Time-Domain Characterization of the EFT/Burst and ESD Measuring Systems

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***Abstract* — The scope here is to describe a time-domain measurement technique capable to characterize the measuring systems used for the calibration of the electrical fast transient/burst generator and the electrostatic discharge gun. The technique is based on the use of the convolution integral between the measured step response of the measuring system and the theoretical standard impulse waveform. The distortion operated by the measurement system is directly quantified in terms of the critical parameters of the impulse waveform (rise-time, peak and width). The fundamental assumption for the validity of the proposed technique is that the waveform applied at the input of the measuring system does not differ too much from the standard theoretical waveform. In particular, the generator under calibration must comply with the relevant standards requirements. The electrical circuit of a generator providing a step of adequate amplitude and rise-time for implementing the proposed technique is described. Experimental results are also presented.**

***Index Terms* — Impulse measurements, electrical fast transient/burst, electrostatic discharge, measurement uncertainty, calibration.**

I. INTRODUCTION

The subject here is the time-domain analysis of the effect of the response of the measuring system (MS) on the rise-time, peak and width of the standard impulse. The impulse phenomena considered are the electrical fast transient/burst (EFT/Burst, or briefly EFT) [1] and the electrostatic discharge (ESD) [2], i.e. those characterized by low-energy and high-frequency content. The time–domain technique adopted is well known and extensively applied in the context of high-voltage measurements [3], [4]. First the step response of the measurement system is experimentally obtained, then the distortion induced to the theoretical impulse waveform ([2], [5]) by the measurement system is evaluated through numerical computation (convolution integral). The novel contribution consists in the adjustment of the original method to the EFT and ESD phenomena.

The measurement system consists of a transducer connected to a digital oscilloscope through a section of coaxial cable. The transducer is a voltage divider (EFT) or current shunt (ESD) whose nominal input impedance is specified by the standard [1], [2] and providing adequate attenuation.

II. THE CONVOLUTION INTEGRAL METHOD

The technique consists of: a) recording the step response $w(t)$ of the MS, b) scaling $w(t)$ by using the scaling factor W_0 thus obtaining $w_0(t)$, c) numerically computing $v_{out}(t)$ as (see [4])

$$v_{out}(t) = \frac{d}{dt}\int_0^t v_{in}(s)\cdot w_0(t-s)ds, \tag{1}$$

where $v_{in}(t)$ is the theoretical impulse waveform. Finally, d) $v_{out}(t)$ is compared with $v_{in}(t)$ in order to evaluate the distortion of the theoretical impulse due to the MS. Note that since

$$W_0 = \lim_{t\to\infty} w(t) \tag{2}$$

and

$$w(t) = \int_0^t \left(\frac{d}{ds}w(s)\right)ds, \tag{3}$$

then, substituting (2) into (3), we have $W_0 = \int_0^\infty \left(\frac{d}{ds}w(s)\right)ds$. Therefore the scaling factor W_0 can be conveniently obtained by integrating the time derivative of the step response $w(t)$.

III. EXPERIMENTS AND RESULTS

Experiments were done in order to verify the feasibility of the proposed technique. An important part of the step generator is the shielded mercury-wetted relay (ALEPH model ZH1A12NZ). A special setup has been realized to measure the response of the MS. The basic circuit model of the step generator is represented in Fig. 1. A DC power supply V_1 is connected to the switch S_1, which represents the mercury-wetted relay, through a 1360 Ω resistor and a section of 50 Ω coaxial cable T_1. The 50 Ω resistor and the 10 nF capacitor provide for impedance matching at the left side of T_1. The length of T_1 ensures the constant step level, across the transducer input impedance Z, over its duration. To this aim, a 10 m cable length was used in the experiments with a propagation delay of T_1 equal to 50 ns. The impedance Z at the right side of T_1 represents the input impedance of the transducer (50 Ω or 1000 Ω for EFT and 2 Ω for ESD). The switch S_1 is controlled by the voltage source V_2 which is assumed to be an ideal step.

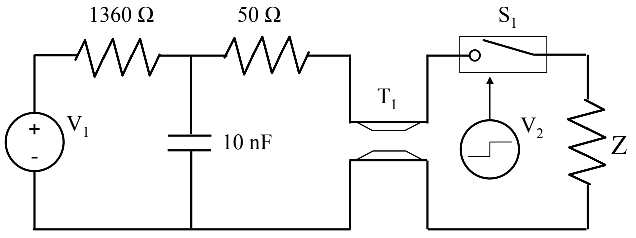

Fig. 1. Basic circuit model of the step generator.

When the relay is open the cable is charged by the DC supply V_1. When the relay is closed the charged cable behaves as an equivalent 50 Ω source until the complete discharge takes place. During the first 100 ns after the closure of S_1 the voltage step has a flat-top shape, then the 10 nF capacitor discharge initiates with the typical exponential shape. The DC supply is set to 30 V, according to the voltage limit of the relay contact.

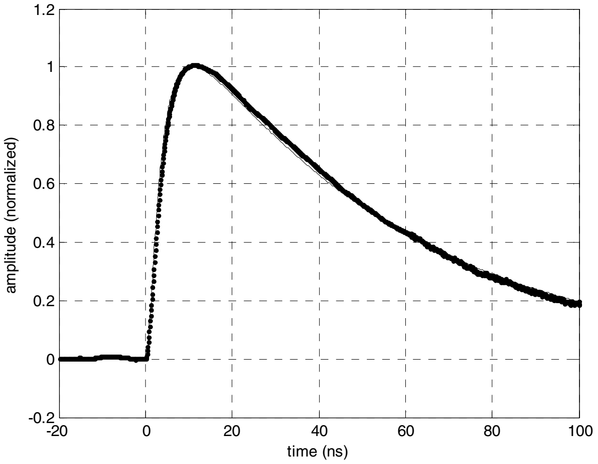

Fig. 2. Comparison between the standard EFT impulse (v_{in}, continuous line) and the MS response (v_{out}, dotted line, 50 transducer).

The rise time of the step generator is about 135 ps, as measured through a 12 GHz, 40 GS/s scope. The output of the step generator is connected to the input (Z) of the 50 • and 1000 • EFT voltage divider or to the 2 • ESD shunt through the appropriate conical adapter. The voltage at the output of the transducer is then measured by a digital storage oscilloscope. The bandwidth of the oscilloscope used for the experimental results shown in Fig. 2 and Fig. 3 is 3 GHz and its sampling rate is 10 GS/s. The acquired data are numerically processed by using a Matlab script.

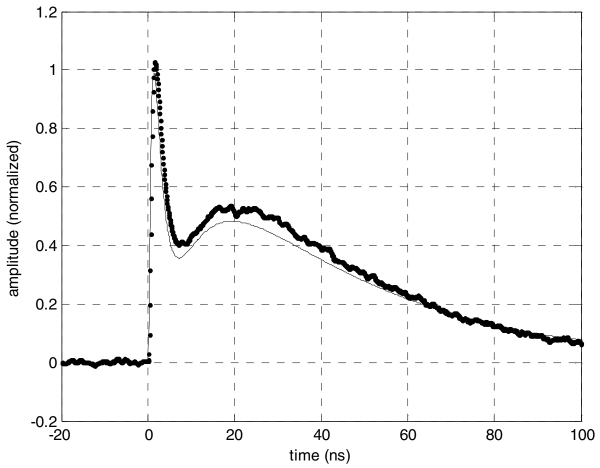

Fig. 3. Comparison between the standard ESD impulse (v_{in}, continuous line) and the MS response (v_{out}, dotted line).

VI. CONCLUSION

The problem of the calibration of EFT generators and ESD guns is a subject of considerable interest in the metrological community. In this paper a time-domain method based on the measurement of the step response and a simple numerical computation is presented. The distortion due to the measurement system is readily quantified.

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