Modal Series of an unbraced soundboard(0)

Charles F Morrison, Luthier

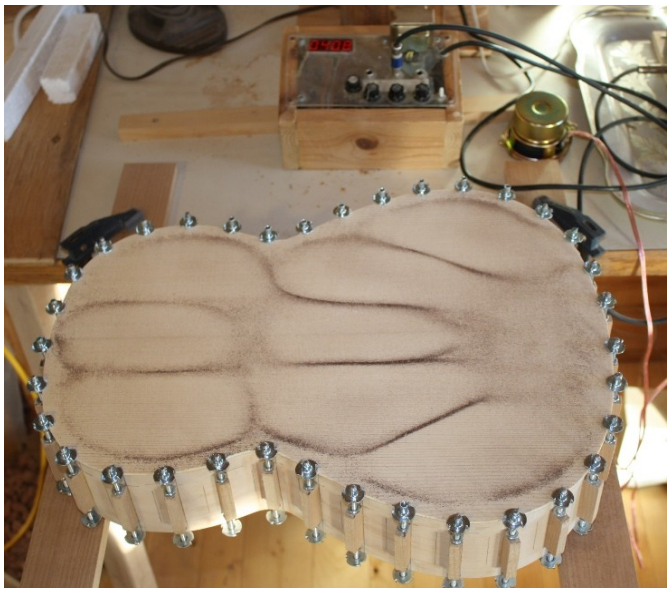


Illustration 1: 408Hz

This article is somewhat an afterthought. Several previous works have shown various stages of a guitar top under construction and the modal patterns at the resonant frequencies. For completeness, I've included this series, which is not the same top. This is a very stiff piece of German Spruce at 2.2-3mm thickness. This top does not have a sound hole cut or any kind of bracing. Some of the patterns and the frequencies they appear at differ somewhat from what the other top would because of the difference in the woods. The top shown in the other articles is a rather floppy Englemann spruce at 2.3mm thickness.

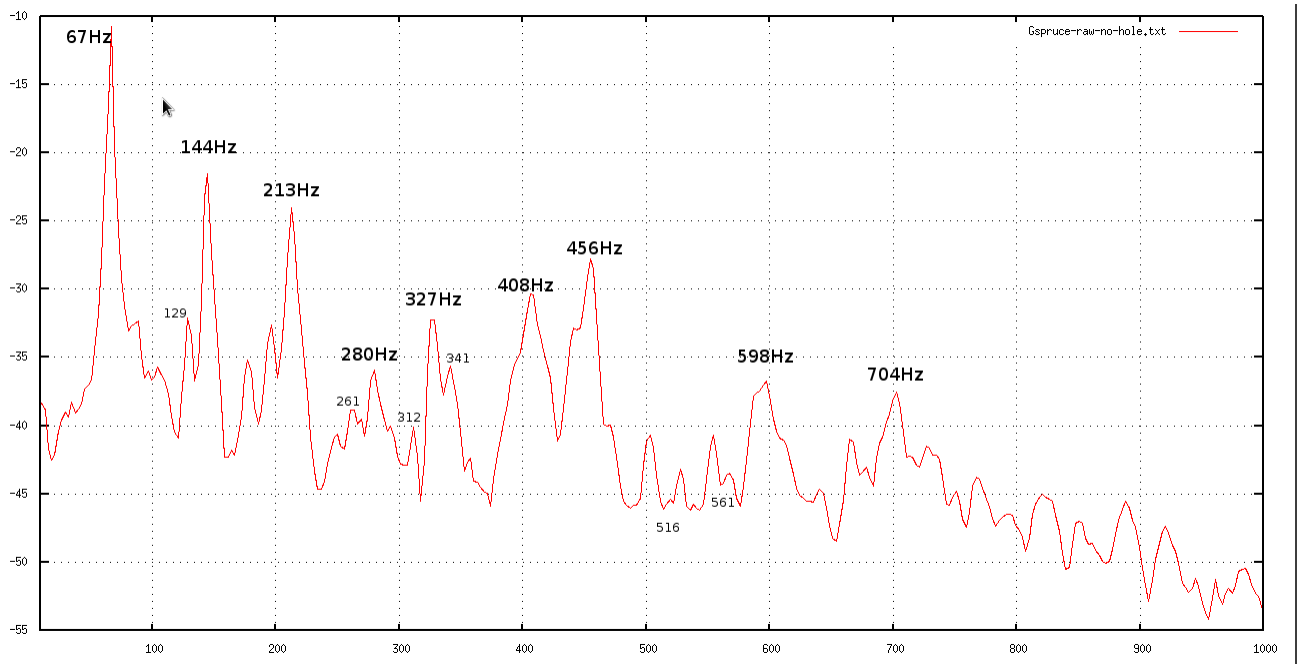
The Test Environment:

The primary tools for this exercise are the “rack” to hold the top, a frequency generator with LED readout, an amplifier and a 2.5” speaker. These are plainly visible in most of the photos presented here. The “rack” is placed on two 1” x 3” boards suspended 30” over the floor such that there is no closure to the air below the soundboard. This should eliminate interference from an air cavity. The medium used for the modal patterns was sawdust from bandsawing dark woods.

Each photo is plainly labeled to indicate the frequency at which the mode manifested. Dark lines indicate nodes (non vibrating areas) while lack of color or fuzzy spots of color indicate vibration.

I will note here that the equipment and experimental technique used here results in patterns often missed by researchers. A larger speaker tends to overdrive the top in lower ranges and can't focus the energy to a small enough area to induce patterns in the upper ranges. The result is that everything below 120Hz looks like a monopole and patterns over 300Hz can be missed entirely. This distorts our perception of the top's resonances.

At the lowest modes the patterns are tied in to very specific frequencies, often changing to a completely different pattern a few Hz away. As the frequencies increase, the patterns can span ranges of 20Hz or more. I tend to photograph the most active spot, which may not be the highest amplitude. Several patterns actually exhibit at dips in amplitude, so are negative modes.



The plot shown above is the “tap tone” of the top shown in the following photos. I've marked the major peaks with the corresponding frequencies. All of these peaks, and a few of the valleys, are represented by a photo. The photos were taken at the most active point for the patterns they represent. Refer back to this plot as you look at the pattern photos that follow.

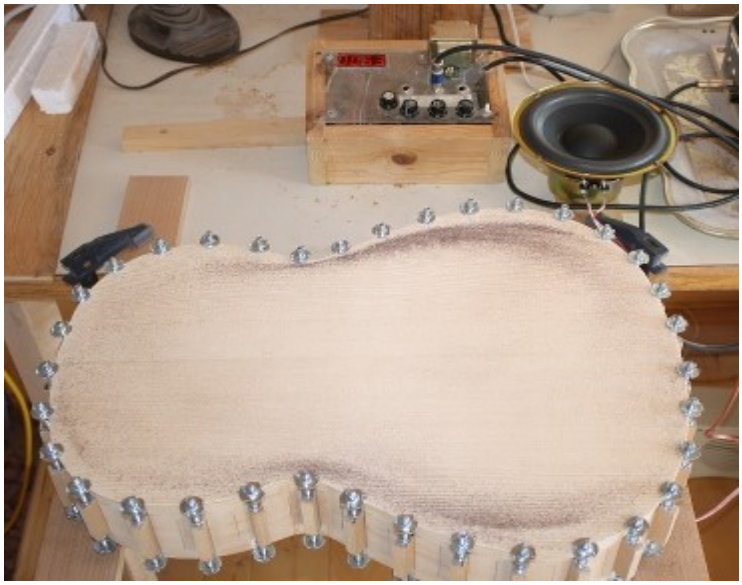


Illustration 2: 63Hz - Monopole

At 63Hz this top displays a monopole. Monopoles are often associated with the Main Top Resonance, which is the frequency that has the highest amplitude when the top is struck. At this point of construction, this is not the main top resonance. Looking at the frequency plot, we see that 67Hz is the dominant frequency and 63Hz is just a point along the slope approaching it.

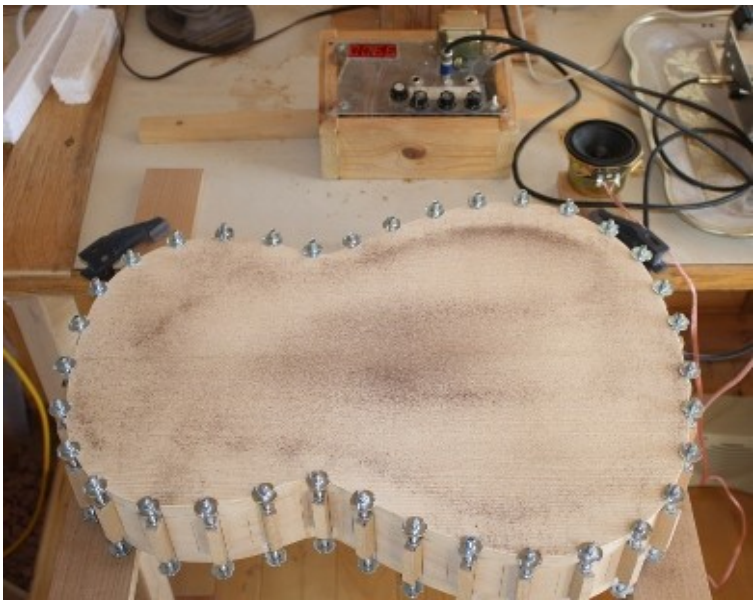


Illustration 3: 66Hz

These two photos represent the main tap tone resonance, which is 67Hz on the plot. As can be seen from these examples, this is a tripole, or more specifically, a cross tripole because the the 3 poles manifest across the grain. The first example was actually 66Hz and the last is 70Hz. Each shows a variation of the cross tripole. Both show the outer two poles extending beyond the middle pole up into the upper bout. This is something that does not happen after the transverse bracing is glued above and below the sound hole.

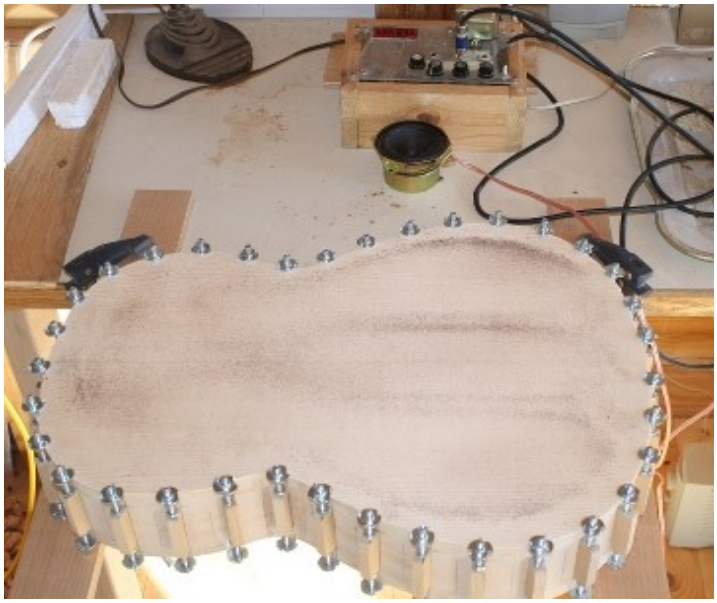


Illustration 4: 70Hz

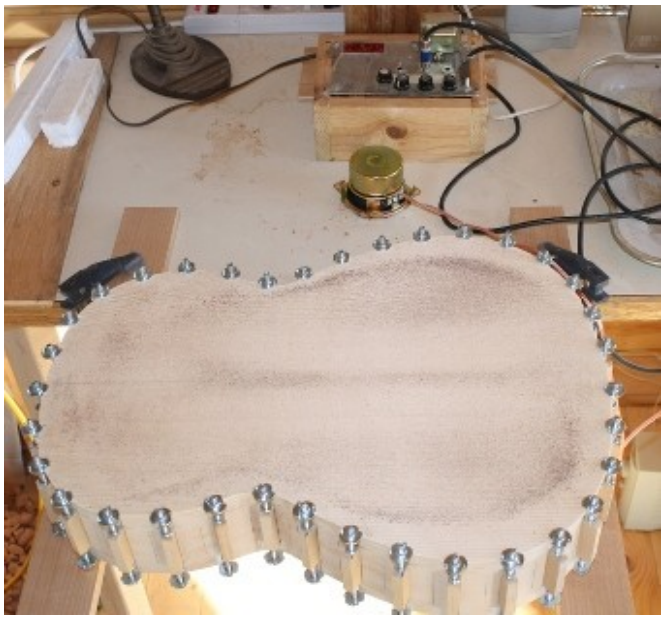


Illustration 5: 125Hz

The cross dipole appears at 125Hz. Again it can be seen extending well up into the upper bout.

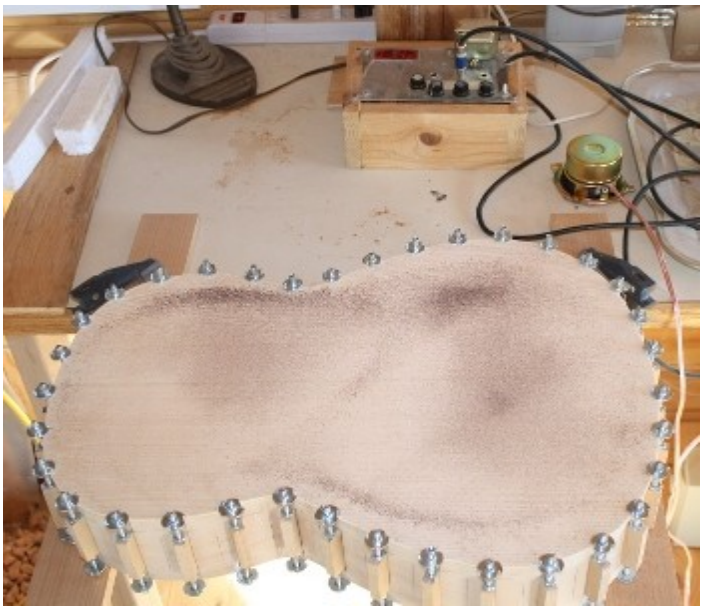


Illustration 6: 142Hz

At 142Hz the long dipole emerges. The properties of this top determine that it displays a diagonal node line rather than a line perpendicular to the grain. Could this be the reason behind the diagonal brace many makers use ? Note that this is very close to 2 x the main resonance at 67Hz.

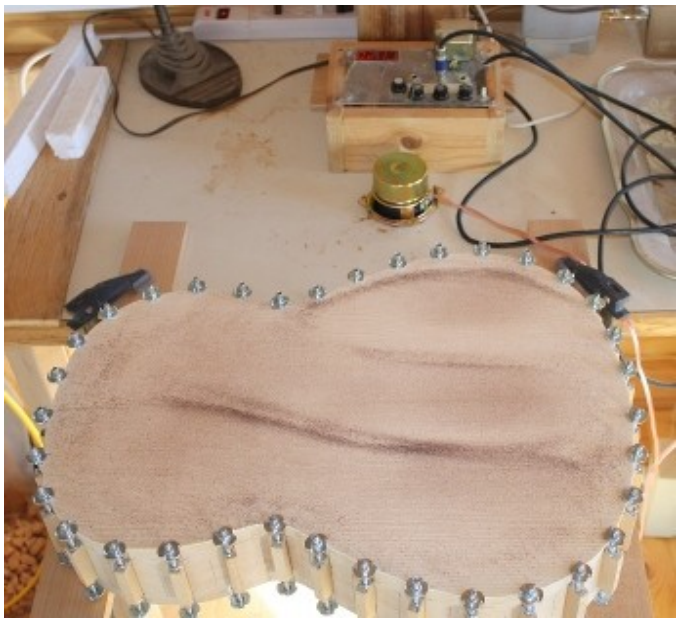


Illustration 7: 211Hz

This is a variation on the cross tripole we saw earlier at 66-70Hz. Now, 3 times the frequency and we have another one. This time it's almost like a 2 ½ pole as the first two poles extend the full length of the body while the third is only in the lower bout. This kind of variation on a theme shows up all the time in modal patterns.

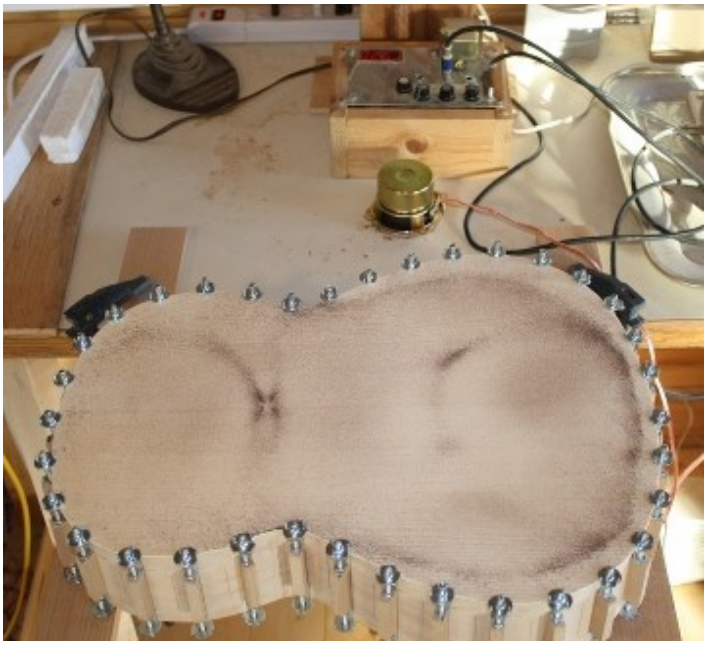


Illustration 8: 261Hz

In contrast to the cross tripole, this is the long tripole, which divides the top lengthwise rather than crosswise. As mentioned previously, these patterns can extend for quite a range and change subtly throughout that range. Below is the same pattern at 278Hz.

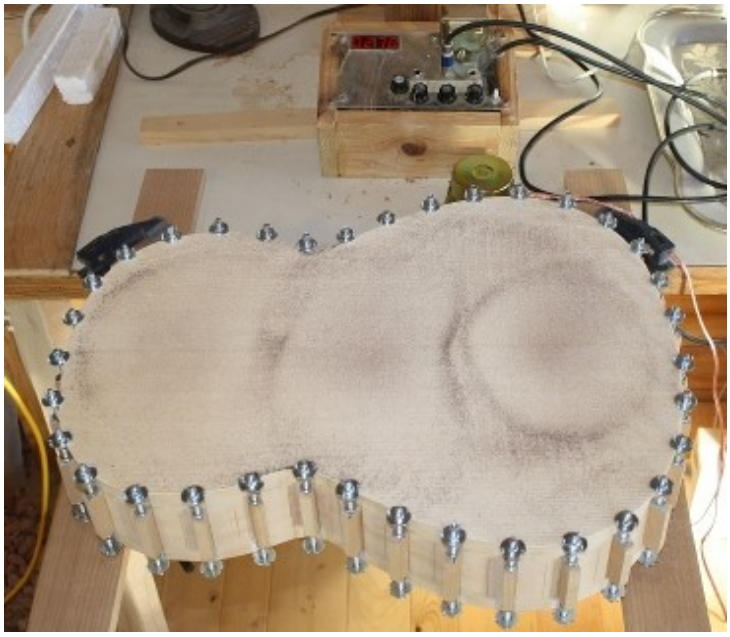


Illustration 9: 278Hz

So far we've seen the top divided lengthwise and crosswise. These are the simplest patterns we will see. Starting with the next one we start to see mixed modes. These are actually lengthwise modes that hybridize with crosswise modes. We can describe them as “stacked”, where crosswise modes are stacked on top of each other. I refer to these as odd fractions. The above long tripole can be described as 3 monopoles stacked on each other, or 1/1/1. I refer to the stacked modes in this kind of notation.

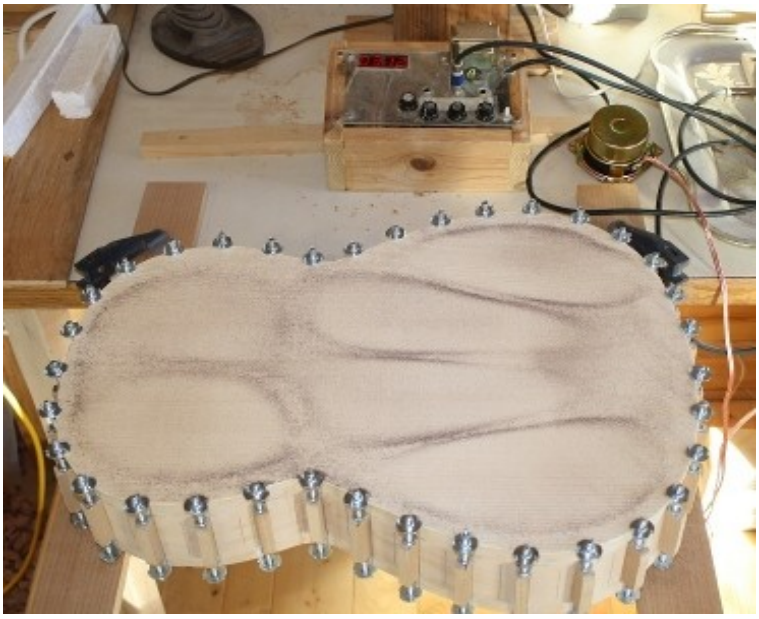


Illustration 10: 312Hz

This is the 2/4 mode, being a cross 2 pole mode stacked over a cross 4 pole mode.

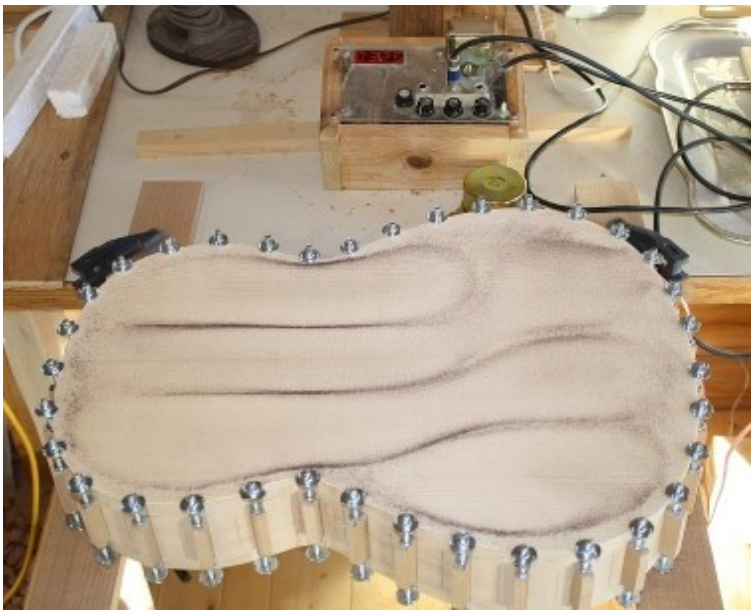


Illustration 11: 325Hz

These are the last unstacked cross pole modes we'll see on this top. It is a cross 4 pole in two variations.

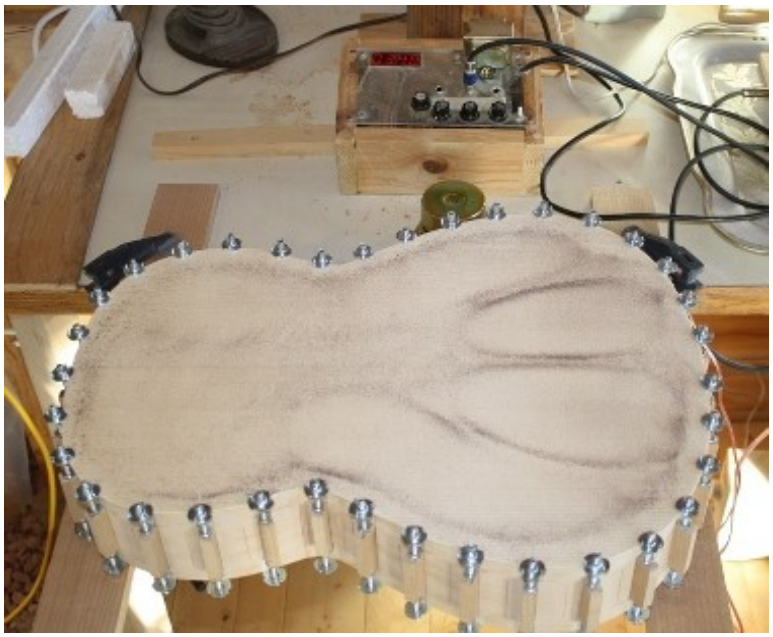


Illustration 12: 348Hz

Very often when we see this kind of thing, there is a continuum between the two patterns with subtle variations as the frequency moves up and down. Other times the patterns appear to stop and pick up again on the new, but similar pattern. The double peak on the plot appears to cover the pair of patterns above.

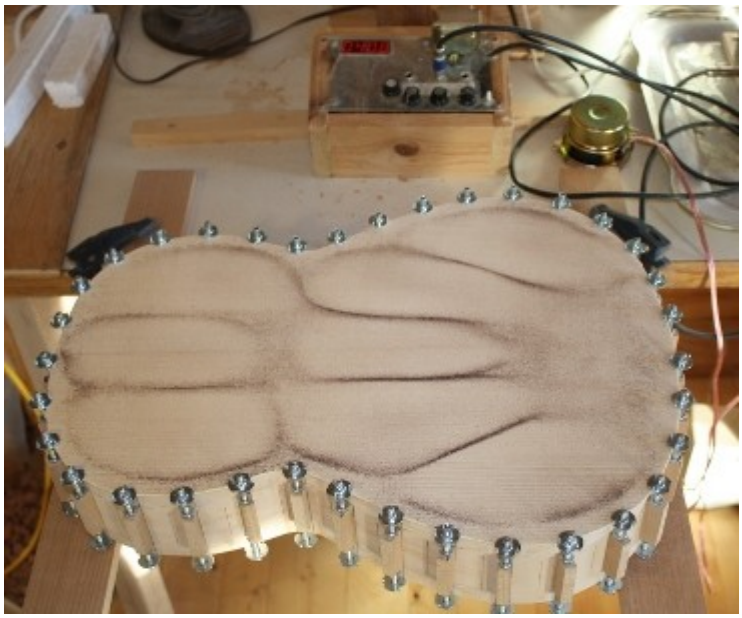


Illustration 13: 408Hz

This is a 3/5 stacked mode. Note the peak on the plot at 408.

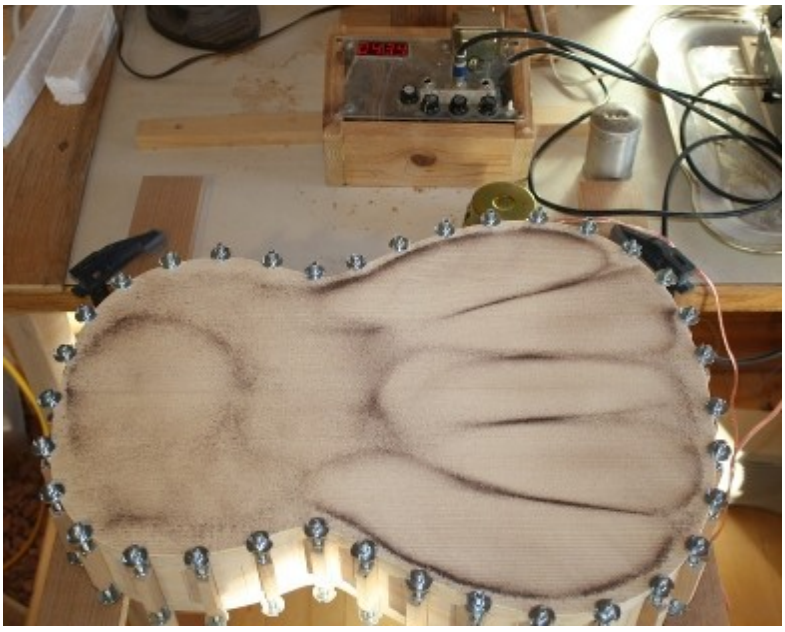


Illustration 14: 434Hz

This is a tough one to label. I'll suggest that it's a 1/1/5. If so, it's the first triple stacked multimode. It makes sense when you take into account that the lengthwise modes seem to require higher frequencies to manifest than the crosswise modes. The wood is stiffer lengthwise, which may explain that effect.

Illustration 15: 454Hz

1/1/1/1 or the long 4 pole. Note that the location of the nodes approximates the standard back bracing of a classical/flamenco guitar. Coincidence ?

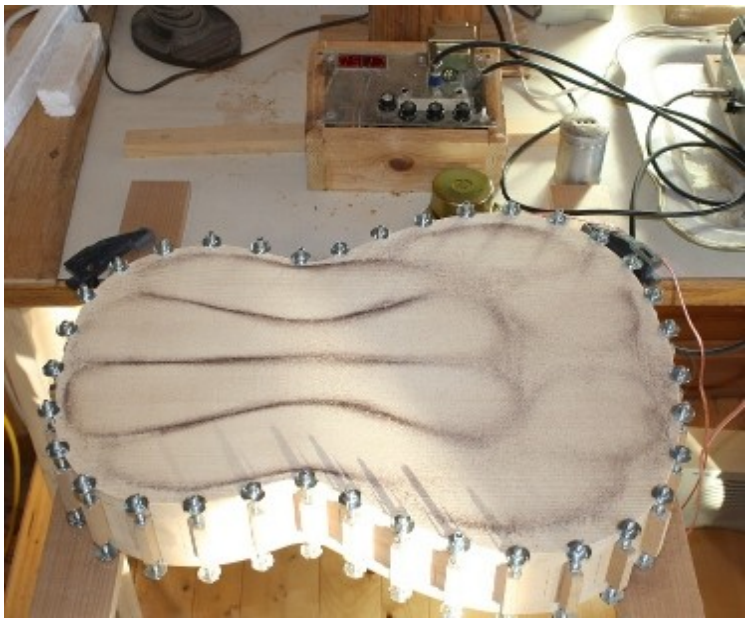


Illustration 16: 517Hz

4/4 multi-modal pattern. This could also be called a 4/2/2, it's a judgment call. Note how the four long poles seem to create a mirrored upper bout within the lower bout.

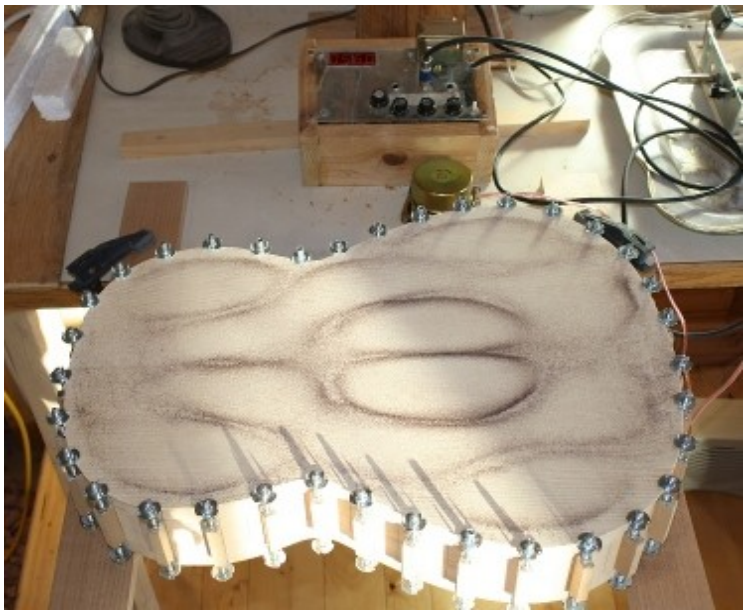


Illustration 17: 560Hz

Sometimes you get some really interesting patterns that you can't really explain. In this case there is a nodal line running right up the center of the top. If you look at this long enough you just might be looking down at an automobile. This is almost as fun as watching clouds. :-)

Seriously, this is a tough one to call. It might be a 2/2(2)/2 or a 2/4/4. It's difficult to see from the photo if the long poles are actually divided into multiples where there are thin areas or where it changes direction. I tend to need to see a line to define a node. Often the difference between a node and a wildly vibrating area is the location of the driver.