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Reverberation Chamber Immunity Testing : A novel methodology to avoid accidental DUT damage

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***Abstract*—This paper shows a novel method of measuring the immunity of electronic devices inside reverberation chambers. Rather than using mode stirring or mode tuning with a constant power input into the chamber, we will present a method based on variable power that protects the DUT against accidental damage and also gives more information about the hardness of the DUT than the traditional methods.**

Keywords: system immunity, reverberation chamber, mode tuned

I. INTRODUCTION

The principle of radiated immunity testing is based on the exposure of a test object to electromagnetic fields of defined strength and polarisation. The measurements aim to provide confidence that the tested devices are capable to perform their desired operation even if exposed to certain levels of electromagnetic interference. Since the immunity of a test object varies with the polarisation and direction of the impinging wave, measurements from different angles are required to ensure that the maximum susceptibility is found. As Wilson[1] shows, the number of individual measurements required is strongly dependent on the electrical size of the test object which is the relation between its physical size and the wavelength of the disturbance signal. A test object is considered to be electrically small if its physical size is small compared to the wavelength. In cases where the physical size becomes comparable to the wavelength it has to be considered electrically large.

While electrically small devices show a dipole like radiation pattern that allows sufficient testing with as little as 12 independent measurements, electrically large devices develop highly complex radiation patterns which compel a large number of individual measurements. Since for electrically large devices the number of measurements required is (approximately) proportional to the squared product of wave number and device diameter[1], compliance testing of such devices becomes a time consuming and cost intensive task. With increasing operating frequencies of modern electronic devices and the subsequent need to perform measurements up to (and beyond) these frequencies, the proportion of electrically large devices constantly grows and with it the significance of the above problem.

This particularly applies to the commonly used anechoic chamber (AC) method since for this technique the overall testing time is directly associated to the number of individual measurements required.

A way to overcome this is the use of Reverberation Chambers (RCs) as described by Hill[2]. Compared to the AC method that only allows testing from one direction and with one polarisation at a time, the RC method provides a constant illumination of the test object from all directions, through which its radiation pattern becomes irrelevant. The use of a stirrer which can be rotated to change the boundary conditions of the room and subsequently the strength and polarisation of the waves impinging the test object ensures that the most susceptible direction is found. Because of this ubiquitous illumination from all directions, the need for test object rotation ceases which is particularly advantageous for physically large devices (vehicles, aircrafts, etc) or such which require to be operated in upright position.

II. REVERBERATION CHAMBER IMMUNITY TESTS - MODES OF OPERATION

To perform RC immunity measurements, the Device Under Test (DUT) has to be placed inside the working volume of the chamber. The chamber is then illuminated with a constant RF power and the operation of the DUT is monitored over one stirrer revolution. The current standard for immunity measurements using RCs IEC61000-4-21[3] allows to either constantly rotate the stirrer (mode stirred operation) or to perform measurements at discrete stirrer positions (mode tuned operation). Both mode stirred and mode tuned operation have their advantages and disadvantages which will be outlined in the following.

Mode stirred operation exposes the DUT to a constantly changing field which allows the detection of errors caused by rapidly changing field distributions across the proximity of the DUT. However, the constant rotation of the stirrer holds the potential of missing out error occurrences due to the time required to execute one cycle of the DUTs test code as well as the response time of the monitoring system. To avoid missing out error occurrences, the rotary speed of the stirrer has to be set very low which directly results in a high time demand per individual test run.

When operating the chamber in mode tuned mode instead, the duration of a test program cycle does not affect the measurement result since the electric field distribution remains constant for one stirrer position. Even though this is advantageous, this mode of operation only produces a quasi static scenario that can not trigger or detect device failures caused by changing field distributions across the test system. Compared to mode stirred operation which allows to test only one power and frequency combination per rotation, mode tuned operation has the capacity to test multiple frequencies and power levels at the same stirrer position.

III. USE OF A FLEXIBLE POWER LEVEL

One aspect that both modes of operation have in common is that during the entire test cycle a constant amount of power (per frequency) is injected into the room. While such a constant power input is easy to realise, and the field strengths inside can be statistically analysed using the probability density function as described by Hill[2], it has a main disadvantage: Since the boundary conditions of the room change with every stirrer position, the fields impinging the DUT also vary significantly. This means that in certain cases the DUT might be exposed to field strengths which cause (cumulative) damage or may even lead to its immediate destruction. It is obvious that such a scenario is highly undesirable given the costs and additional testing time related to it. This particularly applies to cases in which the DUT is either very costly or unique.

To overcome this problem, a method was developed that combines the advantages of a mode tuned reverberation measurement with the benefits of a gradual power increase which is already known from other test methods as for example the Direct Injection (DI) method[4]. To record the immunity vs frequency profile of a system or component, it is exposed to a low power RF disturbance signal of a set frequency. The power is then increased until a device failure is observed. The power level that corresponds to the failure point is recorded and the experiment is repeated with a different frequency.

This procedure helps to find the immunity level of the component at this particular frequency and also ensures that the component under test is only exposed to the very minimum disturbance power necessary to cause a failure which significantly reduces the risk of damage.

This principle was directly applied to a mode tuned reverberation chamber immunity test. Figure 1 shows the flowchart of the measurement procedure.

At each stirrer position a full immunity profile of the DUT is recorded. The procedure is repeated until a stirrer revolution is complete.

IV. DATA ANALYSIS

One may think that the previously described measurement procedure might make it difficult to analyse the immunity of the DUT since Hill's field statistics can not be applied as there is no constant power input into the room. However, quite the contrary of this is the case: The main advantage of this method is that the obtained data can be used to carry out 'mind experiments' which give the same results as experiments based on a constant room power would do.

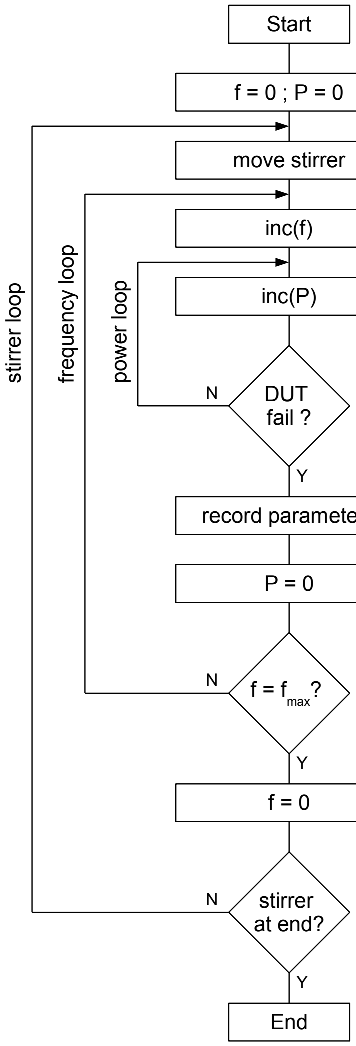

Fig. 1. Flowchart of the reverberation chamber immunity measurement procedure

Since for each stirrer position and frequency the power injected into the chamber is known, it can be easily calculated how many times the DUT would have failed if a constant power was injected into the room. Figure 2 shows an example outcome of a reverberation chamber immunity measurement where the stirrer position is represented by the x-axis, the frequency by the y-axis and the power level into the room required to cause a DUT failure by the z-axis.

If one wanted to know at how many positions a device failed for a constant input power, a plane (grey) parallel to the x-y plane has to be drawn which corresponds to the theoretically injected power level. All values above the plane represent cases where the system under test continued its normal operation as the assumed power represented by the plane was insufficient to cause a failure. For cases in which the value lies in or below the plane, the system failed as the power was at least equal to

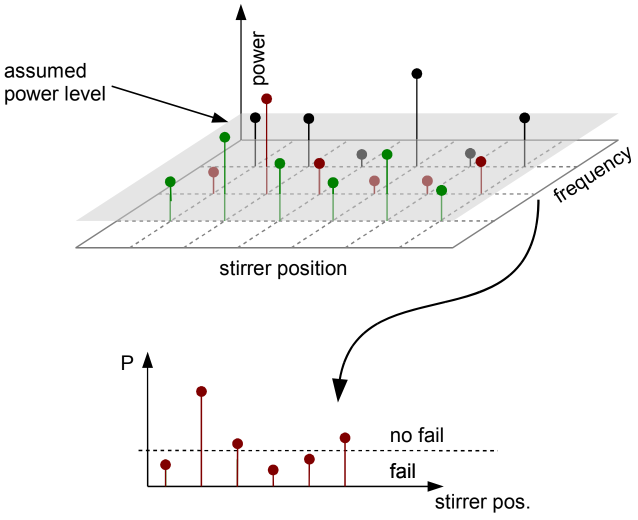

Fig. 2. Example result of a reverberation chamber immunity test including a reference plane used to determine the number of failure positions for an assumed fixed power level

the minimum failure power. This allows one to determine the number of failure positions by simply counting the number of values in and below the plane. It is then possible to perform a statistical analysis of the data in conjunction with Hill's description of the field statistics and hence produce the same result as an experiment with a fixed power level would do.

However, for practical applications the dynamic range of the test equipment as well as the maximum available power have to be taken into account since they might limit the usability of the data.

V. CONCLUSION

We have successfully shown an improved mode tuned reverberation chamber immunity test method that prevents the DUT from taking accidental damage caused by excessive field strengths. Even though the presented method increases the overall testing time, it avoids delays and extra costs related to physical damage of the DUT. It furthermore removes the need to test the DUT for different operational environments (commercial , industrial) which subsequently leads to a reduction of the overall testing time. The fact that the DUT is only exposed to the minimum disturbance energy required also provides a level of safety that might allow the experiments to be carried out without the need of constant human supervision. This is an advantage compared to the traditional methods where human supervision is necessary to ensure that severe device failures do not lead to unacceptable consequences (i.e. a DUT catching fire). Finally, existing equipment can be used if it provides a sufficiently high dynamic range.

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