”Noisy” instruments

Concerning bow hair and rosins, we have been discussing how the bow-generated noise in violins for the greater part is a characteristic of their sound, rather than an undesirable feature. (“Noise” is usually defined as undesired sound.) Most “unplugged” instruments have a fair amount of stochastically (randomly) generated sound energy in addition to the “deterministic” part, which contains the tone itself in terms of a combination of partials, the frequencies of which might be harmonically[1] related or not. Generally you’ll find four quite different types of noise in acoustical instruments:

(1) Hiss or rumble, randomly created.
(2) Jitter (quick fluctuations in pitch, randomly distributed).
(3) Alien frequencies (not part of the partial series).
(4) Mechanical noise.

Hiss or rumble

Typical instruments with noise of the first kind are bowed instruments and flutes. Some years back, I made a computer program for separating the “noise” of different instruments from their “tones”[2]. It gave some quite interesting close-ups of features we are so used to that we hardly notice them:

In the row, where you invoked this text, you will find sound examples referred to here. The first one (**Ex. 1**) analyzes the violin tone, exemplified by a noisy attack (see spectrogram, Fig. 1, where the noise is easily seen in between partials). The corresponding sound example contains (1) three times the original recording (2) three times the same attack with the noise removed (3) three times the noise alone.

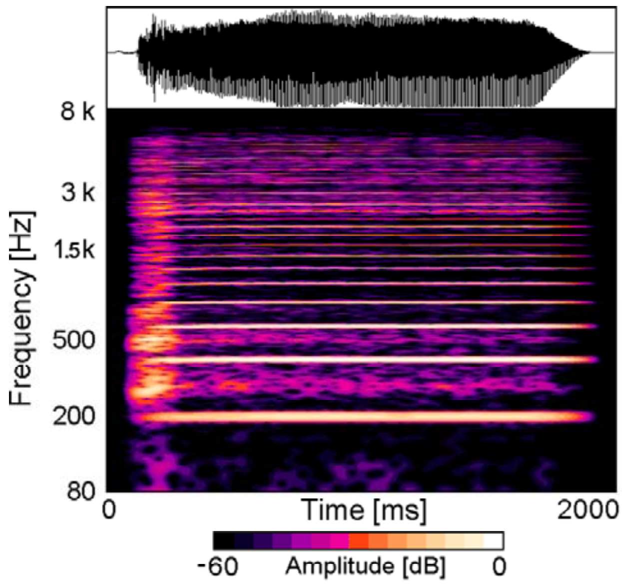

Figure 1: Example of violin tone (open G-string with much noise in the attack.

Notice that in this example the buildup is slow when the noise is removed. Notice also that by listening to the noise alone, there is not much doubt about which instrument it is originating from. Sometimes, when you need a powerful tone start, you may add “noise” to achieve a percussive effect.

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[1] ”Harmonically” means here: related as integer-multiples of the fundamental frequency.

[2] The separation technique is described in my paper from 2004: "Applications of the Bluestein filter in bowed-string analyses". Proc. International Symposium: Frontiers of Research on Speech and Music, Annamalai University, India.

My noise-separation program was constructed so that it could be clearly determined how the noise was distributed along the time line. From the figure below, it is quite clear that most of the noise comes in bursts during the short intervals the string is slipping on the bow-hair ribbon (i.e., when in the figure the string velocity goes negative). The remaining part might be small echoes on the string, combined with partial slips across the bow-hair ribbon.

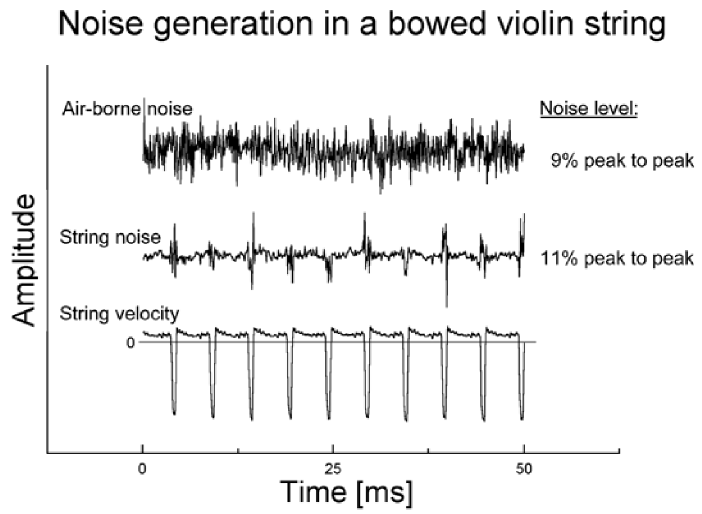


Figure 2: Example of noise separation in the time domain. While in the airborne sound it is hard to localize at what time the noise is generated, the noise extracted from the string signal shows a clear connection with the slipping intervals (large negative values in the string-velocity signal).

In the flute, the air vortices around the mouth hole create noise that excites resonances of the entire instrument. In **sound example** (**Ex. 2**) and the corresponding plot (Fig. 3) one can hear/see "extra tones" (for this tone, an octave below the fundamental frequency, ca 1100 Hz, C#$_6$, with overtones). This gives more depth to the flute sound, as demonstrated in the sound example (3 × original recording; 3 × noise removed; 3 × noise only).

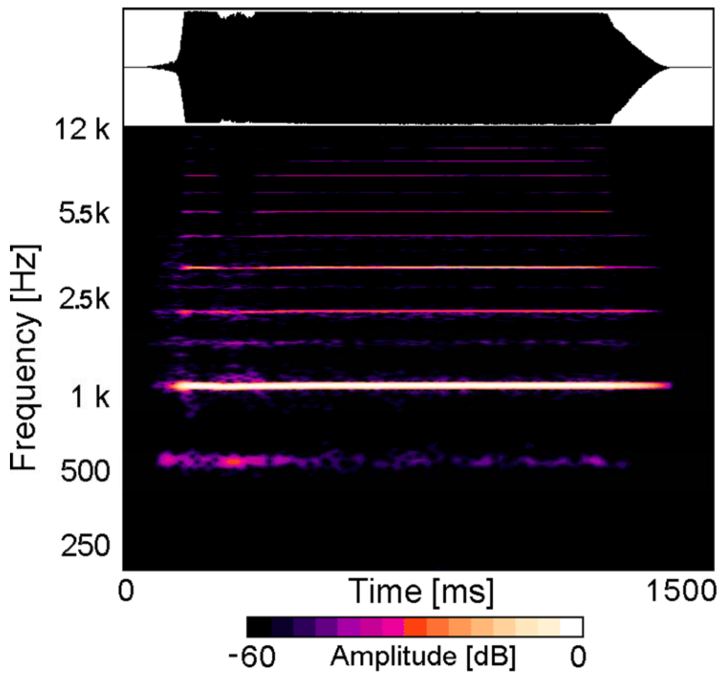


Figure 3: The C#$_6$, ca 1100 Hz, is played on a transverse flute. Accompanying the high note is the octave below (ca 550 Hz) with overtones in form of narrow noise bands. Notice the difference in timber when this "noise" is removed in sound example (**Ex. 2**).

In **sound example** (**Ex. 3**), the same separation routine has been applied once more: this time with a recorder flute playing D_4 (ca 295 Hz). For this low note there is no sub-octave present. The sound of a recorder (tenor) flute is very recognizably painted through the noise.

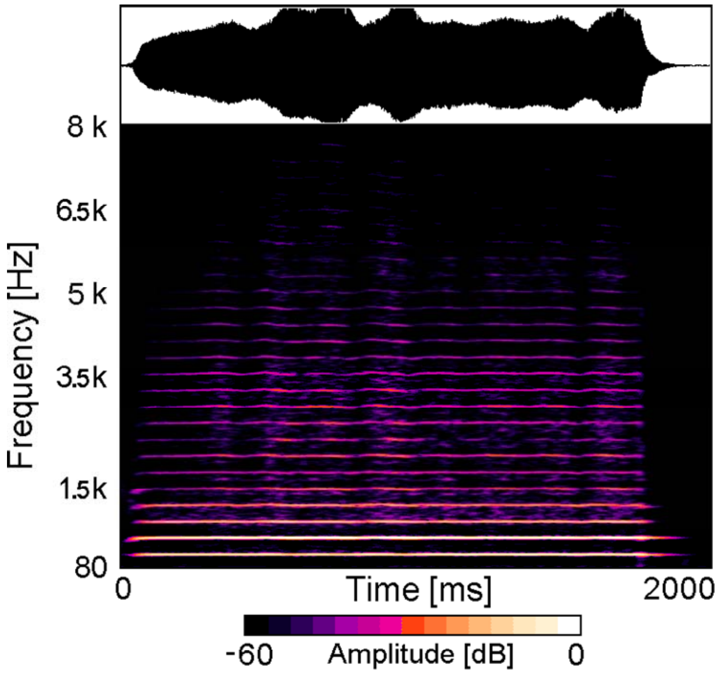


Figure 4: Spectrogram of the original recorder sound from (**Ex. 3**). The example consists of: 1 × original recording; 1 × without noise; 1 × noise only; the same series repeated once.

Jitter

These three instruments (violin, transverse flute, and recorder flute) all possess jitter, i.e., small and rapid fluctuations from the intended pitch. This because they lack some clearly defined triggering mechanism that: would bring the string from stick to slip in absolutely defined intervals; would trigger the air from blowing inside the instrument to outside of it with the same precision (see Fig. 5).

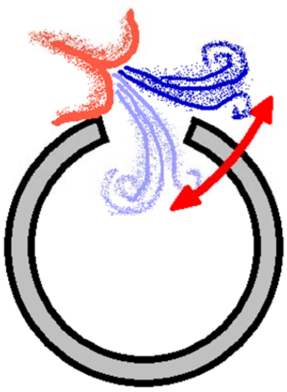


Figure 5: In flutes the air stream alternates between entering the instrument tube (when the inside air pressure is low), and escaping the instrument to outside (when the inside pressure is high). This causes significant jitter, while the vortices cause stochastic noise.

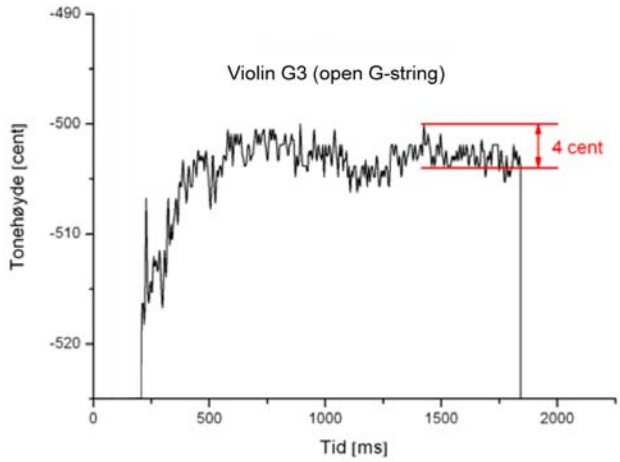
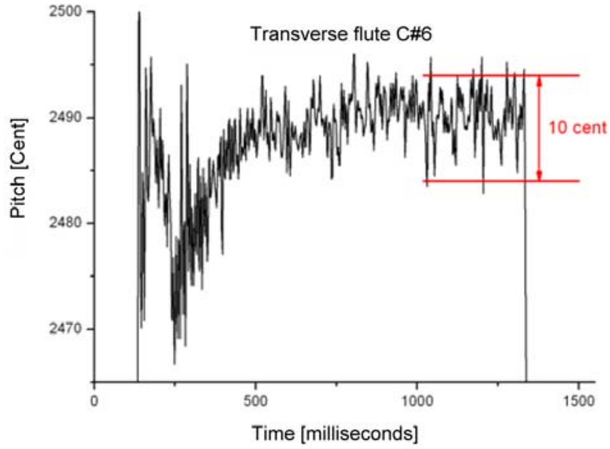


Figure 6 (a): Typical jitter in a violin. It is also quite typical for a bowed-string tone, started on the string, to be slightly flat at the onset. This is usually not perceived by the listener/player.



Fgure 6 (b): Typical jitter in a transverse flute. The jitter here is considerably more than in the violin.

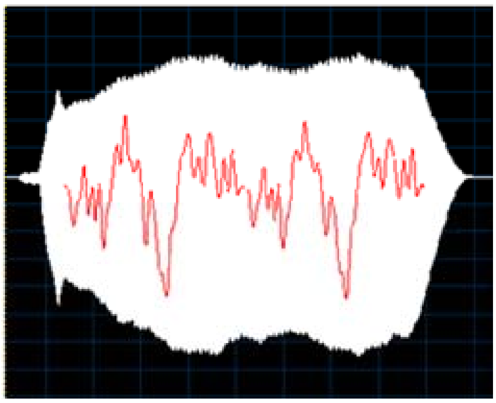


Figure 7 (a): As an experiment, we shall hear a violin without noise and jitter, but with the dynamic envelope equal to that of Fig. 1 and (Ex. 1). In **sound example** (**Ex. 4**), the waveform of one single period was copied for the total duration of the tone, and given the original dynamics. You hear: original sound; noise and jitter free sound; repeated.

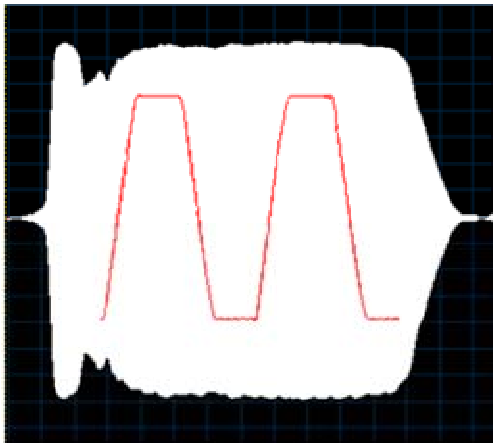


Figure 7 (b): The same procedure as in Fig. 7 (a) is repeated for the transverse flute, and can be heard in **sound example** (**Ex. 5**).

Alien frequencies

In electroacoustic instruments, *hum* due to electromagnetic fields caused by the domestic AC supply, is the most common alien-frequency disturbance. In acoustical instruments, this problem does not exist, but still alien frequencies can occur (e.g., ringing of open strings on bowed string instruments—I used to have a collegue in the Oslo Phil. who was notorious on that, acquiring a certain deafness for open strings, I believe). The most typical example is the upright piano. Every musician knows that piano strings are tuned by adjusting their tension. However (as you soon will hear), there exists a second group of frequencies, not related to the transverse vibrations excited by the hammer, namely those of the *longitudinal waves* in the same strings. Once the string is mounted in the piano, there is no way to tune its quite audible longitudinal waves! These are related to the string length, which of course is given by the dimensions of the frame. We can only hope that the piano designer took that into account when calculating the different string lengths…

Anyhow, **sound example (Ex. 6)** gives you amusing examples of the same pitch played repeatedly on strings of different lengths. Sound example (**Ex. 7**) is a demonstration of upright pianos of different design qualities. Obviously someone didn't do his math on some of these.

The sound examples (**Ex. 6**) and (**Ex. 7**) were produced by Harold Conklin Jr.[3] of the Baldwin piano factory.

Mechanical noise

With mechanical noise I mean audible fingering on the fingerboard, slaps of key pads, piano keys rebounding, etc. The piano makes a special case because if you remove the mechanical noise in a fortissimo attack, the sound deviates quite a bit from what you are used to hearing. In the **sound example (Ex. 8)**, I have the following three demonstrations: 3 × original sound; 3 × without noise; 3 × noise only; then the total series repeated. Admittedly, this has not so much with bowed-string instruments to do, but I included the example anyhow,

Conclusion:

We have to admit that much of the noises we hear from our instruments are valuable features and a major parts of the instrument's intrinsic characteristics.

[3] Harold A. Conklin Jr., "Piano design factors - their influence on tone and acoustical performance" from the book "Five lectures on the acoustics of the piano" (A. Askenfelt Ed., 1988)
Available at http://www.speech.kth.se/music/5_lectures/