UNIVERSITY of York

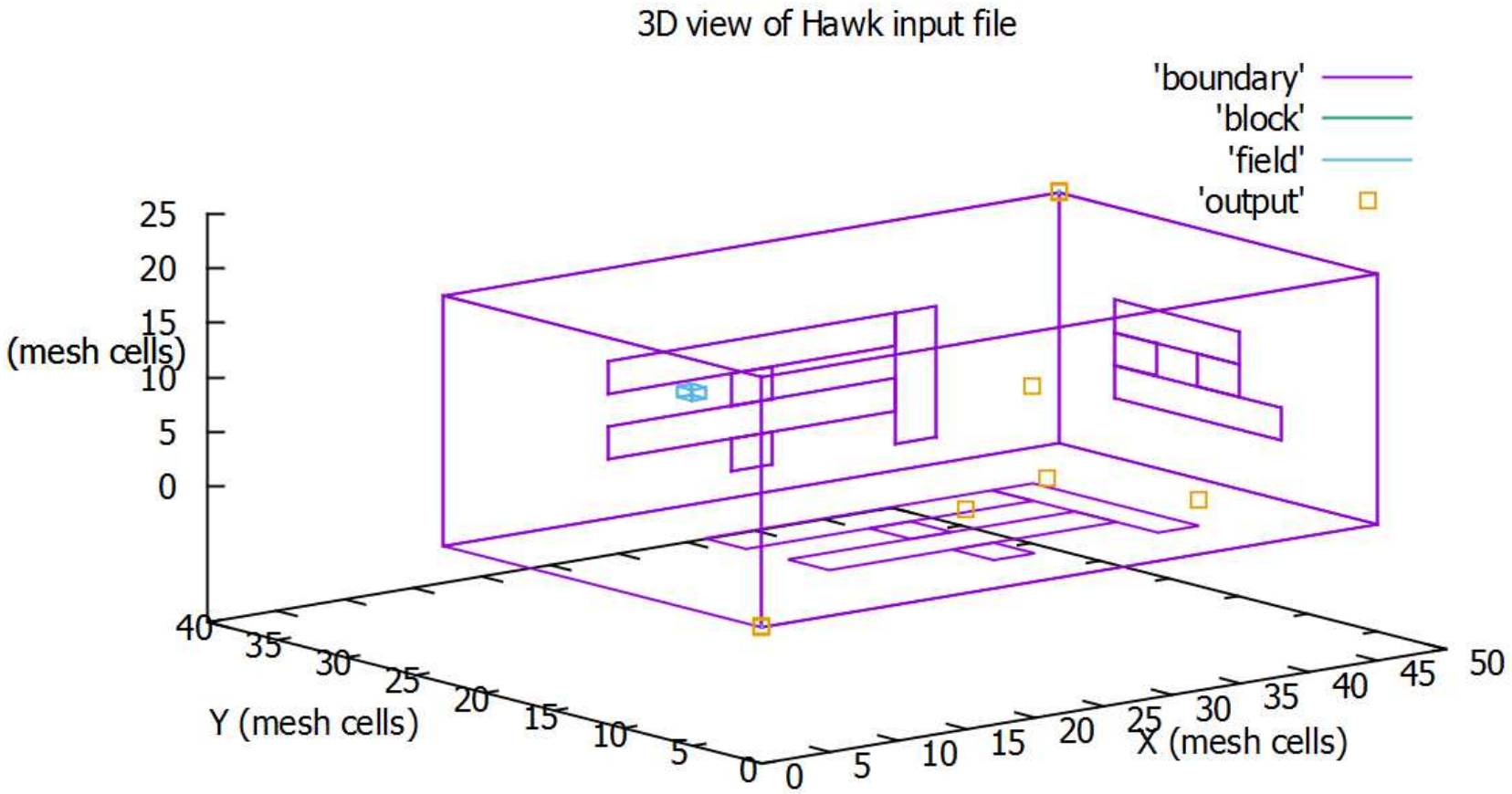
Measurement and analysis of shielding materials

Presented by: John F Dawson

With help from a cast of many including : Linda Dawson, Jackie Cole, Ian Flintoft, Janet Clegg, Iain Will, Andy Austin, Andy Marvin, Stuart Porter, Martin Robinson, John Clapham, Ran Xia, and anyone else who knows me...

And support from BAE Systems, DG Teer, Emerson and Cuming, Technical fibre products, EPSRC, York EMC Services, and University of York priming fund

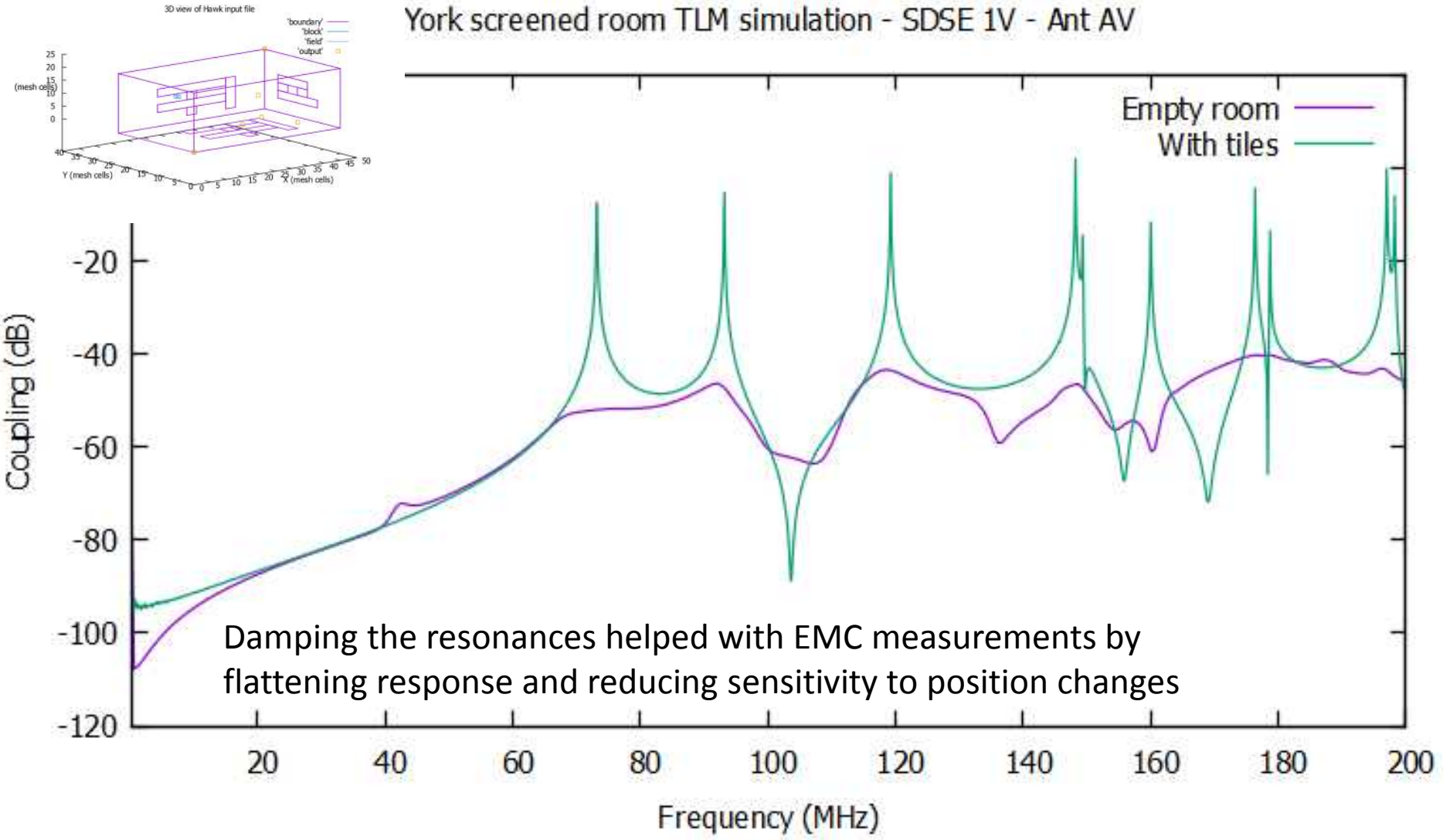
Damping of resonances in screened rooms



It all started with trying to model ferrite tiles in a screened room…
To do this we invented a new way of modelling thin layers in the TLM method.

Dawson, L.; Dawson, J.; Marvin, A. & Welsh, D. , "Damping resonances within a screened enclosure" , *IEEE Transactions on Electromagnetic Compatibility , vol. 43, no. 1* , 45-55 , Feb. , 2001 , DOI: 10.1109/15.917935

Damping of resonances in screened rooms



Dawson, L.; Dawson, J.; Marvin, A. & Welsh, D. , "Damping resonances within a screened enclosure" , *IEEE Transactions on Electromagnetic Compatibility , vol. 43, no. 1* , 45-55 , Feb. , 2001 , DOI: 10.1109/15.917935

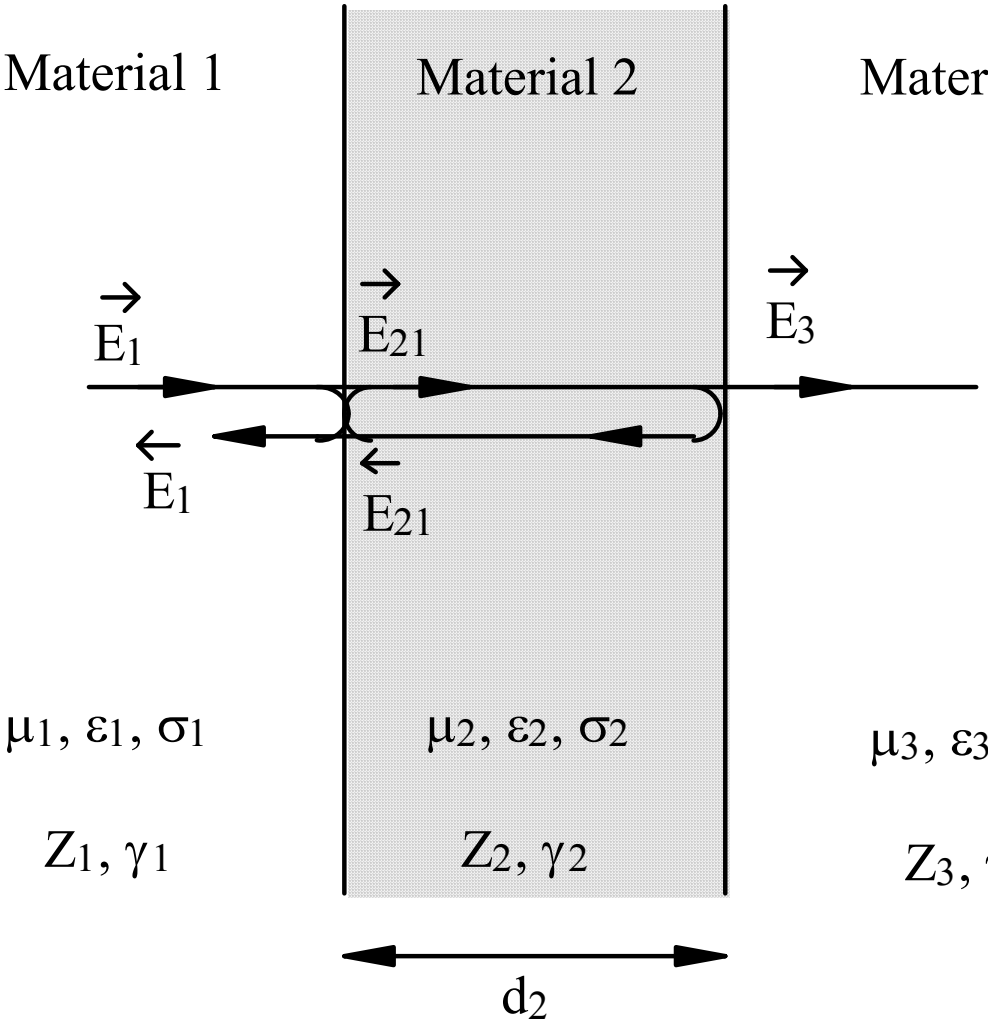
Eurofighter (Typhoon)

Meanwhile BAE Systems were trying to model the new Carbon fibre Eurofighter and asked us to look at efficient TLM models for Carbon fibre

Cole, J. A.; Dawson, J. F. & Porter, S. J. , "Efficient Modelling of Thin Conducting Sheets within the TLM method" , *Computation in Electromagnetics, Third International Conference on (Conf. Publ. No. 420) , no. Conf. Publ. No. 420* , 45-50 , 10--12 April, 1996 , DOI: 10.13140/2.1.2628.4320

https://commons.wikimedia.org/wiki/File:RAF_Eurofighter_Typhoon.jpg

Shielding of planar sheets



Shielding Effectiveness

$$SE = \frac{\overrightarrow{E_1}}{\overrightarrow{E_3}} = \frac{1 - \left(\rho e^{-\gamma d_2}\right)^2}{(1-\rho^2)e^{-\gamma d_2}}$$

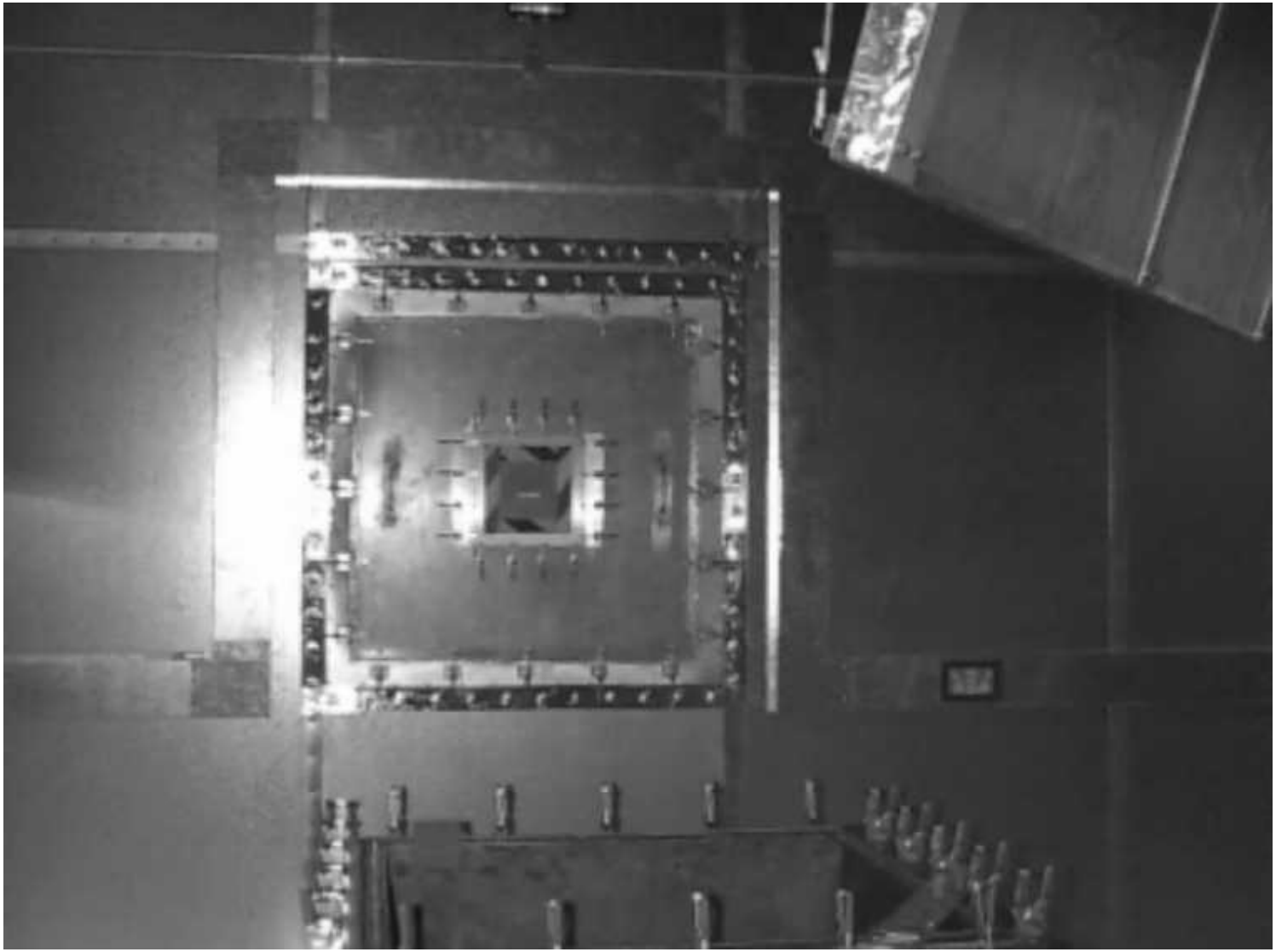
Shielding Ratio or Transmission coefficient

$$SR = \frac{\overrightarrow{E_3}}{\overrightarrow{E_1}} = \frac{(1-\rho^2)e^{-\gamma d_2}}{1-(\rho e^{-\gamma d_2})^2}$$

The plane-wave shielding of an infinite sheet depends mostly on the reflection coefficient ρ

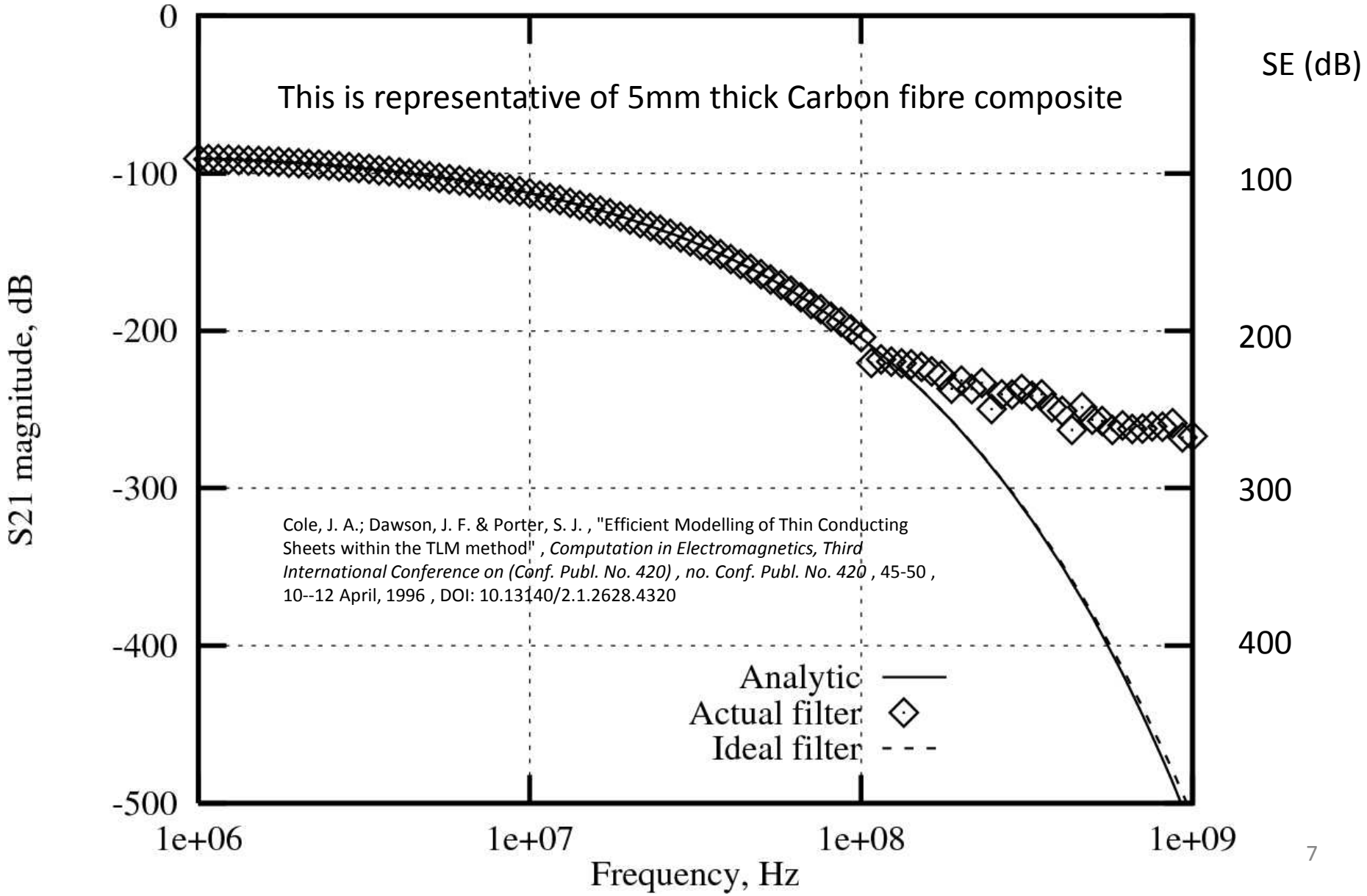
The absorption loss through the material dominates at high frequencies $e^{-\gamma d_2}$

Sample in wall between two chambers

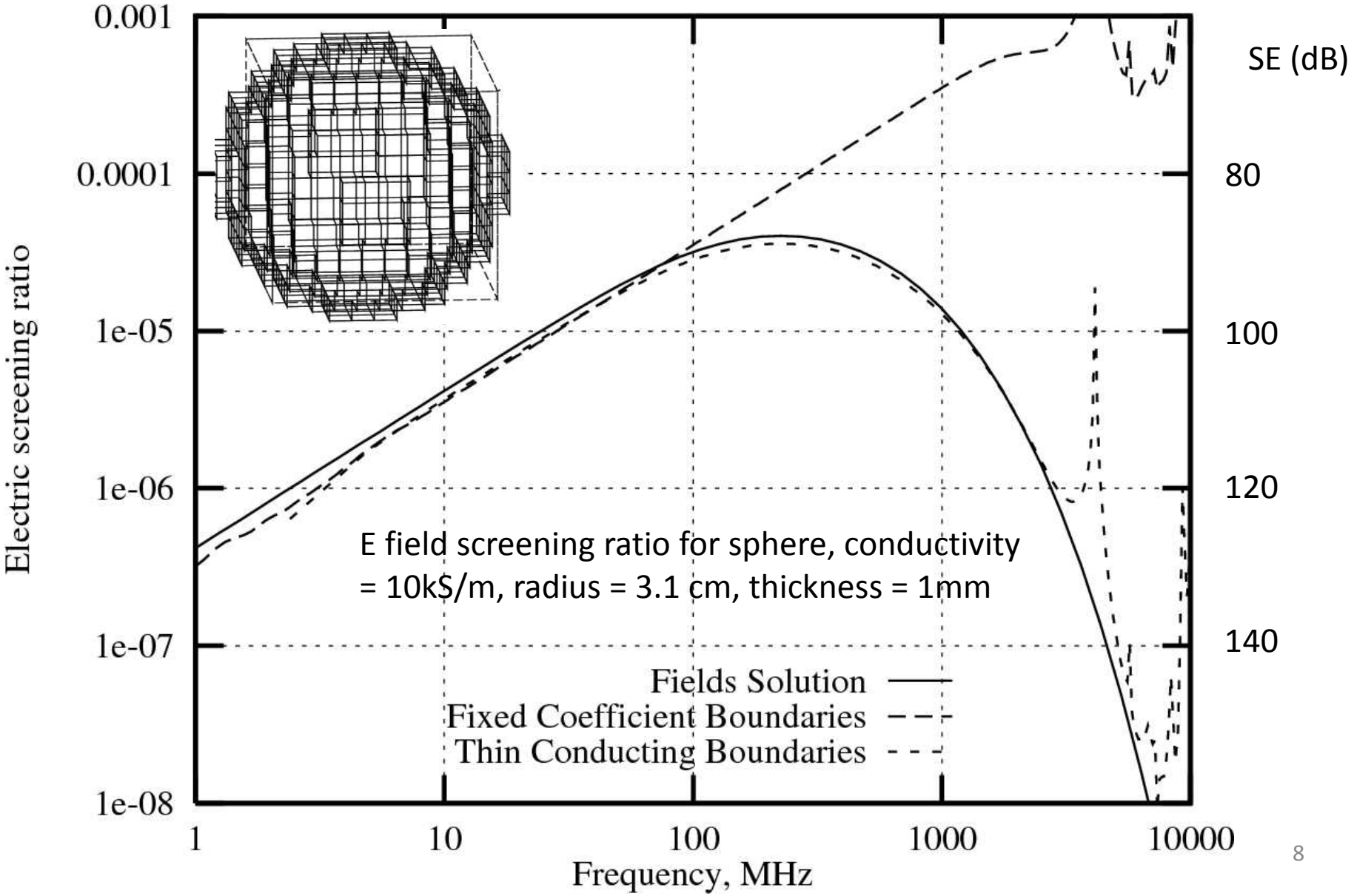


Cole, J. , "Electromagnetic modelling of composites“, PhD Thesis , *Department of Electronics, University of York , Department of Electronics, University of York , - ,* 1998

Transmission (SR) though 5mm 30kS/m sheet

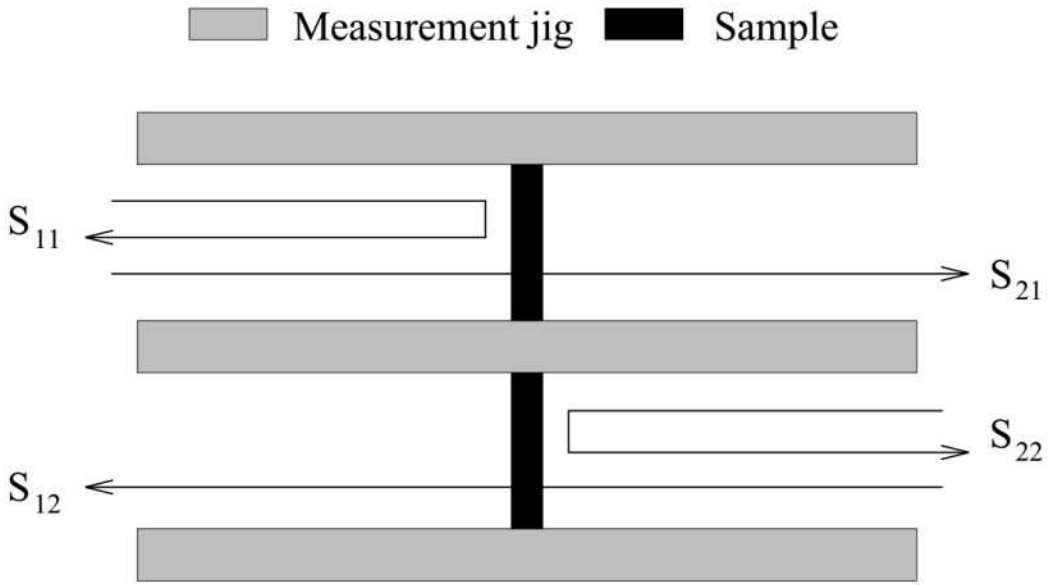


TLM models – Spherical enclosure SE



The Coaxial test-jig

Planar sample in a coaxial waveguide

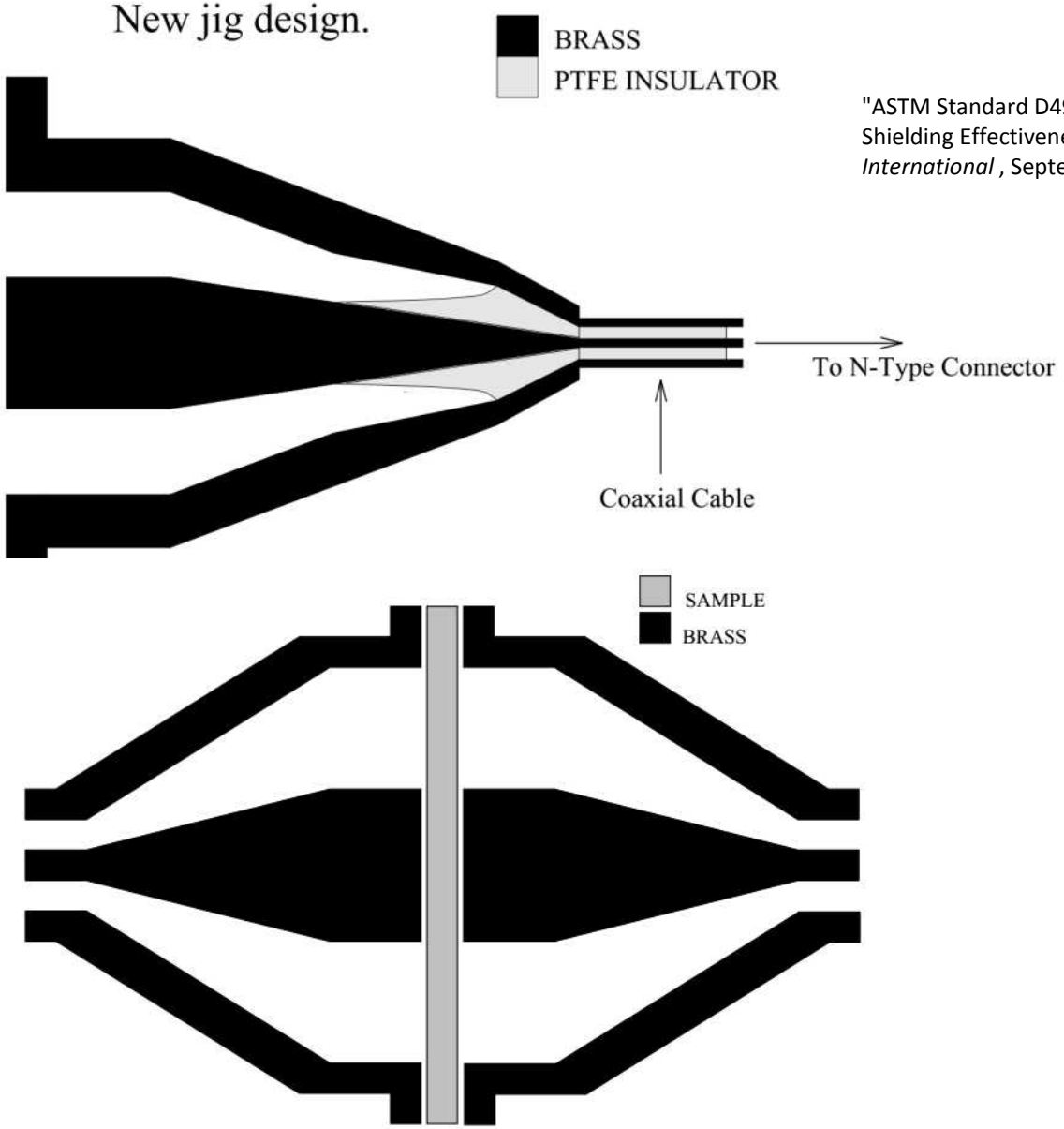


Cole, J. , "Electromagnetic modelling of composites" , PhD Thesis, *Department of Electronics, University of York* , 1998
Fig 4.3

In order to measure the transmission (SR) and hence SE of a planar sample we may

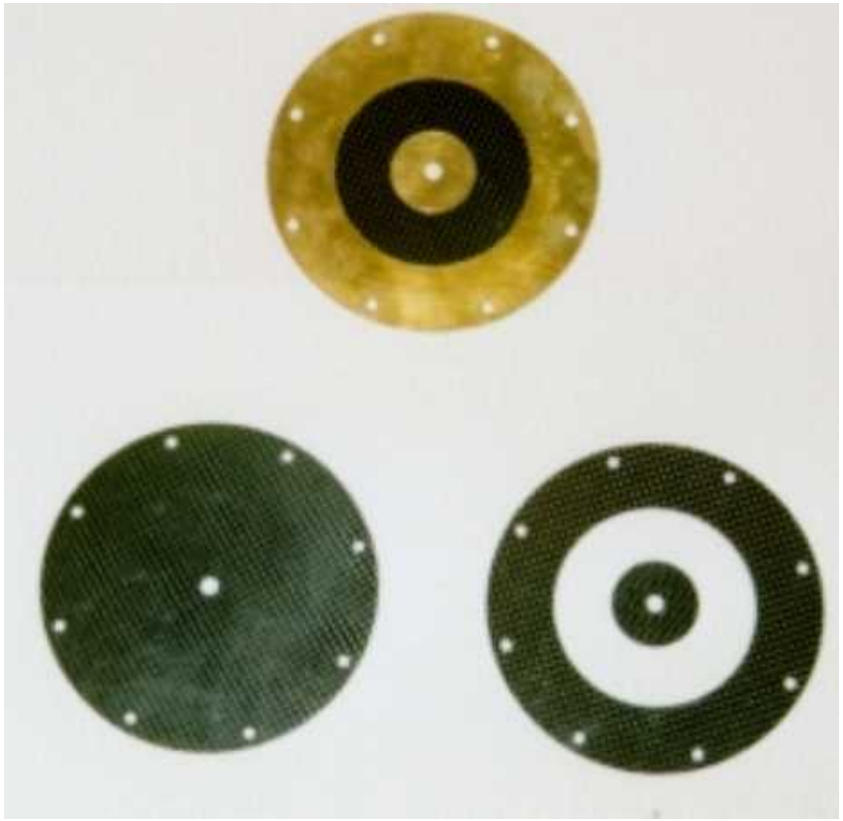
- Put it in a waveguide (as above)
- put it a gap between two screened enclosures
- Try to measure in free space

The ASTM Coaxial test-jig



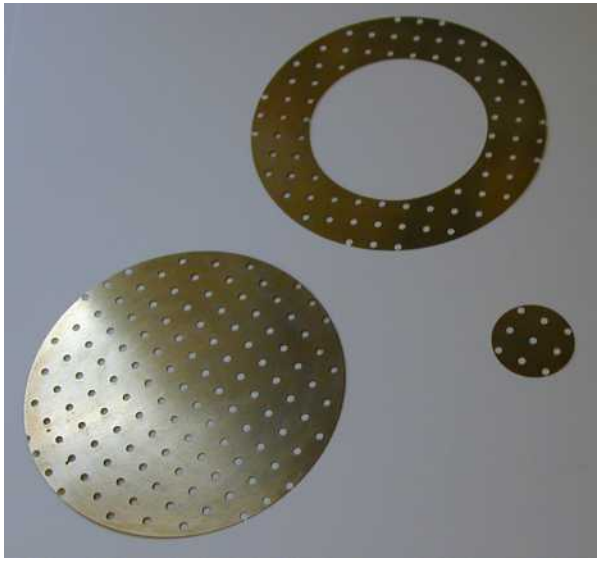
"ASTM Standard D4935-10 Test Method for Measuring the Electromagnetic Shielding Effectiveness of Planar Materials" , *ASTM International* , *ASTM International* , September 2010. , DOI: 10.1520/D4935-10

Coaxial test samples



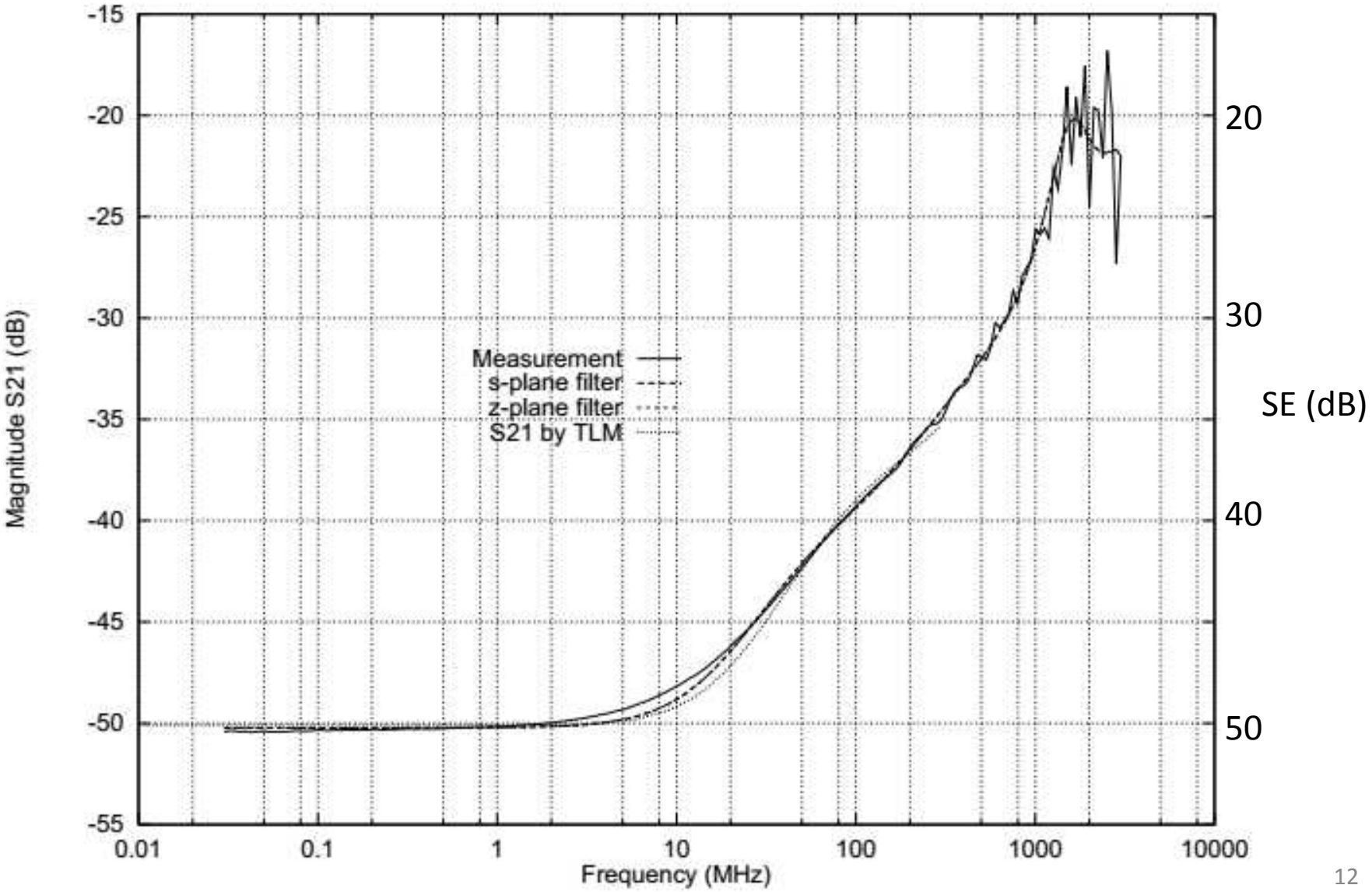
CFC Samples

Knitted Sample



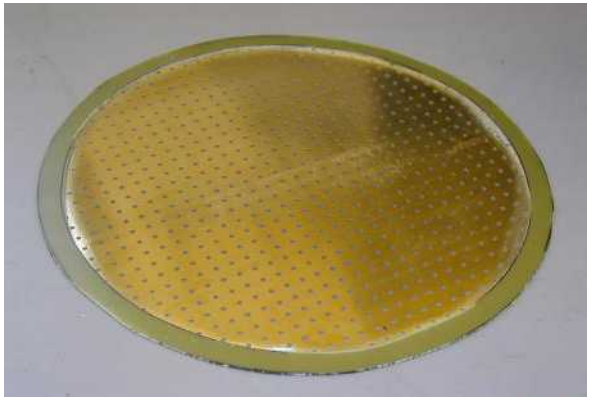
Perforated Brass Samples

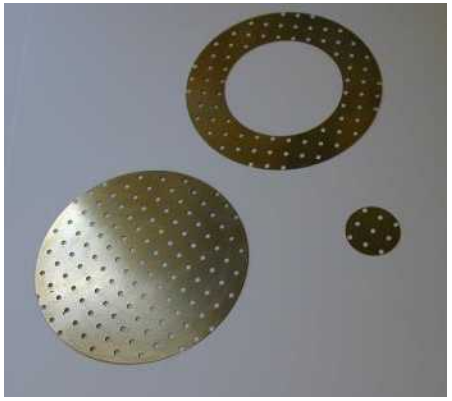
Knitted Pre-preg with PVD metalisation

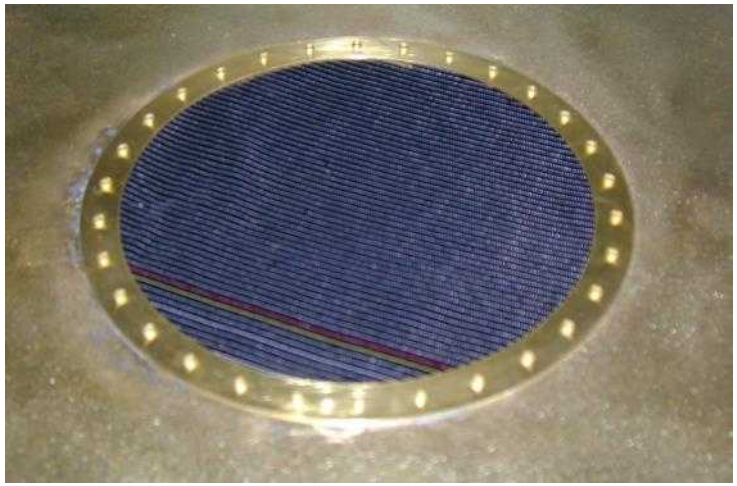


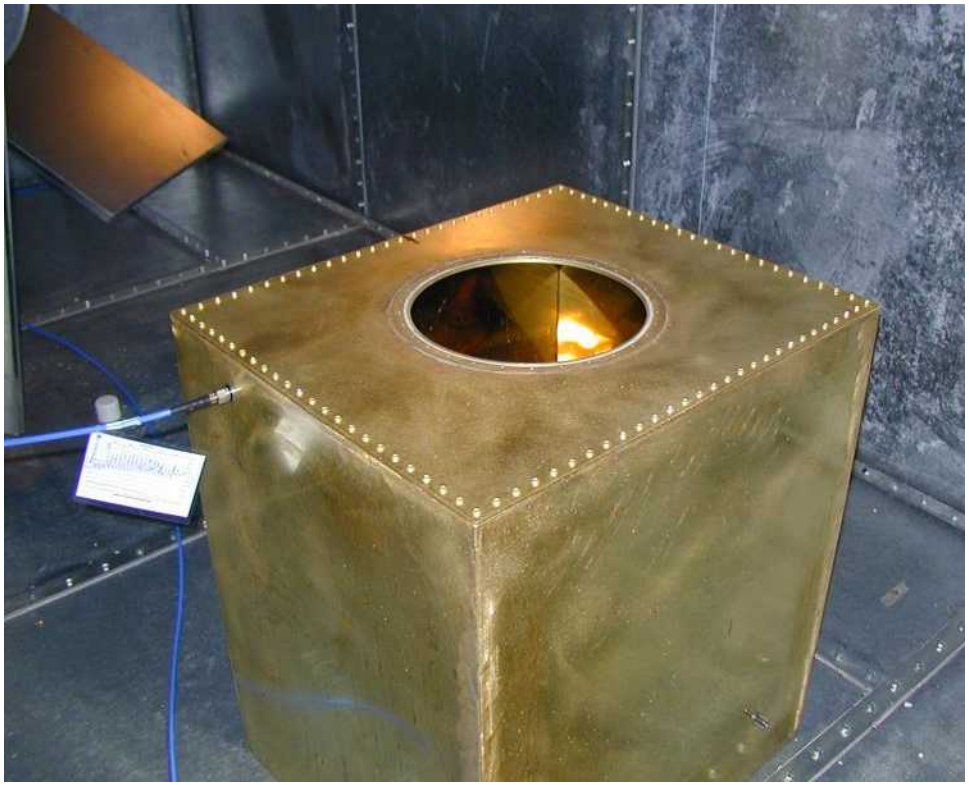
Going up in frequency: the reverb chamber

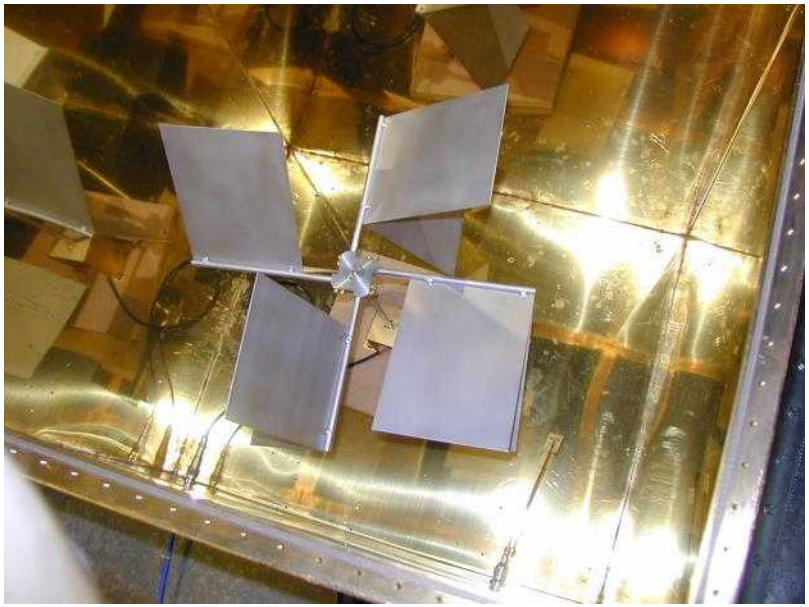
Going up in frequency: the reverb chamber



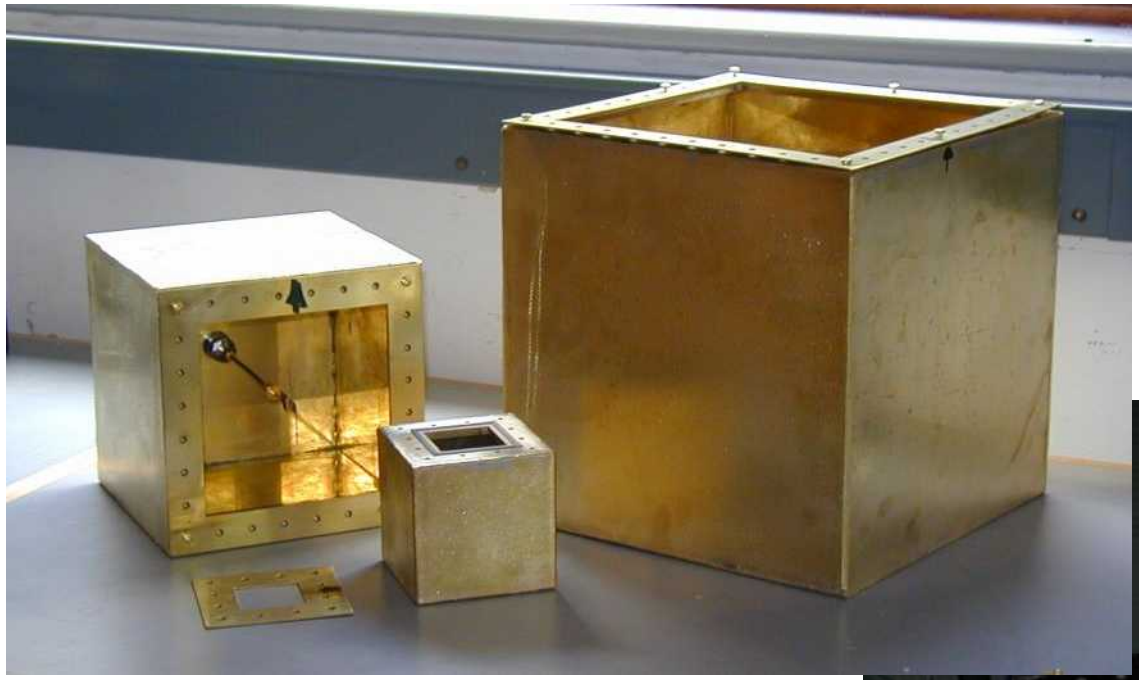




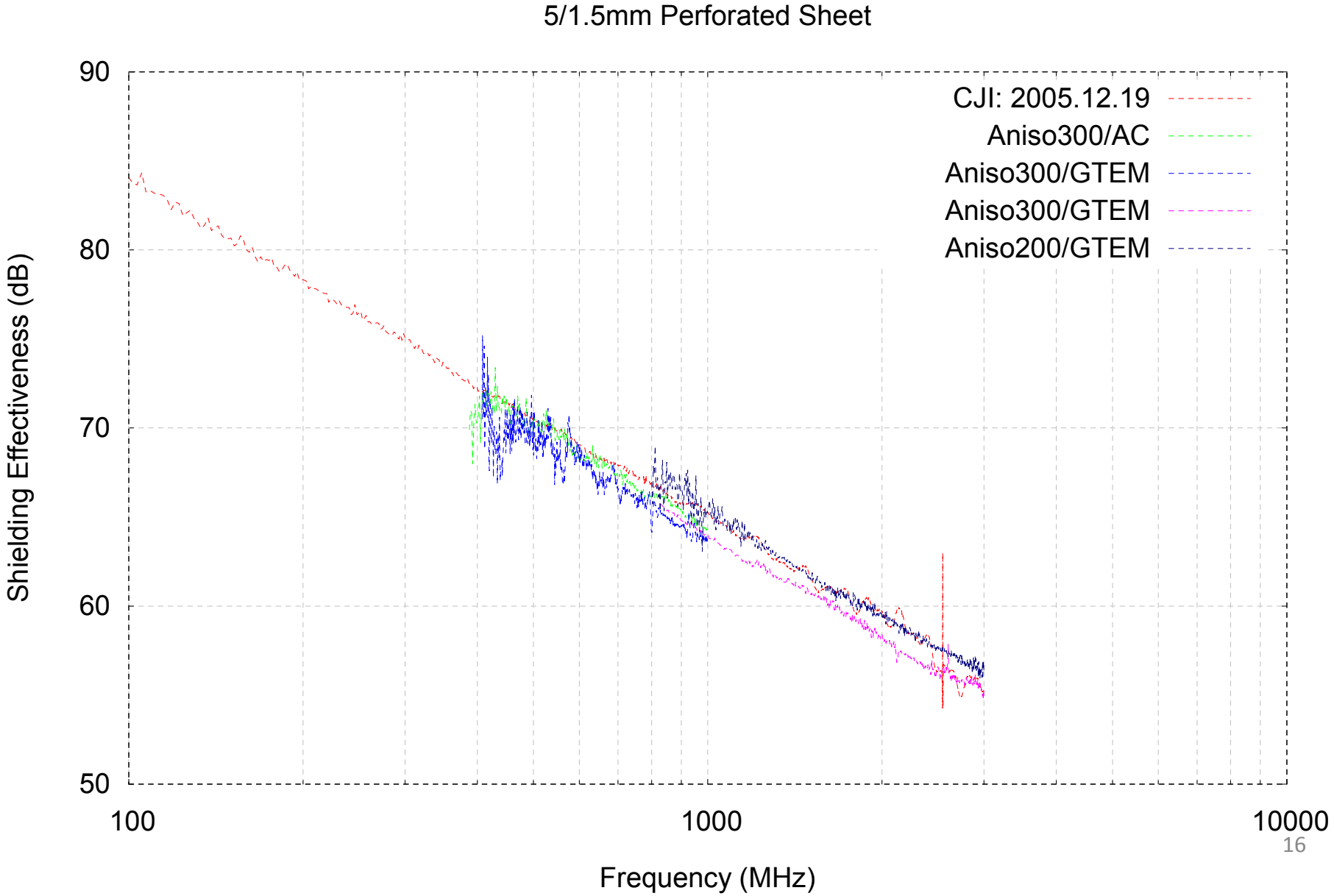




Anisotropy

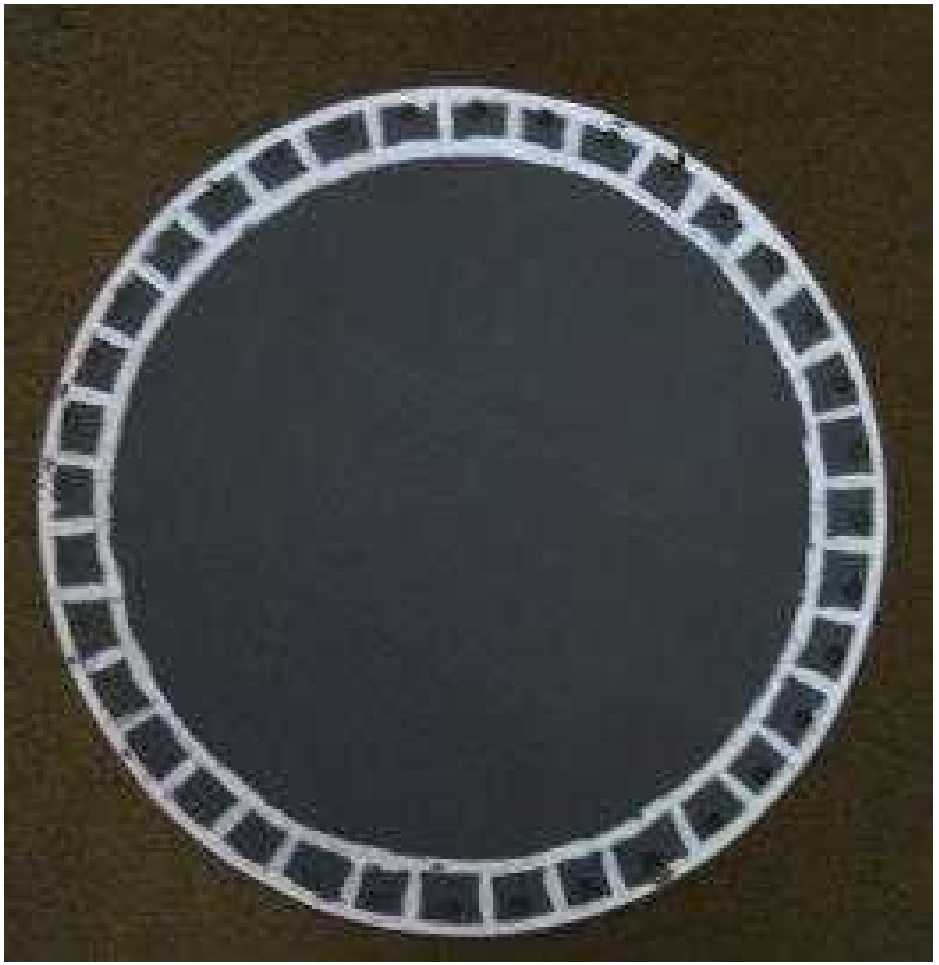


Comparison of methods

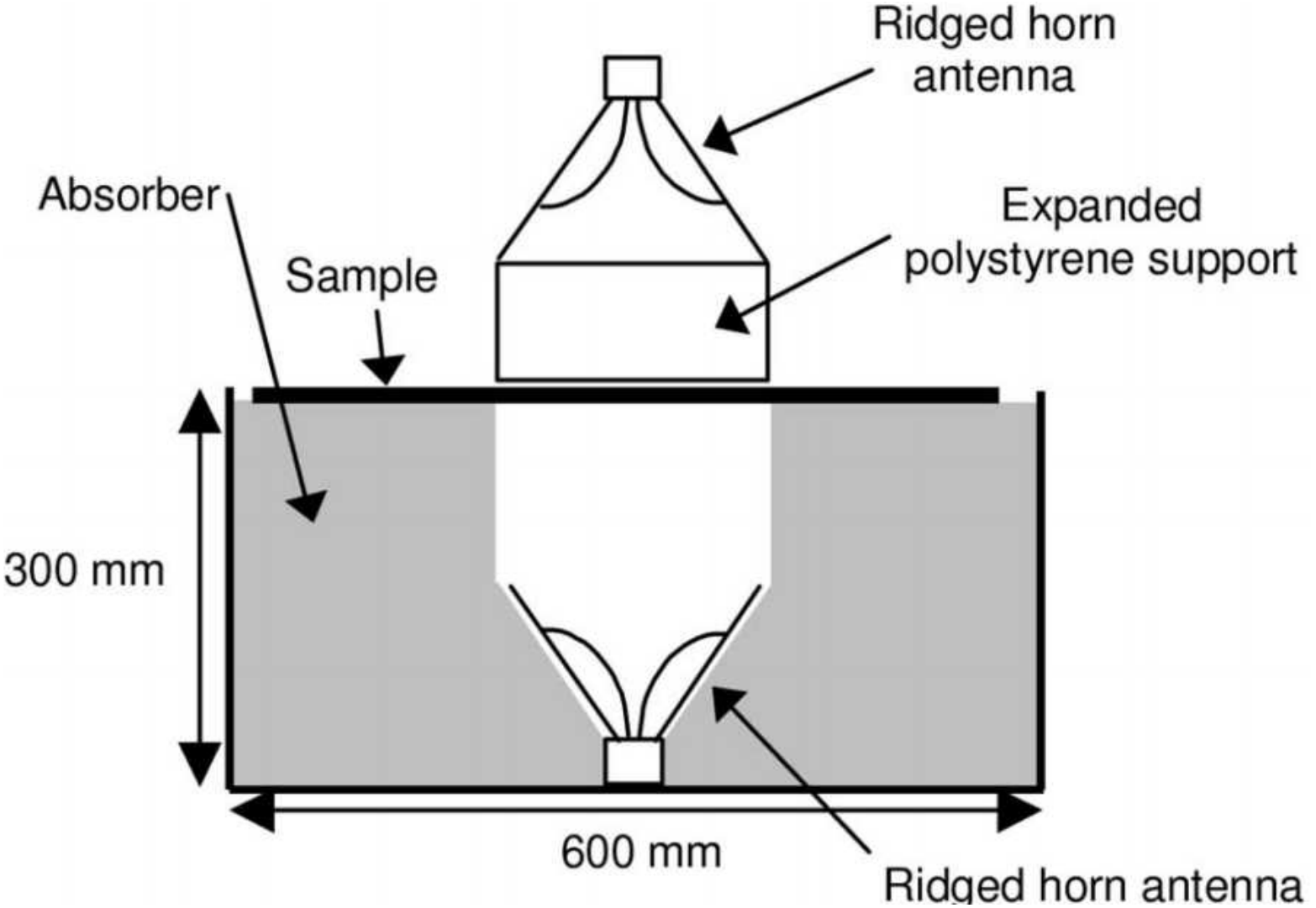


The problem of surface preparation

- Sample and surface preparation is a difficult and time consuming process
- Samples with non-conducting surfaces present particular problems



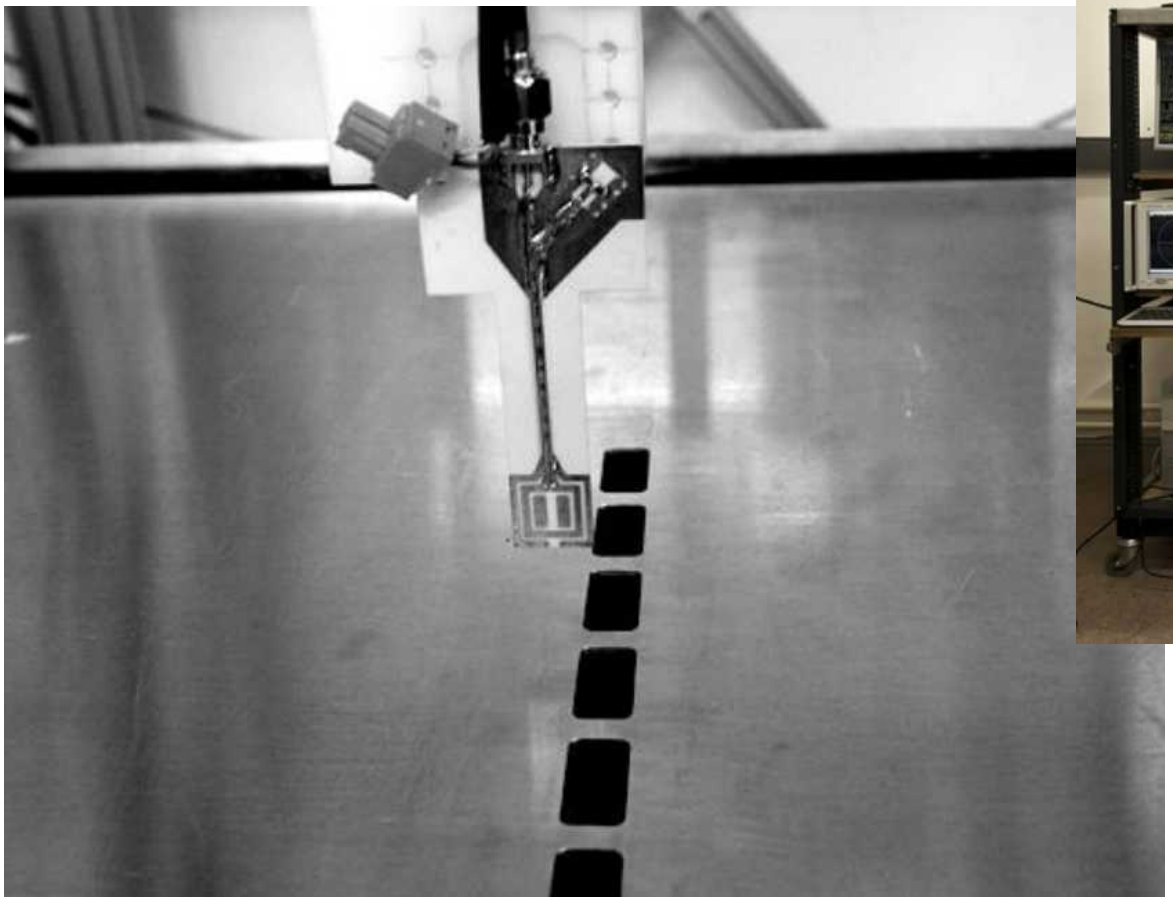
The Absorber box method for SE measurement



Marvin, A. C.; Dawson, L.; Flintoft, I. D. & Dawson, J. F. , "A Method for the Measurement of Shielding Effectiveness of Planar Samples Requiring No Sample Edge Preparation or Contact" , *IEEE Transactions on Electromagnetic Compatibility* , *vol. 51, no. 2* , 255-262 , May, 2009 , DOI: 10.1109/TEMC.2009.2015147

The Absorber box

The Absorber box with 3D scanner



Xia, R.; Dawson, J. F.; Flintoft, I. D.; Marvin, A. C. & Porter, S. J. , "Use of a Genetic Algorithm in Modelling Small Structures in Airframes" , *EMC Europe 2012* , 1 - 5 , 2012 , DOI: 10.1109/EMCEurope.2012.6396718

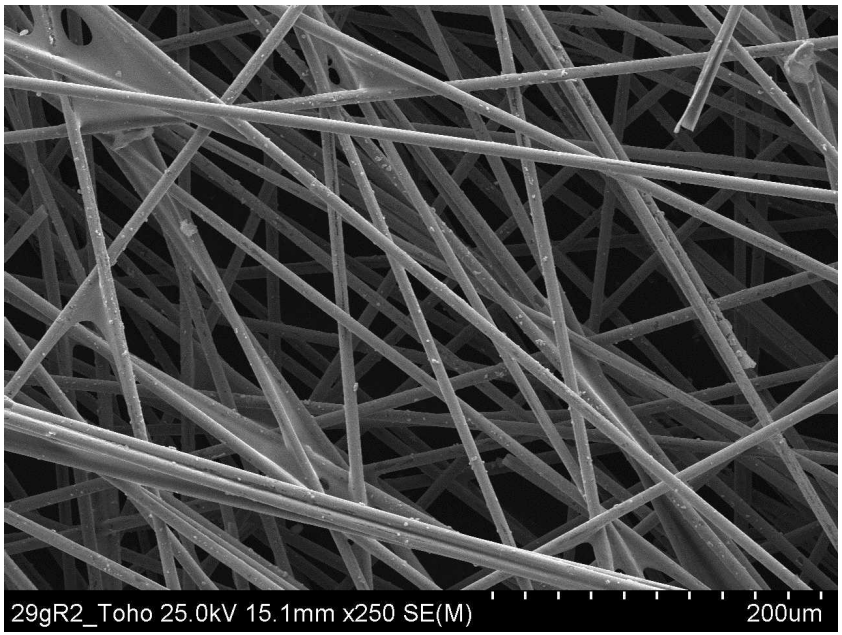
Scanning fields penetrating the slot panel

Non-woven materials

Nonwoven carbon fibre sheet

http://www.tfpglobal.com/products/optiveil/optiveil-for-emi-shielding/

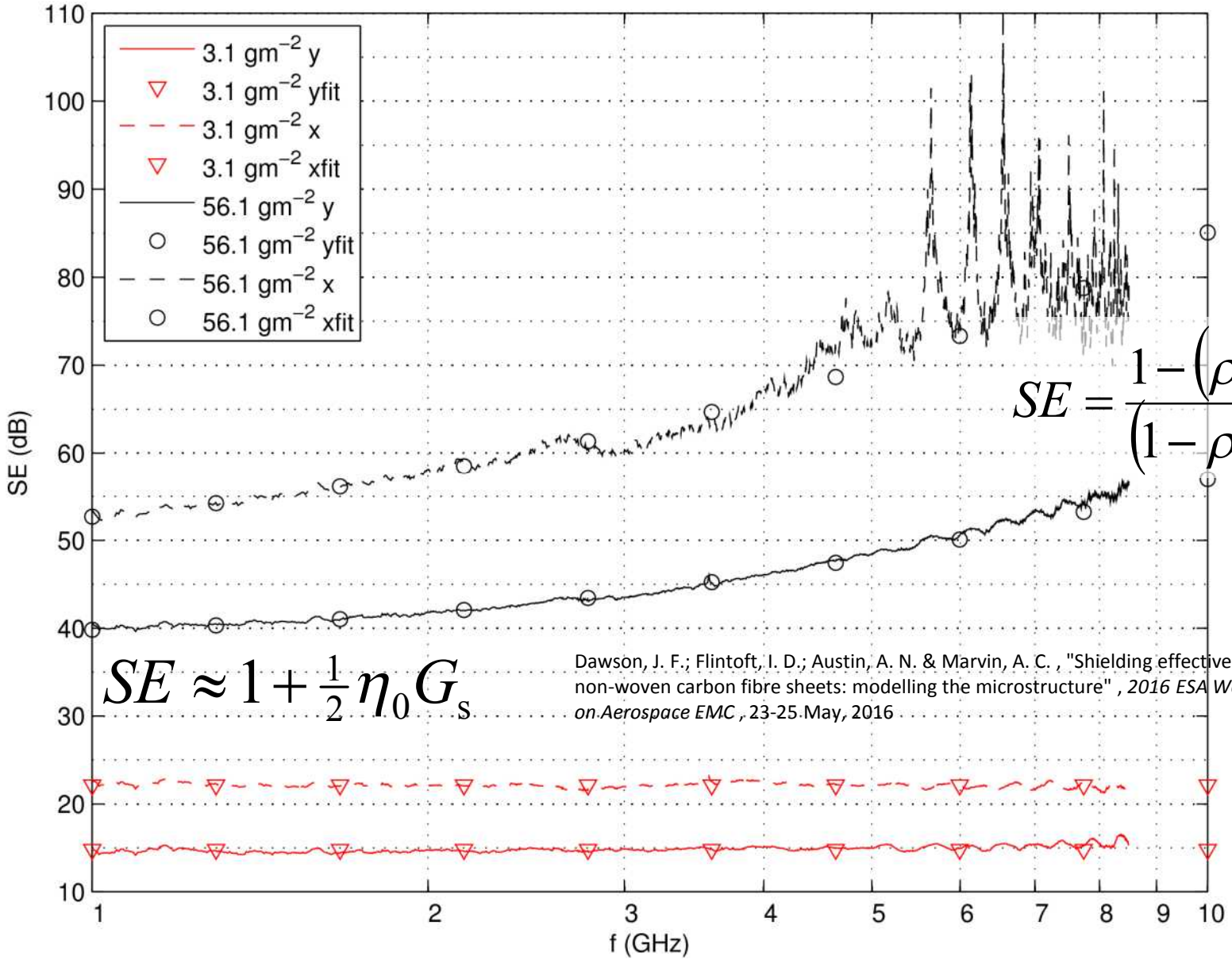
Nonwoven carbon fibre sheet (SEM)



Courtesy of technical fibre products

12 mm long carbon fibres
7 um in diameter
σ = 72 kS/m
Areal densities 4-75 gm^{-2}

Shielding Effectiveness of CF Nonwoven

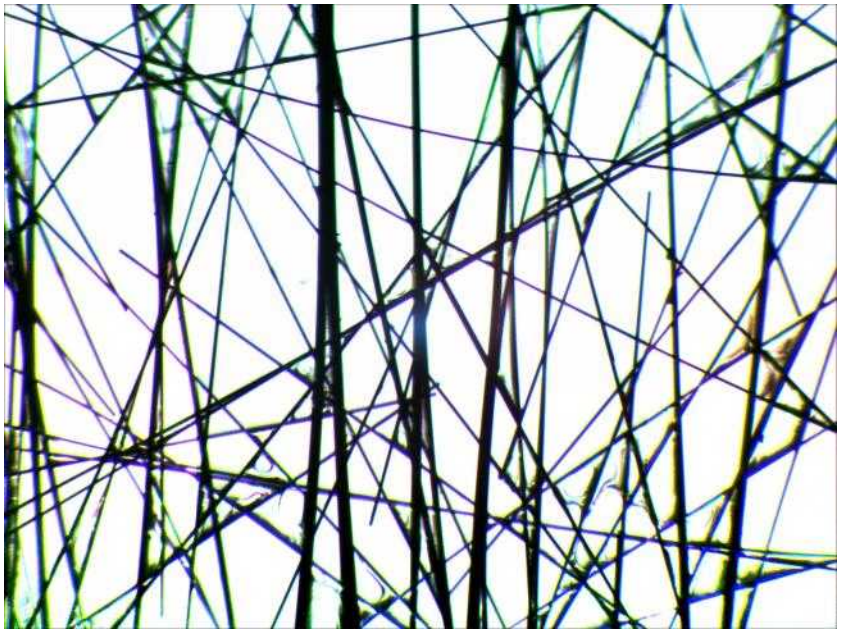


$$SE = \frac{1-\left(\rho e^{-\gamma t}\right)^2}{\left(1-\rho^2\right)e^{-\gamma t}}$$

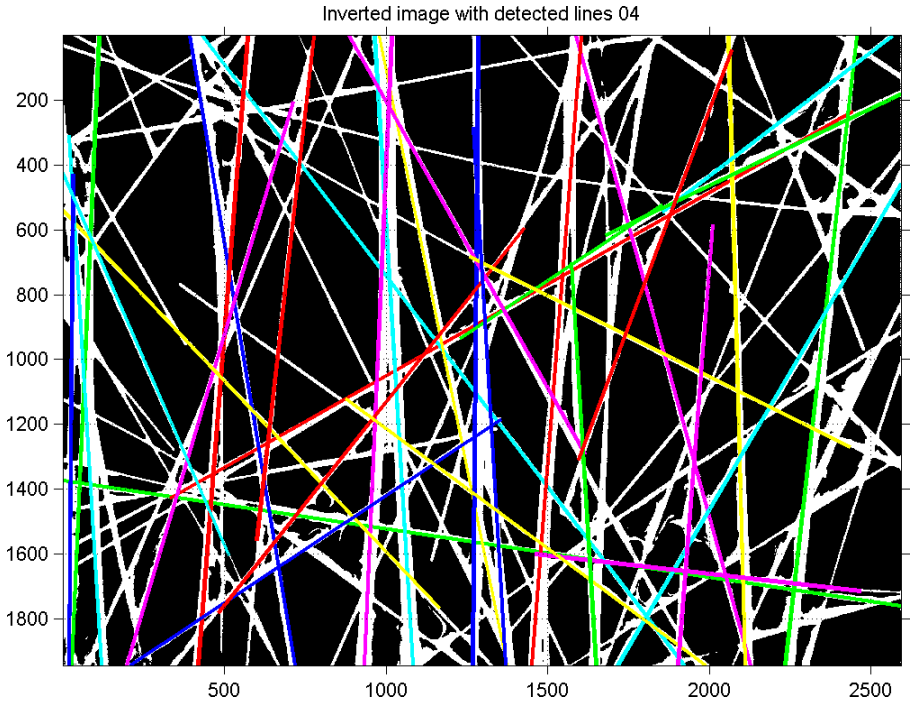
$$SE \approx 1+\tfrac{1}{2}\eta_0 G_s$$

Dawson, J. F.; Flintoft, I. D.; Austin, A. N. & Marvin, A. C. , "Shielding effectiveness of non-woven carbon fibre sheets: modelling the microstructure" , *2016 ESA Workshop on Aerospace EMC* , 23-25 May, 2016

Finding the fibre angle distribution



Optical microscope image



Line detection using Hough transform

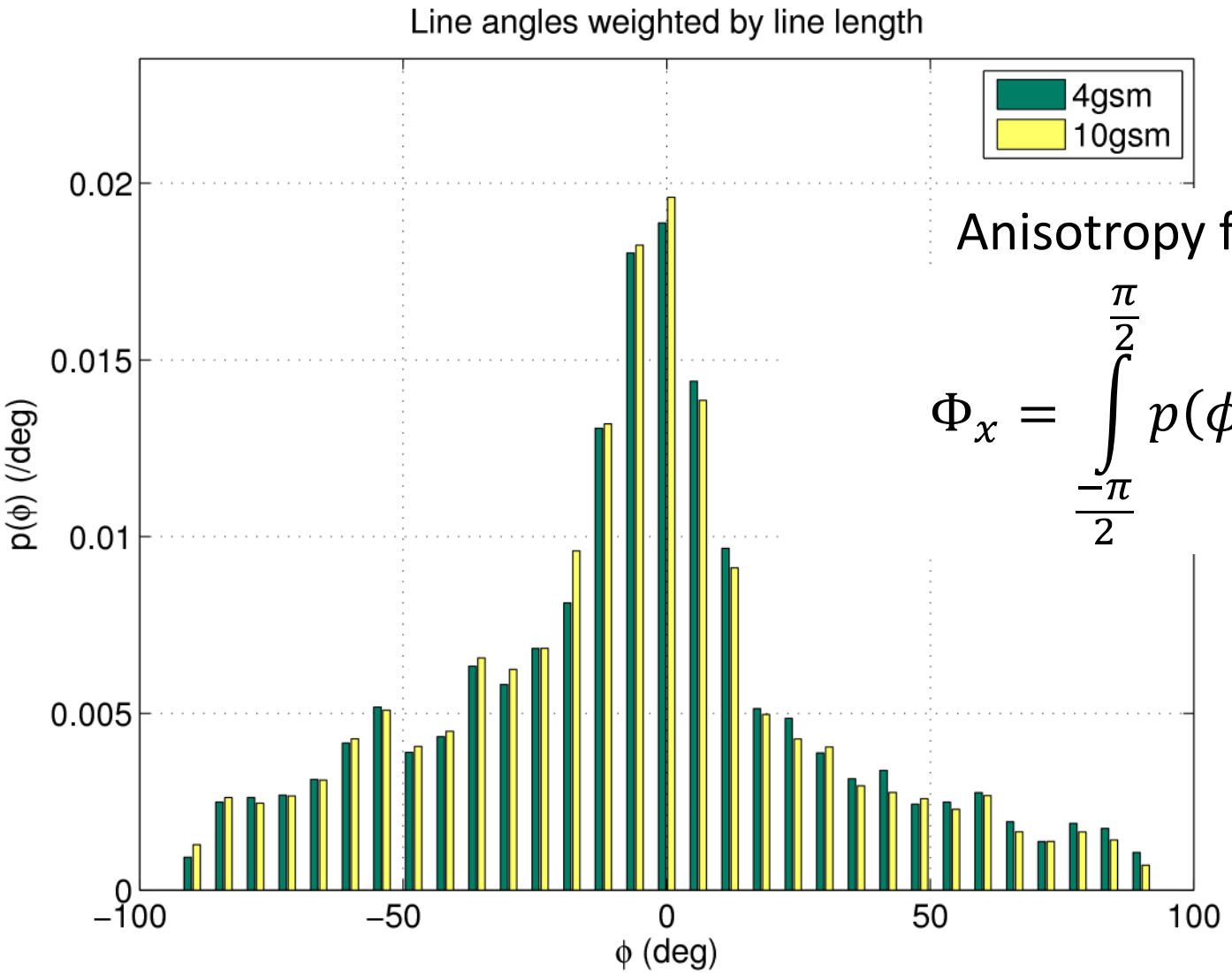
50 images were analysed each for 4gm^{-2} and 10gm^{-2} materials

Heavier materials were too opaque

Lines detecting using Hough transform

Austin, A. N.; Dawson, J. F.; Flintoft, I. D. & Marvin, A. C. , "Modelling the micro-structure of non-uniform conductive non-woven fabrics: Determination of sheet resistance" , *Electromagnetic Compatibility (EMC Europe), 2015 International Symposium on* , 1-6 , Aug. 16-22, 2015 , DOI: 10.1109/ISEMC.2015.7256122

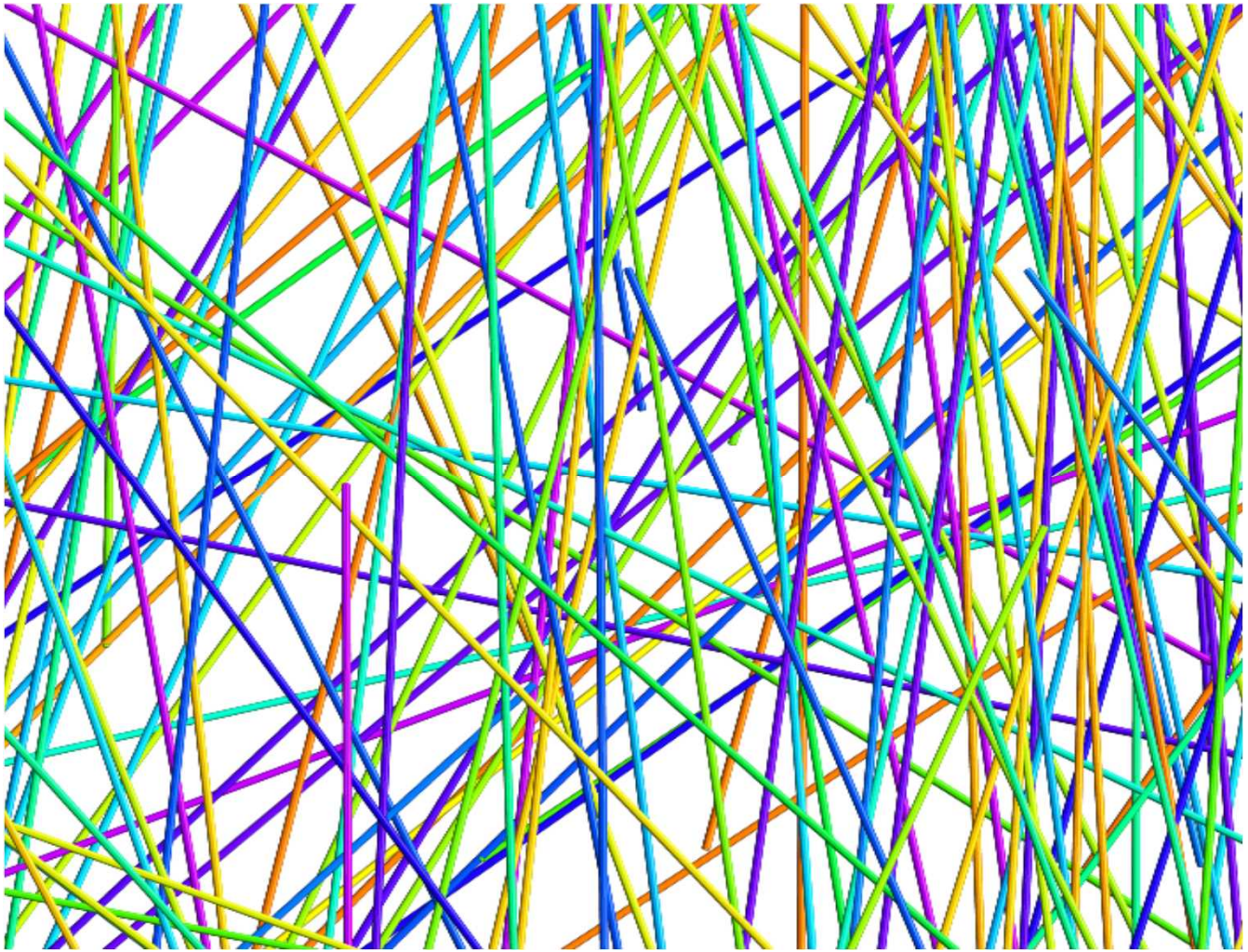
Fibre angle PDF is simply related to anisotropy



Anisotropy factor:

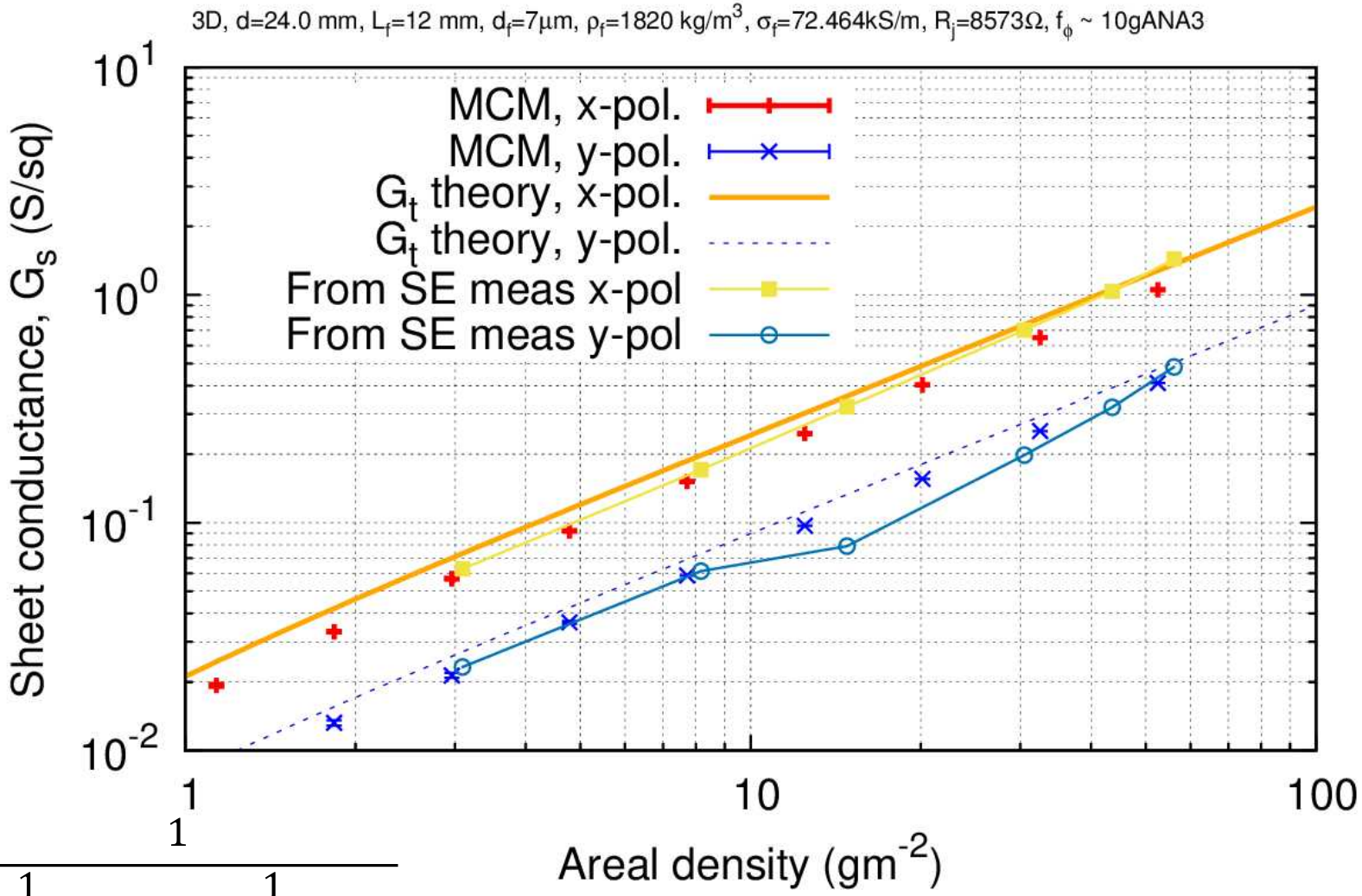
$$\Phi_x = \int_{\frac{-\pi}{2}}^{\frac{\pi}{2}} p(\phi)\cos^2\phi d\phi$$

Computer Generated Model



Austin, A. N.; Dawson, J. F.; Flintoft, I. D. & Marvin, A. C. , "Modelling the micro-structure of non-uniform conductive non-woven fabrics: Determination of sheet resistance" , *Electromagnetic Compatibility (EMC Europe), 2015 International Symposium on* , 1-6 , Aug. 16-22, 2015 , DOI: 10.1109/ISEMC.2015.7256122

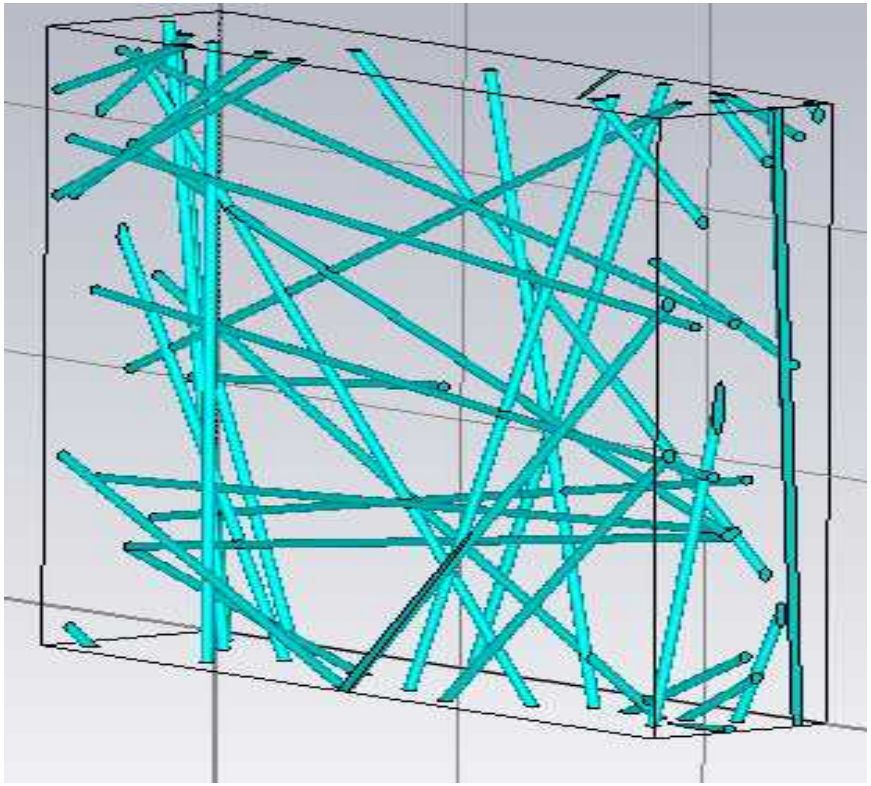
Real Material v MC Model and UoY theory



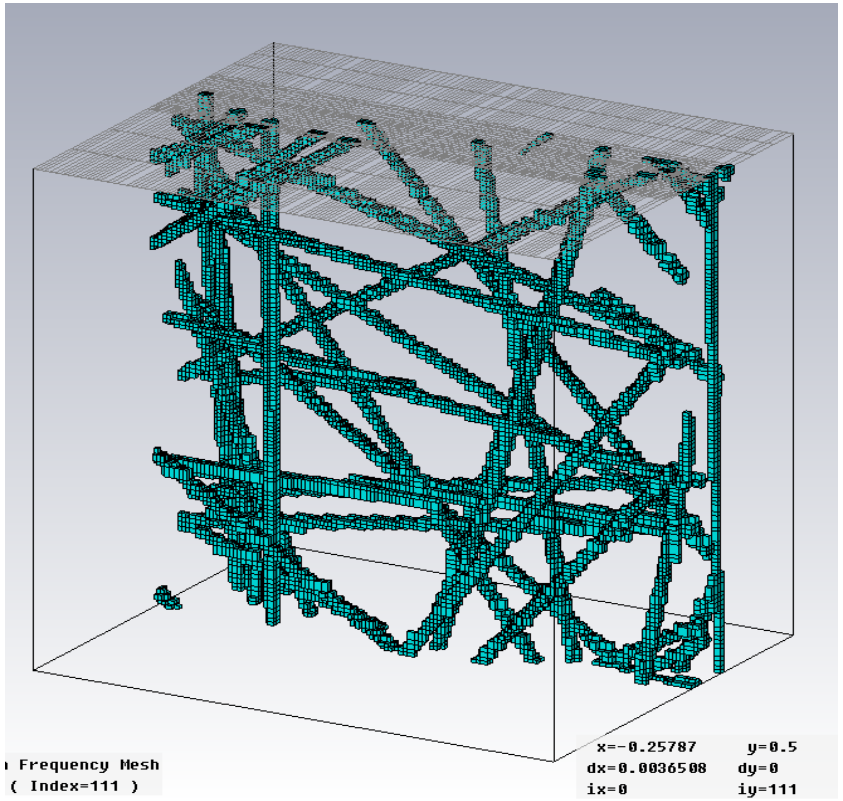
$$G_s = \frac{1}{\frac{1}{G_f \tilde{n}_A \Phi_x} + \frac{1}{\frac{k_e N_{cf}}{2} G_c \tilde{n}_A \Phi_x}}$$

Dawson, J. F.; Austin, A. N.; Flintoft, I. D. & Marvin, A. C. , "Shielding Effectiveness and Sheet Conductance of Nonwoven Carbon-fibre Sheets" , Accepted for publication in *Electromagnetic Compatibility, IEEE Transactions on*

FDTD Model of Non-woven

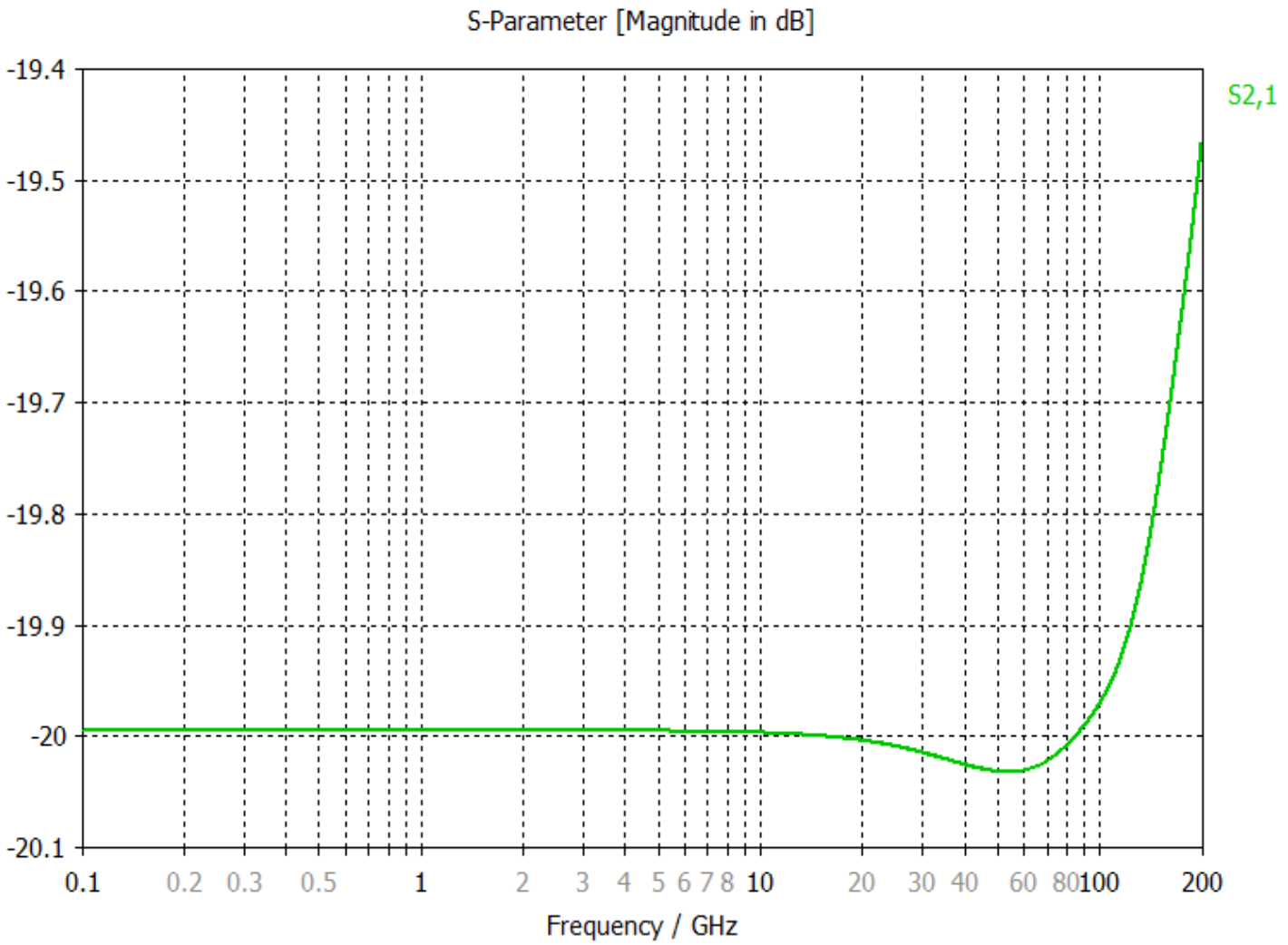


CAD model

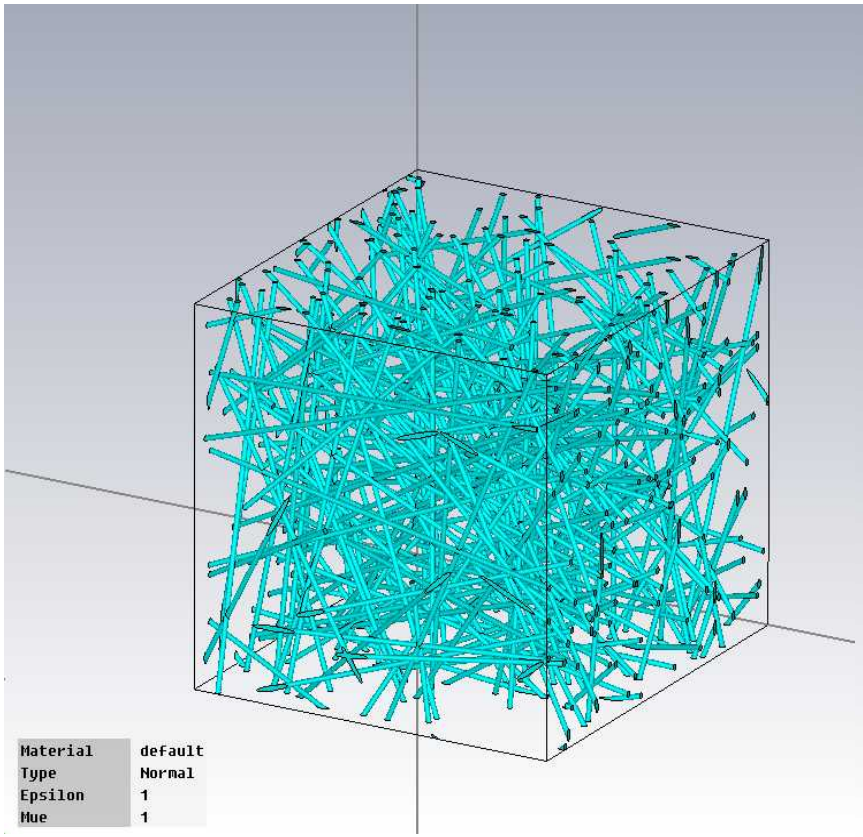


FDTD Mesh

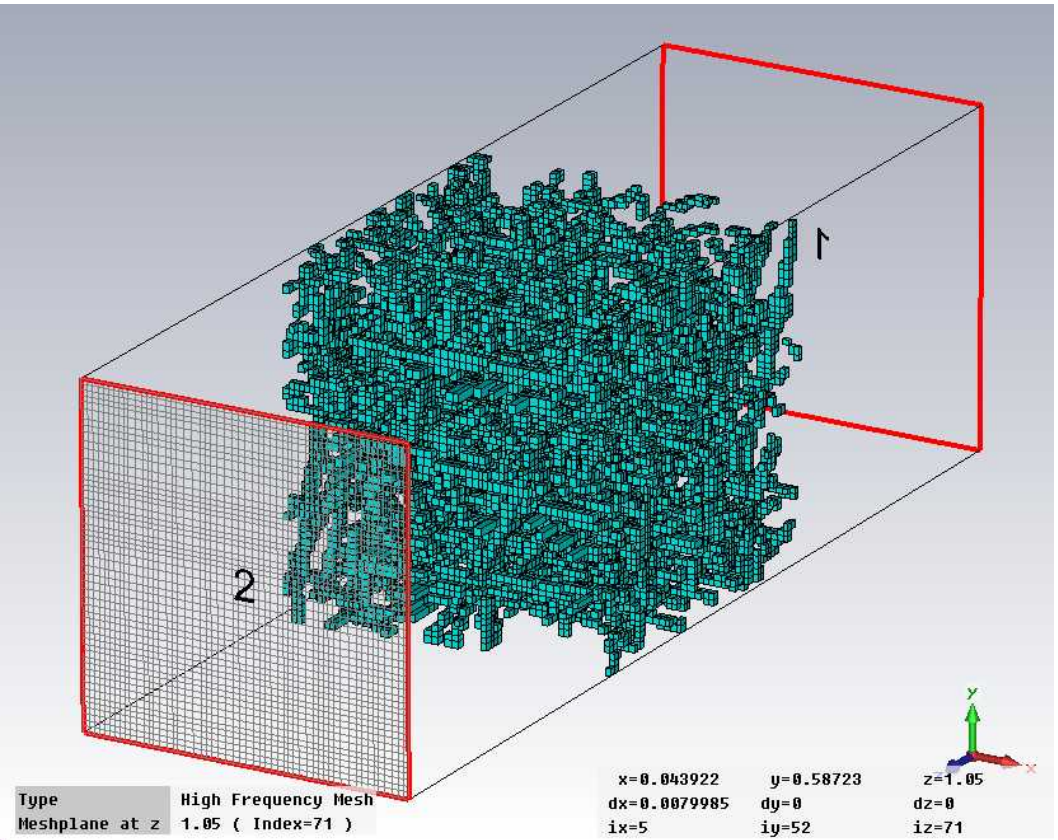
FDTD Model of Non-woven - transmission



FDTD Model of Non-woven

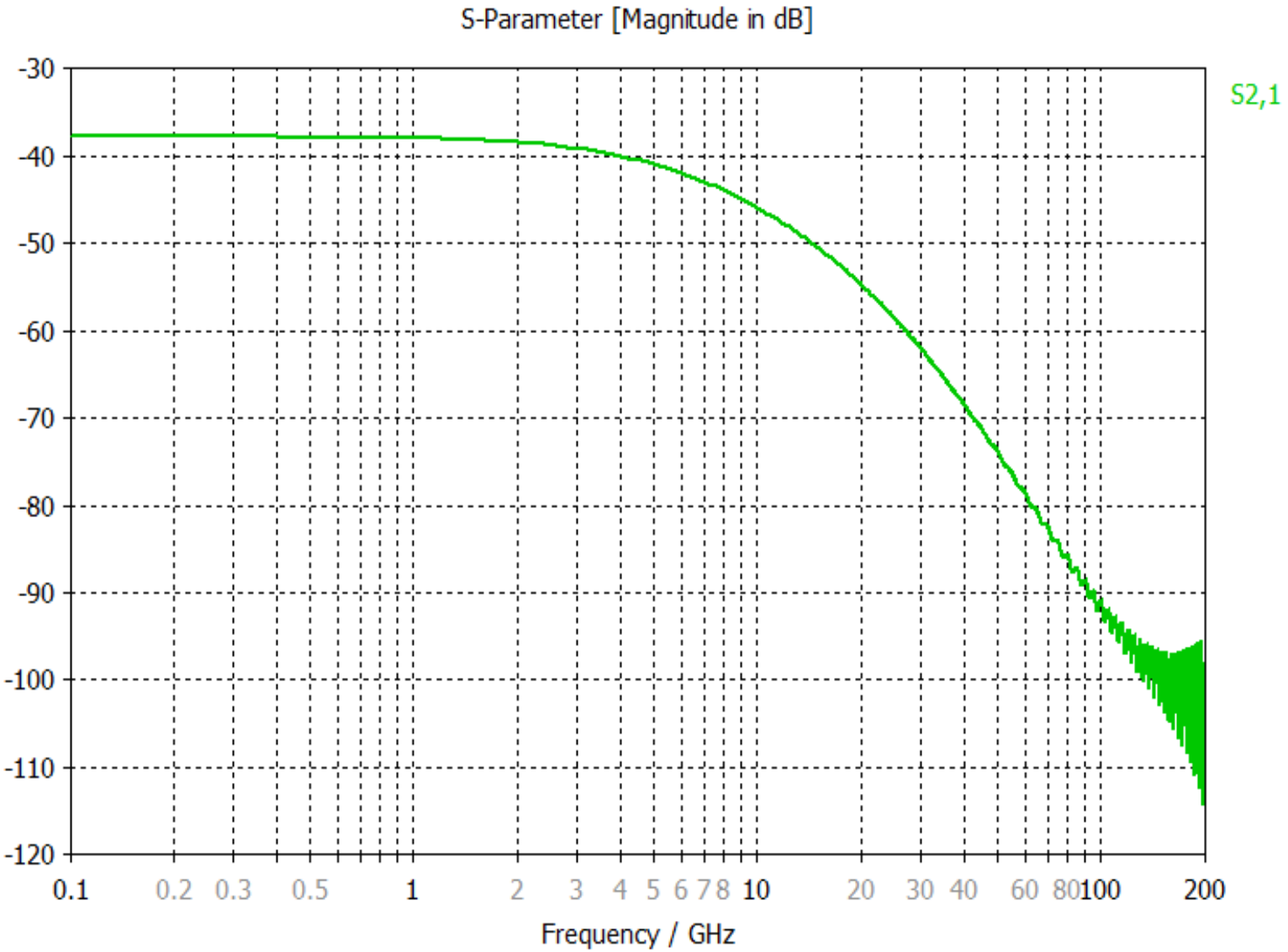


CAD model



FDTD Mesh

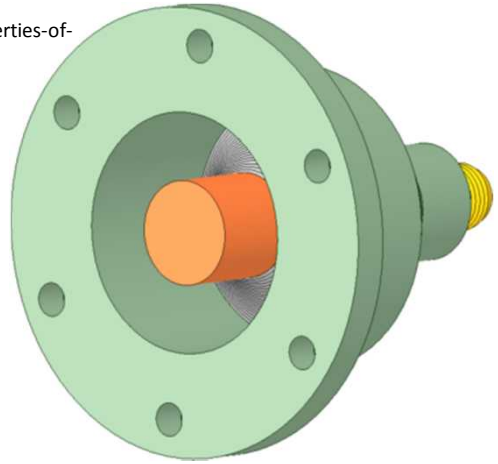
FDTD Model of Non-woven - transmission

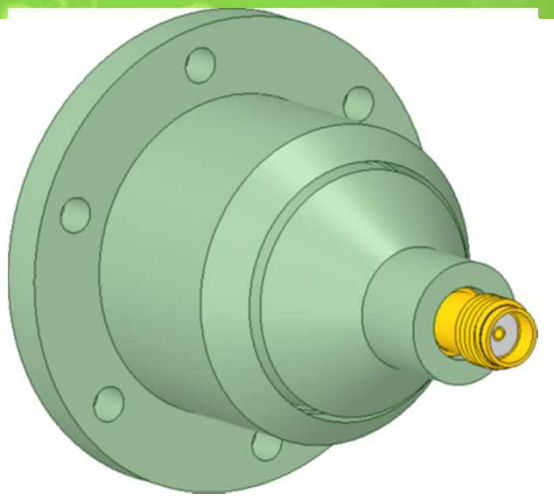


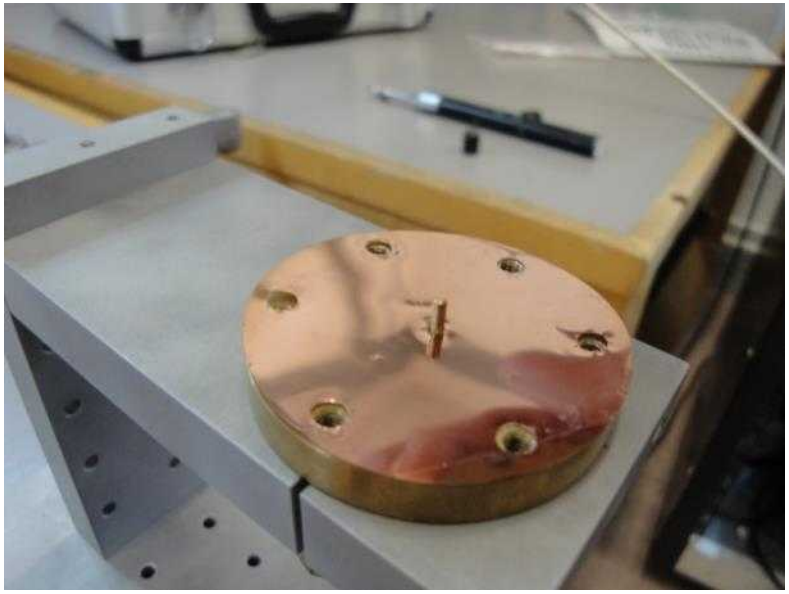
Coax jig - graphene/carbon nanotube samples

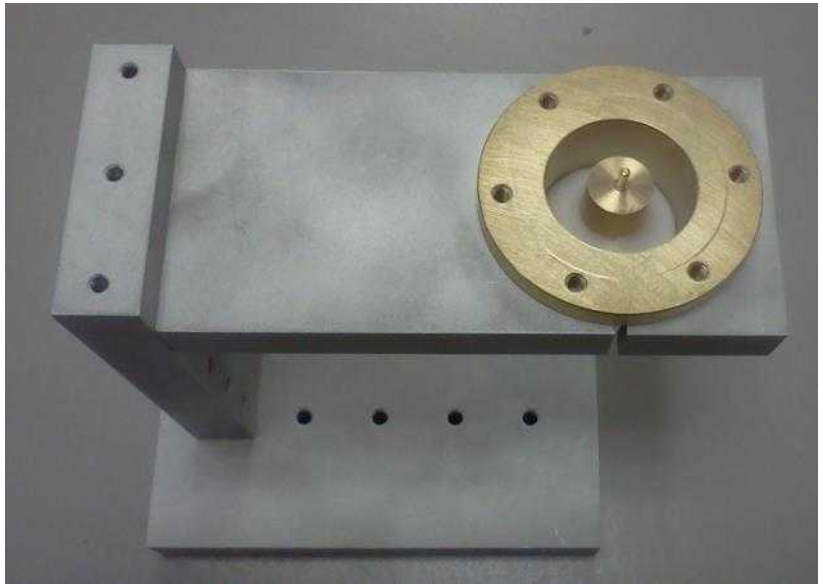
https://pure.york.ac.uk/portal/en/projects/rpf-1314-electromagnetic-properties-of-nanostructured-materials(6e91b761-e036-4532-af02-f6af08ba3682).html

New jig under test for small samples up to 20GHz









Copper coated kapton test sample

Questions?

- Shielding enclosure measurements
- Shielding enclosure standards
- Analysis of shielding
- Simple models for designers
- Shielding Materials measurement
- Macro models for TLM and FDTD
- Analysis of material structure
- Effects of slots and joints
- Effect of contents