A cyber musician, a bow and a string

The bowed string
Maybe you have tried it once. You experienced that it was not easy to get a nice tone without squeaking or scratching. In fact, such a bowed string is an interactive process between bow and string.
Condition one: provide the hair of the bow with sufficient resin. If you don't, the bow will slide over the strings. That produces some noise, but that was not the intention.

Well, with resin then. If you now start the bowing movement, the resin will ensure that the string sticks to the bow. Now you pull the string out of its equilibrium point. At a given moment the counterforce in the string, which wants to return to its rest position, overcomes the adhesive force of the resin. The string now jumps back to its rest position.

Then the cycle starts again. That is, if you bow the right way, at least: correct pressure in combination with bowing speed. This creates the interaction that we want. The pulling out of the string and the jumping back is now in sync with the lowest eigenfrequency, the fundamental tone.

By lightly touching the string with, for example, a finger during bowing at distances that form a whole fraction of the total vibrating string length, the string can also vibrate with frequencies at integer multiples of the fundamental: the harmonic overtone series. These kinds of tones are called flageolets in music jargon.

We can make an abstraction of the above process description. We then see a system that basically consists of two parts: a driver oscillator (the bow) and the harmonic resonator (the string). These two parts form under the correct playing conditions a so-called self-oscillating system, which is also described as forced oscillation.

Sound-determining characteristics
The bowing movement, the actual driving force of the system, results characteristic properties with regard to the sounding result. If you want to play very long tones it can only be done by bowing slowly, otherwise your bow length will be too short. This has consequences for the resulting tone, the amplitude of the vibration. That will be smaller than with quick bowing.

Very slowly played tones sound softer. This can only partly be compensated by increasing the ironing pressure. Therefore modalities arise in the sound that are directly related to this driving force, the way of bowing.

That is a fact that partly provides for the sound identity of the string instrument. Even if you think you can bow perfectly, the movement of the bow and string is not a precise sawtooth shape. As there are fluctuations in bowing pressure and speed, as well as differences in the amount of resin applied over the hair, small deviations of the exact regularity occur, which manifest themselves in a clearly perceptible, noisy character.

The expansion of the S&H PLL model
In the initial PLL model with a sample and hold basis, the slave oscillator (the driver oscillator) was locked to the periodicity of a master oscillator. As a result, the slave, obedient to the master, could only vibrate on whole multiples of his masters frequency: the harmonic overtone series, the natural overtone series.

The characteristic transitions from one harmonic to another produced a striking sounding resemblance with a wind brass instrument. However, once you have blown the natural overtone series on a trumpet, trombone or similar instrument, you will also have discovered that it did not sound exactly the same. How did that happen?

Well, we can interpret such S&H PLL model as an abstraction of a wind brass or bowed string model. Only, with this distinction: the reference periodicity is formed in the PLL model by the signal from the master oscillator. This means that the attenuation is equal to zero, or in other words that the resonance value is 1.

In the real instruments, however, the reference periodicity is formed by the Resonator, the effective tube (or) string length of the instrument. The resonance value of a resonator is by definition smaller than one. In this case, therefore, an incoming signal that does not have exactly the same frequency as one of the resonant frequencies of the resonator can still be partially transmitted, albeit attenuated.

So if you blow the third harmonic on a real brass, you can vary the pitch a bit before going to the next overtone.

That is why we are now going to expand the S&H PLL model with a resonator, which is replacing the master oscillator. The flow chart of the system now looks like this:

the output of the driver oscillator goes both to the input of the resonator and to the audio input of the S&H. The output of the resonator is connected to the sampling command input of the S&H. In fact the sample commands work on the zero crossings of connected signal. The S&H output is inverted, multiplied by -1 and returned to the FM input of the driver (slave) oscillator. This means that the interactive system is complete.

By tweaking this simple S&H PLL model it acts as a bowed string model.

Do not forget to open the text pad in the G2 patch. Listen to all eight variations and then tweak your own versions.

Ernst Bonis

This article was originally published in Dutch as ‘Een cybermuzikant, een strijkstok en een snaar’ in Interface 93 november 2005.

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