Resonator-Resonator Banjo – an Adventure in Amateur Lutherie and a Lesson in Musical Acoustics

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An internal resonator is fitted to the inside of a resonator banjo. From the perspective of simple acoustics theory, there is nothing new here beyond previous separate analyses of resonator backs and internal resonators. Their linear effects simply add (or multiply) as sound filters or transfer functions. However, the effect of the internal resonator on the resonator-back sound, while audible, is subtle and certainly a matter of taste. (Recorded sound samples are included.)

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Within a span of a couple of months, a few people contacted me to discuss adding internal resonators to existing banjos. I mused on how I might add one myself, in a non-destructive fashion, to one of my favorite instruments, a modern, high-end tubaphone. That banjo has two coordinator rods. I came up with the crude but simple design shown in FIG. 1 by itself and mounted as intended.[1] The resulting sound was pretty much as anticipated based on previous efforts and analyses.[2] However, in as much as it was an instrument whose voice I really love, not all changes were deemed positive. The issues were subtle, but a change in bridge from 2.9 gm to 1.6 gm made me *very* happy with the whole contraption.

FIG. 1. Internal resonator assembly — by itself and mounted on a tubaphone open-back

But why stop there?

The pair of coordinator rods were just like what's found in any typical resonator banjo. The quick-and-dirty approach was to cut down one of the research-grade internal resonator units I had left over from the work of ref. [2] and use a similar mounting strategy. The height of the internal cylindrical wall was determined by what was on hand. (Starting from scratch, I would have chosen higher — and would do so were I still playing any resonator banjo.) The only design choice remaining was the dimension of the flat bottom piece. In principle, that piece could be removed completely (which would require some alternative mounting method). Or it could cover the bottom edge of the rim. However, that choice would reduce the gap between the rim and (outer) resonator, which is already pretty small

and chosen with some care. I opted to cut down that flat annulus so that it just fit inside the rim. The photo on page 1 shows that internal resonator installed with the resonator back removed.

Resonator banjos have a sound-hole whose geometry is fixed by the relation of the resonator back to the rim.[3] That would be unchanged in the no-flat-anulus design. In the language of the Helmholtz resonator, the design I chose increases the volume of the "neck" and decreases the interface area between the "neck" and the central volume. This suggests that the Helmholtz resonance frequency is lowered by adding this construction. (Note: It is essentially impossible to draw quantitative conclusions relating real geometry to the observed Helmholtz frequency — which is, in fact, the lowest resonance of the pot assembly. However, the signs of the relative shifts due to changes in geometry agree with this interpretation in each of the examples I explored previously.)

Resonator-Resonator Sound

Despite the similarity in names, the two resonators do different things. There is no redundancy in having both. The first-order linear acoustics theory describing each is as described previously.[2][3] One just combines their effects in the obvious way. Each has impact over the instrument's whole frequency range. However, that doesn't say how it sounds. The connection between measurable sound features and what is desirable, pleasing, or satisfying remains a major challenge to psychoacoustics.

So, despite having not worn picks in over twenty years and unable to three-finger pick my way out of a paper bag, here is a sense of what it sounds like. (Lap-top speakers may not be up to the task of discrimitaing between the sounds.) The melody, learned as a kid from The Almanac Singers' *Talking Union* goes back at least to a 19^{th} Century Baptist hymn.

`The original unmodified resonator banjo is the file: stock-stock.mp3; to play, download, or otherwise access, click anywhere on this sentence or go to http://www.its.caltech.edu/~politzer/resonator-resonator.`

`The resonator banjo with the internal resonator installed is res-stock.mp3. (Just click or go.)`

The totally standard bridge used in both those samples weighs 2.5 gm. Among other effects, the internal resonator increased the sustain. So I re-recorded the internal resonator set-up with a 1.2 gm bridge — probably overkill:

`The resonator banjo with the internal resonator and a 1.2 gm bridge. (Click or go.)`

Most bluegrass pickers have very clear ideas about desirable sound. I don't have that sense but suspect that many would regard the original banjo as superior to the modified one, perhaps opting for brighter over richer.

Theoretical Acoustics Advisory

The simplest physics account of some minor design or set-up modification is to treat it as a small perturbation within a totally linear theory. This produces a modifying filter or transfer function. From the theory standpoint, if there are more than one of these, then their effects would be given by the product or sum. However, the perceived sound may not go quite like that. Here is a cartoon version of the issue: Imagine that a particular modification is shown to enhance feature A over feature B. If A is already very strong compared to B, that enhancement might not be noticeable. Conversely, if A were initially virtually absent, an enhancement might still leave it imperceptible. Perception is definitely *not* linear.

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[1] I used a coping saw, hand drill, and some hardware store items. The deluxe aspect was having a distributor of drum shells and the Finnish birch plywood within driving distance. They sell remnants at reasonable prices; so I did not have to buy a $4' \times 8'$ sheet. The flat is 8-ply 4mm; the $8''$ drum shell is 5-ply 3mm.

[2] http://www.its.caltech.edu/~politzer; D. Politzer, *Physics of the Bacon Internal Resonator Banjo*, HDP:16-02 June 2016

[3] See, for example, http://www.its.caltech.edu/~politzer; D. Politzer, *The Resonator Banjo Resonator, part 2: What makes em really crack?*, HDP:15-05 June 2015