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**IEEE STANDARDS ASSOCIATION** IEEE P2716: IEEE Guide for the characterization of the effectiveness of printed circuit board level shielding

# What makes characterizing the SE of Board Levels Shields so challenging?

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## Shielded Enclosure Basics!

- A Shielded Enclosure is an electrically conducting enclosure that surrounds a piece of electronic equipment.
- Its shielding function is to prevent unwanted electromagnetic energy getting to or from the electronics inside.
- It usually has other structural and aesthetic functions.
- It can be regarded as a stand-alone structure and its Shielding Effectiveness can be assessed using standards such as IEEE 299.1.



# Shielding Effectiveness: Simple view

- A simple view of Shielding effectiveness:

- As a field ratio

$$\triangleright SE = 20 \log_{10} \frac{|E_0|}{|E_S|} \text{ dB}$$

- As a ratio of power densities

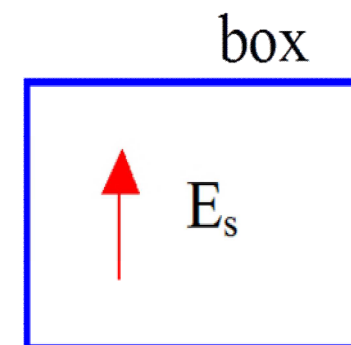
$$\triangleright SE = 10 \log_{10} \frac{S_0}{S_S} \text{ dB}$$

$$\triangleright S = \frac{E_t^2}{\eta_0}$$

← Total field  $E_t^2 = E_x^2 + E_y^2 + E_z^2$

← Free space impedance

EM wave →



no box

EM wave →



# Shielding Effectiveness: Reality

- SE of an enclosure depends on:
  - Illumination
  - Measurement antenna
    - Type
    - Position
    - Polarisation
    - Orientation
  - Enclosure contents
    - Absorbs energy
    - Alters field structure



[https://commons.wikimedia.org/wiki/File:Touchless\\_Car\\_Wash.jpg](https://commons.wikimedia.org/wiki/File:Touchless_Car_Wash.jpg)

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## Power Balance View : Reverberant Case

Power balance:

$$\triangleright \langle P_{10} \rangle = \langle P_{01} \rangle + \langle P_1^a \rangle$$

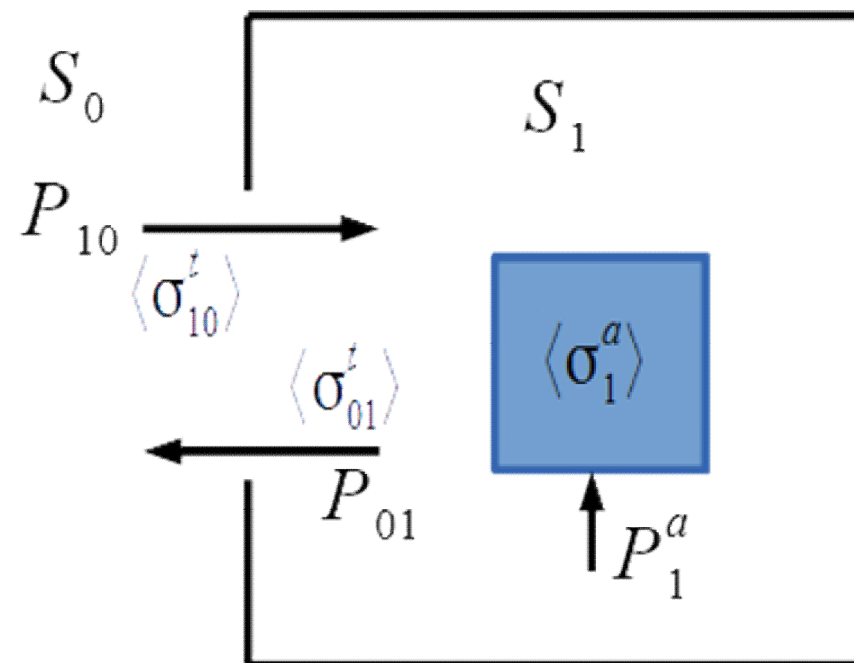
$$\triangleright \langle \sigma_{10}^t \rangle S_0 = \langle \sigma_{01}^t \rangle S_1 + \langle \sigma_1^a \rangle S_1$$

■ So

$$\triangleright SE = \frac{S_0}{S_1} = \frac{\langle \sigma_{01}^t \rangle + \langle \sigma_1^a \rangle}{\langle \sigma_{10}^t \rangle} = \frac{\langle \sigma^t \rangle + \langle \sigma_1^a \rangle}{\langle \sigma^t \rangle}$$

■ ACS is sum of antenna, contents, and enclosure wall losses

$$\triangleright \langle \sigma_1^a \rangle = \langle \sigma_{1enc}^a \rangle + \langle \sigma_{1ant}^a \rangle + \langle \sigma_{1cont}^a \rangle$$



# The Meaning of Enclosure Shielding Effectiveness

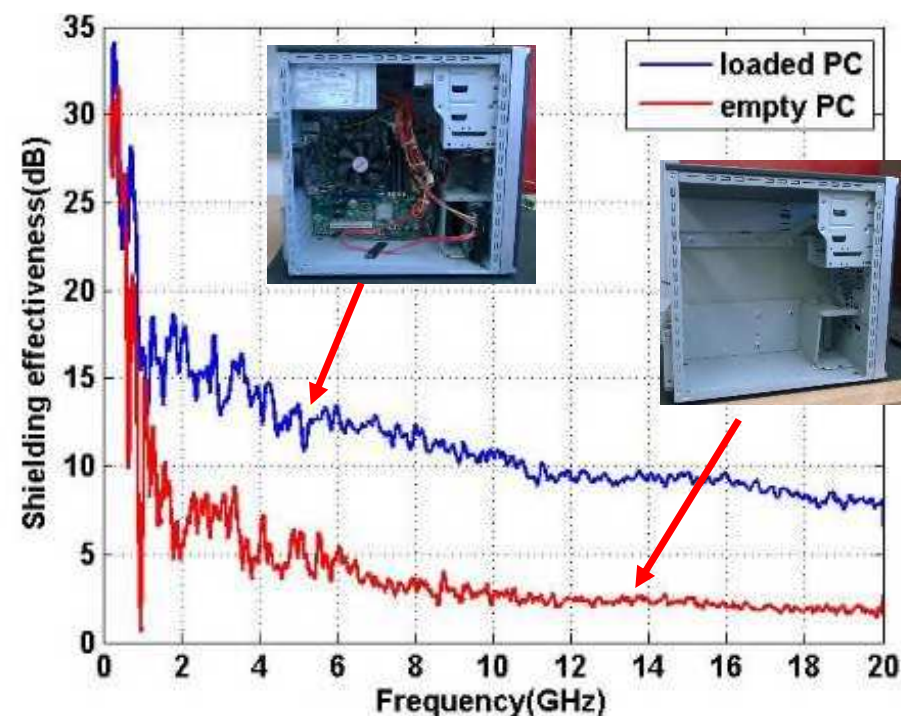
- Knowing SE is not sufficient to define

Enclosure shielding:

$$\text{SE} = \frac{S_0}{S_1} = \frac{\langle \sigma^t \rangle + \langle \sigma_1^a \rangle}{\langle \sigma^t \rangle} \rightarrow \langle \sigma_{1enc}^a \rangle + \langle \sigma_{1ant}^a \rangle + \langle \sigma_{1cont}^a \rangle$$

- To characterise an enclosure we must know ACS and TCS of enclosure and any contents (e.g. Antenna)
- We can then predict the effect of changing the contents, if we know the ACS of each item added or removed

Effect of contents on PC Enclosure SE





# What makes a Board Level Shield Different?

*Typical Board Level Shield installation.*



- Board Level Shields are much smaller than normal Shielded Enclosures. Typical dimensions are 100 mm or less.
- They normally have five rather than six sides. The sixth side is the circuit board ground-plane.
- Their size makes the installation of internal measurement antennas impractical in most cases meaning that standard Shielding Effectiveness measurements are not applicable.
- **Their only function is to act as a shield.**

## What makes Board Level Shielding Challenging?

- Board Level Shields (BLS) are installed on circuit boards usually inside an outer enclosure that may itself have a shielding function.
- The function of the BLS is to isolate its internal circuits from other interference sources or sinks within the same outer enclosure, probably on the same board.
- Its external environment may be resonant, reverberant, or have multiple antennas within a few tens of mm.

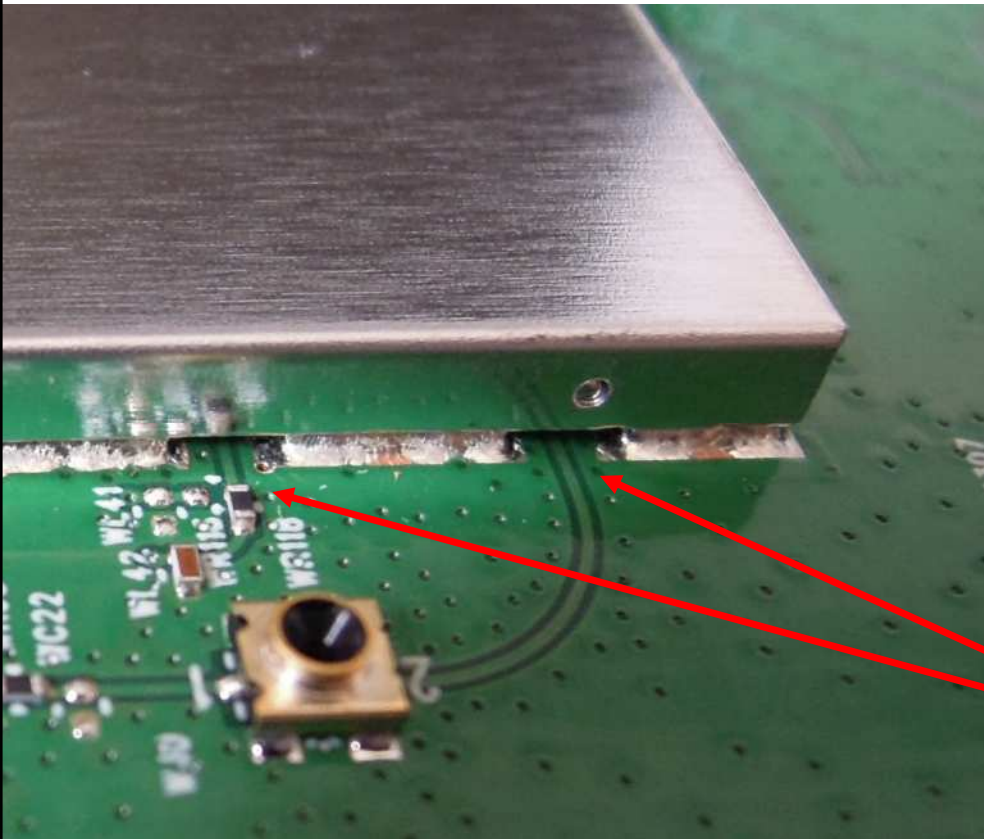
*Same Board Level Shield showing frame with clip-on outer shell removed.*



# What makes Board Level Shielding Challenging?

- BLS are non-resonant at lower frequencies  $< \sim 1$  GHz, may be come resonant at higher frequencies  $> \sim 1$  GHz, and may be reverberant at even higher frequencies  $> \sim 10$  GHz. Depends on their size.
- External environment is reverberant in some measurement techniques, and not in others
  - transmission cross-section depends on illumination ( $\sigma_{10}^t$ ), and internal fields ( $\sigma_{01}^t$ )
- Absorption cross-section ( $\sigma_1^a$ ) comes from the internal circuits and depends on internal field structure
- SE depends on position at which the fields are measured and antenna type (how it couples to fields).

# What makes Board Level Shielding Challenging?



- The BLS may be installed so as to allow the propagation of desired signals between the interior and exterior of the BLS.
- Assessment of the shielding performance of BLS's must exclude these signal paths.

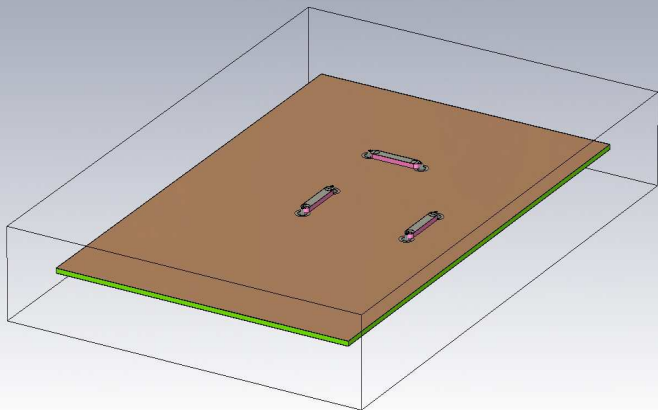
*Signal ingress/egress paths*

## Measurement Techniques

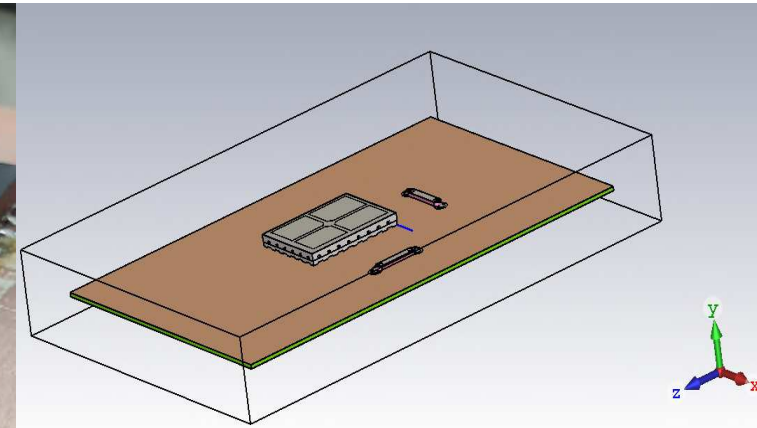
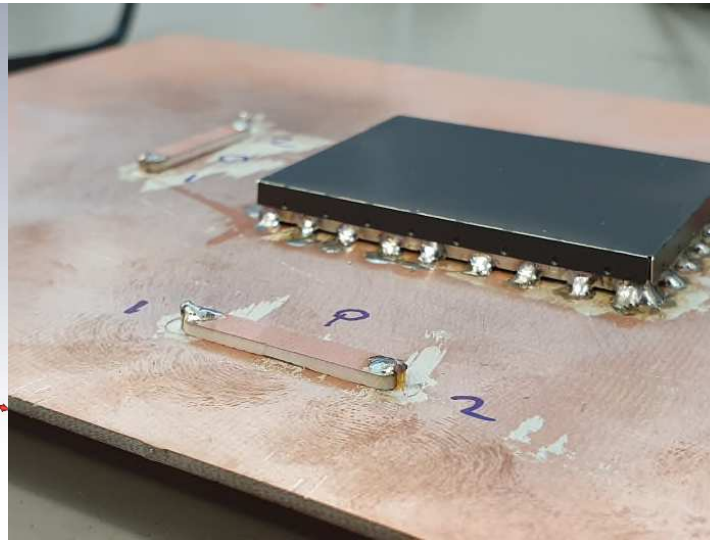
- There are several types of measurement environment applicable to Board Level Shielding Measurement; Single Reverberation Chambers, Dual Reverberation Chambers, GTEM Cells, Stripline Cells.
- They all share the same issues of variability and repeatability of installation of the Board Level Shield on the measurement system.
- The different techniques common factor is that the power measured has to pass through the Board Level Shield.
- The different ways of measuring this power in different measurement environments lead to a significant variability of different SE results.

## A Prototype SE Measurement Jig

The Measurement Jig shown below has strip-line circuits to mimic the internal and external stripline circuits on the circuit board allowing measurement of the coupling between them.

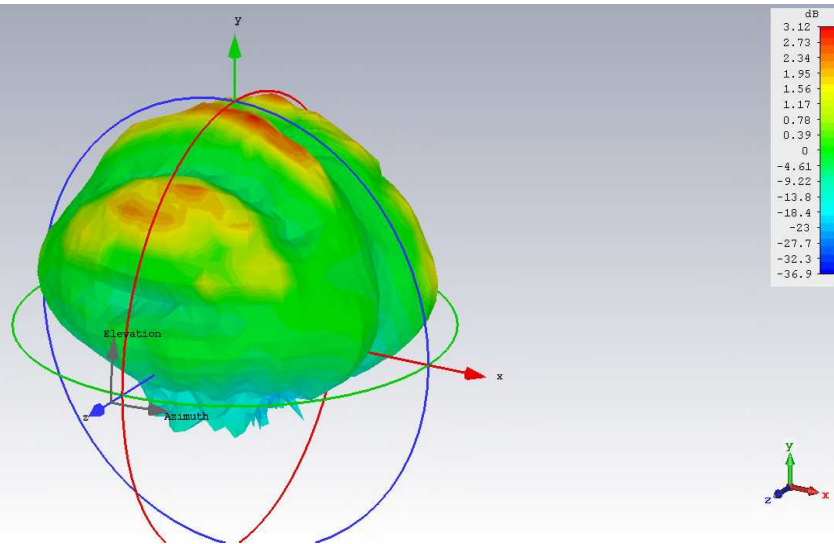


Bare jig

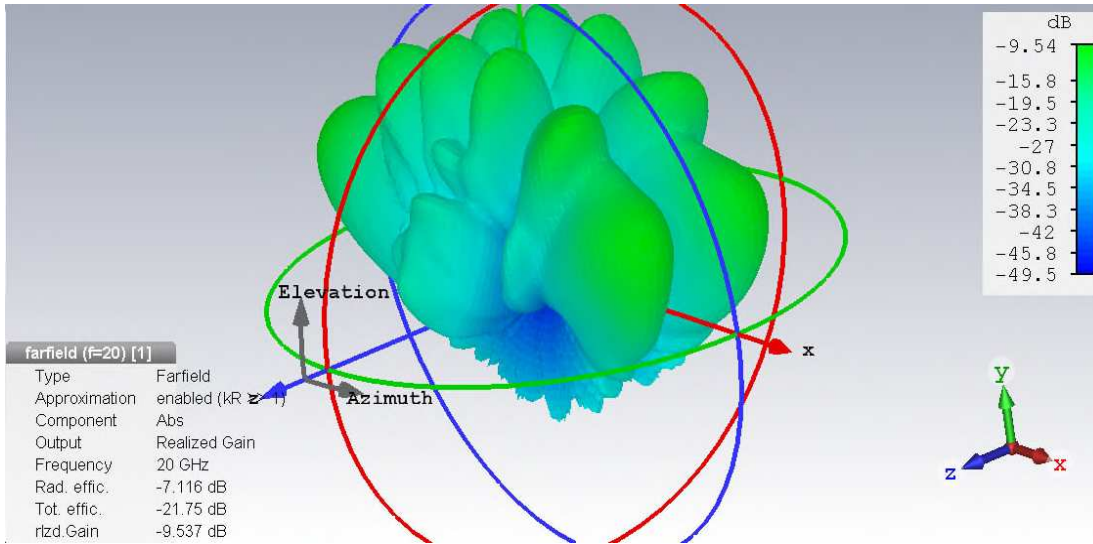


Jig with BLS

# A radiation view of SE



Bare jig



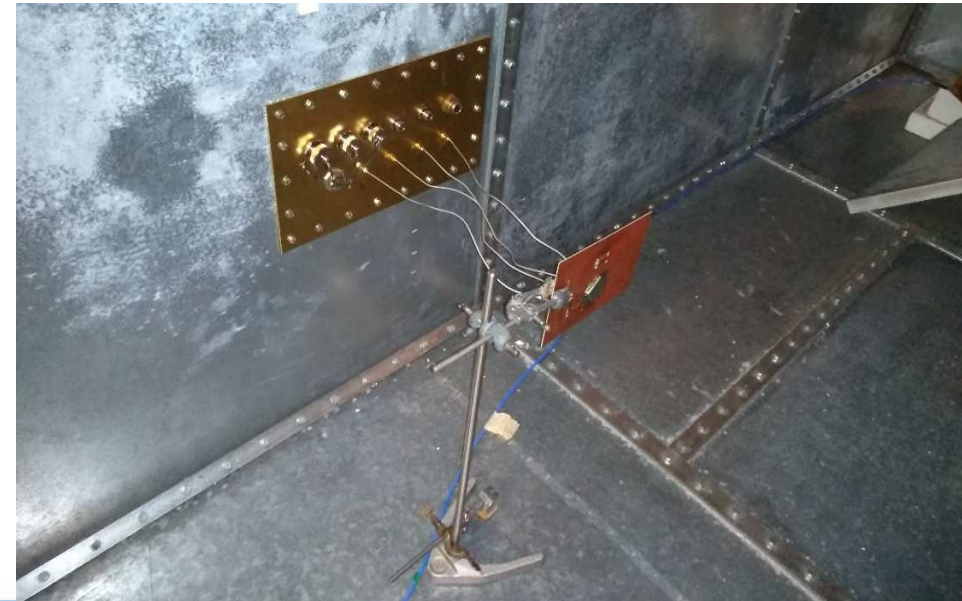
Jig with BLS

- The presence of the shield affects the radiation pattern so a fixed external antenna measurement may not give a meaningful SE measurement

# Reverberation Chamber Measurements

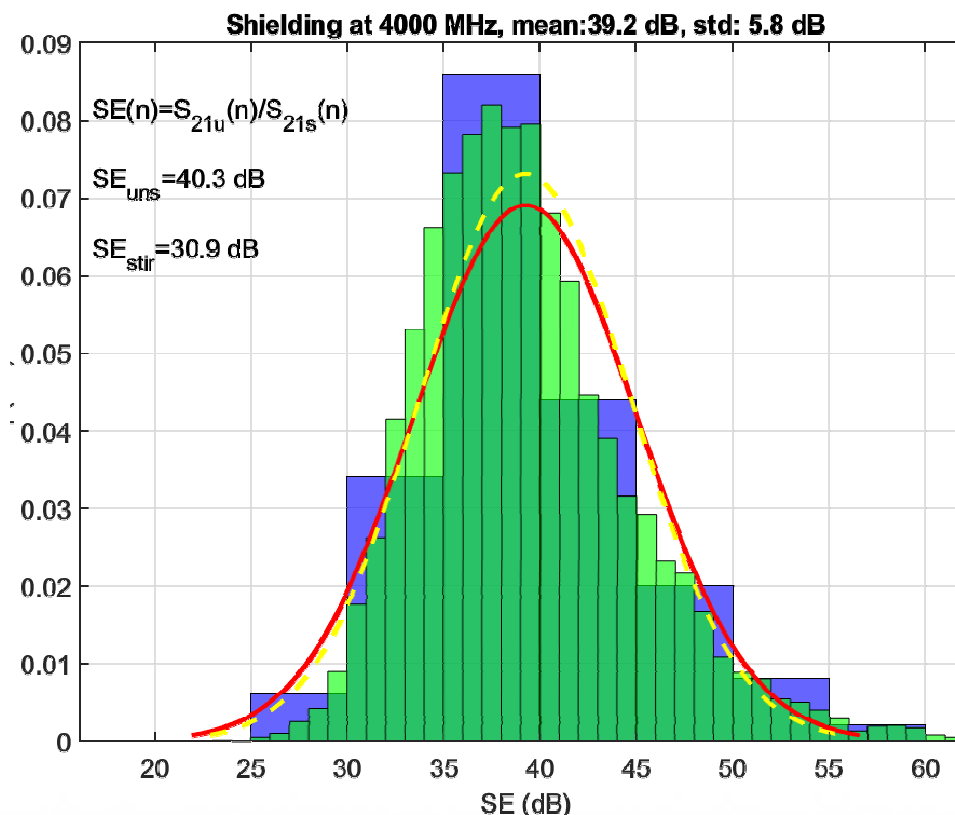
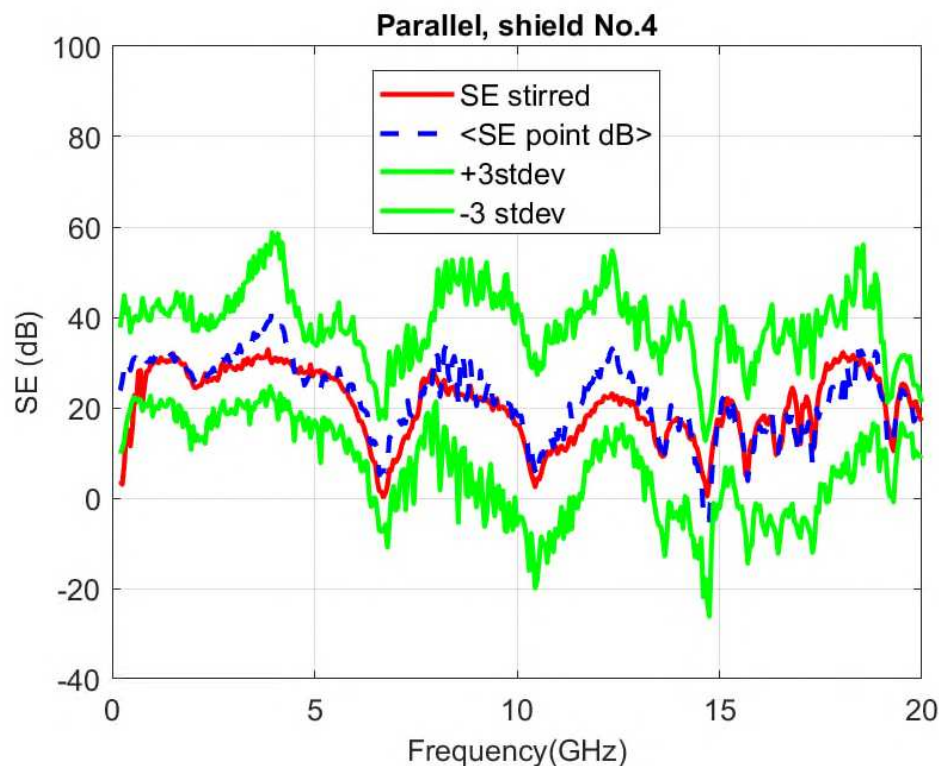
- The unknown external environment of the installed Board Level Shield can be mimicked in a reverberation chamber.
- The variability of the SE can be measured by comparing the coupling between the strip-lines on the jig at each stirrer position with and without the Board Level Shield installed.
- This is the Point SE.

*Prototype SE Measurement Jig in the Reverberation Chamber.*





# Statistics of SE measured in a Reverberation Chamber



## Conclusions

- SE can be defined and measured in many ways
  - It is not a single meaningful measure of a Board Level Shield
  - It depends on the position and orientation of the internal and external circuits that couple together ( $\sigma_{01}^t, \sigma_{10}^t$ )
  - It depends on how the internal circuits absorb energy ( $\sigma_1^a$ )
- SE is possibly a useful measure to compare similar shields
  - As long as you measure them with the same method
  - BUT different shields may have different variation of SE with variations of the external environment
  - So SE is not a simple absolute comparison. The SE variation statistics need consideration.
- SE is probably not a useful measure to predict installed performance
  - ACS and TCS may be more useful, but only maybe practical for reverberant fields