TRANSIENT FIELDS IN MODE-STIRRED CHAMBERS

H.G. Krauthäuser(1), **J. Nitsch**(2)

(1)***Otto-von-Guericke University Magdeburg, IGET, P.O.-Box 4120, 39016 Magdeburg, Germany, hgk@ieee.org***

(2)***As (1) above, but E-mail: Juergen.Nitsch@et.uni-magdeburg.de***

ABSTRACT

Field transients are an intrinsic feature of mode-stirred chambers. Three different cases are investigated here. The free energy decay corresponds to transients on a microsecond time scale. The time for transients due to a change of frequency depends on the equipment used. In any case it is significantly longer, usually several milliseconds. If a mechanical tuner is used to change the boundary conditions, the inertia of the construction leads to transients within a time period up to several seconds whenever the tuner is moved to a new position. All these field transients may affect equipment under test. Moreover, the free energy decay can be used to determine the chamber quality factor in the time domain. For this task, a method using a spectrum analyzer instead of an oscilloscope is introduced leading to a much higher dynamic range.

INTRODUCTION

During the last few years, mode-stirred chambers have become more and more popular for radiated emc testing. For susceptibility testing this is mainly due to the fact that very high field strengths can be achieved with moderate input power. Both, for susceptibility and emission testing, the statistic nature of the chamber fields might be helpful to perform more robust tests, especially at high frequencies (above 1 GHz).

An international standard — IEC 61000-4-21 — is in development dealing both with the calibration of mode-stirred chambers and mode-stirred chamber measurements.

The main future research task is to investigate real and generic systems in mode-stirred chambers and to compare the results with measurements performed in well established test environments (OATS, SAC, GTEM).

Mode-stirred chambers are high quality resonators. According to the high quality factors, steady state conditions are reached only after a considerable long time period, typically several microseconds (Figure 3 shows the quality factor and the chamber time constant for the Magdeburg mode-stirred chamber). Although this is the shortest time period where transients exist in mode-stirred chambers, it might be already a long time for fast digital electronic [1]. Therefore, field transients in mode-stirred chambers might be important for emc test results.

Figure 1: Picture of the Magdeburg mode-stirred chamber.

The measurements presented here are conducted at the Magdeburg mode-stirred chamber [3]. The chamber dimensions are 8 m x 6 m x 3.5 m, approximately. The first chamber resonance frequency is about 30 MHz. The chamber is calibrated according to IEC 61000-4-21 in the frequency range from 200 MHz to 4.2 GHz.

In the next section, the free energy decay is investigated. From the slope of the free decay the chamber quality factor and the chamber time constant are evaluated for the empty and the heavily loaded chamber.

Most emc tests in reverberation chambers are performed in mode-tuned operation. In that mode, the tuner is sequentially moved to statistically independent positions. At these positions, the test is performed for all frequencies without moving the tuner. For theses frequency sweeps, the generator can be set to banking or non-blanking operation. In the second part, field transients due to the changing of the frequency are investigated, both for blanking and non-blanking operation.

The oscillations of the (mechanical) tuner are relevant on a much longer time scale (seconds). Field transients due to tuner oscillations are described in the third part of the paper.

All measurements presented here are performed without the usage of amplifiers. Generally, amplifiers will cause additional effects due their own transient behavior.

FREE ENERGY DECAY

The quality factor Q is one of the most popular parameters to characterize reverberation chambers. In general, Q is defined by

$$Q = \omega \frac{\text{overall reactive energy in the enclosure}}{\text{dissipated power}} \quad . \tag{1}$$

In time domain, the quality factor is given by

$$Q = \frac{\pi}{d} = 2\pi f \cdot \tau \tag{2}$$

where d is the average logarithmic decrement of the free-decay field of energy density stored in any point of the enclosure [2]:

$$\begin{aligned} d &= \frac{1}{f \cdot \Delta t} \ln \left(\frac{E(t_0)}{E(t_0 + \Delta t)} \right) & (3) \\ &= \frac{\ln(10)}{20 \cdot f \cdot \Delta t} \Delta E_{dB} & (4) \\ &= \frac{\ln(10)}{20 \cdot f \cdot \Delta t} \Delta P_{dB} & (5) \end{aligned}$$

The energy (field) decay time constant τ is given by

$$\begin{aligned} \langle E(t_0 + \tau) \rangle &= (1/e) \langle E(t_0) \rangle & (6) \\ \langle E_{dB_{V/m}}(t_0 + \tau) \rangle &= \langle E_{dB_{V/m}}(t_0) \rangle - 8.7 dB_{V/m} & (7) \end{aligned}$$

From (5) and (2) follows

$$Q = \frac{20 \cdot \pi \cdot f[\text{MHz}] \cdot \Delta t[\mu s]}{\ln 10 \cdot \Delta P_{dB}} \approx 27.29 \cdot \frac{f[\text{MHz}] \cdot \Delta t[\mu s]}{\Delta P_{dB}} \tag{8}$$

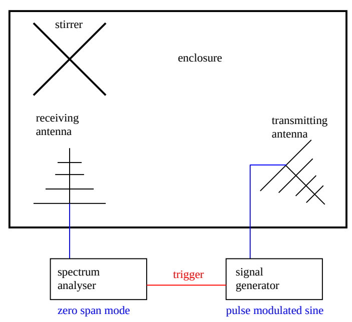

Figure 2: Setup for Q-factor measurements in time domain.

To perform the time domain measurements it would be obvious to use a real-time or a sampling oscilloscope. Due to the much better dynamic range, it is advantageous to use a spectrum analyzer in zero span mode (narrow band measurement). The setup is illustrated in Fig. 2.

The measured slopes are given in Fig. 3 (left) for five different positions of the tuner (the curves have been shifted on the time axis in order to clarify the illustration). The free-decay slopes are of complex structure making the determination of the decay time practically impossible. In mode-stirred operation of the chamber (i.e. tuner rotates continuously) it is now possible to average all the slopes for different tuner positions. The ensemble average curve is given in Fig. 3 (left) also.

The right graph of Fig. 3 shows the resulting quality factor and decay time constants for the empty and heavily loaded chamber respectively.

The free decay is the shortest time period in which a device under test may be influenced by transient fields if the boundary conditions (tuner) or the excitation (frequency, amplitude) are changed.

CHANGE OF FREQUENCY

Most modern high frequency generators are capable to perform frequency sweeps. Depending on the model several operation modes can be distinguished:

- Non blanking operation only: Here, the output power is no reduced during the time within the generator changes the frequency.

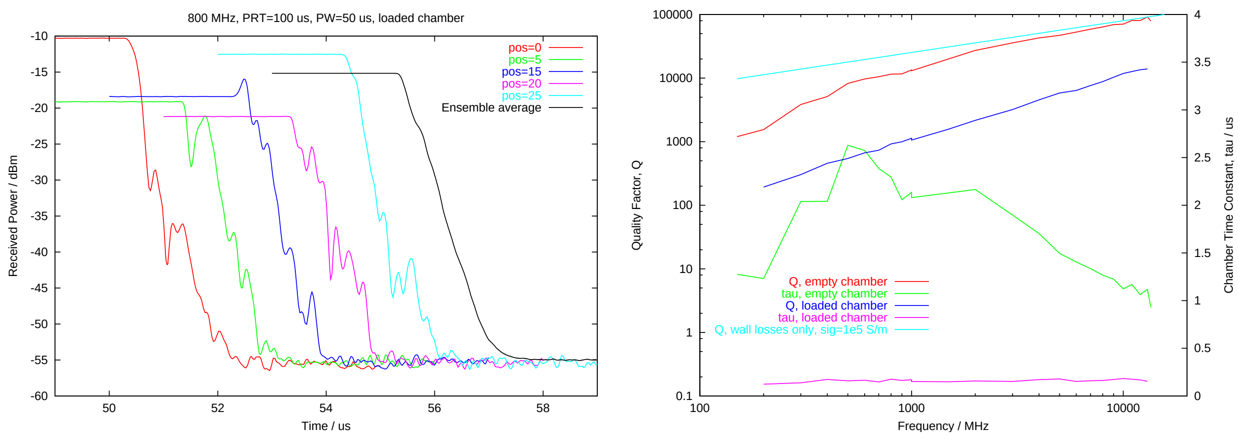

Figure 3: Left: Time domain response due to pulse modulated sine excitation of the (loaded) chamber. Right: Chamber quality factor Q and decay time constant τ for the Magdeburg mode-stirred chamber.

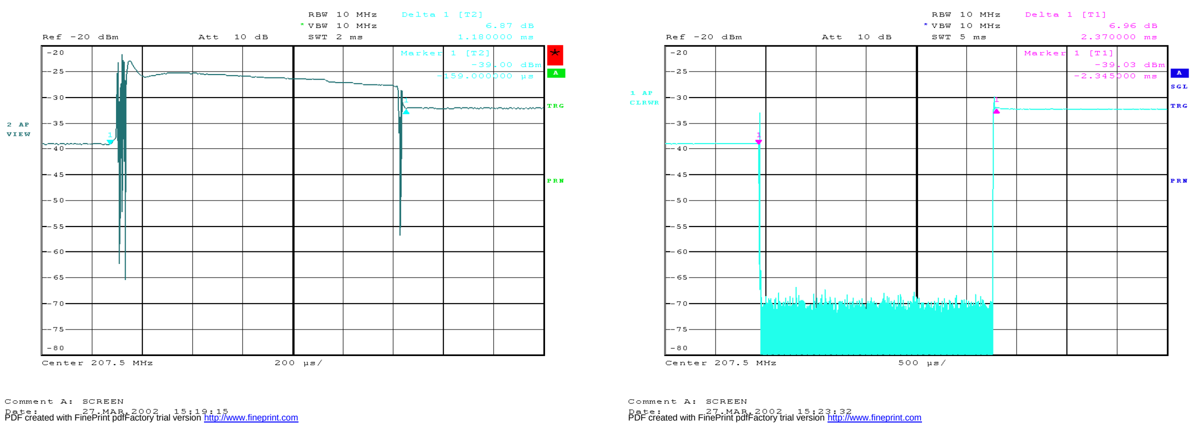

Figure 4: Transient E-field during a frequency step from 205 MHz to 210 MHz. Left: without blanking Right: with blanking

- Blanking operation: The generator reduces the output power (e.g. 80 dB attenuation) while it changes the frequency. Usually, this results in a much slower sweep.
- Automatic switching between blanking and non-blanking operation depending on the step width.
- Configurable frequency sweep: User can define, whether to use blanking or non-blanking operation.

The differences for the fields inside a reverberating enclosure are illustrated in Fig. 4.

In the left graph (non-blanking), a transient region is observed for a time period of approximately 1 ms. Depending on the frequency range, the frequency step, and the tuner position, the transients can look completely different. For the example given in Fig. 4, the field strength during the transient time period is up to 10 dB higher compared to the corresponding steady state fields.

TUNER MOVEMENT

Most mode-stirred chambers are equipped with one or more mechanical tuners. These tuner ought to be large in order to perform well even at the lowest usable chamber frequencies. Due to the size and weight, tuners usually are inertial and tend to oscillate on a time scale of seconds.

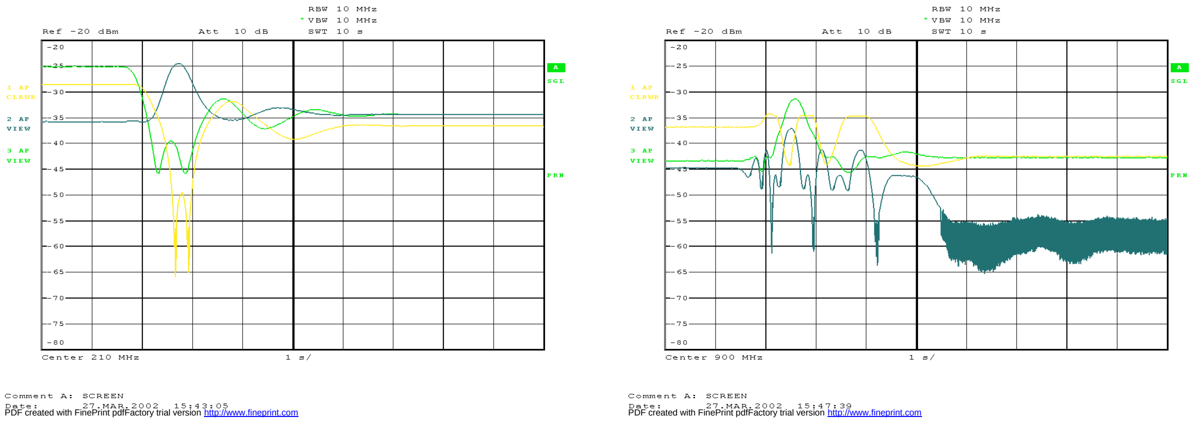

Figure 5: Transient E-field due to the tuner movement to a new position. Step width is 5 degrees here. Left: at 200 MHz; Right: at 900 MHz

This can be observed for the Magdeburg mode-stirred chamber also. This chamber is equipped with one large vertical tuner (refer to Fig. 1).

Figure 5 shows field transients due to the tuner movement from one fixed position to another. The different curves correspond to different starting positions. The left graph is measured at a carrier frequency of 200 MHz. The right graph gives examples for 900 MHz.

In both cases strong oscillations can be observed. Steady state conditions are reached after approximately 4 seconds.

CONCLUSIONS

The phenomena of field transients is an immanent feature of any high-Q resonator, such as mode-stirred chambers. The fields have to be transient whenever either excitation parameters (e.g. frequency and amplitude) or the boundaries are changing.

Changing of the amplitude takes place when e.g. the chamber is operated with a (pulse) modulated signal. The corresponding transients of the free energy decay can be used to determine to the chamber quality factor in the time domain, and, on the other hand, might upset the device under test.

Changing the frequency can't be omitted in emc testing. The time period until steady state conditions are reached once again depends on the used equipment (generator, amplifiers), and is in any case significantly larger (milliseconds) than the free energy decay time constant (microseconds). Obviously, these transients can disturb the device under test also. Care must be taken, to switch down power during this time period, e.g. by the measurement software.

On a much larger time scale are the oscillations of a mechanical tuner (seconds). If mechanical tuners are used, power has to be switched down until the tuner is standing still.

This research is supported by the Deutsche Forschungsgemeinschaft DFG under contract number FOR417.

References

[1] Ch. Braun, P. Guidi, H.U. Schmidt, A. Taenzer, H. G. Krauthäuser, and J. Nitsch. Messung von Ausfall-Schwellwerten an modernen Hochgeschwindigkeits-Prozessor-platinen mit gepulsten Hochleistungs-Mikrowellen und in Moden-Verwirbelungs-Kammern. In *Elektromagnetische Verträglichkeit EMV 2000*, pages 573–580, Düsseldorf, Germany, 2000.

[2] P. Corona, L. Gaetano, and E. Paolini. Performance and analysis of a reverberating enclosure with variable geometry. *IEEE Transactions on EMC*, EMC-22(1):2–5, 1980.

[3] H. G. Krauthäuser and J. Nitsch. Characterization of mode-stirred chambers in the time domain. In *Proceedings of the International Symposium on EMC*, pages 389–392, Magdeburg, Germany, October 1999.