

# Attack transient analysis of flue organ pipes with different cut-up height

Christian Taesch, Tilo Wik, Judit Angster and András Miklos

Fraunhofer-Institut für Bauphysik IBP, D-70569 Stuttgart, Germany, E-mail: angster@ibp.fhg.de

## Introduction

The attack transient is very important for the perception of the sound character of pipe sounds [1]. Analysis of this early part of the sound signal is needed for understanding the complex physical processes in the onset of the pipe sound that are determined by the coupling phenomena of the oscillating and resonating systems.

The properties of the transients can be varied very sensitively in the voicing process, which is still not entirely understood due to its complexity.

An experimental pipe with variable cut-up height was driven with constant air pressure on a windchest in the anechoic room and recorded. This way a set of sounds with different transients were generated and the influence of the cut-up, an important voicing parameter was studied.

## Analysis method

### Pitch-synchronous spectrogram

Analysis based on Fourier Transformation has been used. Time-shifted, overlapping windows were applied on the signal and an FFT was performed on each window. This provides a time-frequency representation of the signal, a spectrogram or sonogram (see Figure 1 and 2).

The nature of this method implies to find a compromise between frequency and time resolution. Several settings with changes in the parameters FFT-Size, overlap and window-type have to be performed to get an overall impression of the sound.

To increase the localization of the harmonic series, that are always full number multiples of the fundamental, the sampling rate of the signals was synchronised to the fundamental frequency by a resampling step. This way the resulting frequency bins of the FFT will exactly detect the harmonic partials and offer a good understanding to follow the harmonic and nonharmonic frequencies in the attack stage.

### Frequency tracking

In the given method, analysis of frequency modulations of the partials is not possible, because of the low frequency resolution. Amplitude or frequency modulations cannot be separately analysed.

Therefore an additional iteration step was applied based on the comparison of the 3 frequency bins of the main-lobe of the applied window function (here: hanning) and readjusting the resampling rate in every time window. This way every chosen partial can be followed accurately in frequency, in the attack and the stationary sound (see Figure 3).

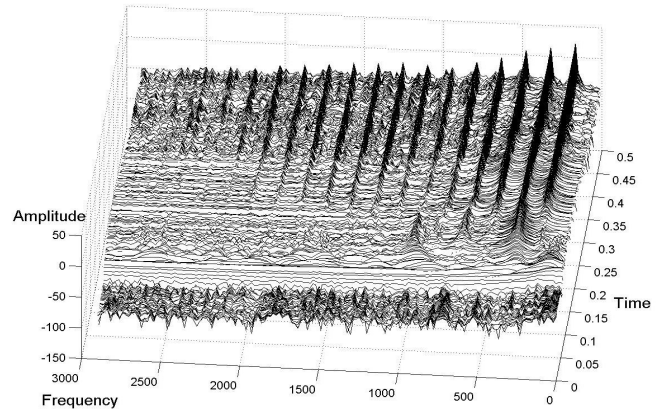


Figure 1: Surface plotted spectrogram of attack stage (FFT-Size 512, overlap 97 %, rectangular window).

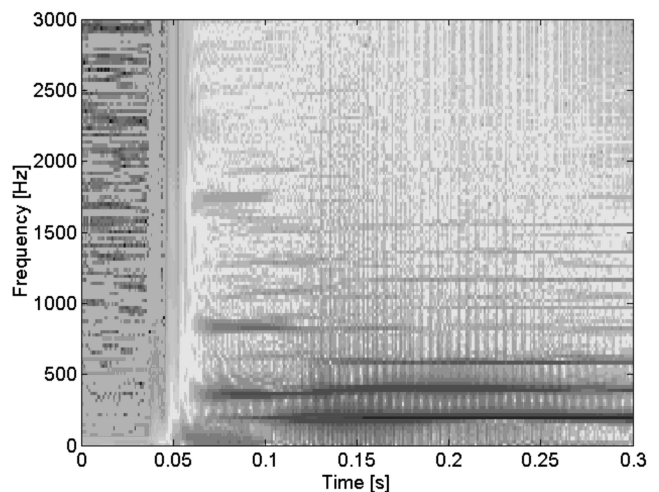


Figure 2: Sonogram view of attack stage (cut-up 16,1 mm, FFT-Size 512, overlap 97 %, rectangular window).

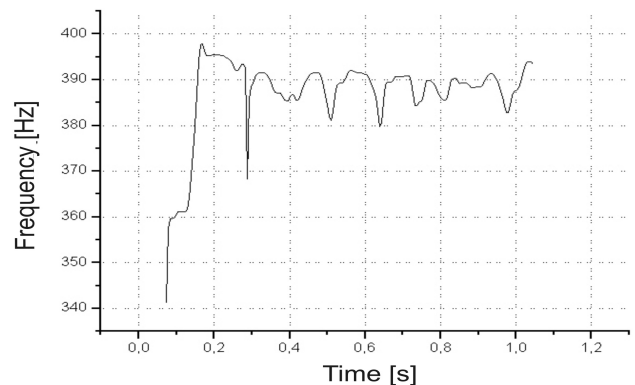


Figure 3: Tracking of the frequency of the 2<sup>nd</sup> harmonic (cut-up 16,1 mm) in attack and stationary sound.

## Mouth Tones

The measurement of the mouth tones, tones that are generated by the oscillating system (see [2]), was carried out by filling the pipe with absorbing material, so that no standing waves could emerge and therefore the resonator's effect is switched off.

The steady spectrum of the mouth tone of the experimental pipe with a cut-up height of 16.1 mm is given in Figure 4. Several peaks indicate the mouth tone modes. In the 6 investigated pipes their number varied from 3 to 4, their amplitudes and Q-factors varied in a wide range. The first mode has always maximal amplitude and Q-factor.

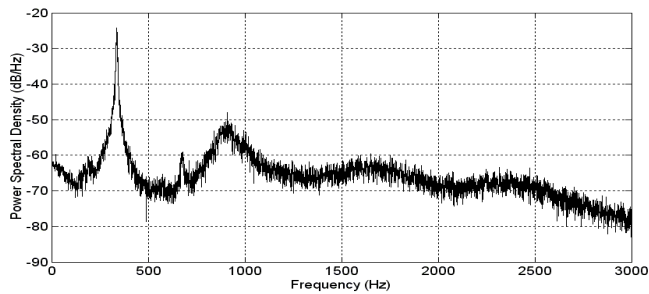


Figure 4: Steady spectrum of mouth tone.

## Results

It can be shown that the mouth tone modes are involved in the very early attack stage of the sound signal. It is seen in Figure 2 that close to the mouth tone frequencies 336 Hz and 909 Hz high amplitude components appear in the attack and disappear when the pipe sound is in steady state.

Several other components that are not harmonic to the fundamental frequency can also be observed. Their origin is partly explained by the mouth tone modes, but also the incitation of resonator modes must be taken into account, as published by Miklos [1].

Furthermore a linear dependence between the cut-up height and the mouth tone mode frequencies were found for the 6 investigated cut-up heights, as illustrated in Figure 5. In terms of voicing, this means that the mouth tone modes can be linearly frequency-shifted by increasing the cut-up.

Another phenomenon is inherent in Figure 3. Analysis of the 2<sup>nd</sup> partial shows a very modulated frequency behaviour around its nominal value of 388 Hz. It is likely that this is due to spectral proximity to the 1<sup>st</sup> mouth tone mode which influences the partial even during the stationary sound. This tendency can be followed for all mouth tone frequencies throughout the measurements. Amplitude, Q-factor of a mouth tone mode and its spectral proximity to a harmonic partial contribute to modulations of the affected partials.

In case of an accurate adjustment of a mouth tone mode on a frequency of a partial, this partial can be perceptually emphasized or "accelerated" [3].

Also the typical "chiff" transients could be achieved by making the mouth tone more broadband-noisy with less spectral preference [4].

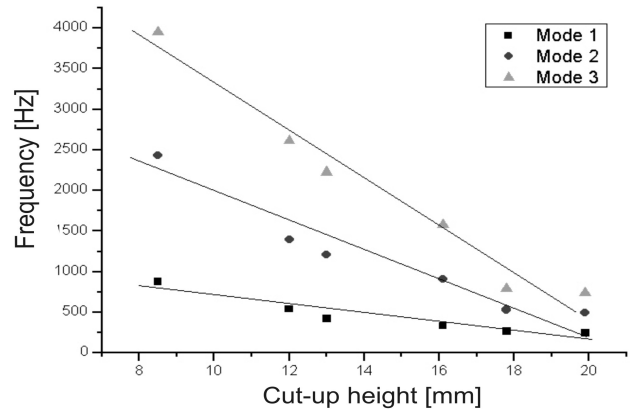


Figure 5: Connection between cut-up height and frequencies of mouth tone modes.

Obviously the described features are important for perception. Therefore it is essential for the voicing process that the mouth tones are properly adjusted in relation to the harmonic partials to reach a desired sound and above that to form the sound in an artistic way through voicing.

In the running research, the dependence of voicing and also scaling parameters on the pipe sound is investigated. Therefore several other experimental pipes have been built and analysed.

## References

- [1] Miklós, András; Angster, Judit: Properties of the sound of flue organ pipes. *Acustica/acta acustica*, Vol. 86 (2000), S. 611-622
- [2] Castellengo, Michèle: Acoustical analysis of initial transients in flute like instruments. *Acustica/acta acustica*, Vol. 82 (1999), S. 387-400
- [3] Angster, Judit, Pitsch Stephan, Miklos, Andras; Objektive und subjektive Untersuchung der Klänge verschiedener Orgelregister. *Instrumentenbau-Zeitschrift* 51 (1997), H.1-2, S.62-70
- [4] W. Nolle: Some voicing adjustments of flue organ pipes. *J. Acoust. Soc. Am* 66 (1979) 1612-1626

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