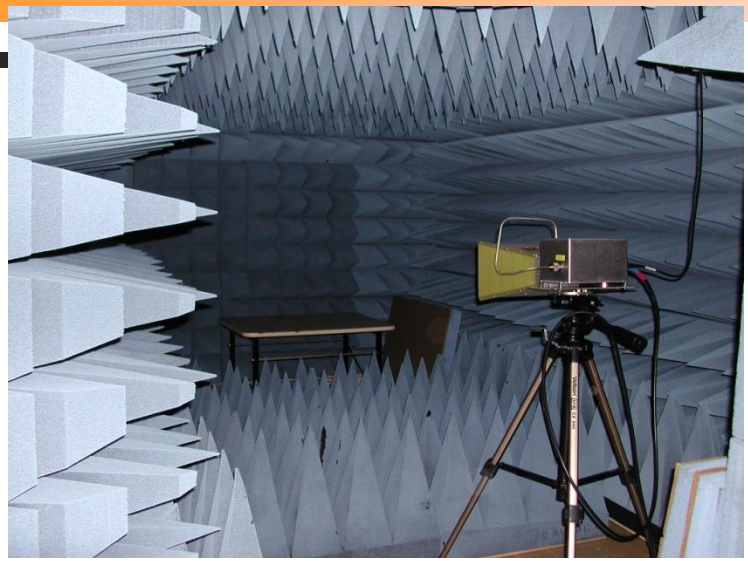
Rationale for RC Testing

Vignesh Rajamani, PhD.
Research Engineer
Oklahoma State University

Overview

- What is a reverberation chamber?
- Immunity testing
- Emissions testing
- Shielding effectiveness measurements
- Characterization of EM environments

Anechoic / Reverb Chamber



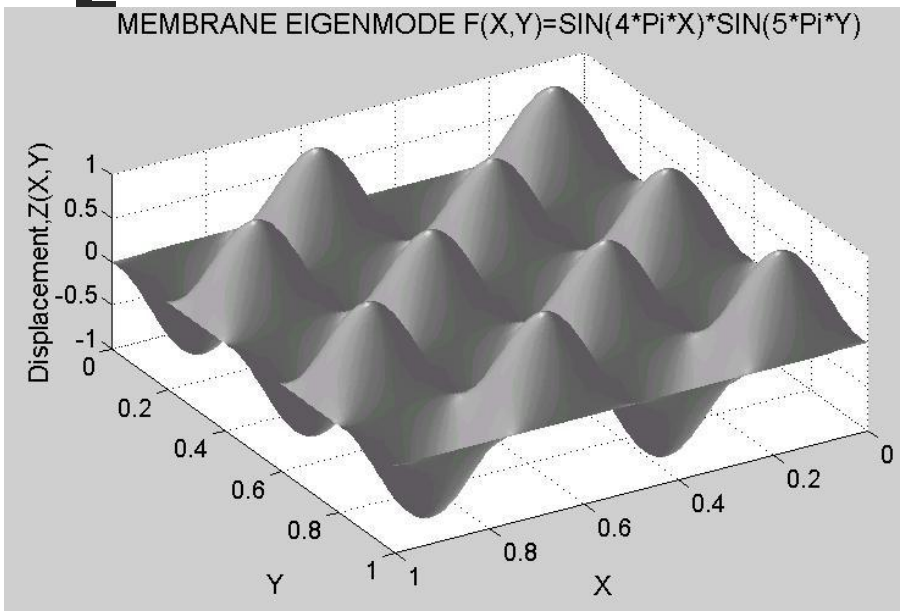
- **Pros**
  - Plane waves from one specific angle and polarization – great for antenna pattern measurements
  - Susceptibility – Large impact can be made if the characteristics of the device being tested are known
  - Emissions –Measures the radiated power in a specific direction
- **Cons**
  - Test time will be large if a complete test is done
  - Uncertainty levels are huge

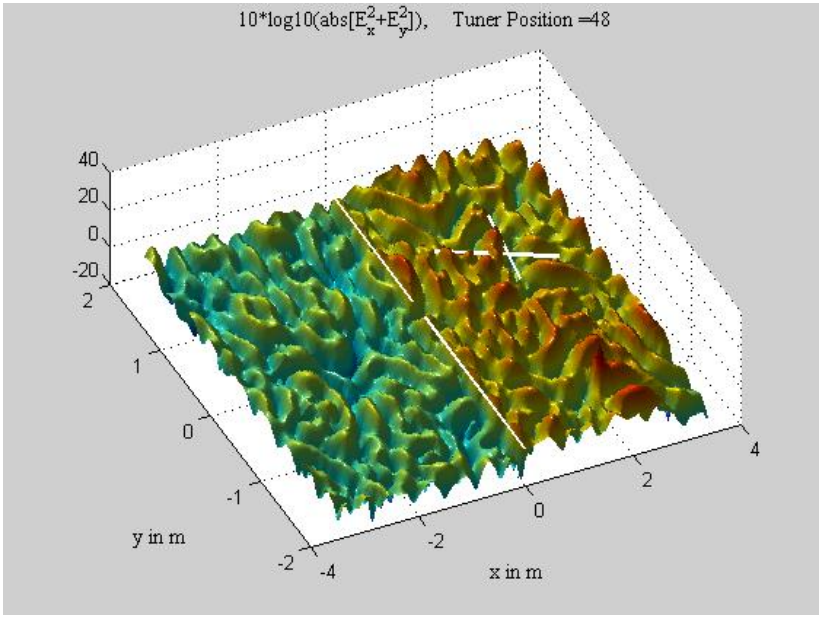
- **Pros**
  - Plane waves from all angles and polarizations – great model for complex environments
  - Susceptibility - Uncertainty levels are much smaller and predictable (statistically)
  - Emissions – Directly measures max. radiated power
- **Cons**
  - Test time is large (especially for susceptibility)
  - No directivity information

What is a Reverberation Chamber

- A cavity enclosed by conducting surfaces with a method of exciting the modal structure changes within the cavity
- The EME, resulting from repeated reflections from the conducting surfaces is a superposition of plane waves with random phase
- The modal structure changes are established by
  - Moving the tuner (Stepping and Stirring)
  - Varying the position, orientation, polarization of the antenna/EUT
  - Vibrating a conducting cloth
  - Changing the input frequency
  - Combination of any/all of the above

Modal Structure inside RC





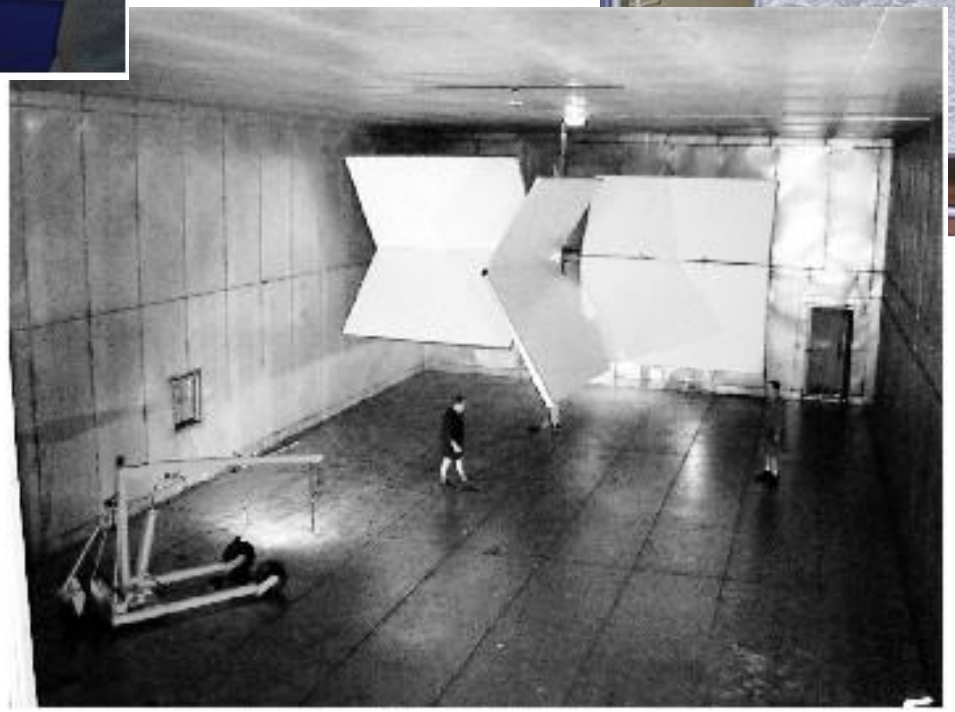
- Avoid cubical cavity or cavities that have dimensions as multiples of one side
- The more complex the structure, the better the reverberation but also think about structural rigidity and repeatability

1. http://aemes.mae.ufl.edu/~uhk/mem2.jpg
2. C. F. Bunting, *"Statistical Characterization and Simulation of a Reverb Chamber Using Finite-Element Techniques,"* IEEE Trans. on EMC, Vol 44, No.1, Feb 2002.

Theory

- Modal Structure
  - Sum of set of basis functions, useful for visualizing variations in fields as a function of location
  - Hard to include complex tuner boundary conditions (BC)
- Ray tracing
  - For simple geometries can evaluate amplitude and phase
  - Convergence is a problem for complex configurations
- Plane wave integral
  - Electromagnetic Environment (EME) inside a (Reverb Chamber) RC can be expressed as a sum of plane waves (Hill)
  - Applies only to source free region
- Chaos model
  - Can predict the large change in EME for small changes in BC
  - Limited work and relevance to RC not demonstrated; (Arnaut work might change things here!)

Chambers



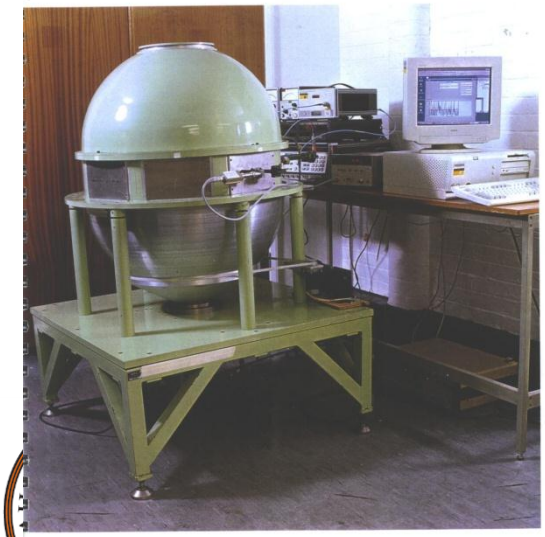
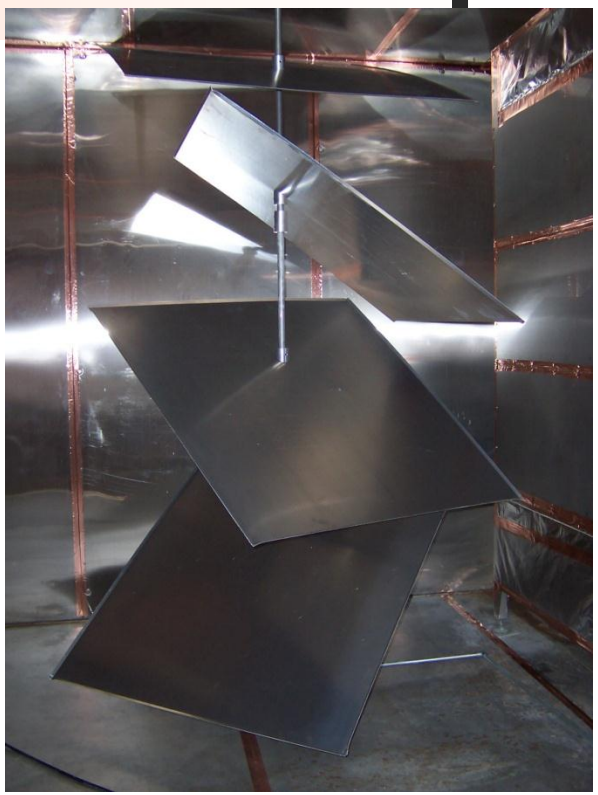


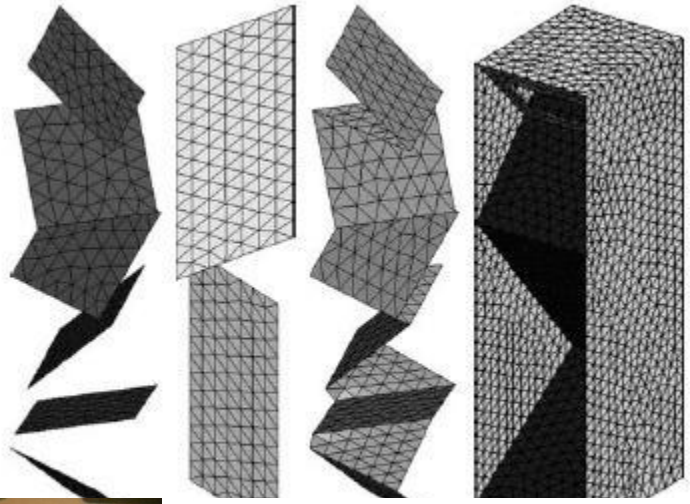
Fig 2.2

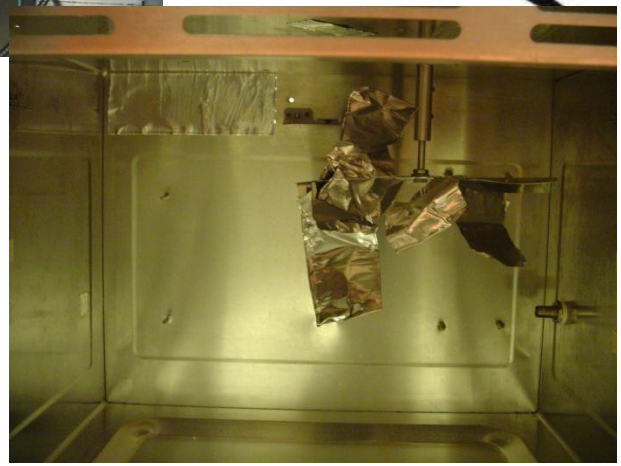
Tuner

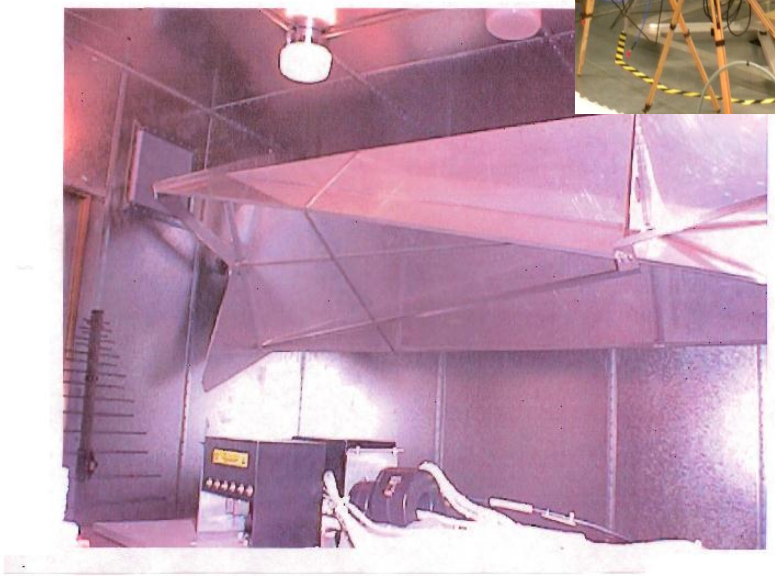
- The tuner is used to stir the field inside the chamber thereby creating a statistically uniform field over a specified volume of the chamber
- Tuner usually occupies considerable (25-30%) volume of the chamber
- Though reverb chamber testing asks for randomness, for repeatability the effects must be deterministic
- Measurement time is also proportional to the tuner settling time



Tuners







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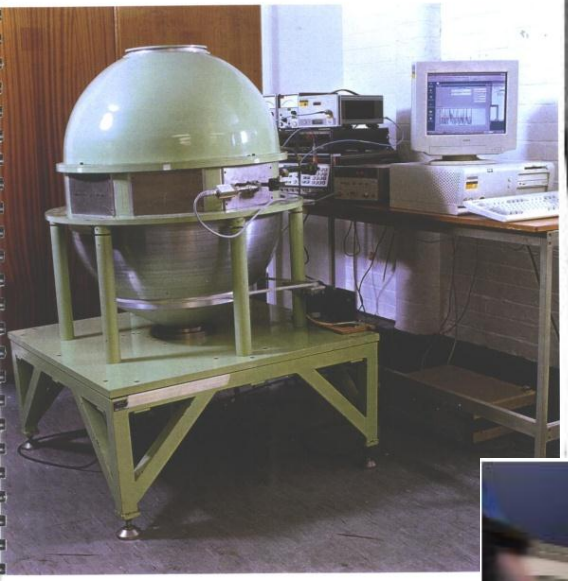
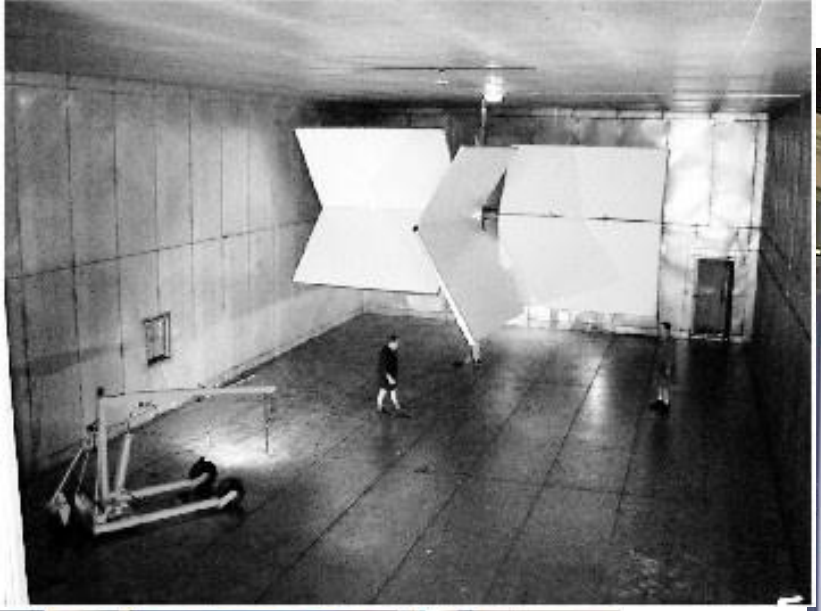
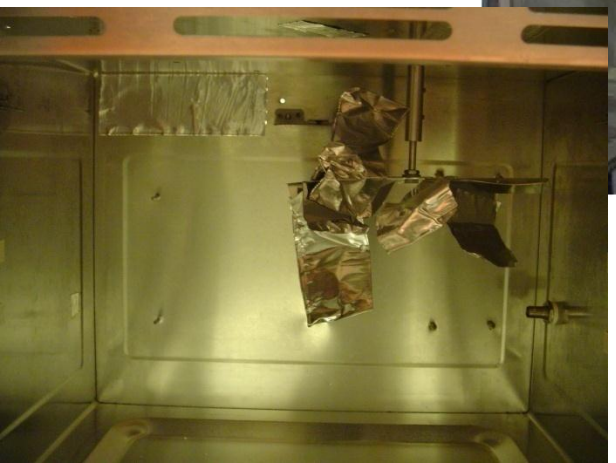
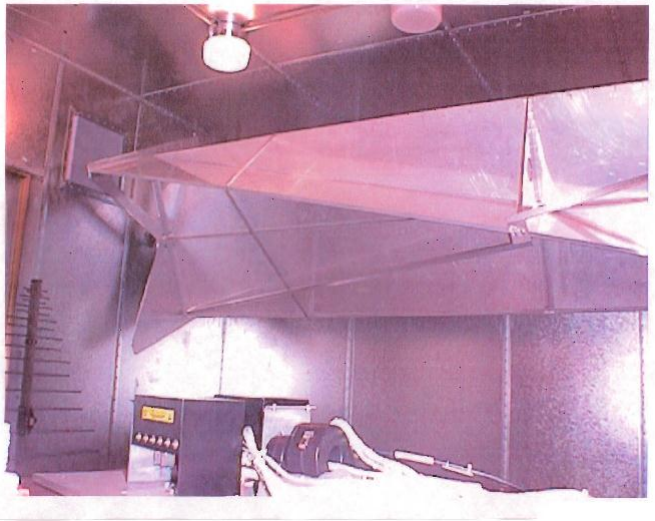


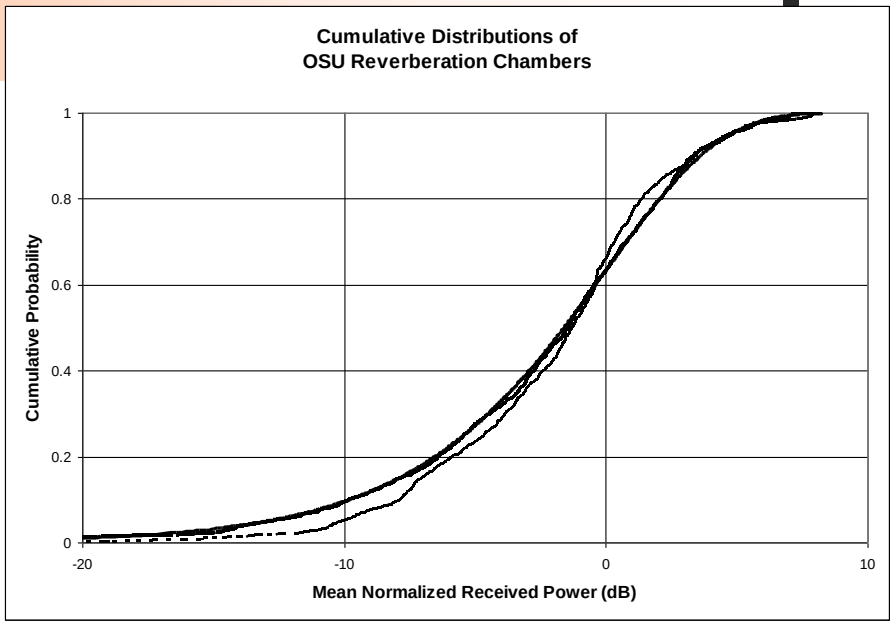



BLUETEST.se





OSU Chambers



RC EME

- A well stirred RC provides a test EME that is statistically isotropic, randomly polarized and uniform within an acceptable uncertainty and confidence limit
- ***Isotropic*** implies RC EME is the same in any direction (inside the usable volume)
- ***Random polarization*** implies that the phase relationship between polarized components is random
- ***Uniform*** implies all spatial locations within the usable volume of the RC are equivalent

Why use a Reverberation Chamber

- EMC test results depend both on EUT characteristics and the test facility
- Represents the operational EME for electronics in a cavity
- Robust test
- Repeatability/Reproducibility of tests
- Better predictability of uncertainty associated with the test

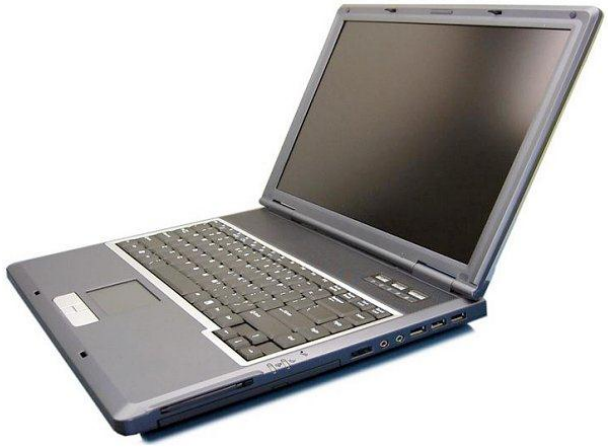
Radiated Immunity Test

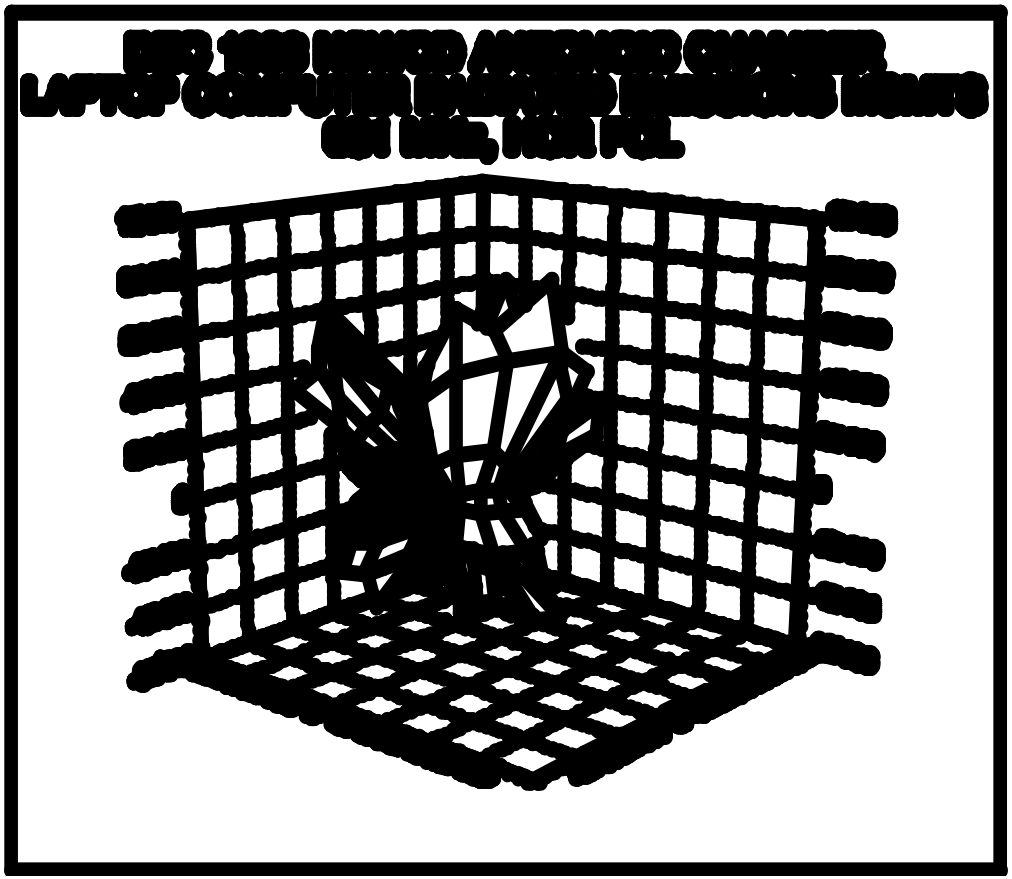
- For a susceptibility test on a device, the direction at which the device is radiated by the incident field is important
- For a complete test, the EUT must be exposed to incoming energy in all directions, polarizations at every frequency
- The time involved in performing these tests makes it prohibitive
- The possibility of under testing is large when limited number of aspect angles is used in the test

RC – Immunity Test

- EUT is subjected to field strengths as specified by the applicable standard to harden the EUT against intentional or unintentional electromagnetic interference
- In a RC, a typical way of performing an immunity test is to use mode stirred or mode tuned approach in conjunction with a sweep in frequency
- Independent samples - number of statistically independent field configurations that can exist inside the chamber (frequency dependent)

Emissions from a Laptop





OATS, FALC and TEM – Test Responses

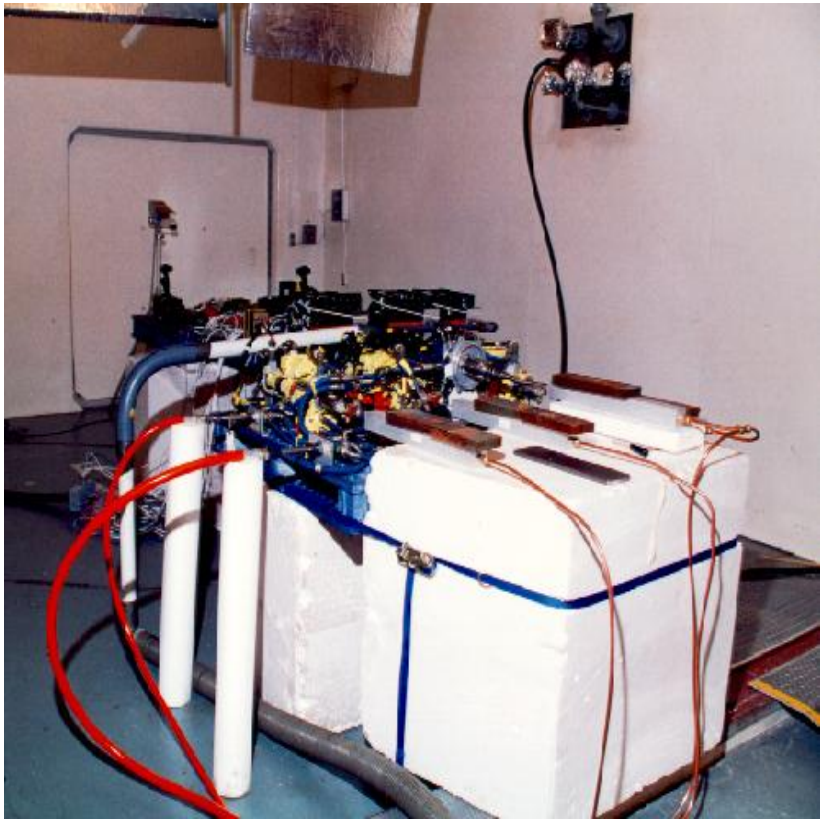
- OATS will provide the maximum value of constructive interference of all direct and indirect paths within a spherical segment
  - Would miss the strong upward directed emissions
- Typical FALC test consist of two polarizations with one or four aspect angles normal to the face of the EUT
  - Most of the structure in the directivity response will be missed
  - Difference between the measured and true maximums increases with gain of the EUT especially if the test aspect angles happen to be in a null of the pattern
- TEM cell test results will be similar to the FALC test

RC Test Response

- Statistically isotropic and randomly polarized RC test EME provides an all aspect angle test with predictable uncertainty
- Gain/Directivity effects of the EUT are not observed
- For immunity test, the EUT is immersed in a RF field and for emissions test, all emissions from any part of the EUT are measured

Complex test articles

- An EM engineers nightmare, is to test something like this for susceptibility and emissions!
- Consistent results possible with reverberation chamber



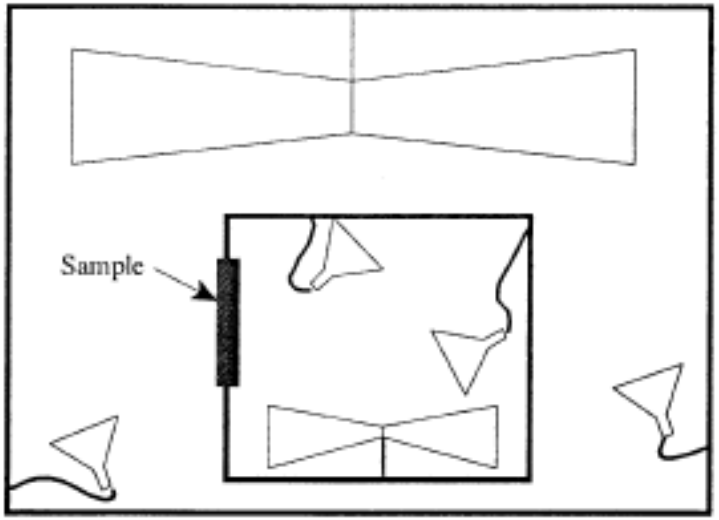
Statistical Equivalence

Certain EME parameters of all complex cavities are equivalent

- Conditions for statistical equivalence
  - Complex cavity
  - Sufficient modal structure
  - Appropriate mode excitation
- Statistical equivalence independent of
  - Cavity geometry, volume, construction, interior configuration

Applications of RC

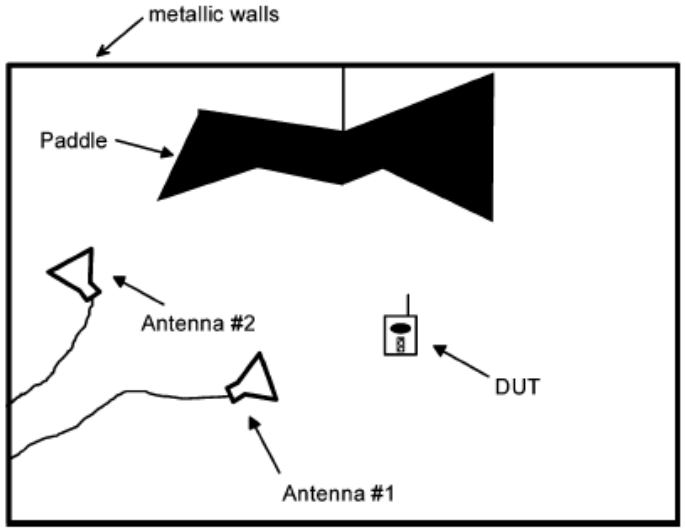
- Shielding Effectiveness
  - The use of reverberation chambers for determining the shielding effectiveness has the advantage over other techniques in that the reverberation chamber exposes the material to a more realistic environment



Ref: Shielding Effectiveness Measurements of Materials Using Nested Reverberation Chambers; Christopher L. Holloway, David A. Hill, John Ladbury

Applications II

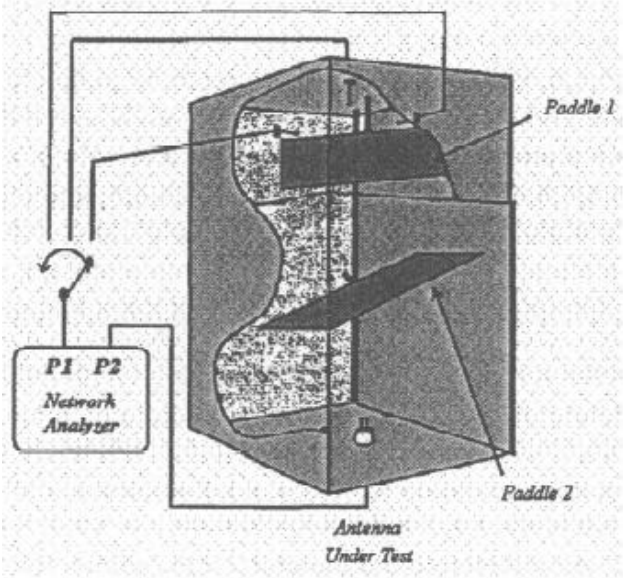
- Simulation of a Radio Environment
  - Reverberation chamber can be used to simulate a controllable radio environment for the testing of a wireless device; by varying the characteristics of the reverberation chamber and/or the antenna configurations in the chamber, any desired EME can be obtained



Ref: On the Use of Reverberation Chambers to Simulate a Rician Radio Environment for the Testing of Wireless Devices; Christopher L. Holloway, David A. Hill, John M. Ladbury, Perry F. Wilson, Galen Koepke and Jason Coder

Applications III

- Measuring antenna efficiency
  - For antenna efficiency measurement, the scattering parameters for transmission and reflection coefficient at the excitation antenna with respect to antenna under test is needed
  - The scattering parameters are measured at two antenna ports between one port of the fixed transmitting antenna (Port 1) and the port of AUT (Port 2) from the network analyzer



Ref: A Comparative Study of Small Antenna Efficiency Measurements; A.A.H. Azremi, H. Ghafouri Shiraz and Peter S. Hall

Applications IV

- Characterizing below deck and aircraft cockpits EM environment

Ref: Electromagnetic Environment Characterization of Below-Deck Spaces in Ships; Greg Tait and Mike Slocum

Pros and Cons

- Pros
  - Repeatability and reproducibility
  - Robust test
  - Replicates the EME close to real world (esp. electronics inside cavity)
  - More field strength for less input power
  - Facility cost is significantly less
  - Lower uncertainties
  - Results are correlatable under certain conditions
- Cons
  - Directivity of the device cannot be measured in RC
  - For emissions, RC measures the maximum radiated power and AC measures the field strength at a distance
  - With the current method specified by the standard, the test time associated with susceptibility is large
  - RC is gaining wide popularity in the EMC community but some gray areas have to be addressed
  - Statistical procedure

Summary

- RC test EME provides all aspect angle testing capabilities over large and complex EUT configurations
- Typical standards tests can have large uncertainties compared to what can be obtained with robust testing
- Statistical nature of the RC testing provides the mechanism to quantify the test uncertainty and to trade-off required input power, test time and uncertainty
- Not a test ***panacea*** but provides a cost effective EMC test capability