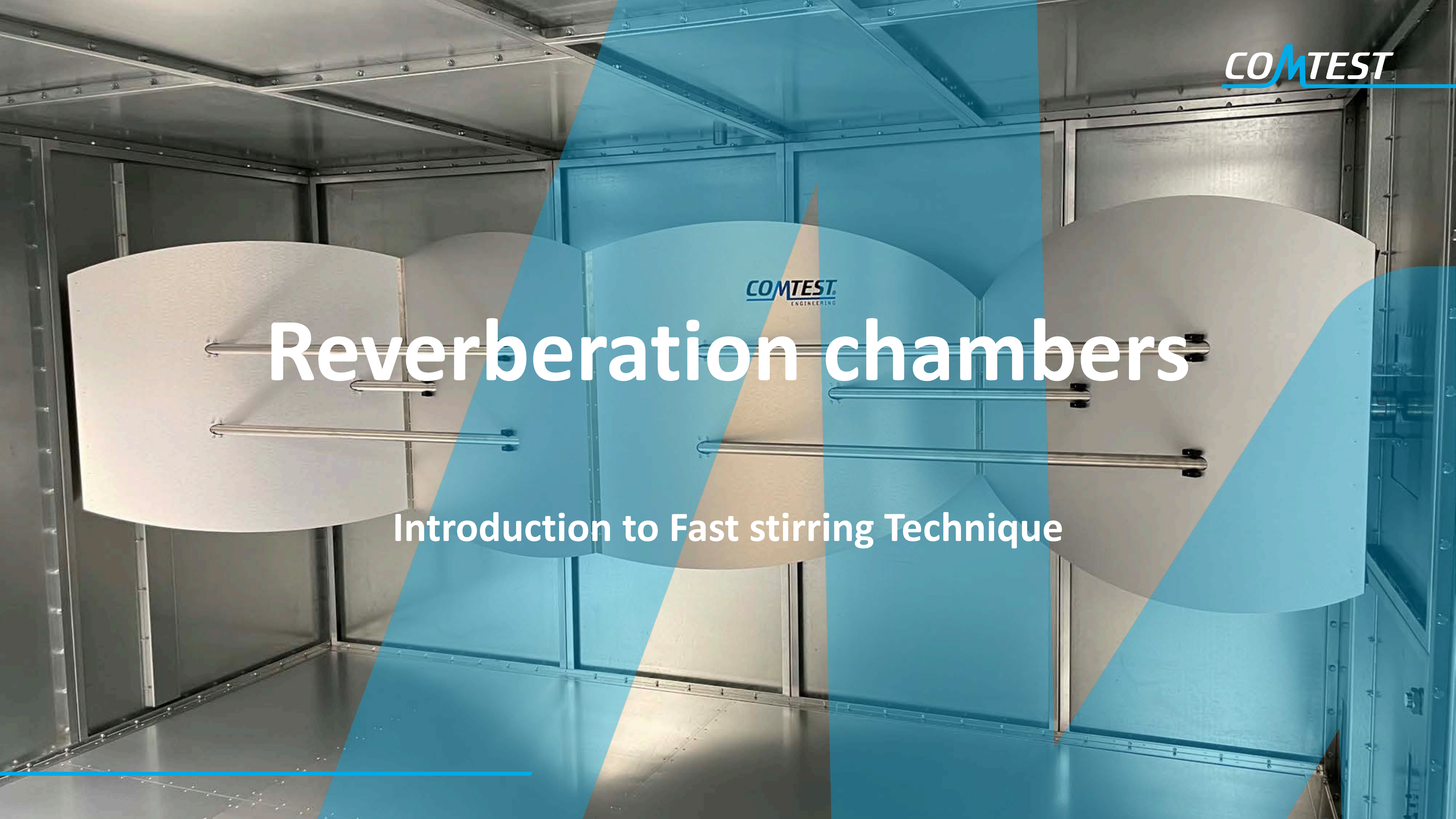


# Reverberation chambers

## Introduction to Fast stirring Technique

# Electronics need RC testing

# Agenda

- RC operating principle & advantages
- Overview of ISO 11451-5
  - Proposed test methods
  - Focus on fast stirring method
- Chamber design for fast stirring

  (based on experimental data)
- Take out

# Reverberation Chambers

Operating Principle

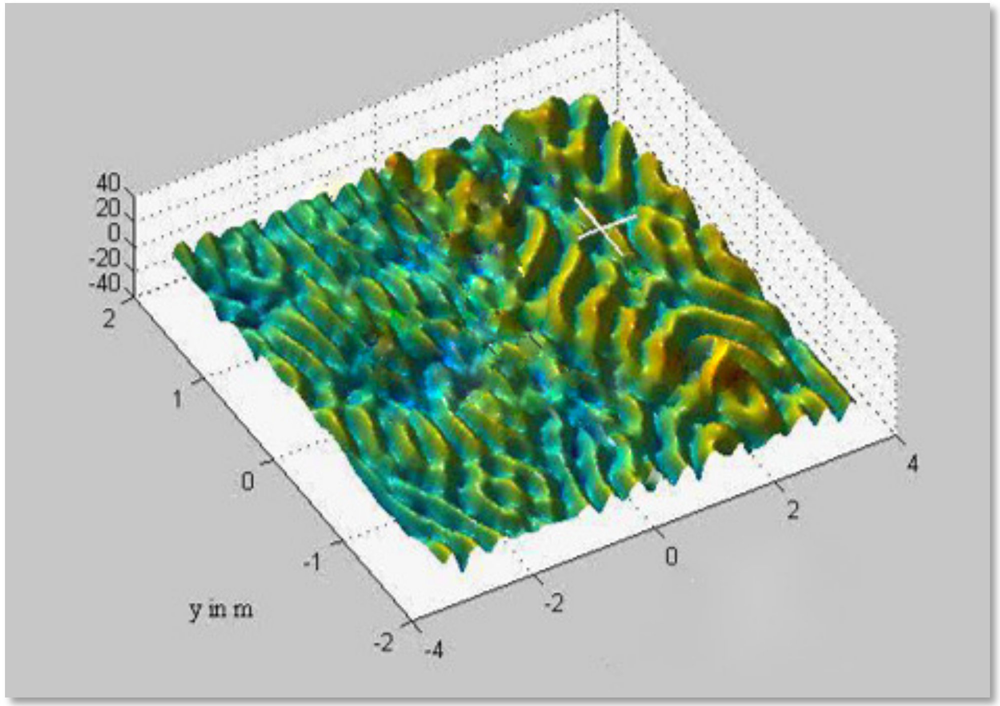
COMTEST

# RC Operating Principle

1. Electromagnetic resonance

2. Mode-stirring

# RC Operating Principle




Field inside a cavity

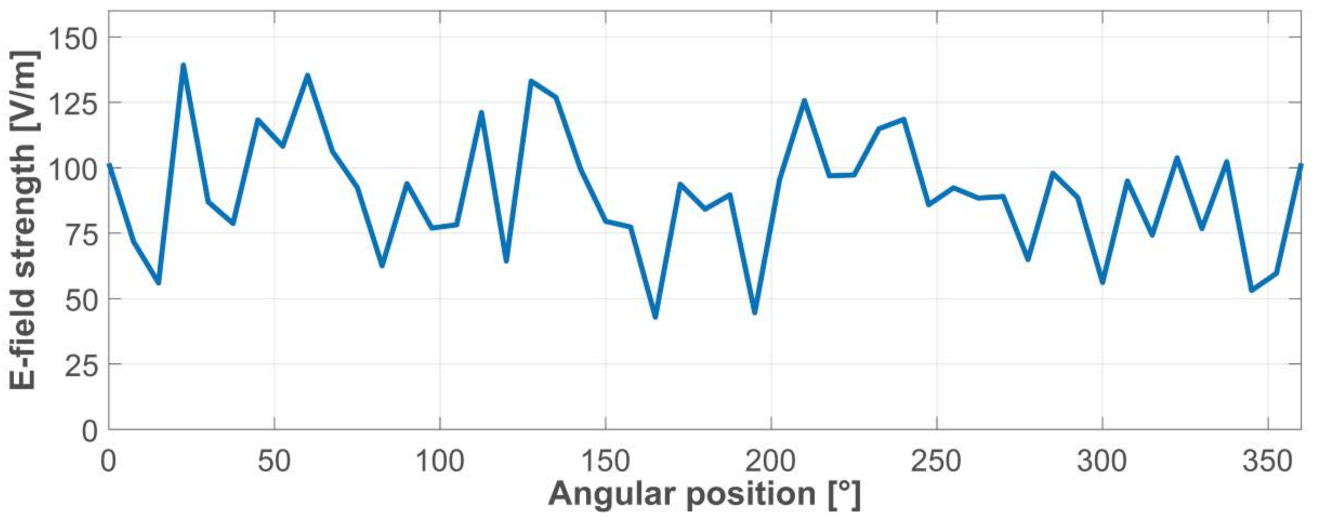
Average Field inside a Reverberation chamber for a stirrer revolution

COMTEST

# RC Operating Principle

Electric field strength [V/m], Freq = 2 GHz

**Position 1**
x = 0.4 m
y = 0.4 m
z = 0.4 m




Max: **139.2** V/m

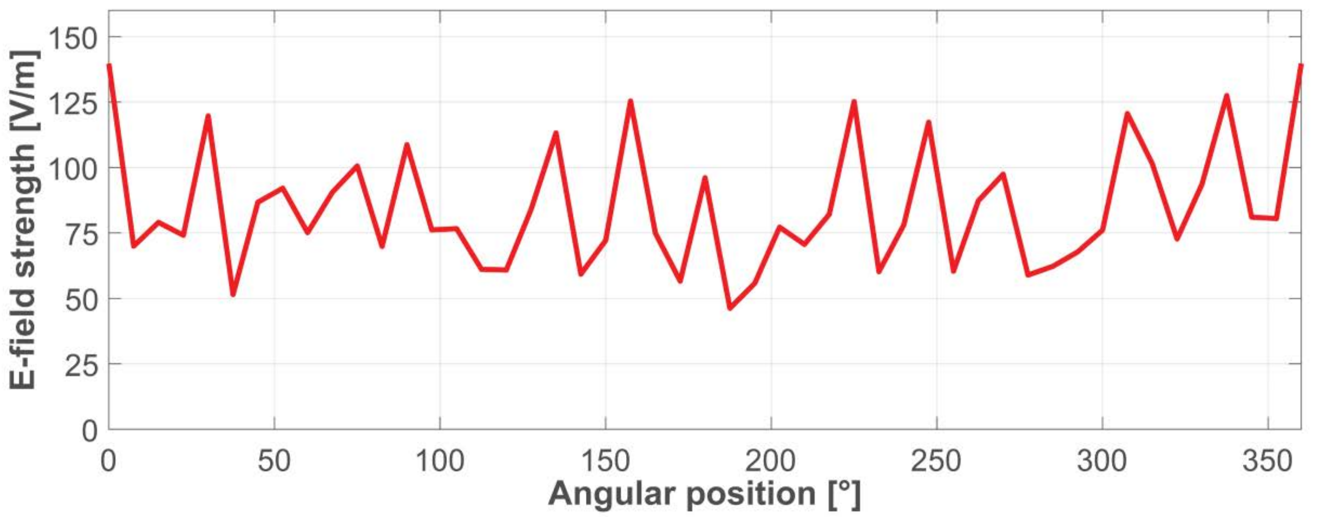
Min: **42.9** V/m

Average: **90.4** V/m

Max to Min: **96.3** V/m

SD: **23.3** V/m

**Position 2**
x = 1.2 m
y = 1.2 m
z = 1.6 m




Max: **139.7** V/m

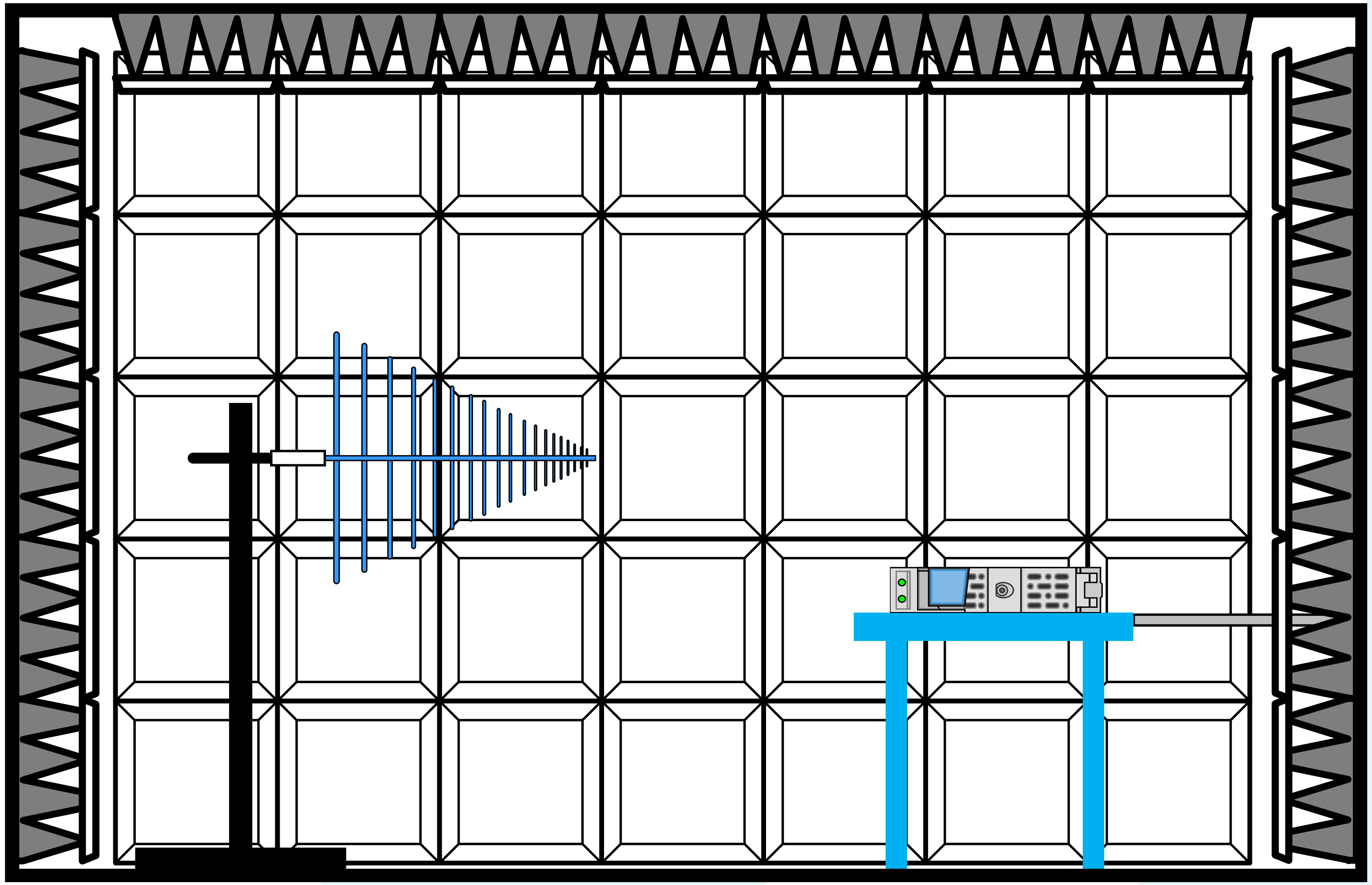
Min: **46.2** V/m

Average: **83.6** V/m

Max to Min: **93.5** V/m

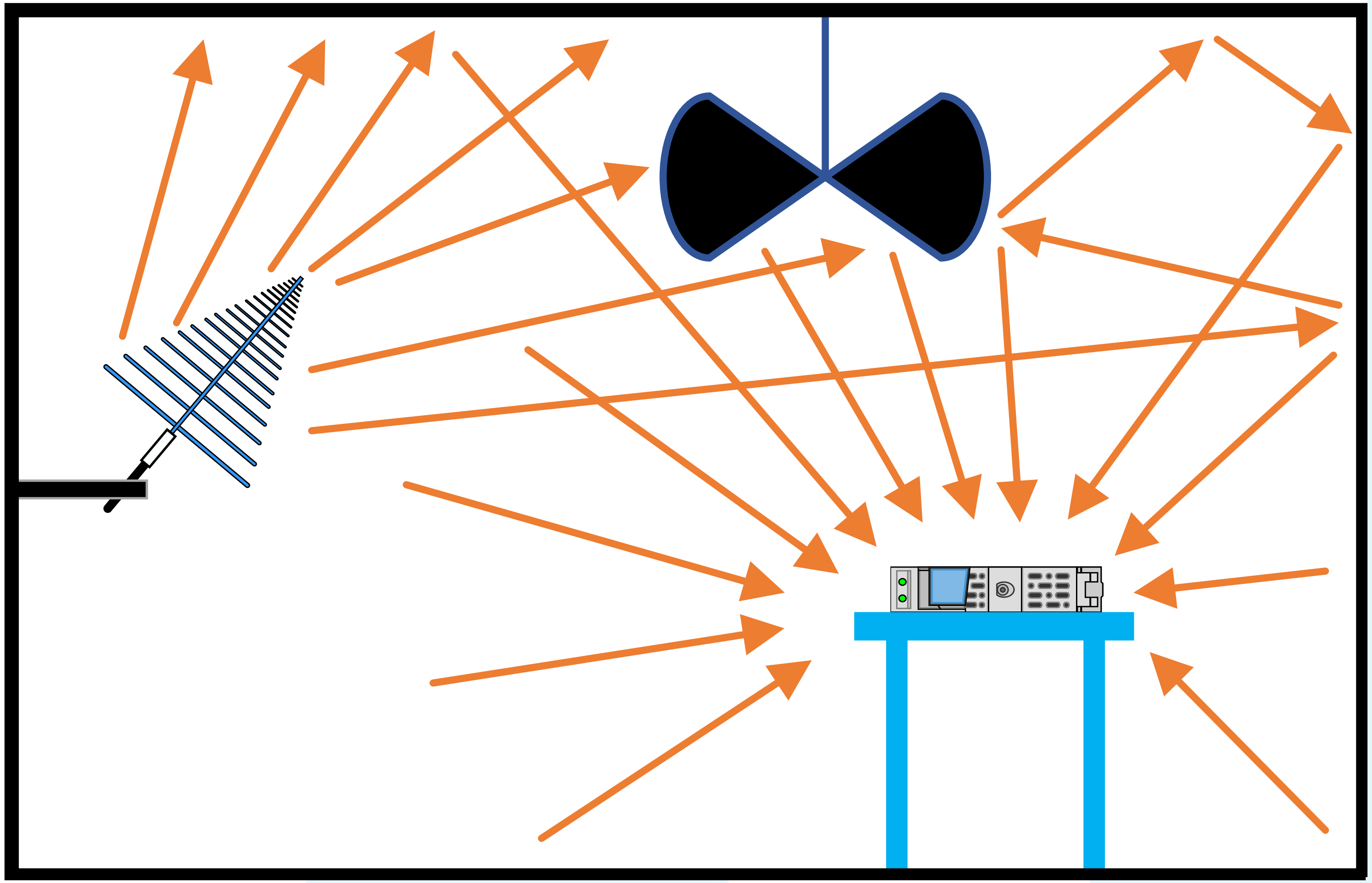
SD: **22.5** V/m

# Anechoic radiated immunity testing



Direct Wave illumination

# RC radiated immunity testing



Problems cannot be hidden in RC

# RC advantages

- Statistical field uniformity
- High field strength
- High reproducibility and repeatability
- Test heavy and large EUTs
- Better representation of real-life environments

# ISO 11451-5

Full vehicle testing

COMTEST

# ISO 11451-5

- **Radiated immunity of passenger cars**
  - Spark ignition engine
  - Hybrid
  - Fully electric
- **Numerous test methods**
- **Wide frequency range: 10kHz – 18GHz**
  - TLS method: 10 kHz to LUF
  - Cavity mode method: 30 MHz to LUF
  - Reverb methods: LUF to 18 GHz

COMTEST

# Test methods

| Test method | Frequency range | Stirring |
| --- | --- | --- |
| **Reverb method with substitution method power control + Loading factor method** | LUF to 18 GHz | Mode tuned & mode stirred |
| **Reverb method with substitution method power control + Field calibration with the vehicle present** | LUF to 18 GHz | Mode tuned & mode stirred |
| **TLS method** | 10 kHz to LUF | Mode stirred |
| **Cavity mode method** | 30 MHz to LUF | Mode tuned & mode stirred |
| **Reverb method with closed-loop power control (fast stirring)** | LUF to 18 GHz | Mode stirred |
| **Reverb method with substitution method power control + Chamber time constant method** | LUF to 18 GHz | Mode tuned & mode stirred |
| **VNA method** | LUF to 18 GHz | Mode tuned & mode stirred |

COMTEST

# Fast stirring method advantages

**Reverb method with substitution method power control + Loading factor method**

The method is performed in four phases:

— field calibration of the empty chamber (see 8.5.2.1);

— determination of the maximum loading factor (see 8.5.2.2);

— determination of the chamber loading factor (see 8.5.2.3);

— vehicle test (see 8.5.2.4).

**Minimum test time for every frequency = dwell time * stirrer steps**

**Reverb method with closed-loop power control (fast stirring method)**

This method is performed in a single phase:

— test of the vehicle.

**Minimum test time for every frequency = dwell time**

COMTEST

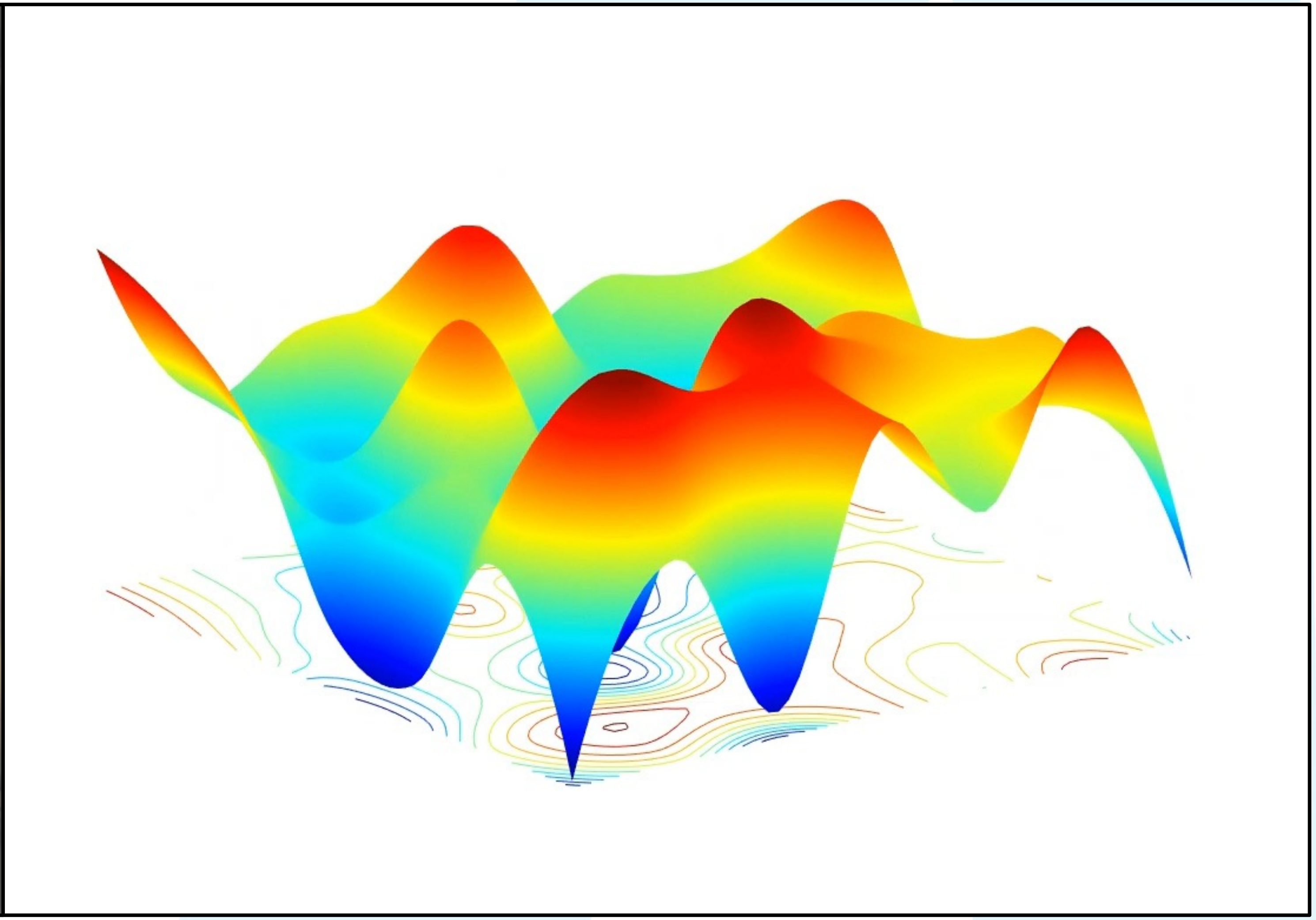
# Fast stirring method

## Reverb method with closed-loop power control, a.k.a. Fast stirring method (Annex G)

- **Benefits:**
    - No Field uniformity calibration of the RC is required
    - No need for determining the EUT loading is required
    - **Reduces significantly testing time**
- **Requirements**
    - Deep understanding of reverberation chamber statistics
        - **E-field test level calculation:** Fast field probe system (8x)
        - **Stirring evaluation :**Number of independent stirring configurations $(N_{ind})$

COMTEST

# $N_{ind}$



COMTEST

# $N_{ind}$ investigation

1. Define the stirring scheme

2. Measure the received power, S parameter or E-field

3. Calculate the autocorrelation

$$r(l) = \frac{\sum_{i=0}^{N-1} (p(i) - \overline{p})(p((i+l) \bmod (N)) - \overline{p})}{\sum_{i=0}^{N-1} (p(i) - \overline{p})^2}$$

COMTEST

# $N_{ind}$ investigation

4. Derive the Number of Independent Stirring Configurations (ISC)

$$r(l_{\text{ind}}) < 0{,}37\left(1 - \frac{7{,}22}{N^{0{,}64}}\right)$$

$$N_{\text{ind}} = \frac{N}{L_{\text{ind}}}$$

5. Calculate the coherence time $(t_{coh})$

$$t_{\text{coh}} = \Delta t \min(l_{ind})$$

ISO 11451-5 criterion: $N_{ind} \geq 12$

COMTEST

# Minimum dwell time

$$t = max(\{ t_{dwell,ISO11451-1};\ 12 \times t_{coh} \})$$

Example 1 : $\begin{cases} t_{dwell,ISO11451-1} = 1\ s \\ 12 \times t_{coh} = 2\ s \end{cases} \Rightarrow \boxed{t = 2\ s}$

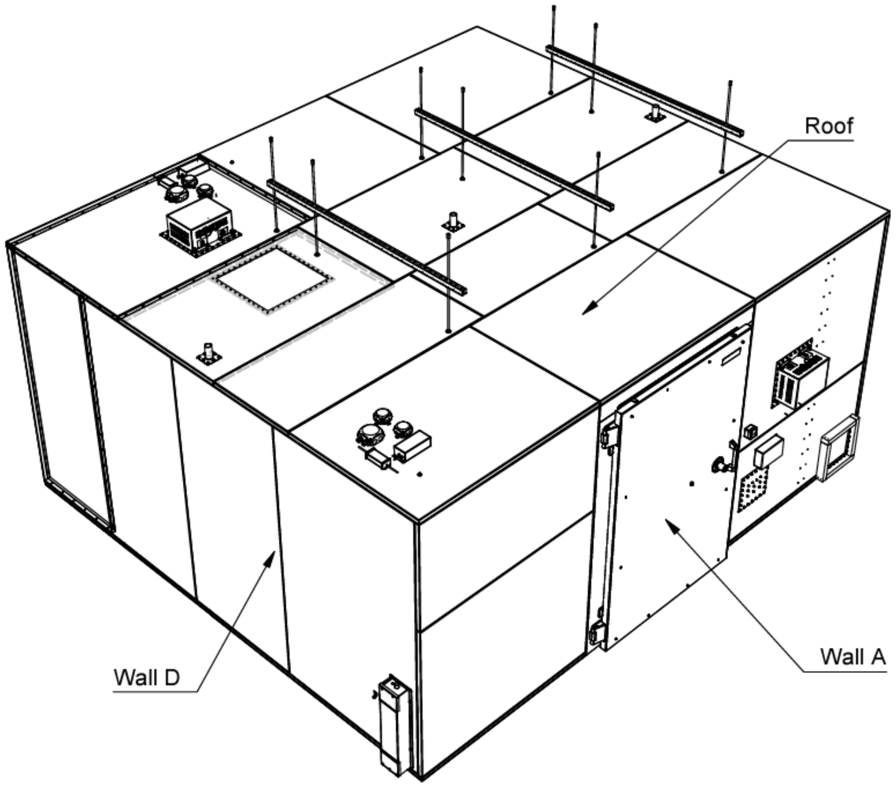
Example 2 : $\begin{cases} t_{dwell,ISO11451-1} = 1\ s \\ 12 \times t_{coh} = 0.5\ s \end{cases} \Rightarrow \boxed{t = 1\ s}$

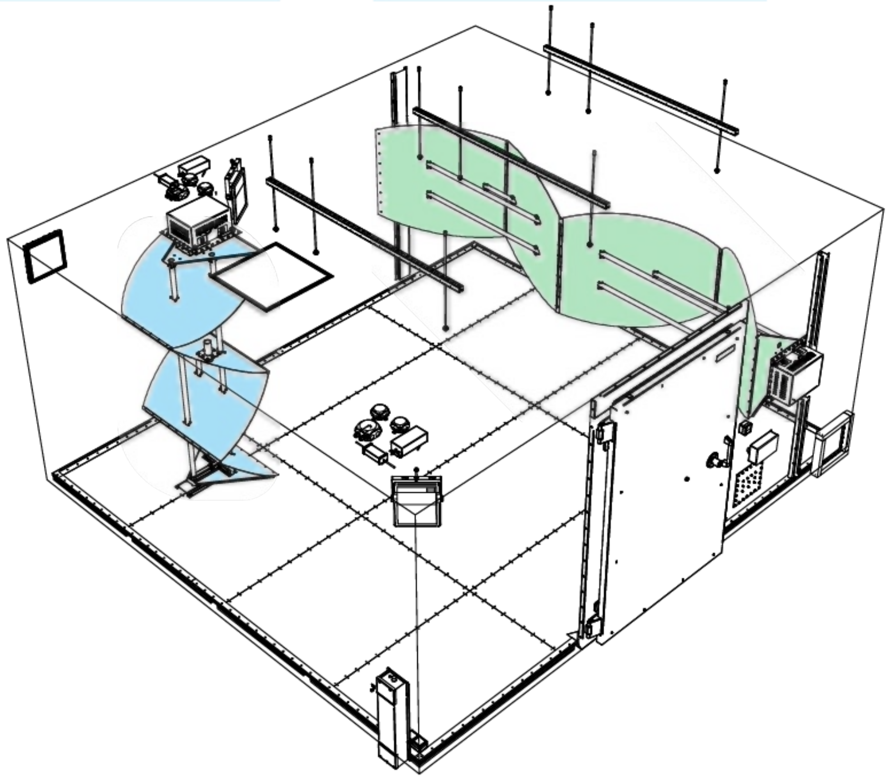
# Full Vehicle RC Concept

Fast stirring investigation

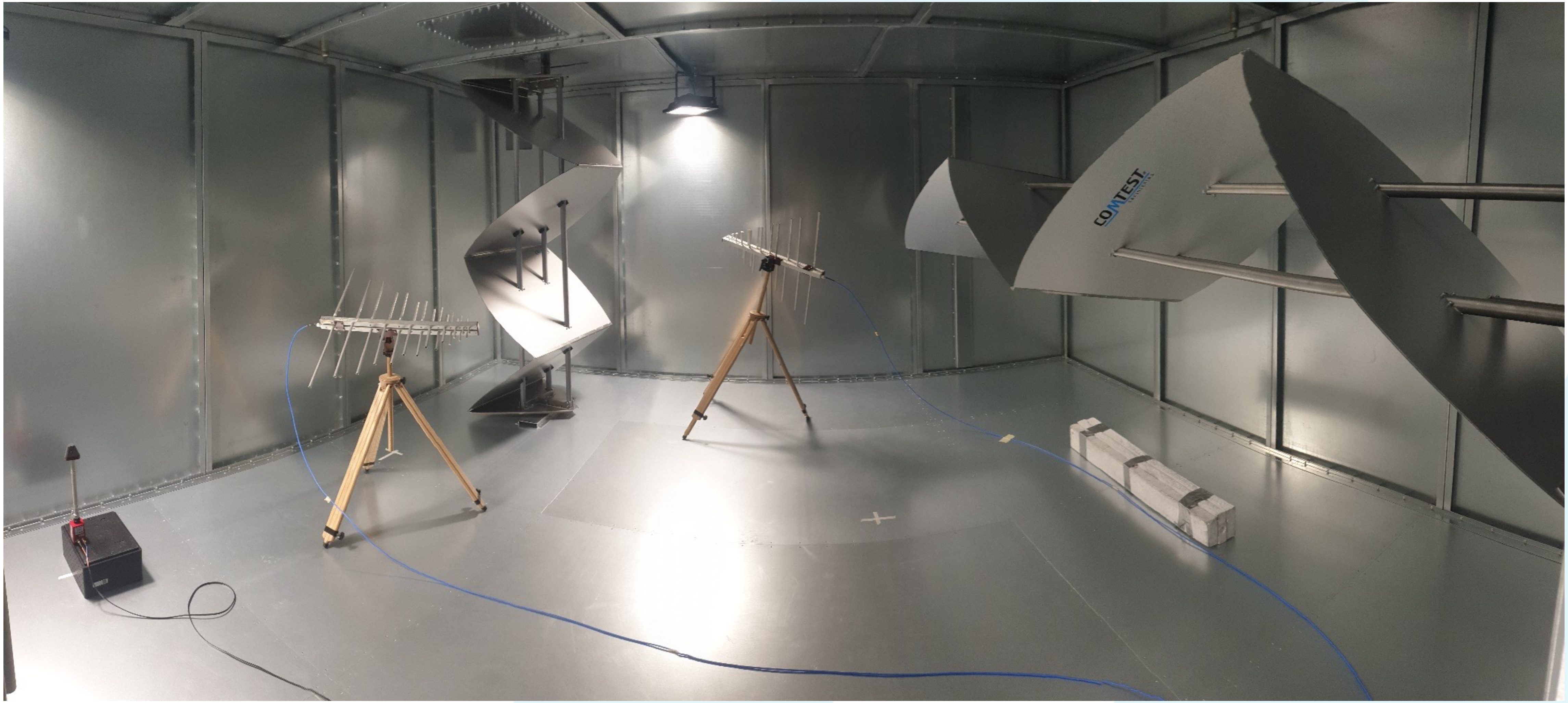
# Fast stirring investigation

**Chamber dimensions : 5.0 x 4.3 x 2.3 m (L x W x H )**



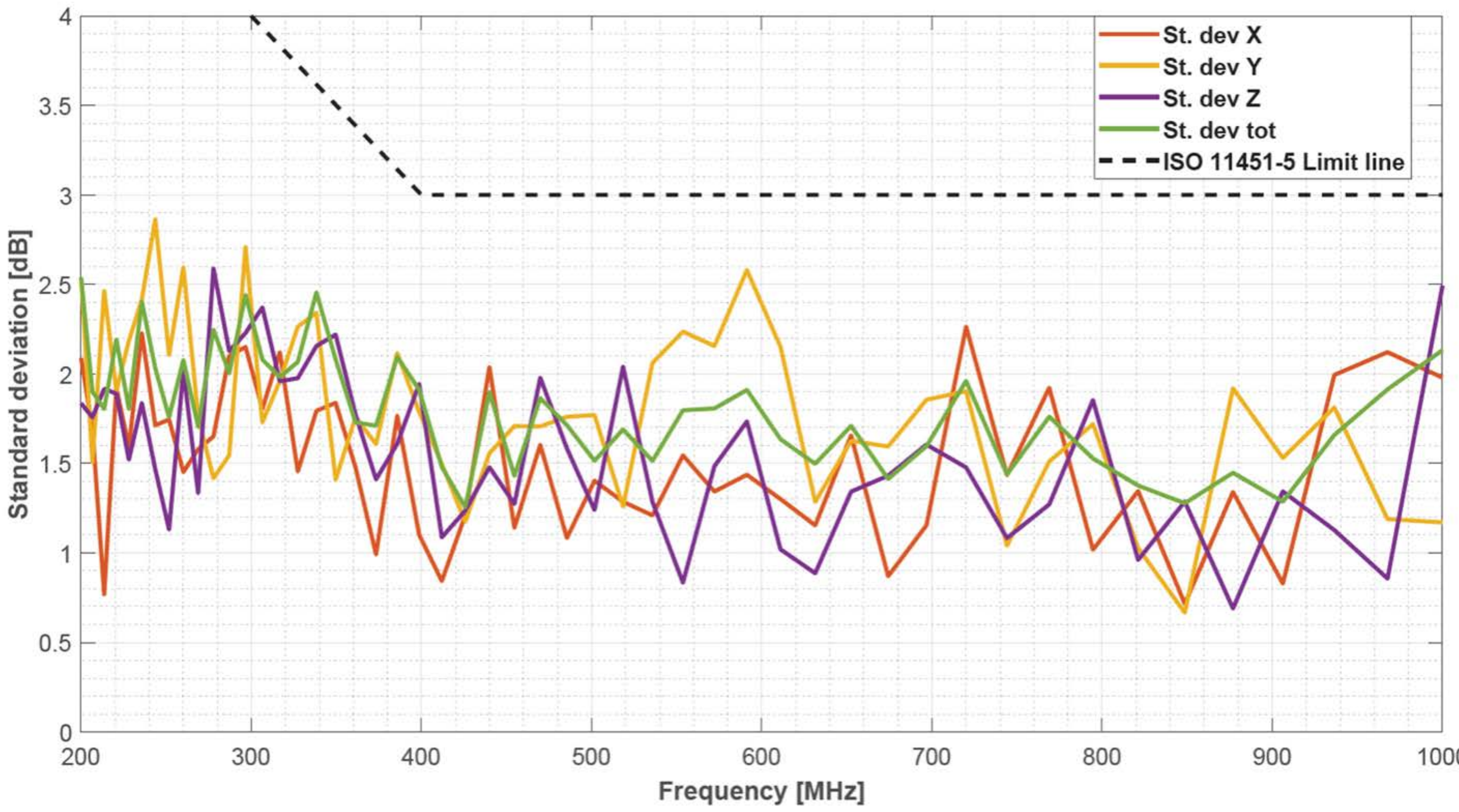



# Field Uniformity



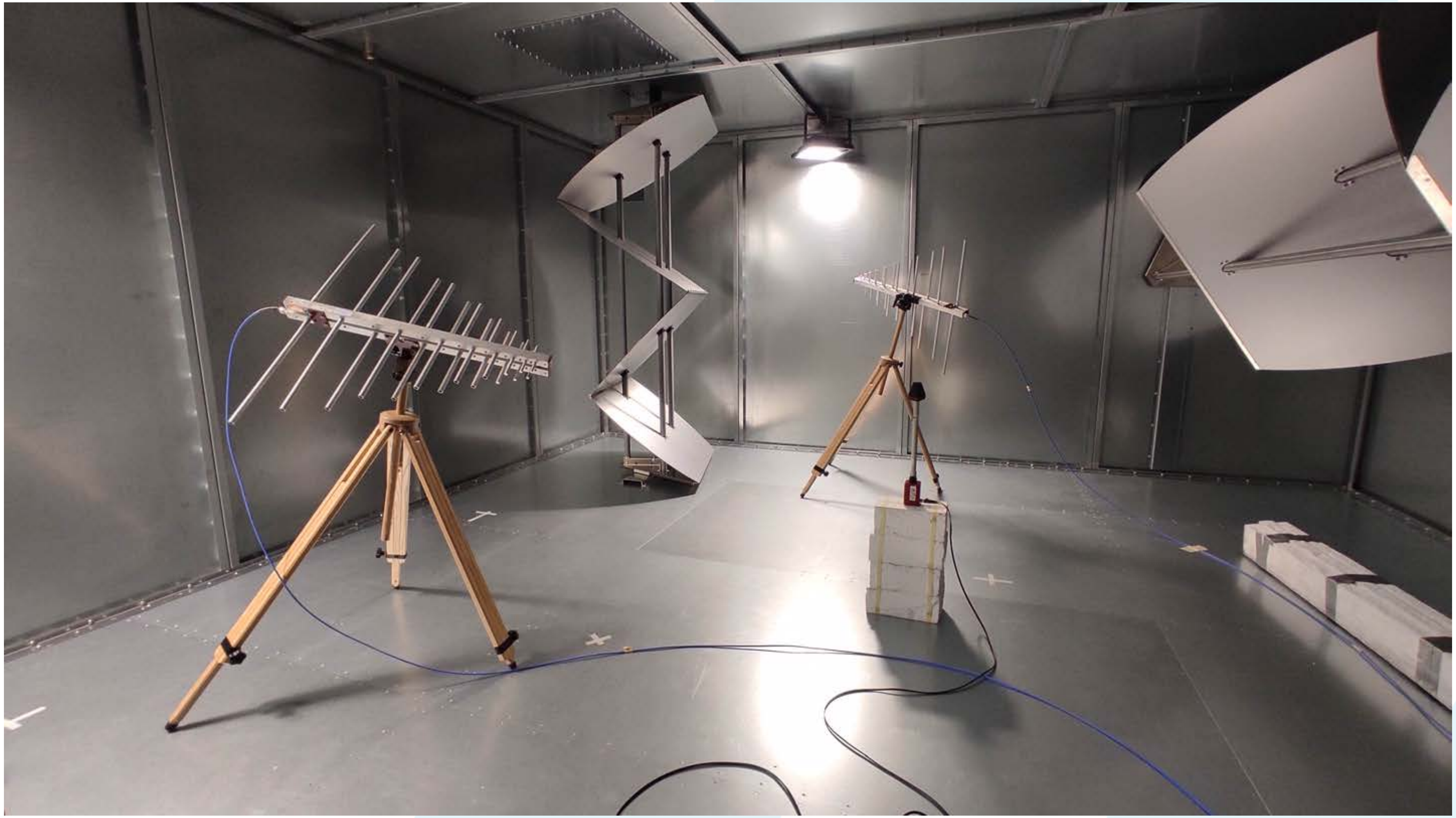

COMTEST

# Field Uniformity (32/18 stirrer steps)




COMTEST

# Independent stirring configurations



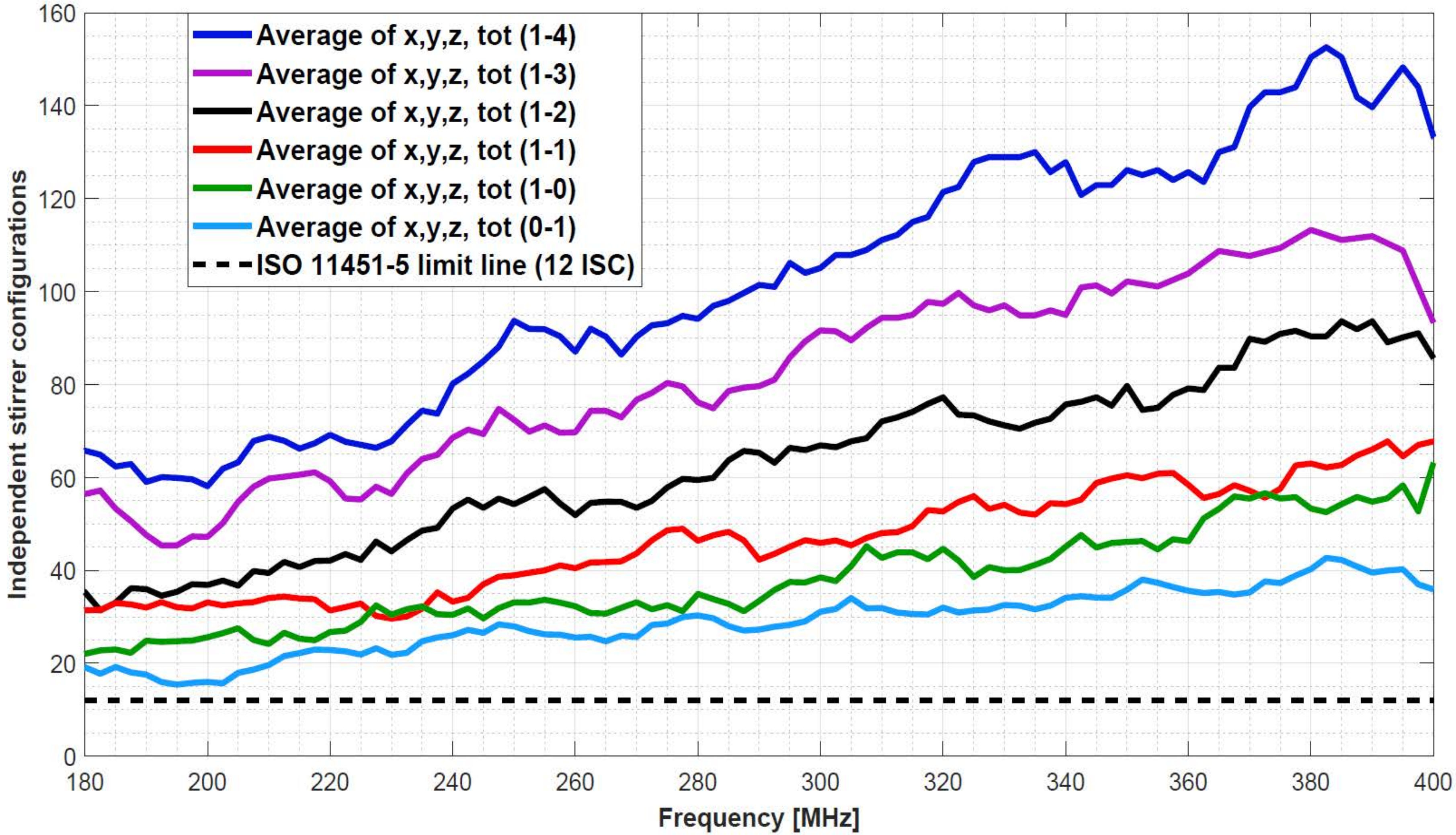
COMTEST

# Independent stirring configurations

- **<u>Independent stirring configurations investigation</u>**
- Six different stirring schemes were examined:
- (0-1): Only the vertical stirrer was used.
- (1-0): Only the horizontal stirrer was used.
- (1-1): Both stirrers were used, rotating with the same speed.
- (1-2): Both stirrers were used. The vertical stirrer was rotating with 2x the speed of the horizontal stirrer.
- (1-3): Both stirrers were used. The vertical stirrer was rotating with 3x the speed of the horizontal stirrer.
- (1-4): Both stirrers were used. The vertical stirrer was rotating with 4x the speed of the horizontal stirrer.

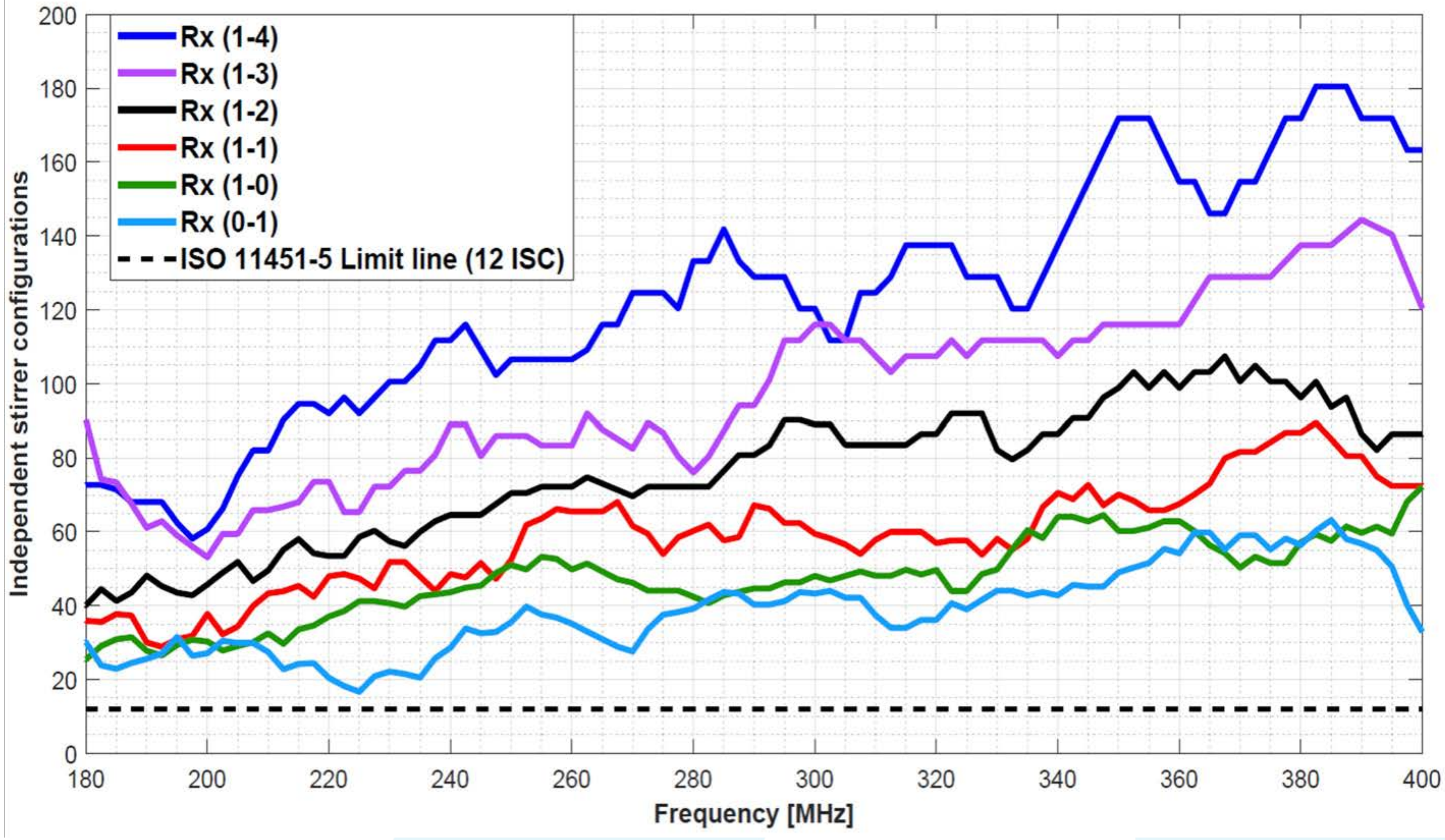
# Independent stirring configurations

## Field probe results



# Independent stirring configurations

## Rx results




COMTEST

# LUF80-FV vs [TU/e], comparison table

| | TU/e | LUF80-FV |
|---|---|---|
| Dimensions | 5.0 x 4.3 x 2.3 m | 13.8 x 11.4 x 6.0 m |
| Targeted LUF | 200 MHz | 80 MHz |
| Number of modes at LUF | 115 | 142 |

COMTEST

# RC@LUF80, dwell time calculation

Considering the parameters of the RC@LUF80 solution shown above as well as test results obtained from the research/test campaign at the TU/e, we propose the following two stirring schemes / approaches for the RC@LUF80 chamber **that can ensure 12x Independent Stirring Configurations (ISCs) in a dwell time t = 4 seconds:**

- Scheme (1-2): $\left.\begin{array}{r}\text{Horizontal stirrer} \rightarrow 15\ \text{rpm} \\ \text{Vertical stirrer} \rightarrow 30\ \text{rpm}\end{array}\right\} \Rightarrow\ \geq 30\ \text{ISC in 4 sec} \Rightarrow$

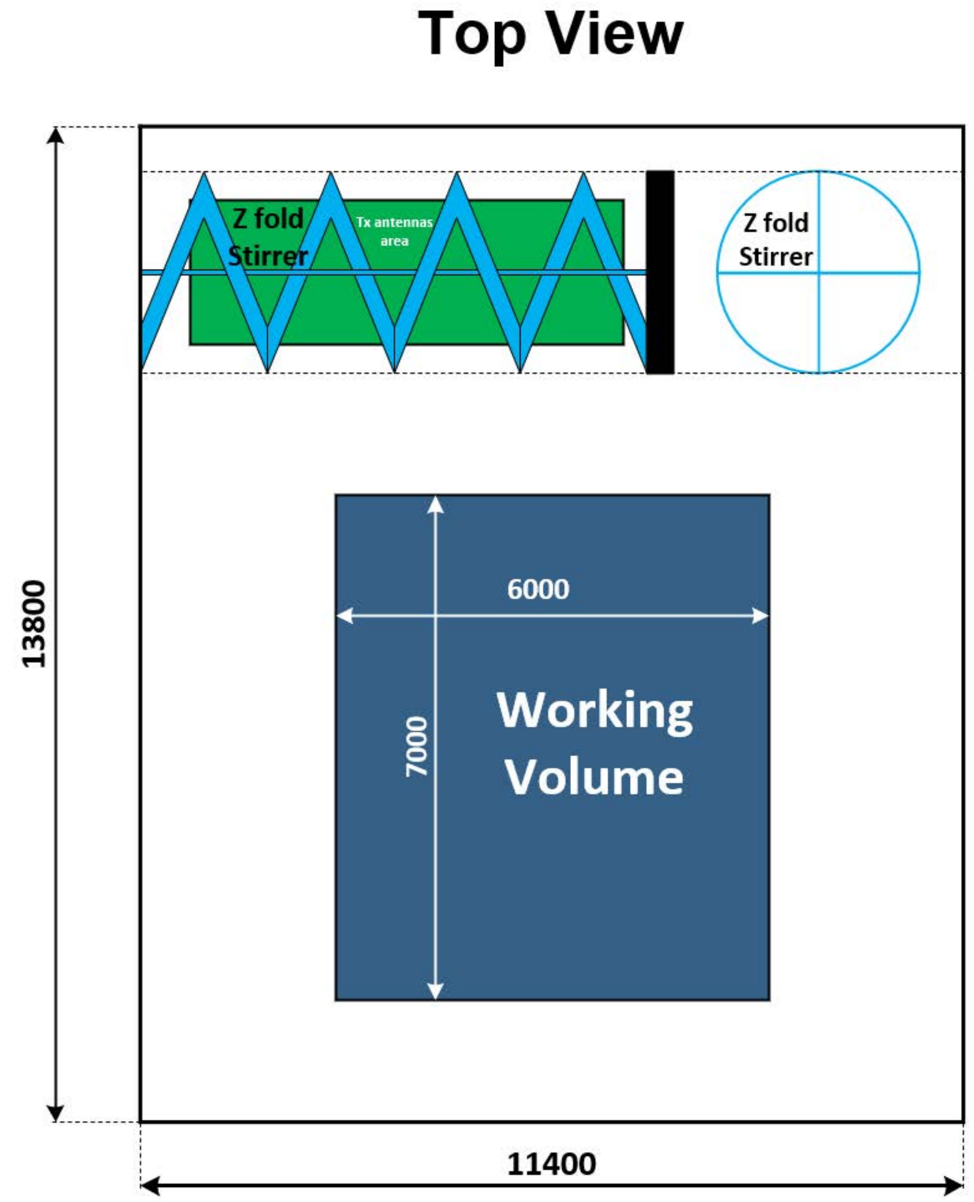
  $\left.\begin{array}{r}\textbf{Horizontal stirrer} \rightarrow \textbf{7.5 rpm} \\ \textbf{Vertical stirrer} \rightarrow \textbf{15 rpm}\end{array}\right\} \Rightarrow\ \geq \textbf{15 ISC in 4 sec}$

- Scheme (1-4): $\left.\begin{array}{r}\text{Horizontal stirrer} \rightarrow 10\ \text{rpm} \\ \text{Vertical stirrer} \rightarrow 40\ \text{rpm}\end{array}\right\} \Rightarrow\ \geq 45\ \text{ISC in 6 sec} \Rightarrow$

  $\left.\begin{array}{r}\textbf{Horizontal stirrer} \rightarrow \textbf{5 rpm} \\ \textbf{Vertical stirrer} \rightarrow \textbf{20 rpm}\end{array}\right\} \Rightarrow\ \geq \textbf{15 ISC in 4 sec}$

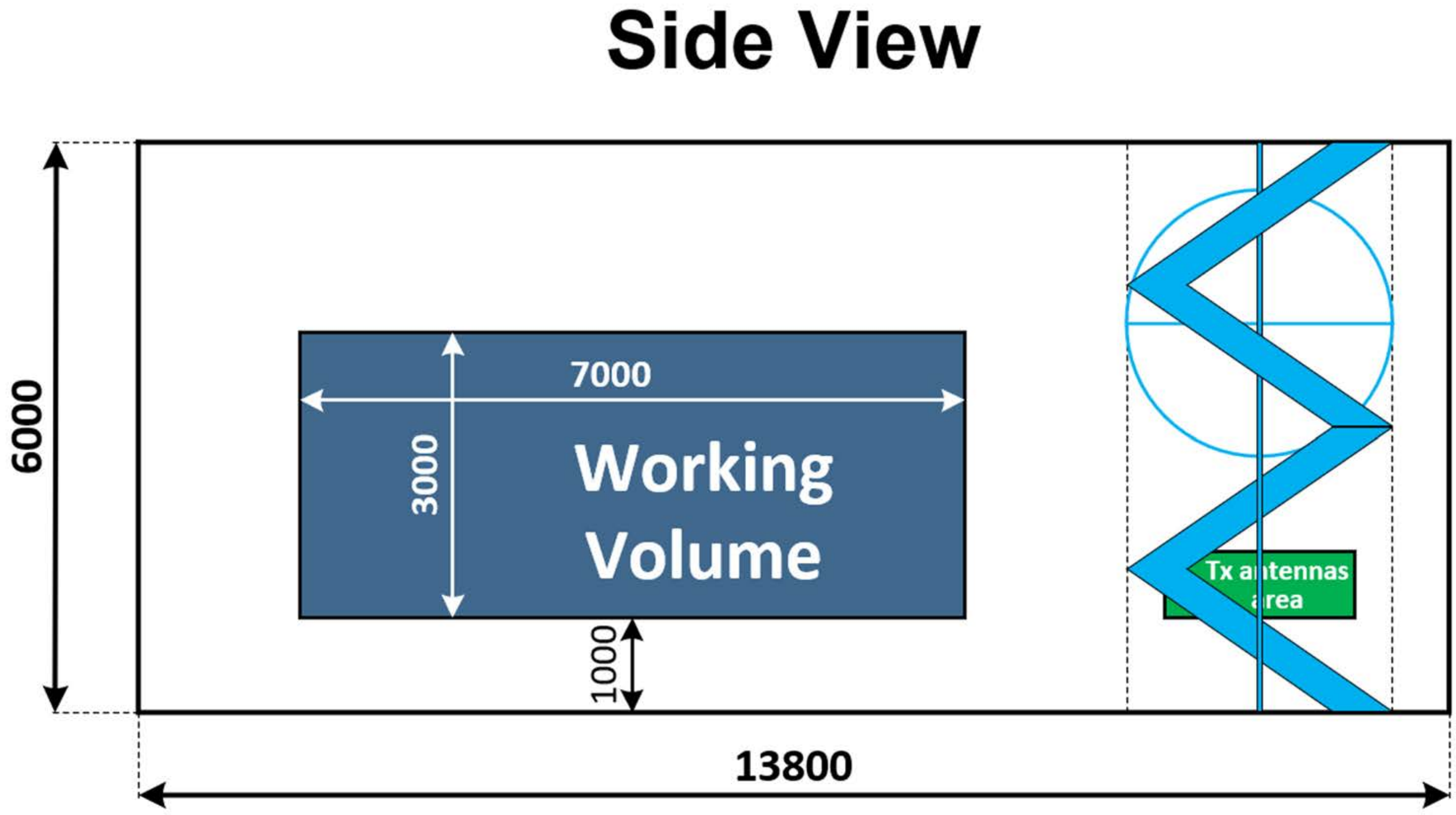
COMTEST

# RC@LUF80, concept design



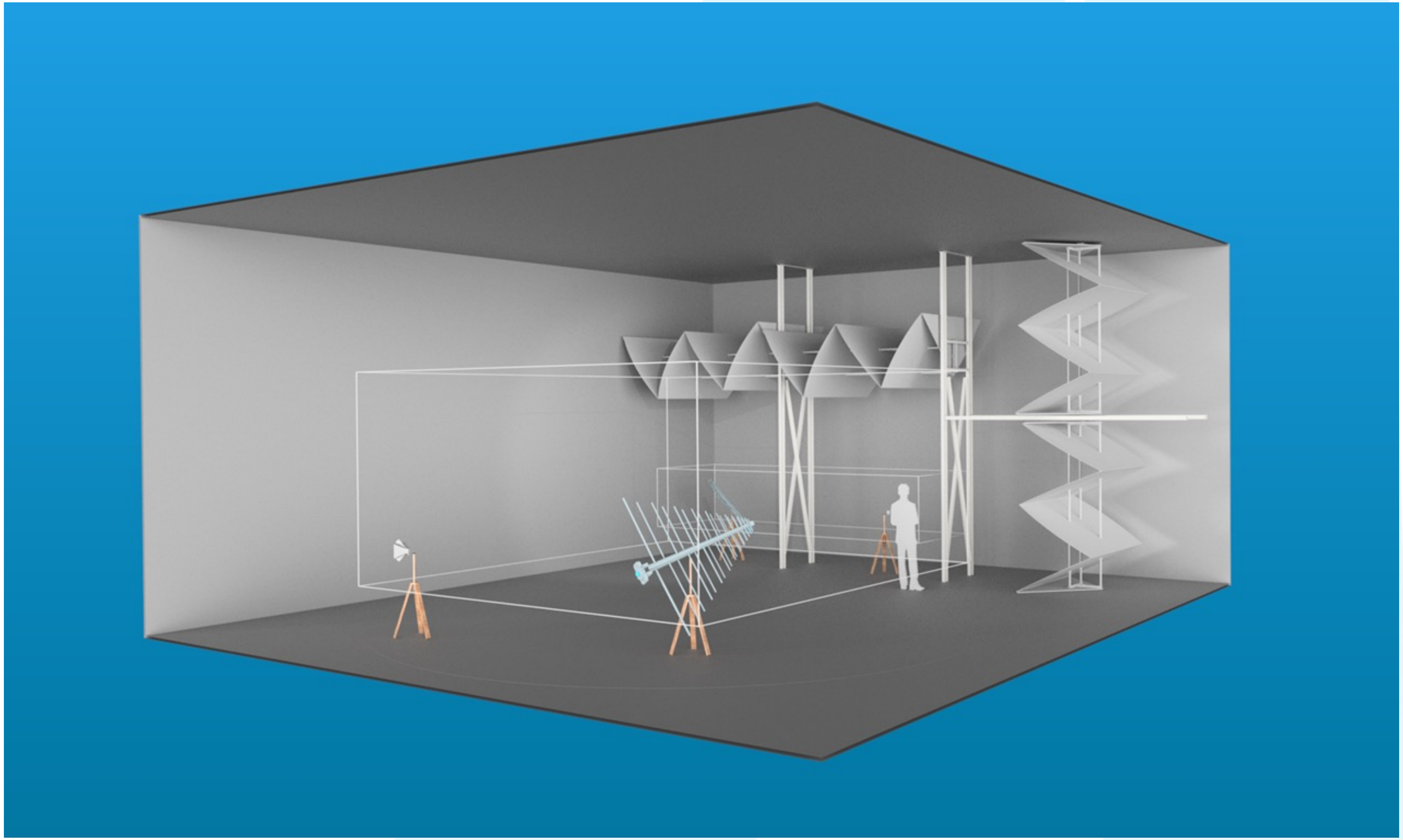

COMTEST

# RC@LUF80, concept design



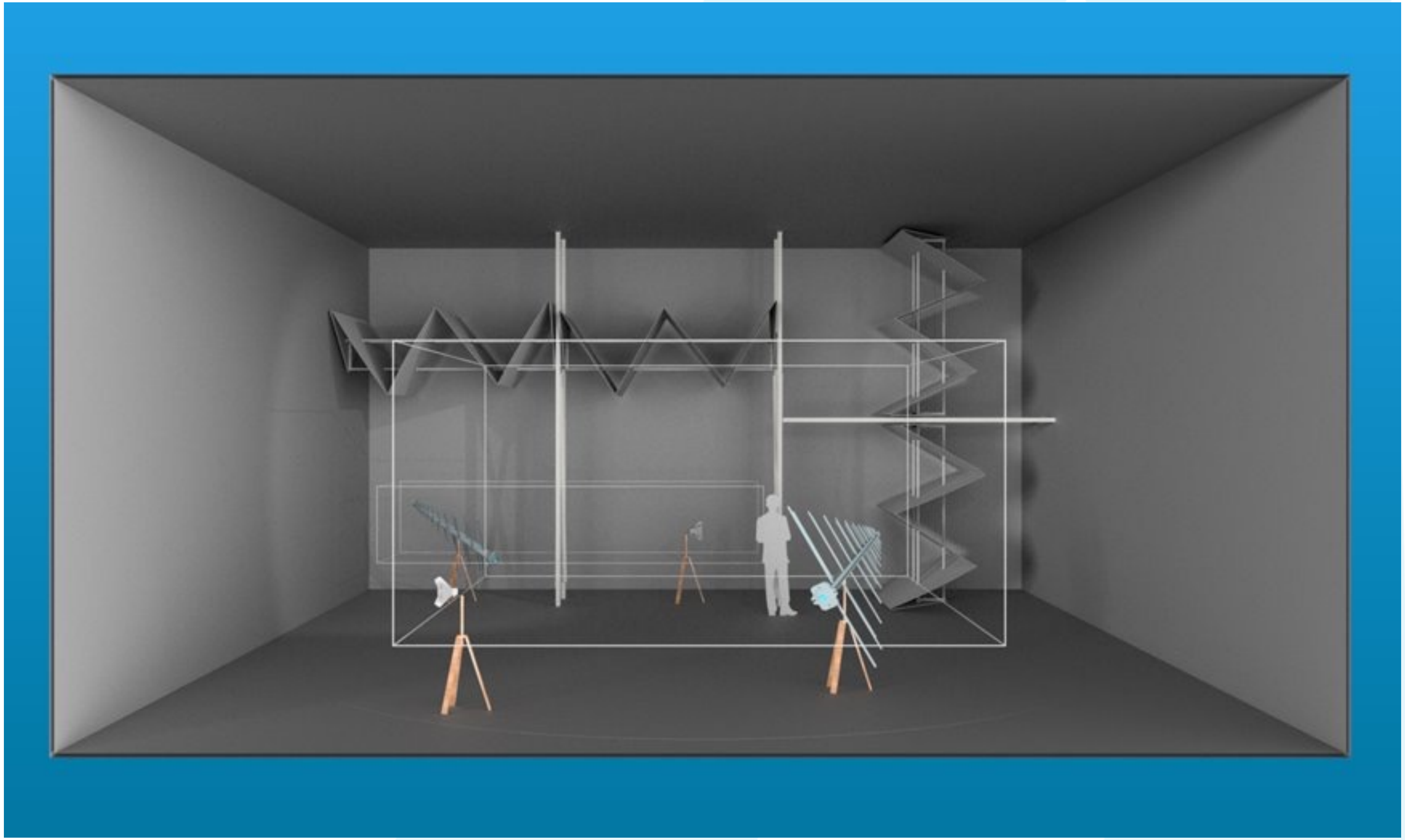

COMTEST

# RC@LUF80, concept design



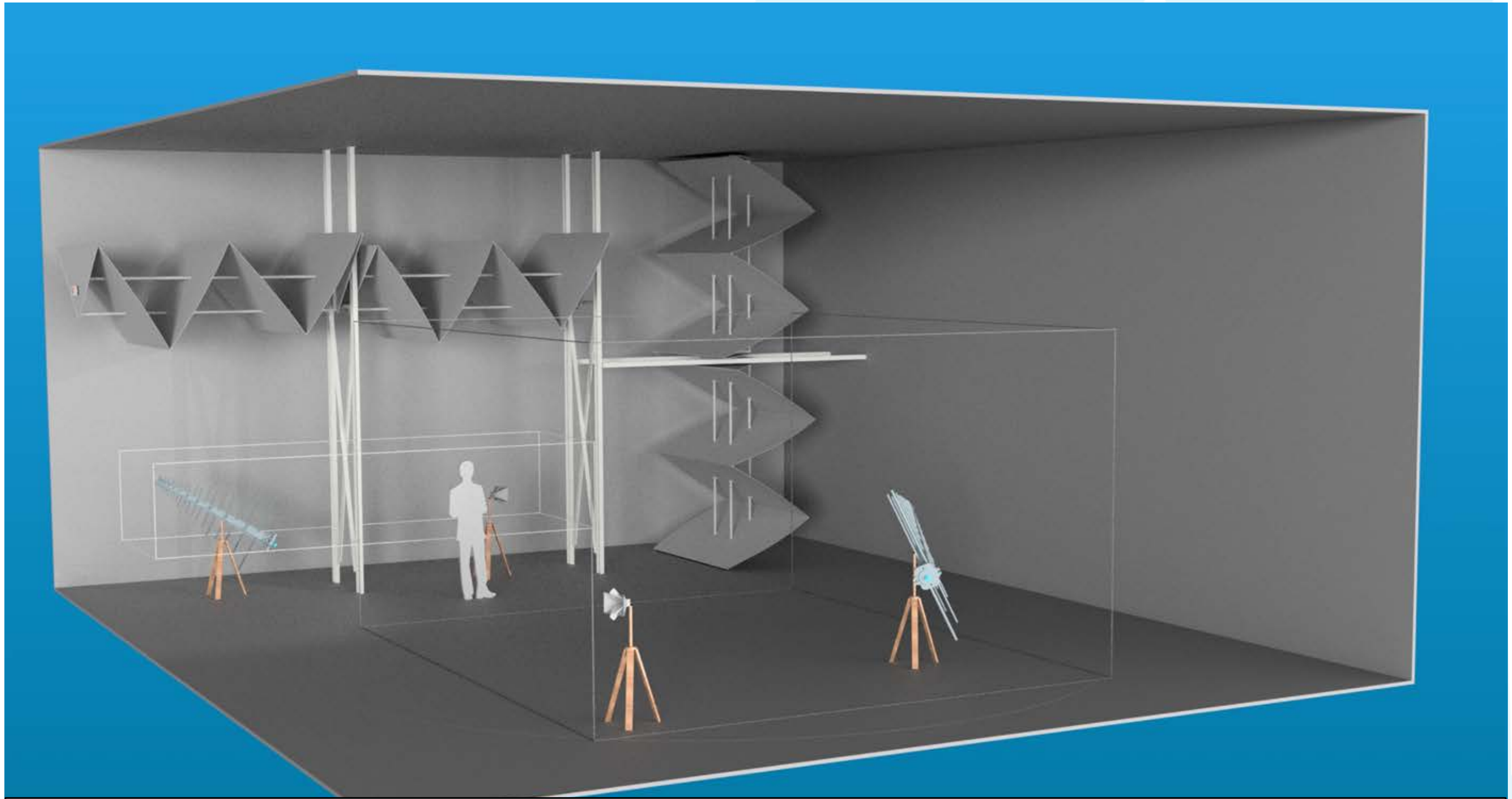
COMTEST

# RC@LUF80, concept design



COMTEST

# RC@LUF80, concept design



The working volume for testing vehicles starts directly on the ground plane in order to contain the full vehicle. Although this differs from the IEC 61000-4-21 working volume definition, for the purpose of chamber calibration, the reverb reference points described in IEC 61000-4-21 shall be used.

# Take out

- RC unique property
- ISO 11451-5 => Full vehicle RI testing
- Fast stirring method
  - no need for determining EUT loading
  - reduces significantly testing time
- Proposed chamber solution LUF80
- Future work: from LUF80 to LUF50

# Thank you

For your time and interest.