The Friedman Test as a Statistical Tool to Deal with Measurement Noise in Electromagnetic Compatibility Analysis

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Performing replicated measurements is a common practice in noisy-data experiments, where uncertainties coming from the equipment can turn analysis unpractical. In Electromagnetic Compatibility tests, the noise contribution might be random and hence the number of replicates to recognize its shape might be unknown. Statistical techniques like the Friedman Test are usually adopted in other fields of study like Psychology and Medicine in an attempt to predict this contribution with basis on a sufficient number of replicates. In this work, the use of such technique is proposed for a Radiated Immunity test study, where signal generators with different signal-to-noise ratios are available. A reference has been established through an ideal generator created with simulation software. The obtained results confirmed the suitability of the Friedman Test for Electromagnetic Compatibility analysis.

***Index Terms* — Electromagnetic Compatibility, Friedman Test, Noise, Radiated Immunity.**

I. Introduction

The presence of spurious signals over measurements is known in many Engineering branches. In the Electromagnetic Compatibility (EMC) field [1], the cause of this type of phenomenon can be attributed to low Signal-to-Noise Ratio (SNR) equipment and also to non-ideal laboratorial facilities. This field has shown a lack of studies towards a great mathematical rigor involving the experimental analysis. Although not always true, in such scenarios it is common to assume that the results of the variables investigated are reliable. Once the measurement uncertainties are not known in advance, conclusions about the Device Under Test (DUT) performance might be compromised or even corrupted. On the other hand, it has been identified a growing amount of studies with theoretical tools to deal with measurement uncertainties, noise and other stochastic events, in areas like Bioengineering [2] and Electric Systems [3].

The main goal of this paper is to propose the use of the statistical technique called the Friedman Test as a suitable tool to deal with noisy data in EMC analysis. In order to do so, there was an effective use of experimental and statistical analysis, as well as simulations. The methodology looks to complement the results from [4] based on an EMC test called Radiated Immunity (RI) [1,5].

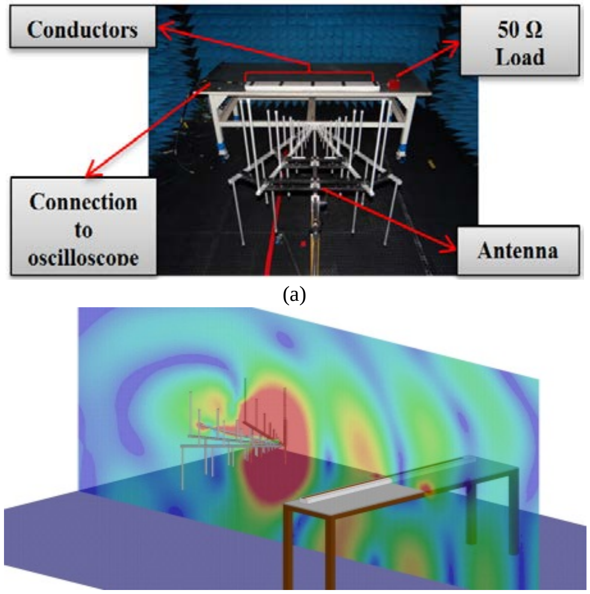
II. Development

A. Methodology

The present investigation involves studying a type of test that verifies the DUT behavior when exposed to electromagnetic fields, in order to verify if the recent RI standards faithfully represent the actual disturbances the DUT is exposed to during its lifecycle. A RI test is then executed in the 210-216 MHz frequency range, using an ISO 11452-2 adapted test setup, as illustrated in Fig. 1(a). The computational representation of this setup can be seen in Fig. 1(b) where the ANSYS HFSS® software graphical interface was used. Once the test environment is set, a pair of conductors (used as an electromagnetic field sensitive element) is separately submitted to two radiated signals: the Integrated Services Digital Broadcasting Terrestrial (ISDB-T) digital television standard, representing an actual Telecommunication service that operates in the same frequency range mentioned earlier and its standardized representation, a Carrier Wave (CW). These waveforms have been created with the ANSYS Designer® software and recreated in laboratorial environment through an arbitrary signal generator.

The induced voltage levels are measured in one of the two terminals of the pair of conductors, expressed in terms of their Root Mean Square (RMS) values and later on categorized according to Table I. This table summarizes those values in four groups; each one is then associated to two waveform characteristics: amplitude and modulation. Every set, called treatment [2-3], is constituted of 10 measurements (replicates) and presents a certain dispersion around its average level, caused by the stochastic events (inherent to the measurement processes). By using the Friedman Test, we are able to check if all four data sets come from the same population and, therefore, if they are independent from the characteristics of the electromagnetic fields waveforms [2-3].

The intent of this paper is not only to check the differences between the four data populations but also the dispersions related to each treatment under the following two circumstances: when the data is generated by an equipment with SNR = 14.61 dB and when SNR = 1.66 dB. However, to classify these values as “high” or “low”, a reference is required. An ideal generator ($SNR \rightarrow \infty$) is then virtually created with the use of simulation software. The computational modeling requires two steps: three-dimensional electromagnetic field numerical calculations and introduction of lumped elements to excite and terminate the circuits.



(a)

(b)

Fig. 1. Test setup. (a) Experiments. (b) Simulation.

TABLE I
INDUCED VOLTAGE MEASUREMENTS.

Electric field amplitude	Modulation	
	Standards (CW)	Telecomm. (ISDB-T)
Telecomm. (6 V/m)	Treatment 1	Treatment 2
Standards (100 V/m)	Treatment 3	Treatment 4

The comparison between the treatments dispersions can be done over the two following ways:

- Quantitatively, through the numerical results from the Friedman Test.
- Qualitatively, through box plots, which illustrate the dispersions related to each treatment.

Quantitative statistical approaches have increasingly been adopted in EMC studies, since such techniques are related to more reliable measurement results [5-6].

B. The Friedman Test

The Friedman Test is a nonparametric technique, which means that the input data do not have to constitute specific statistical distributions [2-3]. It was chosen for the present investigation seeing that the measured RMS voltage levels do not comply with the common gaussian distribution, required by the parametric methods such as ANOVA.

The main metric of the Friedman Test is a variable called P-Value [2-3]. It represents the probability of making a wrong statement about the measured data populations. Its value must be lower than the maximum tolerance (called significance level, α), which is related to the number of replicates of the experiment. Once the P-Value and α are known, it is possible to conclude if the treatments from Table I come from the same population or not.

III. RESULTS AND CONCLUSIONS

The data dispersions for both SNRs considered are illustrated in Fig. 2. Based on theses numbers, the graphics indicate that the effects of non-ideal SNRs manifest changes in

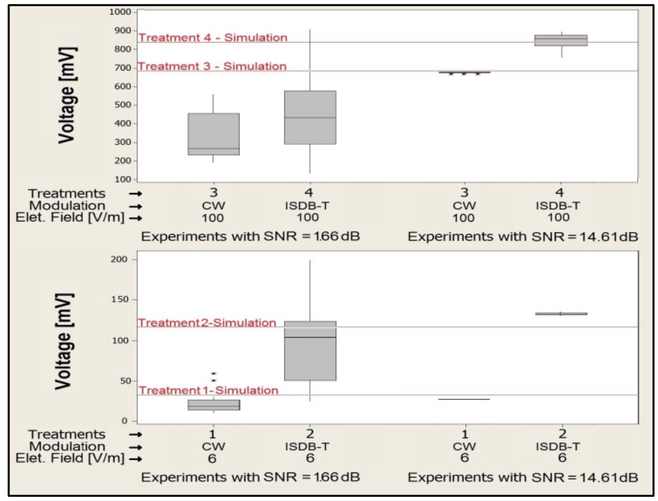


Fig. 2. Box plots showing the measured and simulated data.

TABLE II
P-VALUES

SNR	P-Value (Amplitude effect)	P-Value (Modulation effect)
14.61 dB	0.002	0.002
1.66 dB	0.002	0.011

the average voltage levels and higher dispersions, considering the simulated values as references.

Table II shows the Friedman Test results obtained by the Minitab software. The P-Values indicate that, from a statistical point of view, the analyses performed with different signal generators are equivalent, since all of them are lower than the test significance level, $\alpha = 0.0268$.

The Friedman Test has shown to be a suitable tool for EMC analysis in noisy environments. More details about the generators SNR estimates, statistical calculations and simulations will be found in the full version of this paper.

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