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Towards new Engineering Standards Accounting for Uncertainty in Electromagnetic Compatibility

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Theory of Electrical Engineering

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Overview

- Introduction
- EMC Susceptibility Testing according to Test Standards
- Problems Identified by Statistical Analysis
- Problems with modern DUTs (1): Complexity
- Problems with modern DUTs (1): Ageing
- Uncertainties of the test setup: OATS, Anechoic Chambers, Reverberation Chambers
- Future work

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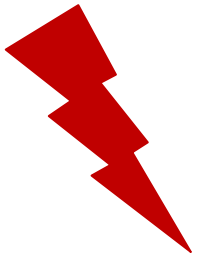
Introduction

- EMC test standards stem from the sixties
- Do not account for rapidly growing complexity of devices
- Do not account for rapidly growing numbers of devices in the field (and thereby neglecting component tolerances)
- Do not account for possible use of low quality components
- More demanding test = higher field magnitude



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Motivation

Recent HEMP field tests(*) at Munster facilities showed several peculiarities:

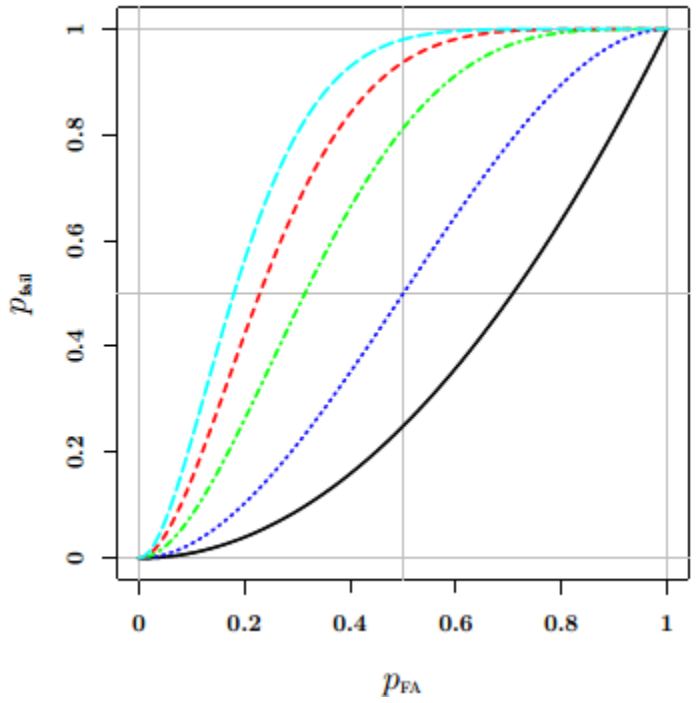
- Output of HEMP generator can alter within given tolerances
- DUTs of high complexity will display a non-zero probability of failure even without external interference

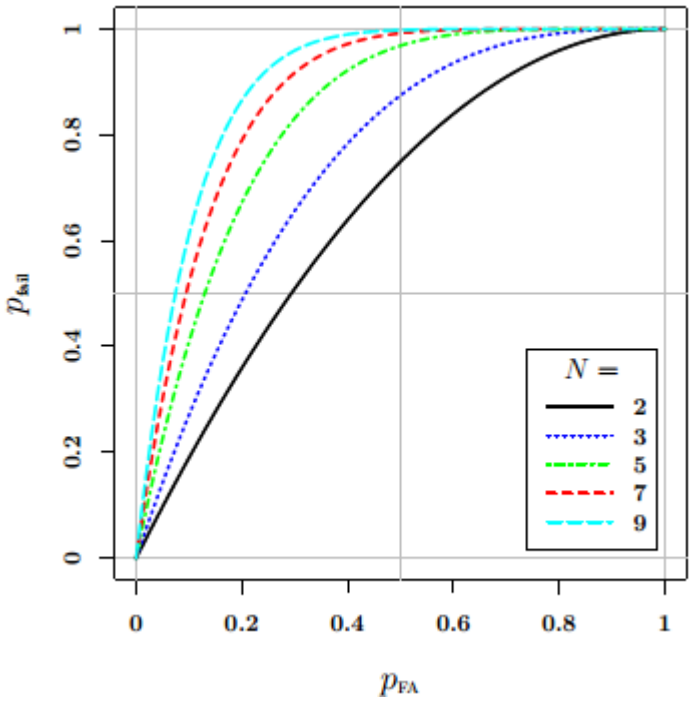
Consequences:

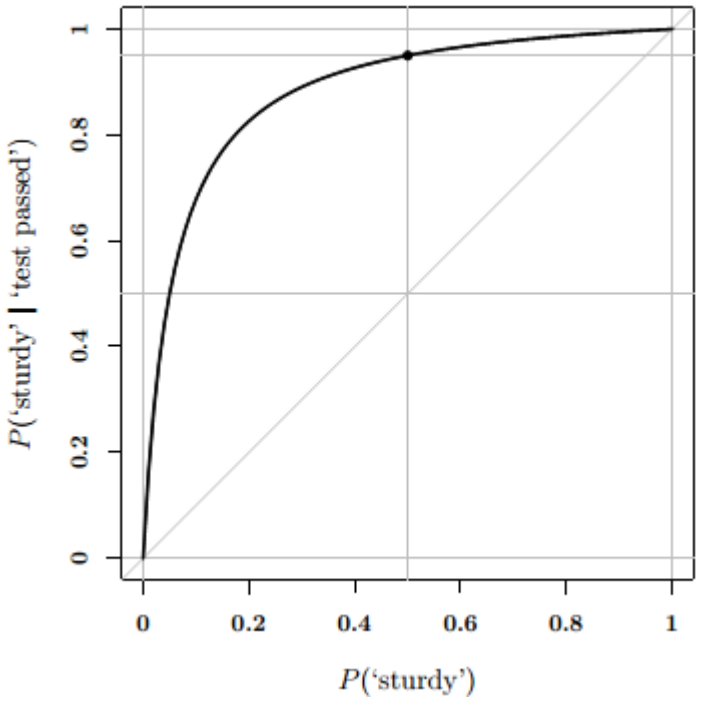
Additional test to allow for single failures

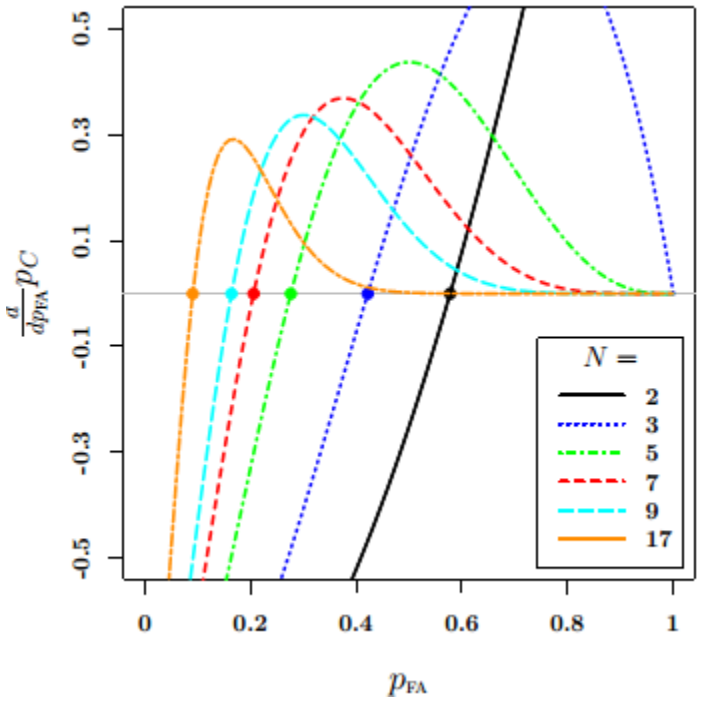
Statistical evaluation of test procedures were performed.

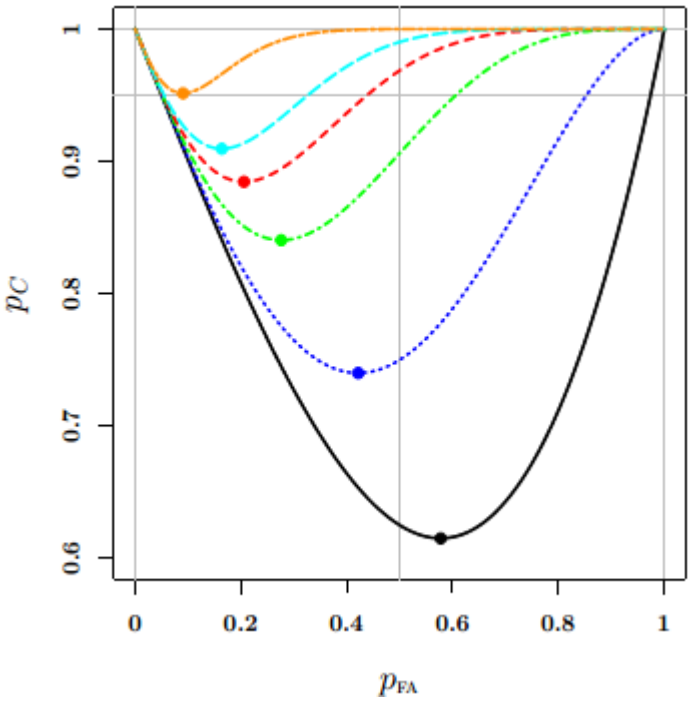
(*) HEMP test = very advanced testing @ high field magnitudes and short rise times

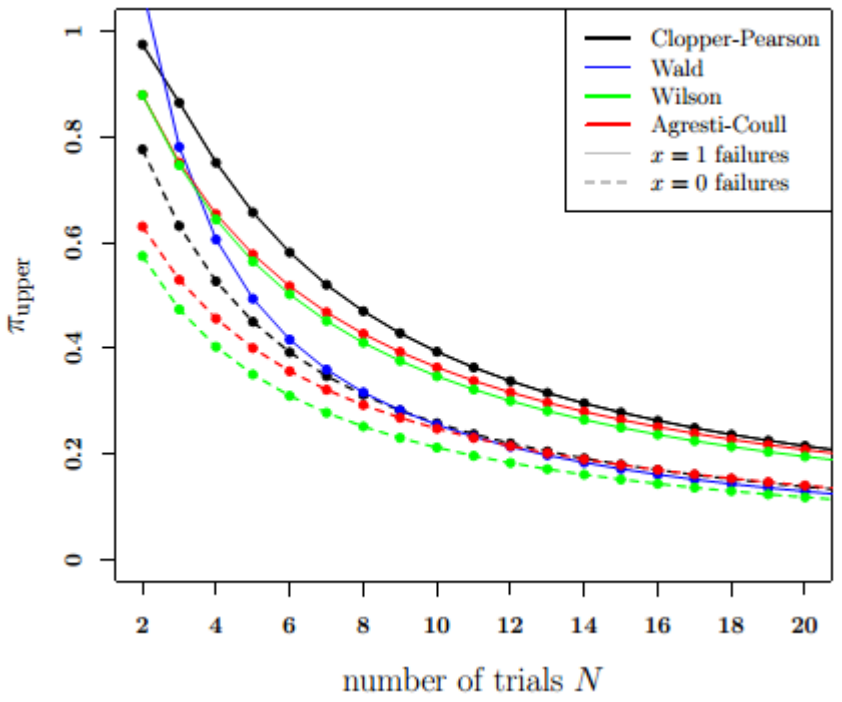

p_{fail}
0
0.2
0.4
0.6
0.8
1
p_{FA}


p_{fail}
0
0.2
0.4
0.6
0.8
1
p_{FA}
$N =$
2
3
5
7
9


P('sturdy' | 'test passed')
0
0.2
0.4
0.6
0.8
1
P('sturdy')


$\frac{d}{dp_{FA}} p_C$
0.5
0.3
0.1
-0.1
-0.3
-0.5
0
0.2
0.4
0.6
0.8
1
p_{FA}
$N =$
2
3
5
7
9
17


p_C
1
0.9
0.8
0.7
0.6
0
0.2
0.4
0.6
0.8
1
p_{FA}


Clopper-Pearson
Wald
Wilson
Agresti-Coull
$x = 1$ failures
$x = 0$ failures
π_{upper}
0
0.2
0.4
0.6
0.8
1
2
4
6
8
10
12
14
16
18
20
number of trials N

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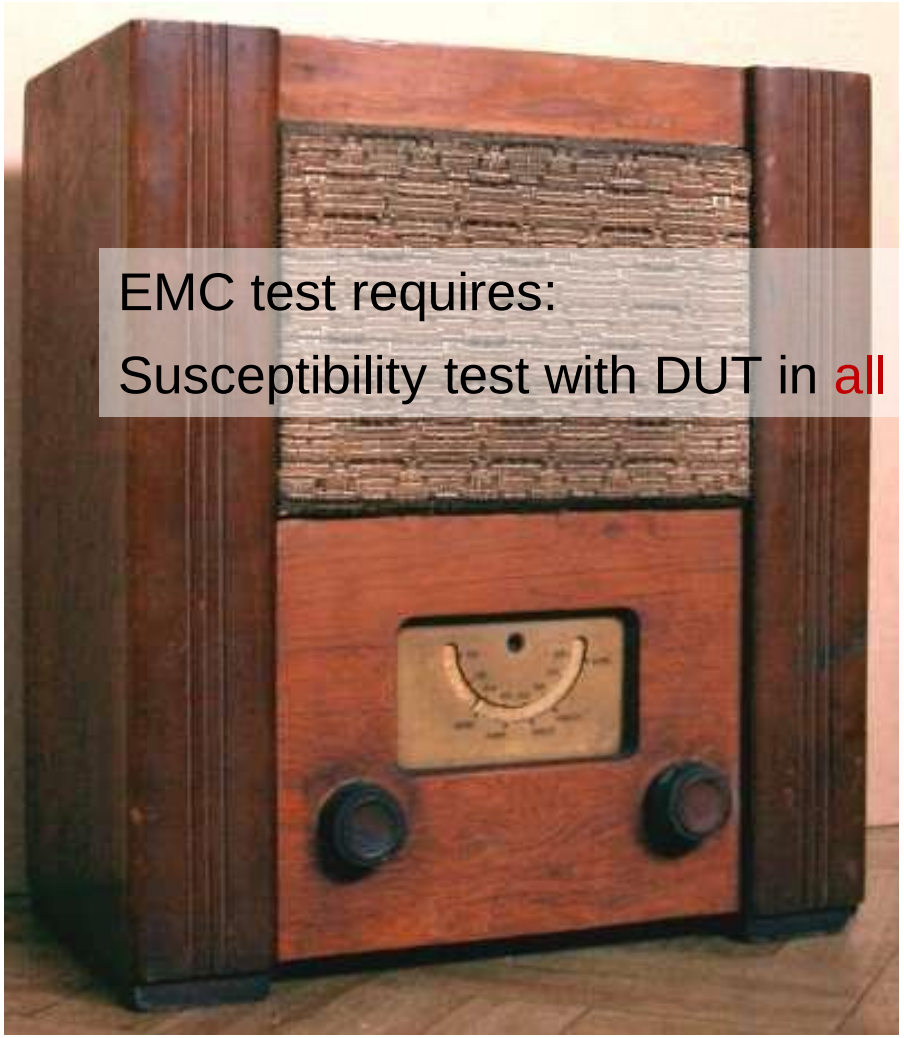
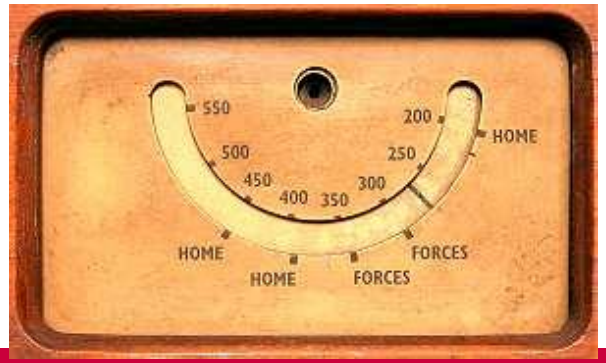
In the goode olde days …



EMC test requires:

Susceptibility test with DUT in all relevant modes of operation



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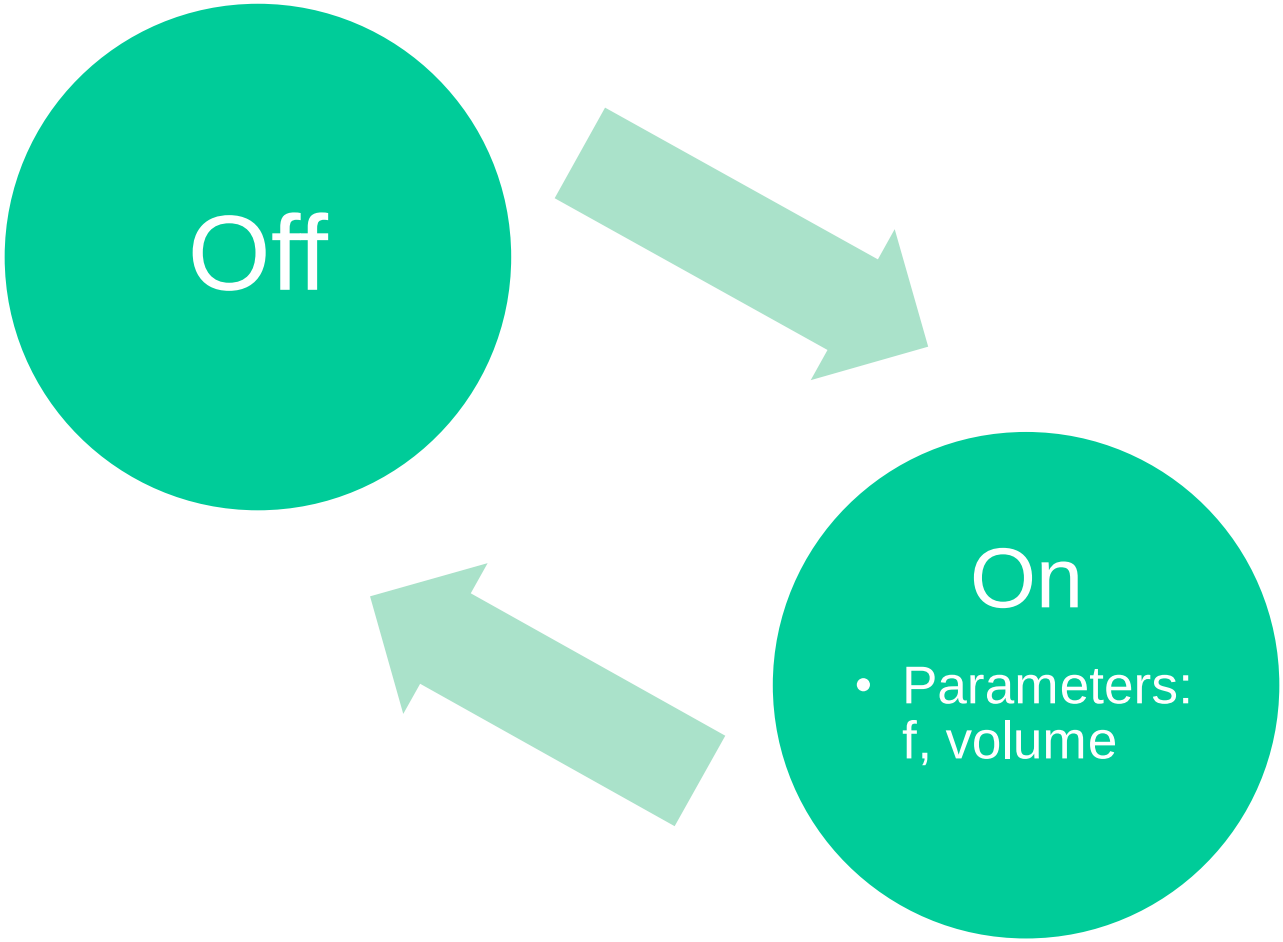
Complexity of analog radio receiver



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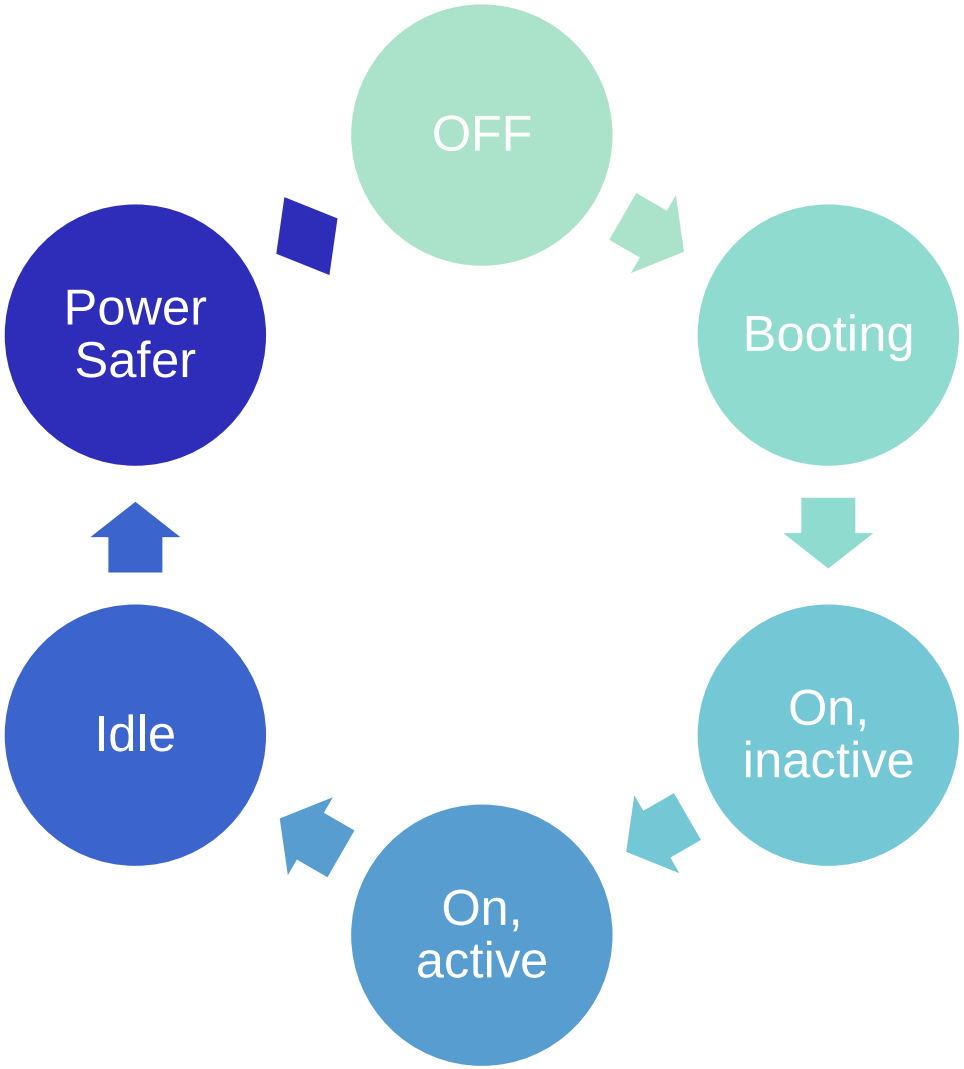
Complexity of computer



Possible parameters:

- Accessing hard disk
- Accessing peripheral drive/ printer
- Accessing network /Wifi
- Numberchrunching
- Multiprocessor computing with hi amount of network data transfer
- External USB device connected
- Comm with power unit

Possible Solution

Use reverb chamber

Longer test duration

???

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Ageing

First tests with decommissioned Long Range Communication Shelters of German Military:

- Negative Shielding Effectiveness due to mechanical destruction of RF shielding
- Several additional apertures

Problem:

EMC test with prototype or pre-production sample is valid through fill lifetime of device

Ageing ? … maybe included in test standards

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Ageing (2)

Conceivable ageing effects:

- Degradation of components (capacitors, semiconductors)
- mechanical destruction of protective devices (esp. HEMP!)

Possible solution:

Repeated emission tests during life time of device

More strenous test during certification process

Artificial ageing during certification process

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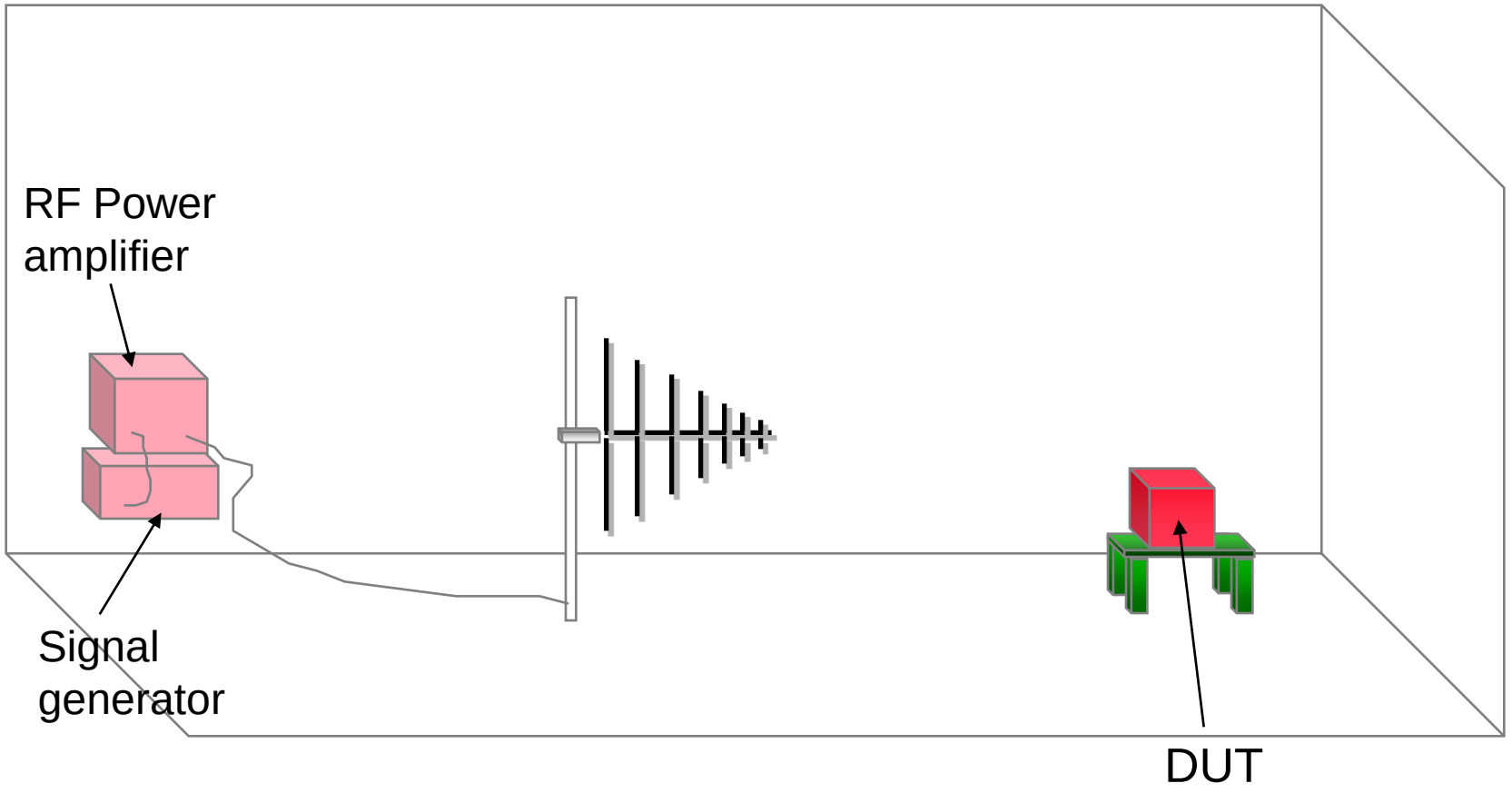
OATS



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OATS

- Free space propagation
- Adavantages: simple setup, no artificial signals free space
- Disadvantages:
  - ***Huge amount of space needed***
  - No shielding
  - Interaction with third parties
- Used if
  - Disadvatages are not important
  - For special purposes (large DUTs, high Field mag)

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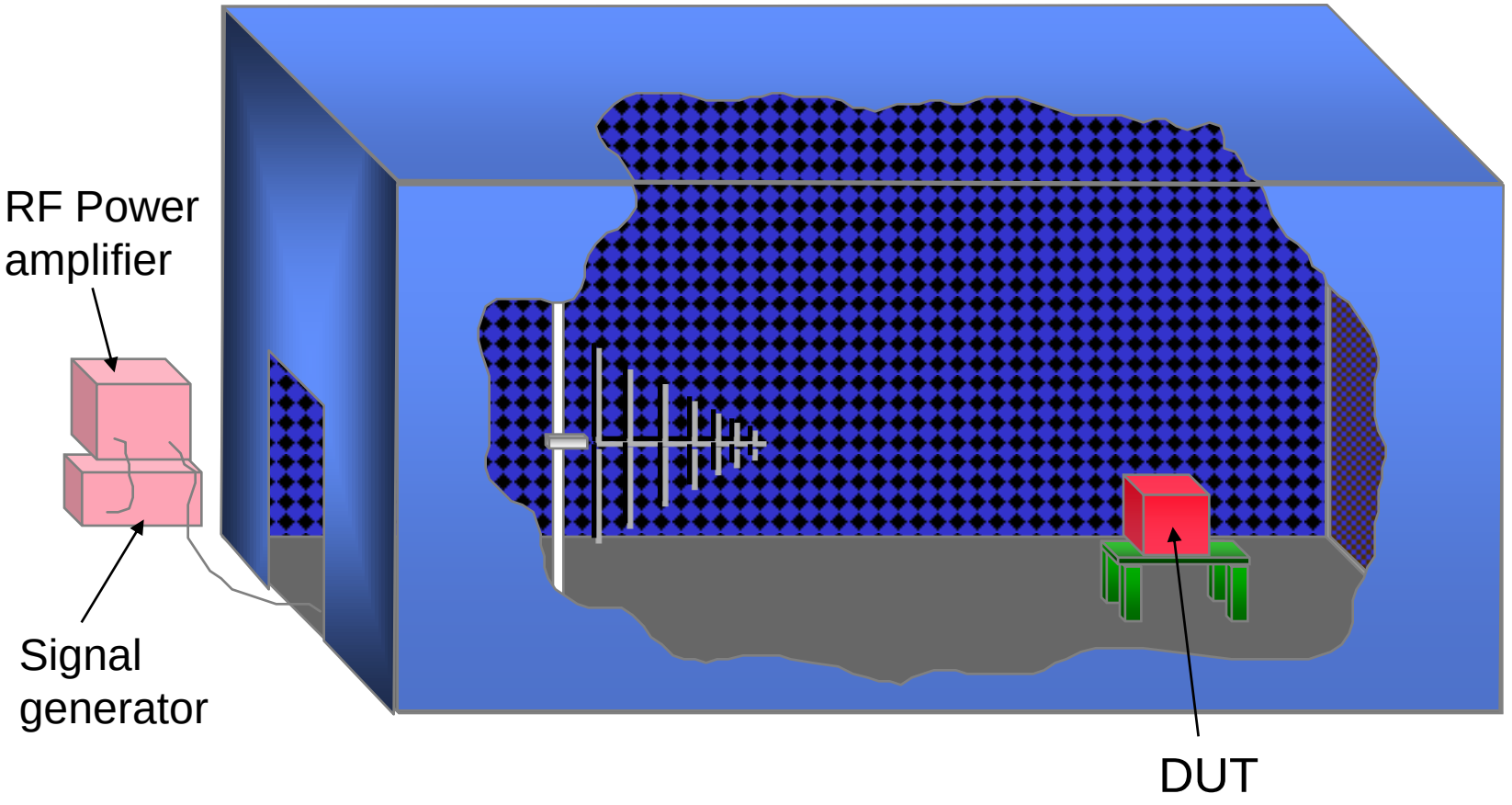
(Semi)-Anechoic Chamber (Absorberkabine)

Shielded enclosure, walls with absorbers



(Semi)-Anechoic Chamber (Absorberkabine)

- Emulation of free space propagation
- Advantage: small area needed
- Disadvantages:
  - Expensive because of absorbers, esp. low freq.
  - Not effective atr hi power levels (power -> absorbers)
  - Size of chamber limits lowest usable frequency

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(Semi)-Anechoic Chamber (Absorberkabine)

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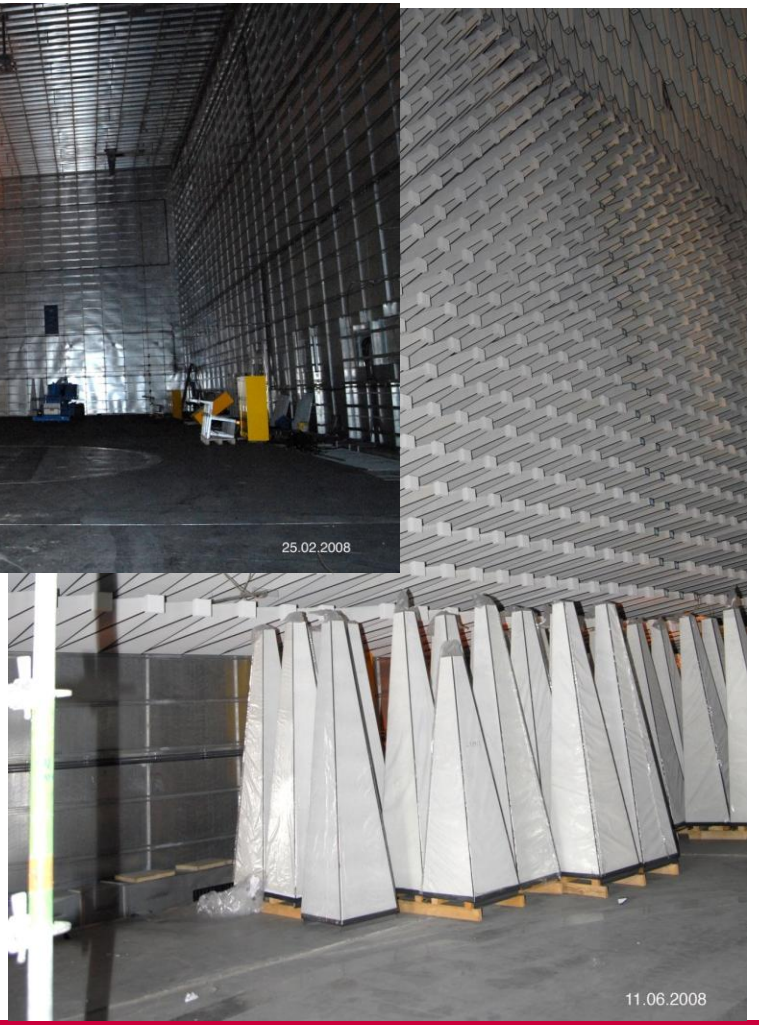
(Semi)-Anechoic Chamber (Absorberkabine)

Details



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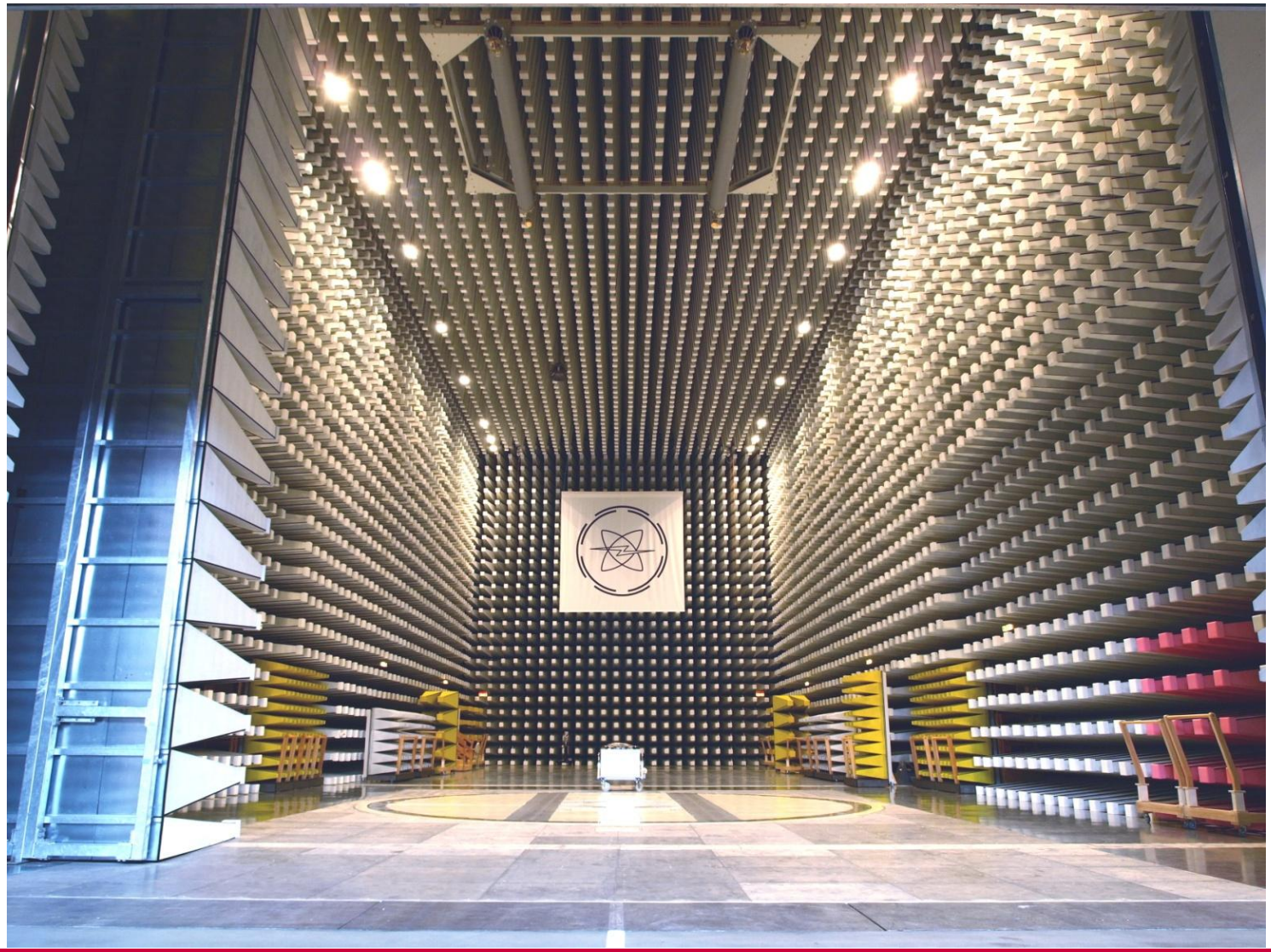
Semi-Anechoic Chamber



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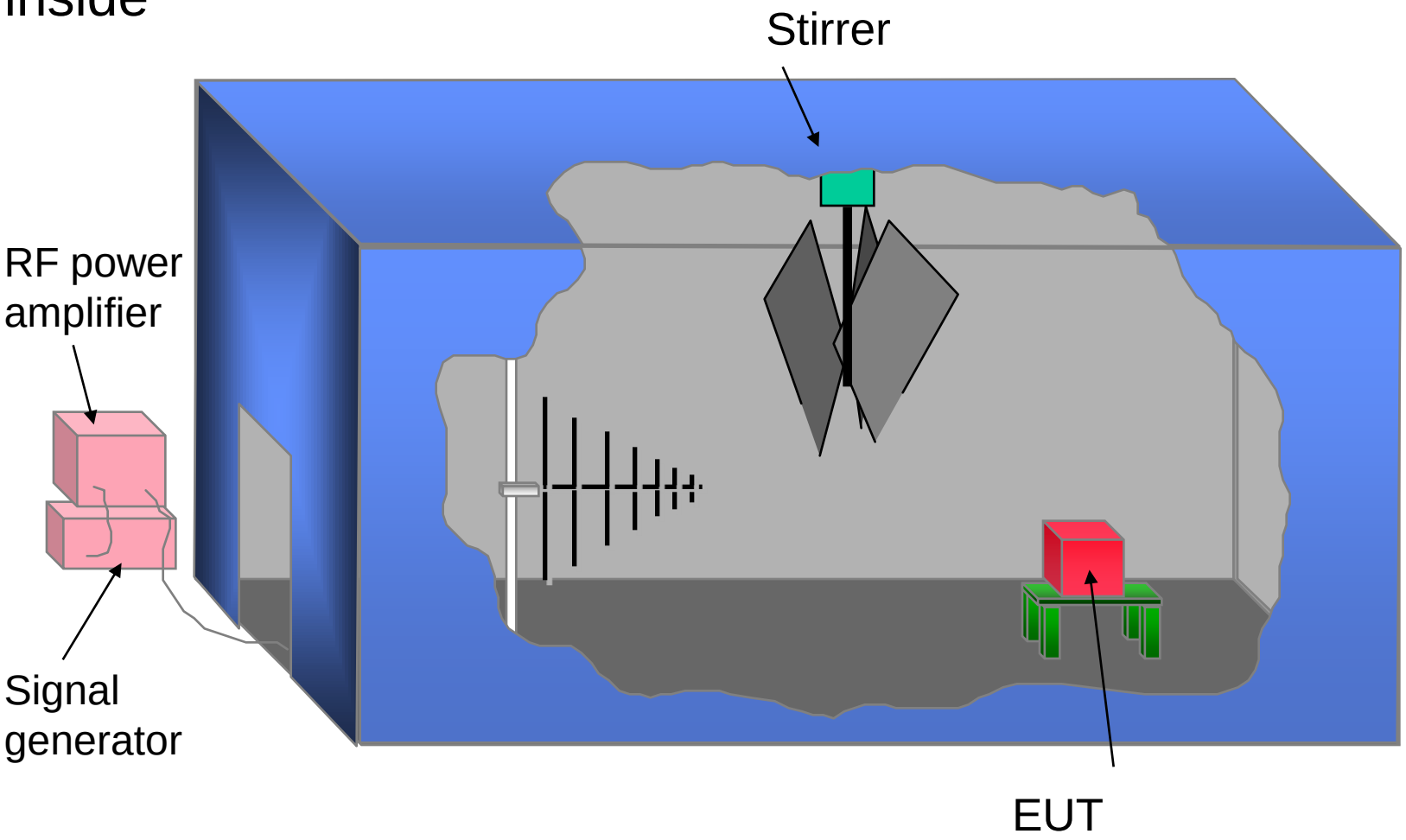
Reverberation Chamber

Shielded enclosure, without absorber, mode stirrer inside



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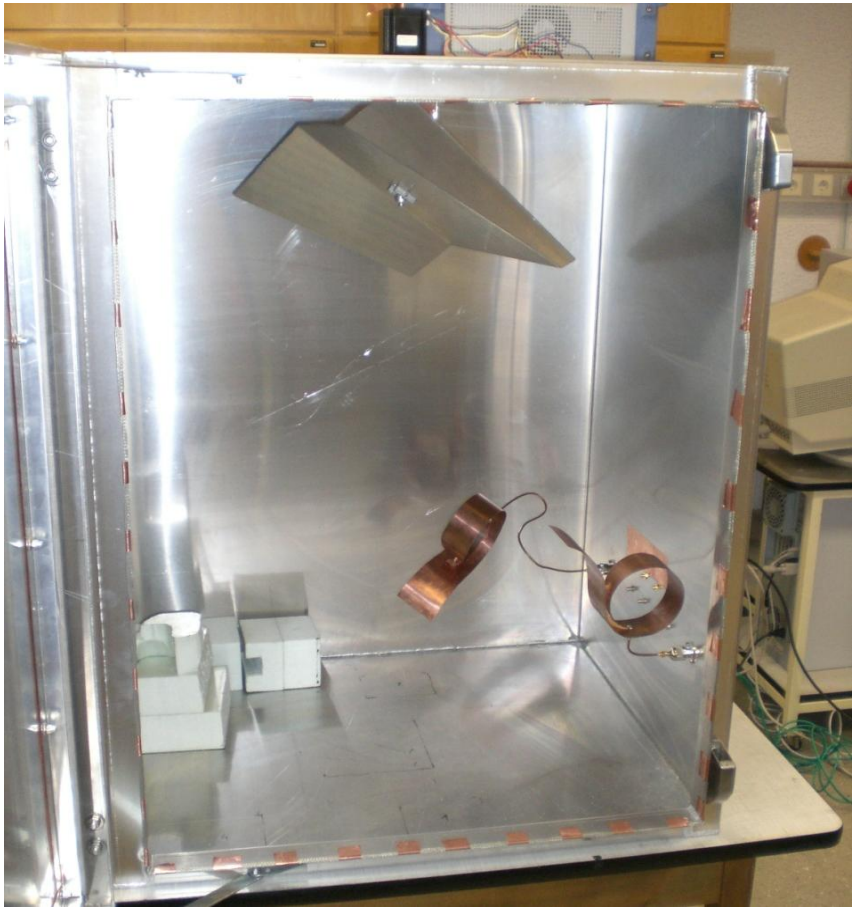
Reverberation Chamber

„worst case“ testing



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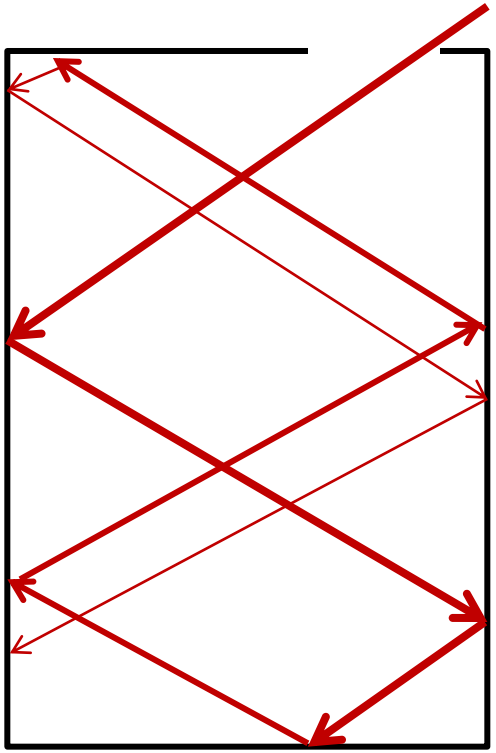
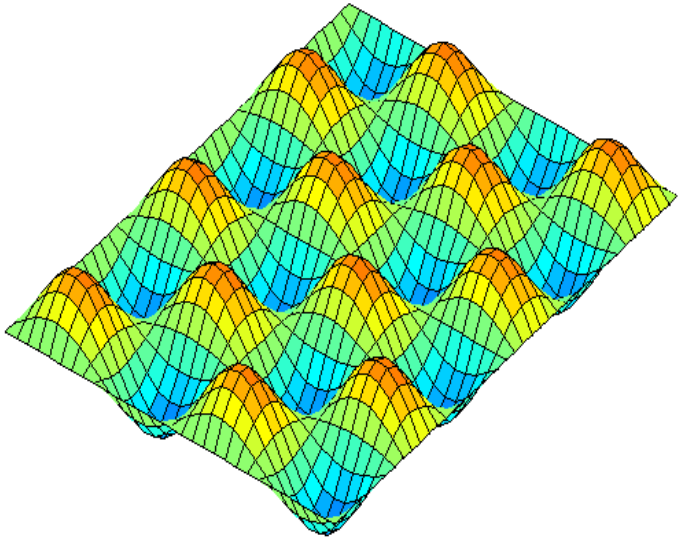
Electromagnetic resonators

RF range electromagnetic waves inside resonator: spatially inhomogeneous field: resonant moden = standing waves





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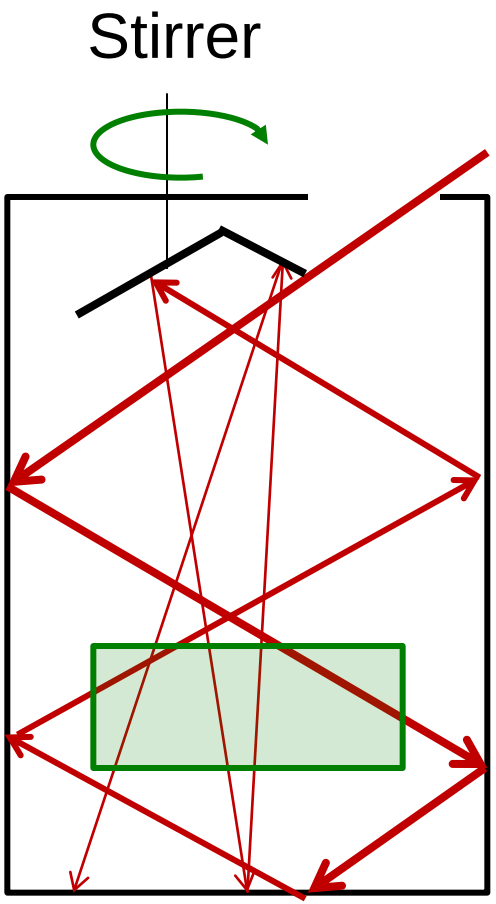
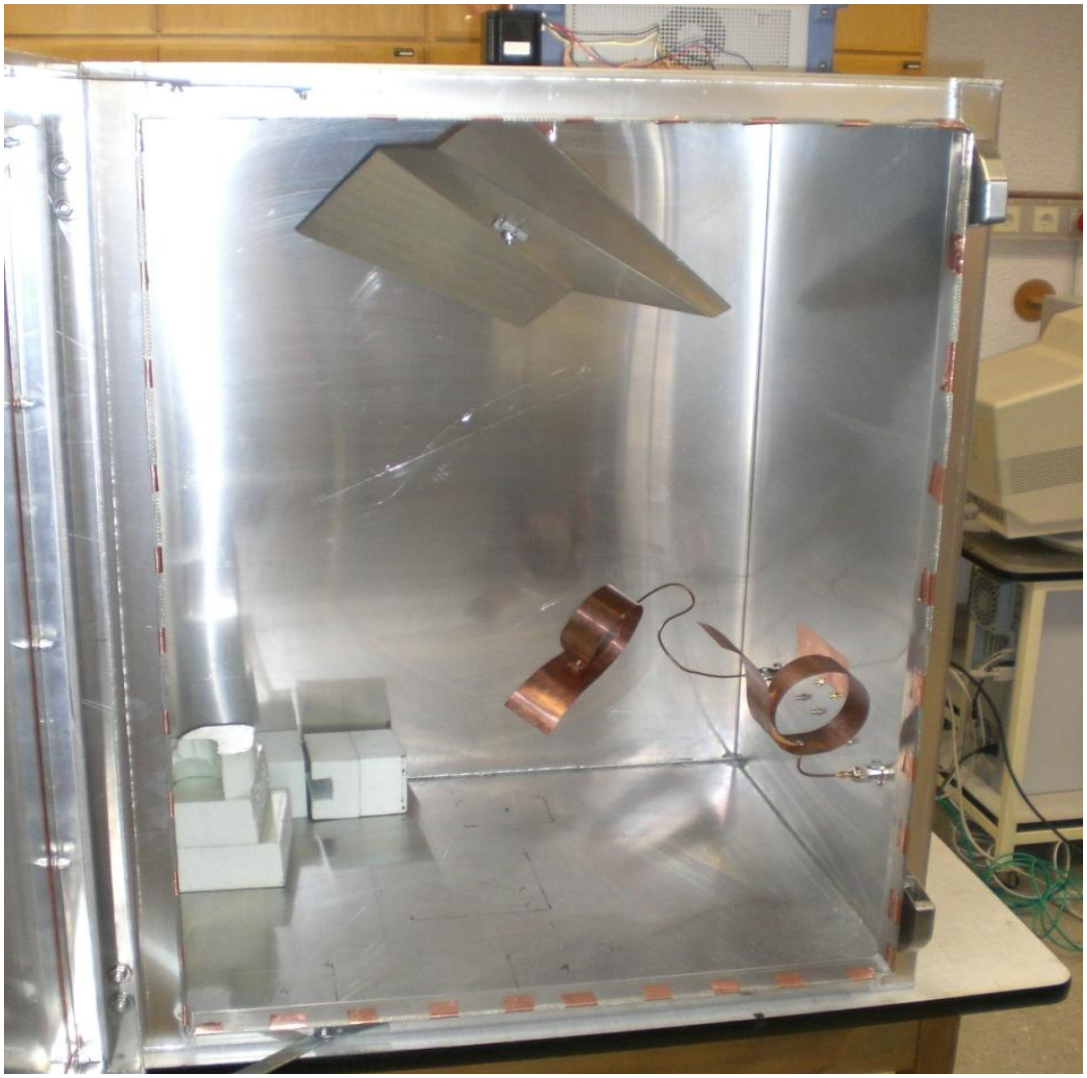
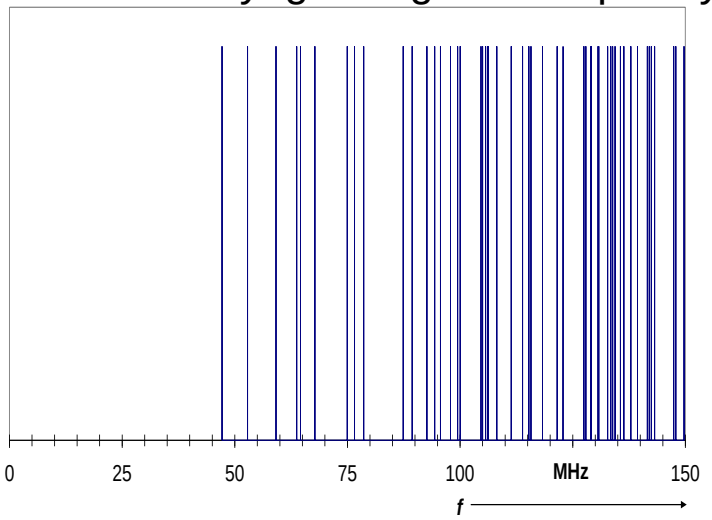
Influence of mode stirrer



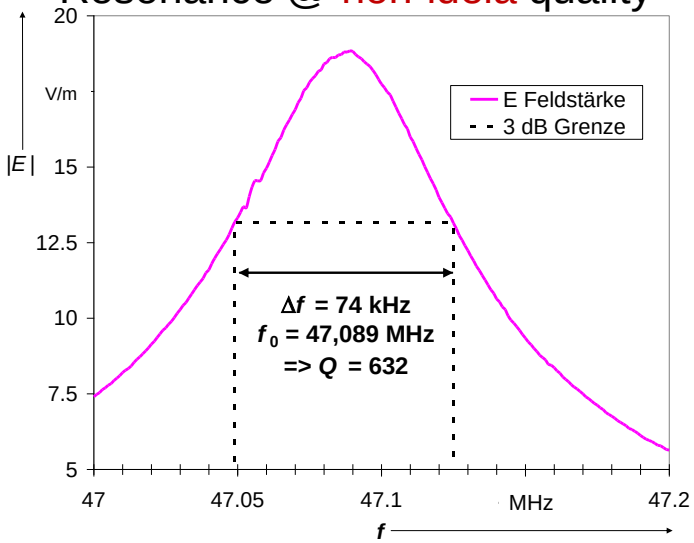


Overmoded Chamber: Simulateous excitation of modes

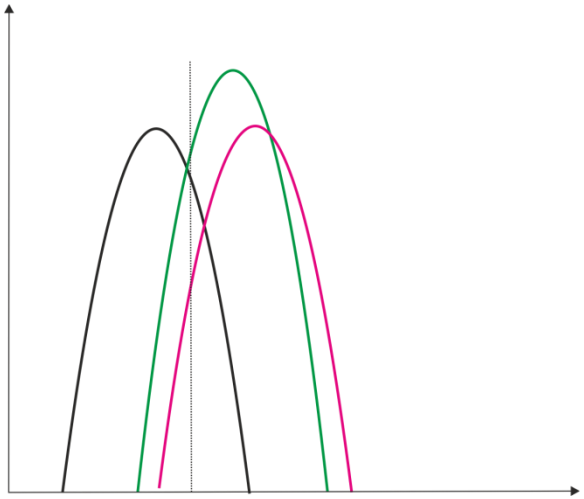
Mode density: growing with frequency



Resonance @ non-idela quality



Simultaneous excitation of resonant modes



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Properties of reverberation chamber

Electric and magnetic field in **test volume** of chamber (distance to walls > $\lambda/4$)

- Expectancy of magnitude is constant
- direction of propation is normally distributed
- polaritation plane is normally distributed

$\Rightarrow$ DUT is tested with all angle of incidence and pol planes at once

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Future work

Recommendations for future EMC test standards:

- Multiple tests of single DUT to account for „extra“ failure
- Test of multiple DUTs for certification to account for production tolerance
- Supervision of selected DUTs during livetime, or
- Inclusion of artificial ageing during certification test

Additional ideas

- Use of reverberation chambers since traditional EMC´test procedures suffer from similiar disadvantages

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Technische Herausforderung

Deterministische Feldverteilung

- technisch aufwendig
- kleines Testvolumen
- sehr lange Versuchsdauer
- keine statistisch valide Aussagen

Chaotische Feldverteilung

- Einfach zu realisieren
- sehr großesTestvolumen
- kurze Versuchsdauer
- nur statistische Aussagen

Neuartig und (noch) nicht etabliert