A Martinetta sounds better – 50 years of pulse forming synthesis

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Origins of the pulse forming synthesis

In 1966 and 1967 Frans Fransson discovered that the excitation function of double-reed instruments can also be interpreted as a sequence of pulses whose width (τ) decisively characterises the spectral envelope of the oboe (τ = 0.4 ms), English horn (τ = 0.48 ms) or bassoon (τ = 1.2 ms) [1]:

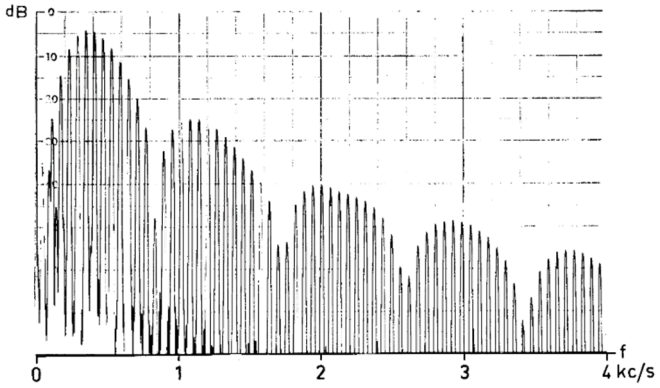

Figure 1: Source spectrum of a pulse sequence typical for a bassoon sound [2].

Depending on the width and arrangement of the pulses, pitch-independent minima appear in the spectrum and formant-like areas between them. Based on Fransson [1][2] and Eugen Skudrzyk [3], Wolfgang Voigt [4] was able to prove the postulated pulse sequence with the help of high-speed camera recordings of the opening and closing times of the double-reeds of bassoons.

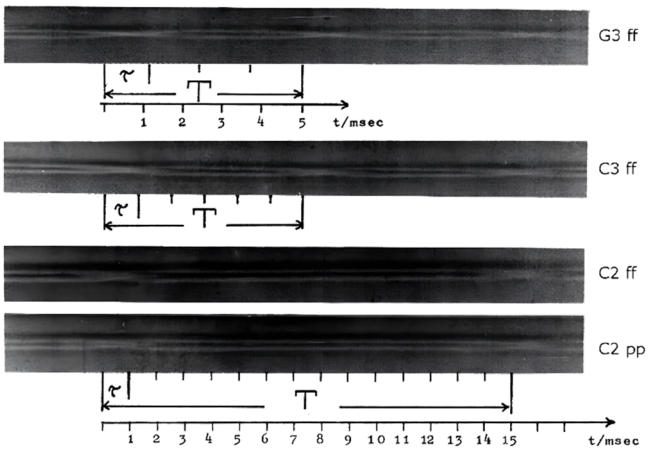

Figure 2: Highspeed recording of a bassoon double-reed movement at different pitches and dynamics. The pulse width τ always remains at around 1.2 ms [4][5].

Voigt as well as Jobst Fricke [5] assumed that the principles of timbre observed by Erich Schumann [6] could be explained on the basis of the pulse forming principle:

The pulse forming principle

The continuous opening and closing of the reeds or lips is reproduced electronically in the pulse forming synthesis by replacing the short-term lip or reed opening with electronic pulses.

With a pitch-independent pulse width of τ, the minima in the spectrum are located pitch-independent at the partial positions n*1/τ (or n*1/T-τ if the constant period T-τ is less than or equal to the period T) (corresponding to principle of formant areas [6].

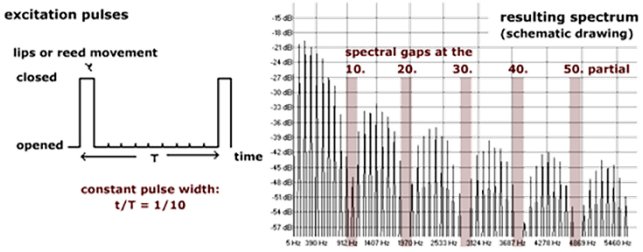

Figure 3: Constant pulse width (τ/T = 1/10) and the resulting spectral envelope [7].

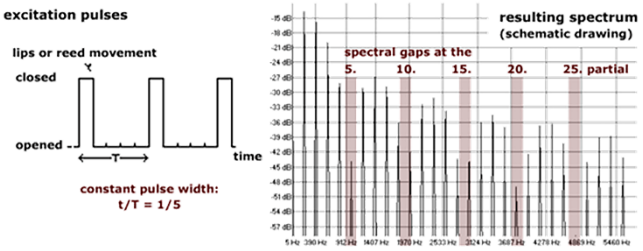

Figure 4: Constant pulse width in an octave (τ/T = 1/5) and the resulting spectral envelope [7].

With ***pp***-sounds, the pulse shape becomes more rounded. For the spectrum, this means that the higher partials are less pronounced than normal. With ***ff***-sounds, the pulse shape becomes more sharp-edged. For the spectrum, this means that the higher partials are more pronounced than normal. In other words: the more edgy the pulse shape, the more pronounced are the higher partials in the spectrum.

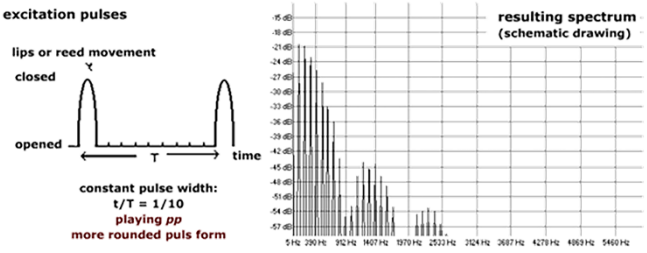

Figure 5: Constant pulse width (τ/T = 1/10) played ***pp*** and the resulting spectral envelope [7].

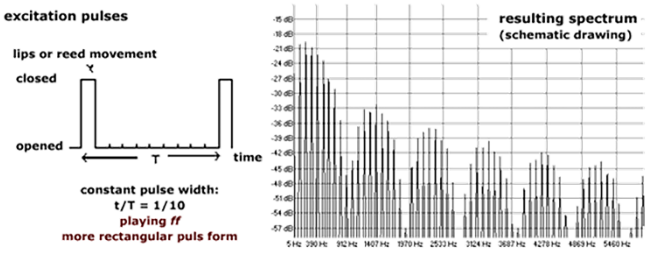

Figure 6: Constant pulse width (τ/T = 1/10) played ***ff*** and the resulting spectral envelope [7].

If the pulse width is minimally shortened, the minima in the spectrum and the formant areas in between are shifted upwards whilst the partials do not move with them. Thus, when playing a crescendo the partial maxima are shifted upwards and previously quieter partials become emphasized.

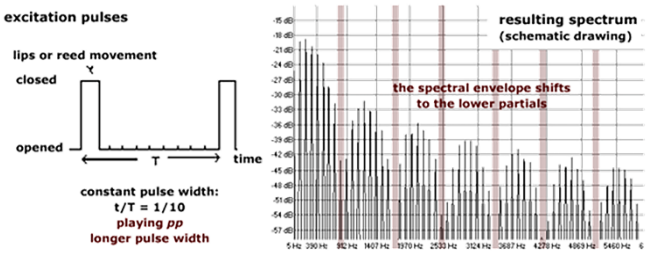

Figure 7: Constant a bit longer pulse width (τ/T = 1/10) played ***pp*** and the resulting spectral envelope [7].

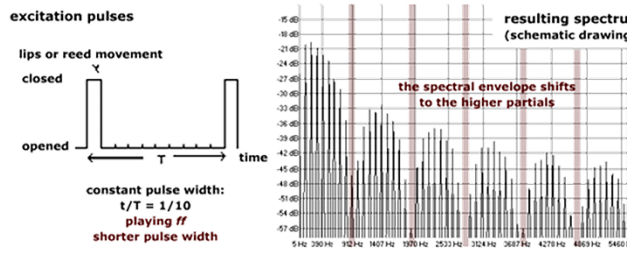

Figure 8: Constant a bit shorter pulse width (τ/T = 1/10) played ***ff*** and the resulting spectral envelope [7].

Further information and literature on the theory of pulse forming one can find in [8][9][10][11][12][13].

The Martinetta

The electrotechnician Jürgen Schmitz developed the Martinetta in 1975 on the basis of pulse forming synthesis, as well as the Variophon in 1979 [12].

While blowing into the Martinetta, the air flows through a small tube onto a little whistle. Behind the whistle is a kind of microphone that converts the noise of the airflow into voltage fluctuations. By low-pass filtering these fluctuations, the control voltages for the transient processes as well as for the pulse amplitude, shape and width are generated.

These pulse-formed timbres can be played over 2.5 octaves using the 32 sensor keys on the front of the breath controller. Three sensor buttons on the back can be used to switch between the timbres bassoon, trumpet and saxophone.

Figure 9: Martinetta breath controller with amplifier (Photo: Reuter, Schefczik 2024)

Figure 10: Martinetta breath controller, top: front side, bottom: back side (Photo: Reuter, Schefczik 2024)

The virtual Martinetta

The virtual Martinetta is freely available as an online application

- in 2D (https://muwiserver.univie.ac.at/martinetta)
- in 3D (https://muwiserver.univie.ac.at/martinetta/3D)
- and as a Native Instruments Kontakt sample library (https://muwiserver.univie.ac.at/martinetta/kontakt.zip).

All the sounds of the original instrument were recorded in ***pp***, ***mf*** and ***pp*** as well as in crescendo.

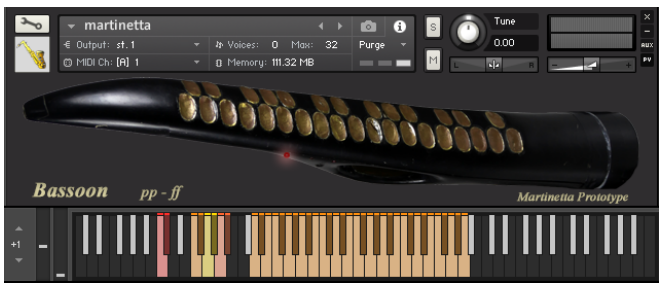

Figure 11: Virtual Martinetta as a Native Instruments Kontakt Library (Reuter, Schefczik 2024)[14]

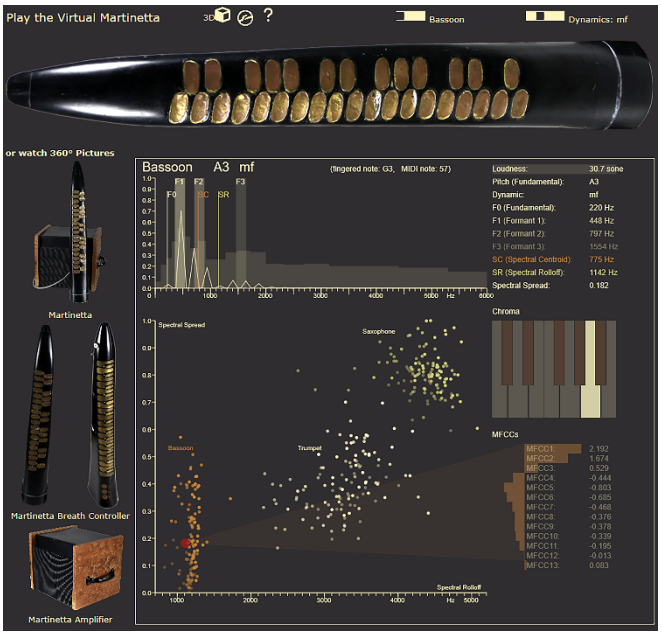

Figure 12: Virtual Martinetta as a playable 2D online application with 360° views of the instrument, breath controller and amplifier as well as interactive displays of formants, spectral spread, spectral rolloff, MFCCs etc. (https://muwiserver.univie.ac.at/martinetta)[15]

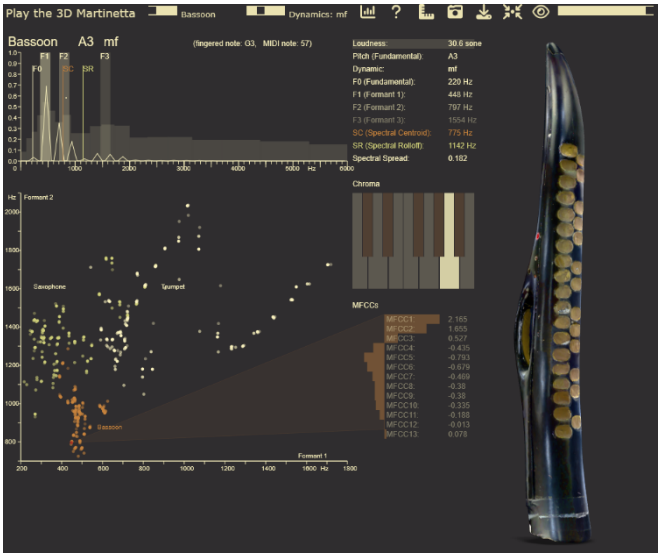

Figure 13: Virtual Martinetta as a playable 3D instrument, with interactive displays of formants, spectral spread, spectral rolloff, MFCCs, 3D model download, dimensions display etc. (https://muwiserver.univie.ac.at/martinetta/3D) [16]

The virtual Martinetta can be played with both the mouse and the PC keyboard: the individual letter keys are used to access the pitches, the arrow keys are used to control the dynamics and the numbers 1, 2 and 3 are used to select the instruments (1: bassoon, 2: trumpet, 3: saxophone). The 3D Martinetta can additionally be rotated in all directions with the left mouse button, zoomed in and out with the mouse wheel and moved in its position on the screen with the right mouse button. One can save the 3D model of the breath controller as an image file (*.png) or as a *.glb model file and use it in one's own applications.

As the Martinetta is regarded as a proof-of-concept for the generation of formants in wind instruments via pulse forming at the (double) reeds or player lips, it is particularly easy to distinguish the timbres it produces on the basis of their first and second formant.

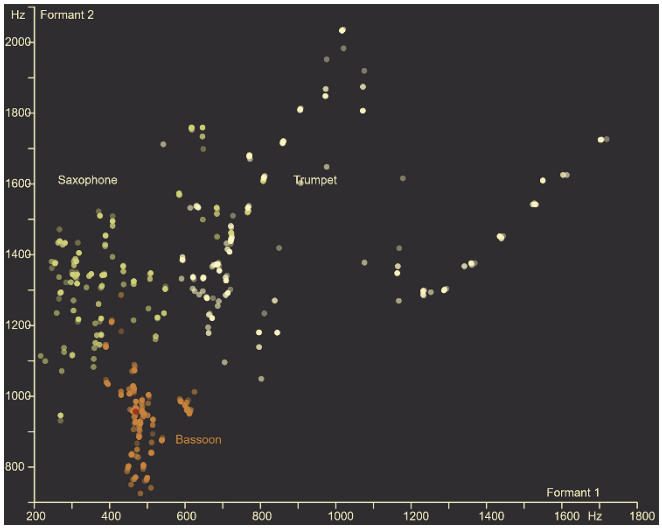

Figure 14: Formant map of bassoon, saxophone and trumpet synthesized by the Martinetta

With the help of modern audio signal analysis [17], an even more precise differentiation of the synthesized wind instrument timbres is possible via spectral spread and spectral rolloff.

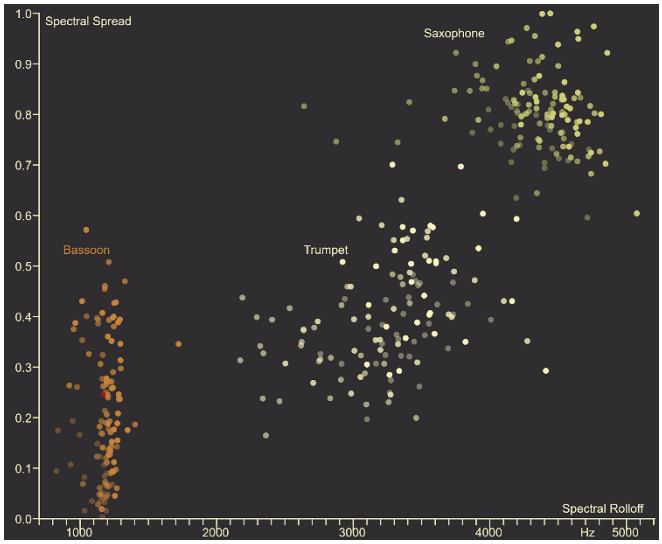

Figure 15: Spectral spread and spectral rolloff of bassoon, saxophone and trumpet synthesized by the Martinetta.

Conclusion

As the first wind synthesizer based on pulse forming synthesis, the Martinetta was a proof of concept for the generation of formants in wind instruments through pulse forming, as well as a prototype for the Variophon wind synthesizer made by Realton Company. In order to preserve and document this pioneering instrument (the last of its kind) for posterity, the virtual Martinetta has been created as a freely available web application (both 2D and 3D) and as a Native Instruments Kontakt sample library (Teaser video at [18]).

Literature

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