

SITE-TO-SITE REPRODUCIBILITY IN CONDUCTED IMMUNITY TESTS ON PC-BASED DATA ACQUISITION SYSTEMS

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Abstract-This paper deals with electromagnetic susceptibility of PC-based data acquisition systems (DASs) when subjected to electromagnetic disturbances considered in the EMC applicable standards. A suitable measurement procedure that allows the DAS susceptibility to be highlighted is proposed. Furthermore, a preliminary analysis of the measurement reproducibility is carried out with the aim of investigating some aspects that could affect the result reliability: the environmental and instrumentation features, the configuration set-up. To these aims, a number of tests are carried out by considering many data acquisition systems, different test set-up, and performing the experiments in two different sites. The connected results are compared and commented.

I. Introduction

Nowadays, data acquisition systems (DASs) are often approached as a standard PC with an embedded data acquisition board. In fact, this solution is attractive mainly due to its versatility, easiness of use and relatively low implementation costs.

However, given that the main applications of the PC-based DASs concern with monitoring of production lines and super visioning of industrial processes, these systems often operate in a hostile electromagnetic environment due to other electronic/electric devices located nearby, that generate conducted (through power lines and I/O lines) and radiated interferences (intentional and non-intentional) during their normal operation. As a consequence, the DAS is interested by electromagnetic disturbance that could compromise their nominal operation and performances.

In [1]-[2] suitable standard disturbances in agreement with EMC immunity applicable standards [3] were applied to the DAS and it was proved how both conducted and radiated disturbances can determine the decreasing of many A/D converter quality indices such as SINAD (Signal-to-Noise and Distortion ratio), SFDR (Spurious Free Dynamic Range), Offset and Gain [4]. Moreover, in [5], the authors have proposed a procedure to evaluate the susceptibility of PC-based data acquisition systems when subjected to conducted disturbances considered by EN 61000-4-4 [6] and EN 61000-4-6 [7]. The proposed test methodology was applied to different DAQ boards of different manufacturers and the achieved results proved the ability of the procedure to evaluate the electromagnetic susceptibility of PC-based data acquisition systems. On the other hand, one of the most critical tasks concerning the electromagnetic compatibility measurements is the site-to-site reproducibility [8]-[10]. In fact, small differences both in the arrangement of test set-up [11]-[13] and in the laboratory features [14]-[15], as well as the apparatus configurations during the test could bring to different results thus introducing non-negligible uncertainty in the EMC conformity/non conformity decision of the tested equipment. As a consequence, a detailed analysis of the measurement reproducibility should be carried out with aim of improving the results reliability. Of course, the DAS electromagnetic susceptibility test belongs to this context. Consequently, the investigation on the connected measurement reproducibility has to be made. In this paper, the analysis will be referred to the conducted immunity test on AC power port of the DAS defined by EN 61000-4-6.

II. The proposed approach

In order to investigate the results reproducibility, many experiments on different DASs and a comparison between different measurement sites are indispensable. In fact, as previously mentioned, there are many parameters concerning the set-up and the characteristics of instrumentation used to perform the tests, as well as the electromagnetic features of the test laboratory that could introduce

considerable differences in the obtained results. More in detail, when electromagnetic measurements are carried out, the main parameters that should be taken into account as possible source of measurement uncertainty and that could compromise the reproducibility are:

- Test set-up, mainly in terms of cable lengths and layout. In fact, when a conducted disturbance involves the supply cable, the emissions radiated by the cable itself could couple with the EUT and alter its performances. Therefore, the length, type of shielding and layout of the supply cables should be carefully defined and characterized;
- Equipment Under Test (EUT) configuration during the test (in the specific case of data acquisition systems, it means the use of shielded/not shielded cable, shielded/not shielded connector block, channel settings);
- Instrumentation used to execute the immunity tests (generator of disturbance, coupling/decoupling networks, possible auxiliary apparatus);
- Electromagnetic features and environmental conditions of the site during the tests;

As a consequence, many factors could contribute to the final test results, thus influencing the site-to-site reproducibility, even if the tests are carried out strictly following the applicable standards. The tests should be carried out for many DASs bearing in mind all the above listed aspects and following the recommendations of EMC applicable standards [3], [7]. Moreover, they should be executed in different EMC laboratories to take into account their different electromagnetic and environmental features.

In [5], [14], the authors have already investigated the effect of the conducted disturbances for different data acquisition systems. In this paper, the analysis concerns mainly with the evaluation of the influence of laboratory and instrumentation features on the results. To this aim, the tests are carried out in two different sites placed at the University of Cassino and I.S.S.I.A - C.N.R. of Palermo, both equipped with full-compliance EMC instrumentation and by considering two identical data acquisition systems.

III. The test set-up

In order to perform a reliable result comparison, in both laboratories, the data acquisition systems were realized with two standard PC equally equipped with identical data acquisition boards (12 bits, 100 kHz maximum sampling frequency) and cable accessories (flat , unshielded connector cable and passive connector block).

As for the test set-up (Figure 1), it was carefully arranged following the specification of the EN 61000-4-6 EMC standard. In particular, it requires that tests be made by using specific instrumentation to couple the injected disturbance (provided by a suitable standard disturbing generator) with equipment under test (EUT), in this case the DAS. The amplitude of the disturbing signal was fixed at 3 V and the frequency was varied in the range 150 kHz ÷ 80 MHz with 1 kHz AM modulation, by considering a step frequency increase of 2 %. The instrumentation used to generate and to couple the disturbance was EN 61000-4-6 full compliant.

Each module of the EUT was suitably placed 0.1 m far away the ground plane as required by the

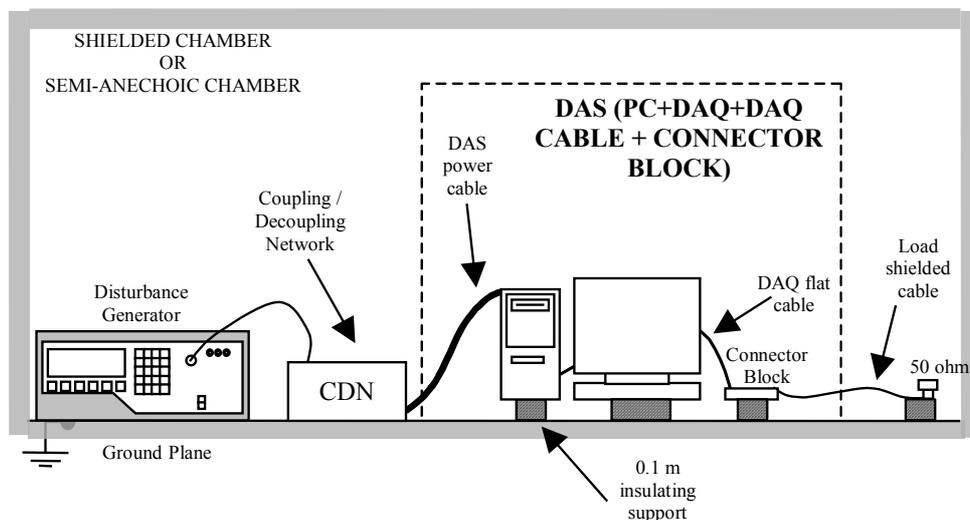


Fig.1 Test set-up used (compliant with EN 61000-4-6)

standard.

The EN 61000-4-6 does not require placing the EUT and instrumentation used for the test in a well-defined environment. As a consequence, with aim of analysing also the possible influence of the environment on the results, the experiments were carried out in two different electromagnetic environments, a semi/anechoic chamber (at I.S.S.I.A - C.N.R. of Palermo) and a shielded chamber (at University of Cassino).

In order to avoid any influence introduced by auxiliary equipment that could be used during the tests, no signal was applied to the DAQ board analog input channel, which was connected to a coaxial cable terminated with a 50Ω load. The DAQ settings were the same in both laboratories and the sampling frequency was chosen equal to the maximum allowable, 100 kHz, following the suggestion given in [5].

Moreover, the standard does not define some set-up parameters such as the cable layout and cable length, leaving some freedom degree to the test operator. Therefore, with the aim of investigating the consequences of this aspect, the most common set-up was considered. In order to simplify the analysis, the most probable practical cases were considered among all possible configurations and therefore some set-up parameters were fixed. More in detail, the DAS power cable and the DAQ flat cable are kept fixed to a typical length, 1.2 m and 1 m, respectively, whereas the load cable layout and cable length were varied as follows:

- I. cable layout: the load cable was oriented in three different ways with respect to the radiating cable (DAS Power Line), looking for the maximum DAS susceptibility;
- II. cable length: different load cable lengths were considered, 1.4 m, 1 m and 0.6 m, respectively.

For each configuration, the influence of the disturbance was evaluated by analysing the power spectrum of the corresponding acquired signal and in particular, by evaluating the amplitude of the maximum spurious harmonic. In fact, as already described in [1] [5] [16], a continuous wave disturbance applied on the AC port of the system causes a spurious harmonic clearly visible on the spectrum of the sampled signal. As an example, in Figure 2 the power spectra of the acquired signal with no disturbance applied (Figure 2a) and in presence of a noise injected at 1.04 MHz with 1 kHz AM modulation (Figure 2b) are reported. The power spectra were evaluated by considering an interpolated FFT algorithm on 10000 samples with 100 kS/s sampling frequency. They show that the disturbance introduces some spurious harmonics not negligible with respect to the acquired signal and clearly visible in the power spectrum because of the aliasing effect.

It is interesting to point out that even if the disturbance is applied in a conductive way the coupling mechanism is clearly that of a radiated disturbance. This was evidenced in previous papers [1], [5], [6] and confirmed by all the experiments carried out in this context. Consequently, it was proven that some layout parameters, not completely defined in the standards, could influence the test results and then have to be considered as influencing parameters to be varied looking for their effects.

IV. Experimental results

All tests were carried out in both measurement sites. For each set-up, a statistical analysis was performed by considering a suitable number of measurements achieved in different days and every time by rearranging the set-up.

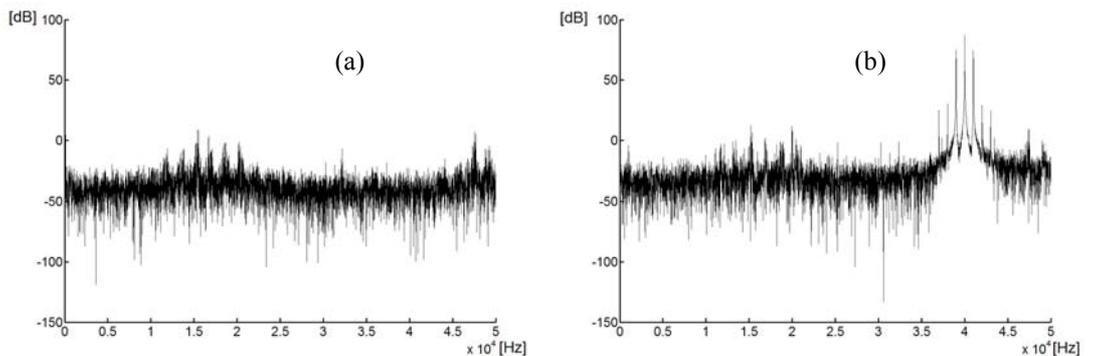


Figure 2. Power spectra of the acquired signal: (a) no disturbance applied (b) noise injected at 1.04 MHz with 1 kHz AM modulation

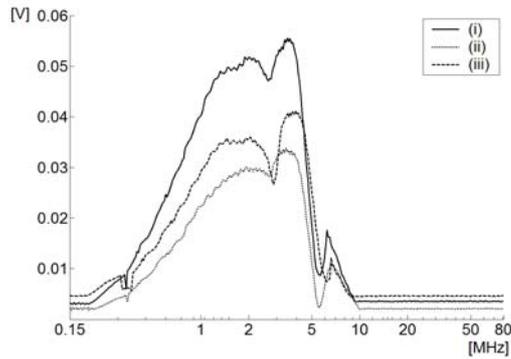


Figure 3. Maximum harmonic measured by the DAQ in function of the disturbance frequency, for different cable layout

all the set-up, the maximum value was found at 3.5 MHz with corresponding amplitudes of 0.055 V, 0.034 V and 0.041 V, respectively. The maximum mean standard deviation evaluated on 1000 experiments was equal to 50 μ V. For all the considered set-ups, the maximum disturbance influence is achieved in the frequency range 0.5 MHz - 4.5 MHz, while negligible effects are identified for frequency greater than 10 MHz. The worst set up was the (i) one, with the greatest spurious harmonic amplitude equal to 0.055 V. In any case, bearing in mind that the test purpose is the verification of the DAS susceptibility to the considered disturbance, it is possible to say that even if the cable layouts influence the results, the tested system is always susceptible whatever the arrangement of the test set-up.

Repeating all tests in the semi-anechoic chamber of the C.N.R. Institute, some differences with respect to the other measurement site were observed in terms of both maximum amplitudes and frequencies at which the maximum is evidenced. In particular, considering the layout i) the maximum spurious harmonic amplitude was 0.028 V, obtained at 21.9 MHz, whereas in ii) and iii) layouts the maximum values were 0.016 V and 0.019 V, respectively, and also in this case at the same frequency of i). In this case, the mean standard deviation evaluated on 1000 experiments was about 40 μ V.

These results prove that some differences between sites are evident in terms of both, amplitude of the spurious harmonic and of the corresponding disturbance frequency. Anyway, it is interesting to note that in both sites the worst frequency is not influenced by the layout and that the relative variations between layouts are similar (about 40 % between (i) and (ii) layouts). This suggests that some

A. Influence of cable layout

Keeping constant all cable lengths, among all possible layouts the most probable ones were considered. Namely they were:

- i) load cable as far as possible from both flat cable and power cable;
- ii) load cable parallel and close to the flat cable and orthogonal to the power cable;
- iii) load cable parallel and close to the power cable and to the flat cable.

In Figure 3, the evolution of the mean values of the maximum spurious harmonics versus the frequency of the injected disturbance are reported for the experiments carried out in the shielded room of the University of Cassino and by considering each layout i), ii) and iii).

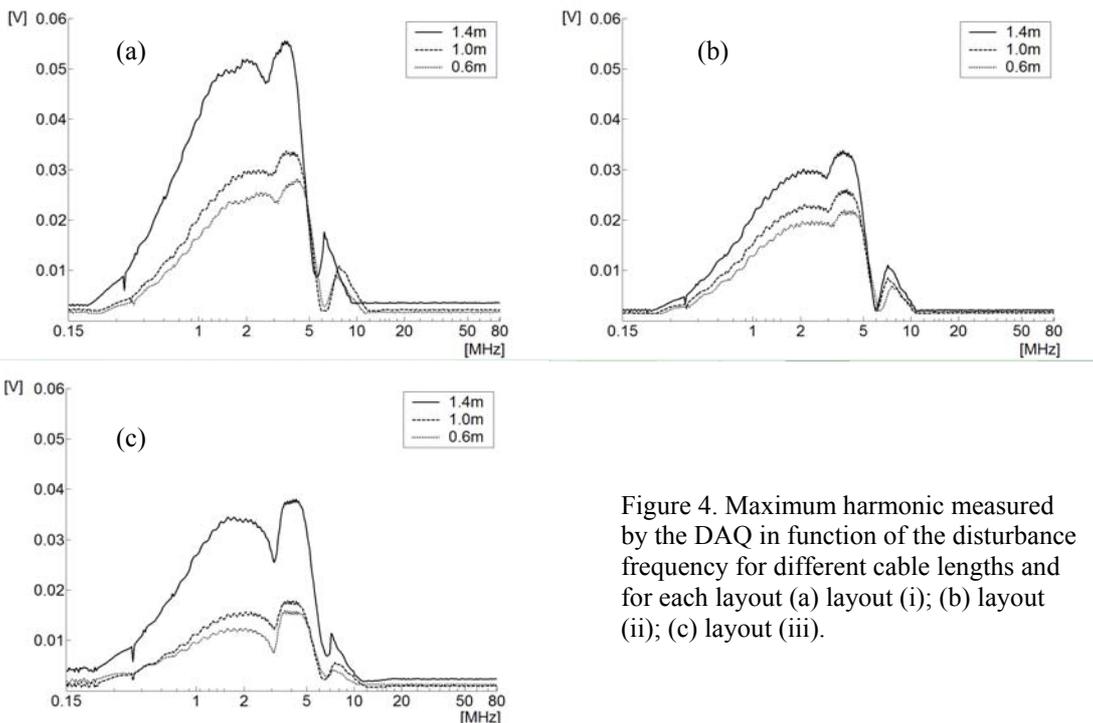


Figure 4. Maximum harmonic measured by the DAQ in function of the disturbance frequency for different cable lengths and for each layout (a) layout (i); (b) layout (ii); (c) layout (iii).

differences between sites are possible but the effect of the analysis carried out has a general applicability.

Concluding, the evaluation of the spurious harmonic amplitude is a suitable method to highlight the DAS susceptibility to this kind of conducted disturbance.

B. Influence of cable lengths

For each set-up considered in the previous section, the following load cable lengths were considered: 0.6 m, 1 m and 1.4 m.

Figure 4 shows the results for test carried out in the shielded chamber. They highlight that different lengths of the load cable bring to different results mainly in terms of amplitude, whereas the frequency ranges corresponding to the maximum disturbance are independent on load cable length. In particular, by analyzing Figure 4a, it is possible to say that the maximum harmonic (amplitude of 0.055 V) is achieved at 3.5 MHz, for cable length equal to 1.4 m. As the cable length decreases the maximum amplitude harmonic decreases (0.033 V for 1.0 m, 0.027 V for 0.6 m) but the corresponding frequency is the same.

Similar results are obtained in the semi-anechoic chamber: as an example, referring to the set-up (i) and load cable length equal to 1.4 m, as previous said, the maximum amplitude of the spurious harmonic was 0.028 V at 21.9 MHz. Considering 1 m and 0.6 m load cable lengths, the amplitude of the corresponding maximum spurious harmonic was 0.019 V and 0.017 V, respectively, while the frequency range in which the influence of the disturbance is amplified was the same.

Comparing the results carried out in the two measurement sites, some differences are evidenced both in terms of the amplitude and frequency of the maximum spurious harmonic. However in both cases, the increase of the cable length causes a greater spurious harmonic and therefore, the susceptibility of the DAS is more evident.

V. Conclusions

In this paper the analysis of the electromagnetic susceptibility of PC-based data acquisition systems (DASs) was carried out. Among all possible EMC measurements, the immunity conducted test defined by EN 61000-4-6 was performed.

A suitable measurement procedure that allows the DAS susceptibility to be highlighted is proposed. It is based on a simple FFT analysis performed on the signal sampled in presence of the considered disturbance and in absence of input signal. In order to verify its general applicability a suitable comparison between the results obtained in two measurement sites was executed. Different electromagnetic and environmental features characterized these test laboratories and in both cases, the instrumentation used was EMC full-compliant. This comparison was necessary since in EMC context, small differences in the set-up used during the test such as the cable length, cable layout and instrumentation used are source of additional measurement uncertainty. In particular, the effects of the cable layout and the cable length were analysed in detail.

The tests carried out clearly highlight not negligible differences between the two test sites. However in both cases the configuration of some set-up parameters such as the cables layout and cables length bring to similar results, thus proving the generality of the method proposed to evidence the DAS susceptibility. Further studies will concern with the identification of the causes that could influence the differences obtained in the measurement sites.

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