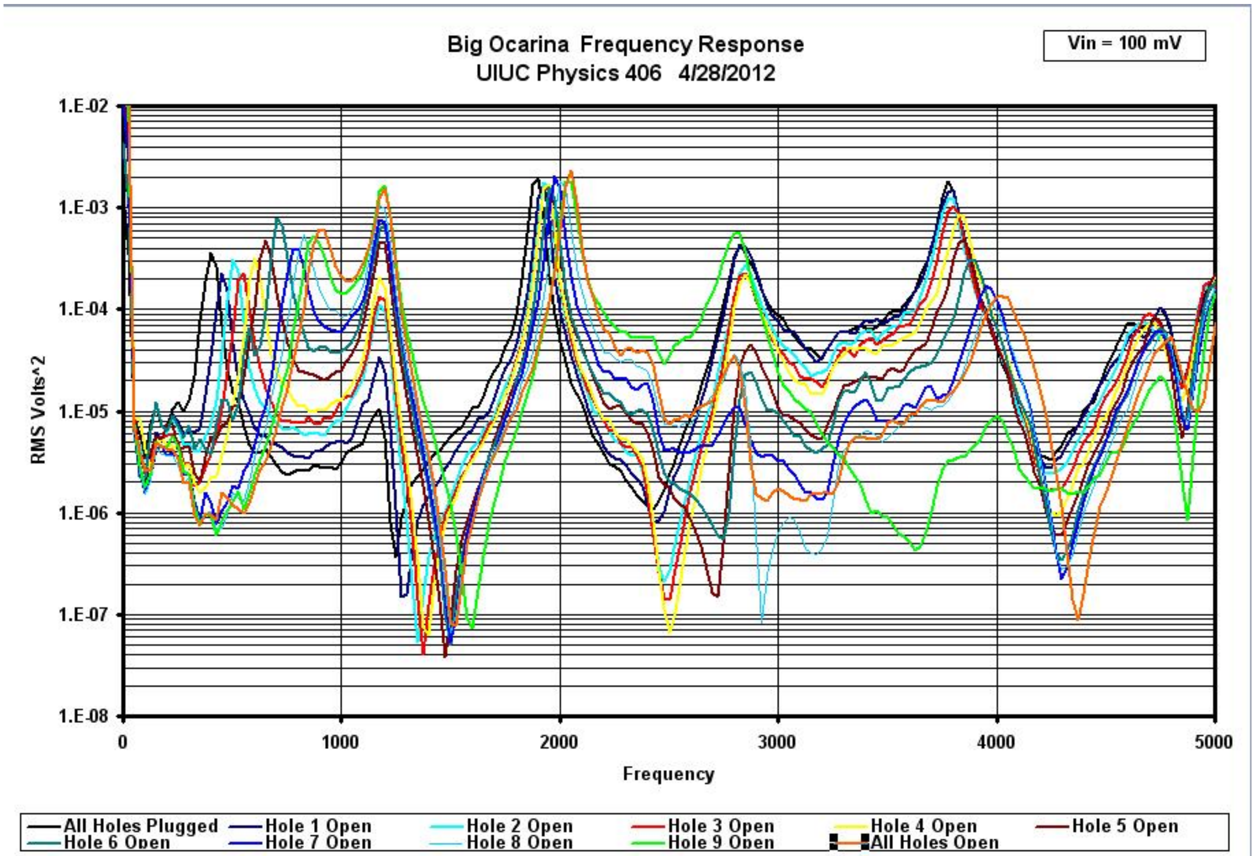
The next step was to test the frequency response of the large ocarina to white noise. At the end of this test I was able to see the different resonances of the ocarina. As this test is much more in depth, I was able to observe the higher frequency resonances associated with the ocarina. At first glance, the graph produced looked just like a bunch of uncorrelated scribbles. A few deductions were made immediately. There was an increasing frequency trend at the lowest frequency harmonics. This was to be expected as these peaks were associated with the main frequencies of each note. Also the general trend of each note's harmonics followed the about the same basic path. I found this to be interesting.



My previous observations became more apparent upon rescaling the frequency to a logarithmic scale. Each note had a first harmonic frequency about 40-50 Hz greater than the previous note. The fundamental note of the ocarina however on this graph more closely resembled a G in frequency rather than an F. While the clay dries, it shrinks. In most cases this doesn't affect the tuning between notes on an ocarina. Instead it raises the pitch of each note a more or less equal amount. The result is an ocarina that plays a higher scale than it was originally tuned to. The switch from F to G was to be expected.



As I decreased the frequencies visible on the graph to only those between 0 and 5000 Hz an oddity appeared. The differences between the first harmonics became more apparent which made sense; however my problem was with the second harmonic. According to my graph, there was fixed resonance in my ocarina. As the notes increased in frequency, the second harmonic didn't increase like the fundamental. Instead they all stayed at about ~1100 Hz and just increased in intensity. As for why this occurred I have no clue. All of the higher harmonics seemed to follow the trend of the first harmonics. The third harmonic stayed at the same intensity but moved to higher frequencies as each note moved to higher frequencies. The fifth harmonic on the other hand steadily decreased in intensity but increased in frequency.



Conclusion:

After all was said and done, I believe I was successful in my goal. While I was not able to create multiple ocarinas out of different materials as I first intended, I did create two working instruments and compared the waveforms produced by them. I was also able to observe the frequency response of the larger ocarina so that I may make more detailed changes in the future. This class helped me to understand all that goes into making instruments and how complex each sound can be. Through testing each instrument I will be able to adjust intonation until I have two near perfect music making devices. If I had the chance, I would love to continue this research by assembling an ocarina made of wood. I have heard the wood produces a much more rich sound when compared to the clay and would be interested in why that is so.