Test device for radiated immunity tests

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***Abstract*— A test device for radiated immunity tests has been developed. It allows obtaining a frequency dependent measurement value up to 3.4 GHz instead of a common pass/fail result. The characteristics of this test device have been investigated theoretically by numerical simulations and experimentally in GTEM cells.**

I. Introduction

The increasing market of high speed clocked electronic devices and the existence of many radiation sources like mobile phone, radio and television antennas in the public air requires that other high frequency sensitive devices have to be immune against electromagnetic radiation.

To make sure that an electric or electronic device is able to function without failure in its electromagnetic environment a manufacturer of a new product has to perform EMC tests. In order to carry out radiated immunity tests on these devices EMC laboratories provide different test environments defined in individual standards as anechoic chambers [1], GTEM cells [2], reverberation chamber [3] and fully anechoic chambers [4]. The aim of the immunity test procedures is to stress the device under test in a test volume with a test severity given by the standard. Being exposed to the incoming electromagnetic field the functionality of the test device will be checked.

Since a radiated immunity test normally results in a simple pass/fail statement it is necessary to obtain a measurement value for a detailed analysis and comparison of the different test environments. Thus a test device has been developed which provides a frequency dependent power value, to allow an adequate evaluation of the test severity corresponding to the radiated electromagnetic field strength.

II. Test Device

Preliminary investigations using a measurement receiver expanded by electromagnetic coupling structures gave a picture of replacement reproducibility in several test facilities and a first comparison of the test severity on a dedicated device between them [5].

This former test device has been completely redesigned in order to achieve an extended frequency range up to 3.4 GHz and simple outlines to facilitate numerical modelling and field simulation of the device.

A. Requirements

The new test device shall provide the behaviour of a typical electrical test device and allow a simple embedding in a fast test setup using a network analyser. The **im**munity **t**est **o**bject (IMTO) has to fulfil several important requirements in order to get reliable results:

- high stability for good repeatability and reproducibility of test results
- dimensions as “real” test objects for realistic loading and field distortion properties
- sensitivity against electrical high frequency fields within the range from 80 to several GHz
- different coupling structures for electric and magnetic field coupling, such as slots, loops and grids
- mechanically robust design for many tests in several test facilities
- simple test object structure suitable for numerical field simulations
- analogue optoelectronic data transmission network via fibre ribbon cable to avoid additional disturbances of the surrounding electromagnetic field
- supply with a rechargeable battery (1 day minimum)

B. IMTO setup

Fig. 1 shows the schematic of the cubic test device and the placement of the coupling structure on top of the metal box. In this figure the electromagnetic field couples into a loop antenna.

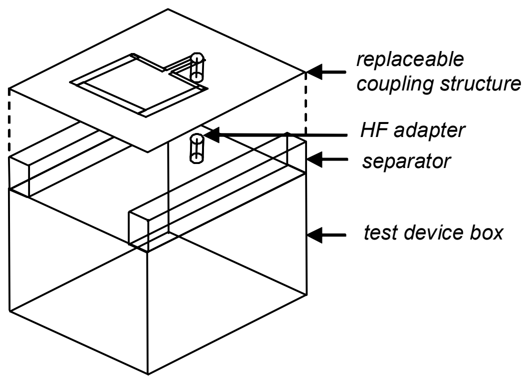

Fig. 1 Schematic of outline of IMTO

The power corresponding to test field strength will be transferred through a coax to the electro-optical transmitter and passes a fibre ribbon cable to the electro-optical receiver outside the test device and thus the test facility – see Fig. 2.

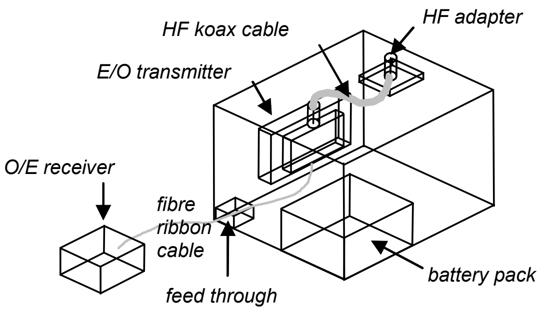

Fig. 2 Schematic of inner setup of IMTO

The developed test device IMTO expanded by the loop structure called "loop" for investigations in a frequency range up to 3.4 GHz is shown in Fig. 3.

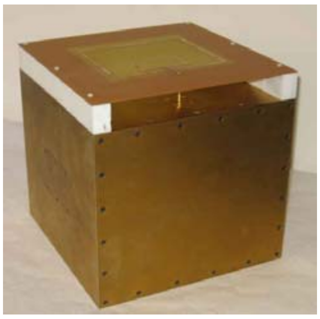

Fig. 3 IMTO with loop coupling structure

C. Obtaining and evaluating data

Fig. 4 shows the test setup for the scattering parameter measurement of transmission (S_{21}) using a network analyser.

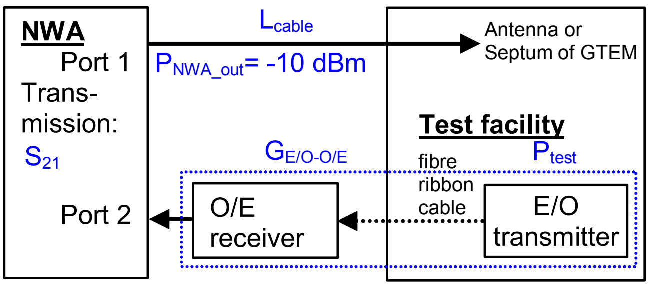

Fig. 4 Test setup with IMTO and network analyser

The test facility is treated like a two port device. A constant test signal is injected into the test facility and generates an electromagnetic field around IMTO. The coupling structure of IMTO operates as an antenna and picks up the field. A signal corresponding to this electromagnetic field is transferred via fibre ribbon cable to the analyser. Obtaining data from 10 MHz up to 3.4 GHz takes only 6 s using 201 measurement points and a bandwidth of 100 Hz for each frequency.

In order to evaluate the obtained data the individual reference file of each test facility that contains the vector of input power values P_{cal} that is necessary to generate 10 V/m field strength at the uniform field area has been added to the calculation of the IMTO power for 10 V/m:

$$P_{IMTO}[dBm] = P_{cal}[dBm] + S_{21}[dB] - G_{E/O-O/E}[dB] - L_{cable}[dB]$$

$\mathbf{P_{IMTO}}$	IMTO power calculated for 10 V/m
$\mathbf{P_{cal}}$	Calibration power of empty field (10 V/m)
$\mathbf{P_{test}}$	Power obtained by IMTO (NWA test)
$\mathbf{S_{21}}$	Transmission parameter (NWA test)
$\mathbf{G_{E/O-O/E}}$	Gain of optoelectronic converter module
$\mathbf{L_{cable}}$	Loss of cable to test facility

D. Different coupling structures

To analyse the behaviour of real test devices typical coupling structures have been prepared for the tests. Fig. 5 shows the investigated structures such as 2 different loop antennas, 2 slot antenna structures (slot S on a single sided PCB, slot D on a double sided PCB) and a grid structure that is intended to represent a ventilation grille of a device allowing significant coupling in the operating frequency range.

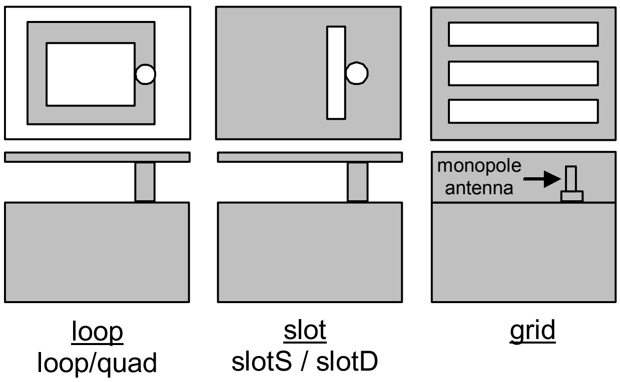

Fig. 5 Different shapes of IMTO coupling structures

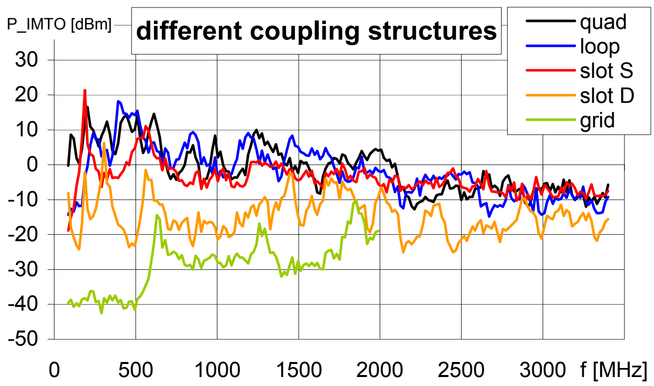

Fig. 6 IMTO power calculated for 10 V/m using different coupling structures

Depending on the antenna shape the different coupling structures are detecting different RF power spectrums as shown in Fig. 6.

The loop antennas obtain higher power signals because they are bigger in size. The slot antenna has only a short slot of 5 cm and thus couples less energy. The signal detected by the high impedance monopole antenna of the grid structure has been amplified by an internal impedance converter enhanced by a Darlington amplifier.

The dynamic range of all kind of these structures vary from -40 dBm up to 20 dBm in the lower frequency range and from -20 dBm up to -5 dBm in the upper frequency range.

The absolute power values are not really important for the investigation because it was intended to use the test device for comparison tests. Main issue of this test device is to provide stable and reproducible values for investigations of test facilities.

E. Directivity

The test device IMTO has a directivity caused by the size and the position of the coupling structure mounted on top of one side. This leads to a complex radiation pattern (directivity) which has been analysed by numerical simulations. The Method of Moments was used for numerical description of the test device and the loop coupling structure. Fig. 7 shows the discretisation of the modelled test device.

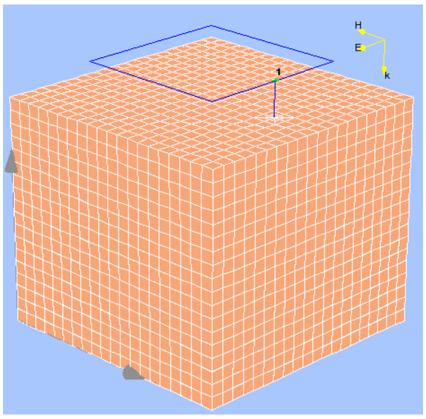

Fig. 7 Test object model and far field diagram at 2 GHz

Based on the model above the directivity of the test device can be characterised theoretically. Thus several radiation diagrams for different frequencies have been calculated. The significant dependence on the frequency is shown in Fig. 8 a)...c). The radiation behaviour of the combined antenna and box structure represents a standard spheric shape at 100 MHz. At 500 MHz the antenna and box structure radiates vertically due to the resonance frequency of the loop geometry. For higher frequencies especially above 2 GHz an excentric and non orthogonal radiation pattern can be observed.

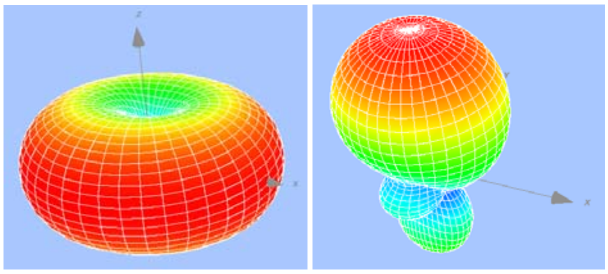

Fig. 8 a) Radiation diagram of IMTO “quad” at 100 MHz, 500 MHz

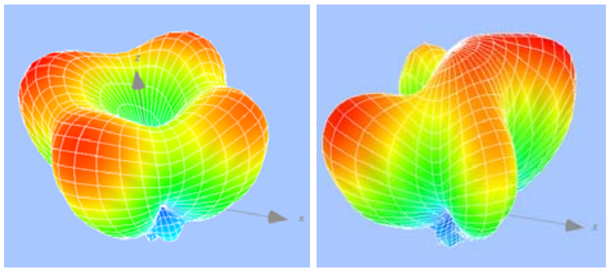

Fig. 8 b) Radiation diagram of IMTO “quad” at 1 GHz, 1.5 GHz

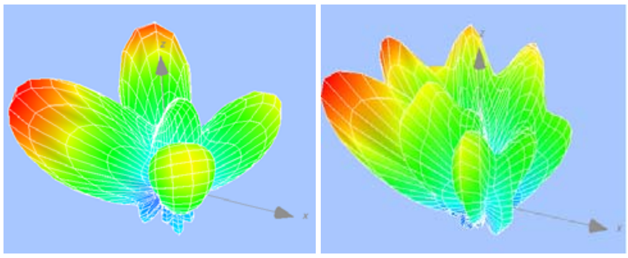

Fig. 8 c) Radiation diagram of IMTO “quad” at 2 GHz, 3.4 GHz

III. Application

A. Orientations

The test device has 6 sides and considering the antenna field polarisation there are 4 essential rotations for each side. That leads to 24 possible orientations for a cubic test device as shown in Fig. 9 for one side as an example.

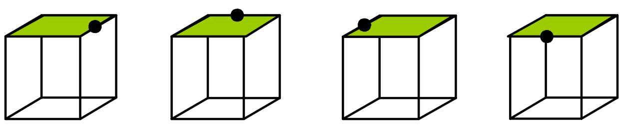

Fig. 9 Orientations around one test device axis

In order to detect the most sensitive spot of the test device against the electromagnetic field it is necessary to orientate all possible device sides to the source of radiation.

Fig. 10 shows the 70 dB spanning dynamic range of the obtained power values for those 24 orientations in a 10 V/m field of test device IMTO carrying coupling structure quad.

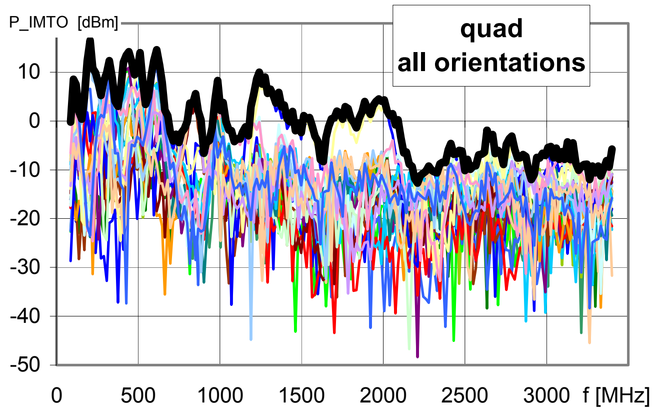

Fig. 10 Test severity of 24 test object orientations

The effort executing tests for all these orientations is high, so that standard committees defined reduced regulations for EMC laboratories to orientate the device using 2x3 or 2x4 orientations selected out of the 24. These schemes have been investigated regarding their ability of achieving the maximum coupling.

The investigated 2x3 scheme line does not reach the maximum line in the most of frequency points. The better approximation gives the 2x4 schema except for the frequency range between 2 GHz and 2.2 GHz. Interestingly the 2x3 scheme matches the maximum there (Fig. 11).

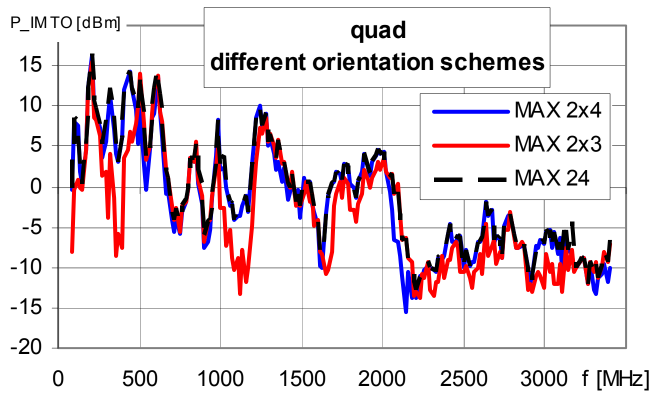

Fig. 11 Different orientation schemes

Background for the deviations corresponding to the orientation is based on the directivity of the test device. Generally the highest sensitivity is achieved if the coupling structure is oriented towards the incident electromagnetic field. However, even in this case the maximum sensitivity may not be seen due to the directivity of the coupling structure, especially at higher frequencies, as shown in Fig. 8.

The choice of the orientation scheme can lead to an uncertainty of several dB as investigated with IMTO in quad version. Since the radiation pattern of real DUTs is a priori unknown, the choice of the orientation scheme may therefore also affect the outcome of an immunity test.

B. Comparison of similar test facilities

The test device can also be used for comparison of different test facilities. The GTEM cells compared with IMTO were of different size and manufactured by different companies.

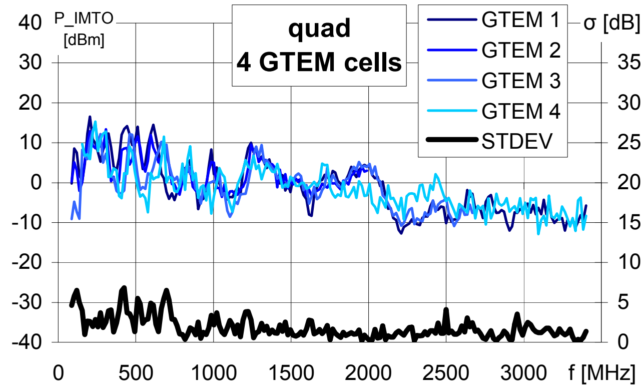

Fig. 12 Immunity tests in different GTEM cells

The standard deviation has been calculated to get a figure for the deviation of the results achieved in the 4 GTEM cells. The maximum standard deviation of the measurement results in GTEM cells was 6.8 dB as shown in fig. 12. Similar tests were carried out in anechoic and reverberation chambers and similar results were achieved for these test facilities. Comparing all 11 investigated test facilities the maximum standard deviation was 7.3 dB.

IV. Conclusions

A new test device for investigation and comparison of different immunity test facilities has been developed. This test device allows traceability of the immunity test to a measurable quantity. The modular setup includes different coupling structures and gives a high flexibility. The test device delivers stable, reproducible test results with a high sensitivity. It allows an extremely fast immunity sweep and can be a valuable tool for a variety of applications.

References

[1] IEC 61000-4-3:2006-02, *Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test*, February 2003

[2] IEC 61000-4-20: *Electromagnetic compatibility (EMC) -Part 4-20: Testing and measurement techniques - Emission and immunity testing in transverse electromagnetic (TEM) waveguides*, January 2003

[3] IEC 61000-4-21, *Electromagnetic Compatibility (EMC) - Part 4-21: Testing and measurement techniques - Reverberation Chamber Test Methods*, September 2003

[4] CISPR/A/704/CD: IEC 61000-4-22: *Radiated emissions and immunity measurements in fully anechoic rooms (FAR)*, October 2006

[5] H. Streitwolf, R. Heinrich, H.-G. Behnke, L. Dallwitz, U. Karsten, *Comparison of radiated immunity tests in different EMC test facilities*, EMC Zurich, Munich, 2007