Contrasting Log Sine Sweep method and MLS for room acoustics measurements

Angelo Farina

Industrial Engineering Dept., University of Parma, Via delle Scienze 181/A

Parma, 43100 ITALY – **HTTP://pcfarina.eng.unipr.it**

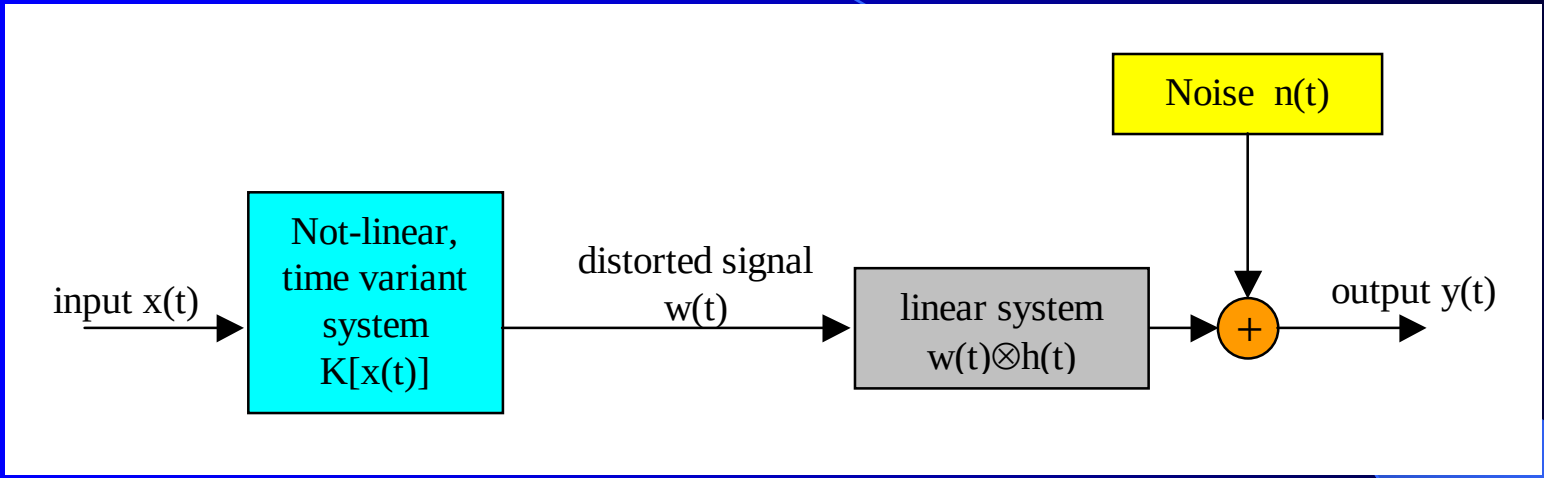
Outline

- The basis of classic MLS and new Log Sine Sweep methods are presented
- The main problems of MLS are related to nonlinearity and time variance of the system
- The new method presented here overcomes to these strong limitations, resulting in improved robustness and better S/N

Methods

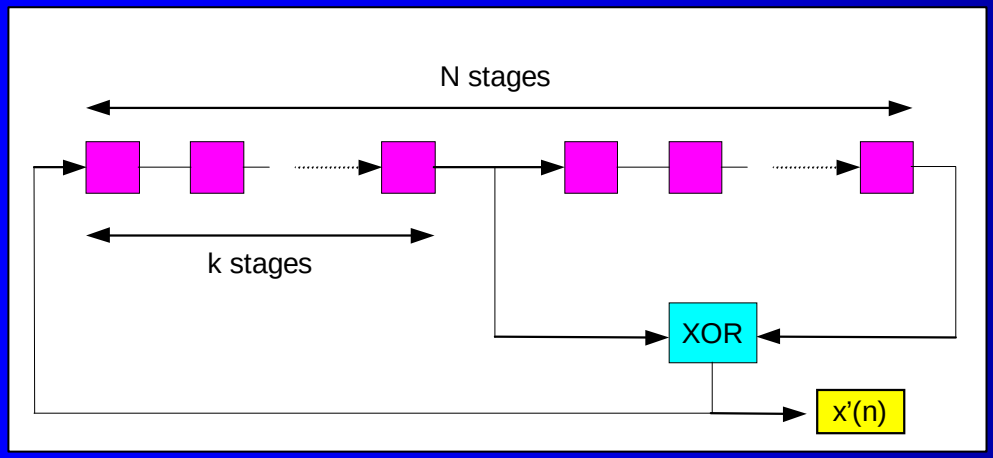
- Theoretical analysis of both MLS and “time reversal mirror” approaches to the determination of the transfer function of a system
- The choice of a special log sine sweep allows for the symultaneous measurement of distortion and linear response of not-linear systems
- Avoiding any kind of averages, the log sweep method becomes substantially immune to clock mismatch and time variance

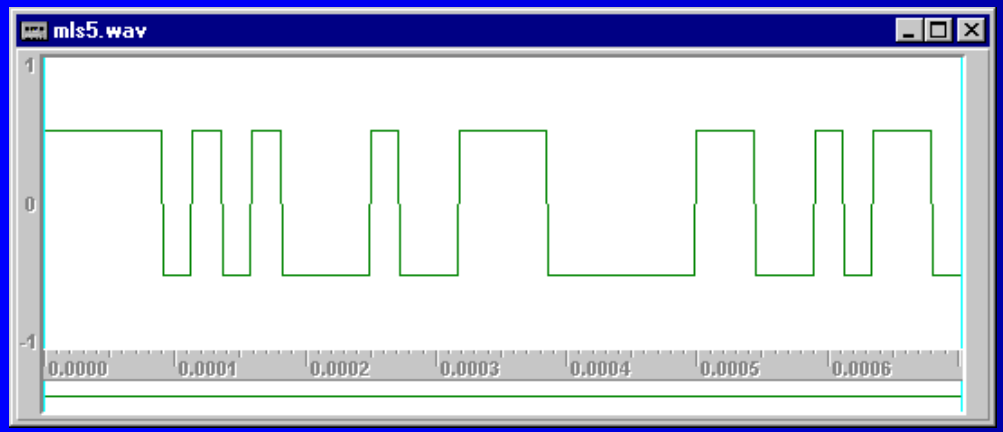
Measurement principle



- We are interested in the linear impulse response h(t). This can be estimated by the knowledge of the input signal x(t) and of the output signal y(t). The influence of the not-linear part K and of the noise n(t) has to be minimized.

THE MLS method





- X(t) is a periodic binary signal obtained with a suitable shift-register, configured for maximum lenght of the period.

$$L = 2^{N-1}$$

MLS deconvolution

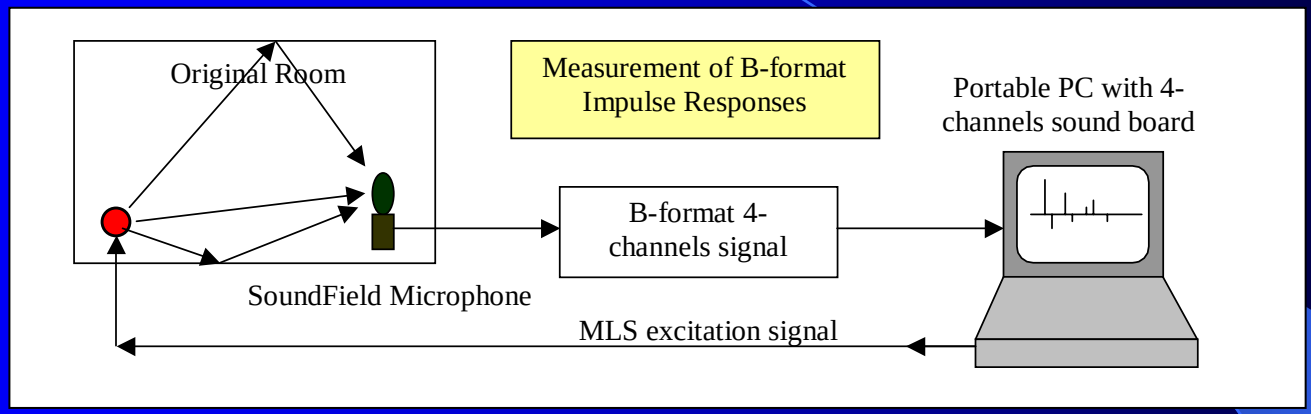
- The re-recorded signal y(i) is cross-correlated with the excitation signal thanks to a fast Hadamard transform. The result is the required impulse response h(i), if the system was linear and time-invariant

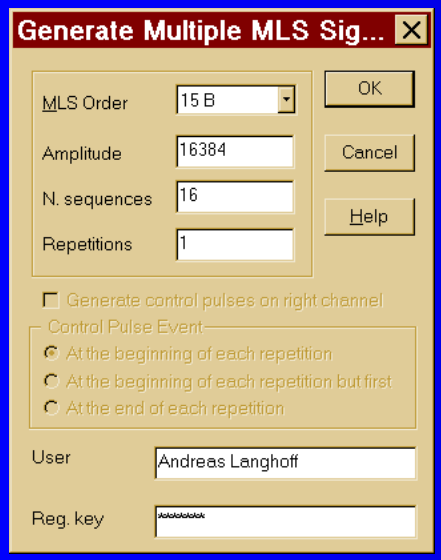
$$h = \frac{1}{L+1} \cdot \tilde{M} \cdot y$$

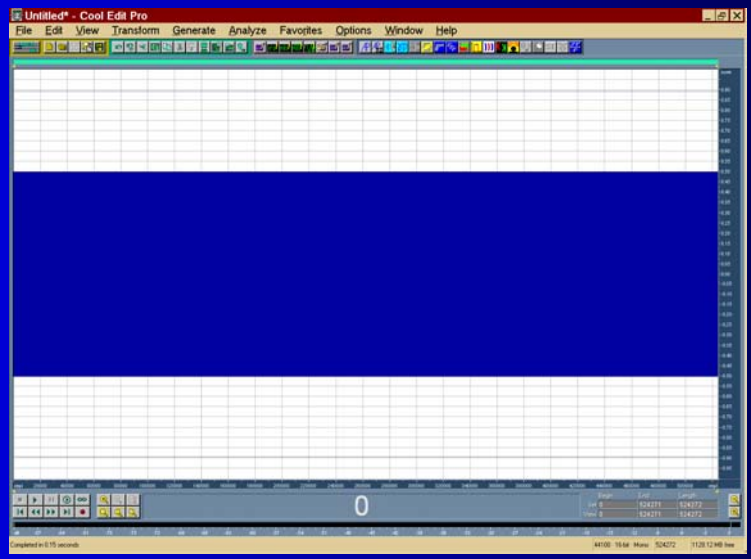
- Where M is the Hadamard matrix, obtained by permutation of the original MLS sequence m(i)

$$\tilde{M}(i, j) = m\left[\left(i + j - 2\right) \bmod L\right] - 1$$

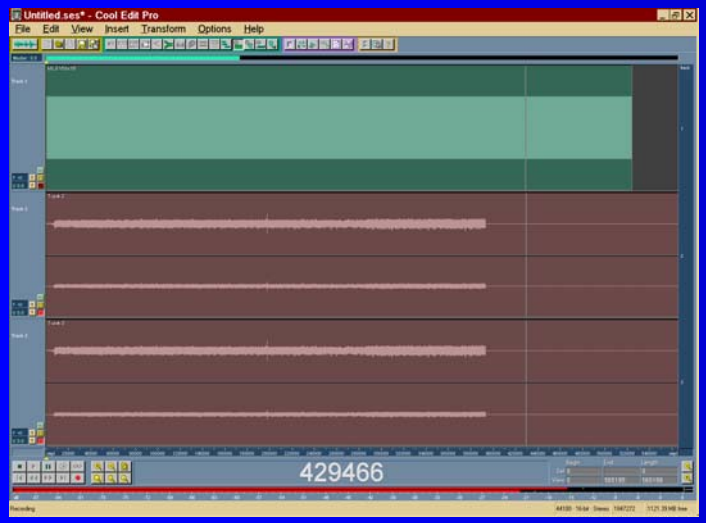
MLS example

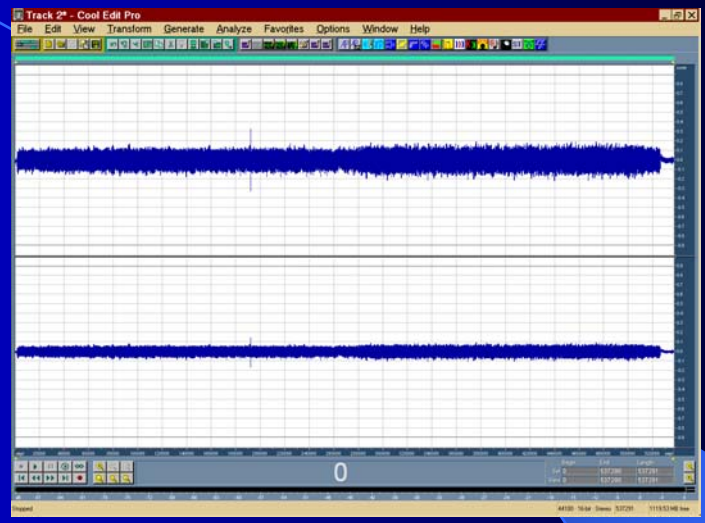

Original Room
Measurement of B-format Impulse Responses
Portable PC with 4-channels sound board
B-format 4-channels signal
SoundField Microphone
MLS excitation signal

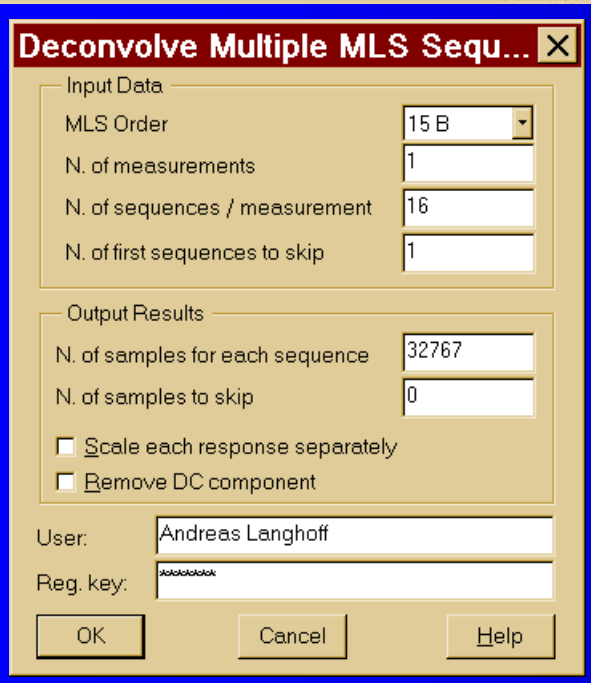

Generate Multiple MLS Sig...
MLS Order
15 B
Amplitude
16384
N. sequences
16
Repetitions
1
OK
Cancel
Help
Generate control pulses on right channel
Control Pulse Event
At the beginning of each repetition
At the beginning of each repetition but first
At the end of each repetition
User
Andreas Langhoff
Reg. key

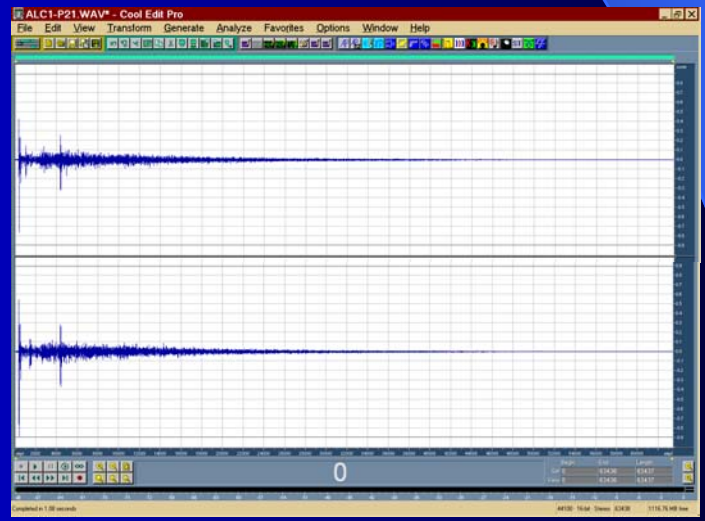

Untitled* - Cool Edit Pro
File Edit View Transform Generate Analyze Favorites Options Window Help

MLS example


Untitled.ses* - Cool Edit Pro
File Edit View Insert Transform Options Help
429466


Track 2* - Cool Edit Pro
File Edit View Transform Generate Analyze Favorites Options Window Help
0


Deconvolve Multiple MLS Sequ...
Input Data
MLS Order
15 B
N. of measurements
1
N. of sequences / measurement
16
N. of first sequences to skip
1
Output Results
N. of samples for each sequence
32767
N. of samples to skip
0
Scale each response separately
Remove DC component
User:
Andreas Langhoff
Reg. key:
OK
Cancel
Help


ALC1-P21.WAV* - Cool Edit Pro
File Edit View Transform Generate Analyze Favorites Options Window Help
0

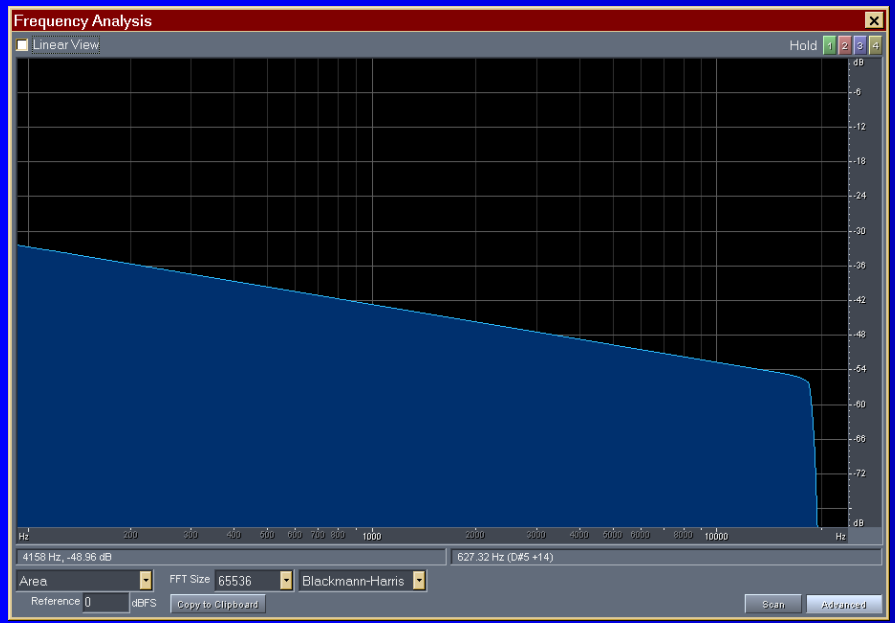
THE Log Sine Sweep method

- X(t) is a sinusoidal signal signal, the frequencing being variable with an exponential function of time.

$$x(t) = \sin\left[\frac{\omega_1 \cdot T}{\ln\left(\frac{\omega_2}{\omega_1}\right)} \cdot \left(e^{\frac{t}{T}\cdot \ln\left(\frac{\omega_2}{\omega_1}\right)} - 1\right)\right]$$

Log Sine Sweep deconvolution

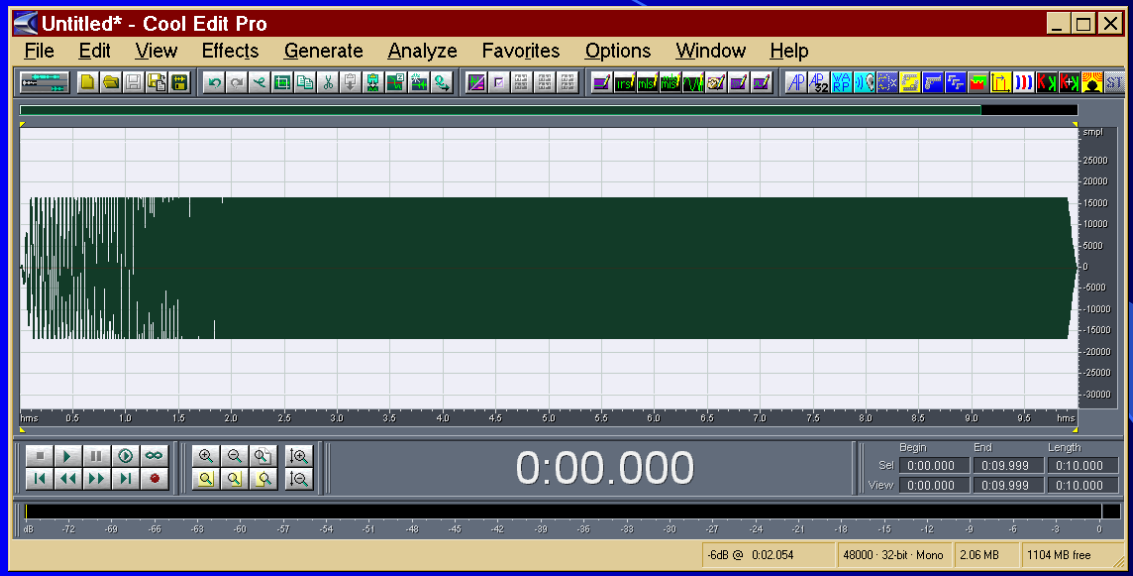
- The “time reversal mirror” approach is based on the convolution with the time-reversal of the excitation signal. If its spectral content is not white, proper amplitude equalization is required.

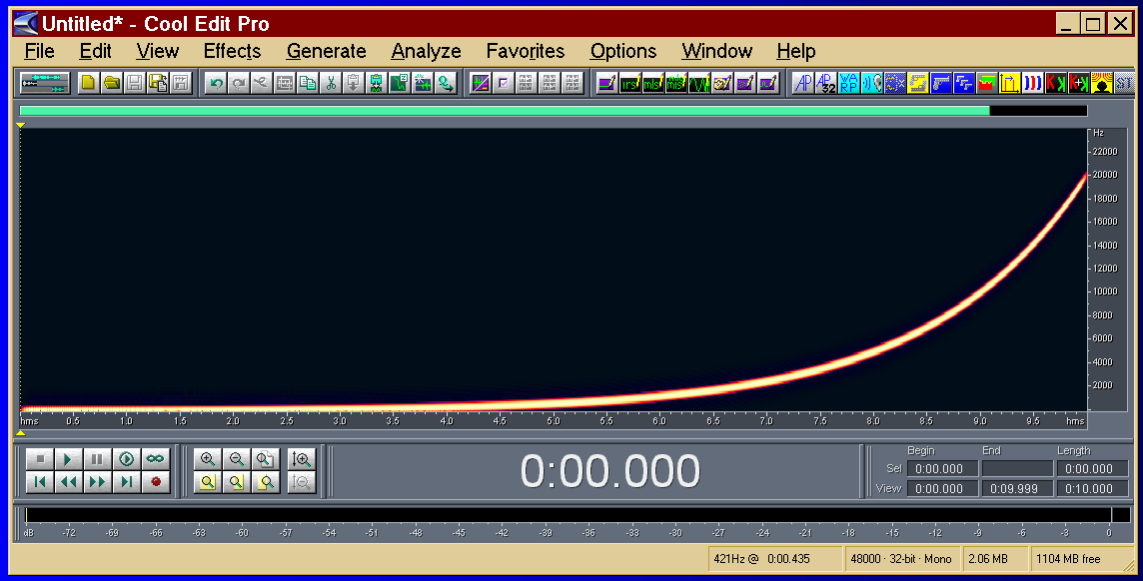


Excitation signal x(t)

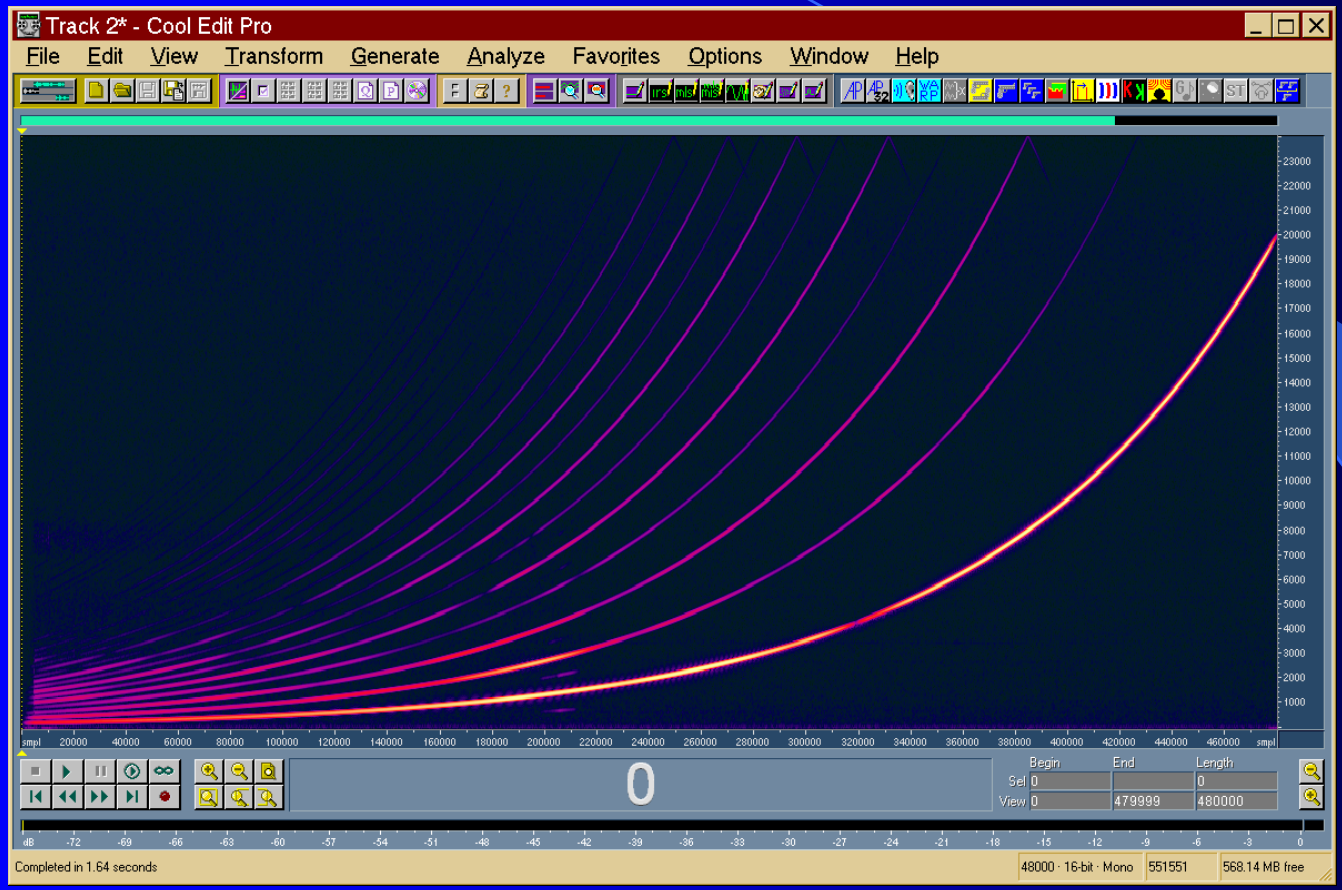
Inverse filter z(t)

Exponential sweep measurement



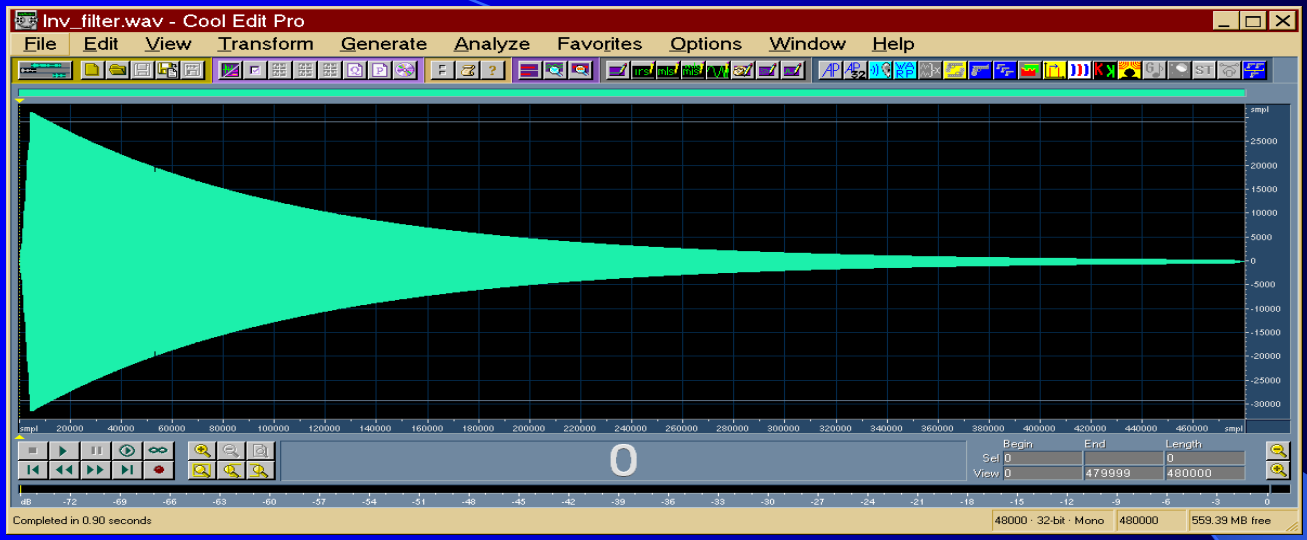


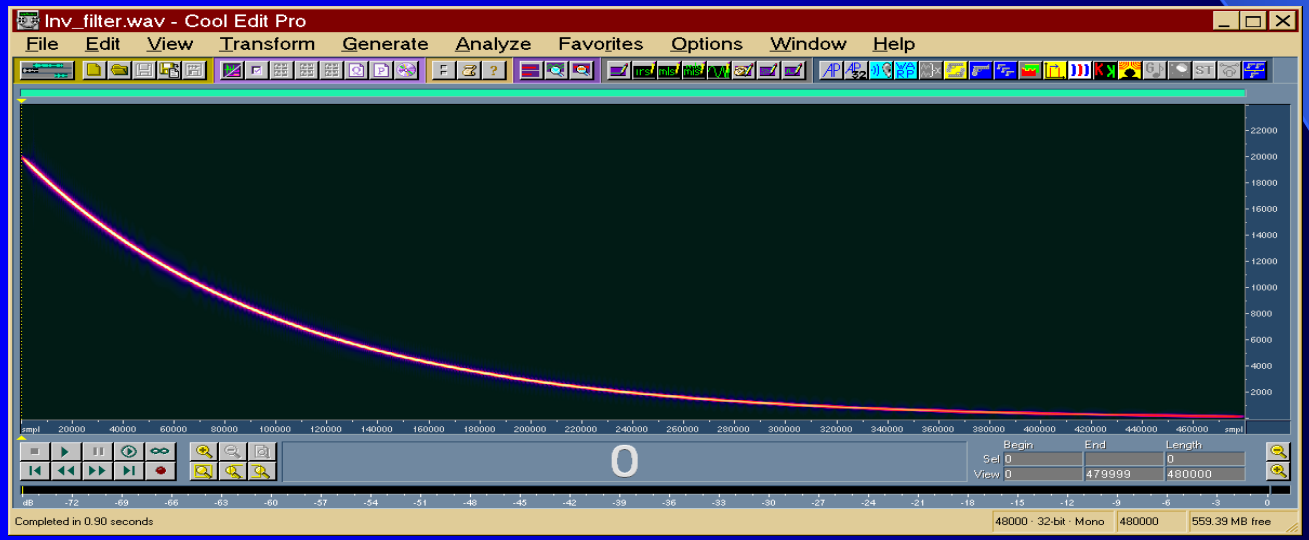
Raw response of the system



Many harmonic orders do appear as colour stripes

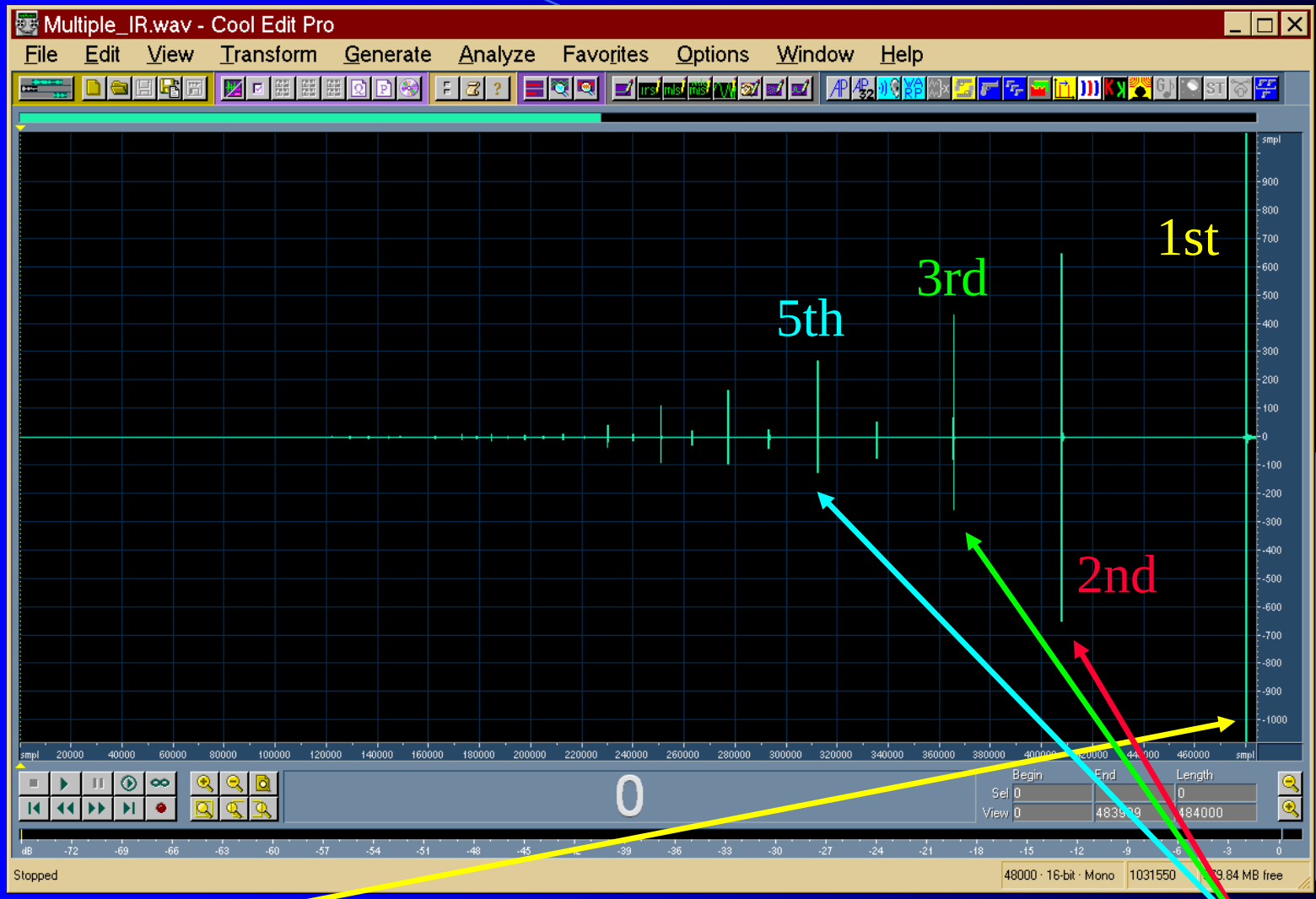
Deconvolution of system's impulse response





The deconvolution is obtained by convolving the raw response with a suitable inverse filter

Multiple impulse response obtained



The last peak is the linear impulse response, the preceding ones are the harmonic distortion orders

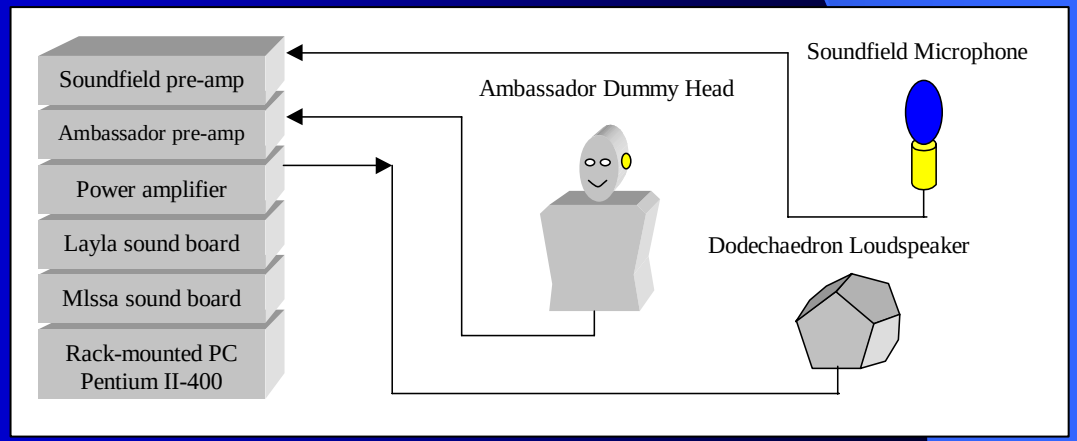
Comparative experiments

Inter-comparison between different room acoustics measurement tools
Organized by the AES Italian Section
(Bergamo's Workshop 1999, 27/28 april 1999)

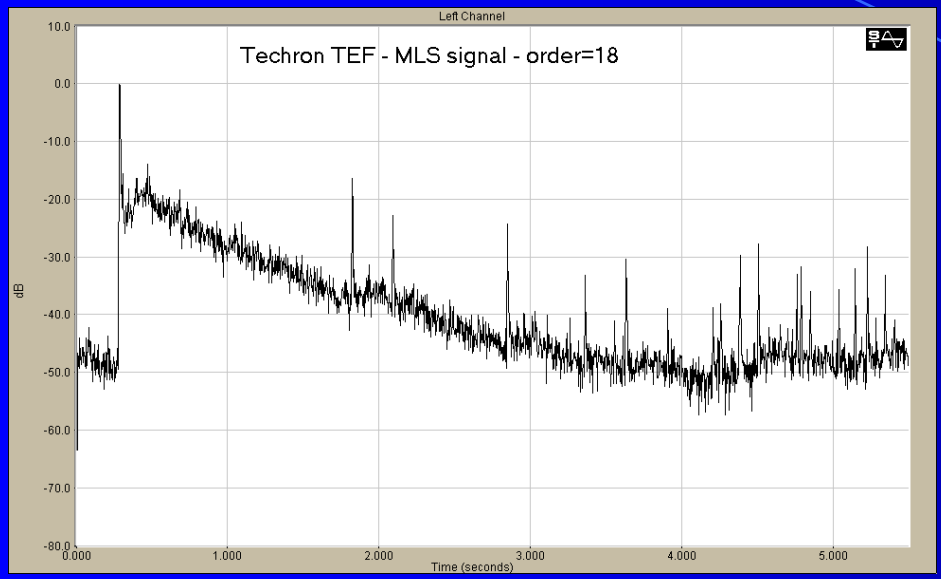
The results are summarized on **HTTP://aurora.ramsete.com**

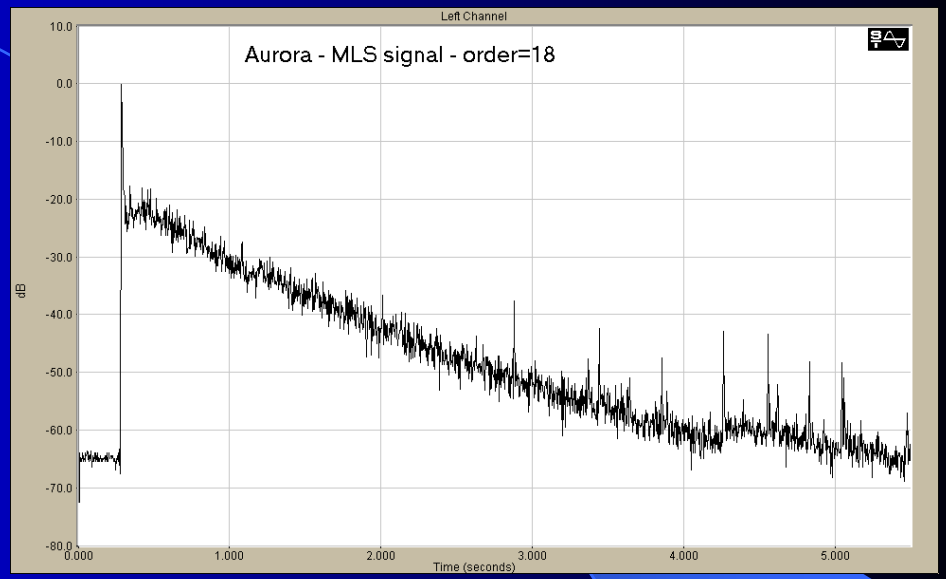
Researcher	Measuring system/method	Loudspeaker	Microphone
Angelo Farina	Aurora (synchronous measurement on PC+Layla) – MLS	Dodechaedron (Look Line D1)	Soundfield MKV + binaural (Ambassador)
Angelo Farina	Aurora (synchronous measurement on PC+Layla) – log sweep	Dodechaedron (Look Line D1)	Soundfield MKV + binaural (Ambassador)
Angelo Farina	MLSSA board – MLS	Dodechaedron (Look Line D1)	Soundfield channel W
A. Ricciardi	MLSSA board – MLS	Directional, custom-made	Stage Accompany omnidirectional
Walter Conti	Techron TEF 20 – MLS & TDS	Directional, custom-made	B&K Omnidirectional
Nicola Prodi	Aurora (asynchronous playback & record through a Tascam DA38 recorder) – log sweep	Dodechaedron (Look Line D2)	Soundfield ST250 + binaural (Neumann KU-100)

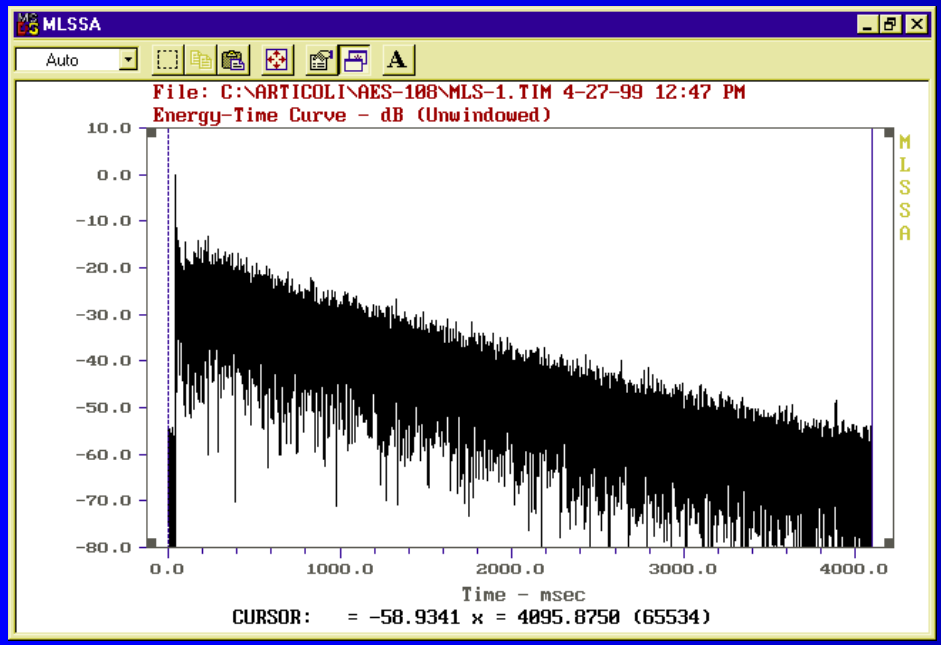
Equipment

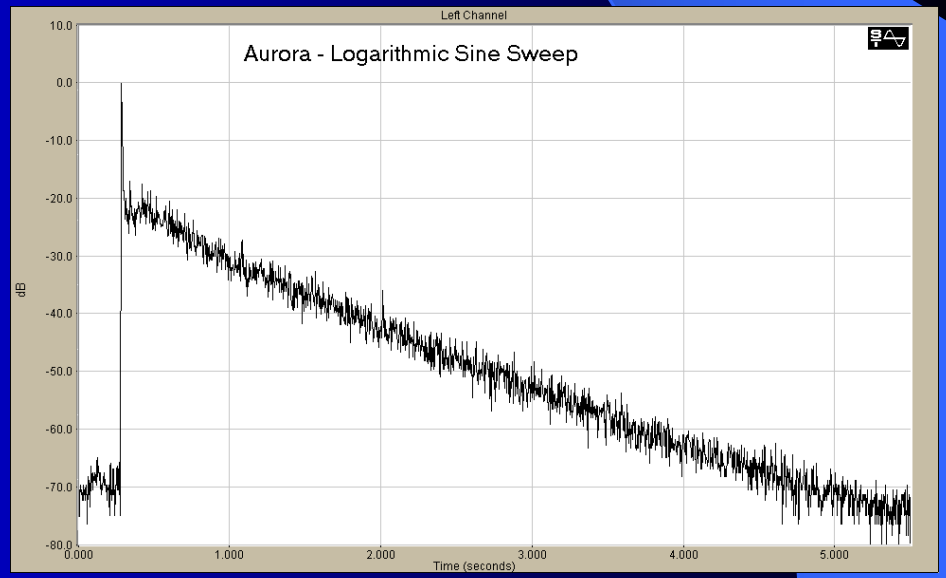

Soundfield pre-amp
Ambassador pre-amp
Power amplifier
Layla sound board
Mlssa sound board
Rack-mounted PC
Pentium II-400
Ambassador Dummy Head
Soundfield Microphone
Dodechaedron Loudspeaker

Results


Left Channel
Techron TEF - MLS signal - order=18
dB
Time (seconds)


Left Channel
Aurora - MLS signal - order=18
dB
Time (seconds)


MLSSA
Auto
File: C:\ARTICOLI\AES-108\MLS-1.TIM 4-27-99 12:47 PM
Energy-Time Curve - dB (Unwindowed)
MLSSA
Time - msec
CURSOR: = -58.9341 x = 4095.8750 (65534)


Left Channel
Aurora - Logarithmic Sine Sweep
dB
Time (seconds)

Conclusions

- The Log Sine Sweep method outperforms all other known (TDS, MLS, etc.)
- The implementation is simple (no specialized software required, CoolEdit already does it)
- Specific plugins for CoolEdit were developed for making even simpler to generate and deconvolve the linear impulse response, and to extract also information about harmonic distortion

Final remarks

- The CoolEdit plugins shown here are shareware: they are downloadable from HTTP://www.ramsete.com/aurora