Reverberation Chambers

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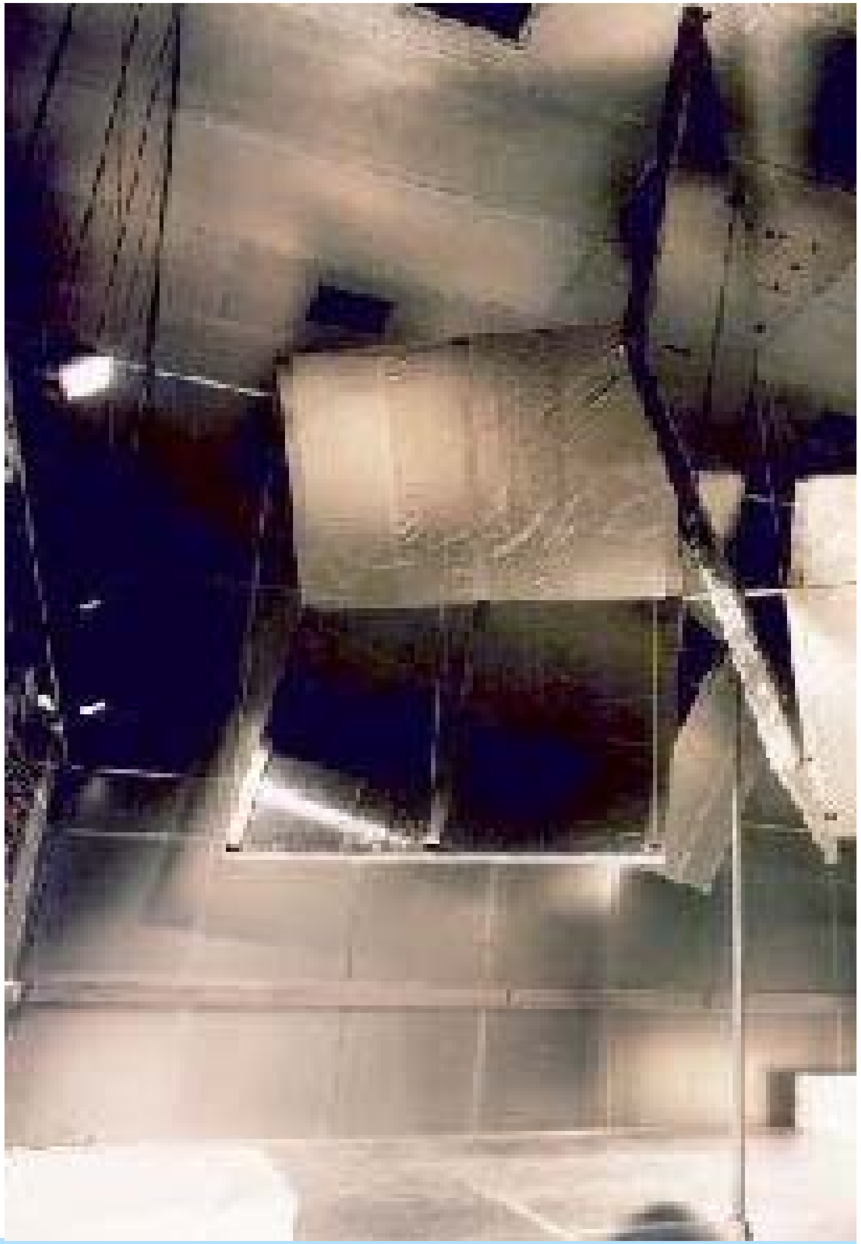
29th November 2007



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01

Introduction

01 Reverberation Chambers

Electrically large, highly conductive overmoded closed cavity

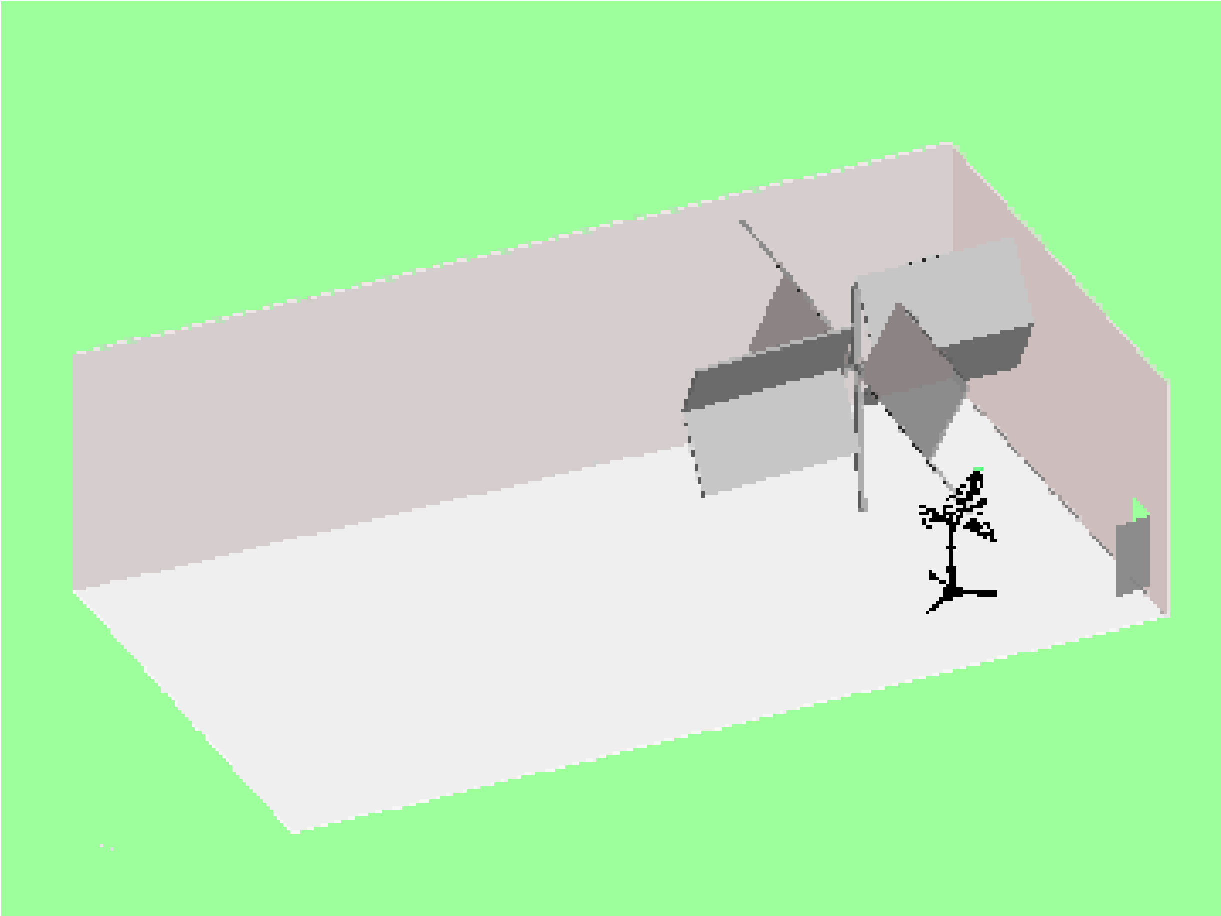
Electromagnetic field uniformity achieved by rotation of conductive tuner or other method

Tuner dimensions must be comparable to wavelength corresponding to Lowest Useable Frequency (LUF)

Advantages:

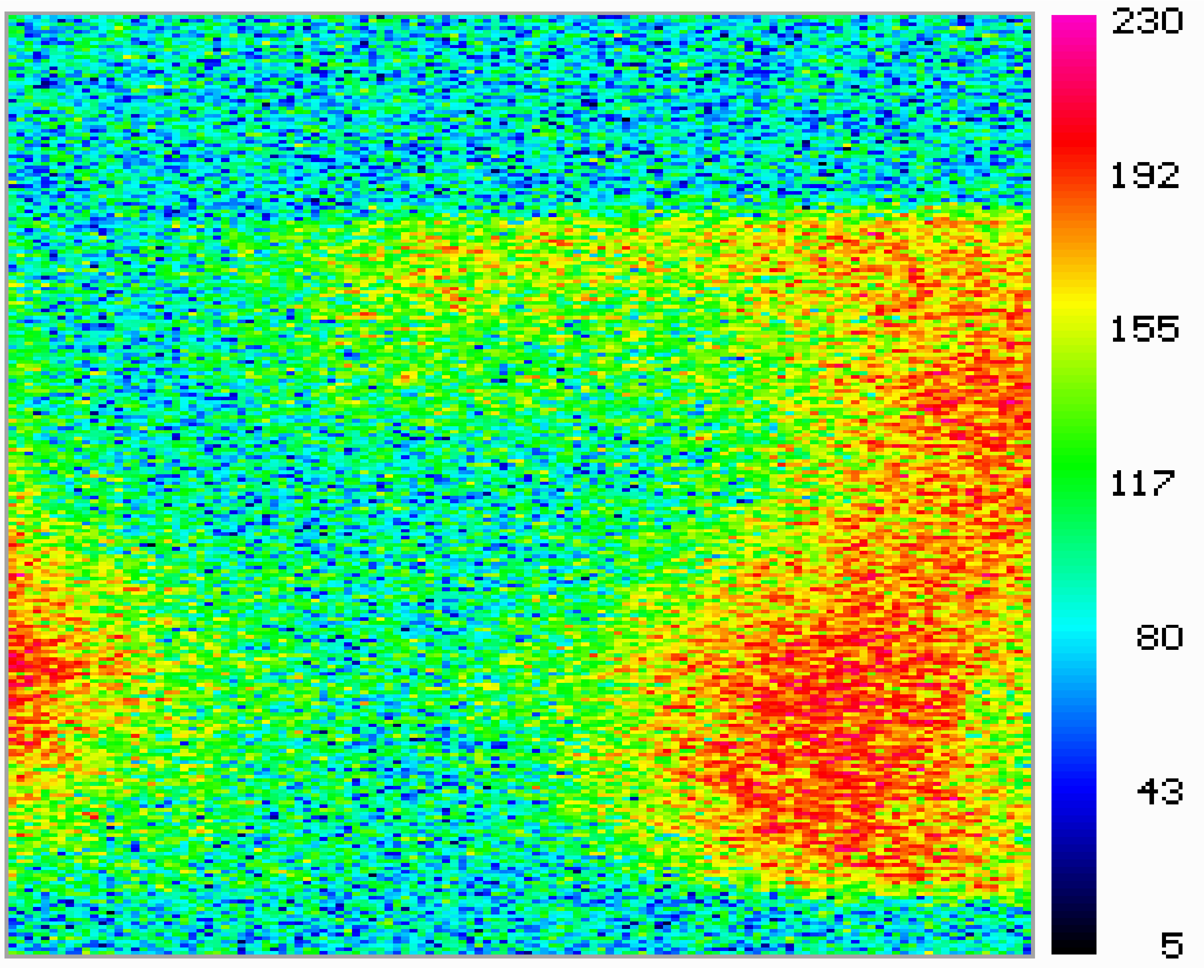
- Supports high field strengths per watt of input power
- Good measurement repeatability
- More thorough test
- Standards compliant (frequency step)

01 Reverberation Chamber – Field Uniformity



Courtesy K. Goldsmith DSTO Australia

01 IR 2D Slice Showing Field Variation



01 Other Types of Reverberation Chamber

Other but less practical methods of field randomisation

Hydraulic wall

- Movement at an internal wall

Vibrating Intrinsic Reverberation Chamber (VIRC)

- Movement of conductive material

02
Uses of Reverberation Chambers

02 Uses of Reverberation Chambers

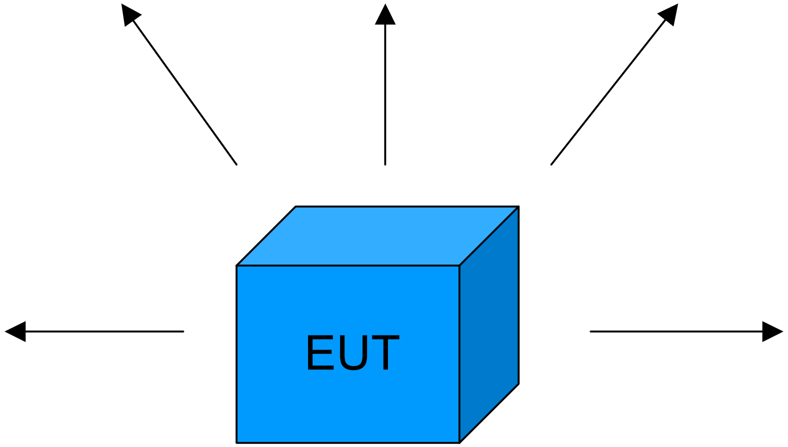
Mainly used for formal EMC Immunity Testing where the test limits are high

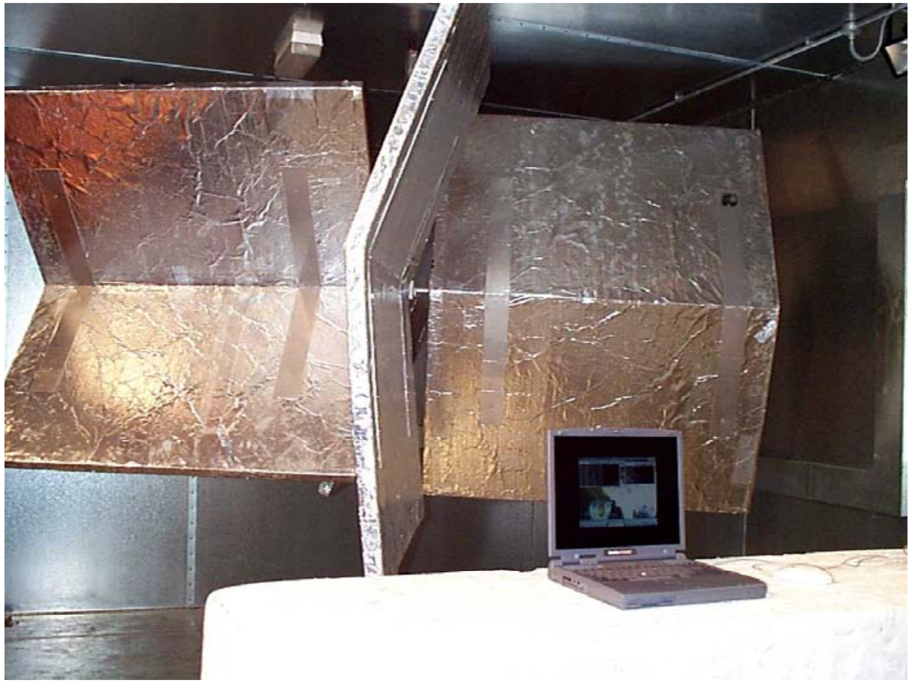
- Aerospace
- Automotive
- Military

Can also be used for:

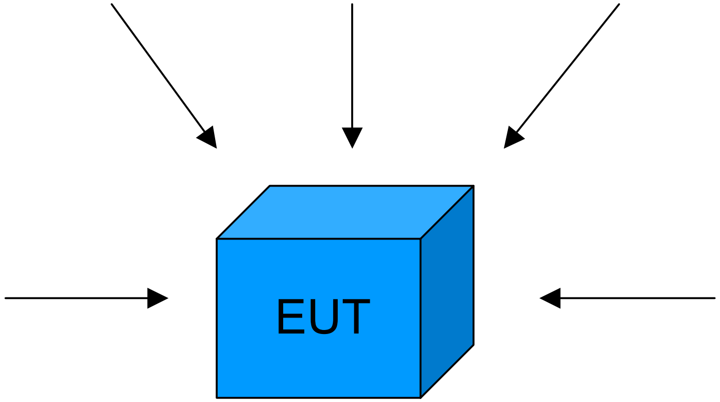
- EMC Emissions testing
- Shielding Effectiveness measurements of:
  - Materials
  - Enclosures
- Investigatory EMC pre-compliance testing
  - Most products are current tested conventionally
  - Reverberation chamber (mode stirred) pre-compliance testing provides:
  - Quick and easy measurement of the total radiated power

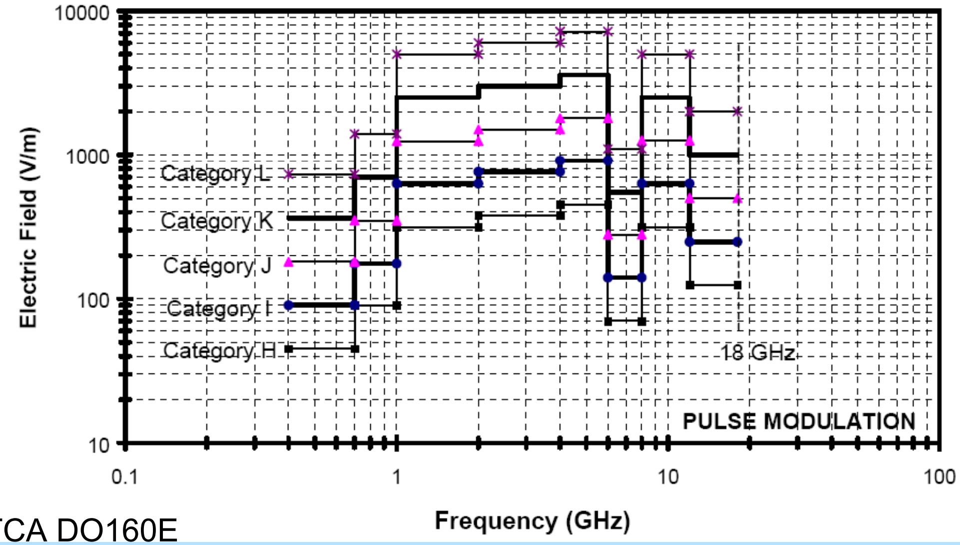
02 Total Radiated Power Emissions Measurement





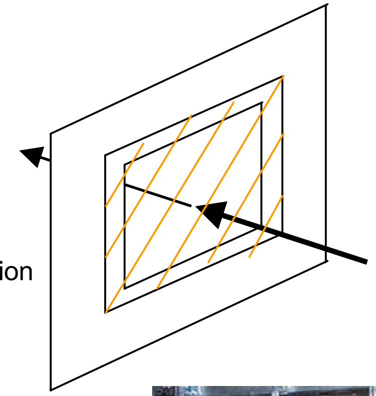
02 Radiated Susceptibility Testing

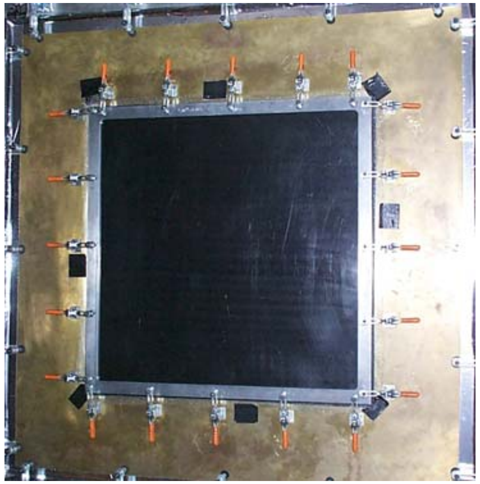


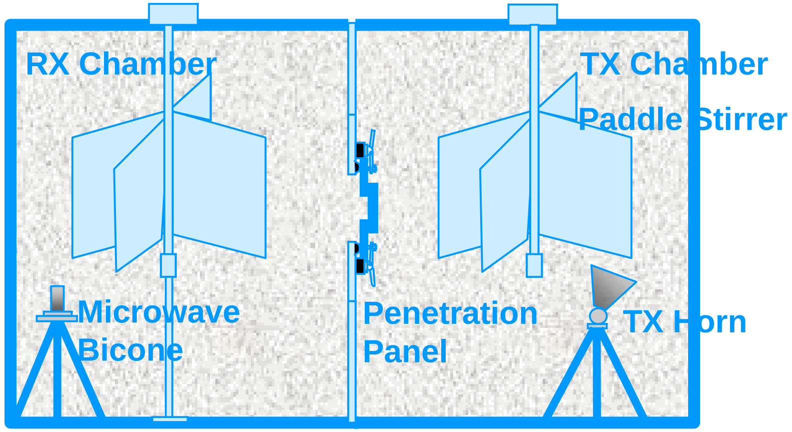


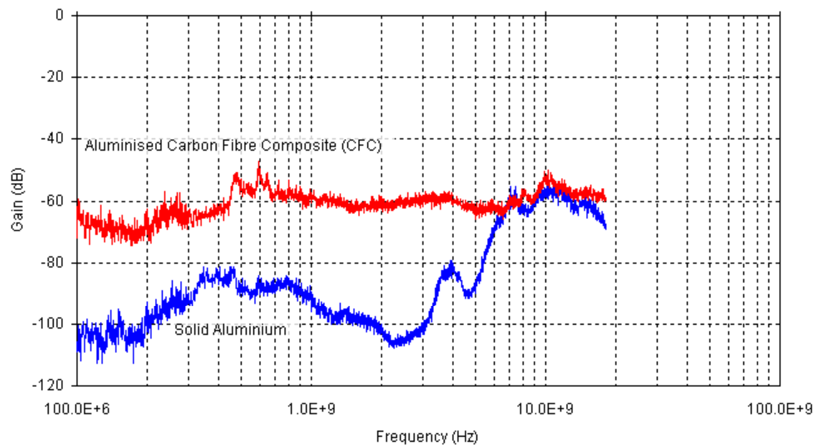
RTCA DO160E

02 Shielding Effectiveness/Attenuation of materials (dual reverberation method)



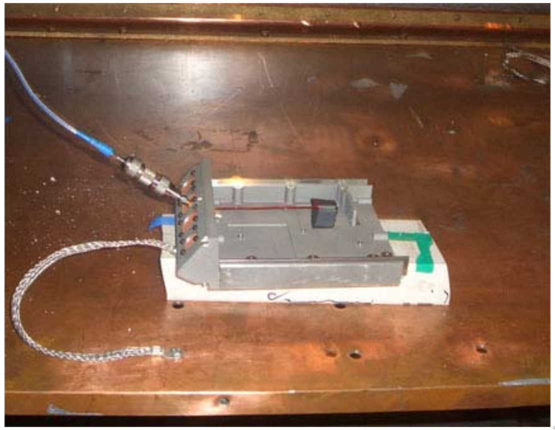


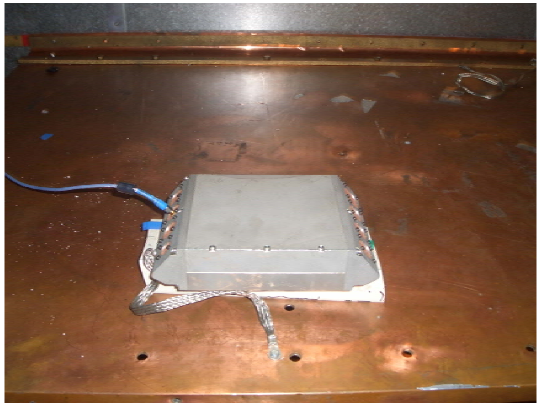


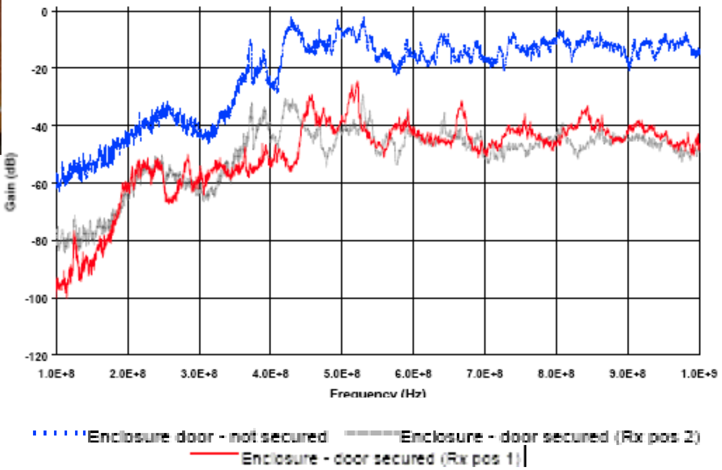


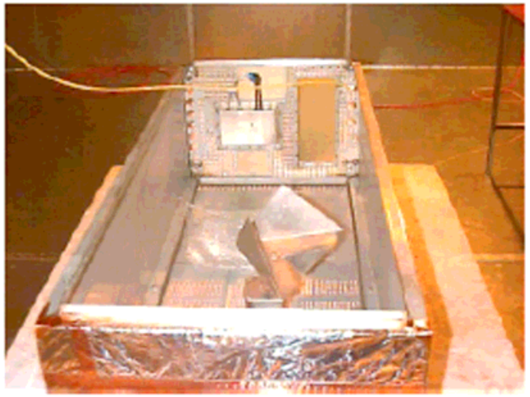
02 Reverberation Chamber SE Measurement (cont.)

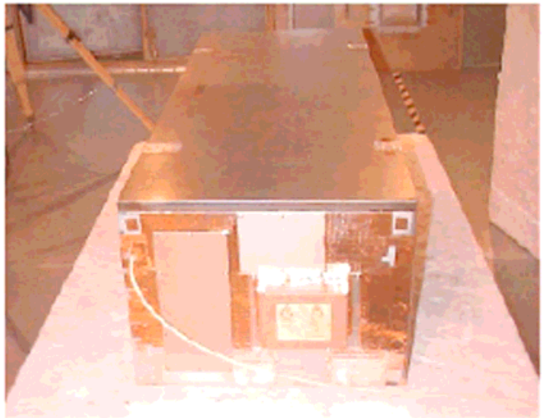
Equipment Enclosure Measurement



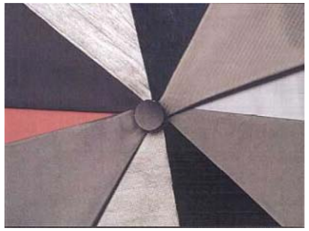
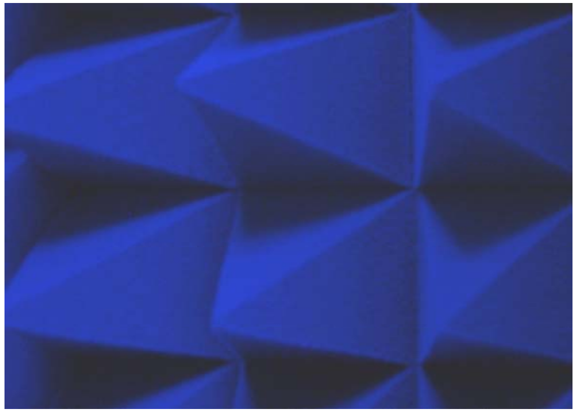








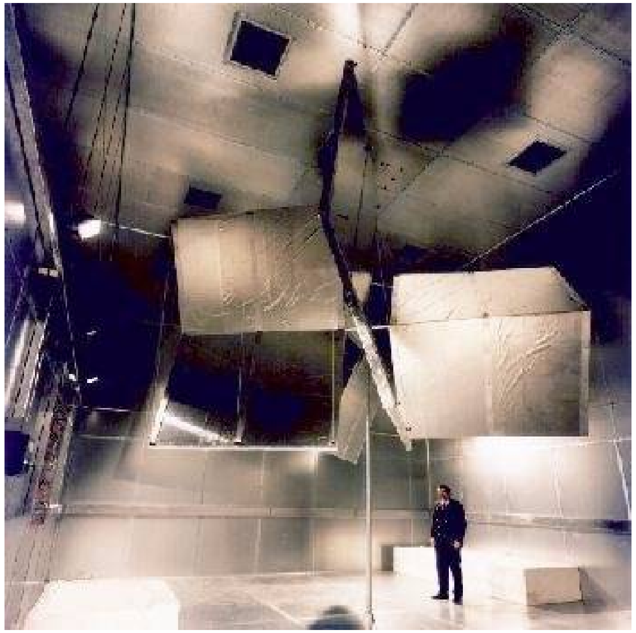
03
Example Facilities

03 Reverberation Chamber Facilities

The large reverberation chamber at QinetiQ Farnborough has the following features:

- Size - 10 m x 8 m x 7 m (560 m^3)
- Entry point - 2 m x 2 m (Double Door)
- Construction - Modular Steel Construction
- Paddle design - Foil Covered Foam



03 Reverberation Chamber Facilities

The medium reverberation chamber at QinetiQ Farnborough has the following features:

- Size - 8 m x 5 m x 3 m (120 m^3)
- Entry point - 2 m x 2 m (Double Door)
- Construction - Modular Steel Construction
- Paddle design - Foil Covered Foam

03 Reverberation Chamber Facilities

The small reverberation chamber at QinetiQ Farnborough has the following features:

- Size - 3 m x 2.5 m x 2 m (15 m^3)
- Entry point - 1 m x 2 m (single door)
- Construction - Modular steel construction
- Paddle design - Honey Comb Aluminium

03 Reverberation Chamber Facilities

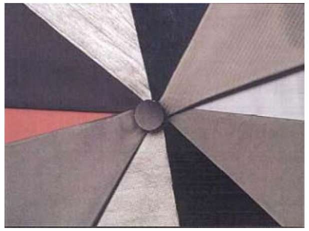
The PIG at QinetiQ Farnborough has the following features:

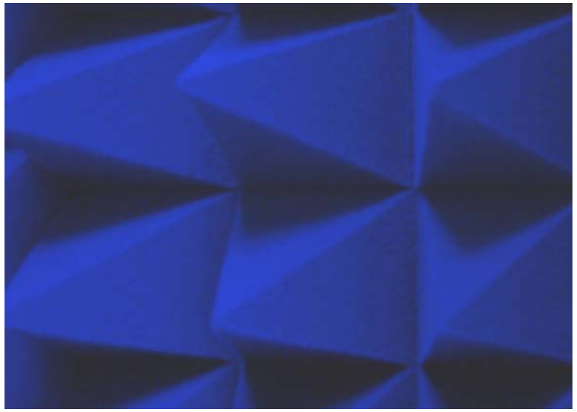
- Size - 0.36 m x 0.36 m x 0.24 m (0.04 m^3)
- Entry point - 100 mm x 70 mm (single door)
- Construction - Aluminium construction
- Paddle design - Sheet Aluminium

03 Reverberation Chamber: DSTO Adelaide

Photo courtesy of the Royal Australian Air force Aircraft Research and Development Unit

04
Chamber Properties





04 Chamber Q Factor

The Q Factor describes the chambers ability to store RF energy.

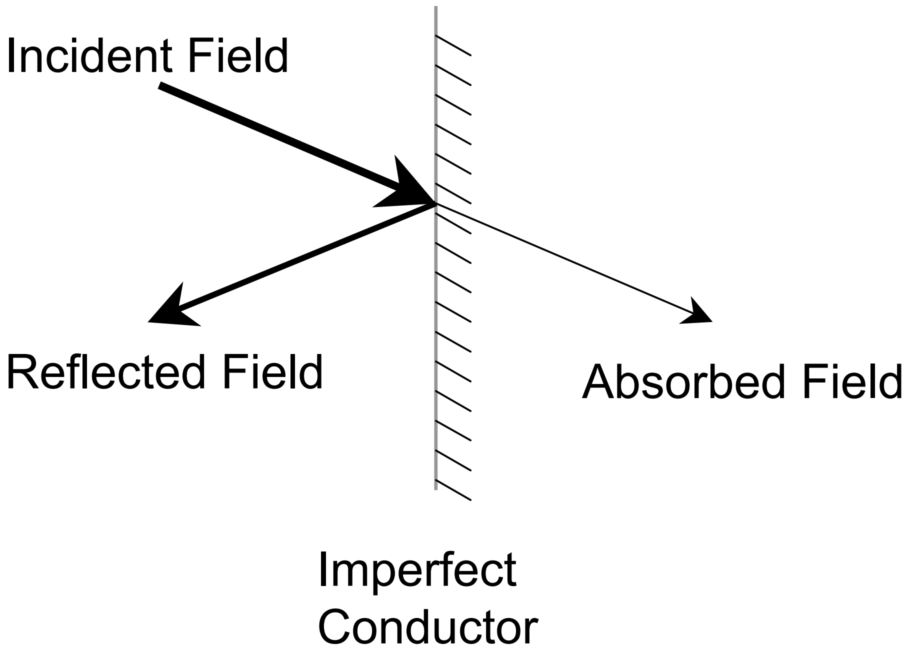
The largest contributing factors are:

- Chamber surface losses
- Chamber aperture losses
- Chamber loading

04 Chamber Losses

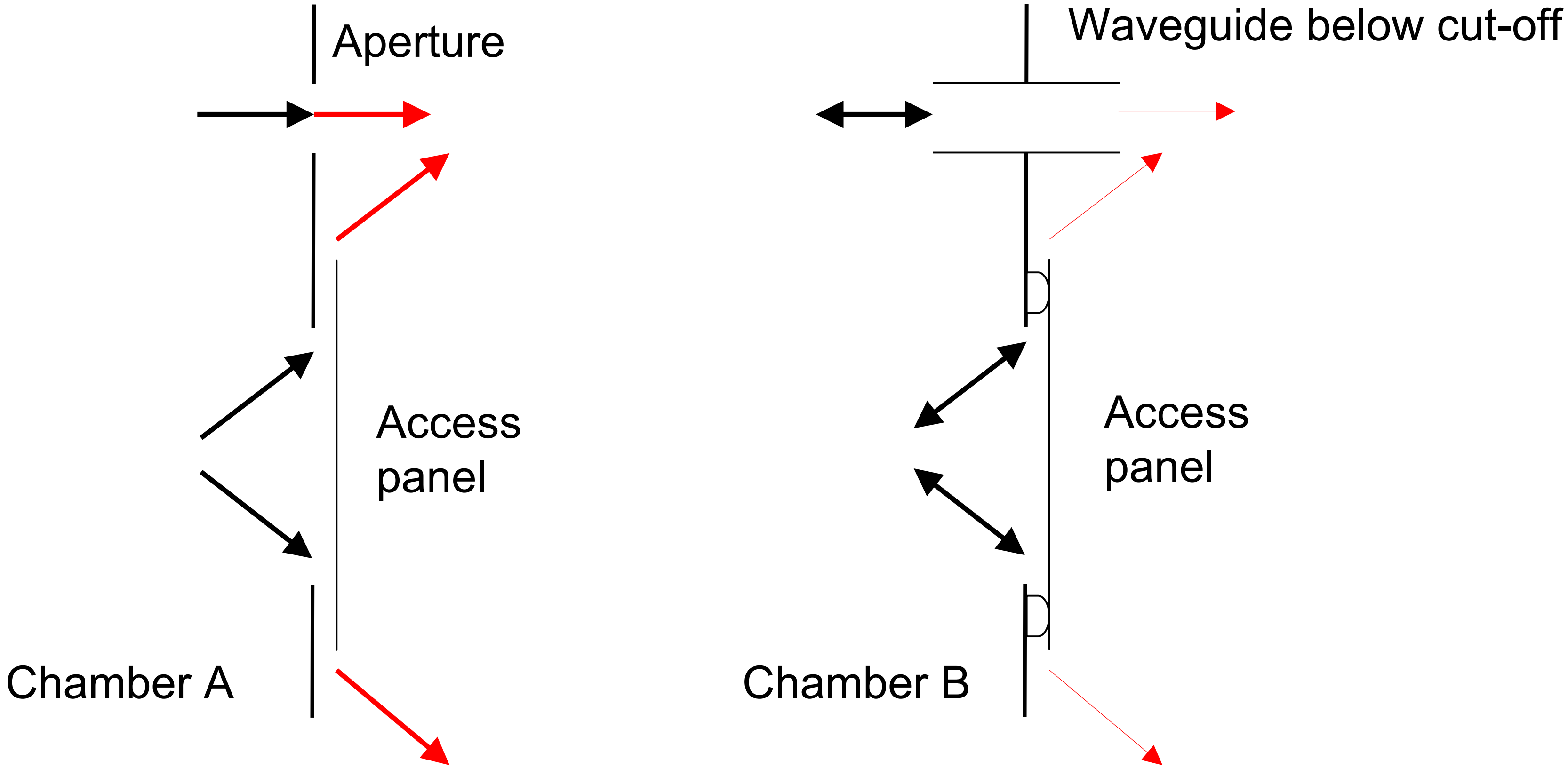
Conductive internal surfaces

- Imperfect conductor equates to an imperfect reflection and therefore loss.



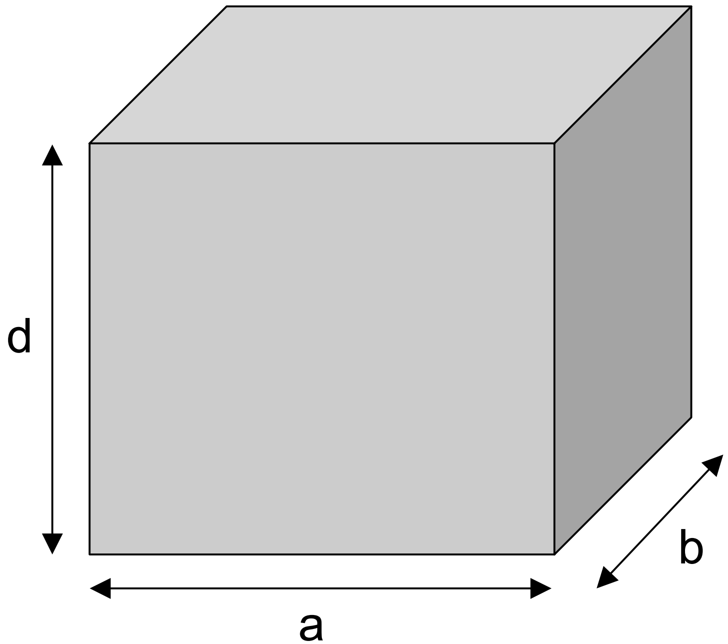
04 Chamber Losses

Minimal chamber losses



04 Operating Frequencies

Wide range of operating frequencies



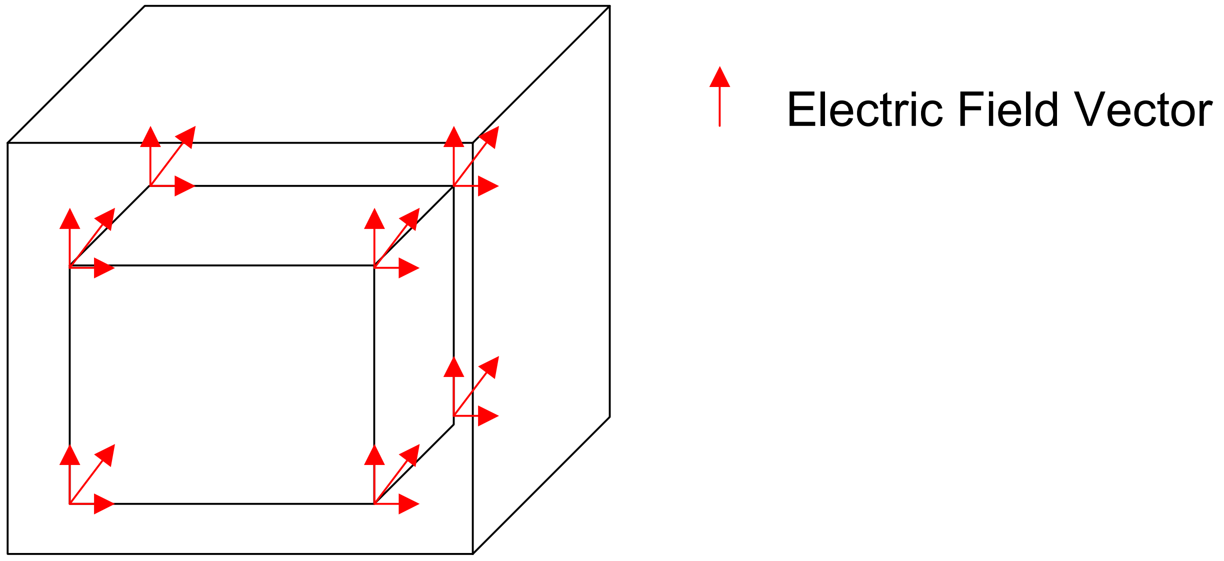
$$f_{011}(Hz) = \left(\frac{c}{2}\right) \times \sqrt{\left(\frac{i}{a}\right)^2 + \left(\frac{j}{b}\right)^2 + \left(\frac{k}{d}\right)^2}$$

Where

- 'a' is the smallest dimension (m)
- 'b' and 'd' are the other dimensions
- i=0
- j=k=1
- and c is the speed of light (m/s).

04 Electric Field Uniformity

Low statistical electric field deviation over the working volume



05
Standards and Test methods

05 Standards

Standards that allow ‘mode tuned’ and ‘mode stirred’ techniques:

Susceptibility testing

- British Standard EN61000-4-21
- Defence Standard 59-411
- MIL-STD-461E
- RTCA DO160E/EUROCAE ED14

Emissions testing

- British Standard EN61000-4-21
- CISPR 16-1
- RTCA DO160F?

05 Standard's Requirements

The requirements of 'mode stirred' / 'mode tuned' calibration:

British Standard EN61000-4-21 (Susceptibility and Emissions)

- Working volume map of 8 points in 3 axes
- Field uniformity conforms as described in the standard
- Rate of change in the field must be measured

RTCA DO160E (Susceptibility – 'mode tuned' only)

- Working volume map of 9 points in 3 axes
- Field uniformity must conform (up to two concessions per octave)
- Rate of change in the field must be measured

CISPR 16-1 (Emissions – 'mode stirred' only)

- Stirring efficiency

05 Reverberation chamber test methods

Reverberation chamber can be configured either for ‘mode stirred’ or ‘mode tuned’:

‘Mode Stirred’

- Continuous rotation of a stirring paddle
- Frequency dwells for a single rotation
- The rotational speed is determined by the rate of change of electric field relative to the equipment dwell time

‘Mode Tuned’

- Stepped rotation of a stirring paddle
- Frequency is swept a each assigned paddle position
- The sweep time is dependant by the dwell time of the equipment

06
Calibration

06 Purpose of Mode Tuned Calibration

Empty chamber calibration verifies field uniformity for selectable test parameters

- Lowest Useable Frequency (LUF)
- Selectable number of Tuner positions
- Dimensions of Chamber, Tuner and Working Volume

Provides benchmark against which the effects of chamber loading by the EUT can be assessed

Empty chamber calibration corrected for EUT loading

- Expected E Field generated per watt of chamber input power

06 Mode Tuned Calibration

Empty Chamber Field Uniformity and Loading Validation Phase

- Nine Point triaxial field probe calibration of empty chamber below $10f_S$
- Three Point triaxial field probe calibration of empty chamber above $10f_S$
- Simulation of EUT loading up to $10f_S$ by artificially loading chamber with absorber – maximum ‘Loading Factor’ measured for simulated loading.

06 EUT Evaluation Phase

Chamber Loading Determination

- EUT installed in chamber
- Chamber Loading Factor measured and compared against 'Loading Factor' derived from simulated loading phase
- If EUT loading excessive then Field Uniformity calibration must be repeated with EUT installed.

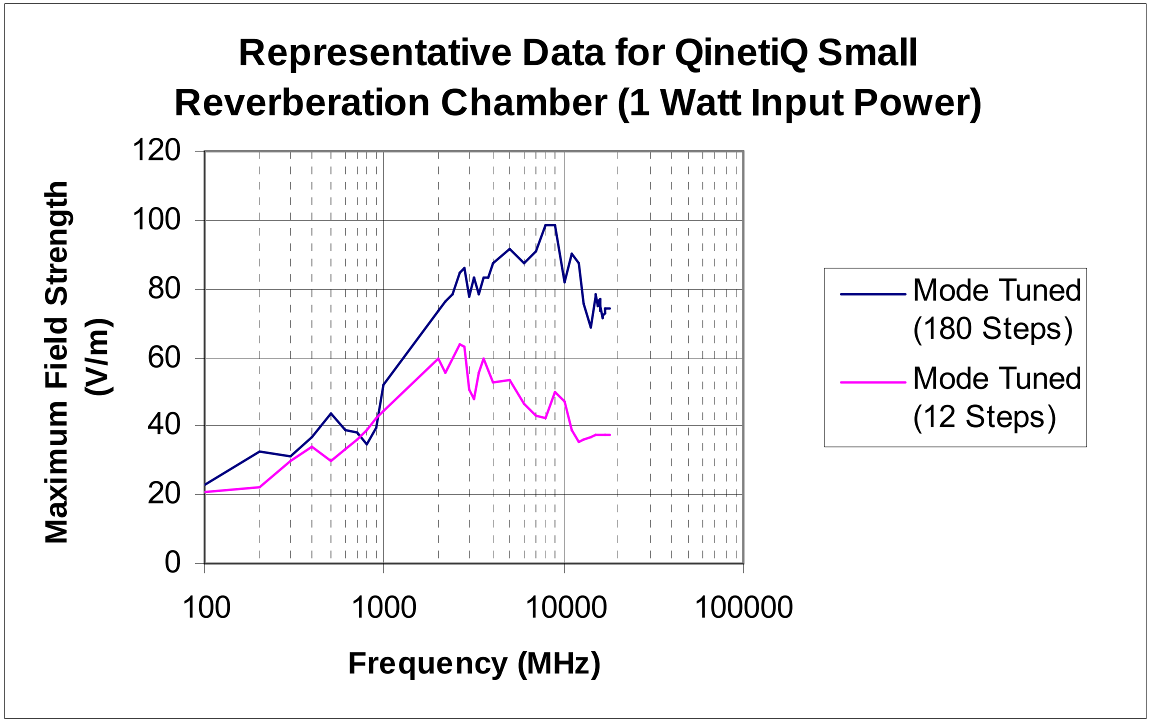
Chamber Q and Time Constant Calibration

- Measured with EUT installed
- Verifies rise time is quick enough to accommodate pulsed testing

06 EUT Radiated Susceptibility Test

Input power necessary to generate required field strength to test EUT is computed from calibration figures

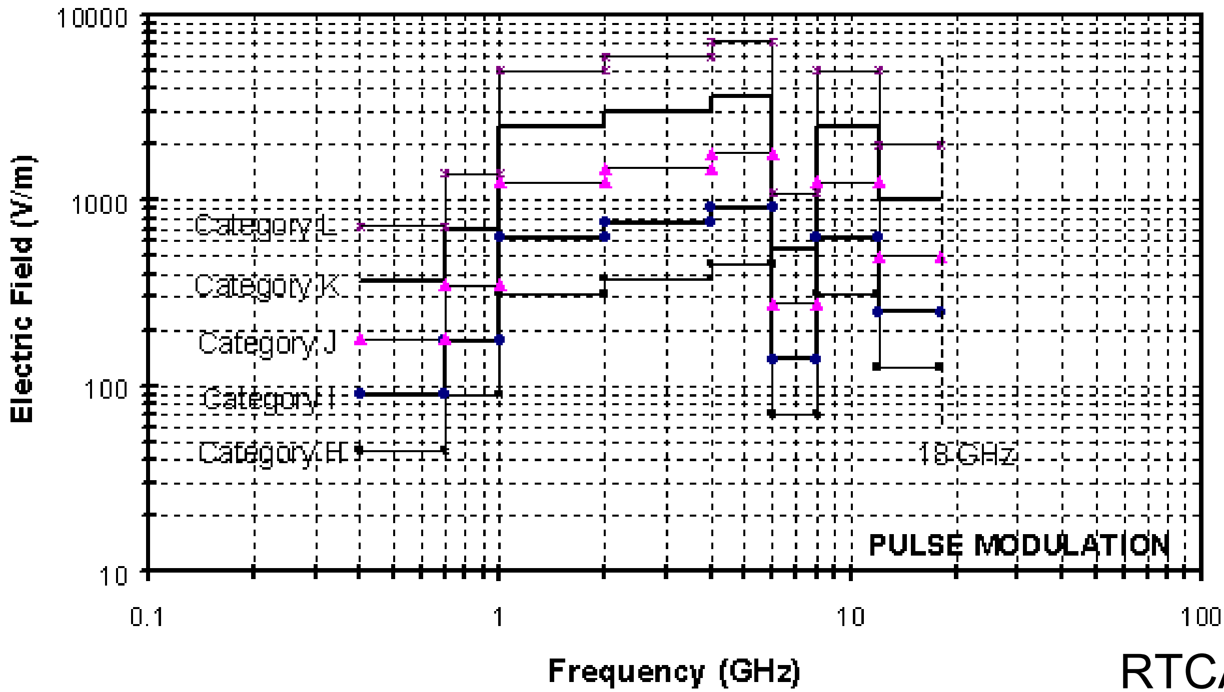
- V/m per W averaged over all calibrated tuner positions



06 EUT Radiated Susceptibility Test

Test limits for peak E-field are increasing as the environment becomes more severe

- Higher number of tuner positions desirable
- Leads to longer test time



RTCA DO160E

06 Mode Stirred Test Time

Assuming:

- 100 MHz to 1 GHz Band (100 frequencies / decade)
- Tuner rotation speed 30 RPM
- Single EUT Operating mode and Test Modulation
- No EUT Failures
- Test at Test Limit level only (no window effects investigation)

Typical Mode Stirred Test Time of 3.5 Hrs

06 Mode Tuned Test Time (Minimum 12 Tuner Steps)

Assuming:

- 12 Tuner Steps
- 100MHz to 1GHz Band (100 frequencies / decade)
- Fifteen seconds per test frequency
- Single EUT Operating Mode and Test Modulation
- No EUT Failures

Typical Mode Tuned Test Time of 5 Hrs (excluding calibration phase!)

More Tuner Steps means longer test durations

06 Mode Tuned Test Time Estimates

Number of Tuner Steps	Estimated Test Time (Hours)
12	5
60	25
75	32.5
180	75

Mode tuning which replicates the field uniformity and achieves the high field strengths associated with mode stirring can take 20 times longer than mode stirring

06 Optimising number of Tuner Steps

Fewer tuner steps reduces test time BUT……

- Reduces available field strength per watt of input power
- Reduces field uniformity

Calibration data should be obtained for high number of tuner steps

Calibration data for fewer numbers of tuner steps can then be evaluated by processing sub sets of this data

Test can then be divided up into frequency bands with optimum number of steps for each band

07
Conclusion

07 Conclusion

Reverberation Chambers

- Application
- Advantages over conventional techniques
- Electrical properties

Standards

- Applicable standards to mode tuned and mode stirred techniques

Calibration

- Mode tuned
- Mode stirred
- Typical test times

Independent expertise where it matters most.

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