Peak Pro 5 Sample Rate Converter
Comparison with Other Audio Applications

BIAS Inc.
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We present the results of our quality assessment of Peak Pro 5's new sample rate converter (SRC). Eleven audio applications were compared with BIAS Peak Pro 5 in terms of sample rate conversion quality. A set of test signals was converted with all applications and spectral analysis was performed to detect artifacts in the converted signals. Results consistently show that the SRC algorithm in Peak Pro 5 provides top-quality conversion in today's market. We provide here all the information necessary for other parties to reproduce our quality evaluation tests: test signals, conversion parameters specific to each application, and spectrogram analysis parameters.

SAMPLE RATE CONVERSION

Sample Rate Conversion (SRC) is a process by which the audio sample rate gets changed without affecting the pitch of the audio. This process is necessary in different situations: Digital Audio Workstation (DAW) users often record and edit at a high sample rate, and then down-sample the audio to get it onto various media. This sample rate conversion can either be done by the DAW during or after the bounce, or in a separate application after bouncing. In another scenario, sample rate conversion is necessary when audio material recorded for a specific media (e.g. CD) gets transferred to a different media (e.g. DVD, DAT or Digital Video). For example, a DVD audio project requires sample rate conversion from 96 kHz to 44.1 kHz in order to be transferred to CD, and a CD audio project requires conversion from 44.1 kHz to 48 kHz to be transferred to Digital Video format.

Needless to say, it is very important for the sample rate conversion to be as transparent as possible. Ideally, when converting from an original into a new sample rate, we would like the converted signal fidelity to be as high as if we had directly sampled it from the original analog signal. This degree of perfect transparency is possible only in theory, since we would need a computer with infinite memory and infinite processing power to achieve it. In practice, however, a very high degree of transparency can be achieved with a high-quality sample rate converter.

The most common source of artifacts introduced by sample rate conversion is aliasing. Aliasing results in spurious frequency components added to the spectrum and it occurs in the following cases:

- The audio is up-sampled and frequency content above half the original sample rate is not sufficiently filtered out by the converter. The spectral "image" (see DSP theory references at end of this section) shows up in the converted audio as spurious frequencies. This kind of aliasing is called "imaging".
- The audio is down-sampled and the converter does not properly filter out all frequency content beyond half the new sample. Frequency components that were **below** half the **original** sample rate, now falling **beyond** half the **new** sample rate, appear as spurious lower frequencies (therefore the term "aliasing") in the

converted audio. The spectral image of the original audio (again, please see DSP theory references) also aliases and creates spurious frequency components.

Other sources of noise introduced by the conversion process are distortion and numerical errors such as round-off and calculation jitter, which typically raise the noise floor.

DSP Theory References

The reader interested in understanding the theory behind aliasing and imaging is referred to an excellent online reference:

http://en.wikipedia.org/wiki/Aliasing

And also to one of the numerous textbooks on Digital Signal Processing theory, such as:

Discrete-Time Signal Processing, Oppenheim Alan, et al., 1989, Prentice Hall.

THE NEW SAMPLE RATE CONVERTER IN PEAK PRO 5

Peak Pro 5 implements a sample rate conversion algorithm of very high quality. The algorithm allows the user to trade-off audio fidelity against CPU load, by setting a "quality" parameter from the DSP preferences (the higher the parameter value, the higher the fidelity and CPU load). Moreover, the flexibility of the algorithm allows conversion into any target sample rate, including non-standard values. For example, a file at 44.1 kHz can be converted to an absolutely arbitrary, non-standard rate of 53,724 Hz.

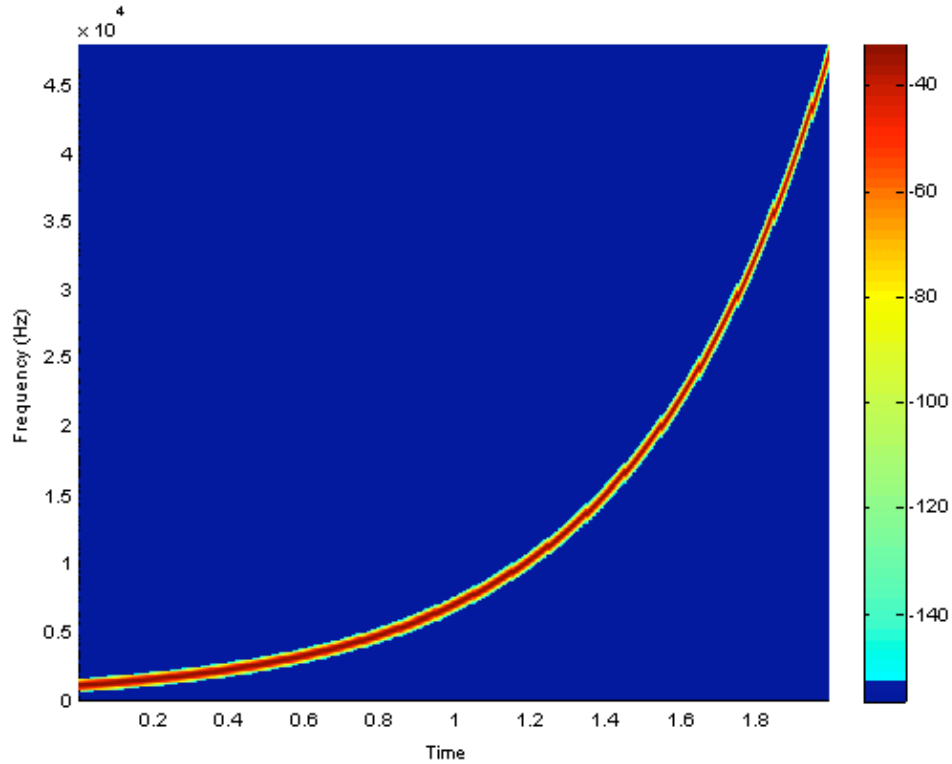
TEST DESCRIPTION

Our tests consisted in performing a series of sample rate conversions between different rates (44.1, 48 and 96 kHz) on a set of test signals, using Peak Pro 5 and other eight popular applications in the audio market. Spectral analysis was performed on the converted signals, and a spectrogram was generated and plotted for each signal.

Spectrogram Analysis

The spectrogram is a very useful way to visualize spectral data and detect artifacts that cannot be easily seen in the time-domain waveform. It consists of a graph with time on the X-axis, frequency on the Y-axis, and a color map that represents energy. In other words, the color of the plot indicates how much energy the signal contains around a certain frequency and at a certain time.

For example, the figure below shows a spectrogram of a frequency sweep, with frequency varying from 1000 Hz to 48 kHz in 2 seconds.



The "color map" showing the mapping from colors to levels in dB is shown as a vertical bar on the right of the graph. The red line in the spectrogram shows high energy at the instantaneous frequency, whereas the blue background shows very low energy elsewhere in the spectrum.

Test Signals

The test signals used in our evaluation are frequency sweeps, that is, sine waves of gradually increasing frequency. Frequency increases logarithmically, thus varying more slowly in the low frequency range and more rapidly as frequency rises. The following three test signals were used, all with 24-bit resolution:

- Sweep with frequency increasing from 1 kHz to 48 kHz in 2 seconds, sampled at 96 kHz.
- Sweep with frequency increasing from 1 kHz to 24 kHz in 2 seconds, sampled at 48 kHz.
- Sweep with frequency increasing from 1 kHz to 22050 Hz in 2 seconds, sampled at 44.1 kHz.

Test Parameters

The following conversions were performed with all the applications:

- 96 kHz sweep converted to 44.1 kHz
- 44.1 kHz sweep converted to 96 kHz
- 48 kHz sweep converted to 44.1 kHz
- 44.1 kHz sweep converted to 48 kHz

Sample rate conversions were done at maximum quality setting for all the applications tested. For each converted signal, a spectrogram was computed using the following parameters:

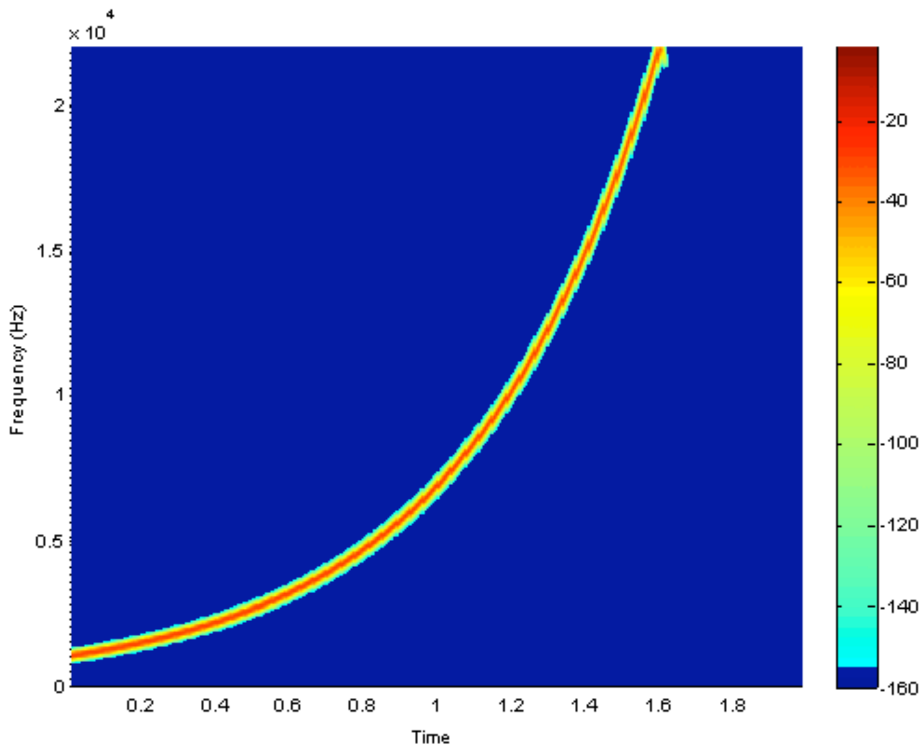
Analysis window length: 1024 samples
Analysis window type: Kaiser, with -160 dB side-lobe attenuation (Kaiser "beta" parameter = 16.6733)
Analysis window overlap: 768 samples (75% overlap)

Version Numbers and SRC Parameters Specific to Each Application

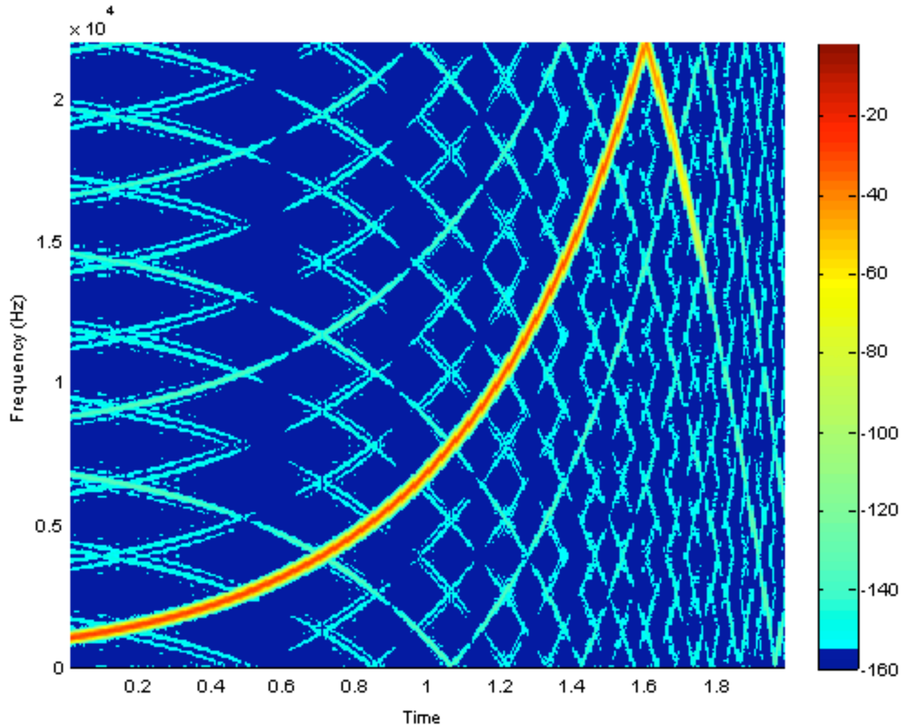
- Peak V5.02: SRC Quality set to "10" (maximum).
- Adobe Audition V1.5: SRC Quality set to "999" (maximum) with pre/post filter checked.
- BarbaBatch V4.0: Quality Setting set to "3" (maximum).
- Protools LE/002 V7.0: "tweakhead" setting (maximum SRC quality).
- DSP Quattro V2.1.1: SRC Quality set to "Excellent".
- Digital Performer V4.6: SRC Quality set to "Best".
- WaveLab 4.0: provides no quality setting.
- Cubase SX 3.1.1: provides no quality setting.
- SoundTrack Pro V1.0.1: provides no quality setting.
- SoundForge V8.0: Interpolation Accuracy Set To: "4" (maximum). The option to apply an anti-alias filter during resample was checked.
- Wave Editor V1.1.1: SRC Quality set to "Max".
- Logic Pro v.7.1.1: provides no quality setting.

INTERPRETING TEST RESULTS

The quality of conversion can be appreciated by looking at the spectrograms of the converted signals. The figure below shows the spectrogram of a frequency sweep converted from 96 kHz to 44.1 kHz with the SRC in Peak Pro 5: the red line represents the sweep, and the color everywhere else is very close to the original spectrogram, showing the transparency of the SRC (i.e. no added artifacts from aliasing or other sources). Notice that, as it is supposed to be, the red line now stops at the new "Nyquist Frequency", which is half the new sample rate (22050 Hz in this case).

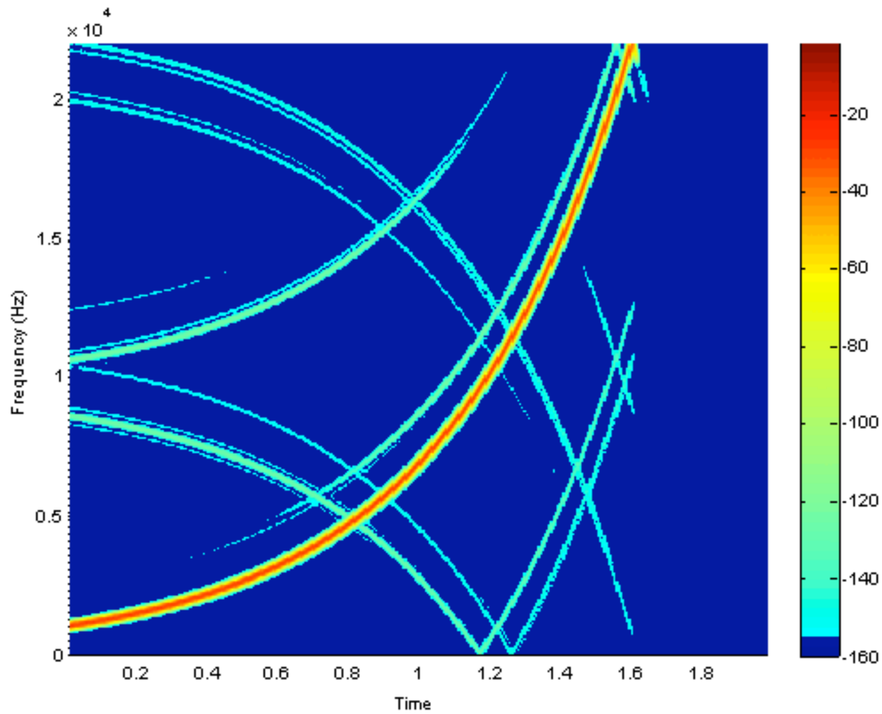


Noise introduced by the sample rate converter will show as lighter colors on top of the blue background. In particular, **aliasing/imaging** will show as spurious lines or dots of brighter color, whereas broadband noise due to **round-off error or calculation jitter** will make the background color brighter as the noise floor is raised. The figure below shows the spectrogram of the same frequency sweep, this time converted from 96 kHz to 44.1 kHz with another application:

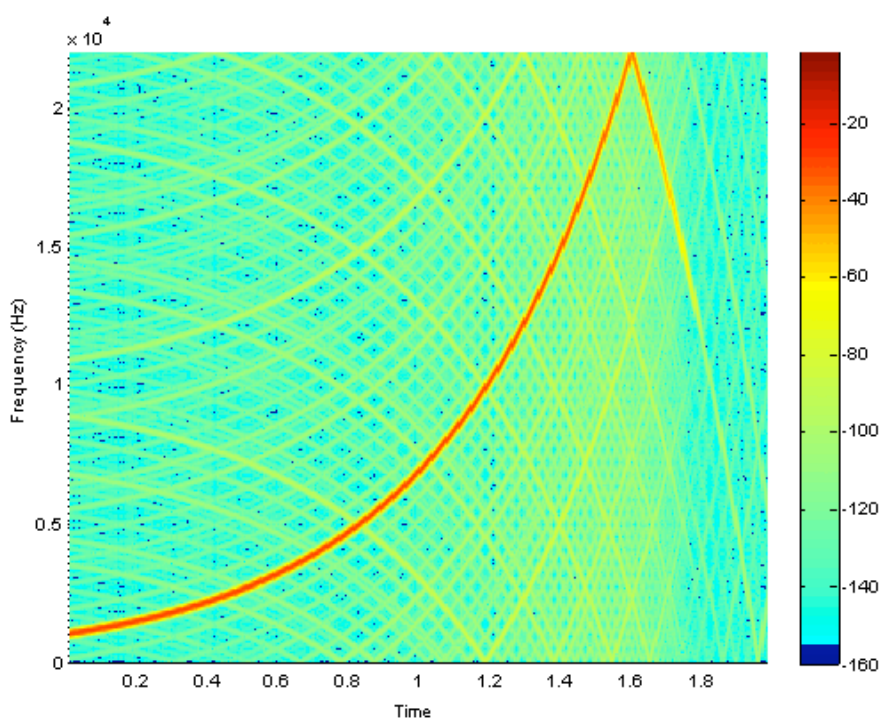


After the sweep frequency (red line) reaches the Nyquist frequency of 22050 Hz (i.e. half the new sample rate of 44.1 kHz), it aliases back towards decreasing frequencies. We can see that the line is still red when frequency starts decreasing, showing a high level of aliasing. The light-blue lines represent imaging artifacts, i.e. frequencies from the spectral image of the original sweep that aliased back onto the converted signal's spectrum.

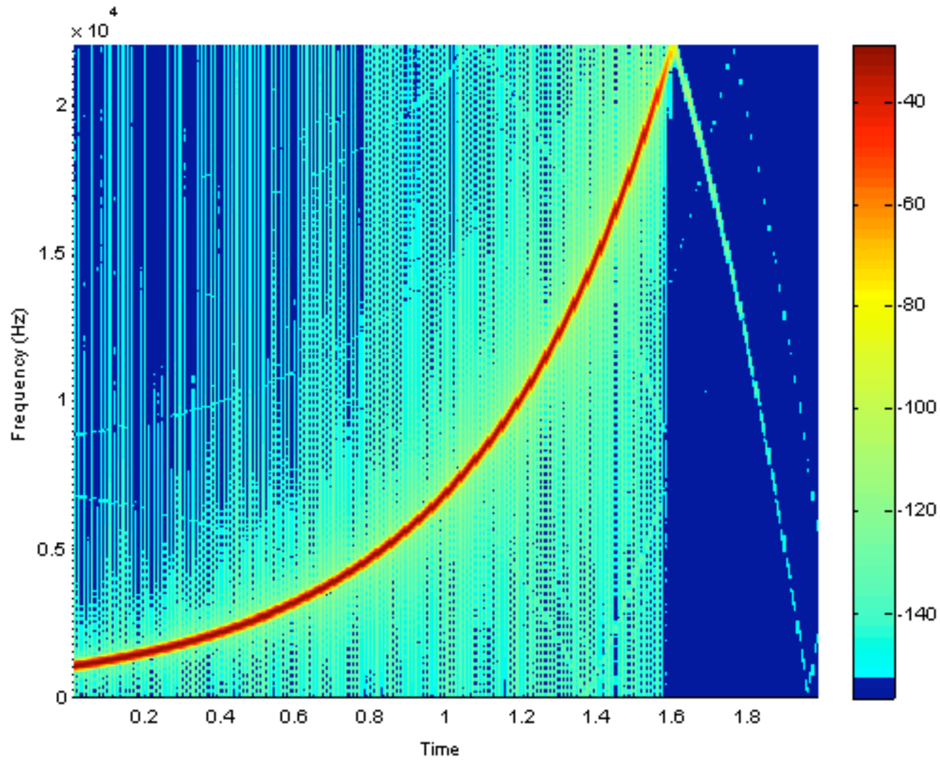
Below is another example of imaging artifacts after conversion with a different SRC, showing spurious frequency components in light blue.



A brighter background in the spectrogram shows the noise floor has been raised as a consequence of numerical errors (round-off, jitter, etc), as shown in the spectrogram below, corresponding to a conversion with a different SRC. We can also see strong aliasing and imaging lines in yellow and red:



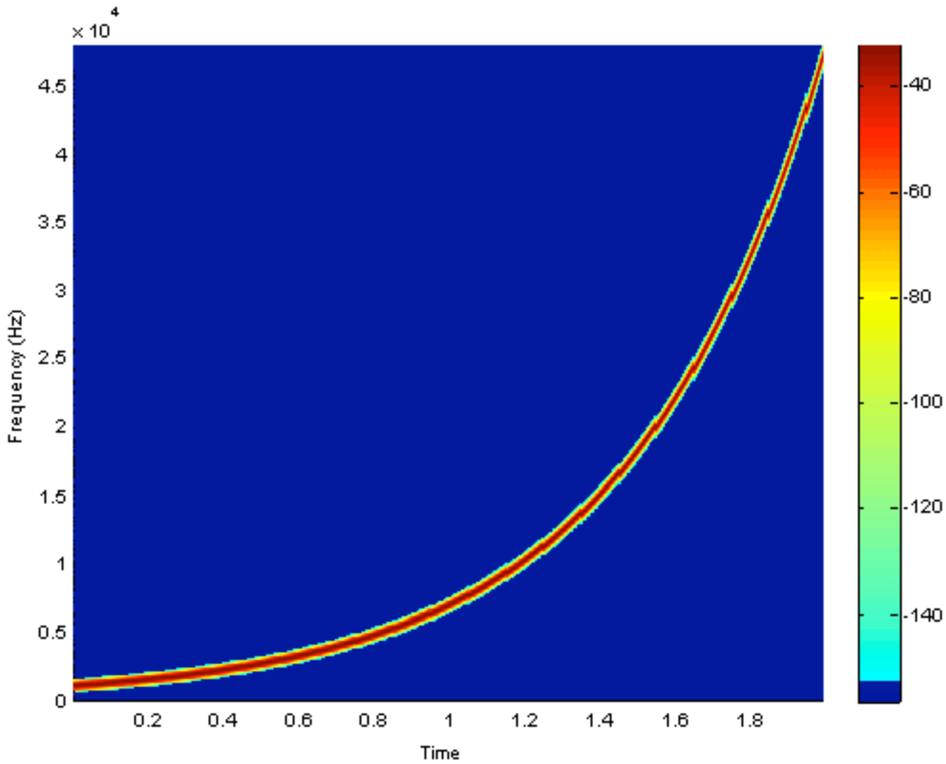
As a last example, some SRC algorithms can introduce distortion in the signal. The spectrogram below shows vertical lines between light blue and yellow, each line corresponding to a sudden raise of the spectrum across the whole frequency range, probably due to low-amplitude discontinuities produced by the SRC. We can also see aliasing lines underneath the discontinuities and after the sweep frequency reaches the Nyquist frequency.



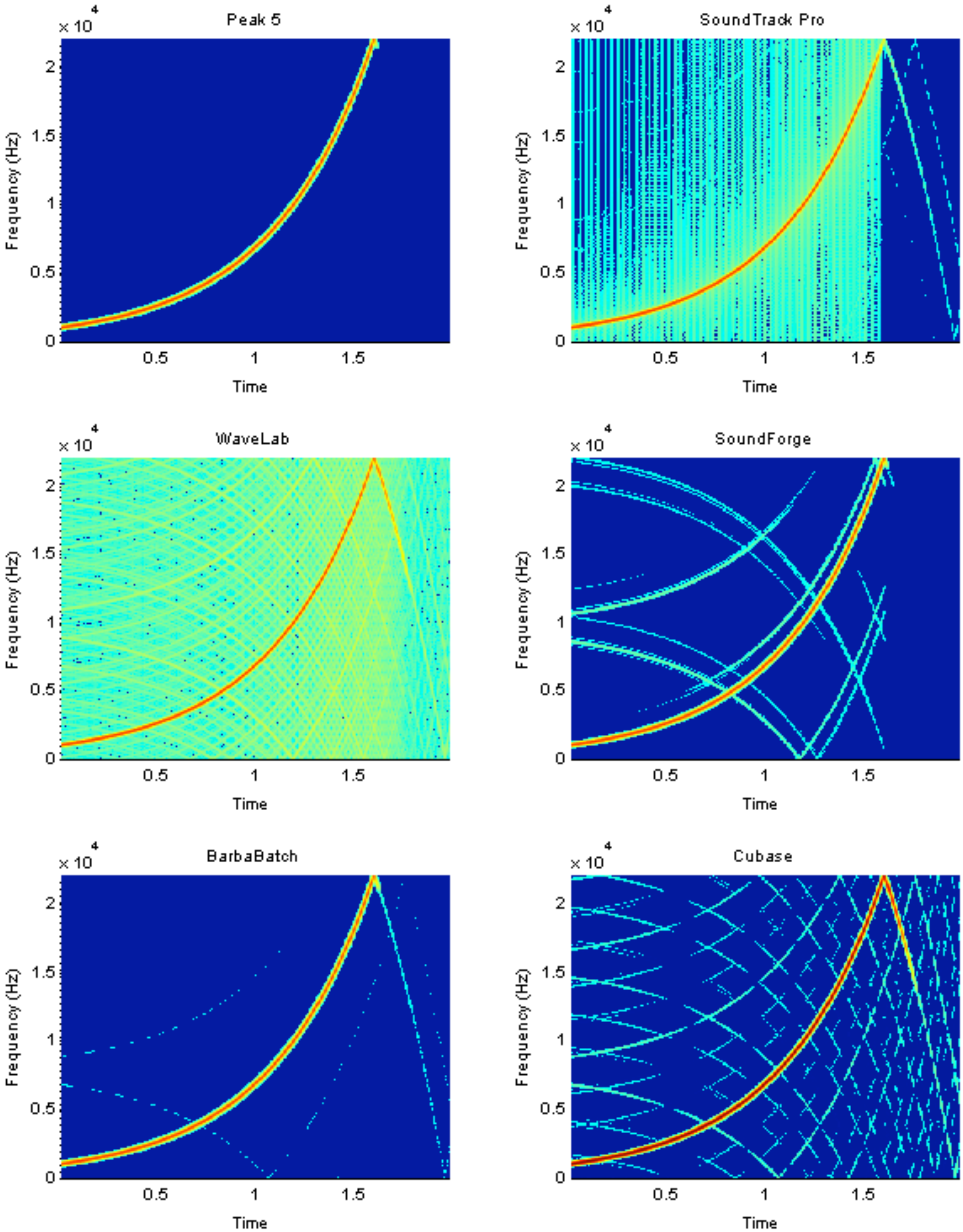
TEST RESULTS

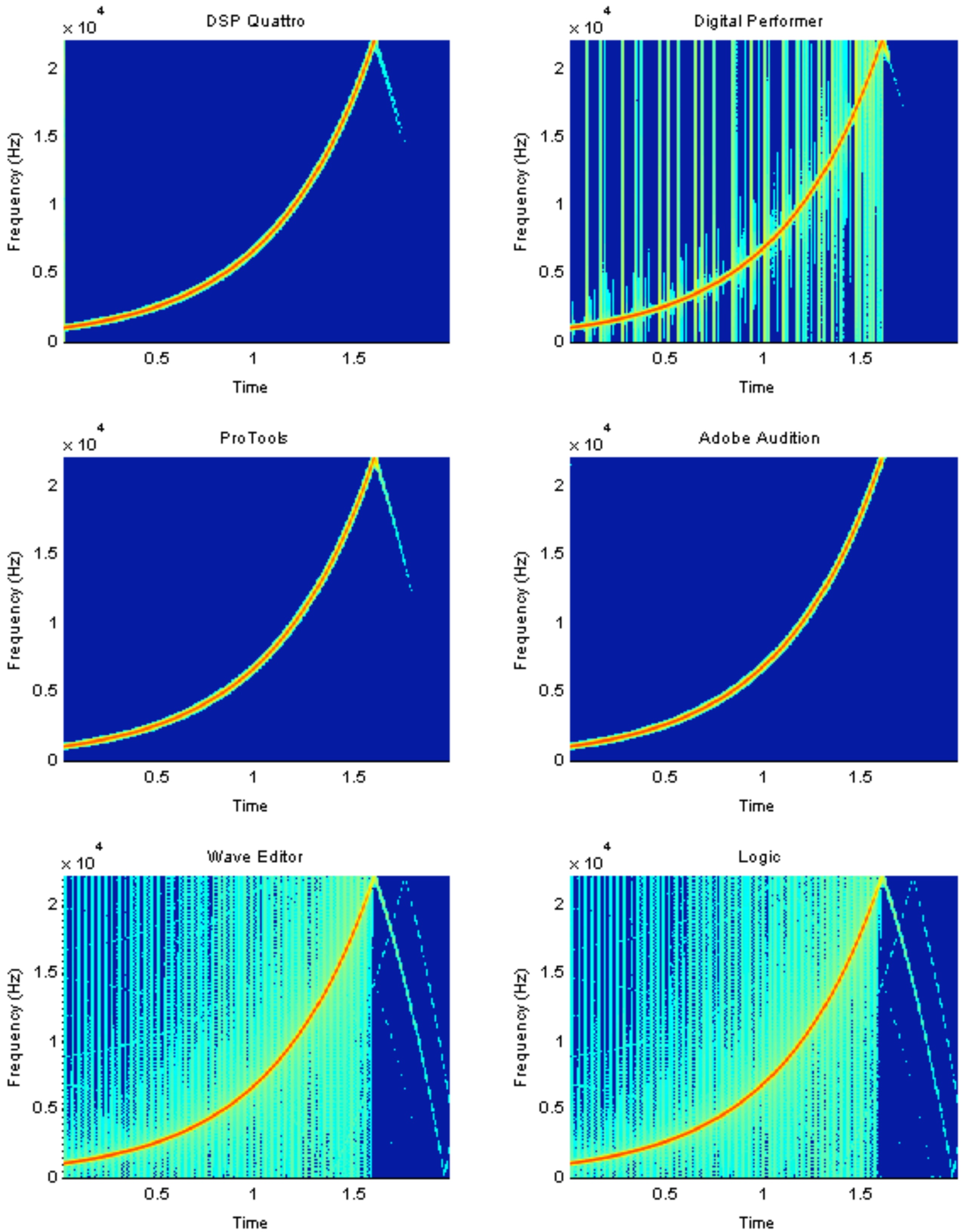
96 kHz to 44.1 kHz

Original test signal: 24-bit frequency sweep sampled at 96 kHz:



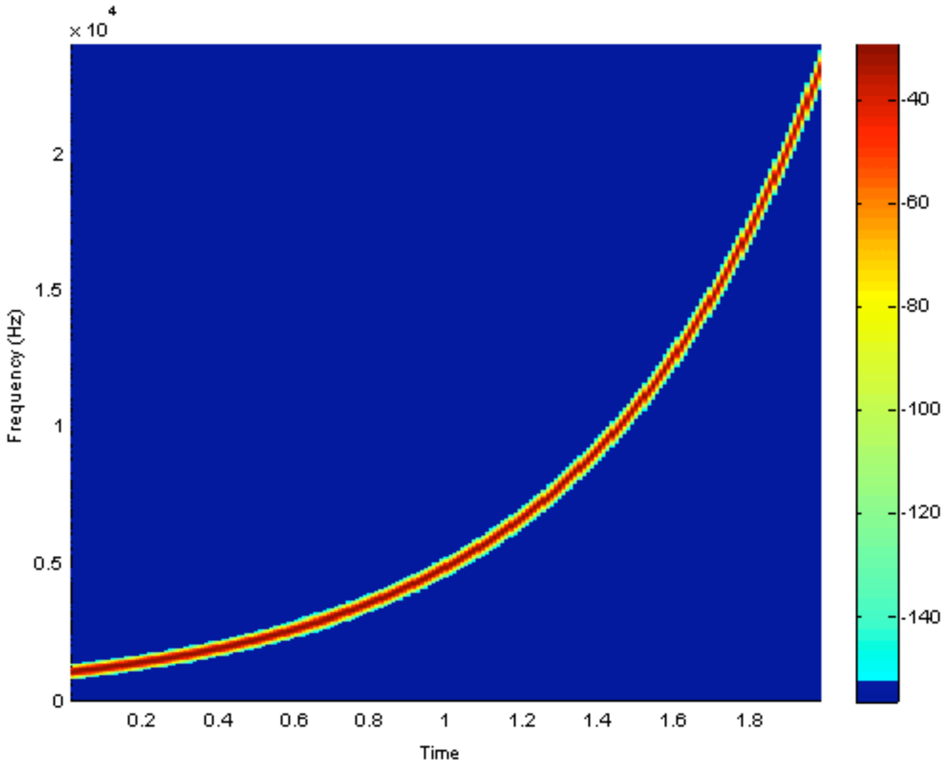
Converted signals, down-sampled from 96 kHz to 44.1 kHz:



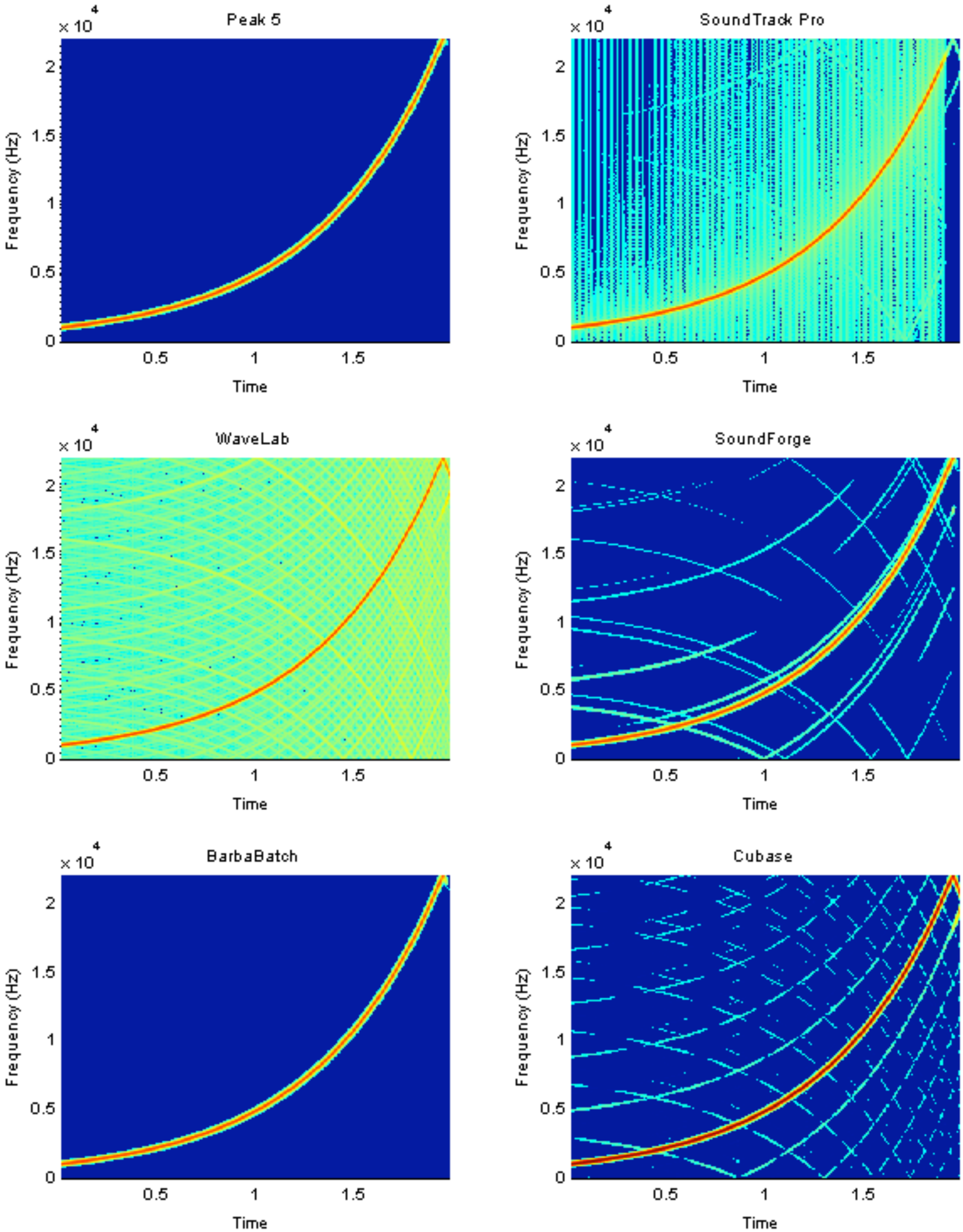

DSP Quattro
Digital Performer
ProTools
Adobe Audition
Wave Editor
Logic
x 10^4
Frequency (Hz)
Time
0
0.5
1
1.5
2

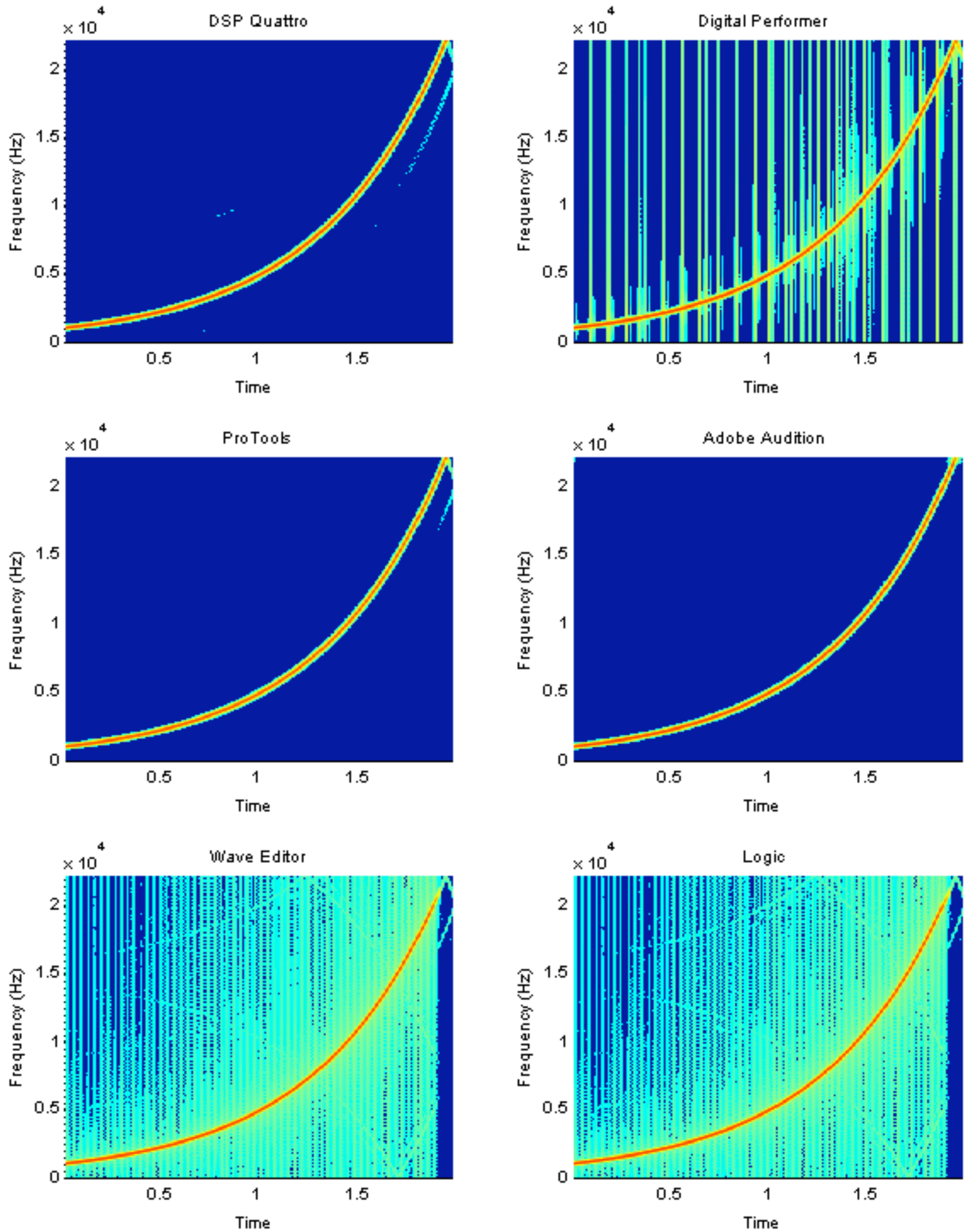
48 kHz to 44.1 kHz

Original test signal: 24-bit frequency sweep sampled at 48 kHz:



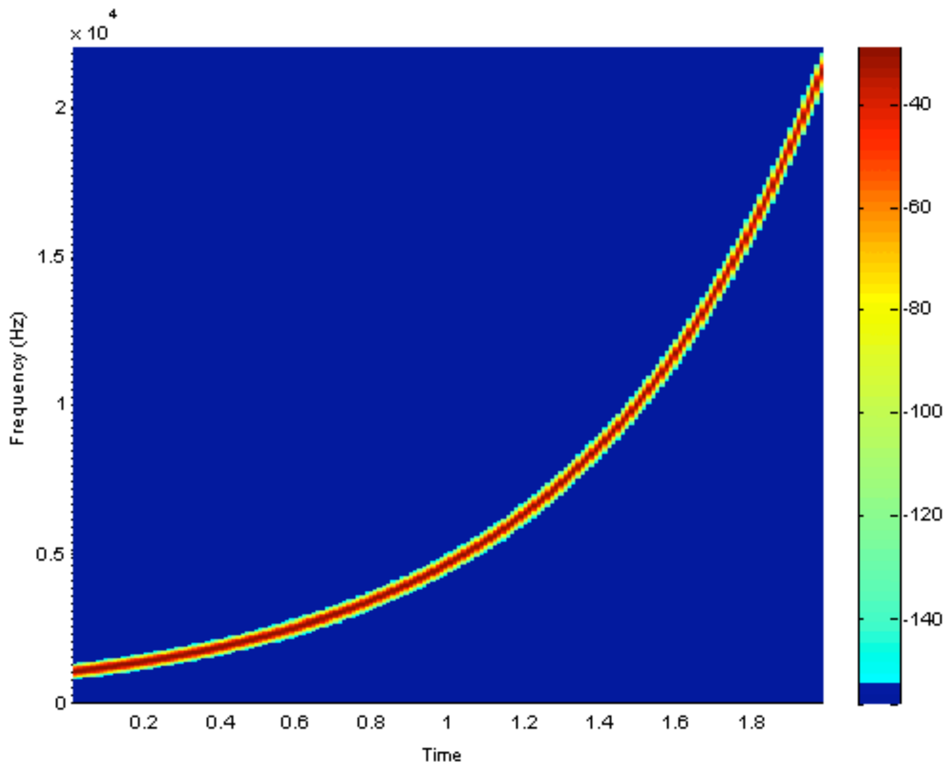
Converted signals, down-sampled from 48 kHz to 44.1 kHz:



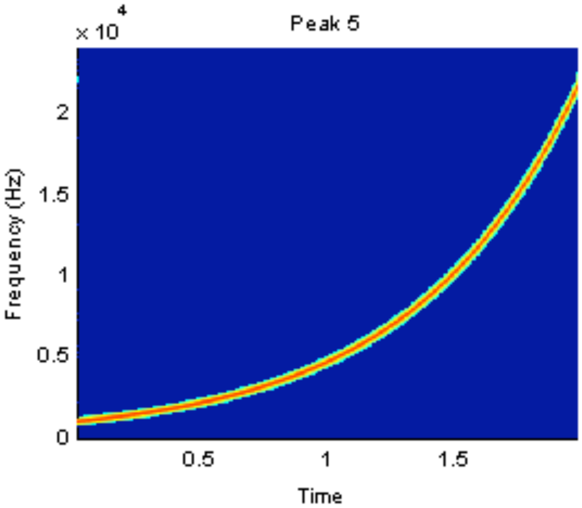

DSP Quattro
Digital Performer
ProTools
Adobe Audition
Wave Editor
Logic
x 10^4
Frequency (Hz)
Time
0
0.5
1
1.5
2

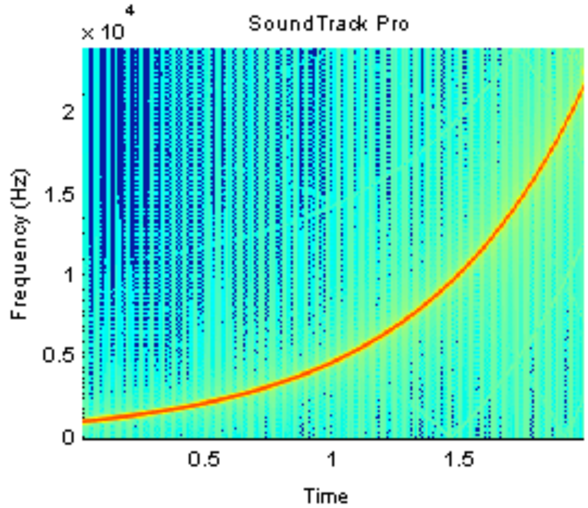
44.1 kHz to 48 kHz

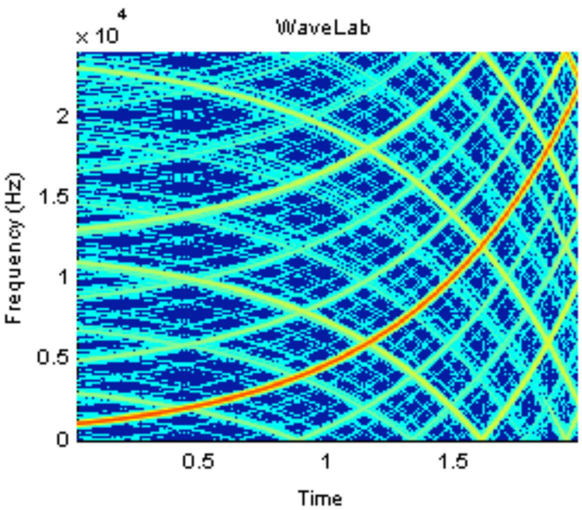
Original test signal: 24-bit frequency sweep sampled at 44.1 kHz:

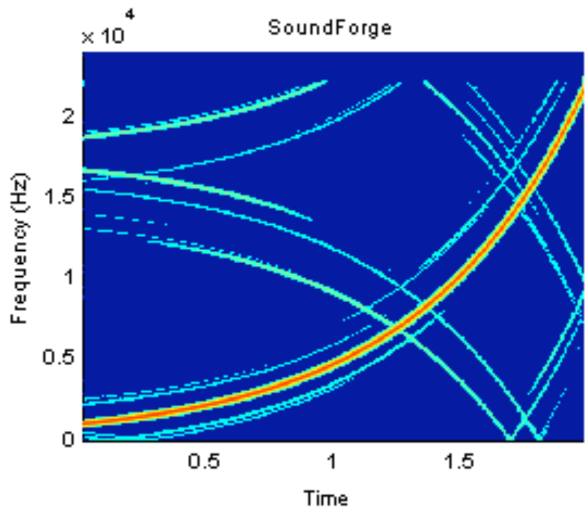


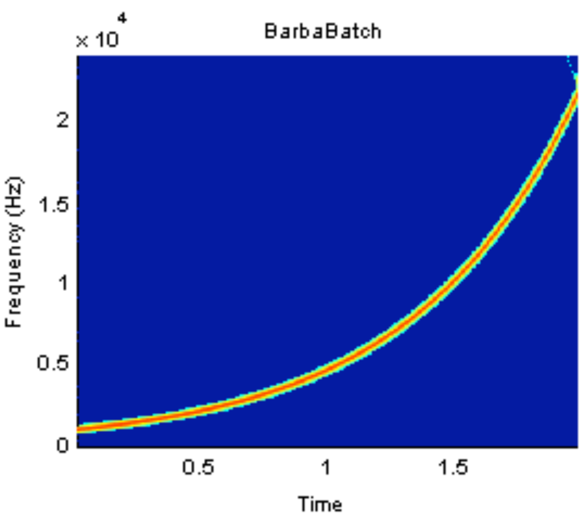
Converted signals, up-sampled from 44.1 kHz to 48 kHz:

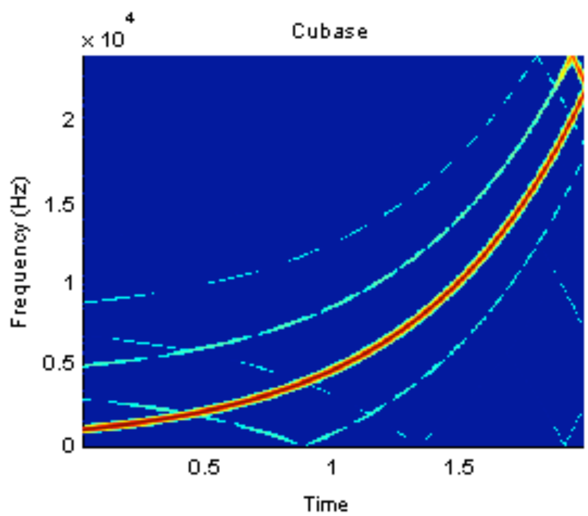


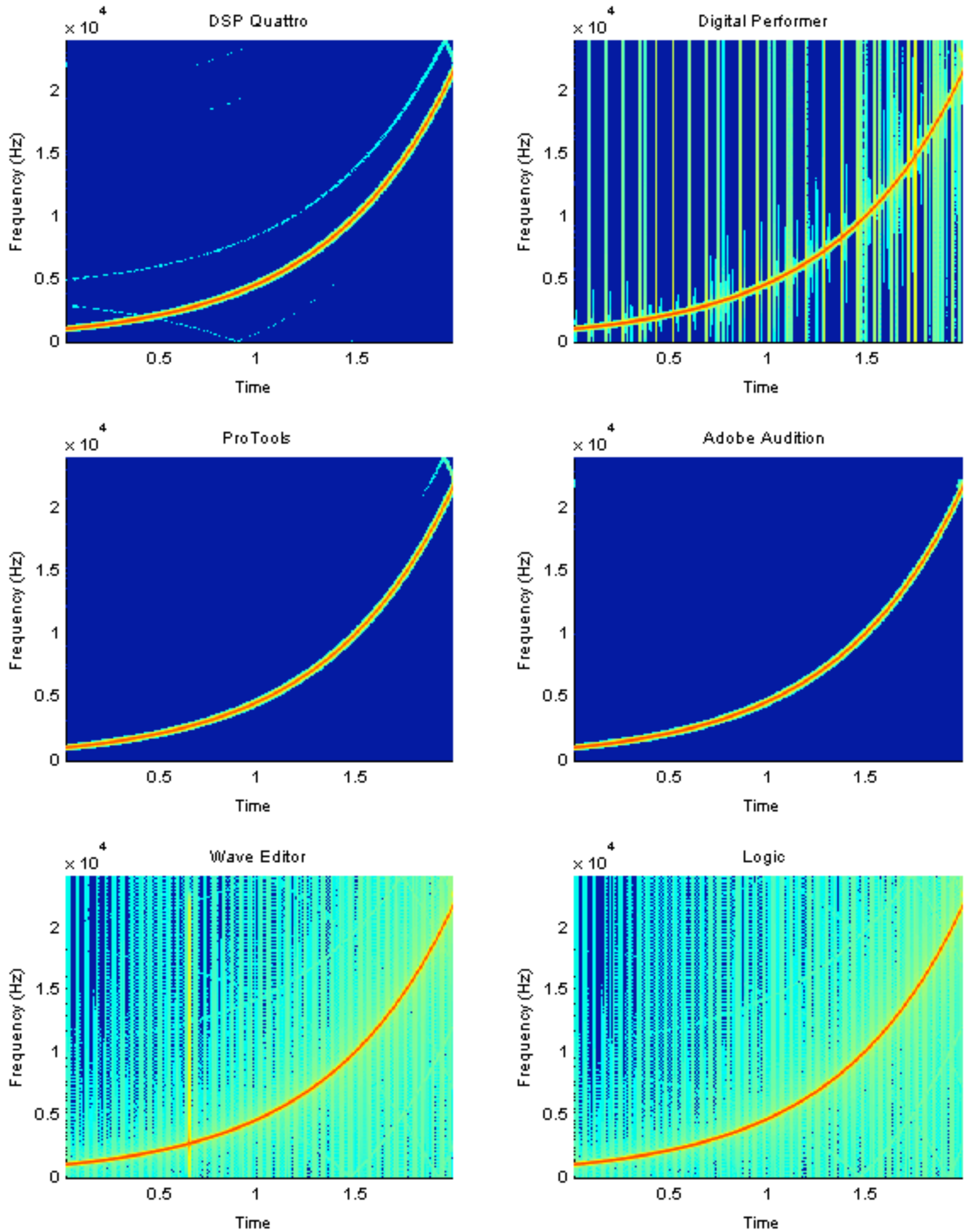






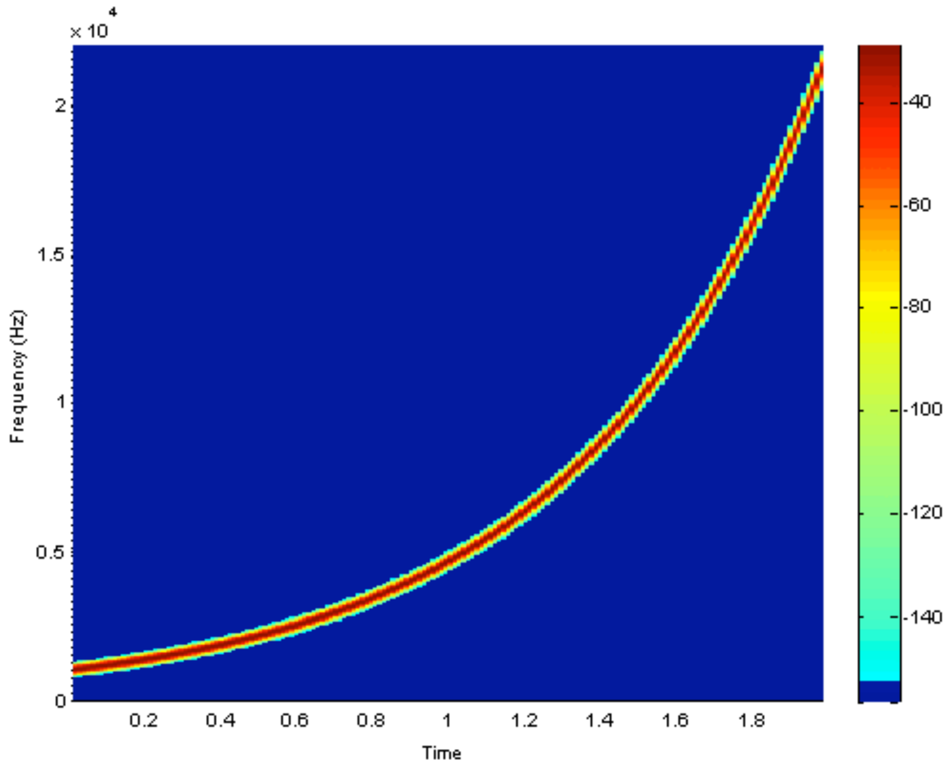




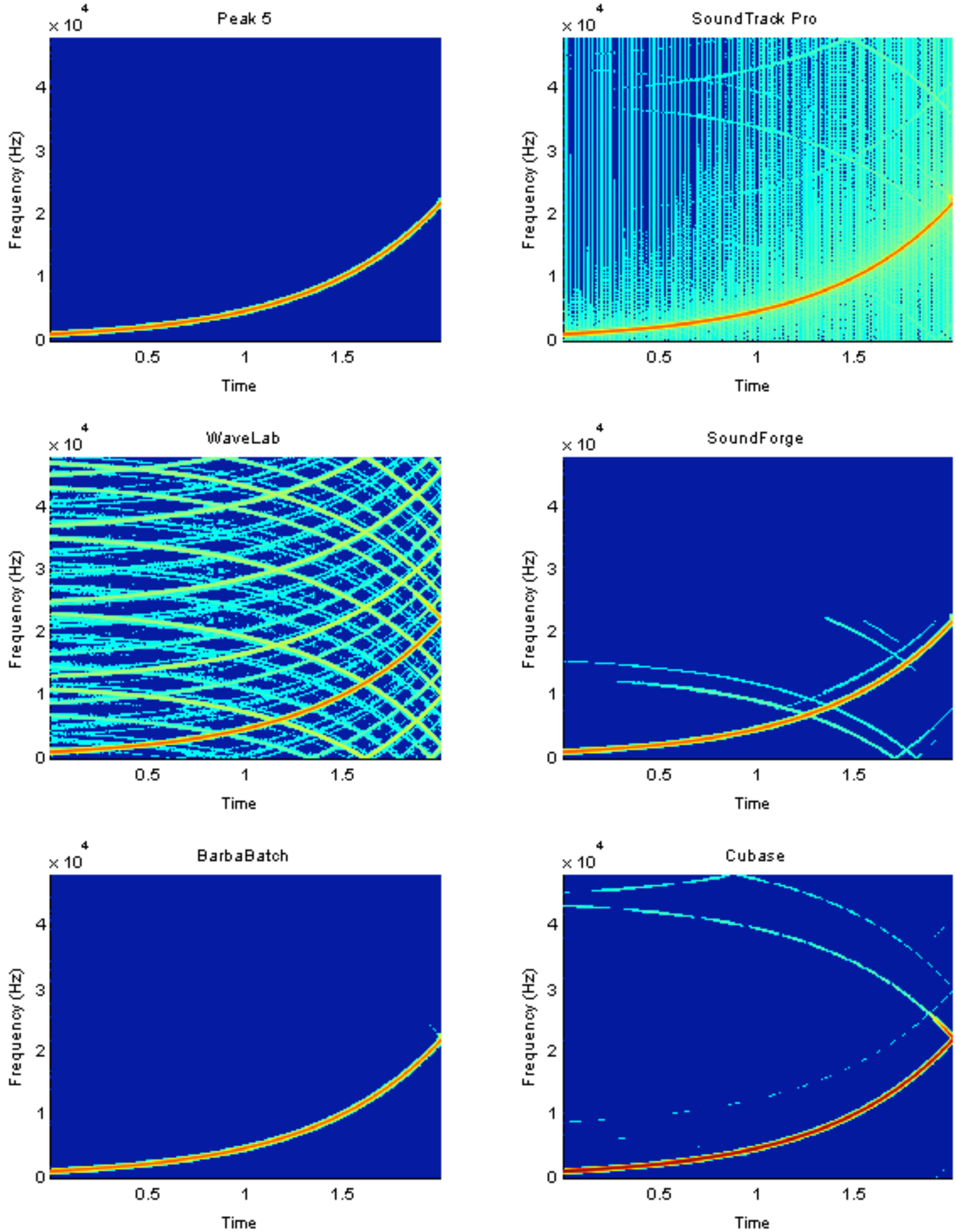

DSP Quattro
Digital Performer
ProTools
Adobe Audition
Wave Editor
Logic
Frequency (Hz)
Time
x 10^4

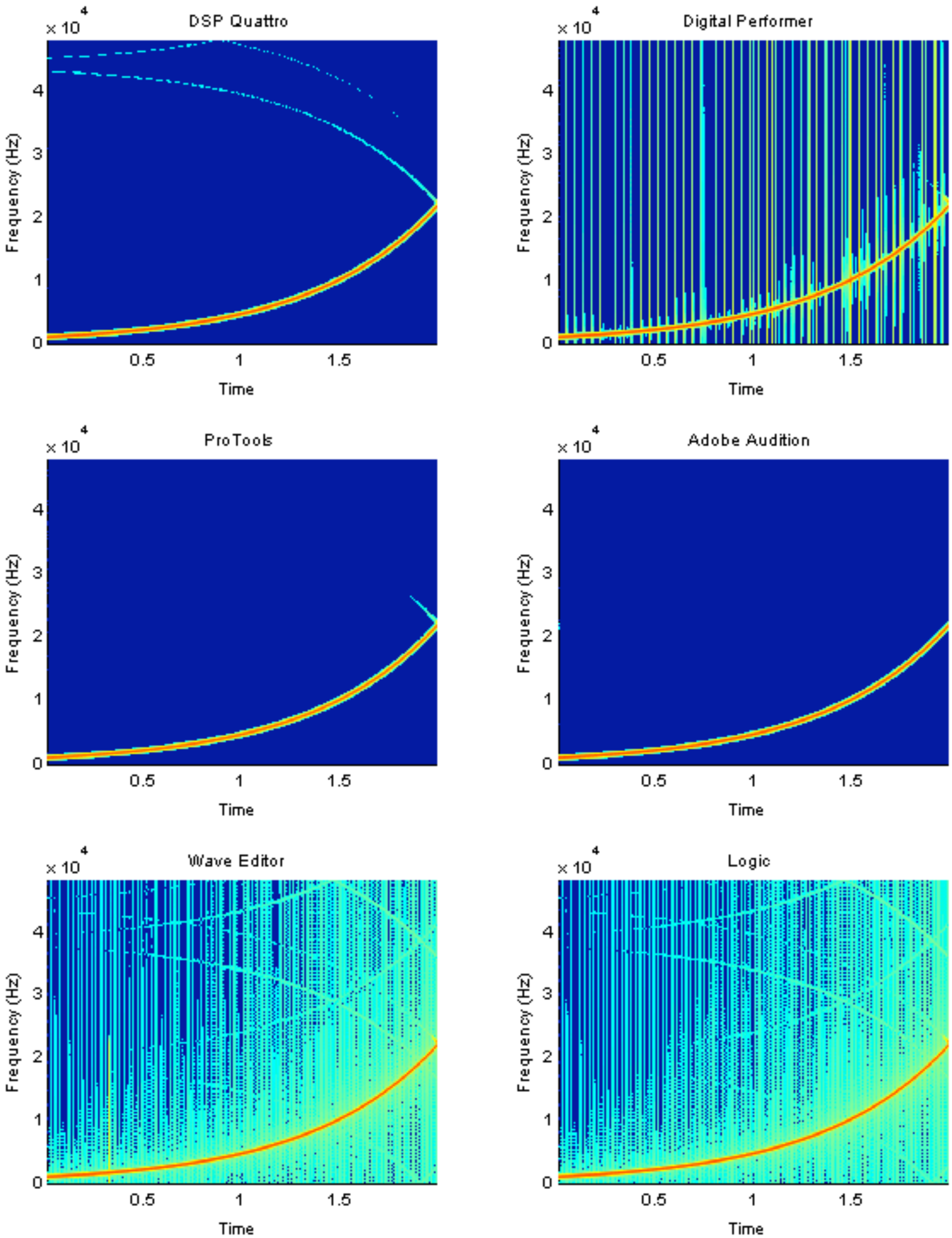
44.1 kHz to 96 kHz

Original test signal: 24-bit frequency sweep sampled at 44.1 kHz:



Converted signals, up-sampled from 44.1 kHz to 96 kHz:




DSP Quattro
Digital Performer
ProTools
Adobe Audition
Wave Editor
Logic
x 10^4
Frequency (Hz)
Time
0
1
2
3
4
0.5
1
1.5

Summary

We performed spectrogram analysis for four scenarios of sample rate conversion: 96 kHz to 44.1 kHz, 48 kHz to 44.1 kHz, 44.1 kHz to 48 kHz and 44.1 kHz to 96 kHz. Conversions were performed with twelve different audio applications including BIAS Peak Pro 5.

Spectrograms show that Peak Pro 5 provides extremely transparent SRC for all conversion scenarios, adding no artifacts such as spurious frequency components from aliasing, broadband noise from numerical errors, or any kind of distortion. If any of these artifacts occurred, we would see brighter colors on the deep-blue background in the spectrogram. We have purposely increased the spectrogram color resolution at very low levels (deep blue directly transitioning into light blue in the color map) in order to detect very low-amplitude aliasing or other artifacts added by the SRC algorithms. Still, the Peak Pro 5 spectrograms display an impeccable blue background, showing the excellent quality of the sample rate conversion algorithm.

The reader is referred to a third-party SRC evaluation matching our results, available online at **http://src.infinitewave.ca**