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ELECTROMAGNETIC IMMUNITY OF A PORTABLE DATA ACQUISITION SYSTEM

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Abstract - In the paper the performance of a portable data acquisition system under radiated electromagnetic disturbances is investigated, in order to find out if and how its peculiar characteristics change with respect to the ones measured in absence of electromagnetic field. The analysis is carried out by means of experimental tests, subjecting the system under test to the threats considered by the IEC-61326 standard and following the test procedures prescribed in the IEC-61000-4-3 standard. The results show that the electromagnetic influence can lead to a worsening of the tested data acquisition system features.

Keywords: Electromagnetic Compatibility, Analog-to-Digital Conversion, Data Acquisition System.

1. INTRODUCTION

The general-purpose data acquisition systems (DAS) have extensively entered each sector of the measurement and instrumentation field. However, their dissemination in the industrial environment and in the test and calibration laboratories has been limited because of the difficulties connected with their characterization, and consequently, with the evaluation of the measurement uncertainties. In fact, for a correct employment in a quality management system, it is essential to characterize all the employed measurement instruments and to estimate the uncertainties associated with the measurement results [1, 2].

We already dealt with the topic and proposed two methods to characterize a generic DAS: a theoretical method [3] based on an original application of the uncertainties propagation law of the GUM; and a numerical method [4] which, by means of an ad hoc developed software tool, estimates the uncertainties using the Monte Carlo approach.

The problems tied to the DAS characterization become more complicated, if we consider that the features of this kind of measurement instrumentation can be altered by the electromagnetic disturbances. The subject matter is quite important since the sources of electromagnetic pollution are becoming more and more numerous and the intensity of their emissions is more and more increasing.

Other Authors have dealt with this theme. In [5, 6] there is the study of the feature decrease due to the PC internal electromagnetic environment, and in [7], the analysis of the behaviour of the PC-based instruments, 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 various instruments to various electromagnetic perturbations, without taking into account the PC-internal electromagnetic environment. As results of this interesting 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 DAS.

For this purpose, according to the ISO – “Guide to the Expression of Uncertainty in Measurement” (GUM) [8], the starting point should be the assessment of the standard uncertainties associated with each error source. Therefore, there is the need to separately examine the influence of the EM disturbances on each error sources. However, 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 [9]. Taking into account the influence of the EM disturbances on all these uncertainty 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 [7], 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 [10], where seven different EM phenomena are considered. In this paper we analyze the behavior of a portable DAS. For this kind of instruments, only radiated EM fields and electrostatic discharges have to be considered.

In the following we report the immunity requirements and criteria for electrical equipment for measurement, control and laboratory use (chapter II). The tested instrument characteristics and specifications, the environment and the instruments used for the immunity tests and the experiment setup are described in chapter III. In chapter IV we experimentally analyze how each considered error source is influenced by the electromagnetic disturbances. The conclusions are presented in chapter V.

2. THE IMMUNITY REQUIREMENTS AND CRITERIA

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 DAS 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 for the DAS, these instruments shows some peculiarity: unlike the stand-alone instruments, that, from the EMC viewpoint, can be characterized by the same manufacturer, a DAS 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 DAS 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 DAS from the EMC viewpoint, and consequently, the correct uncertainty evaluation can be carried out.

As for the immunity requirements, 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.

The performance criteria for the evaluation of the immunity test results are the following:

- Criterion A: during testing, normal performance within the specification limits.
- Criterion B: during testing, temporary degradation, or loss of function or performance which is self-recovering.
- Criterion C: during testing, temporary degradation, or loss of function or performance which requires operator intervention or system reset occurs.
- Criterion D: degradation or loss of function which is not recoverable due to damage to equipment, components, software, or loss of data.

As for the experiment setup and management, the IEC-61236 standard refers to the procedures described in the IEC-61000-4 series.

As outlined in the introduction, we experimentally analyze the behaviour of a portable DAS. 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 electrostatic discharges and radiated EM fields. In this framework, we limit the analysis only to the radiated EM fields, following, for the experiment setup, the procedures described in the IEC-61000-4-3 standard [11].

3. THE TEST SETTINGS

The core of the tested DAS 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 (single channel) 20 kS/s (all channels)	
Input signal ranges	Bipolar	Unipolar
	± 10 V	0 to 10 V
	± 5 V	0 to 5 V
	± 1 V	0 to 1 V
	± 0.1 V	0 to 0.1 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 immunity tests, we applied the procedures described in the IEC-61000-4-3 standard, 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. Associated shielded enclosures shall accommodate the field generating and monitoring equipment, and the equipment which exercises the EUT management. This includes anechoic chambers, modified semi-anechoic chambers, TEM cells or strip lines.

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. Another notebook was used for recording the power levels necessary for the required field strength and controlling the generation of the selected test levels, through GPIB interface.

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. In Fig.1, a schematic representation of the field calibration system is showed.

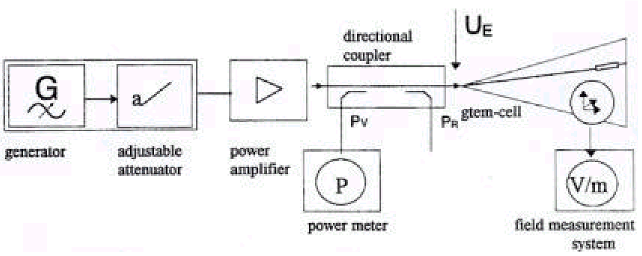

Fig. 1 – A schematic representation of the calibration system.

The instruments used for calibrating the cell and performing the tests, are reported in Tab. II.

Tab. II – Instruments used for the immunity tests

Instrument	**Manufacturer**	**Model**	**Frequency range**
RF Signal generator	Rohde&Schwarz	SMR20	10 MHz-20GHz
Power amplifier	Schaffner	CBA9477B	150kHz-1GHz
Directional coupler	Schaffner	DCP 0100	10kHz-1GHz
Power meter	Agilent	E4419B	
Power sensor	Agilent	E9304A	9kHz-6GHz
GTEM cell	Schaffner	750	10kHz-18GHz

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 test levels of the field strength are prescribed in the IEC-61236 standard:

- 1 V/m for EM controlled environments;
- 3 V/m for EM normal environments;
- 10 V/m for industrial locations.

As inputs for the tested DAS, DC and sinusoidal signals are generated by the Agilent™ 33120A function and arbitrary 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 imperative characteristics required to the generator are its repeatability and its stability.

The signals are sent to the panel connectors of the GTEM, and, inside the GTEM, to the connector box of the DAS, trough a couple of shielded cables (0.6 m).

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 [9]. 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 [9] 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 internal calibration of the data acquisition board, the values of Tab. III are obtained from a set of 300 measures repeated in the space of two hours.

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

Characteristic	**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.

At this point, the target is to detect what is the worst layout of the EUT, from the EMC viewpoint. After a set of tests performed varying, inside the GTEM, the position of the various components of the DAS, and varying frequency and strength of the disturbance fields, it was possible to find out that the position of the notebook is practically not significant for the immunity degree of the EUT; as for the shielded connector box, the immunity of the whole instrument gets worse when it is arranged with its longest side parallel to the disturbance propagation direction. However the differences on the measured values, observed changing the position of the connector box, are smaller than 15%. Obviously all the other tests were performed setting the DAS in the less immune position.

In Fig. 2-7, we report the offset, gain and SINAD values, as a function of the disturbance frequency, illuminating the shielded configuration of the EUT with a 3 V/m and 10V/m disturbance field. Each reported value is the mean of 100 measured values. The dotted lines stand for the values measured without disturbance.

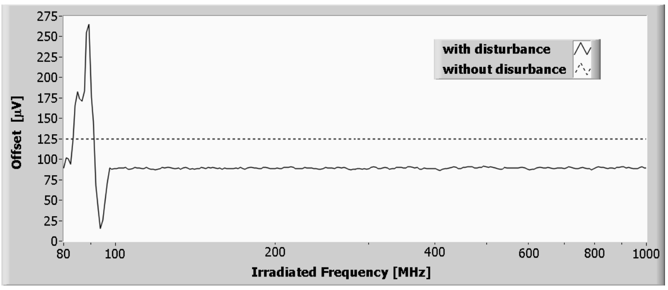

Fig. 2 – Offset values – 3 V/m

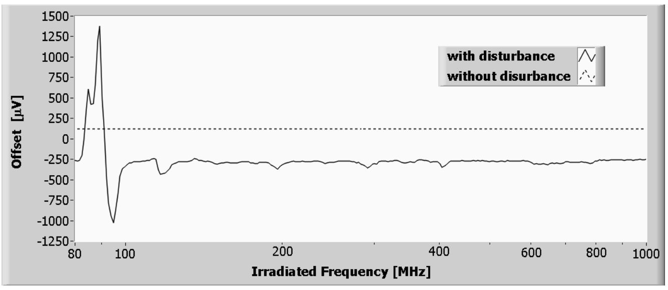

Fig. 3 – Offset values – 10 V/m

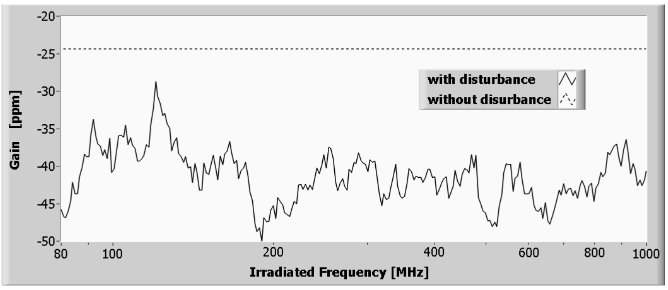

Fig. 4 – Gain values – 3 V/m

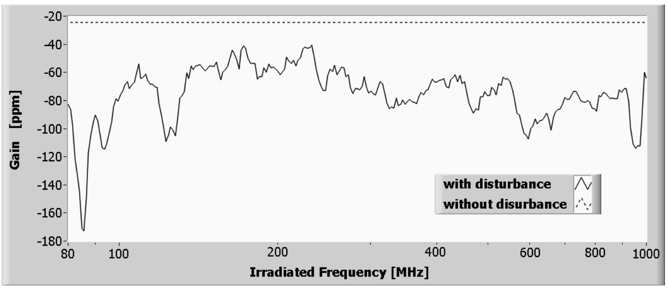

Fig. 5 – Gain values – 10 V/m

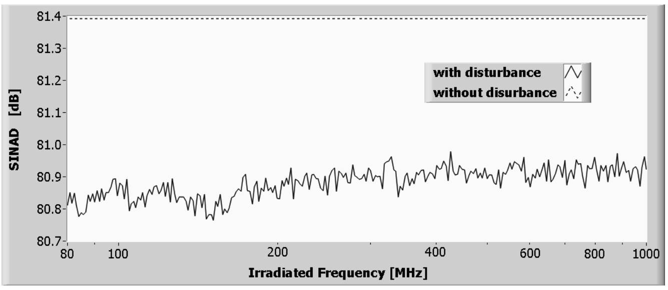

Fig. 6 – SINAD values – 3 V/m

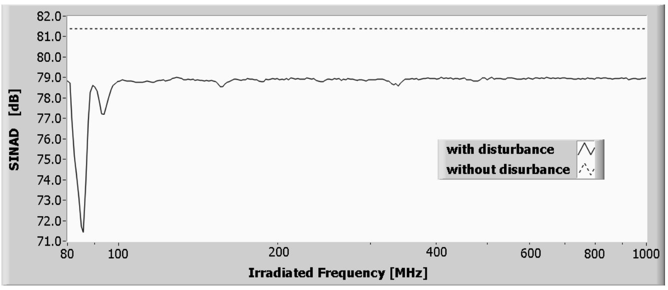

Fig. 7 – SINAD values – 10 V/m

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 presumably caused by the connection wiring between the GTEM panel connector and the DAS. In fact the length of this connection 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.

In Fig. 8-10 we report the offset, gain and SINAD values, as a function of the field strength at the main resonance frequency.

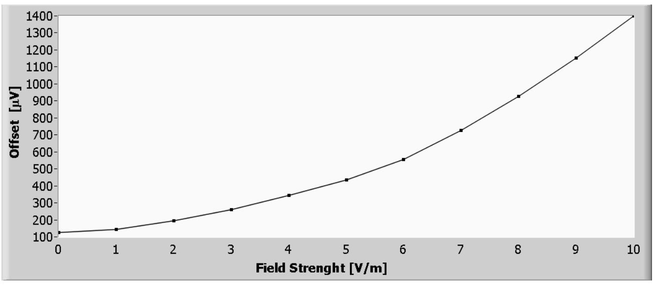

Fig. 8 – Offset values at the main resonance frequency

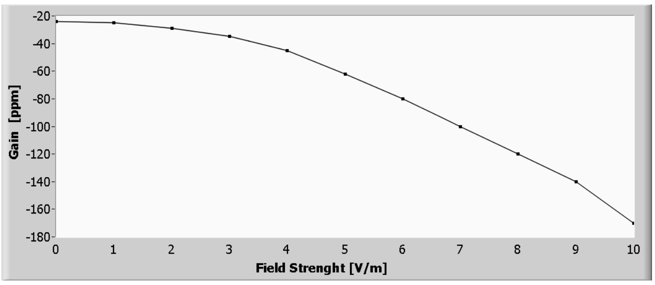

Fig. 9 – Gain values at the main resonance frequency

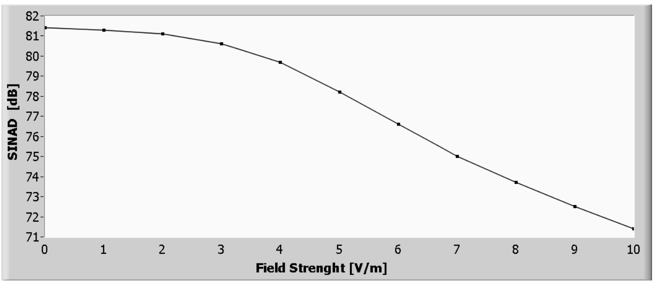

Fig. 10 – SINAD values at the main resonance frequency

The maximum shifts from the values calculated without disturbances are reported in Tab. IV.

Tab. IV – 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. IV change sign. This means that, when the DAS is subjected to EM fields, the manufacturer specifications have to be increased of these maximum deviation values, obtaining the values of Tab. V (the SINAD value is not declared in the specification, so the actually measured values are reported).

Tab. V – 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. For instance, in Fig. 11, we report the offset values for the shielded configuration of the second EUT, subjected to a 10 V/m disturbance field.

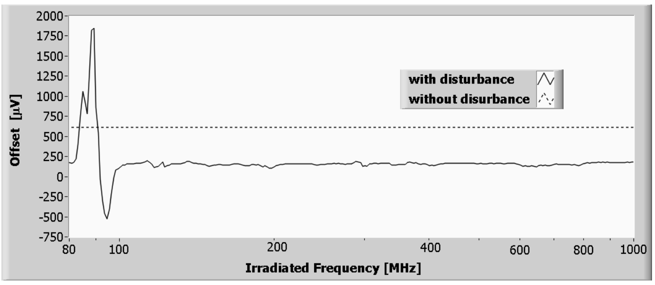

Fig. 11 – Offset values of the second EUT– 10 V/m

All these results show that, when the EUT is subjected to the considered radiated EM fields, the performance could exceed the specification limits, and therefore the EUT does not respect the criterion A of the IEC-61236 standard.

However, during the experiments with 10 V/m field and at the resonance frequencies, the PC was happened to reset or even to turn off, losing the acquired data and needing the operator intervention. In these cases, neither the criterion C of the IEC-61236 standard was respected.

5. CONCLUSIONS

In this paper, the behaviour of a portable DAS, subjected to radiated 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 radiated EM field, the combined standard uncertainty associated with the measurement result increases, causing deterioration of the measurement quality.

By means of further tests, we are analyzing other configurations and the other EM disturbances considered in the IEC-61236 standard.

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