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# Generating high EM fields using mode-stirred reverberation chambers for RTCA DO 160 applications

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Microwave & RF, March 23rd, 2016.

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# 1. RTCA DO 160 requirements

# RTCA DO 160 - Requirements

## RTCA DO160 G (2010)

EMC tests on airborne equipment

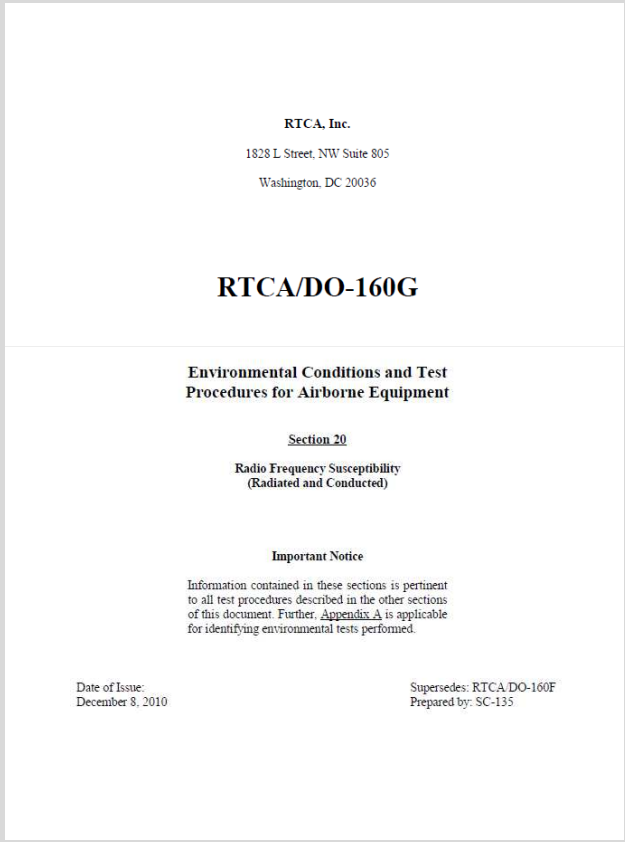
Section 20 : EMS tests

→ Conducted

→ 10 kHz – 400 MHz

→ Radiated

→ 100 MHz – 18 GHz



RTCA, Inc.

1828 L Street, NW Suite 805

Washington, DC 20036

**RTCA/DO-160G**

**Environmental Conditions and Test Procedures for Airborne Equipment**

**Section 20**

**Radio Frequency Susceptibility (Radiated and Conducted)**

**Important Notice**

Information contained in these sections is pertinent to all test procedures described in the other sections of this document. Further, Appendix A is applicable for identifying environmental tests performed.

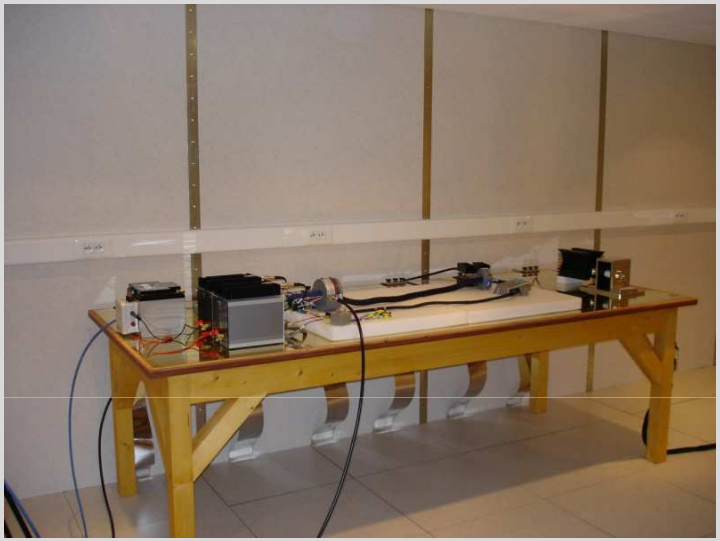
Date of Issue:
December 8, 2010

Supersedes: RTCA/DO-160F
Prepared by: SC-135

# RTCA DO 160 - Requirements

RTCA DO160 G (2010)

Conducted Susceptibility



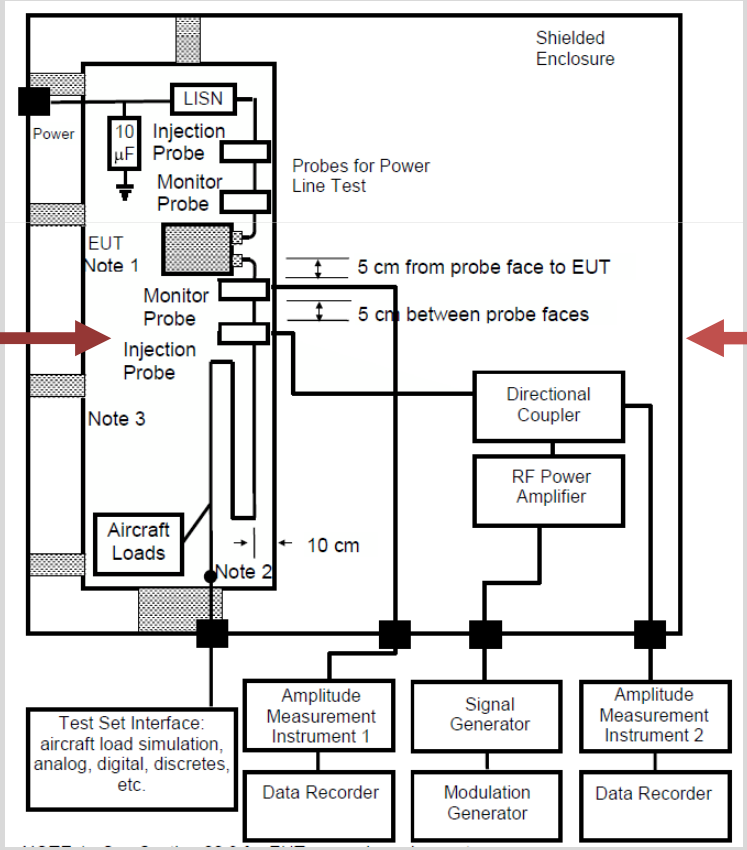
→ Requires a shielded enclosure and test plane

→ Current injected on bundle cables by Injection Probes (10 kHz – 400 MHz)

# RTCA DO 160 - Requirements

## Conducted Susceptibility Test Setup

Test bench with conductive surface (S ≥ 2.5 m²) bonded to the shielded enclosure




A shielded room or an anechoic chamber

# RTCA DO 160 - Requirements

## Radiated Susceptibility : 100 MHz – 18 (40) GHz

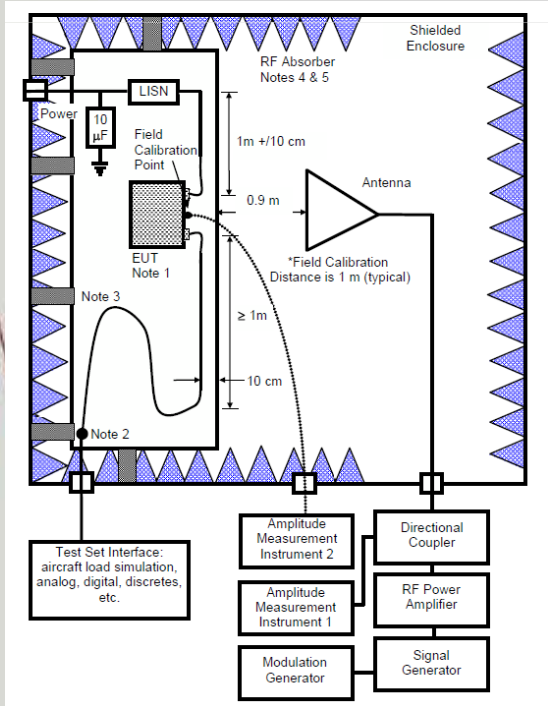
Section 20.5

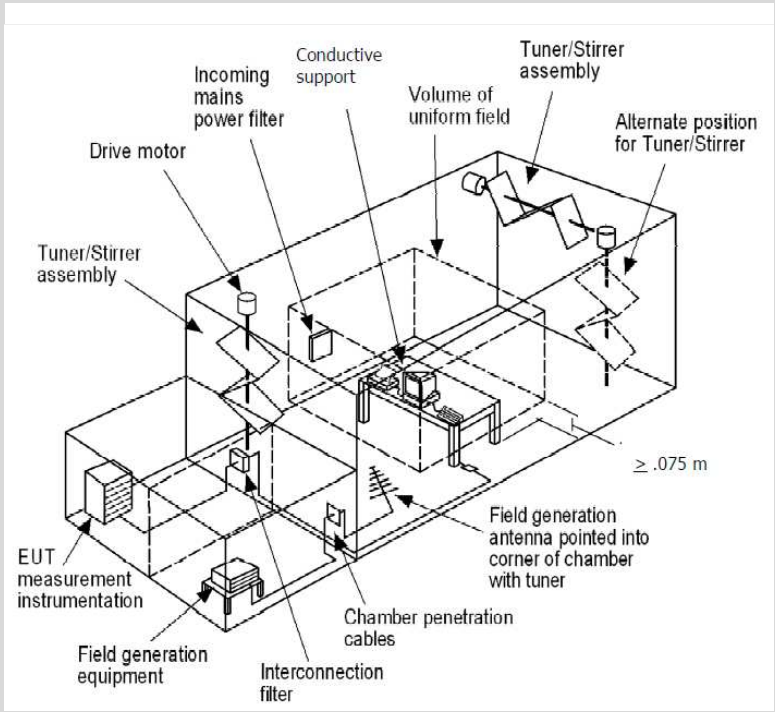
Tests in an anechoic chamber (AC)

And / Or

Section 20.6

Tests in a mode-stirred reverberation chamber (MSRC)



# RTCA DO 160 - Requirements

## Radiated Susceptibility : 100 MHz – 18 (40) GHz

CW tests
up to 490 V/m

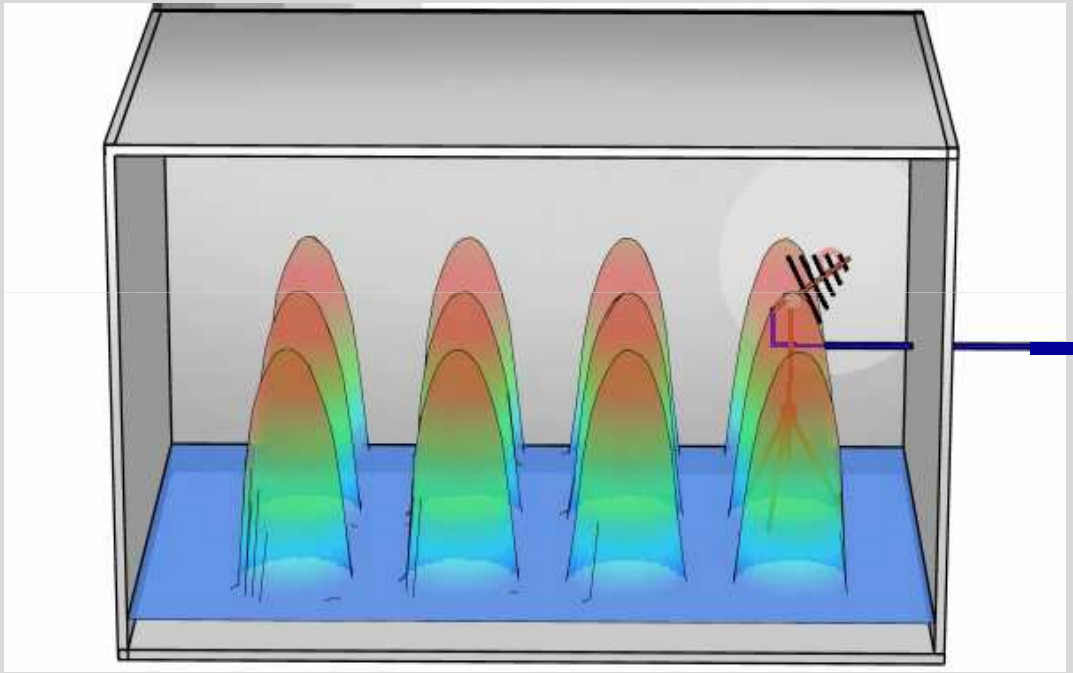
Pulse Modulated Tests
Up to 7,200 V/m

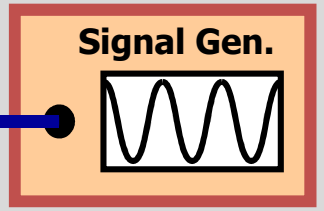
| Environment | Cat B (V/m) | | Cat D (V/m) | | Cat F (V/m) | | Cat G (V/m) | | Cat L (V/m) | | Cat R (V/m) | | Cat S (V/m) | Cat T (V/m) | Cat W (V/m) | Cat Y (V/m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Frequency | | PM | | PM | SW/ CW | PM | SW/ CW | PM | | PM | SW/ CW | PM | SW/ CW | SW/ CW | SW/ CW | SW/ CW |
| 100-200 MHz | 20 | | 25 | | 50 | | 100 | | 200 | | 20 | | 1 | 5 | 100 | 200 |
| 200-400 MHz | 20 | | 25 | | 50 | | 100 | | 200 | | 20 | | 1 | 5 | 100 | 200 |
| 400-700 MHz | 20 | 150 | 20 | 175 | 25 | 350 | 50 | 700 | 200 | 730 | | 150 | 1 | 5 | 100 | 200 |
| 700 MHz-1 GHz | 20 | 150 | 25 | 175 | 50 | 350 | 100 | 700 | 240 | 1400 | | 150 | 1 | 5 | 100 | 200 |
| 1-2 GHz | 25 | 250 | 50 | 500 | 100 | 1000 | 200 | 2000 | 250 | 5000 | | 150 | 1 | 5 | 100 | 200 |
| 2-4 GHz | 25 | 375 | 50 | 750 | 100 | 1500 | 200 | 3000 | 490 | 6000 | | 150 | | 5 | 100 | 200 |
| 4-6 GHz | 25 | 375 | 50 | 750 | 100 | 1500 | 200 | 3000 | 400 | 7200 | | 150 | | 5 | 100 | 200 |
| 6-8 GHz | 25 | 150 | 50 | 250 | 100 | 500 | 200 | 1000 | 200 | 1100 | | 150 | | 5 | 100 | 200 |
| 8-12 GHz | 38 | 375 | 75 | 750 | 150 | 1500 | 300 | 3000 | 330 | 5000 | | | | | 100 | 200 |
| 12-18 GHz | 25 | 250 | 50 | 500 | 100 | 1000 | 200 | 2000 | 330 | 2000 | | | | | 100 | 200 |

# 2. Reverb Chambers Key Points

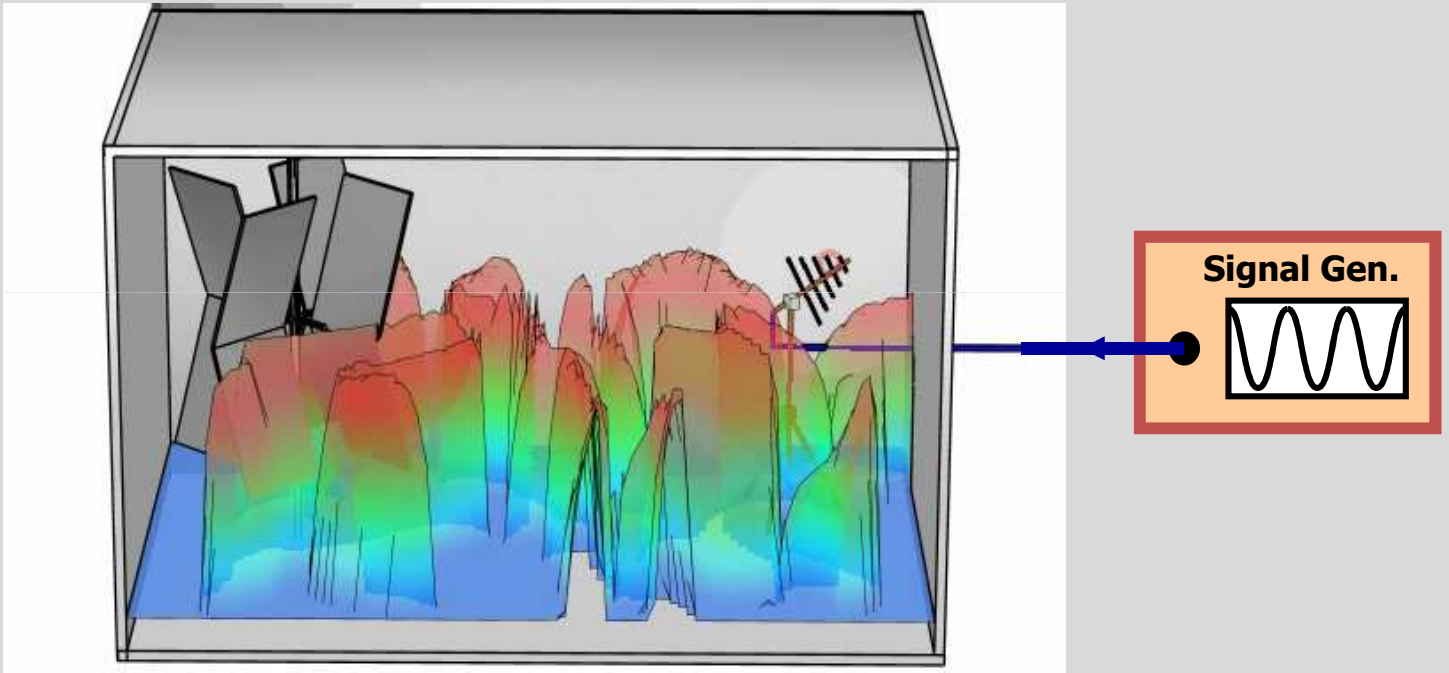
# How does it work ?

**A mechanical mode stirrer modifies field configuration in a cavity**





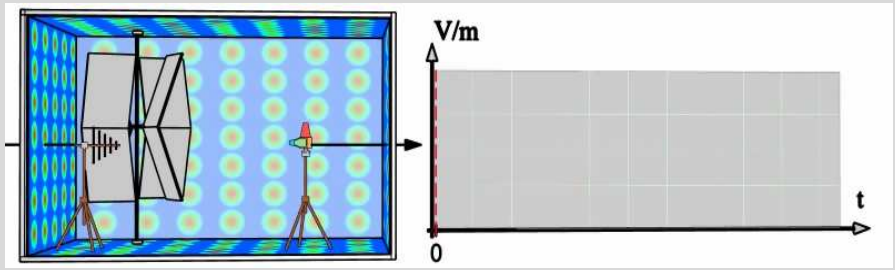
# How does it work ?




Field configuration

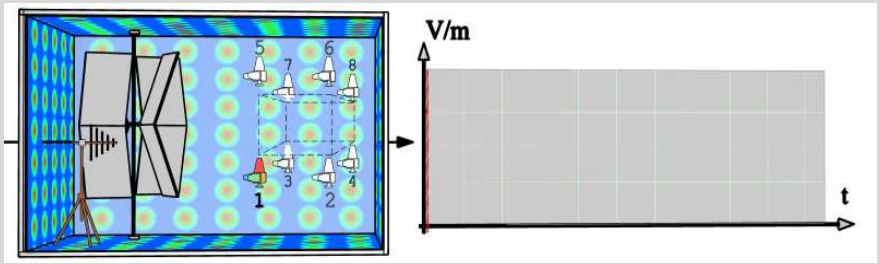
# Statistical uniformity

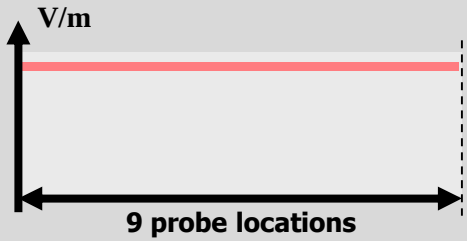
Maximum field level (X, Y, Z, Total) on one rotation (fixed frequency)





Maximum field level (X, Y, Z, Total) on 9 probe locations




The field is statistically **homogeneous** and **isotropic** within the working volume averaged over one complete rotation, from LUF

# How does it work ?

**Calibration of the Reverb Chb provides 2 main characteristics**

**Satistical uniformity**

Deviation on the maximum field of each field component ($E_X$, $E_Y$, $E_Z$) and total field ($E_T$), on each of the 9 probe locations must be below the allowed standard deviation limit of DO 160

Determines Lowest frequency of Use Of the MSRC

**Normalized E Field**

Field which is obtained for 1 W power delivered on the input connector of the Tx antenna

Determines the power level to be provided to reach the target E-fields

# How does it work ?

**Design key point of the Reverberation Chamber**

**Smaller Reverb Chb**

LUF will be higher

Normalized E-Field will be higher

**Larger Reverb. Chb**

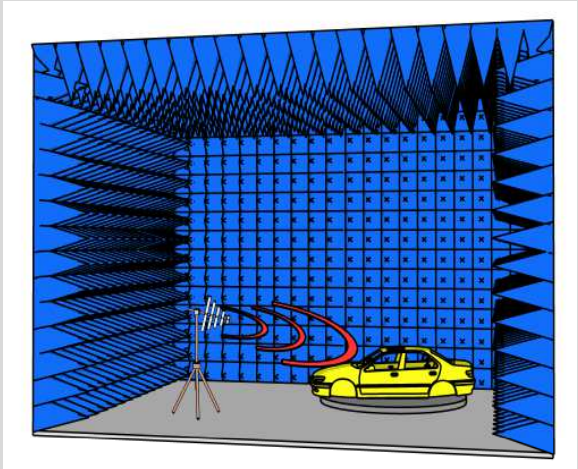
LUF lower (100 MHz)

Normalized E-field will be lower

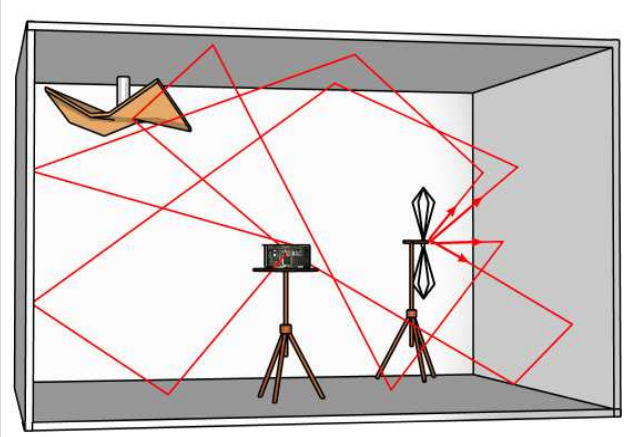
**Trade-off to determine the suitable solution to perform RS tests**

# 3. Comparison of test methods

# Anechoic Ch. *Vs* MSRC

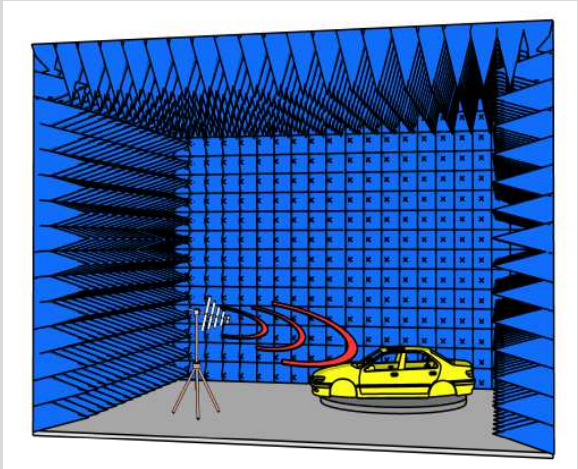


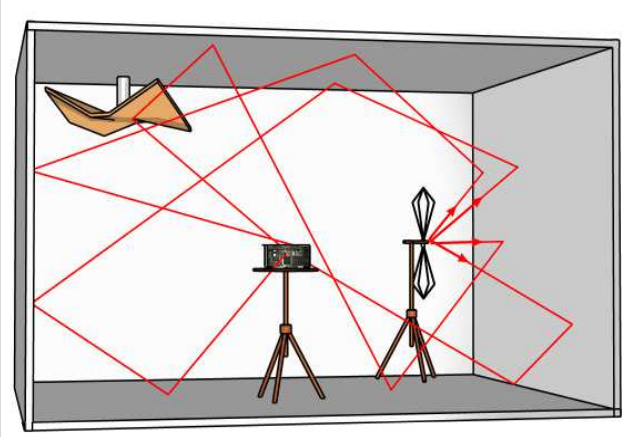
- Free Space environment
- Test distance = 1 m
- Propagated waves, absorbed by the walls
- **Deterministic** description of the fields
- **Anisotropic** tests



- Reverberating environment
- No specific test distance
- Reflections on the walls
- **Random** description of the fields
- **Isotropic** tests

# Anechoic Ch. *Vs* MSRC





- DO 160 G section 20 : both can be used for Radiated and Conducted Susceptibility
- DO 160 G section 21 : both can be used for Radiated and Conducted Emissions
- What are the criterion of choice ?

# Anechoic Ch. *Vs* MSRC

**Anechoic chamber (AC)**

Conducted tests possible on a test bench (shielded room)

Radiated tests possible with RF absorbers on the walls

Compliance of the chamber :

→ Reflectivity level of the absorbers ≤ -6 dB (100 MHz<f < 250 MHz)

→ Reflectivity level of the absorbers ≤ -10 dB (f > 250 MHz)

→ 660 mm high absorbers typically

Radiated tests done on a plane → The EUT must be rotated

Field strength related to test distance (1m)

→ One single AC can be used for all CS & RS tests

# Anechoic Ch. *Vs* MSRC

**Reverb chamber (MSRC)**

Conducted tests possible on a test bench (shielded room)

Radiated tests without absorbers on the walls

Compliance of the chamber :

→ Lowest Frequency of Use (LUF)

→ Normalized Field high enough to provide target field

Radiated tests done on a volume → The EUT needs not being rotated

Field strength related to Normalized Field (dependent on MSRC size)

→ Multiple MSRC can be used for all CS & RS tests (optimization)

# Anechoic Ch. *Vs* MSRC

**Power levels needed to reach target field**

| Target Field (V/m) | Anechoic Chamber @ 1m | Reverb Chamber @ 3dB load |
|---|---|---|
| 200 (CW @ 100 MHz) | 3 kW | ≤ 150 W |
| 300 (CW @ 8 GHz) | 1.5 kW | ≤ 20 W |
| 490 (CW @ 2 GHz) | 4 kW | ≤ 40 W |
| 7,200 (PM @ 4 GHz) | 900 kW | ≤ 5 kW |

Technical difficulties & Budget increase

# 4. Solutions for complete CS/RS tests

# Technical solutions

## 3 main frequency ranges

100 – 400 MHz
CW tests only
Levels ≤ 200 V/m

0.4 – 1 GHz
CW & PM Tests
Up to 1,400 V/m
LPDA Antenna

1 – 18 GHz
CW & PM Tests
Up to 7,200 V/m
Horn Antenna

| Environment | Cat B (V/m) | | Cat D (V/m) | | Cat F (V/m) | | Cat G (V/m) | | Cat L (V/m) | | Cat R (V/m) | | Cat S (V/m) | Cat T (V/m) | Cat W (V/m) | Cat Y (V/m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Frequency | | PM | | PM | SW/ CW | PM | SW/ CW | PM | | PM | SW/ CW | PM | SW/ CW | SW/ CW | SW/ CW | SW/ CW |
| 100-200 MHz | 20 | | 25 | | 50 | | 100 | | 200 | | 20 | | 1 | 5 | 100 | 200 |
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| 400-700 MHz | 20 | 150 | 20 | 175 | 25 | 350 | 50 | 700 | 200 | 730 | | 150 | 1 | 5 | 100 | 200 |
| 700 MHz-1 GHz | 20 | 150 | 25 | 175 | 50 | 350 | 100 | 700 | 240 | 1400 | | 150 | 1 | 5 | 100 | 200 |
| 1-2 GHz | 25 | 250 | 50 | 500 | 100 | 1000 | 200 | 2000 | 250 | 5000 | | 150 | 1 | 5 | 100 | 200 |
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| 12-18 GHz | 25 | 250 | 50 | 500 | 100 | 1000 | 200 | 2000 | 330 | 2000 | | | | | 100 | 200 |

# Technical solutions

## 3 main frequency ranges

**100 to 400 MHz**

CW field levels allow to use an Anechoic Chamber or a Reverb Chamber with available instrumentation

**400 to 1,000 MHz**

CW field levels allow to use an Anechoic Chamber or a Reverb Chamber with available instrumentation

Cat L PM field levels make the use of an Anechoic Chamber costly

**1 to 18 GHz**

CW field levels allow to use an Anechoic Chamber or a Reverb Chamber with available instrumentation

Cat L PM field levels make the use of an Anechoic Chamber unrealistic

# Technical solutions

**It is possible to use several combinations for RS testing :**

1 Anechoic Chb (100 MHz to 400 MHz) + 1 Reverb. Chb (400 MHz – 18 GHz)

→ Realistic for an existing laboratory with AC

→ Possible with affordable instrumentation if cat. G & L not required

1 Anechoic Chb (100 MHz to 400 MHz) + 2 Reverb Chb ([400 MHz ; 1 GHz] & [1 ; 18 GHz])

→ Realistic for a laboratory with existing AC

→ Allows to consider cat. L testing at optimized budget

# Technical solutions

**It is possible to use several combinations for RS testing :**

1 Reverb.Chamber (100 MHz – 18 GHz)

→ Possible but difficult for PM tests > 1 GHz (cat. F/G/L)

3 Reverb. Chambre ([100 ; 400 MHz] & [400 MHz ; 1 GHz] & [1 ; 18 GHz])

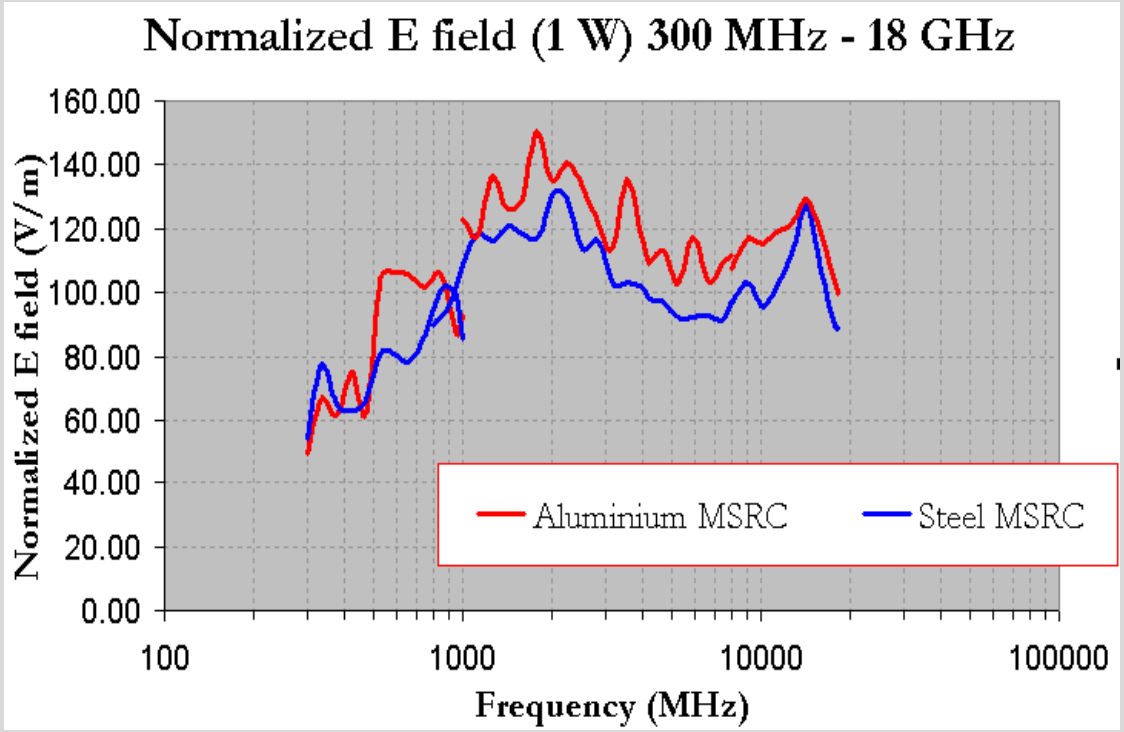
→ Optimized solution for a new laboratory

→ Optimal power amplifier budget

# Microwave & RF 2016

## 5. Siepel EOLE series

# Unique - high conductivity panels




- Comparison between 2 identical MSRC
- 20% more field with aluminum
- Input power reduced by 2 dB

# EOLE 100

- Frequency range of operation : 100 MHz to 18 (40) GHz

- Specifications (typ.)

→ Dimensions 7.5 x 5 x 4 m

→ Test volume 3 x 2.3 x 1.7 m

→ Minimum field strength @ 400 MHz & 1W : 30 V/m

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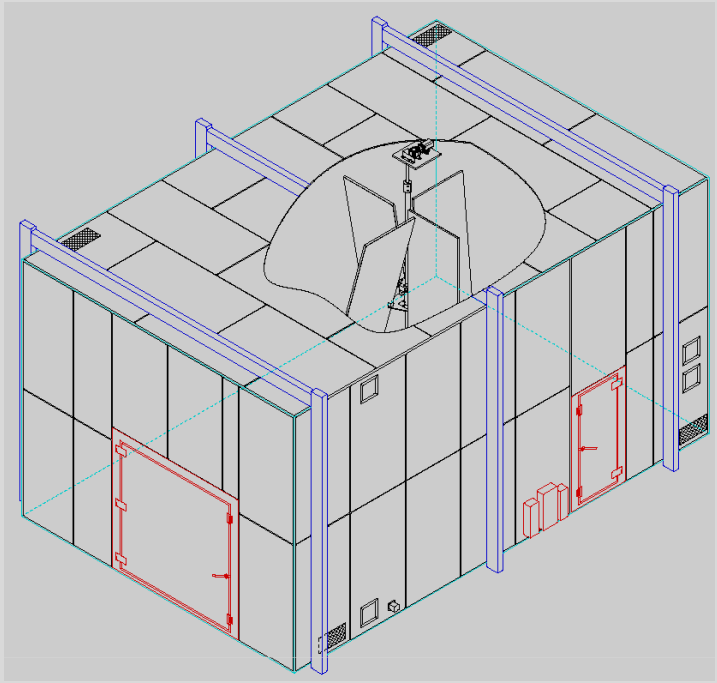
Michael Faraday's Heritage

# EOLE 100



# EOLE 400

- Frequency range of operation : 400 MHz to 18 (40) GHz

- Specifications (typ.)

→ Dimensions 3.45 x 2.52 x 2.94 m

→ Test volume 2.66 x 1.25 x 1.36 m

→ Minimum field strength @ 1 GHz & 1W : 85 V/m

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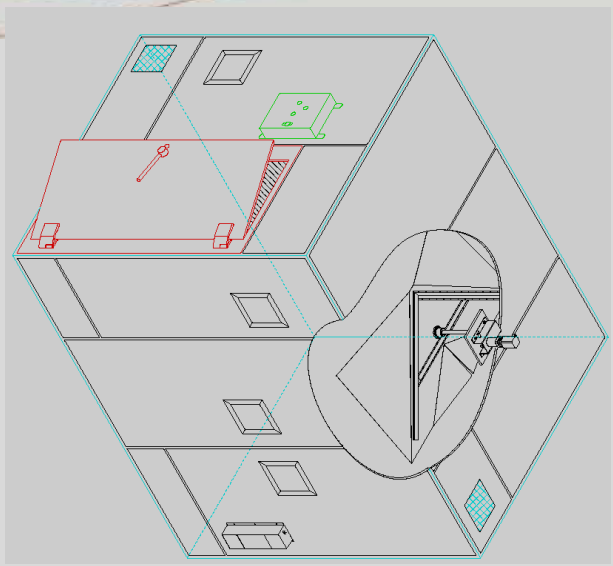

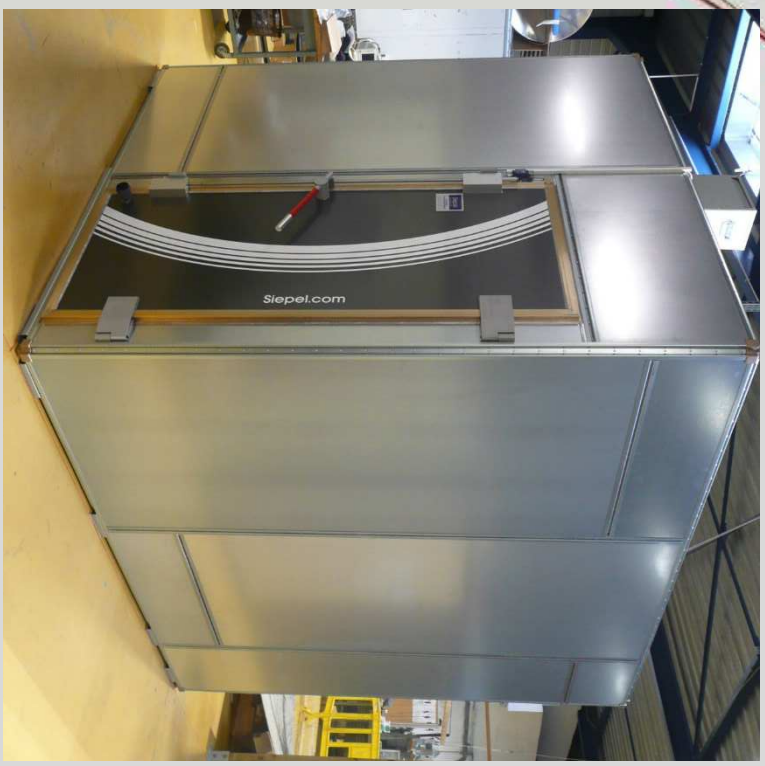


# EOLE 400

# EOLE 1000

- Frequency range of operation : 1 GHz to 18 (40) GHz

- Specifications (typ.)

→ Dimensions 1.02 x 0.86 x 1.28 m

→ Test volume 0.72 x 0.56 x 0.4 m

→ Minimum field strength @ 1 GHz & 1W : 170 V/m

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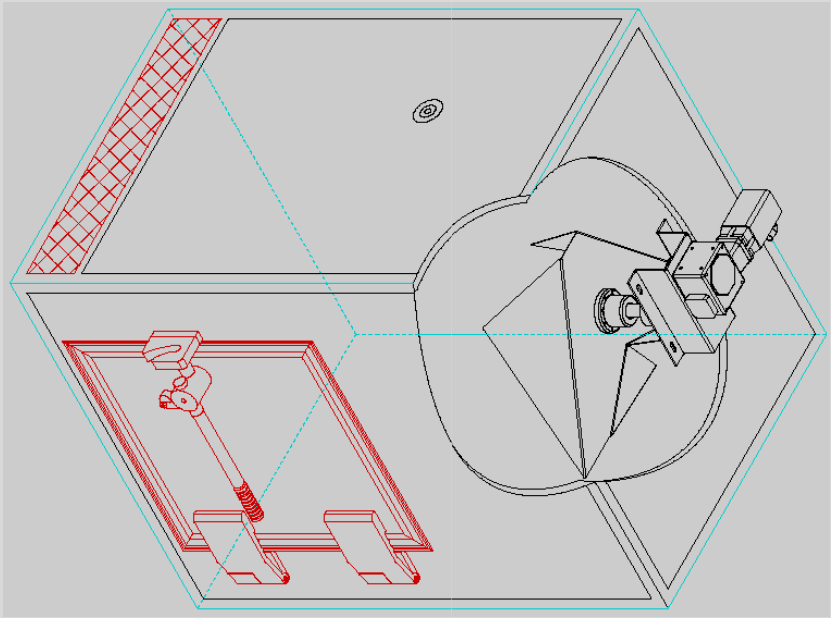
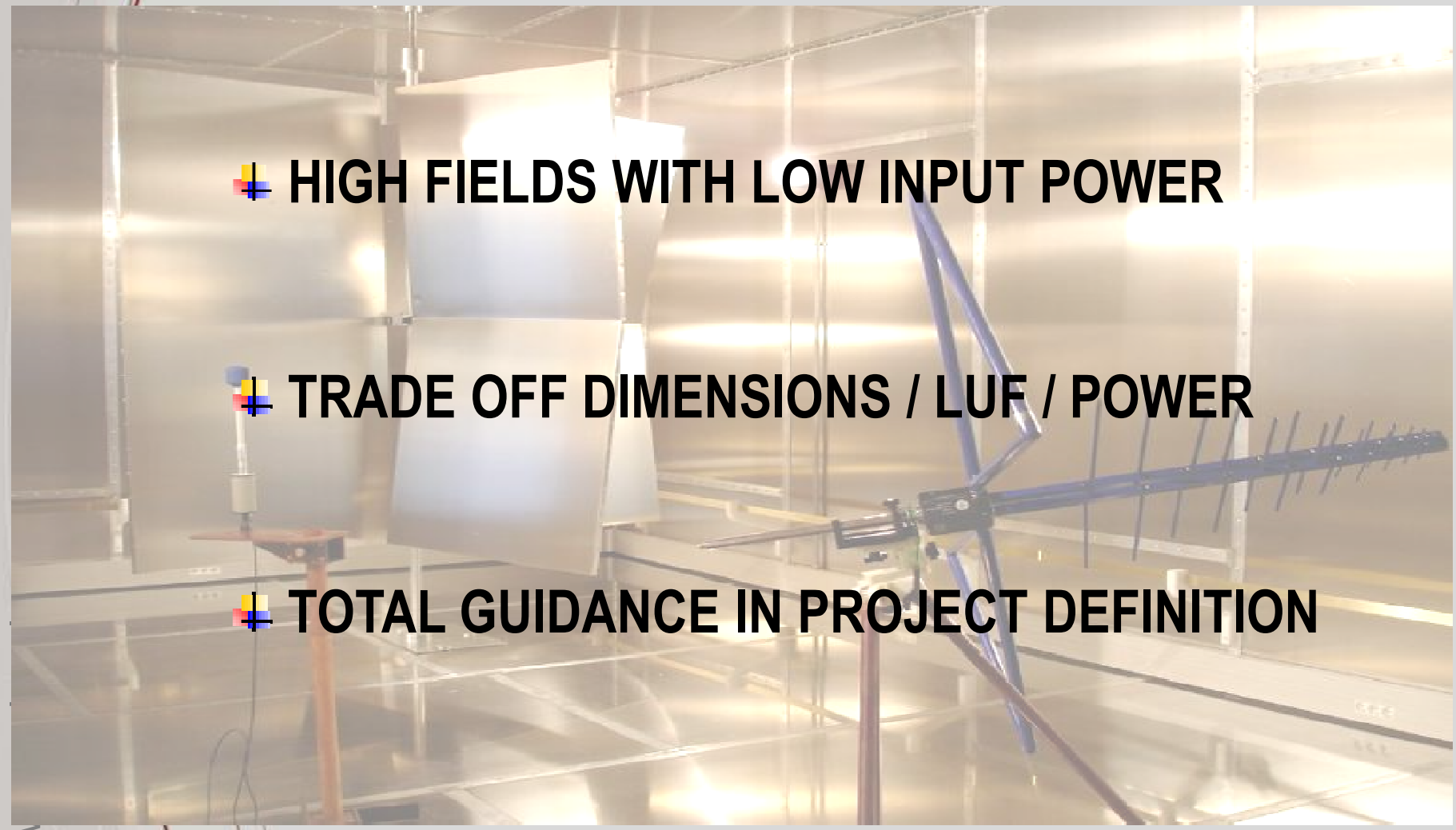


EOLE 1000

# 6. Conclusion

# DO160 - Advantages of MSRC



- HIGH FIELDS WITH LOW INPUT POWER
- TRADE OFF DIMENSIONS / LUF / POWER
- TOTAL GUIDANCE IN PROJECT DEFINITION

# DO160 - Advantages of MSRC

- **TURNKEY CAPABILITIES**
- **SINGLE RESPONSIBILITY**
- **FLEXIBLE AND UPGRADEABLE**

# Questions ?

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or

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