ELECTROMAGNETIC IMMUNITY OF A PORTABLE PC-BASED MEASUREMENT INSTRUMENT

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Abstract - *In this paper we examine the behaviour of a portable PC-based measurement instrument, in the presence of electromagnetic disturbances, investigating how its characteristics change with respect to the ones measured in absence of electromagnetic phenomena. The analysis is carried out by means of experimental tests, subjecting the equipment under test to the threats considered by the IEC-61326 standard. The results show that the electromagnetic influence can lead to a worsening of the tested instrument features.*

Keywords: Electromagnetic Compatibility, Analog-to-Digital Conversion, PC Based Instruments.

1. INTRODUCTION

The characterization of the modular PC-based measurement instruments (PCBMI) involves a series of problems, which are exactly caused by their modularity [1]. These problems become more complicated, if we consider that the features of this kind of instrumentation can be altered by the electromagnetic disturbances. Other Authors have dealt with this subject. In [2] there is the study of the feature decrease due to the PC internal electromagnetic environment, and in [3], the analysis of the behaviour of a PCBMI, in the presence of electromagnetic disturbances, is carried out by means of a series of experimental tests in a shielded and semi-anechoic environment, subjecting the instrument to various electromagnetic perturbations, without taking into account the PC internal electromagnetic environment. As results of this analysis, only the SINAD (Signal to Noise and Distortion Ratio) and the SFDR (Spurious Free Dynamic Range) are reported. But these parameters do not take into account some of the main error sources, such as offset and gain, so they are useful to characterize the overall dynamic performances of an instrument, whereas they lose their validity for a complete characterization of a PCBMI.

Therefore, there is the need to separately examine the influence of the EM disturbances on each error sources. But, only considering the A/D conversion process, we should consider as error sources at least offset, gain, quantization, non-linearity, cross-talk, settling time and timing jitter [4]. Taking into account the influence of the EM disturbances on all these error sources would be a very hard task. But, considering that beside offset and gain, each source gives a contribution to the SINAD value, we examine, using an experimental approach as in [3], only the disturbances' effects on the offset, gain and SINAD values.

In order to apply standard requirements and criteria for the immunity experiments, we take into account the IEC-61236 standard [5].

2. THE IEC-61326 STANDARD

The IEC-61236 specifies minimum requirements for immunity and emissions regarding electromagnetic compatibility (EMC) for electrical equipment for measurement, control and laboratory use.

Since any PCBMI can be considered equipment for measurement, control and laboratory use, it should satisfy the IEC-61326 requirements. But in spite there are no particular rules, these instruments shows some peculiarity: unlike the stand-alone instruments, that, from the EMC viewpoint, can be characterized by the same manufacturer, a PCBMI is usually assembled and programmed by the users themselves, often using components from different manufacturers. Even having access to the EMC specifications of each component, extending these specifications to the whole measurement chain is not completely straightforward. All the components of the PCBMI have to be considered as a single equipment under test (EUT), and for each particular configuration, the immunity tests must be carried out. Only in this way, the complete characterization of the PCBMI, from the EMC viewpoint, can be carried out.

In the standard, the interfaces of the EUT with the external EM environment are classified in five ports: enclosure port; AC power port; DC power port; earth port; input/out port. The EM phenomena considered are: electrostatic discharges; radiated EM fields; conducted EM fields; voltage dips and short interruptions; bursts;

surges; rated power frequency magnetic fields. For each phenomenon and for the suitable port, the immunity testing requirements and limits are given for normal environments, industrial locations and for controlled EM environments. In the latest version of the IEC-61236, there are the requirements for portable test and measurement equipments that are powered by battery or from the circuit being measured. For these instruments, only the enclosure port has to be tested and only with regard to radiated EM fields and electrostatic discharges. As for the experiment setup and management, the IEC-61236 standard refers to the procedures described in the IEC-61000-4 series.

3. THE EXPERIMENT SETTINGS

The core of the tested PCBMI is the National Instruments™ DAQCard-AI-16XE10-50 data acquisition board, inserted in the notebook ASUS™ L7300.

The board characteristics are reported in Tab. I.

Tab. I - DAQCard-AI-16XE10-50 characteristics

Number of channels	16 single ended or 8 differential
Type of ADC	Successive approximation
Resolution	16 bits
Maximum sampling rate	200 kS/s
Maximum input signal range	± 10 V
Bandwidth	39 kHz

The DAQ is linked to the shielded connector box SCB-68 through the shielded cables PSHR68-68M (0.1 m) and SCH6868 (1 m).

As for the radiated fields, we applied the procedures described in the IEC-61000-4-3 standard [6], which suggests that the test facility consists of an absorber-lined shielded enclosure that shall be large enough to accommodate the EUT whilst allowing adequate control over the field strengths. In our case, considered the small dimensions of the EUT, a GTEM cell has been used. The employed test equipment is constituted of an RF signal generator, a power amplifier, and an isotropic field strength probe for monitoring the GTEM cell field uniformity. The measurement signals are sent to the panel connectors of the GTEM, and, inside the GTEM, to the connector box of the PCBMI, trough a couple of shielded cables (0.6 m).

Before starting the immunity tests, it is necessary to carry out a field calibration in the cell, in order to ensure that the uniformity of the field over the EUT is sufficient to guarantee the validity of the test results. The values obtained from the calibration are used to generate the EM field. For testing of equipment, the field-generating signal is in the frequency range 80÷1000 MHz and is 80% amplitude modulated with a 1 kHz sine wave. The frequency range is incrementally swept with a step size equal to the frequency of the previous step after multiplication by a factor of 1.01 (1% step size). The field strength test levels prescribed in the IEC-61236 standard are: 1 V/m for EM controlled environments; 3 V/m for EM normal environments; 10 V/m for industrial locations.

About the electrostatic discharges (ESD), we applied the procedures described in the IEC-61000-4-2 standard [7], which defines the typical waveform of the discharge current and the test equipment, set-up and procedures. Contact discharge is the preferred test method. Air discharge shall be used when contact discharge cannot be applied. For table-top equipments, a ground reference plane shall be provided on the floor of the laboratory, and over it, a wooden table. A horizontal coupling plane shall be placed on the table and connected to the ground plane by a short cable with a serial 470 kΩ resistors inserted in both cable extremes. The EUT and cables shall be isolated from the coupling plane by an insulating support. In order to minimize the impact of environmental parameters on the results, the tests have be carried out in a semi-anechoic chamber with climatic reference conditions. The discharges shall be applied only to such points and surfaces of the EUT that are accessible to personnel during normal usage. The test voltage shall be increased from the minimum to the selected test level, in order to detect any threshold of possible failure. The ESD test levels, for electrical equipment for measurement, control and laboratory use, prescribed in the IEC-61236 standard are: 4 kV for contact discharges and 8 kV for air discharge.

As inputs for the tested PCBMI, DC and sinusoidal signals are generated by the Agilent™ 33120A waveform generator. It is obvious that, in order to correctly characterize a 16-bits data acquisition board and to accurately calculate the offset, gain and SINAD values, we should use input signals with very great accuracy and very high spectral purity, generated by very high-priced generators. However, in this context we are only interested in the variations of offset, gain and SINAD values of the EUT subjected to the EM disturbances, with respect to the not perturbed conditions; consequently the crucial characteristics required to the generator are its repeatability and its stability.

All measurements are performed in differential mode, sampling at the maximum rate (2▪100 kS/s) and setting the gain to 1 (range ±10V). No anti-alias filter is inserted, given that for the used sampling rate, the limited bandwidth of the board amplifier itself minimizes the input of components at frequencies higher than the folding rate.

The evaluation of the characteristics of the EUT is carried out following the procedures prescribed in [4].

Static offset and gain values are calculated by drawing up the transfer characteristic, which, in turn is obtained from a five points least minimum squares method. The SINAD values are calculated using a not-coherent sampling and consequently a Hanning windowing. In spite in [4] the use of coherent sampling is suggested, in this way it is possible to characterize also the internal clock source of the board.

4. THE EXPERIMENT RESULTS

Before starting with the experiments, the repeatability and stability of the system must be checked. Repeating the measurement of offset, gain and SINAD, after the warm-up of the generator and of the EUT, and after the self-calibration of the data acquisition board, the values of Tab. II are obtained from a set of 300 measures repeated in the space of two hours.

Tab. II - DAQCard-AI-16XE10-50 measured characteristics

Feature	Manufacturer specification	Measured mean value	Measured repeatability and stability
Offset	±815 µV	125 µV	±2 µV
Gain	± 95 ppm	-24 ppm	± 9 ppm
SINAD	not specified	81.4 dB	± 0.1 dB

These values are perfectly compatible with the manufacturer specifications and with the characteristics of the used signal generator.

In Fig. 1-3, we report the offset, gain and SINAD values, as a function of the disturbance frequency, radiating the shielded configuration of the EUT with a 10V/m disturbance field. Each reported value is the mean of 100 measured values. The dotted lines stand for the values measured without disturbance.

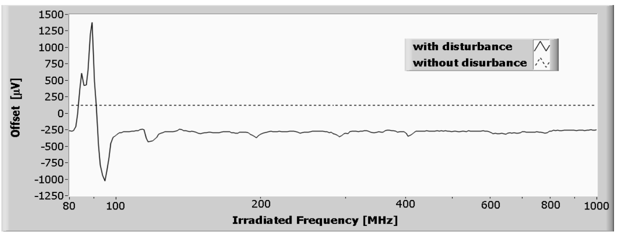

Fig. 1 – Offset values

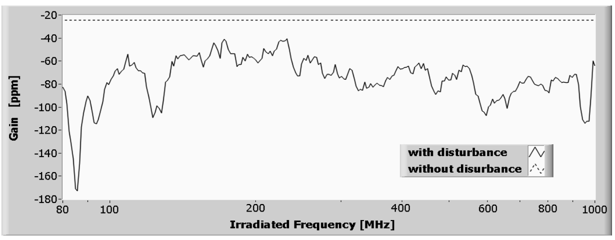

Fig. 2 – Gain values

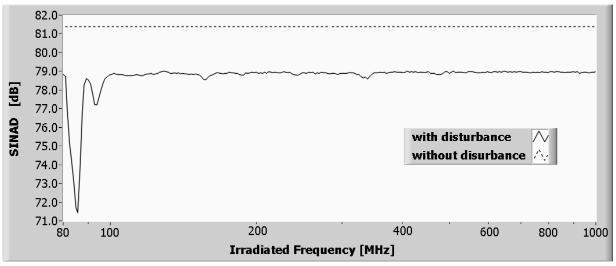

Fig. 3 – SINAD values

Analyzing the results, it is possible to point out that as for offset and SINAD values, the disturbance fields generate an approximately constant shift from the respective values measured in the disturbance absence, except in the range 85÷95 MHz, where the system resonates, causing much greater shifts from the no-field values.

These resonances are caused by the connection wiring. In fact, in our test set-up, the length of this connection, between the GTEM panel connector and the PCBMI, is approximately one half wavelength for these frequency range. In this circumstance, the behaviour of the connection wiring it is similar to the behaviour of an antenna. The same resonance frequencies affect the gain values, however with a smaller impact. Moreover the gain value shows a more irregular behaviour by varying the disturbance frequency. Applying lower disturbance field strengths, we obtained similar results, but obviously with smaller shifts from the values measured without disturbance.

In Fig. 4-6 we report the offset, gain and SINAD values, as a function of the field strength at the main resonance frequency.

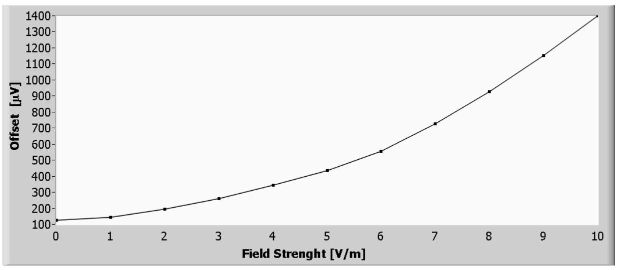

Fig. 4 – Offset values at the main resonance frequency

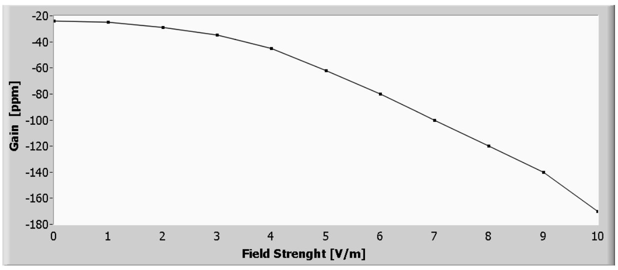

Fig. 5 – Gain values at the main resonance frequency

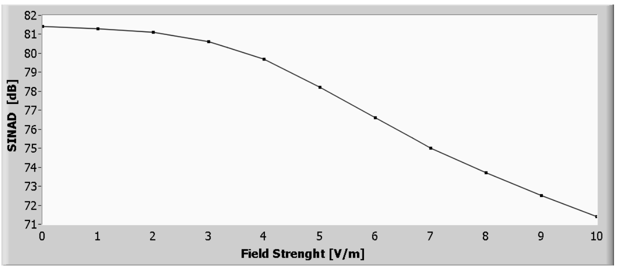

Fig. 6 – SINAD values at the main resonance frequency

The maximum shifts from the values calculated without disturbances are reported in Tab. III, for a 3 V/m and 10 V/m field strength.

Tab. III – Maximum deviation of the characteristics of the EUT from the values calculated without disturbances

Characteristic	Maximum deviation	
	3 V/m	10 V/m
Offset	140 µV	1255 µV
Gain	-26 ppm	-149 ppm
SINAD	0.6 dB	10.0 dB

Another interesting result is that, when the board channels are inverted, the polarity of the induced disturbance changes sign, and therefore also the maximum deviations of Tab. III change sign. This means that, when the PCBMI is subjected to EM fields, the manufacturer specifications have to be increased of these maximum deviation values, obtaining the values of Tab. IV (the SINAD value is not declared in the specifications, so the actually measured values are reported).

Tab. IV – Tested system characteristics under disturbance

Characteristic	Specification		
	No disturbance	3 V/m	10 V/m
Offset	±815 µV	±955 µV	±2070 µV
Gain	± 95 ppm	± 121 ppm	± 244 ppm
SINAD	81.4 dB	80.8 dB	71.4 dB

We repeated the tests using the same configuration but changing only the notebook and the obtained results are practically coincident. We tested also another board of the same model; the undisturbed measured mean values of offset, gain and SINAD are obviously different in comparison with the values obtained for the first DAQ, however the maximum deviation observed under radiated fields, are approximately equals to the Tab. IV values.

All these results show that, when the PCBMI is subjected to the considered radiated EM fields, the performance could exceed the specification limits.

Moreover, during the experiments with 10 V/m field and at the resonance frequencies, the PC was happened to stop, to reset or even to turn off, losing the acquired data and needing the operator intervention.

As for the ESD immunity test, contact and air discharges in the most sensitive polarity were applied in various points of the EUT, starting from 1 kV and increasing the test level value with a step size of 0.5 kV. With respect to the not-perturbed conditions, no changes were detected of the offset, gain and SINAD values. But overcoming the 3.5 kV value for contact discharges and 6.5 kV value for air discharges, almost systematically, the notebook was again happened to stop, to reset or to turn off.

5. CONCLUSIONS

In this paper, the behaviour of a portable PCBMI, subjected to electromagnetic disturbance, has been analyzed. The whole system was characterized measuring some of its performances, and in particular, the offset, gain and SINAD values were calculated, varying frequency and strength of the disturbance fields.

The results shows that, under these conditions, the performances of the instruments get worse, since the specification limits of offset and gain have to be expanded and the SINAD value decreases; consequently, the standard uncertainty associate with each error source increase. For these reasons, when any measurement is performed under electromagnetic threats, the combined standard uncertainty associated with the measurement result could increase, causing deterioration of the measurement quality.

REFERENCES

[1] S. Nuccio, C. Spataro: "Approaches to Evaluate the Virtual Instrumentation Measurement Uncertainties", IEEE Trans. on IM, Vol. 51, N. 6, December 2002.

[2] V.Haaz, A.Pistnek: "Influence of a Disturbing EM Field on the Real Number of Effective Bits of PC Plug-in Boards" in Proc. of XIV IMEKO World Congress, Tampere, Finland, September 1997.

[3] G.Betta, D.Capriglione, C.De Capua, C.Landi: "EMC characterization of PC-based data acquisition systems" in Proc. of ISIE, L'Aquila, Italy, June 2002.

[4] IEEE Std 1241, 2000, "IEEE Standard for Terminology and Test Methods for Analog-to-Digital Converters".

[5] IEC Std 61326, 2002, "Electrical equipment for measurement, control and laboratory use – EMC requirements".

[6] IEC Std 61000-4-3, 2002, "Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test".

[7] IEC Std 61000-4-2, 2001, "Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques – Electrostatic discharges immunity test".