EMC SIPI 2021 VIRTUAL

2021 JOINT IEEE INTERNATIONAL SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY, SIGNAL & POWER INTEGRITY & EMC EUROPE

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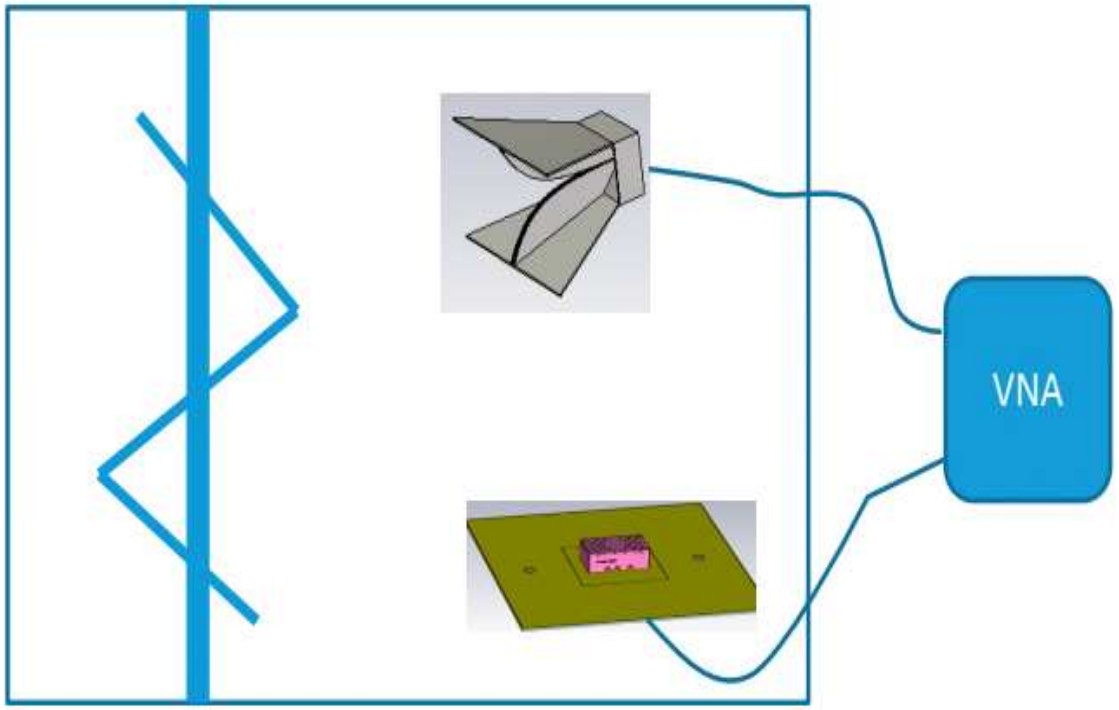
IEEE STANDARDS ASSOCIATION

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

Single Reverb Room

John Dawson, Andy Marvin (University of York) and Brian She (Laird)

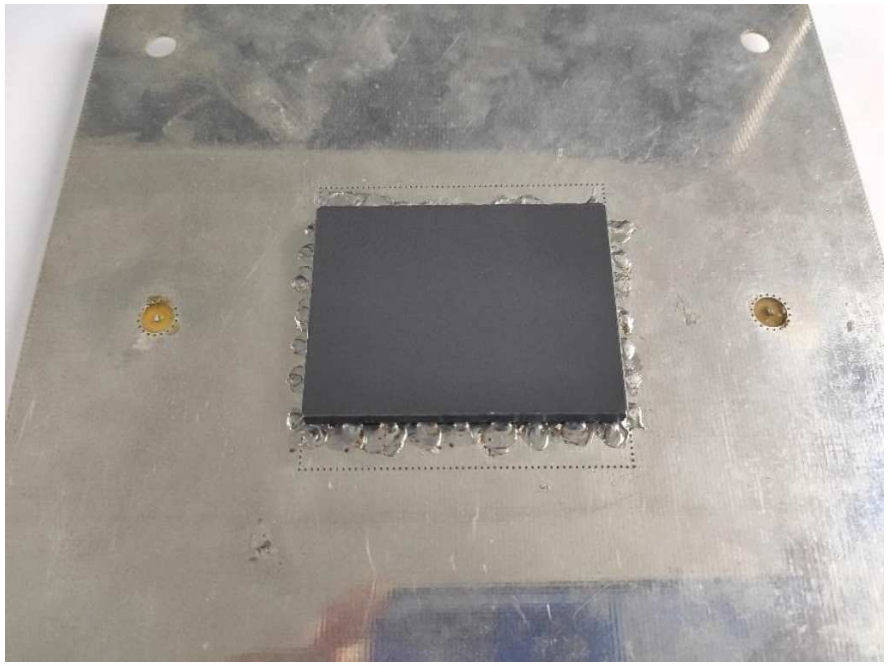
Laird Measurement setup



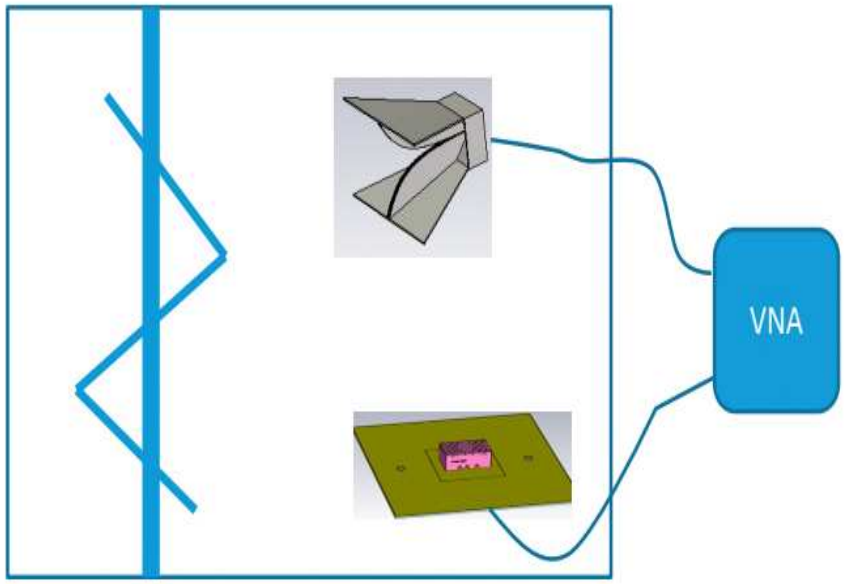
Sample test jig

Laird SE test jig - open

Laird SE test jig – with shield

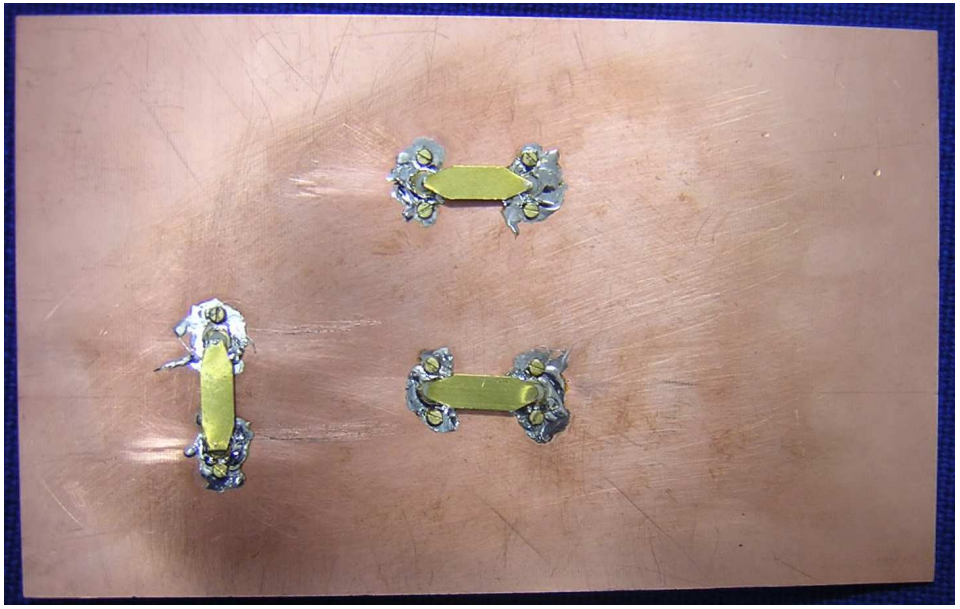


UoY Measurement setup

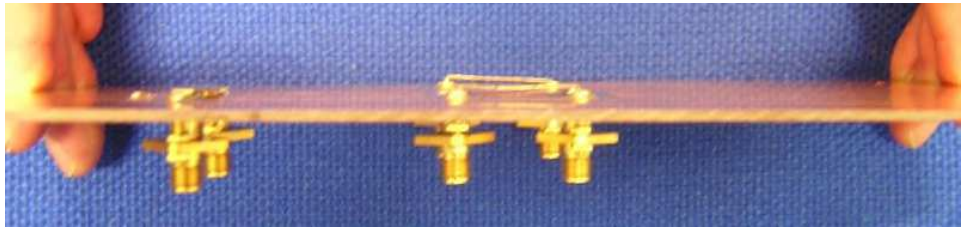


UoY Sample test jig 1

Top view - no shield

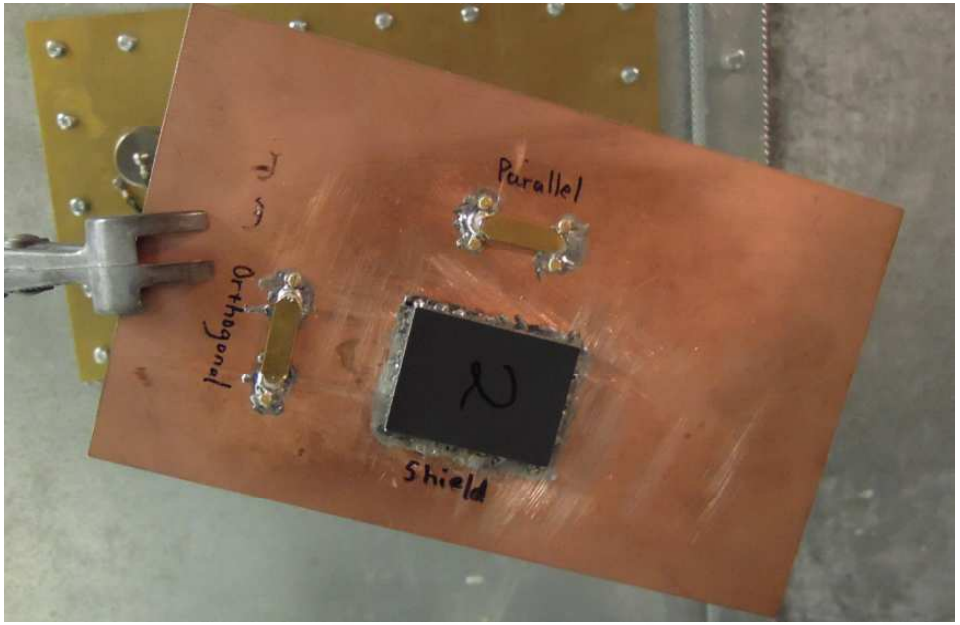


Side view- no shield

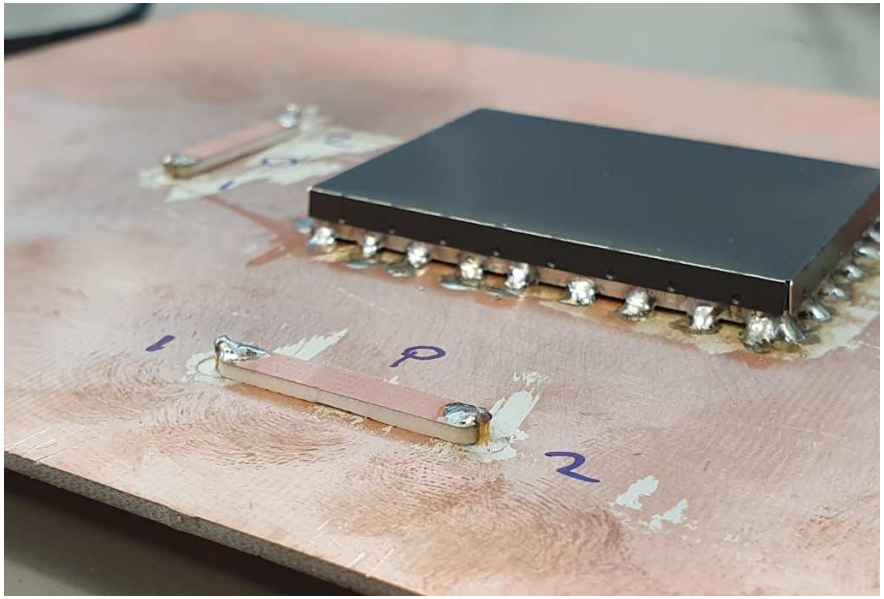


Sample test jig

UoY SE test jig 1 – with shield



UoY SE test jig 2 – with shield

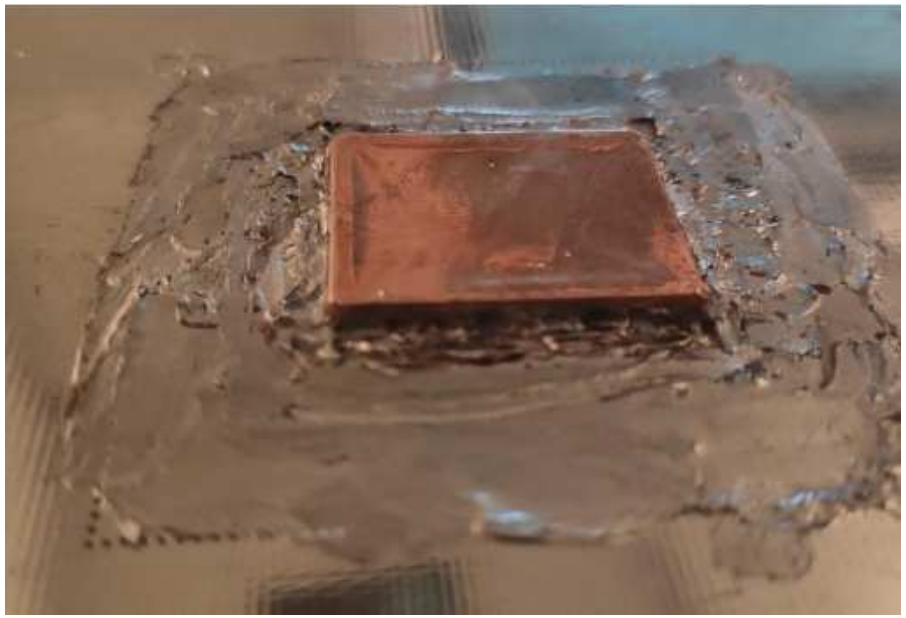


Definitions of SE

- IEEE 299
  - **shielding effectiveness (SE):** The ratio of the signal received (from a transmitter) without the shield, to the signal received inside the shield; the insertion loss when the shield is placed between the transmitting antenna and the receiving antenna.
- IEC 6100-4-21 standard gives a definition:
  - $SE = \frac{\langle P_u \rangle}{\langle P_s \rangle}$ or in decibels $SE = 10\log_{10}\left(\frac{\langle P_u \rangle}{\langle P_s \rangle}\right)$ dB
  - Where P_u is the power coupled to a measurement antenna in the absence of a shield (unshielded) and P_s is the power coupled to a measurement antenna inside a shield (shielded) and $\langle x \rangle$ indicates that x is averaged over a number of measurements with different boundary conditions (stirrer positions, antenna positions, frequencies etc.).

Dynamic range

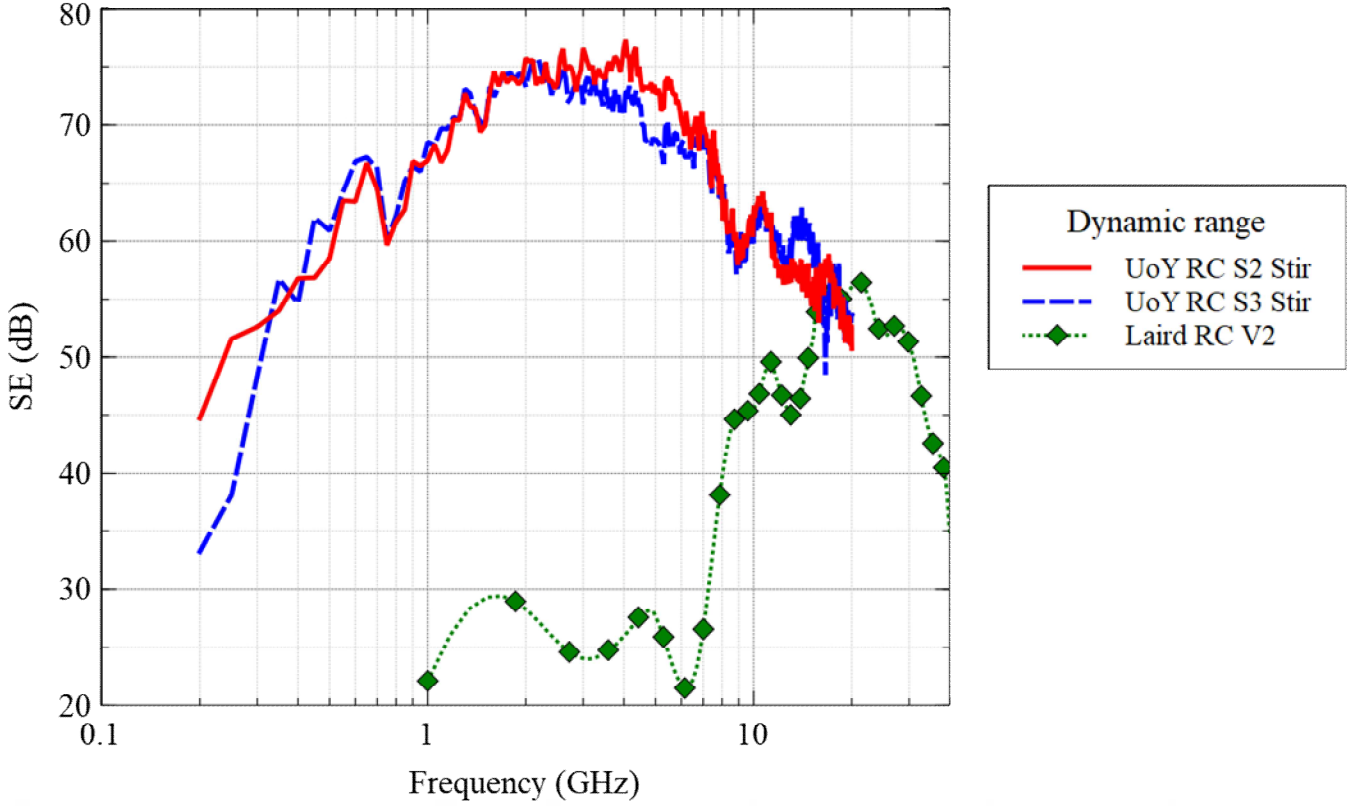
Laird Dynamic range test



Dynamic range – Measure SE with:

- Laird
  - Solid copper shield over track
- UoY
  - Disconnect jig and terminate cable with matched load
  - Antenna remains connected

Dynamic range for Reverb method



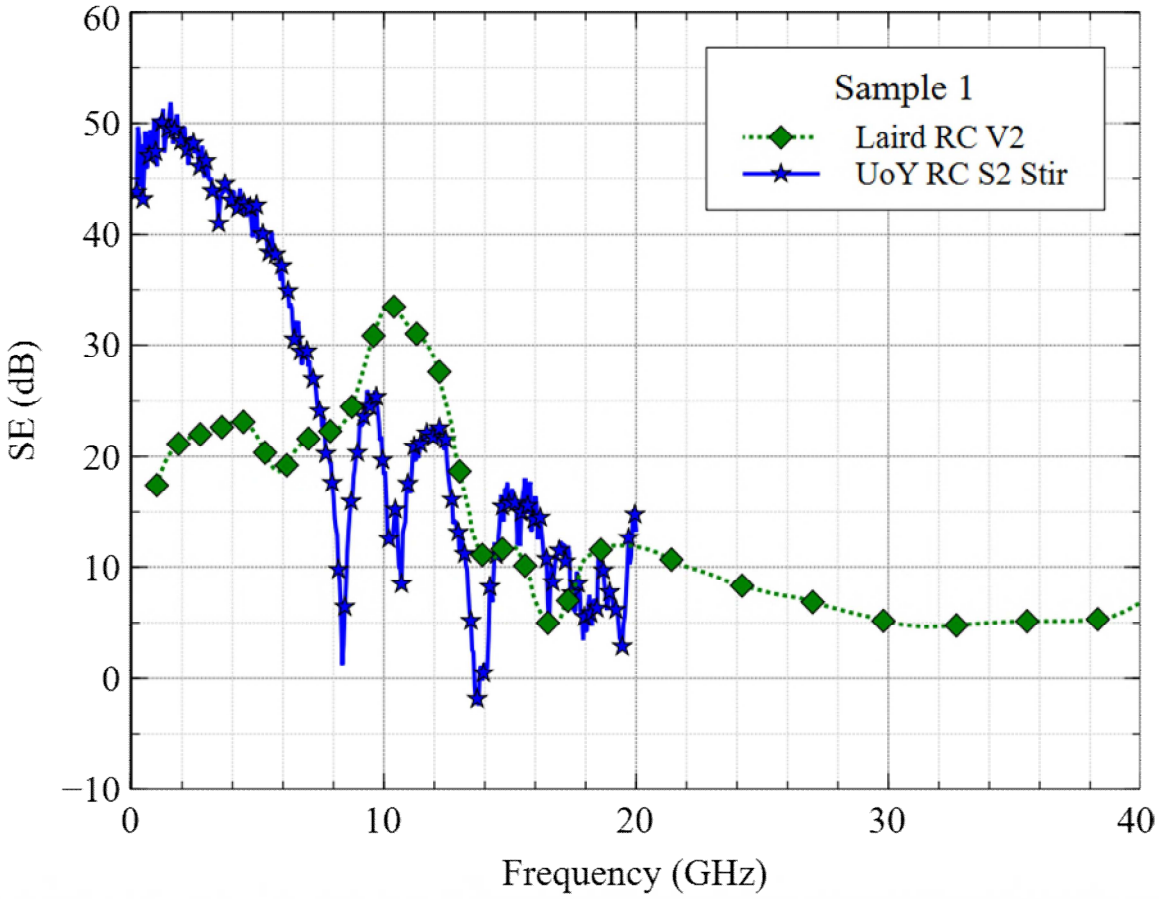
UoY :

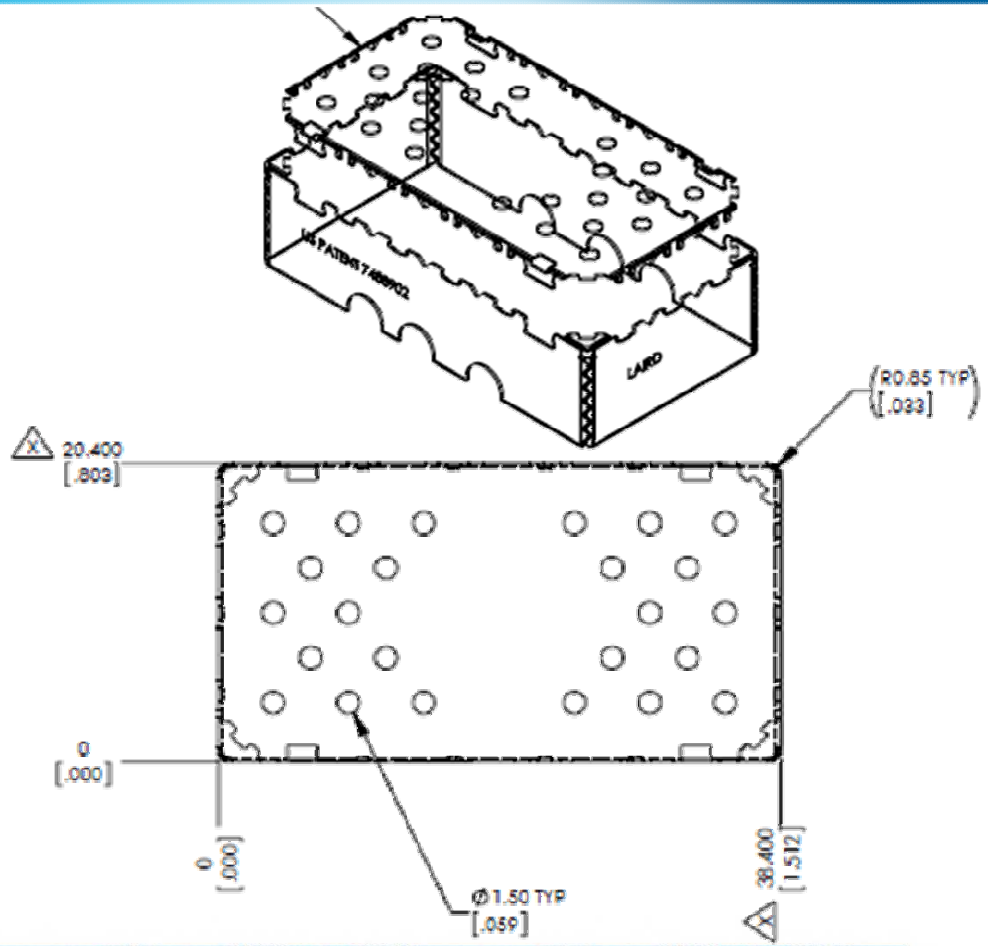
4.7m×3.0m×2.37m $(L \times W \times H)$

100 Stirrer positions

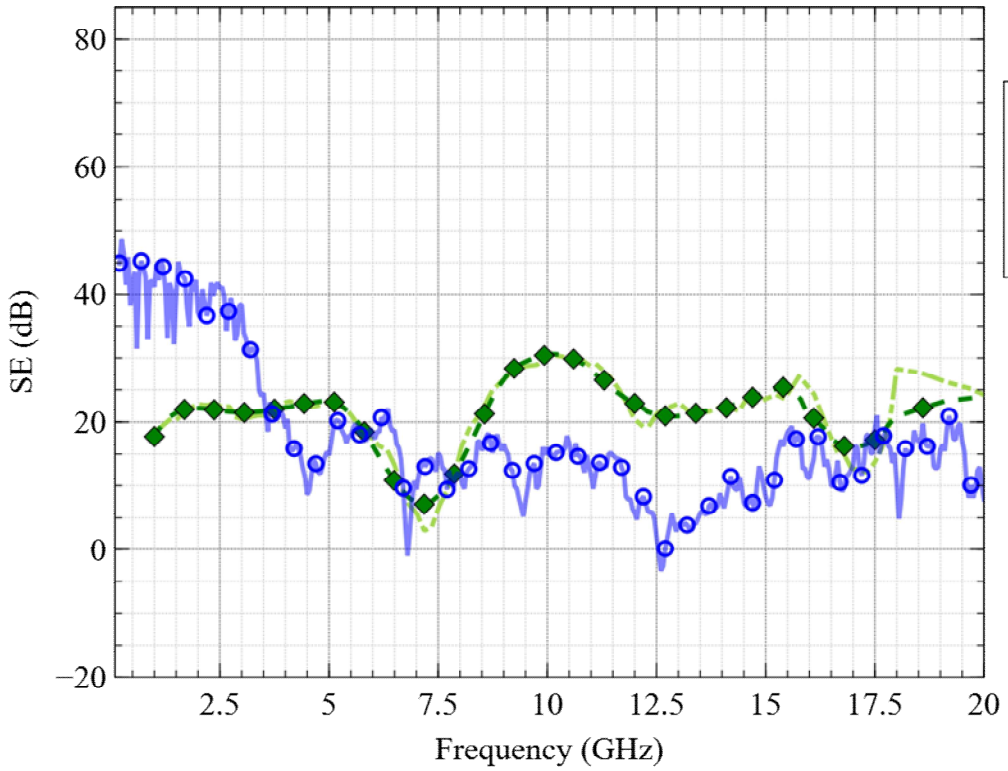
Laird:

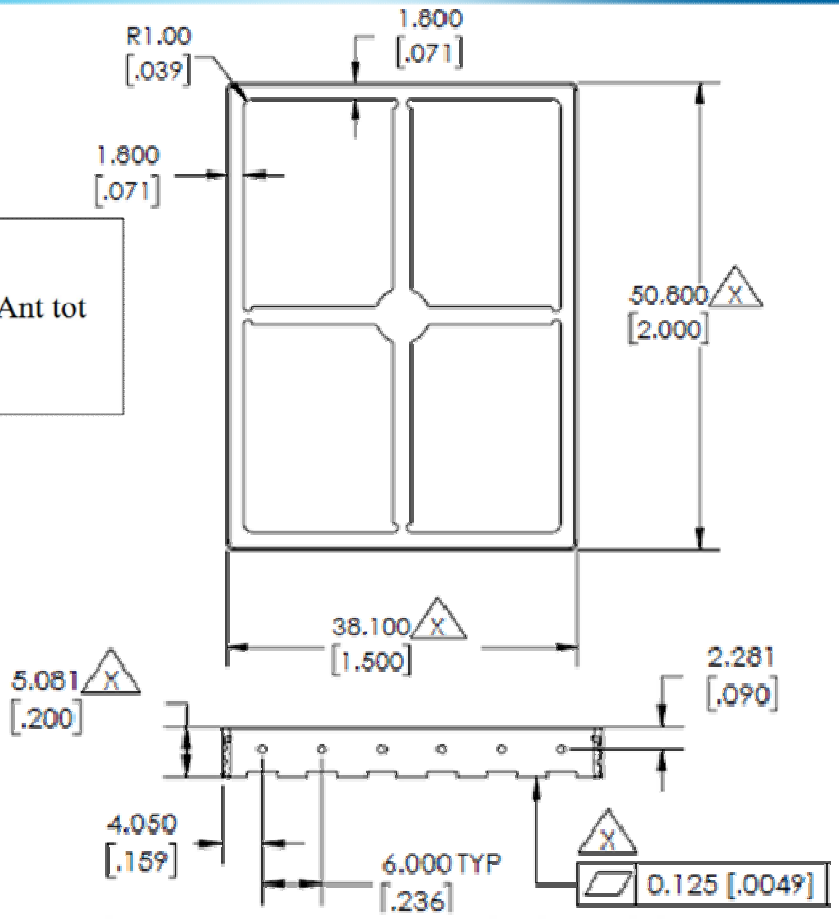
2.5m×2.5m×2.5m


Sample 1
Laird RC V2
UoY RC S2 Stir
SE (dB)
Frequency (GHz)
60
50
40
30
20
10
0
−10
0
10
20
30
40

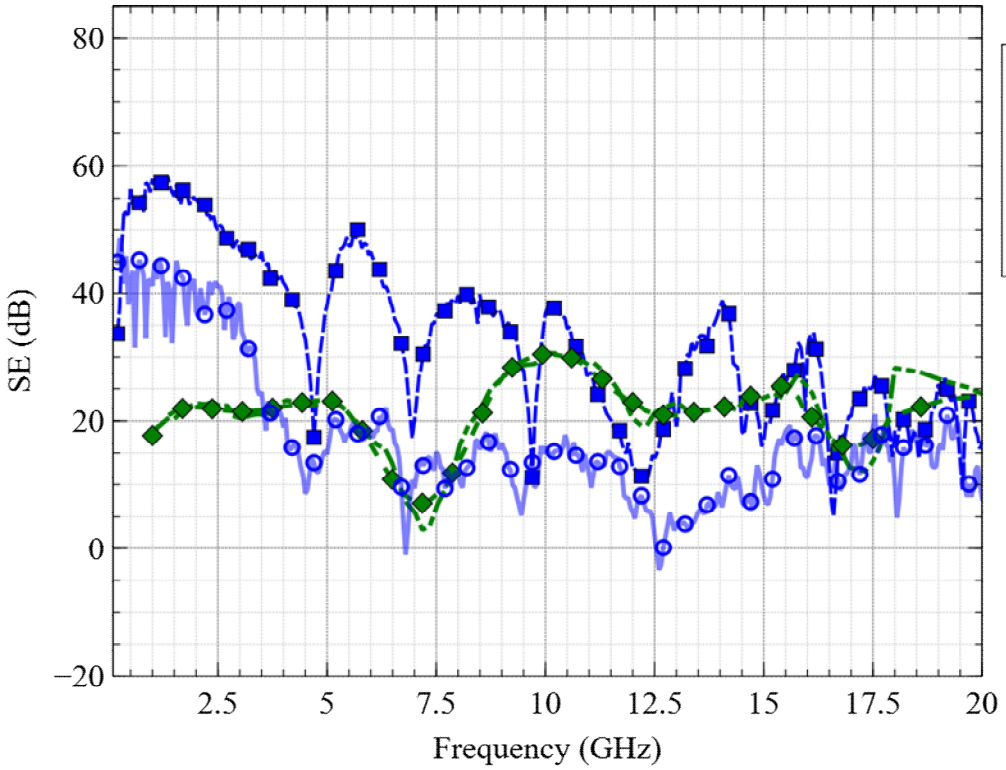

R0.85 TYP
[.033]
20.400
[.803]
0
[.000]
0
[.000]
38.400
[1.512]
Ø1.50 TYP
[.059]

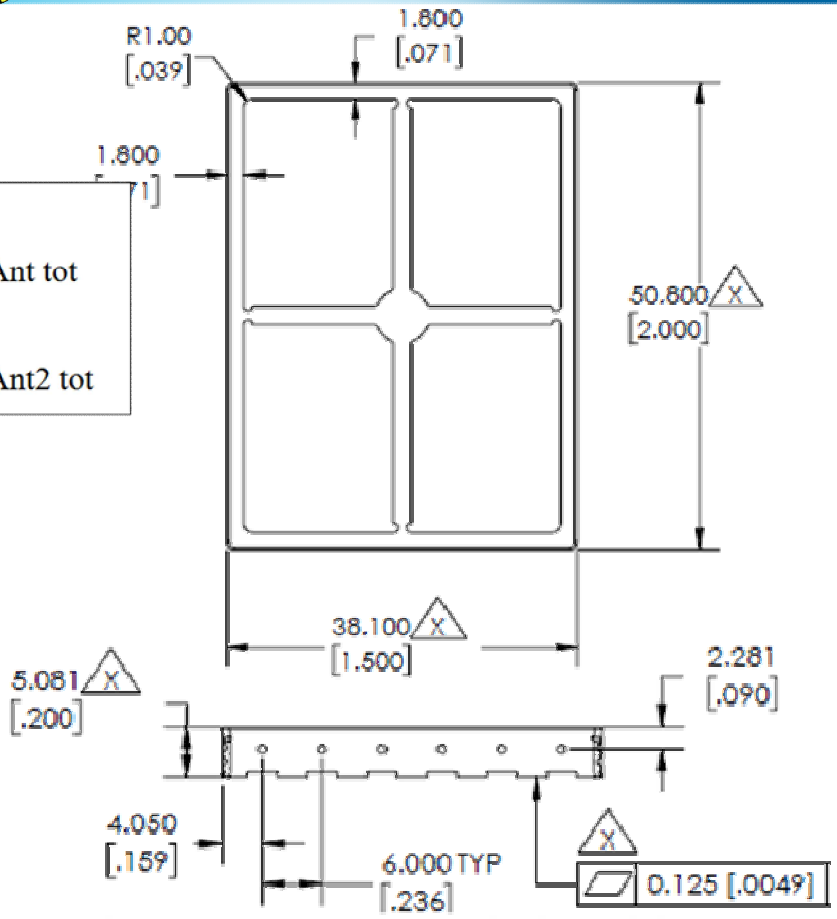
Initial measurements of Sample 2



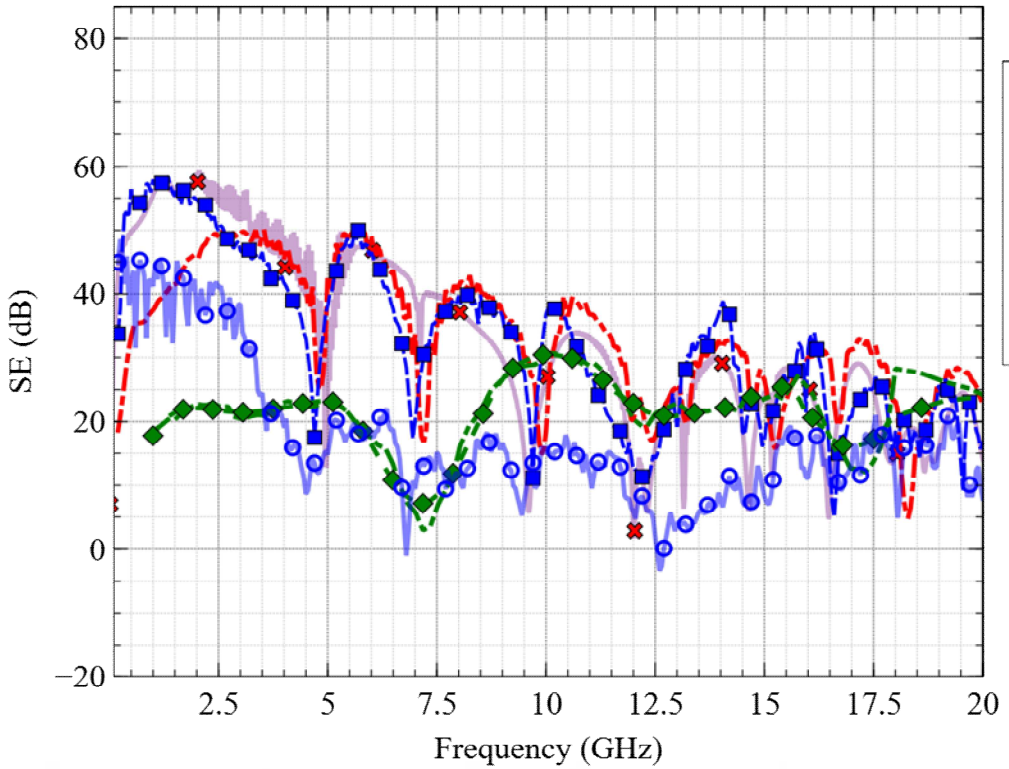


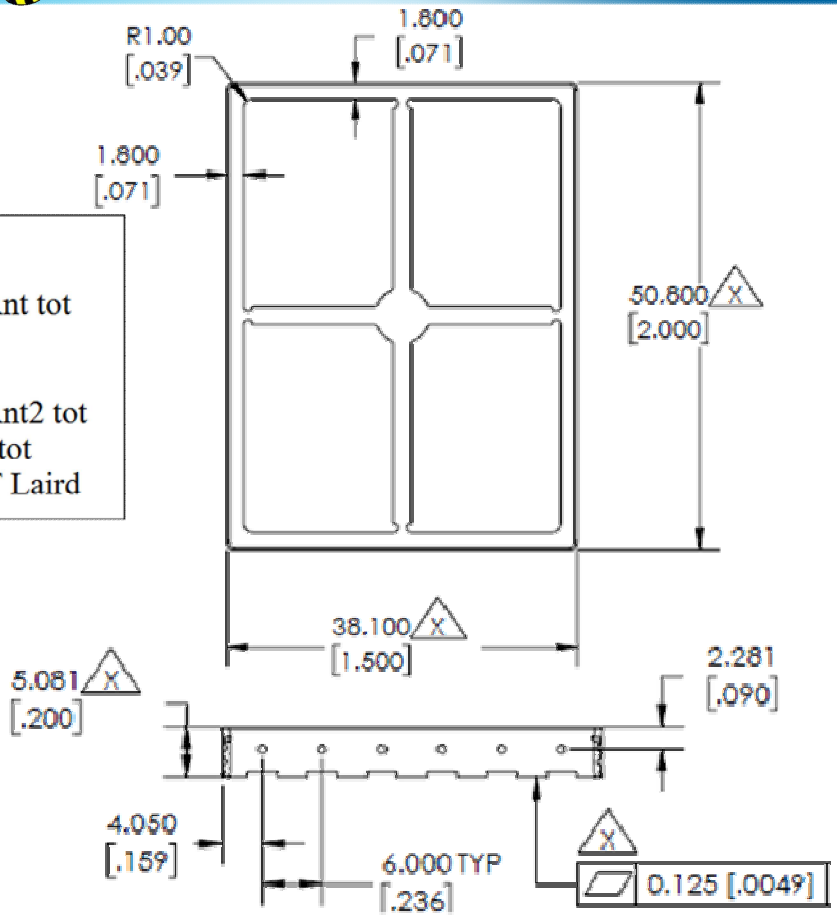
Adding UoY S3 measurement of Sample 2



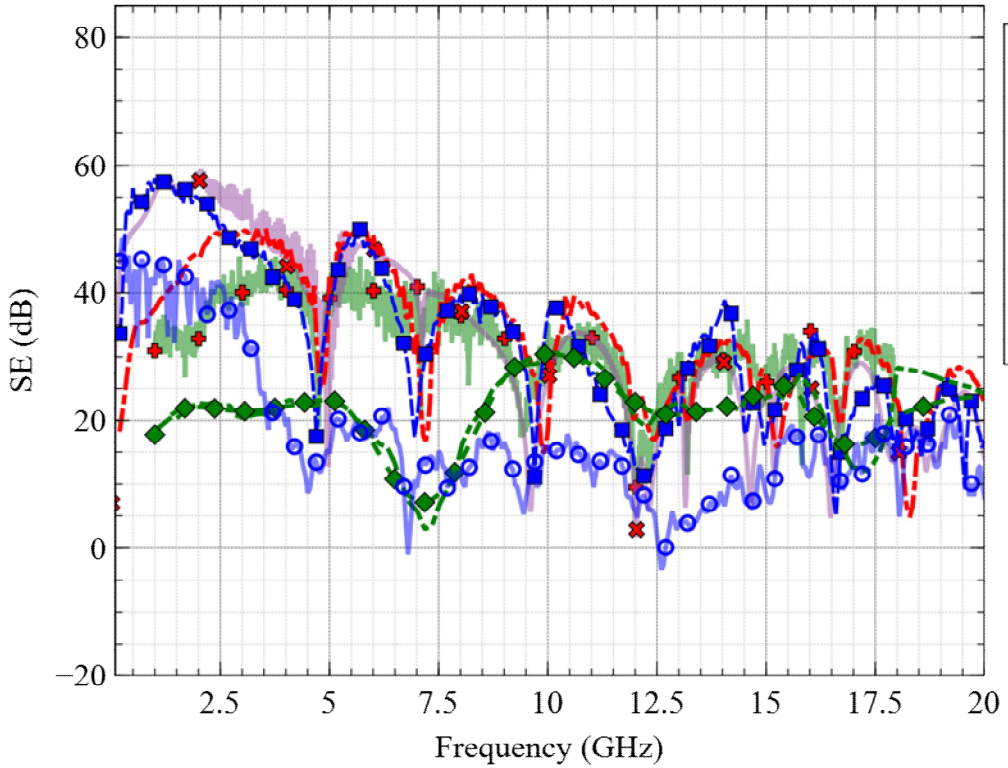


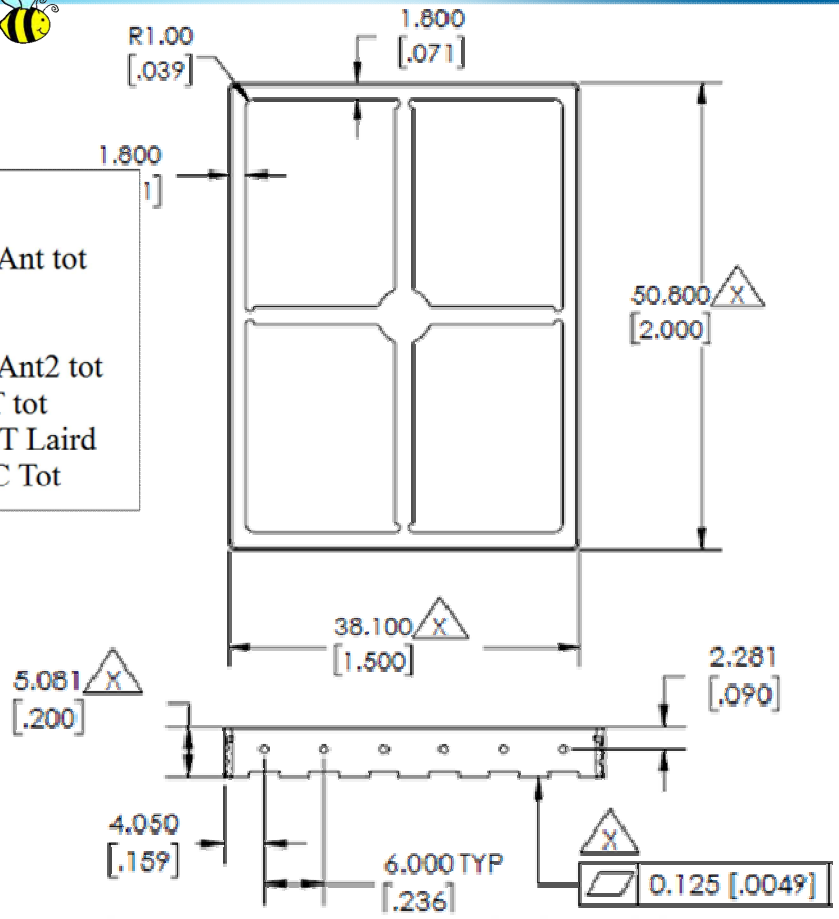
Now add UoY and Laird CST Models of Sample 2

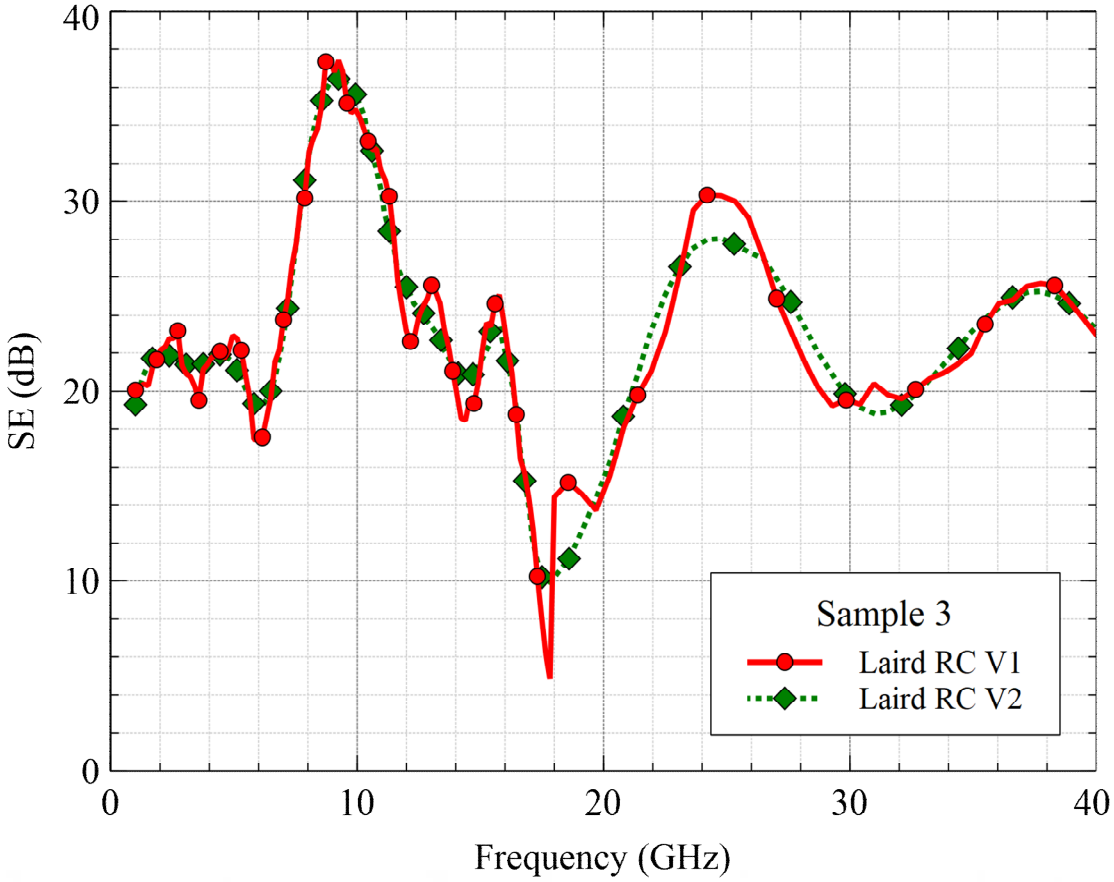


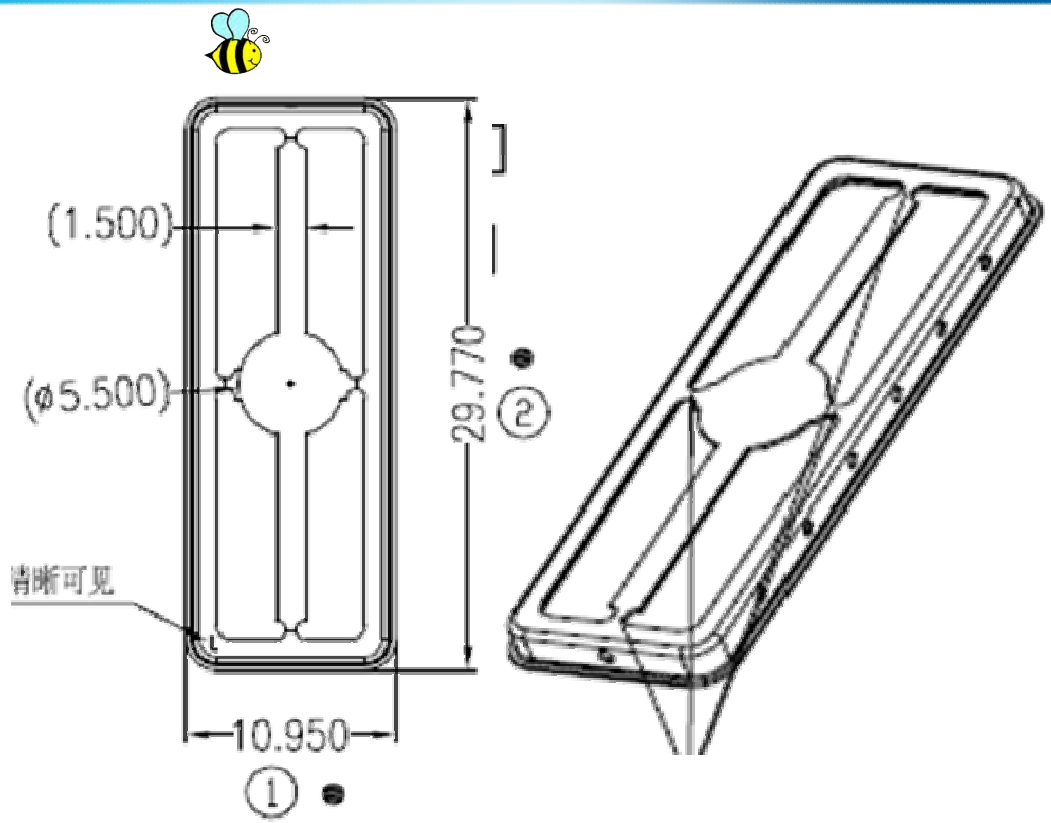


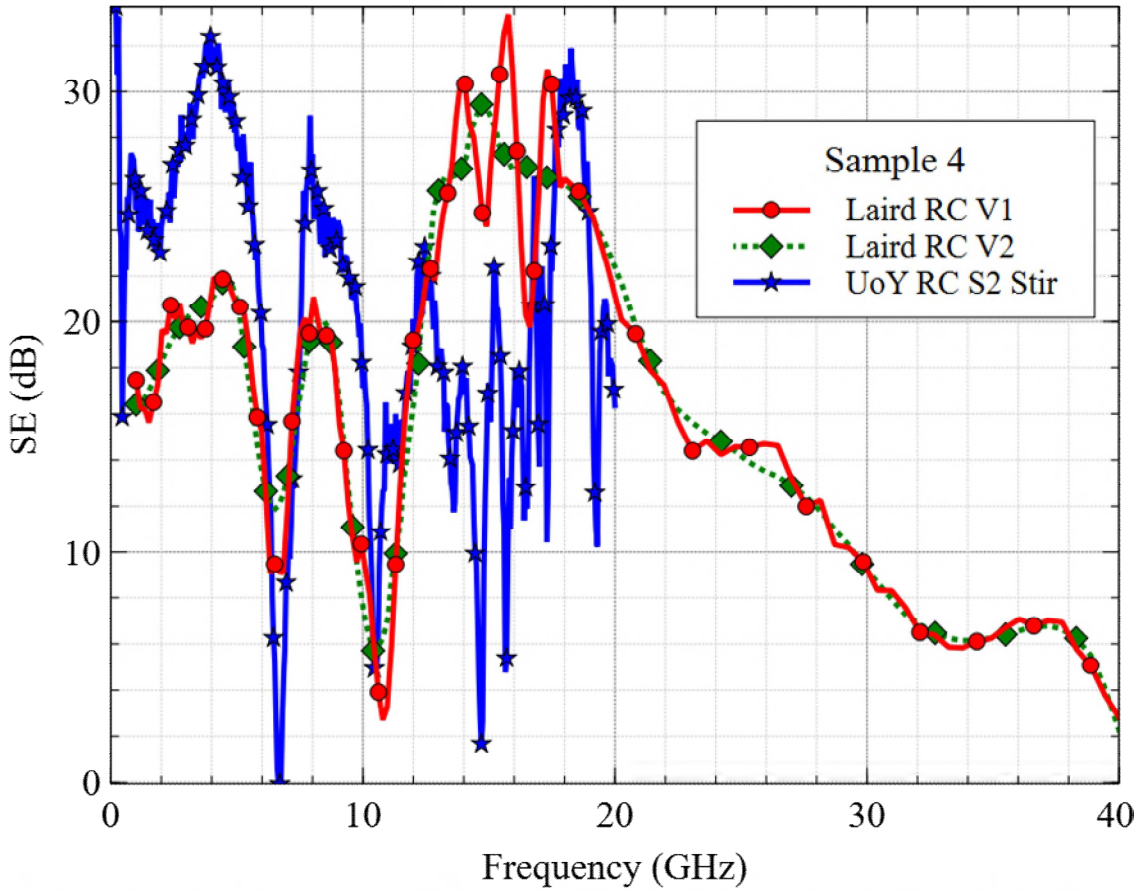
And finally Laird's V3 measurement of Sample 2

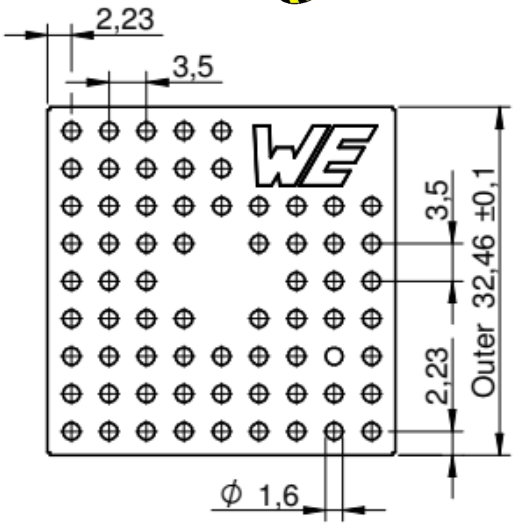


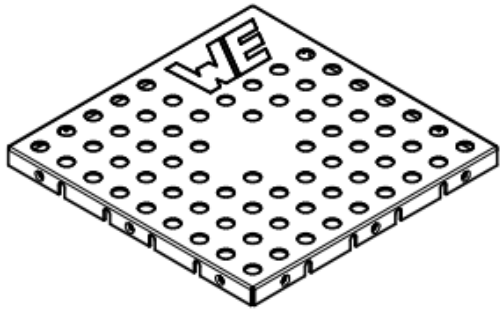


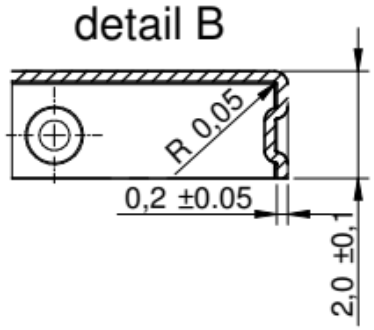

SE (dB)
Frequency (GHz)
0
10
20
30
40
Sample 3
Laird RC V1
Laird RC V2

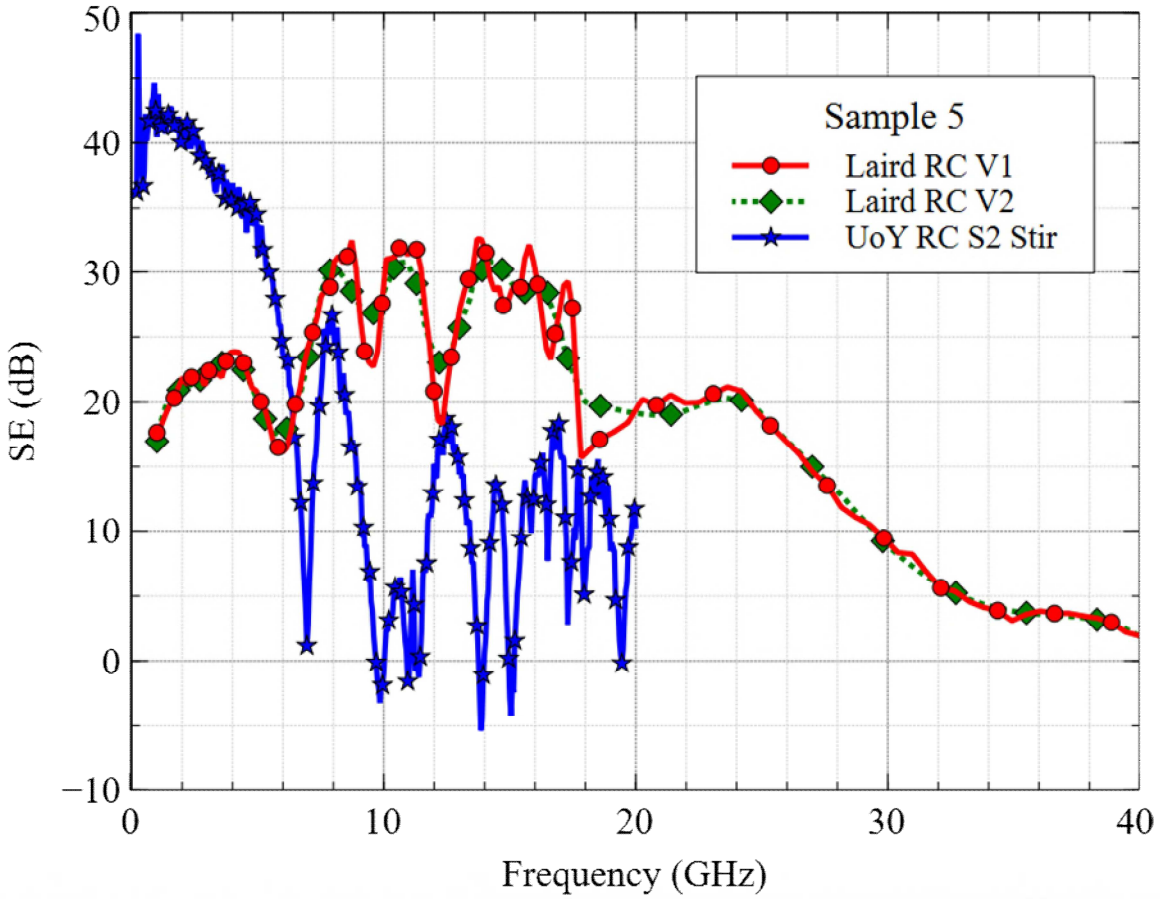

(1.500)
(ø5.500)
29.770
10.950
清晰可见
①
②

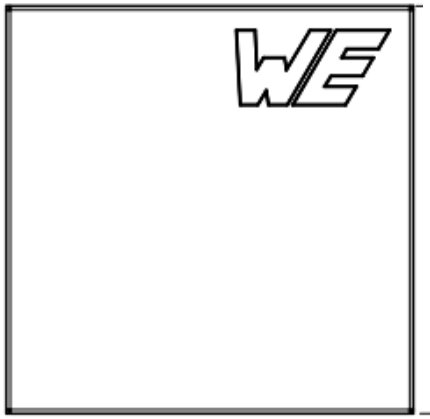

Sample 4
Laird RC V1
Laird RC V2
UoY RC S2 Stir
SE (dB)
Frequency (GHz)
0
10
20
30
40

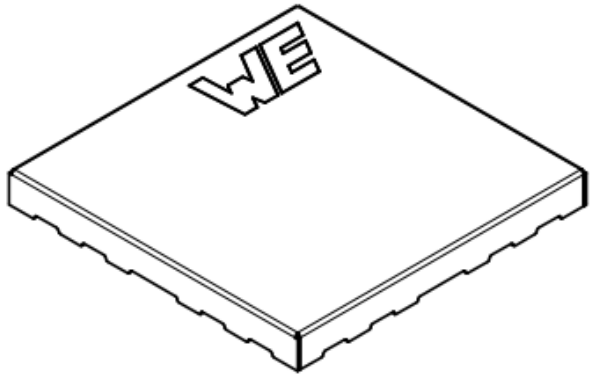

2,23
3,5
3,5
Outer 32,46 ±0,1
2,23
ϕ 1,6

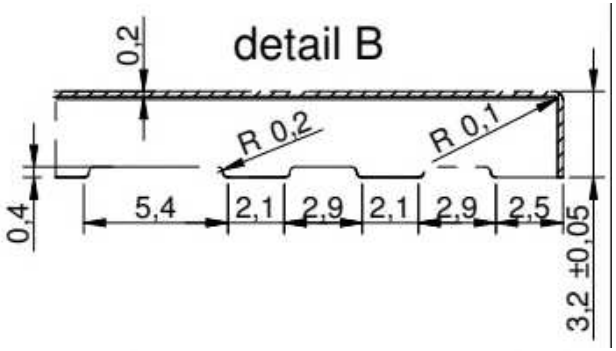


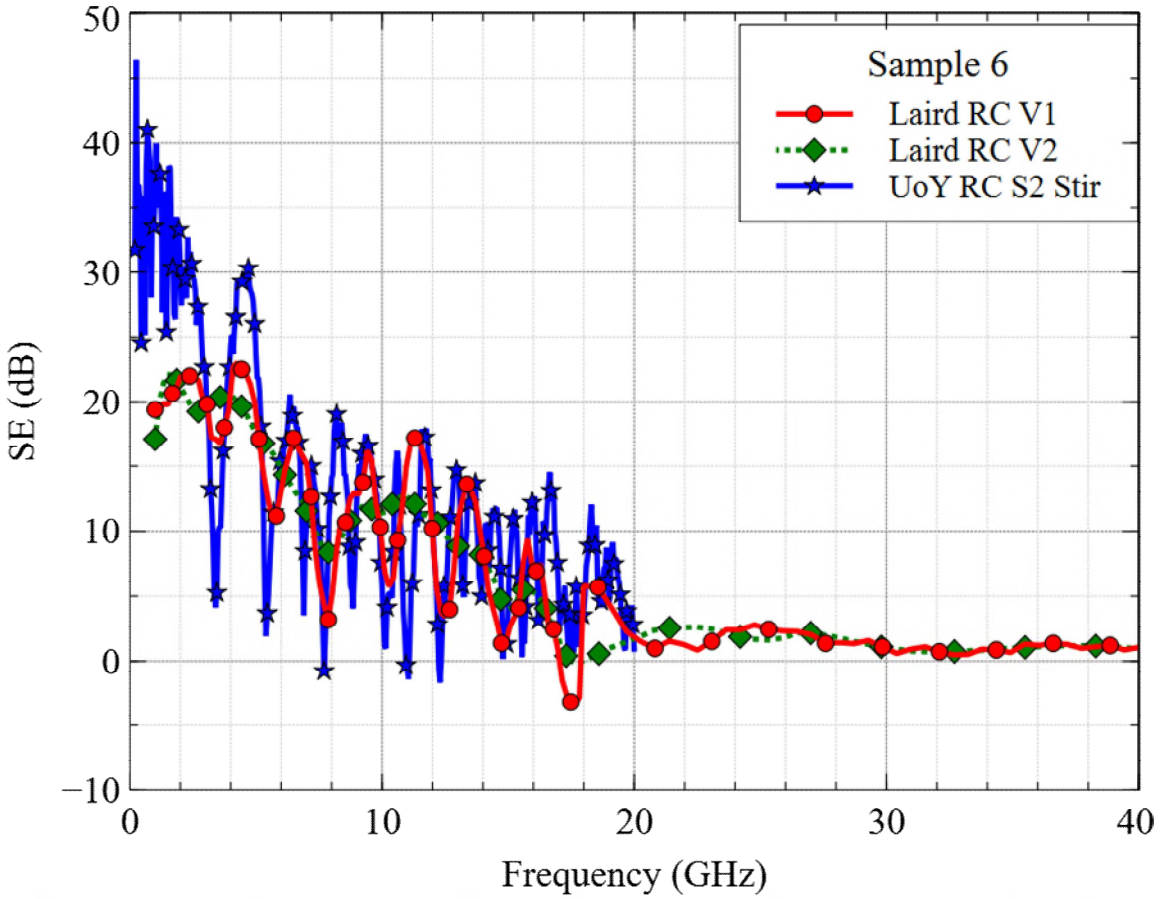

detail B
R 0,05
0,2 ±0.05
2,0 ±0,1

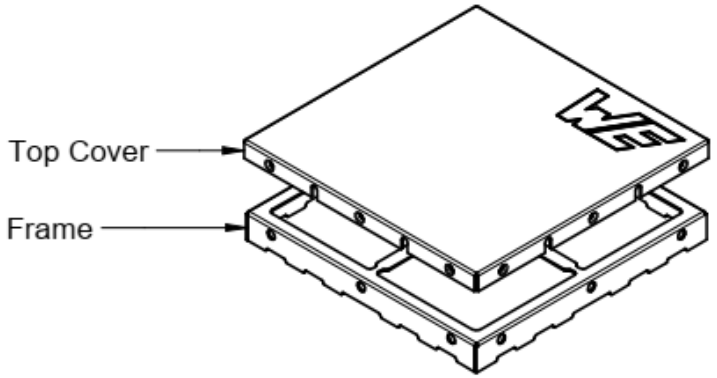

Sample 5
Laird RC V1
Laird RC V2
UoY RC S2 Stir
SE (dB)
Frequency (GHz)
50
40
30
20
10
0
−10
0
10
20
30
40

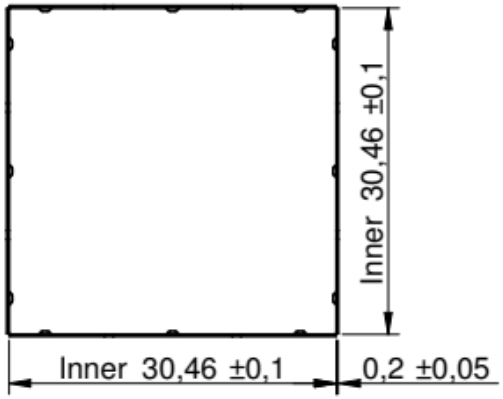

WE

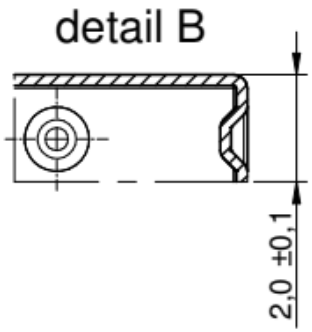

WE

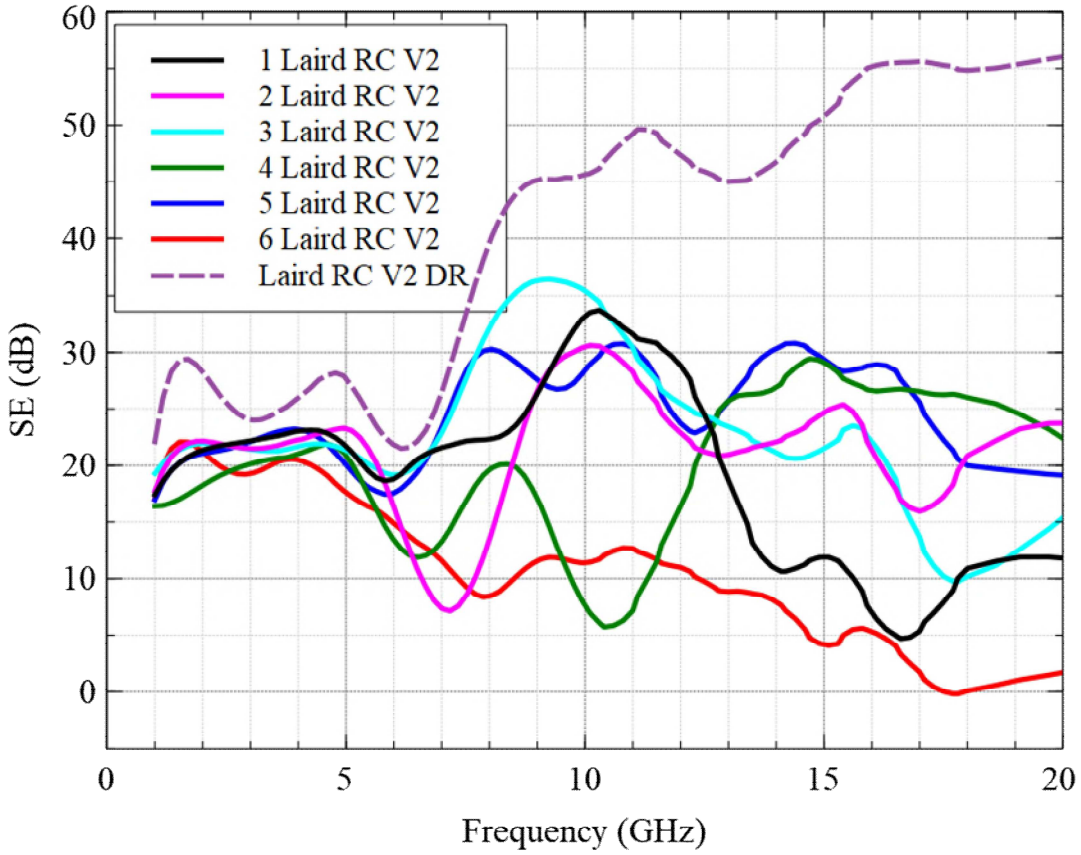

detail B
0,2
R 0,2
R 0,1
0,4
5,4
2,1
2,9
2,1
2,9
2,5
3,2 ±0,05

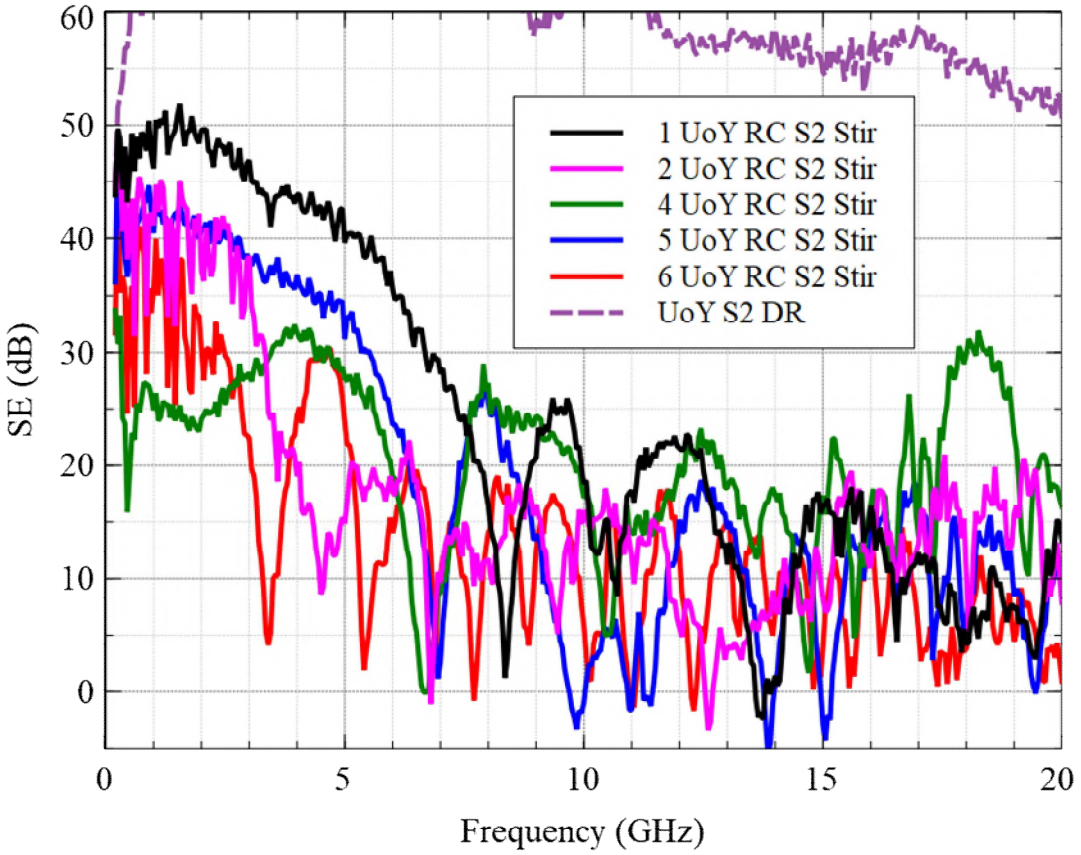

Sample 6
Laird RC V1
Laird RC V2
UoY RC S2 Stir
SE (dB)
Frequency (GHz)
50
40
30
20
10
0
−10
0
10
20
30
40


Top Cover
Frame


Inner 30,46 ±0,1
Inner 30,46 ±0,1
0,2 ±0,05


detail B
2,0 ±0,1


1 Laird RC V2
2 Laird RC V2
3 Laird RC V2
4 Laird RC V2
5 Laird RC V2
6 Laird RC V2
Laird RC V2 DR
SE (dB)
Frequency (GHz)
0
10
20
30
40
50
60
0
5
10
15
20


1 UoY RC S2 Stir
2 UoY RC S2 Stir
4 UoY RC S2 Stir
5 UoY RC S2 Stir
6 UoY RC S2 Stir
UoY S2 DR
SE (dB)
Frequency (GHz)
0
10
20
30
40
50
60
0
5
10
15
20

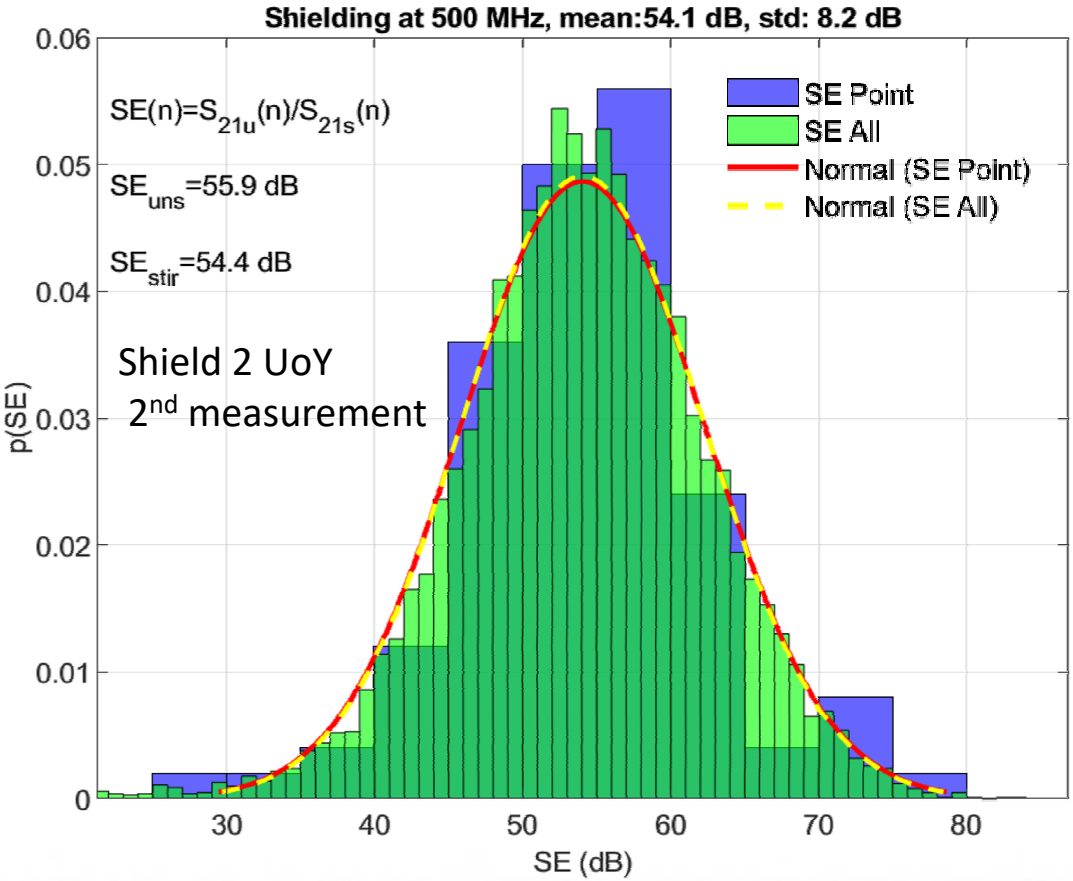
Statistics of SE

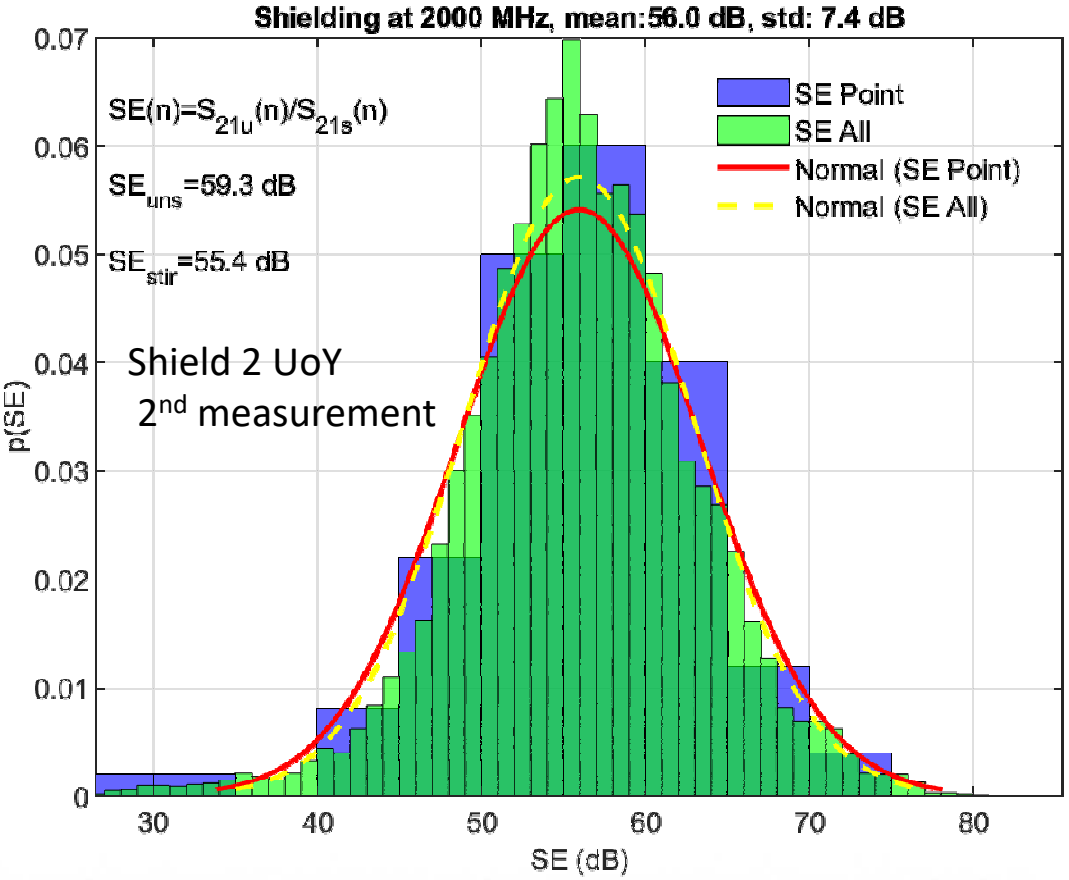
Usual definition of SE taking average of received power.

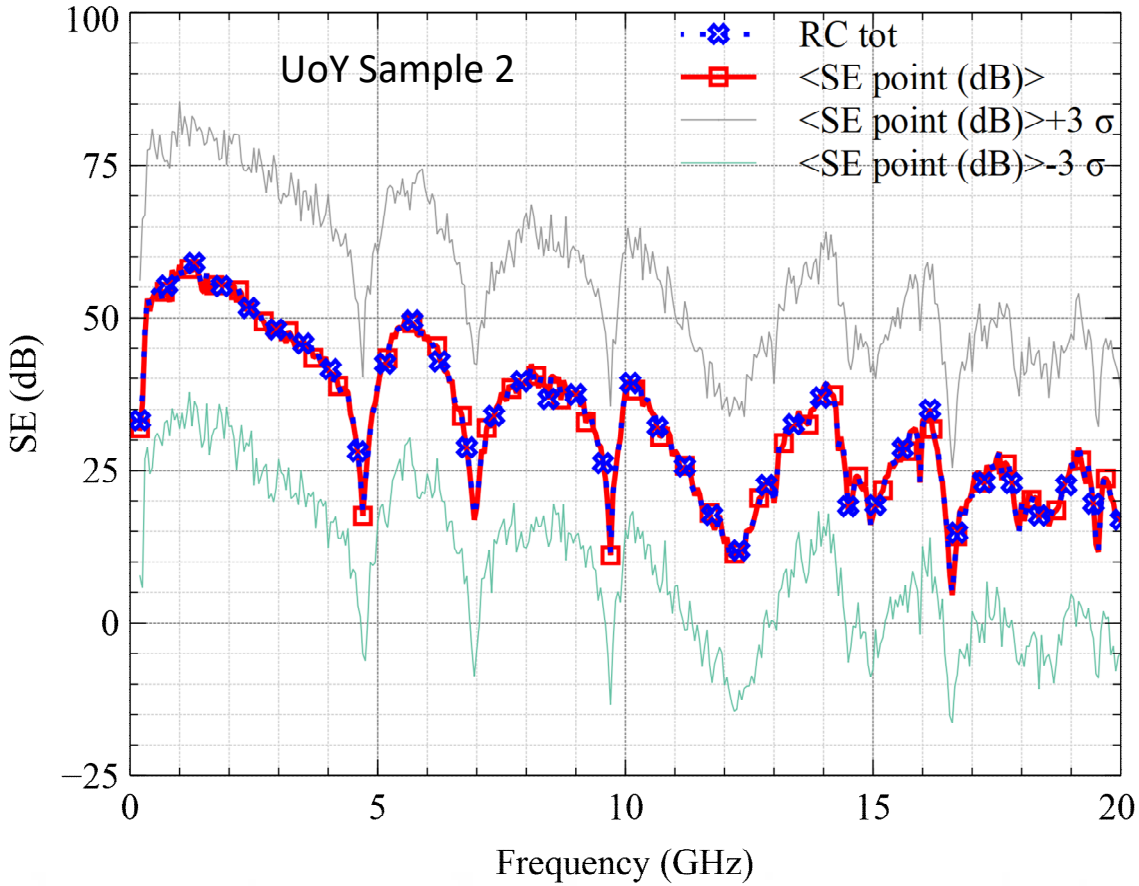
$$SE_{tot} = 10\log_{10}\left(\frac{\langle|S_{21u}|^2\rangle}{\langle|S_{21s}|^2\rangle}\right) \text{ dB}$$

The *Point SE* is the SE of the shield at each stirrer position with both direct and scattered energy included. This shows the range of variability of the SE that may be encountered in a range of external environments.

$$SE_{point(mean\ dB)} = \langle 10\log_{10}\left|\frac{S_{21u}}{S_{21s}}\right|^2\rangle \text{ dB}$$


Shielding at 500 MHz, mean:54.1 dB, std: 8.2 dB
SE(n)=S21u(n)/S21s(n)
SEuns=55.9 dB
SEstir=54.4 dB
Shield 2 UoY
2nd measurement
SE Point
SE All
Normal (SE Point)
Normal (SE All)
p(SE)
SE (dB)


Shielding at 2000 MHz, mean:56.0 dB, std: 7.4 dB
SE(n)=S21u(n)/S21s(n)
SEuns=59.3 dB
SEstir=55.4 dB
Shield 2 UoY
2nd measurement
SE Point
SE All
Normal (SE Point)
Normal (SE All)
p(SE)
SE (dB)



- $SE_{point(mean\ dB)}$ close to Std SE
- Standard deviation $\sigma \approx 8dB$
- So limits of SE variation
  - $\pm 3\sigma \approx \pm 24dB$
- In taking a mean we sometimes lose sight of reality….
- See also
  - 10.1109/EMCEUROPE48519.2020.9245741
  - and
  - "Experimental Verification of Board Level Shielding Variability at Microwave Frequencies"

Final Remarks

- Single reverb method is closest to real use
  - BUT contents still not the same as in real use which may affect result
- Measurements to date show significant difference between slightly different jigs
- Is this jig geometry or measurement/jig fault ?
  - Re-test and modelling of shield 2
  - Modelling suggests jig/measurement problem with initial measurements
  - Repeat measurements and modelling correspond more closely
- Further investigation ongoing