Radiated Susceptibility Testing Using Compact Diagnostic Chambers

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INTRODUCTION

The increasing number of electrical and electronic equipment and mobile communication sets has led to a multitude of malfunctions caused by electromagnetic waves. Microprocessor-driven equipment particularly is more and more sensitive to HF energy due to the widespread use of high-speed clock frequencies.

Malfunctions can simply be annoying but can sometimes have disastrous effects. For example, a failing anti-skid brake on an automobile, or a medical measuring instrument indicating the wrong value can have serious or fatal consequences.

Therefore it is important to determine the susceptibility behavior of specific electrical and electronic equipment. This has to be done by subjecting the equipment under test (EUT) to a well-defined and reproducible electromagnetic field in a frequency range of 80 to 1000 MHz.

This article describes a compact diagnostic chamber (CDC) designed for the performance of electromagnetic susceptibility tests at a reasonable cost. The chamber will allow smaller companies to acquire essential knowledge about electromagnetic compatibility (EMC).

HISTORY

Since 1970 many anechoic chambers have been erected. Some of them were designed to perform emission measurements. Based on the range of use, these chambers included a measurement distance of 3 m or even of 10 m with an internal height allowing for an antenna height of 4 m. This resulted in really large anechoic chambers. Due to the tremendous cost, most of these chambers were built by large companies or by test houses. Smaller companies often lacked information and know-how about electromagnetic compatibility.

A compact diagnostic chamber offers versatility in the performance of electromagnetic susceptibility tests.

Since the EC Directive on EMC 89/336/EWG requires not only emission testing but also susceptibility testing, many activities have revolved around developing smaller anechoic chambers which are optimized to perform susceptibility tests.

TEST SITE REQUIREMENTS

For susceptibility testing the CDC must fulfill the requirements of the newest draft of the international standard IEC 801-3 and of European Standard ENV50140, which is based on the IEC standard.

The CDC must establish an area of uniform field (Figure 1). The area should be 1.5 m by 1.5 m and be located 0.8 m above the floor and in front of the EUT. The field is calibrated by measuring the field strength at 16 equally spaced positions, using field probes. The field strength measured at 12 of the 16 points (comprising 75% of the uniform area) must be within a tolerance of -0 dB and +6 dB. The selection of this tolerance means that each point of the EUT must be tested with at least the defined field strength, and a maximum overstress of +6 dB (which corresponds to + 100%) is acceptable.

EUTs which are smaller than 1.5 m may be tested in a smaller uniform area. If the EUT is larger than 1.5 m, the uniform area can be moved and the complete dimensions of the EUT can be tested partially. In this case, care must be taken that the anechoic chamber is large enough and that the setup and the operational mode of the EUT allow partial testing.

During the design of the CDC, special care must be taken with the arrangement of the uniform area and the antenna inside the chamber. The type and dimensions of the antenna are as important as the interactions between the antenna and the chamber itself. Also, the integration of signal and power cables and the illumination must be arranged carefully so as not to influence the field uniformity.

SHIELDING

The desired field strength is produced by using an RF generator which generates the frequency-

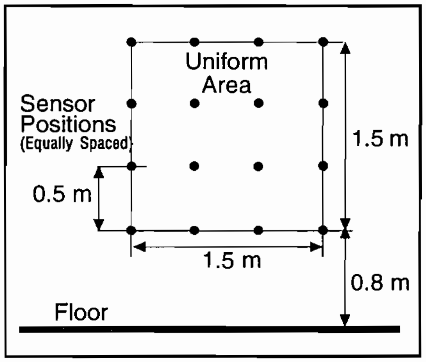

Figure 1. *Area of Uniform Field.*

dependent signal. This signal will be amplified by a broadband amplifier to produce the desired input power of the antenna. The transmitting antenna must be selected carefully to ensure that the uniform area can be illuminated sufficiently.

The compact diagnostic chamber can be equipped with either a standard antenna set consisting of a biconical antenna (80 to 200 MHz), and a small log periodic antenna or a large log periodic antenna which can cover the complete frequency range of 80 to 1000 MHz. By selecting the second type of antenna, the complete test can be automatically performed without any interruption. If a log periodic antenna is selected, the dimensions of the CDC must be larger.

In either case, the generated field strength is substantially higher than the legal limits for RF emissions. For example, a field strength of 10 V/m which corresponds to 140 dB μV/m is about 100 dB above the legal limit. Even a field strength of 3 V/m (129 dBμV/m) exceeds the limit by approximately 90 dB.

The test setup, consisting of the antenna and the EUT, must be surrounded by a high performance RF shielded enclosure. All openings of the shielded enclosure, especially the doors, must be connected to an interlock system which ensures that field generation is possible only when all openings are closed. Also, all incoming and outgoing power and signal lines must be filtered to ensure that no undesired energy reaches the outside environment. Signal lines often require fiber optic technology to allow a sufficient data processing rate at a sufficient RF shielding effectiveness level.

The CDC is designed according to a high performance RF shielding technology which results in attenuation values of more than 100 dB in a frequency range of 30 MHz to 20 GHz. Taking into account the frequency dependent span loss* and the damping effect of the absorbers, there is enough certainty in the design to meet legal requirements.

ABSORBER MATERIALS

The metal walls, ceiling and floor of the shielded enclosure cause significant reflections inside the enclosure. The resulting standing waves have tremendous influence on the field homogeneity. This effect might be prevented by removing the shielded enclosure. But, as discussed above, the generated high power emissions may exceed the legal limits. Therefore the reflections and the standing waves have to be damped to an acceptable degree by using absorber material inside the shielded enclosure. All metal surfaces, including the floor, must be covered with absorbers.

The compact diagnostic chamber can be equipped with pyramidal foam absorbers, flat ferrite tiles, ferrite grids, or hybrid absorbers. The typical reflectivity values of these types of absorbers are stated in Table 1.

During the design phase each absorber type must be evaluated in terms of its unique features. Major aspects will be discussed in the following section and are summarized in Table 2.

Pyramidal absorbers have to be at least 0.5 m long to work properly at the lower frequency of 80 MHz. In comparison, ferrite absorbers have a depth of 5 mm to 20 mm depending on absorber type, material composition and structure. This is one of the main advantages of ferrite absorbers because all outside dimensions of the CDC can be decreased whereas the CDC using pyramidal absorbers can not. In addition, the ferrite absorber shows extraordinary performance in the frequency range below 80 MHz. This allows good pre-compliance measurements for emissions testing starting at 30 MHz.

The other significant advantage of ferrite absorbers is their nonflammability, which is as important for susceptibility testing as it is for emissions testing. Experi-

** Span loss is the distance-dependent site attenuation between the transmitting antenna and the shielding of the CDC.*

FREQUENCY	PYRAMIDAL ABSORBER 0.5 METER	FERRITE TILES	FERRITE GRID	HYBRID ABSORBER
30 MHz	-	17 dB	17 dB	16 dB
80 MHz	6 dB	25 dB	20 dB	18 dB
100 MHz	6 dB	26 dB	20 dB	20 dB
200 MHz	15 dB	25 dB	37 dB	20 dB
300 MHz	25 dB	23 dB	25 dB	20 dB
500 MHz	25 dB	18 dB	23 dB	20 dB
800 MHz	30 dB	14 dB	18 dB	25 dB
1 GHz	35 dB	12 dB	15 dB	25 dB
3 GHz	40 dB	6 dB	10 dB	30 dB
10 GHz	40 dB	-	-	30 dB
18 GHz	40 dB	-	-	35 dB

Table 1. *Typical Reflectivity.*

ence shows that absorbers can be set on fire by the direct electromagnetic wave and by some resonance effects inside the enclosure which can lead to an increase of local energy distribution. RF power cables which are improperly located can also ignite absorbers.

Floor absorbers are mandatory for electromagnetic susceptibility (EMS) test sites, and can be built into false floors or moveable floor panels. Both of these alternatives have disadvantages. Moveable absorber panels are placed on the permanent floor, so they must be partially repositioned to install the EUT or to change the antenna. The use of a false floor above the floor absorbers results in inadequate performance due to the reflectivity of the false floor at higher frequencies.

A third option is the integration of ferrite absorbers directly into the floor construction. The load capability is not significantly reduced and the reflectivity level is maintained. A comparison of ferrite absorbers and pyramidal absorbers illustrates that ferrites are suitable for use in CDCs. In addition to the slightly lower price, the advantage of pyramidal absorbers is that they can also cover the frequency range above 1 GHz. This expanded frequency range is important for manufacturers of products which operate above 1 GHz, such as fast pulse generators, oscilloscopes and high frequency measuring equipment.

HYBRID ABSORBERS

Hybrid absorbers are combinations of flat ferrite tiles and additional foam absorbers. The pyramidal product must be exactly matched to the ferrite to ensure a sufficient reflectivity of the combined absorber. The ferrite portion is active in the frequency range from 30 MHz to several hundred MHz whereas the pyramidal absorber covers the frequency range above approximately 600 MHz. In the intermediate frequency range the exact matching of both absorber types is of utmost importance to prevent reflectivity drops due to mismatch. Equipped with hybrid absorbers with a total length of approximately 30 cm, the frequency range is extended to cover 30 MHz to 40 GHz.

Taking into account the absorber-dependent design parameters of this type of CDC, it is also possible to first build a CDC equipped with ferrite tiles. The pyramidal portion of the hybrid can be installed later when measurements in the frequency range above 1 GHz are necessary.

OTHER DESIGN PARAMETERS

To complete the design of each individual compact diagnostic chamber, several additional features must be considered. Figure 2 shows the most important parameters.

As discussed, the CDC is designed to fulfill the requirements for EMS testing. The pyramidal solution also enables pre-compliant EMI measurements starting at approximately 120 MHz. Due to the good performance of ferrites at low frequencies, EMI measurements are possible starting at 30 MHz.

The results determined in a CDC using ferrite or hybrid absorbers in the frequency range from 30 MHz to 1000 MHz can be correlated to either free space or free field conditions by using special correlation factors. To correlate the measurements to free field conditions they must be performed using an additional moveable ground plane on top of the floor absorbers.

CDCs often have to be installed in existing buildings and the room dimensions must be taken into consideration. If space is limited, CDCs using ferrite absorbers are the optimum solution. On the other hand if the load capacity of the floor is limited, then the pyramidal absorber solution is preferable. The existing or planned measurement equipment will also influence the design of the CDC.

Other important considerations are the number of feedthrough elements and the layout of the necessary cables. These must be carefully integrated into the CDC system to ensure that no degradation of chamber performance can occur.

In general, special equipment like automated turntables, EUT monitoring systems, antenna masts, and audio-video systems must be integrated carefully because each type of CDC exhibits unique limitations. The integration of these subsystems requires special knowledge about the product and the system to reach the guaranteed performance of the CDC.

Without exception, the CDC must be designed around the EUT. Since the EUT can be a member of the ISM or ITE product family, a household appliance, a handheld machine tool or even a small com-

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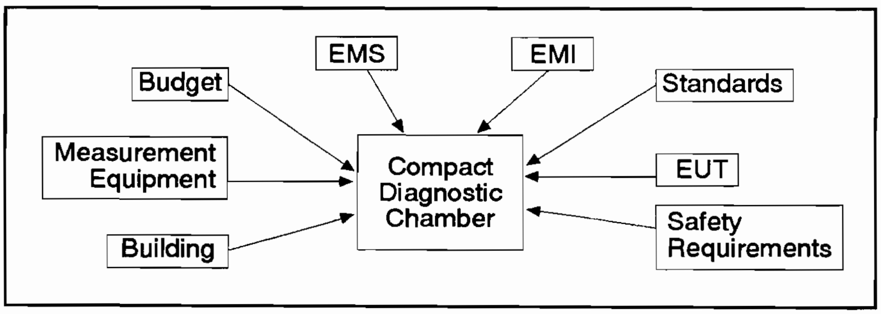

Figure 2. *Design Parameter for CDC.*

The chip designer must become acquainted with all aspects of the new EC Directives since with the ultrafast CMOS devices, decoupling capacitors will have to be "on-chip surface designed" to be more effective. This is possible with six-metal laminar CMOS technology. Better ESD and pulse burst immunity will also result.

To assure that electronic devices can function without interfering with each other, EMC must be designed into each device. Since most electronic devices have dc buses to connect power sources to the electronic circuitry, switching currents, with their high frequency harmonics, are radiated as noise signals from the dc bus. Regardless of how small the equipment is, the length of the dc bus is a finite length, and a finite length of a metallic conductor can act as an unintentional transmitting and receiving antenna. If the interference is strong enough it can interrupt the normal functioning of the electronic device.

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***RADIATED SUSCEPTIBILITY TESTING USING COMPACT DIAGNOSTIC CHAMBERS** . . .* *Continued from page 100*

CDC FEATURES	PYRAMIDAL ABSORBER	FERRITE TILES	FERRITE GRID	HYBRID ABSORBER
Outside dimensions (approx.)	7.5 x 5.2 x 3.6 m^3	7.3 x 3.4 x 3.3 m^3	7.3 x 3.4 x 3.3 m^3	7.9 x 4.0 x 3.6 m^3
Inside dimensions (approx.)	6.3 x 4.0 x 2.8 m^3	7.0 x 3.1 x 3.1 m^3	7.0 x 3.1 x 3.1 m^3	7.0 x 3.1 x 3.1 m^3
Applicable specifications	IEC 801-3 and ENV 50140	IEC 801-3 and ENV 50140	IEC 801-3 and ENV 50140	IEC 801-3 and ENV 50140
EMI pre-compliance performance	Poor	Good	Very good	Very good
Nonflammability	Reduced	Very good	Very good	Reduced
Risk of mechanical damage	Tangible	Negligible	Negligible	Tangible
Floor absorbers	Moveable	Fixed	Fixed	Fixed
Frequency range in MHz	80 to >1000	30 to 1000	30 to 2500	30 to 18000
Relative price	1.0	1.4	2.0	2.3

***Table 2.** Compact Diagnostic Chambers Compared.*

ponent, there are numerous possible interactions between the EUT and the CDC. Therefore all CDCs have been built based on the same physical facts, but none of them are absolutely identical.

Table 2 shows the most important parameters of the compact diagnostic chamber.

SUMMARY

The compact anechoic chamber is a flexible and cost-effective solution for radiated susceptibility testing. Adaption to the needs of the customer and the equipment under test can be made relatively easily due to the flexibility of the design.

***TIMO GREINER** graduated as an engineer from the FH Aalen, Germany in 1984. Most of his early work was involved with the development of software systems to automate EMC measurements. He joined Siemens Matsushita Components, a supplier of EMC test facilities, in 1991. He works in the marketing department and is responsible for shielded enclosures and anechoic chambers used for EMC measurements. FAX: +49-7321-326 ext. 381.*