ACOUSTICS 2012

A Laboratory TOOL for the strings instrument makers

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The discussion that we suggest here relates directly with multiple sessions from Instrument making to measurement techniques. To discuss about the Acoustics of musical instruments, we explain the mathematical form of the acoustic function of the instruments. If we consider the acoustics of the musical instruments as a mathematical formula, we can study it as a 4-port module with an input multiplied in the module function and the output. The mathematical function of this acoustical body of the instrument is a nonlinear Multi order complex function. The produced sound is the application of the function to the input or the mechanical vibrations of the strings. De-correlating and de-modulating the complex sound of the musical instruments and studying the decomposed sound is the first milestone of understanding the behavior of Acoustical Instruments. The strings instrument makers who have the golden ears too, use their very sharp sensitive hearing capabilities to feel the de-correlation, which is why this domain of acoustics remains as an art reserved to some very few genius artisans. To open scientifically the gates of musical acoustic, our S7B module treats the complex results of the acoustical instruments.

1 Introduction

Antonio Stradivari (1644 – 1737) was an Italian luthier making string instruments such as violins, cellos, guitars, violas and harps. The famous violins Stradivarius have still some unknown parameters that the instrument makers try to decode. The used woods in these instruments are the big part of the question. The world is fascinated by the sound of these instruments.

Now, it is possible to see the invisible face of the string instruments and to understand the secrets they contain. Our de-correlation technology allows the luthiers and the crafters to make in full transparency the string instruments they imagine.

A luthier who tries always to achieve the perfection needs to feel the behavior of the parts of the instrument.

The magic sound produced by an instrument is the correlation of the strings and the box response.

It is this magic that we unveil in real time to instruments makers with our de-correlation technology. It offers a new sound analyze of string instruments.

2 Mathematical form

Before we discuss about the acoustic of musical instruments, we should first explain the mathematical form of the acoustic function of the musical instruments.

If we consider the acoustics of the musical instruments as a mathematical formula, we can study it as a 4 ports module with an input multiplied in the module function and the output.

The mathematical function of this acoustical body of the instrument is a nonlinear complex function.

We can schematize the produced vibrations of the strings as the function generators or the sum of some vibrations as:

$$\sum \mathrm{Sin}(Fn)t \quad n=0 \text{ to } n \tag{1}$$

And the simplified behaviour of the box as a Gaussian form,

The produced sound by only one string will be the cross multiplication of the individual Sin(Fn)t and their harmonics by each other, Figure 1;.

The Blue curve, as shown in Figure 3; is the Intermodulation of only 2 frequencies, we can observe that these 2 frequencies are hardly distinguished from each other.

When we apply our technology, the red curve, we observe that the two frequencies are separated from each other and very easily distinguishable in the graph and hear able.

3 We solved the problem

3.1 Craftsman and correlation

The instrument makers works with non-linear parts like wood, strings, varnishes and glue tailored and made in the workshop. They combined them together and by this way built the mathematical function based on correlation and Gaussian form of each strings instrument.

Today, if the artisan tries to modify the shape of a BOX or any element of an instrument, he will hear the complexes sounds that will not permit him to handle the changes that he had brought to his instrument.

This systematic work including the choice of all the parts is too random to allow making similar or dedicated string instruments.

Each one of the 71 elements of a violin, affects the produced sound and the instrument maker has to work simultaneously on some tenth of correlated parameters.

The magnificent result that he had gained from one of his violins will be hardly reproduced by him because mastering the tenth of correlated parameters without mastering the individual elements is a very hard work.

3.2 Craftsman and de-correlation

We see that the instrument makers need to have a real-time monitoring tool to control the manufacturing process and the choice of the parts for each instrument. They need to observe inside the body of the instrument.

To offer this test tool to the industry, we transferred the complex mathematical formula in the monitoring domain to allow the string instruments manufacturing industry to follow in real time the process to achieve high quality instrument.

By using de-correlation they are able to see hidden acoustical effects under the correlated sounds. They can see the signature and the impact of each part, they can choose the right glue and the right drying time at the right temperature and obviously the better varnish.

3.3 Tests and measurements

Of course everyone wants to see what was invisible. It is why our technology treats the complex results of the acoustical instruments.

The following Figures show you different signals from a string instrument.

On Figure 1; and Figure 2; you can see in the frequency domain the signal from one string. The blue curve is the result you see on standard analyzer and also the sound of the instrument you listen. All the resonances from the string itself, from the other strings and from the BOX are correlated (cross modulated) together. The red curve is the output of our de-correlation unit where you see the output signal in red without any cross-multiplication.

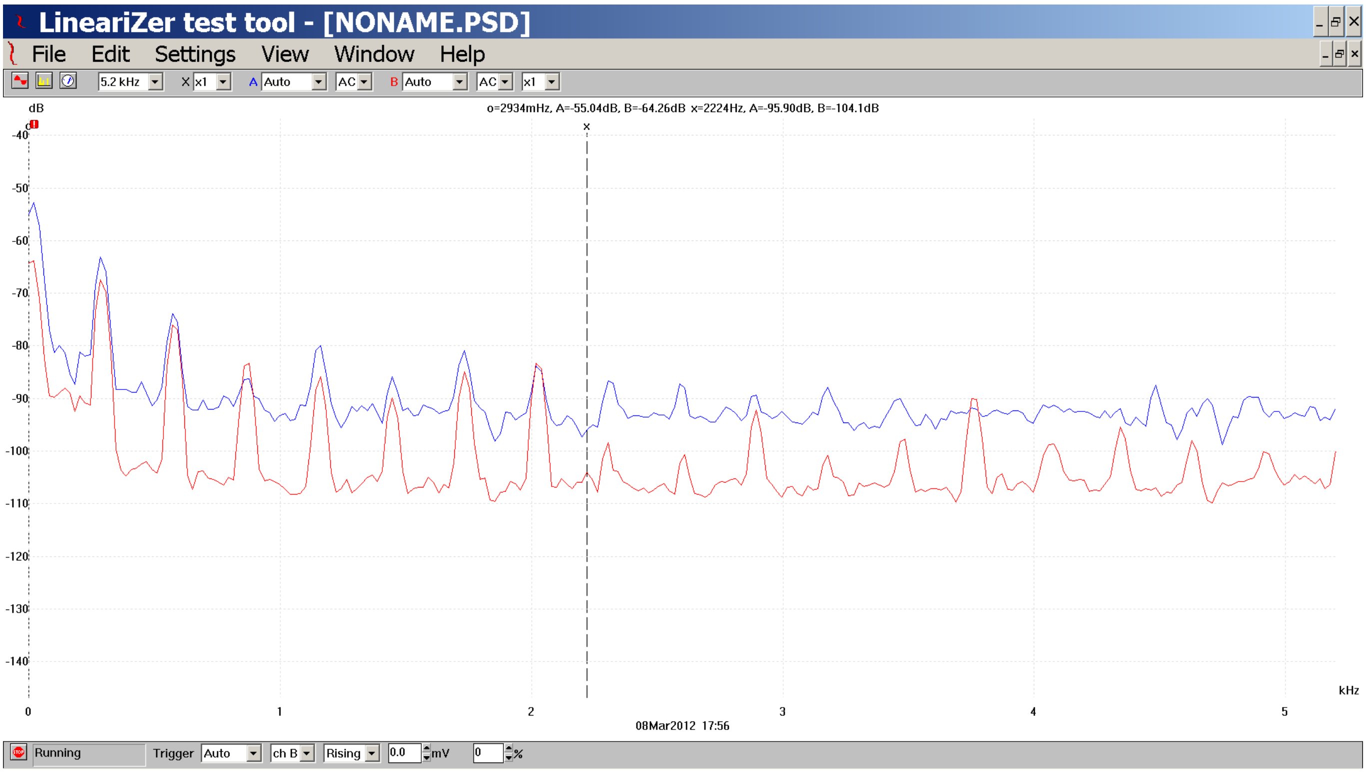

Figure 1: The sound produces by only one string is the cross multiplication
Of the individual Sin (Fn) t and their harmonics by each other

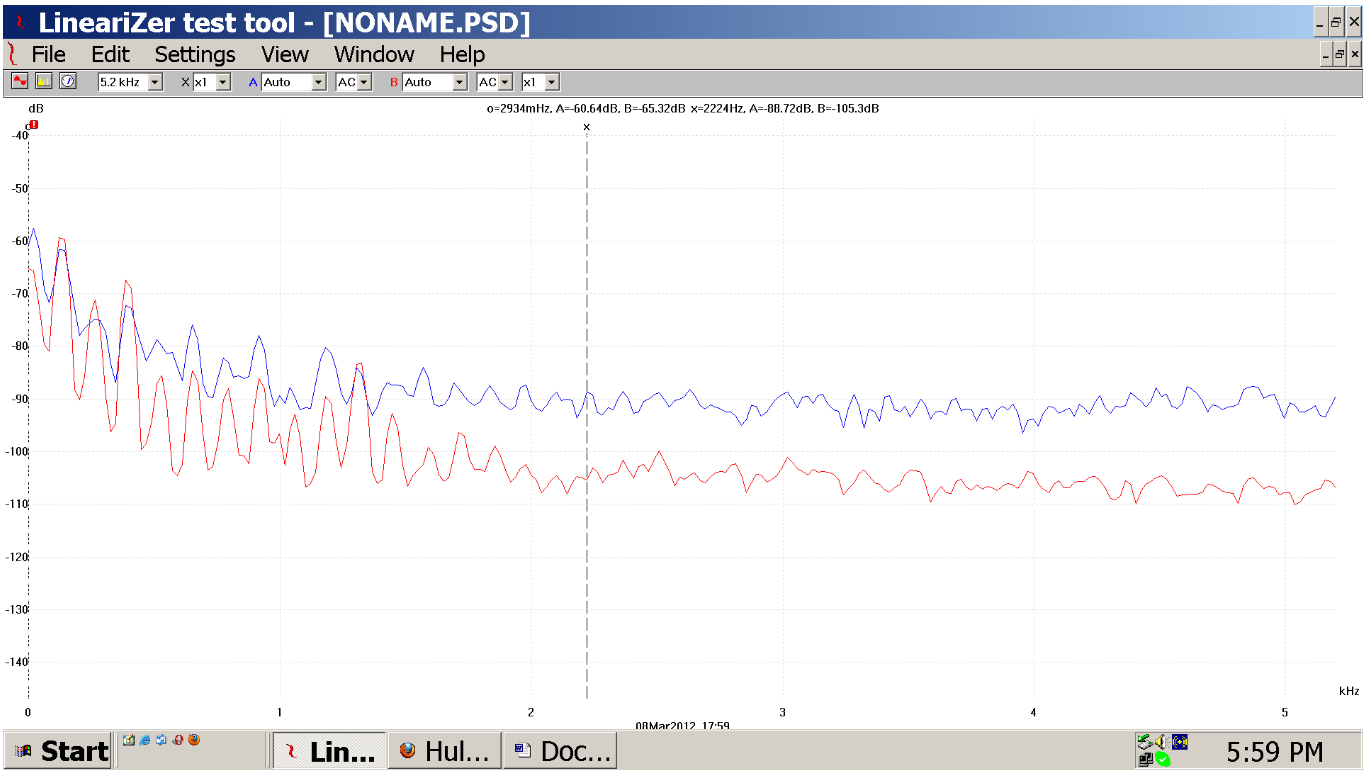

Figure 2: This is the sound produced by a single string.
In blue the correlated sound, in red the same sound after de-correlation

It's important to mention that some peaks were hidden by the correlated sound. A hidden peak generates correlation by cross-multiplication. The effects could be negative or positive on the sound quality of the violin. By analyzing the sound of the instrument with the de-correlation, the luthier can cancel or add this peak to achieve the instrument with the resonances the musician likes.

The Figure 3; shows in frequency domain, how our technology is able to isolate two frequencies hidden under the sound of the instrument. The two frequencies hidden by the sound of the instrument are at 2364 Hz and 2376 Hz.

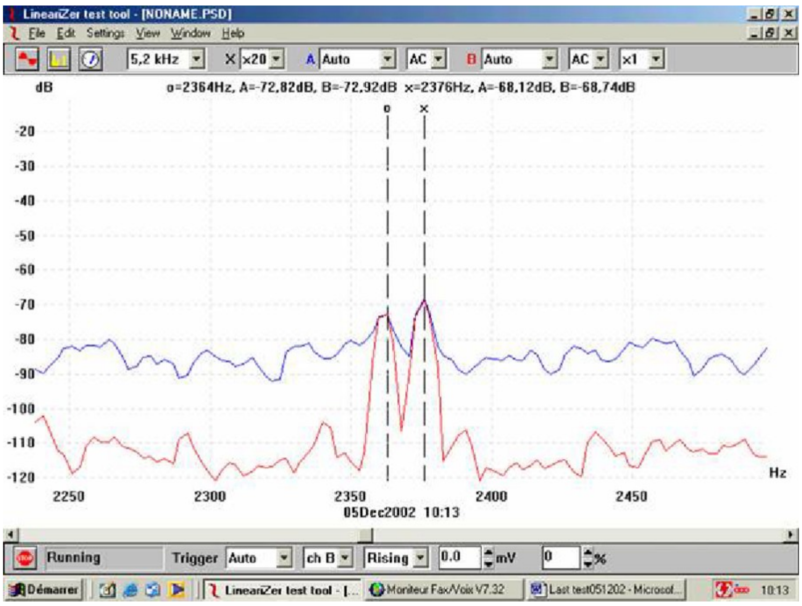

Figure 3: Double frequencies accuracy

The Figure 4; and the Figure 5; show in frequency domain the de-correlation (in red) of the sound of two strings played simultaneously on the instrument. The normal "correlated" sound is in blue.

It is important to notice on the red curve the real level of each individual harmonic and how in the correlated domain (blue) all this harmonics react together to give the sound of the instrument we listen in concerts.

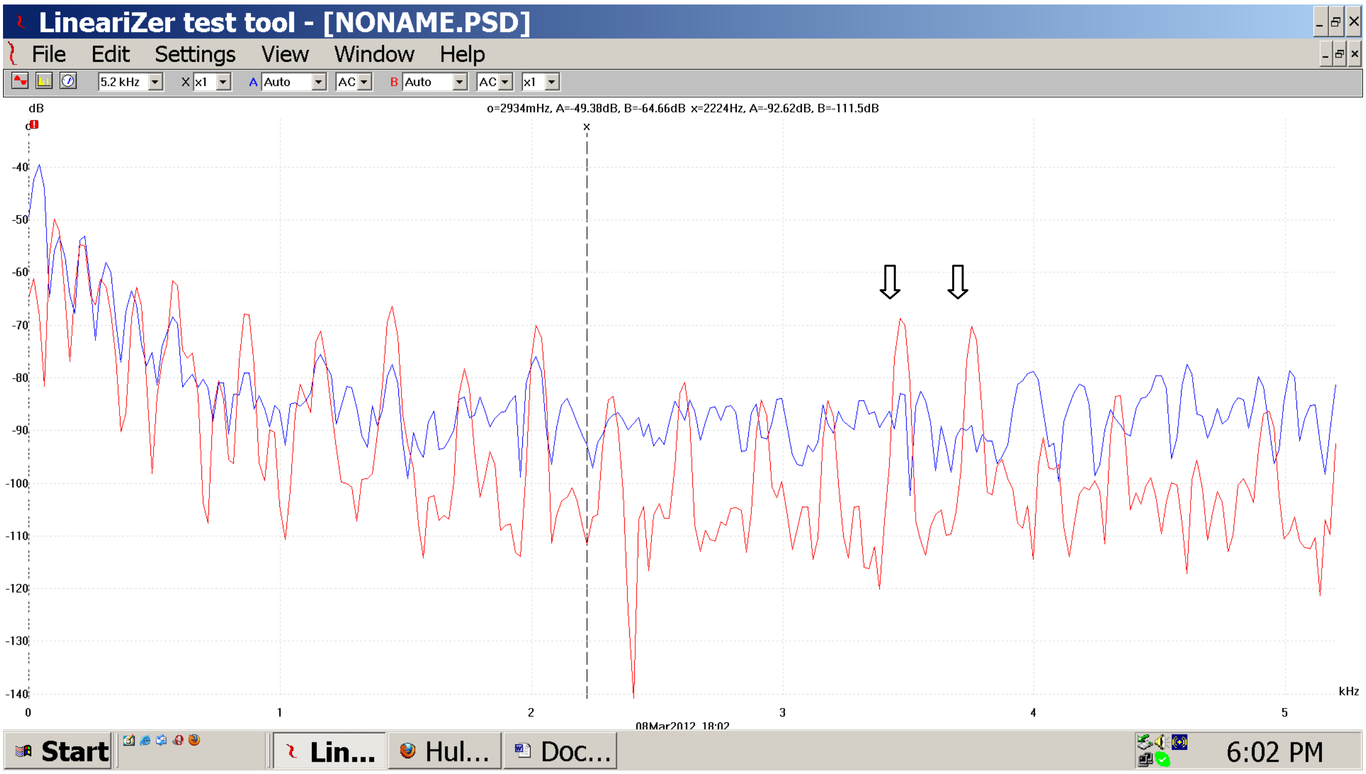

Figure 4: In frequency domain, two strings are played simultaneously on the instrument
In blue the correlated sound, in red the signal after de-correlation. Harmonics are attenuated in the correlated sound

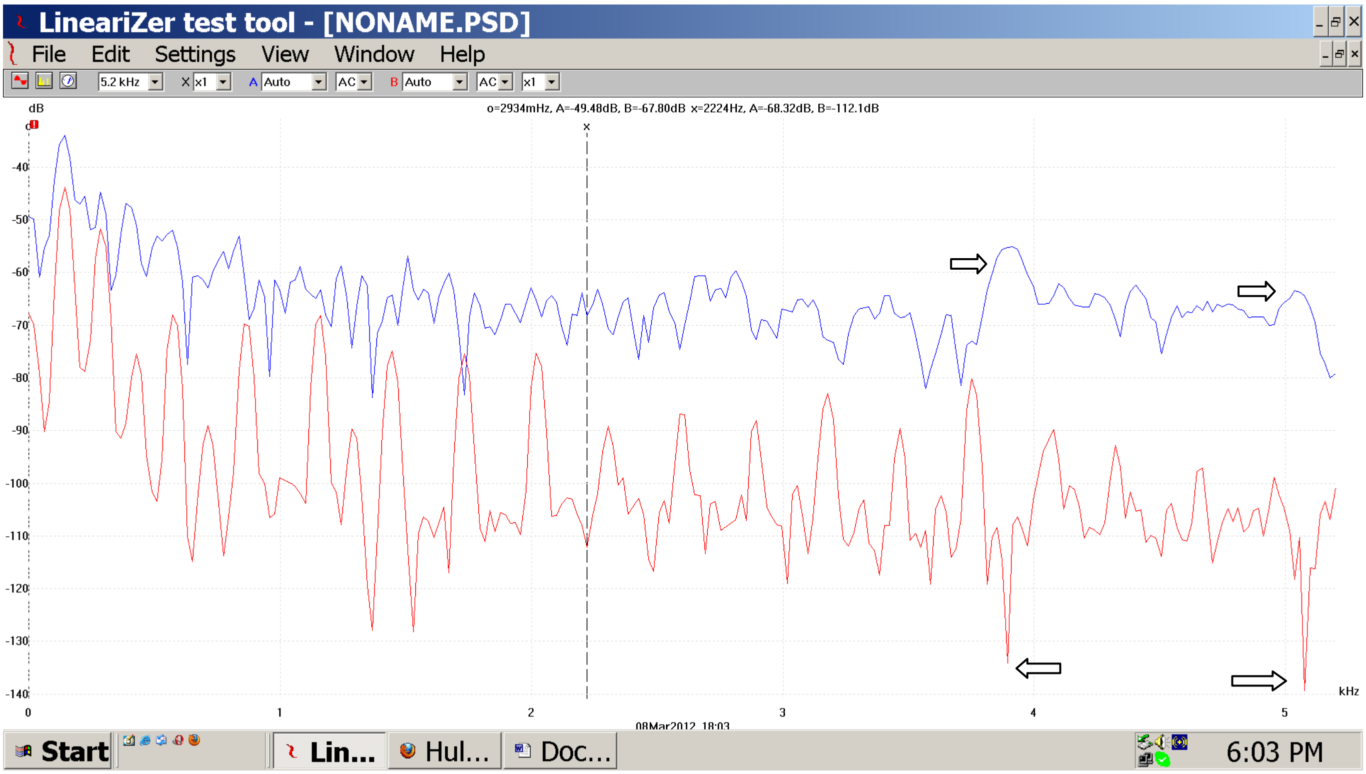

Figure 5: We notice at 3.9 KHz and 5,1 KHz that the cross-multiplication generates
big peaks in the correlated sound (blue) , but after de-correlation (red) at the same frequencies, we see a big hole.

3.4 The performance of our technology

Today, in a natural environment, we de-correlate a signal in a band of 0.7 Hz to 2 MHz regardless of the conditions of dynamic noise. In this same environment, we separate all components of the signal, all individually to find the sources and the original information. We cancel all the phenomena of echoes and reflections (multi-path and multi-source). We also cancel the jitter in the channel that we treat (perfect group delay).

3.5 Characteristics of our technology

Our technology is operating in real time. The processing time is lower than 20 nanoseconds (at 0.7 Hz). This technology does not use any filter, does not change the spectrum, and does not use external sensor and any sampling or digital processing.

Our technology can be used independently or as a pre-processing to reduce the workload of digital processors.

4 Conclusion

Our technology treats the complex results of the acoustic instruments.

This is the perfect solution for all the string instrument makers. The de-correlation allows them to know exactly in details how the parts of the instrument react. They can observe how any small change can change the levels and the combinations of the harmonics, attenuate or increase the level of one frequency.

The real time monitoring is available during all the manufacturing process. The instrument maker take the control of the correlated sound by adjusting tenth of parameters in a de-correlated world.

Obviously, as it’s a real time technology, the instrument maker and the musician can listen the sound of the instrument fully de-correlated to adjust it.