Characterization of High Bandwidth Digitizers

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Abstract: Every year, the last products from most important builders of high bandwidth digitizers are tested in our laboratory which is specialized in the design and the characterization of fast links used in large laser facility.
The purpose of this article is to describe the series of tests conducted during the characterization of such digitizers. More particularly, it takes an interest in the metrology of instruments with more than 5 GHz of bandwidth. It presents the different methods used and the kind of conclusion that we can give after such study.
Such metrology campaign which usually takes one month of work, allows us to observe the smallest details and characteristics that usually builders don't give in their tables specifications.
After the campaign, a copy of our technical report is written and sends to the builder. This report can be used by the technical team to ameliorate the points we noted.

Keywords: Digitizers, Metrology, Instrumentation.

1 – INTRODUCTION

The type of digitizer we have the use to study is currently used in many domains, from the design of telecom circuits to the measurement of high-speed signals during physical experiments. It's legitimate in this kind of experiments to take into account the parameters involved in the measurement to evaluate the uncertainty of measure (e.g., measurement errors in time domain, trigger delay, electromagnetic coupling between signal line). Regarding the cost of this kind of instrument, it is usually necessary for the potential purchaser to have a precise idea of his needs according to operating mode (e.g., single shot, average, external trigger or internal trigger, sampling rate).

One of the specialties of our laboratory is to make a complete characterization of commercial digitizers in order to address more characteristics than the manufacturers usually specify.

We plan in this paper to describe point by point the different measurements made during a typical metrology campaign.

2 – DESCRIPTION OF TEST CONTROL

2.1 Measurement of noise

In the first step, we measure the evolution of the internal noise as a function of the acquisition type (single shot or average). The spectral curve obtained permits us to verify the whiteness of the noise. We can easily note possible parasitic frequencies in the spectrum.

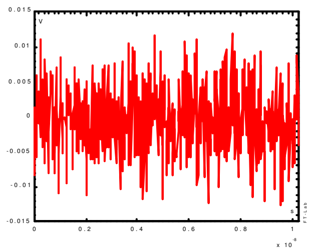

Figure 1 : Example of noise acquisition

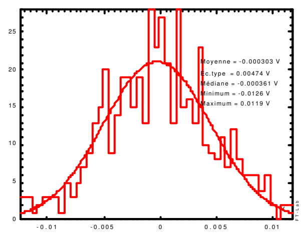

Figure 2 : Normally Distribution of noise

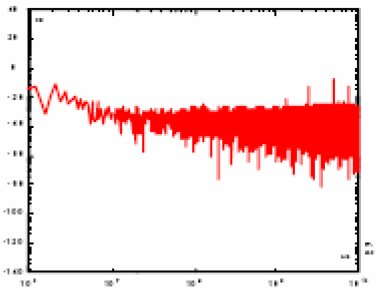

Figure 3 : Fast Fourier Transform of Noise

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In this way, it's possible to identify the presence of harmonics of the sampling frequency. We can also monitor the spectrum to determine the presence of numerical filters used to attenuate the high frequency noise.

This kind of acquisition is repeated for different sampling frequencies to assess the quality of the sampling matrix.

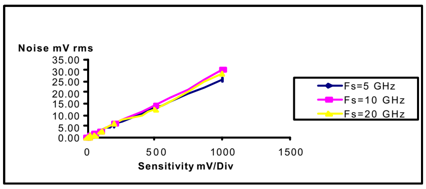

Figure 4 : Evolution of noise in function of the sensitivity

Dividing the full scale by the RMS level of noise, we obtain the vertical dynamic range of the digitizer for a signal to noise ratio of one (S/R 1). For single shot applications it is recommended to consider the dynamic range with S/R 20.

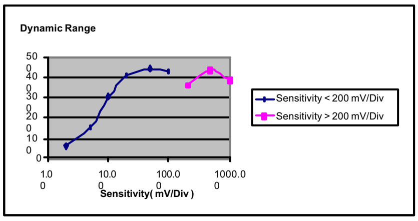

Figure 5 : Evolution of the vertical dynamic range as a function of the sensitivity

2.2 Measurement of bandwidth

This measurement is made by sending a Heaviside pulse in the input signal line. This pulse is derived and deconvolved by a reference signal acquired on a sequential sampler. Drawing the Fast Fourier Transform of the signal, we measure the bandwidth at the -3 dB point.

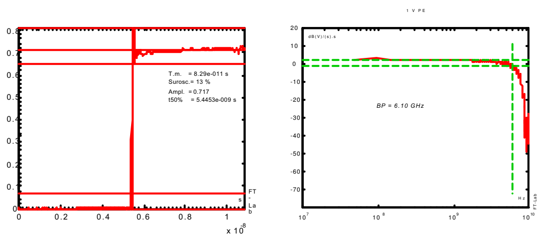

Figure 6 : Impulse Response and Transfert Function Magnitude

This measurement is repeated for different values through the full scale and for different sampling frequency.

These measurements allow us to check the presence of anti-aliasing analog filters and the absence of numerical treatment. We verify also the uniformity of the bandwidth as a function of the sensitivity and the absence of linearity defaults.

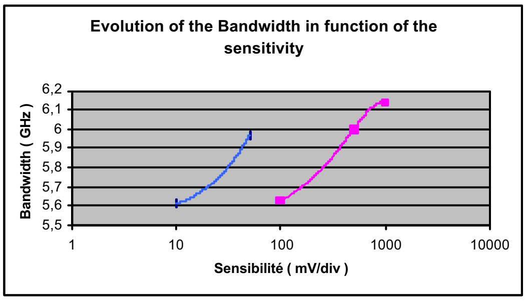

Figure 7 : Evolution of the bandwidth as a function of the sensitivity

2.3 Measurement of effective bits

In this part, we evaluate the digitization quality of a digital oscilloscope as a function of the amplitude of the signal, of the sampling frequency, and of the type of acquisition (e.g., single shot mode or average mode). This measurement allows us to verify the global quality of the instrument because all internal defaults intervene in the calculation of the effective bits (vertical and horizontal linearity, internal noise, jitter, internal clock etc.).

The measurement is made by the comparison between a theoretical sine wave and an experimental sine wave acquired in the digitizer. We calculate by a statistical process the root mean square error and we inject it in the effective bits formula. This formula results in a comparison the full scale and the error.

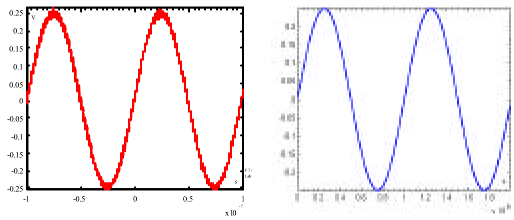

Figure 8 : Experimental and theoretical sinus

$$B_{eff} = Log_2(\varepsilon\frac{\sqrt{12}}{PE})$$, *PE=Full scale, å=error rms*

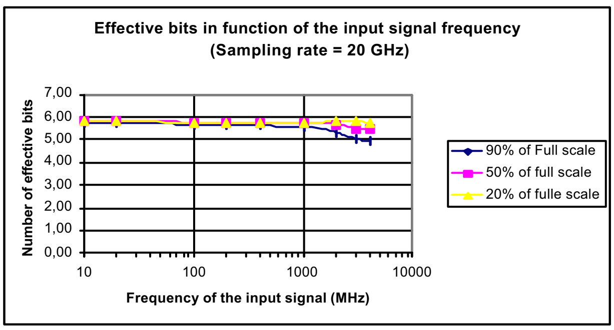

Figure 9: Evolution of the effective bits as a function of the frequency

2.4 Measurement of jitter

This measurement is made to characterize the trigger delay between the arrival of the trigger signal and the effective triggering of the digitizer.

We evaluate the time delay as a function of the amplitude of the trigger signal and its rise time. We measure the statistical time distribution at a crossing level of 50% of the trigger signal. It is the root mean square jitter. This data is very important for time domain measurement and for the datation of a particular event.

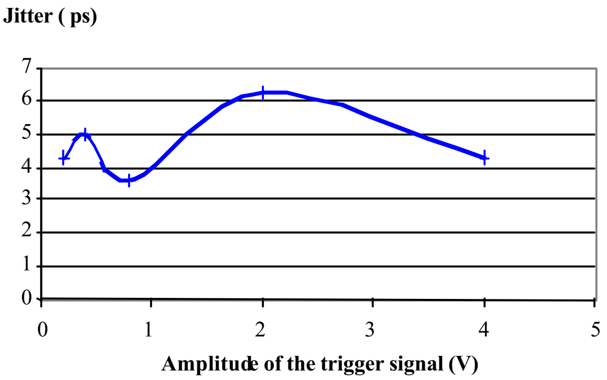

Figure 10 : Jitter as a function of the rise time of the trigger signal

It gives us information about the accuracy of the triggering system as a function of the characteristic of the signal.

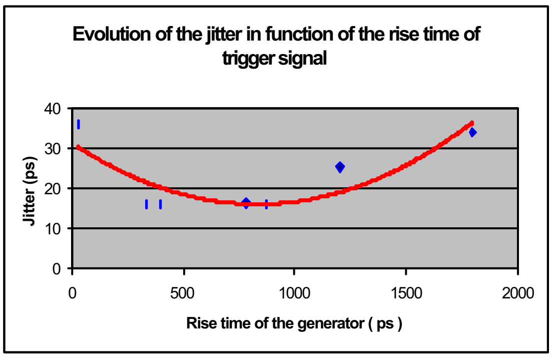

Figure 11 : Jitter as a function of the rise time of the trigger signal

2.5 Measurement of 50Ω adaptation

The majority of high frequency systems used have an input impedance of 50 Ω. We verify in this part the spectral variations of the impedance 50 Ω as a function of the sampling rate and as a function of the sensitivity used. This measurement allows us to identify the number of input blocks (amplifier, attenuator etc.). We evaluate also the quality of the sampling matrix block by watching that the sampling rate does not affect the impedance of the input line. In the figure below, we show the curve obtained for two different range of sensitivity. In fact, when a user changes the sensitivity of his instrument he changes too the impedance of the input line.

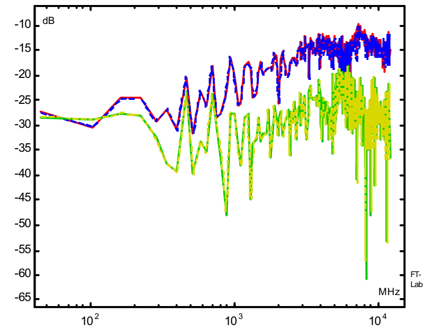

Figure 12 : Reflexion parameter as a function of the frequency

2.6 Measurement of crosstalk between channels

This measurement involves the generation of pulses corresponding to approximately 400% of the full scale on one input signal channel and the measurement of the parasitic tension induced into the next line. The objective of this measure is to verify the electromagnetic immunity of the channels and their capacity not to disturb other channels located in close proximity.

In large physics facilities, the layout of cables used to transport signals can be very different before being connected to the input connectors of the digitizer. In this way, the difference of potential between two lines can be very important because of the difference of electromagnetic radiation coupling in the cables and can result in parasitic signals on all channels if the digitizer is suffering crosstalk.

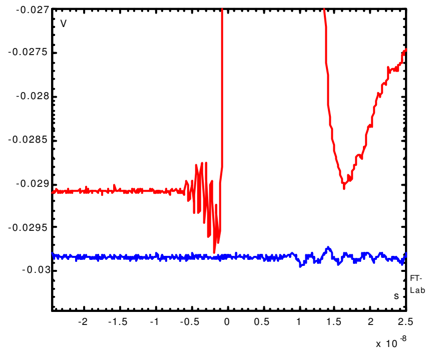

Figure 13 : Example of crosstalk between one satured channel on the next c channel

During this kind of measure, we have the habit to obtain a signal with a very small rise time. The reason is that the coupling is easier for high frequency signal.

2.7 Measurement of time recovery

For some particular experiments, it is interesting to stack several signals one behind others. However, it's necessary to measure the interval of time take by the instrument to find its original level again after an eventual saturation.

The purpose of this measurement is to verify that the second signal will not be disturbed by the previous one in the case of a very high pulse.

This measure is made by the generation of a very high signal saturating the input signal line. We measure the time taken by the digitizer to reach its base line again with an offset close to zero volt.

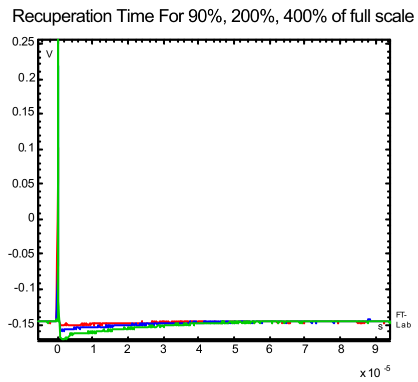

Figure 14 : Measurement of the time recovery

2.7 Verification of the high electromagnetic field imunity

In a large laser facility, it is possible to find very high electromagnetic pulses. This electrical field can disturb the principal function of the digitizer. A commercial Faraday cage will usually offer a good attenuation in an electric field for frequencies less than 1 GHz, but after this point an attenuation of only 40 dB is typical. For example an electric field at 2 GHz with an amplitude of 10 kV/m will have an amplitude of 100 V/m in the cage, which is capable of disturbing a commercial system. It is for that reason that we designed a test system capable of generating an electric field of 10 kV/m for more than 10 ns. We expose the instrument to the electric field and we measure for each value of electrical field the voltage in the signal line. The measurement is made for about ten values of field to obtain a level close to the internal noise level.

We also check the immunity of the trigger system to ensure that it will not trigger the system on a parasitic electromagnetic signal.

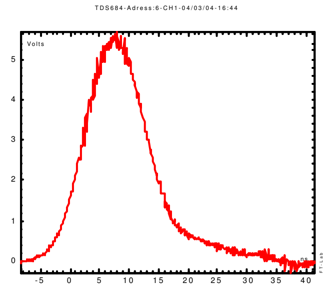

Figure 15 : Visualisation of high pulsed electric field on signal (One meter from the source)

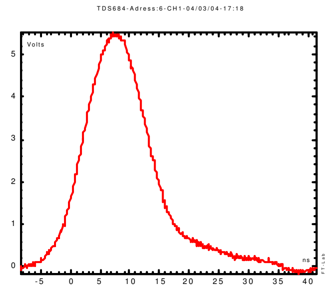

Figure 16 : Visualisation at 10 meter from the source

3 – CONCLUSION

These different tests are performed in our laboratory for the majority of the recent commercial fast digitizers available on the market. These tests are normalised by test procedures and can be used for every type of digitizer. In this way, we are able to set up a sort of database of digitizer characteristics, which allows us to compare them and to choose the more appropriate for our applications.

4 - REFERENCES

[1] J.A COEKIN," High Speed Pulse Techniques", Pergamon International Library, 1975.

[2] D.DECLERCQ, "Le signal aléatoire", Hermes, 1996.

[3] D.DECLERCQ, "Le signal déterministe", Hermes, 1996.

[4] L.S.GARRETT, Overshoot and Ringing in high speed digital systems", *Motorola Semic. Prod. Inc.* Appl. Note AN-277