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THE NATURAL TRUMPET AND ITS VIRTUAL SOUND

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The mainframe:

- A) Virtual reconstruction of the sound quality of musical instruments.

  Violins, trumpets, flutes

- B) Virtual reconstruction of spaces for music and speech.

  Theatres, churches , auditoria

Introduction and Goals

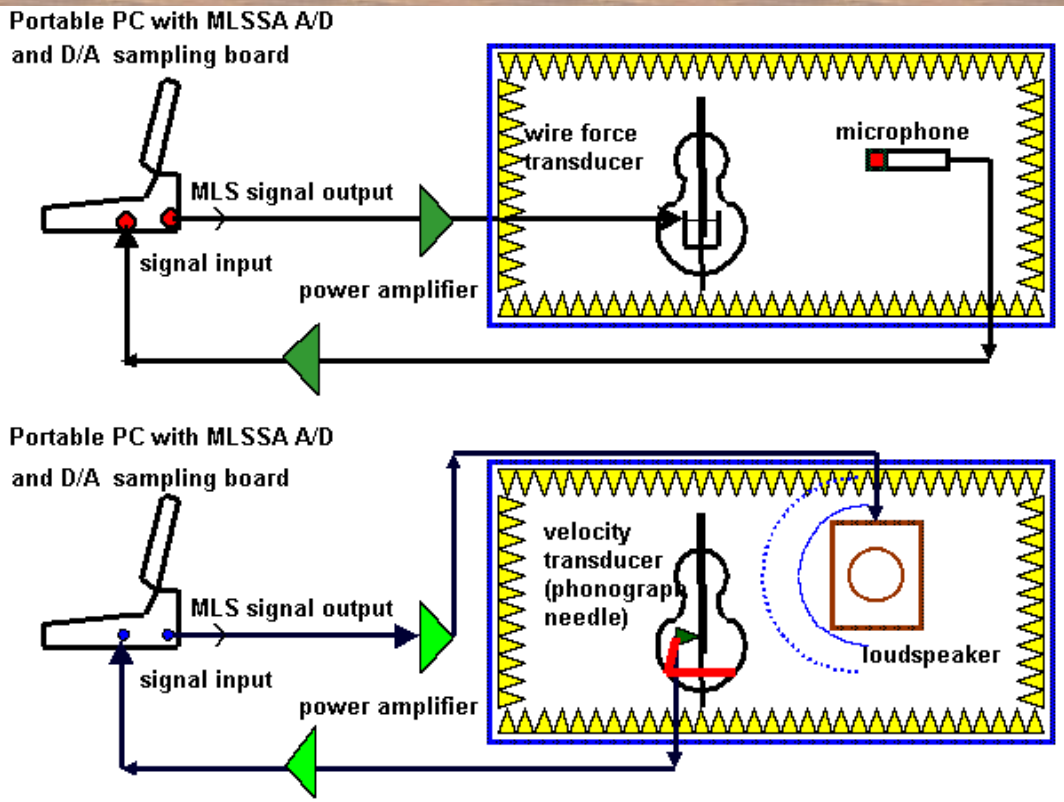
- Restoration → cultural heritage
- Storage → museums
- Sound and music: “visualisation” and “auralisation”.
- Multimediality and acoustics: could they live together?

Previous experiments:

➔ **Evaluation of sound quality of sound chests in different violins**

- Measurements of IR (force ⇒ pressure) on the bridge
- Calculation of inverse filter
- Recordings in anechoic chamber
- Deconvolution: rec $*$ F.I.R. (getting “dry” music)
- Convolution ⇔ virtual sound

The violins (*ISMA*95, *JNMR*97)



Direct (up) and reciprocal (down) method of measurements

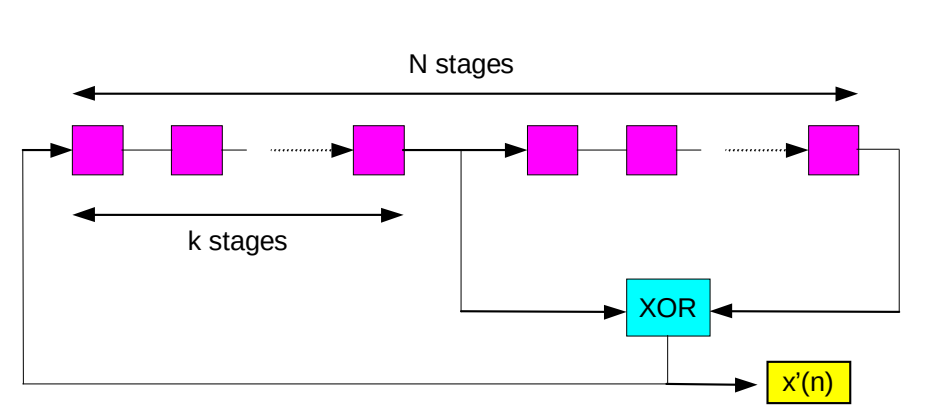
The Trumpets

- Modern trumpets
  - Vincent Bach
  - Yamaha
  - Yamaha custom
- Baroque age trumpets
  - Natural
  - Hunting

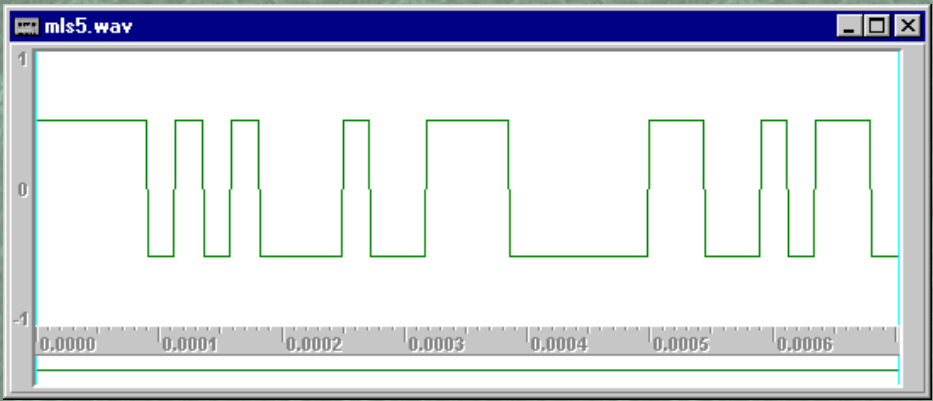
Virtual trumpet reconstruction

- The impulse response (mouthpiece -> radiated field) characterizing different instruments are measured
- A music piece is played on one instrument, and recorded in anechoic environment
- The impulse response of this instrument is inverted
- The anechoic recording is deconvolved by convolution with the inverse filter
- The deconvolved recording is used as the starting point for subsequent reconvolutions with the IRs of the different instruments

Measurement method #1: MLS

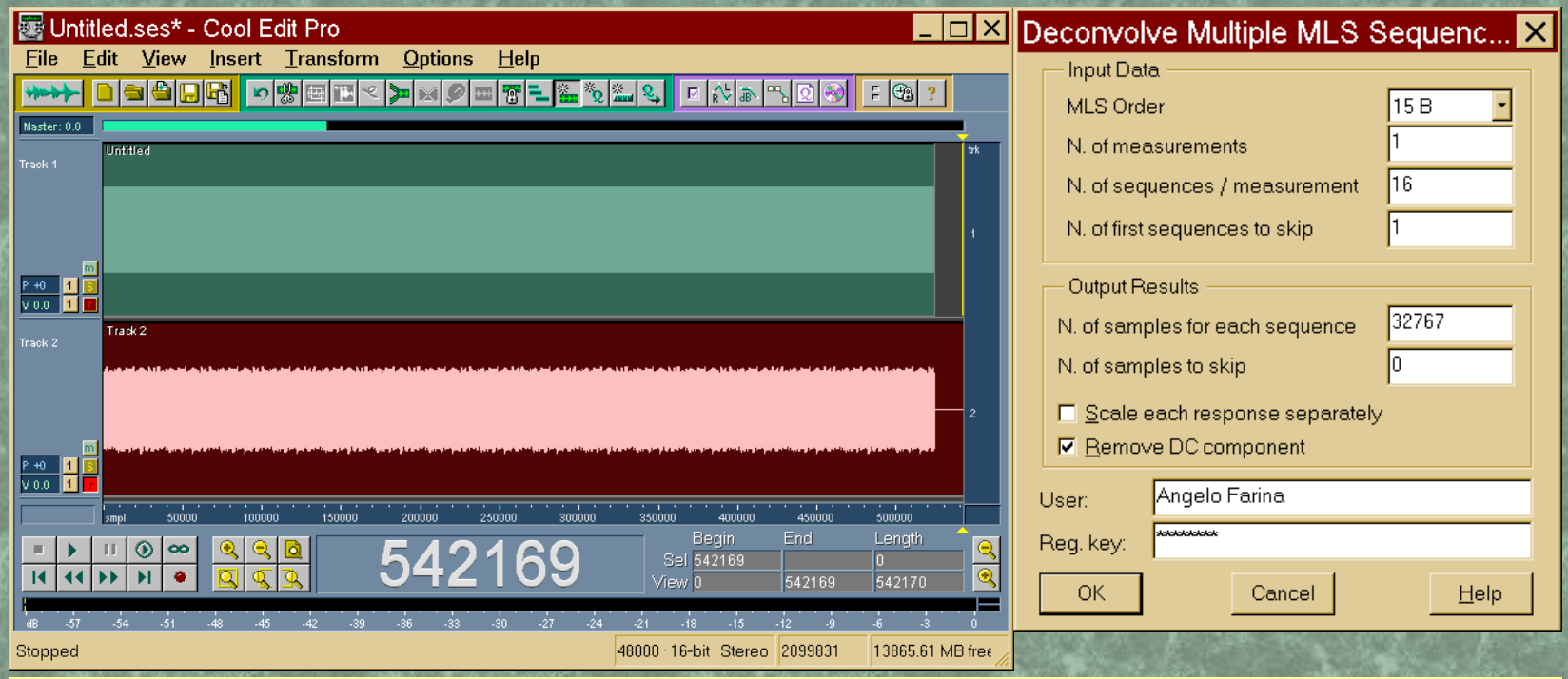


Shift register of order N



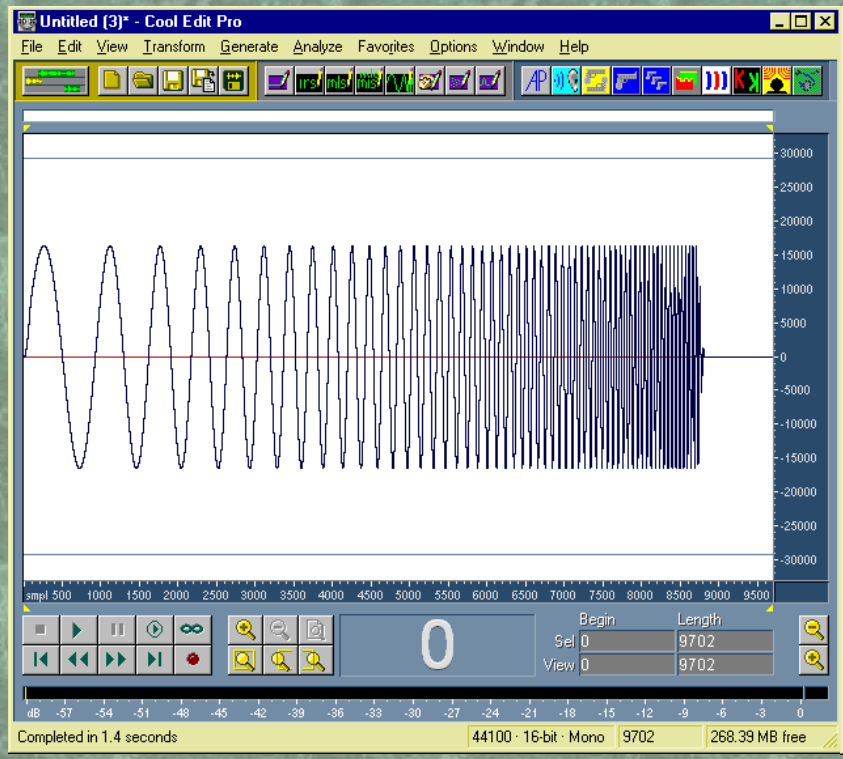
Binary Maximum Lenght sequence of order N=5

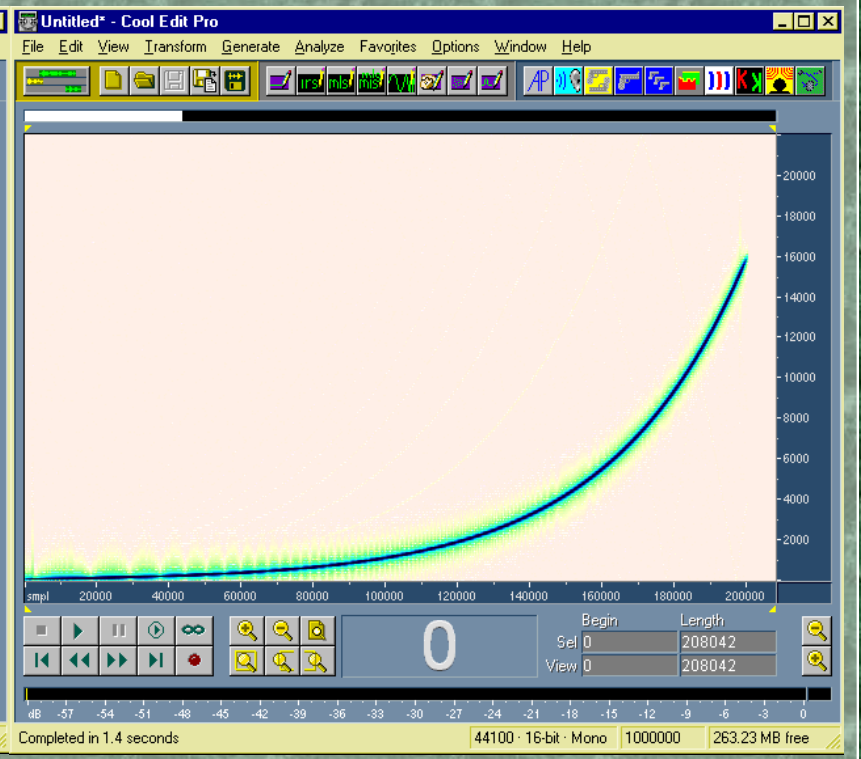
MLS Method: Impulse Response deconvolution



- CoolEditPro is employed for simultaneous playback and recording – thereafter, a special plug-in is invoked for deconvolving the impulse response

Measurements method #2: exponential sweep

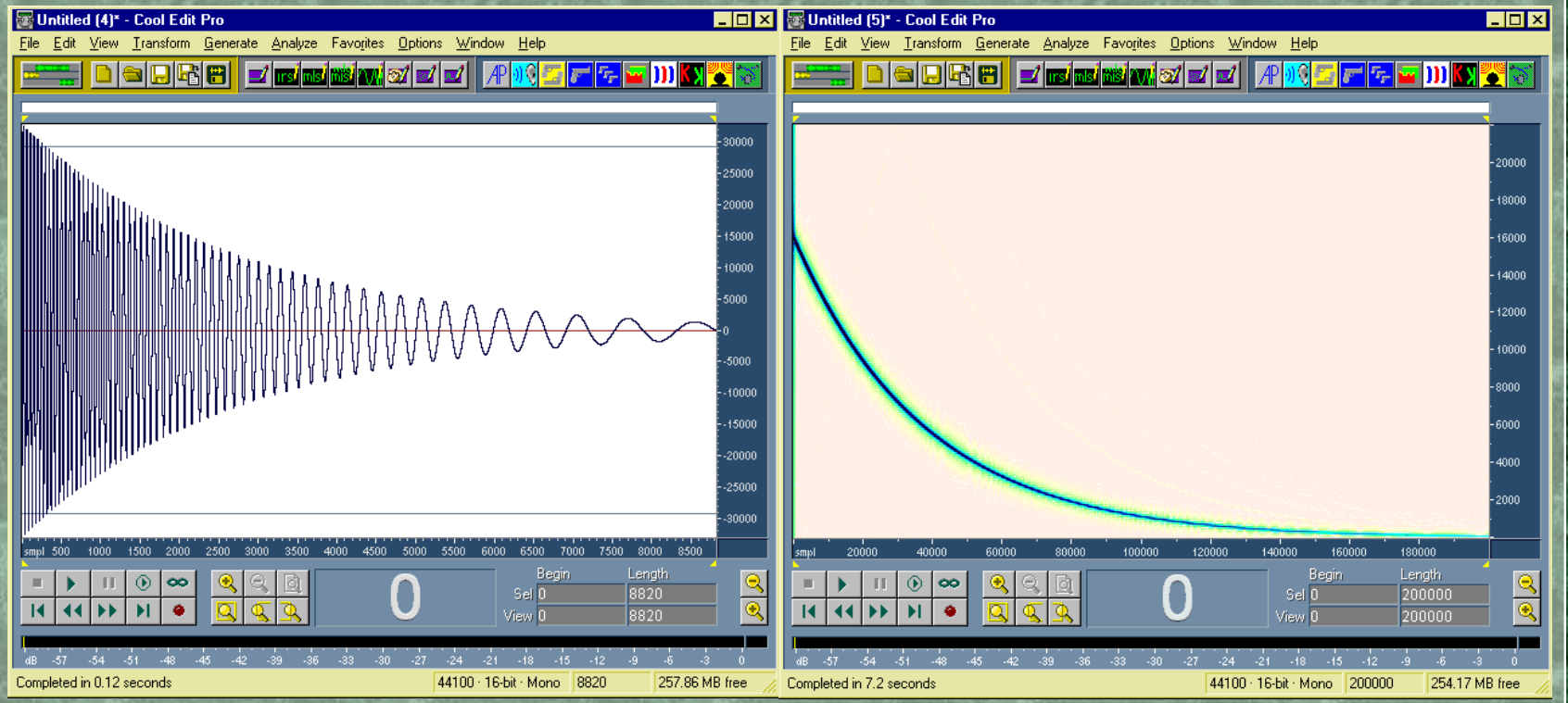




The test signal is a sine sweep:

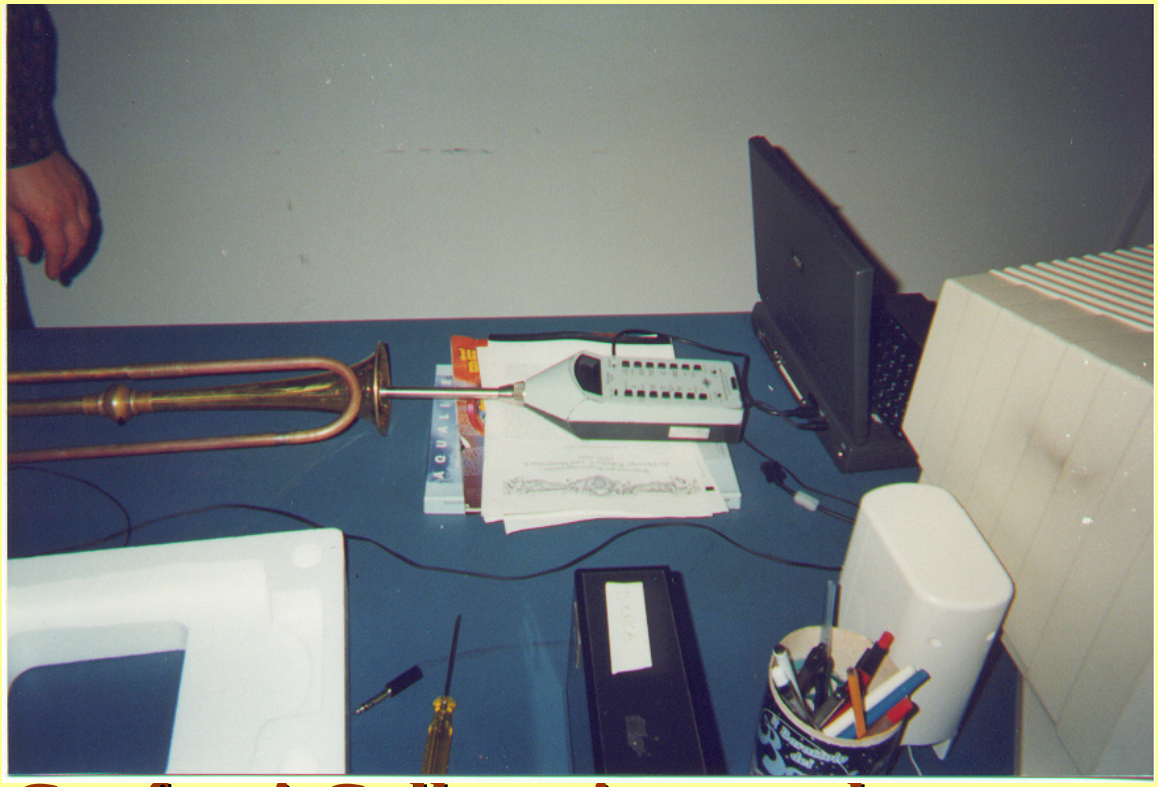
the frequency exponentially increases with time

Sweep method: impulse response deconvolution



- The impulse response is recovered by convolving the system's response with a proper inverse filter, obtained by the time-reversal mirror of the excitation signal, with a 6dB/octave equalization

Measurements on first trumpet



Conforzi-Callegari natural trumpet

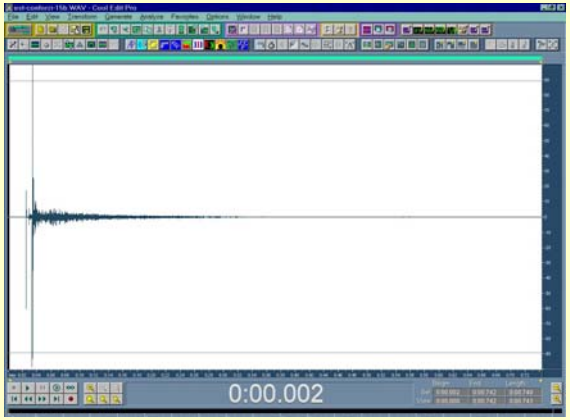
(a tonal copy of the "Wilhelm Magnus Ehe I" model, XVII century)

Measurements on second trumpet

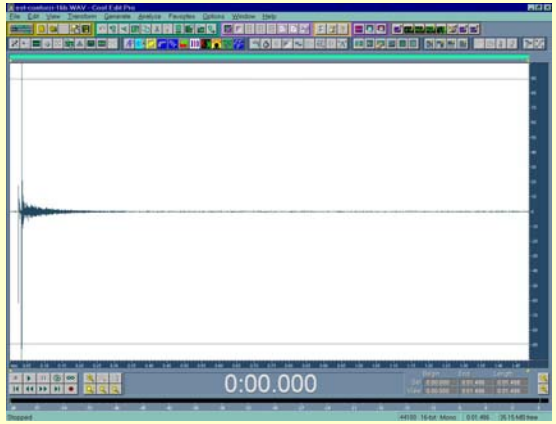
Hunting-trumpet Meinl&Lauber

Results of the measurements

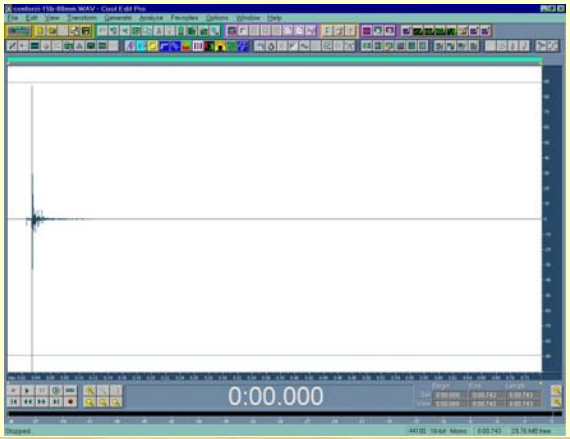
C.C. - MLS 15B



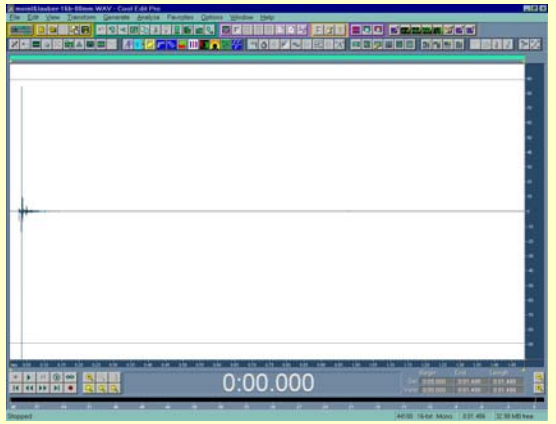
C.C. - exponential sweep



ML - MLS 15B



ML – Exponential sweep



Computation of inverse filters

with the Kirkeby (Farina) method

The original response h(t) is first FFT transformed:

$$C(\omega) = FFT[h(t)] \qquad (1)$$

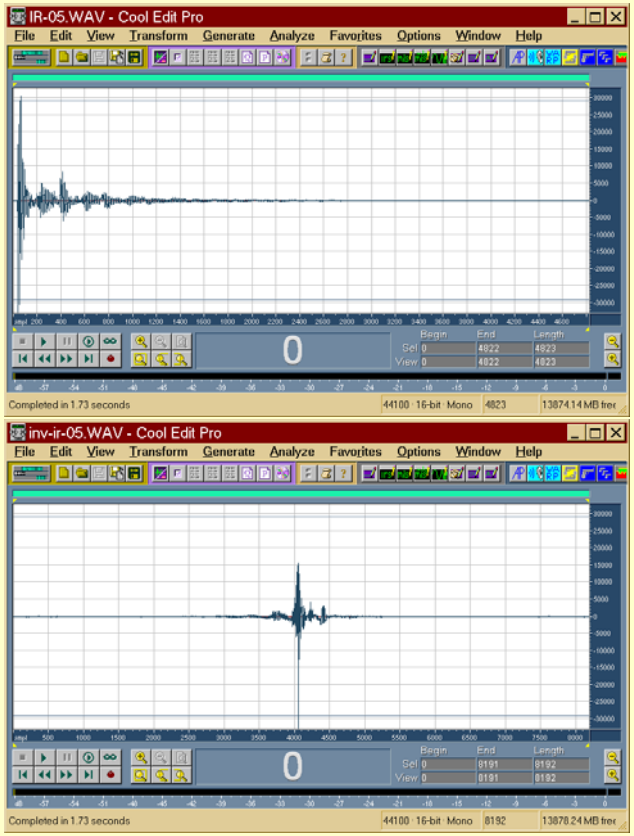
Then the complex spectrum C is inverted:

$$C_{inv}(\omega) = \frac{Conj[C(\omega)]}{Conj[C(\omega)] \cdot C(\omega) + \varepsilon(\omega)} \qquad (2)$$

And the result is back-transformed to time domain

$$h_{inv}(t) = IFFT[C_{inv}(\omega)] \qquad (3)$$

The measurements of IR and FIR



IR measurements:

- Maximum length sequence
- Exponential sine sweep

Inverse Filter calculation:

- Toeplitz technique (Morjoupolous 1985)
- Kirkeby technique (Kirkeby, Farina 1998)

The reconstruction of sound

A

B

C

D

A-original (Conforzi-Callegari)
C-reconvolved (as A)

B-dry (deconvolved)
D-with IR of hunting-trumpet

Conclusions and remarks:

- The measurement of IR is feasible in trumpets – the sweep method is better than MLS
- The computation of inverse filter is better with Kirkeby-Farina method
- The measurements could be improved with smaller microphones (1/4”)

Future developments

- As the new sweep measurement method also characterizes the not-linear response of the instrument, a multiple order convolution will be employed for attempting the virtual recreation of the harmonic distortion.
- The reciprocity method will be attempted (as already done on violins)
- A subjective listening experiment will be started, for trying to understand the connection between measurable objective parameters and the perceived musical quality

Internet references

- CIARM site on musical acoustics:

HTTP://www.ciarm.ing.unibo.it

- Aurora site (software plug-ins for measurements and convolution):

HTTP://www.ramsete.com/aurora (info)

FTP://pcangelo.ramsete.com/aurora (download)