Wind Brass Instruments

8 Variations on the same principle: the brass family, trumpet, trombone, horn and tuba.

Reality and model: the distance at which you view something
Practice is often more unruly than theory. And that holds also for physical modeling synthesis. The usefulness of models is that they are a simplification of reality. Which makes that reality more understandable and gives more insight.

However, always keep in mind that such a model is an abstraction and therefore not equal to it's representation, your model. Sometimes you forget that, or you no longer think about it that way. It may then happen that your implicit modeling becomes your own reality. The handy tool then turns into colored glasses so you perceive a new reality.

The S&H PLL model a simplification of the real world
As an example we take our S&H PLL model. You could simulate very nice wind and string instruments. The resemblance of a trumpet suddenly becomes very clear. The lips as an excitation oscillator coupled to an open tube. In such a tube, which is open at two ends, it is possible to excitate frequencies with a harmonic realation. Frequencies with ratios 1, 2, 3 …

In musical terms, we can thus form the natural overtone series. Back to the PLL model. The excitator, the lips is virtually represented by a sawtooth oscillator. This gives the best results. While other waveforms for example a triangular wave as input for the resonator, seems to transform the whole instrument into a flute.

Yet you may have wondered how that is possible: the lip vibration presented as a sawtooth vibration. In fact, you may have already compared both vibrations. Just blow your lips as if you were playing on a trumpet. Listen and compare that with the sound of a sawtooth. That is quite a big difference ... Although there is no resonator on your lips, but still, such a big difference?

Are we satisfied with your S&H PLL model? Yes and no. Yes because in general terms the interaction between oscillator and resonator via the sample and hold feedback is close to what really happens acoustically in a wind brass instrument.
No because, the practice is indeed more stubborn because the PLL model only partly describes the real event in such a brass instrument. Even worse, there is a fundamental error! The sawtooth as input is not correct.

The faults in the S&H PLL model
With just common sense and practical comparison of lip vibration and saw tooth we could have discovered it. The sawtooth signal sounds much more rich in overtones than the sound that comes straight out of your lips.

In addition to the erroneous excitation signal, there is a second basic error in the model. That is the assumption that the resonator is an almost entirely cylindrical tube that behaves acoustically as if it were open on both sides, as is the case with flutes (except panflutes which are closed at one side). That almost entirely cylindrical tube, which ends funnel-shaped at the end, is true.

On one side closed tube
But, acoustically, the tube is closed on one side, the side of the mouthpiece. You can even try it out by trial and error. Take a PVC tube of about one meter and try to blow it like a trumpet. If you succeed, however, you will not hear the same series of tones as on a trumpet, but a series of tones corresponding to the overblowing on a clarinet (acoustically a cylindrical tube that is closed on one side). An odd series of harmonics: 1, 3, 5, 7…

Yet you may have wondered how that is possible: the lip vibration presented as a sawtooth vibration. In fact, you may have already compared both vibrations. Just blow your lips as if you were playing on a trumpet. Easier to test this yourself is to visit the following website, www.phys.unsw.edu.au/~jw/brassacoustics.html#sound. Here it becomes very clear how reality looks like from a closer view. In addition to that excellent explanation, you will also find a selection of sounding audio examples.

The flare and mouth piece
In short, you discover that practice is indeed complicated. It comes down to the fact that the end of the trumpet, the funnel-shaped flare, causes the lower resonant frequencies to rise. The mouthpiece, on the other hand, lowers the higher resonances.

By careful tuning of mouthpiece and cup shape it can be ensured that the overblowing tones form a harmonic series. The cup also has the effect that high tones are better radiated than low: the operation of a high pass filter. This results in the overtones, present in the lip signal, becoming relatively stronger.

Distortion
Then there is another interaction (other than the S&H feedback) between resonator and lips: the lip signal is also distorted, which means that overtones are added. Distortion is the opposite of filtering. With filtering you can weaken frequencies, remove them.

With distortion you can add extra new frequencies; just think of the large amount of various distortion stomp boxes from the guitar world. On the one hand, the higher frequencies in the lip signal are favored, on the other hand extra frequencies (overtones) are added by the distortion. If you want to see everything from a whole new point of view, go to http://hyperphysics.phy-astr.gsu.edu/hbase/music/brassa.html, another excellent university site, no audio samples, but very insightful images.

`PLL-Brass.pch2`, an update
This patch is essentially only an extension and refinement of my original S&H PLL model. The adjustment lies in the more reality-based input signal, the lip oscillator on the one hand, and on the other hand the addition of the distortion function.

ICMC Cologne 1988
In preparation for this workshop I thought back to a long time ago, 1988. The ICMC (International Computer Music Conference, organized every year in another country by the International Computer Music Association) then took place in Cologne. A whole bunch of music technology students (from Utrecht School of Music and Technology) went there. No, not me. Apparently I had missed something. Euphoric stories about physical modeling synthesis of R. W. Berry from the School of Music of the University of Durham from England.

R. W. Berry's Physical modeling synthesis
Never had they heard such incredible trumpet simulations. Everything got even more relief from the way and with what means he realized it. When we were busy with Atari's and Macs for a long time, Berry used a simple 6502-based microcomputer with which he controlled a modular analog synthesizer. In addition to the familiar standard modules, he had extended the system with self-built resonators based on an analogue delay line with bucket memory, also known as BBDs (Bucket Brigade Delay).

In addition to the enthusiastic stories, these students also brought Berry's paper with a description of some of his patches based on physical reality. I have always used that paper as a supplement to lessons. Well, I suddenly had to think about making this workshop, because I remembered that he described a distortion function with regard to a trumpet patch.

Berry's model implemented in NMG2Demo
I had never tried this patch until now. Nice reason to do that now. The transfer function: x (x + offset). x Presents the input signal. This signal is now multiplied by itself after an offset value (between 0 and 1) has been added to it. You can see how this function is realized in the light pink modules in the patch.

Together with the more reality-based input signal, it delivers what you hear in the 8 variations of `PLL Brass.pch2`. With a little bit of common sense I approached the lip oscillator: the lips are of a rather soft 'material', which can therefore never produce a vibration with such an abrupt transition as in a sawtooth.

The basis for this is a sine wave oscillator followed by a Shape Exp module. The degree of distortion is controlled by a mix of the Dynamics Lfo and

Embouchure Lfo (which together represents the blowing force). In this way it is obtained that with 'harder blowing' also more distortion arises, just like it is in reallity.

Experiment with the offset value in the distortion function and hear how the brass sound is no longer visible when the value is too low. This mix control signal also controls the noise modulation on the Pitch input of the Lip Osc (via DrF-Pitch, a mixer module with which the degree of dynamic noise modulation can be set). Of course, the amplitude of the Lip Osc in a multiplier module is also controlled dynamically by the same control signal.

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Internet
http://hyperphysics.phy-astr.gsu.edu/hbase/music/brassa.html