Enclosure Shielding

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Shielding Effectiveness

- **The electromagnetic environment inside an equipment enclosure at microwave frequencies is strongly dependent on the absorption of energy by the enclosure’s contents.**
- **This effect is neglected by current shielding measurement standards.**
- **Here we extended the concept of shielding measurements using surrogate “representative contents” we first proposed at lower frequencies into the regime were the enclosure is electrically large.**

Enclosure SE Measurement

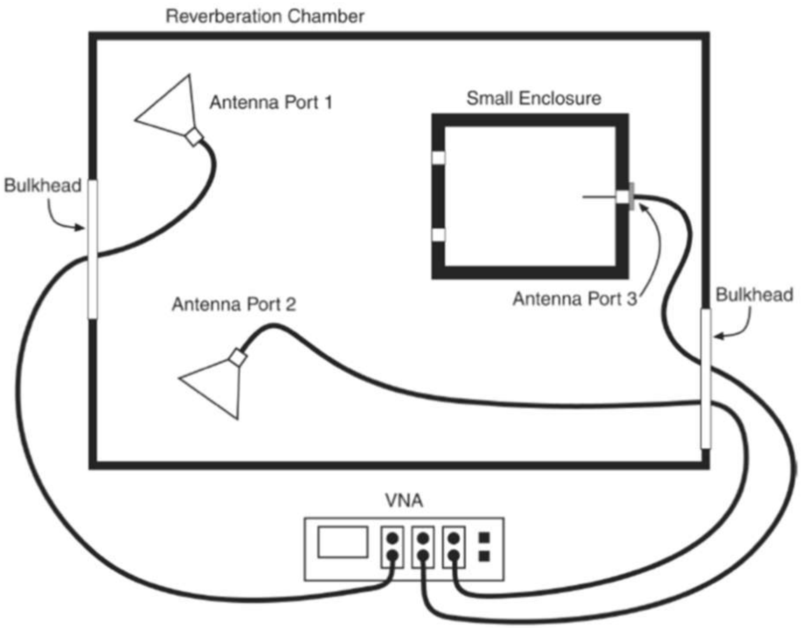


Figure 14—Measurement setup for determining SE of a small enclosure

$$SE = -10 Log_{10}\left(P_{in} / P_{out}\right)$$

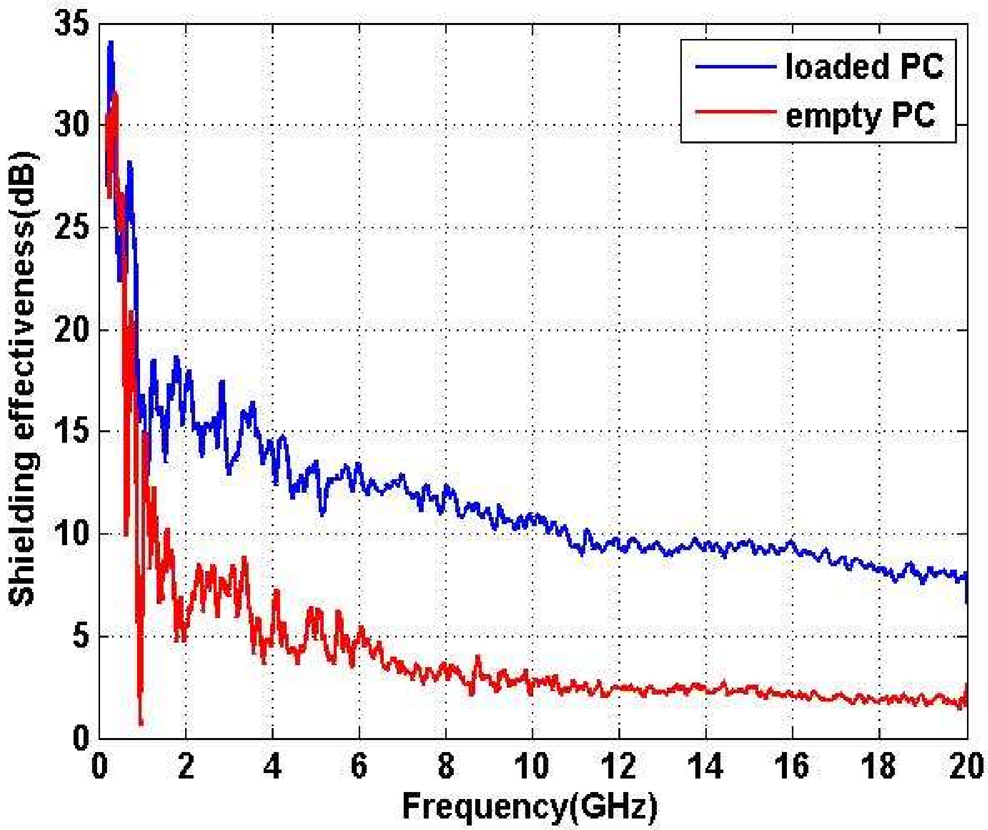
$$SE = \frac{\left\langle \left|S_{31}\right|^2 \right\rangle}{\left\langle \left|S_{21}\right|^2 \right\rangle} \frac{1 - \left|\left\langle S_{22} \right\rangle\right|^2}{1 - \left|\left\langle S_{33} \right\rangle\right|^2}$$

SE is measured according to the procedure detailed in IEEE Std™ 299.1

SE of a PC Enclosure

The PC enclosure SE is measured as detailed in the previous slide with and without its contents. The number of frequency points is 10001 and averaging is with a 50MHz frequency stirring window combined with 100 mechanical stirrer positions.

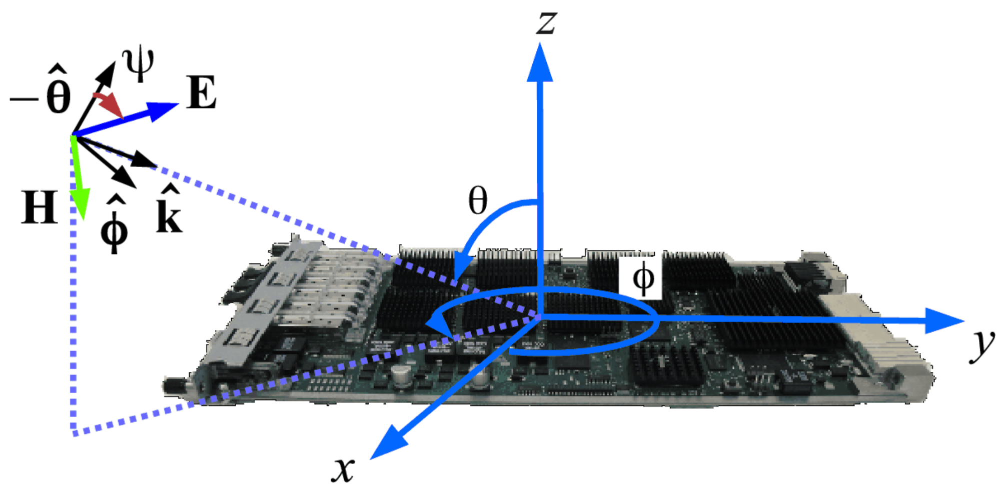
PC Enclosure SE Results



The SE of the PC enclosure depends on whether it has contents or not. Note the higher SE of the loaded enclosure resulting from the internal field reduction caused by energy absorption into the enclosure contents.

Absorption Cross-Section

- **The absorption cross-section (ACS) of an object is the total power it absorbs from an incident plane-wave per unit power density**
- **Far-field quantity (could be limiting**



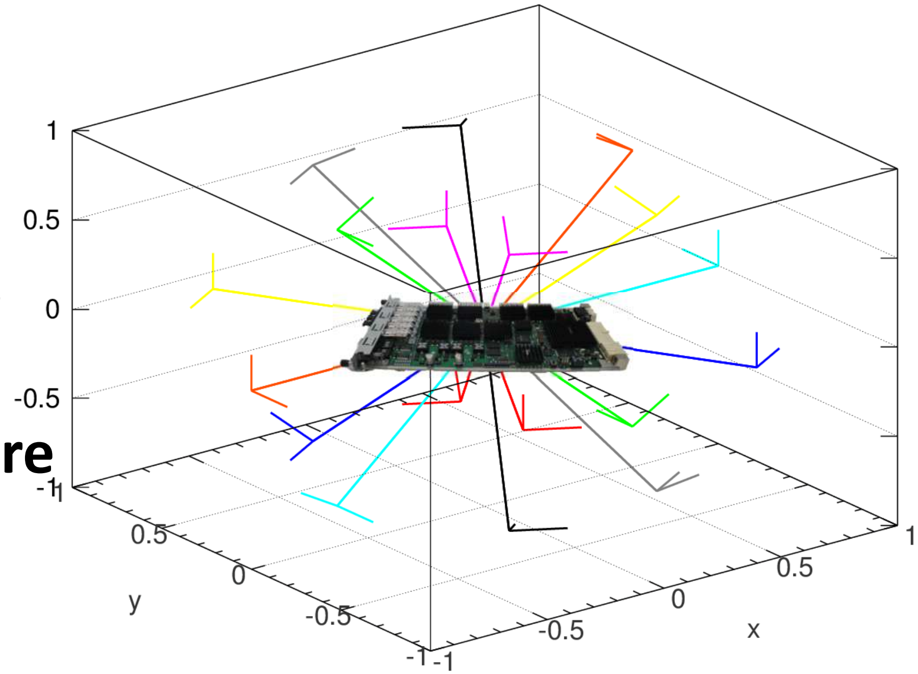
- **Depends on angle or arrival of the plane-wave (θ, φ) and its polarisation angle ψ**
- **Many absorption process in PCBs: trace loads (including devices), substrate, packaging,…**

$$\sigma^{a}(\theta, \varphi, \psi) = \frac{P^{a}(\theta, \varphi, \psi)}{S_{inc}}$$

$$S_{inc} = \frac{|E_{inc}|^2}{\eta_0}$$

Average ACS Measurement

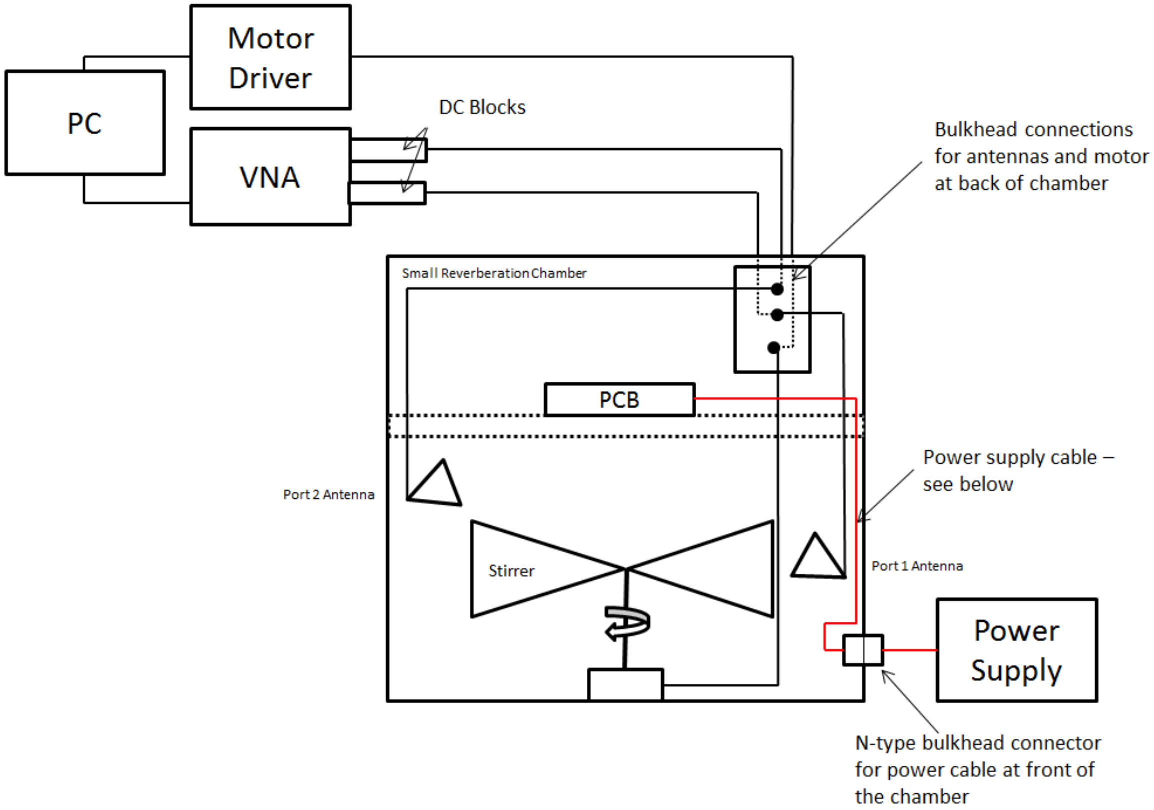
- **Reverberation Chamber (RC) is most efficient environment for high frequency SE measurement**
- **Good RC – uniform and isotropic plane-wave spectrum (Hill)**
- **Measure average ACS of enclosure contents in RC**
- **Use to predict SE in loaded enclosures**



$$\langle \sigma^{\mathrm{a}} \rangle = \frac{1}{2}\frac{1}{4\pi}\left\{ \iint_{4\pi} \sigma^{\mathrm{a}}(\theta,\varphi,0^{o})d\Omega + \iint_{4\pi} \sigma^{\mathrm{a}}(\theta,\varphi,90^{o})d\Omega \right\}$$

Measurement Setup

- **Average ACS determined by difference in insertion between loaded and unloaded chamber**



Insertion loss

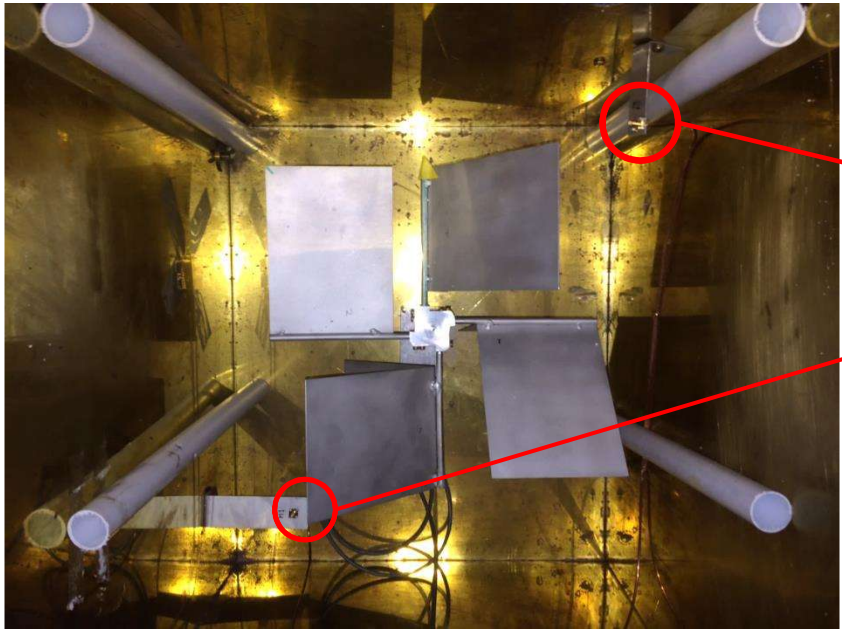
$$IL = \frac{1}{\langle |S_{21}|^2 \rangle}$$

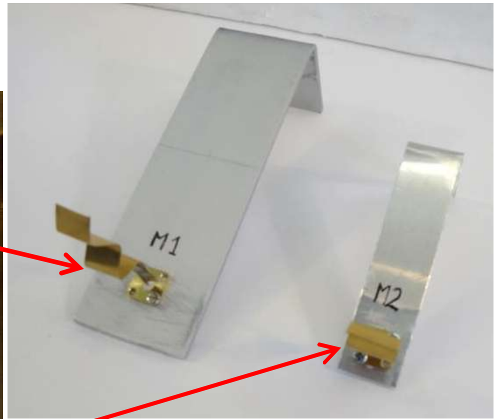
Total efficiency of antennas

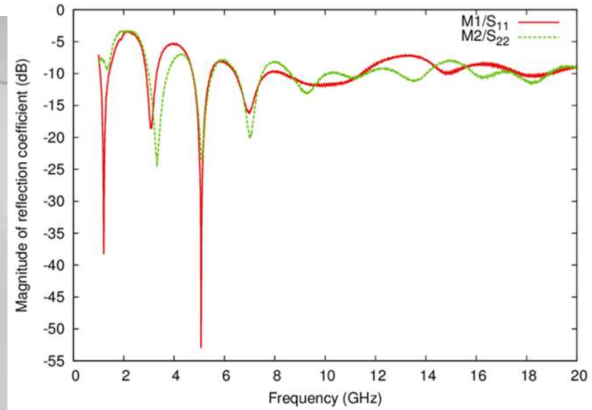
$$\eta_i^{\mathrm{T}} = \eta_i^{\mathrm{rad}}(1 - |\langle S_{ii} \rangle|^2)$$

$$\langle \sigma_{\mathrm{EUT}}^{\mathrm{a}} \rangle = \frac{\lambda^2}{8\pi} \eta_1^{\mathrm{T}} \eta_2^{\mathrm{T}} (IL_{\mathrm{loaded}} - IL_{\mathrm{unloaded}})$$

Measurement Implementation



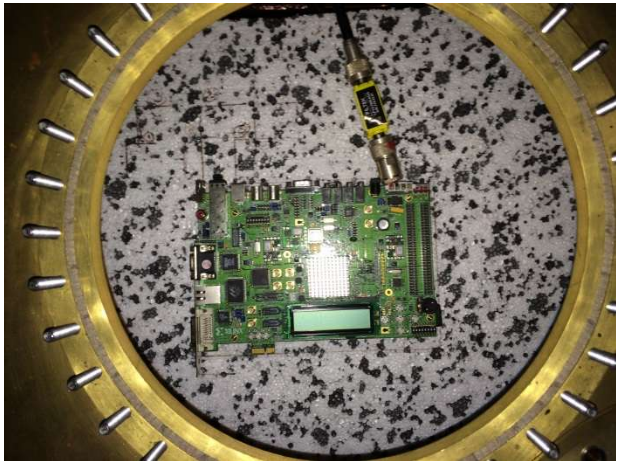




Broadband monopole antenna

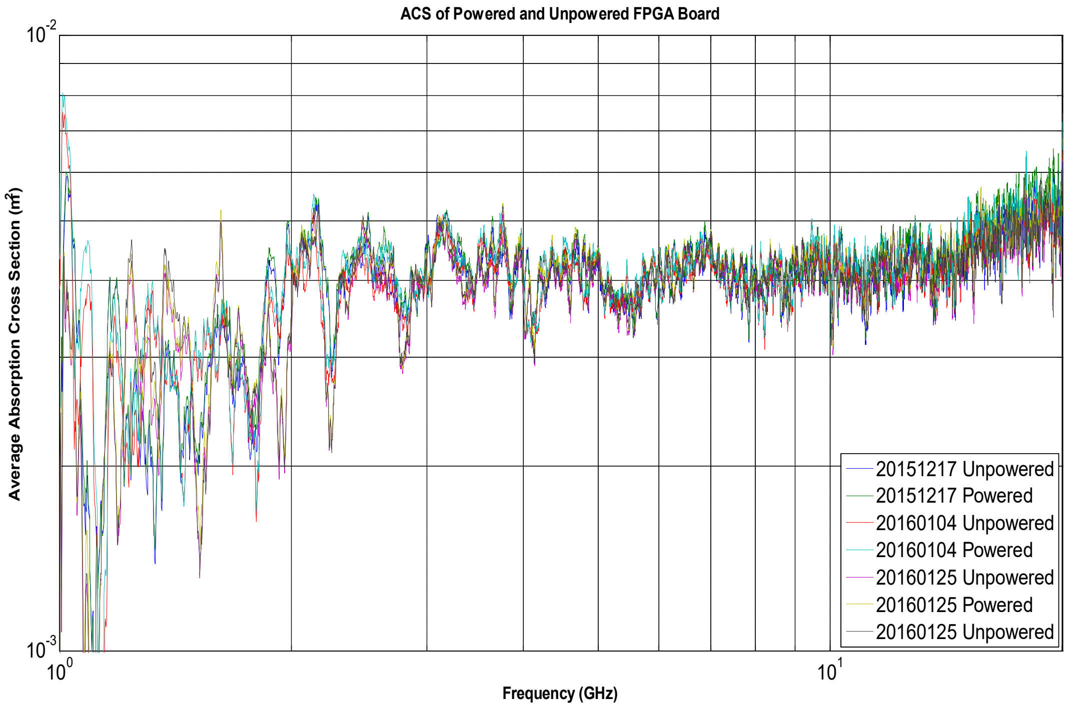
Lower part of RC with stirrer
RC dimensions 600mm x 700mm x 800mm

100 stirrer positions **50/100 MHz frequency stirring bandwidth**



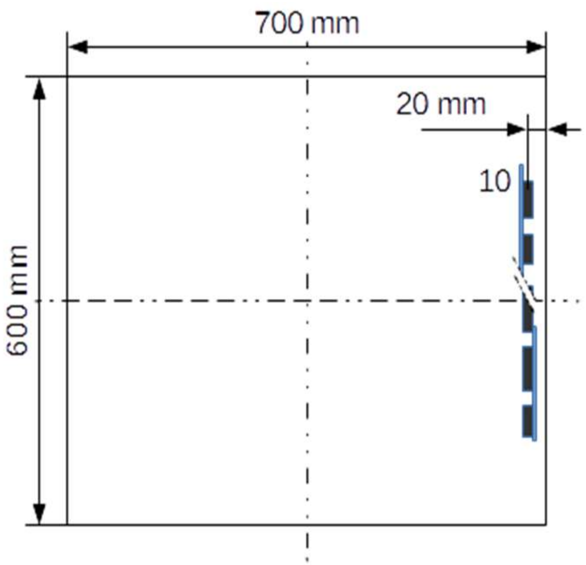
Expanded polystyrene support with FPGA PCB

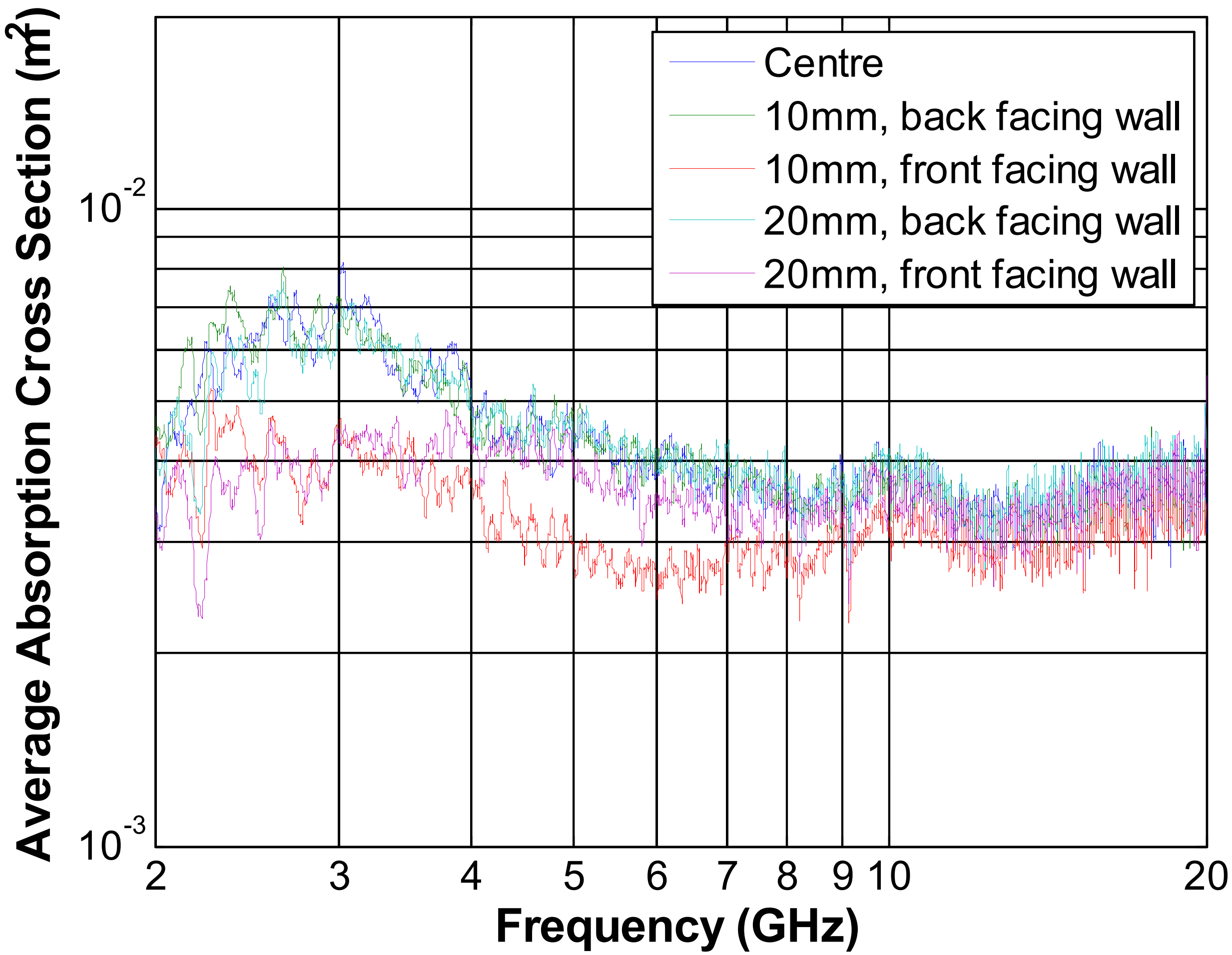
Measured ACS of an FPGA board



The measured ACS of an FPGA board is shown here in the frequency range 1GHz to 20GHz. Note the surprising result that the ACS appears independent of whether the board is powered and running a programme or unpowered.

Effect of wall proximity on ACS



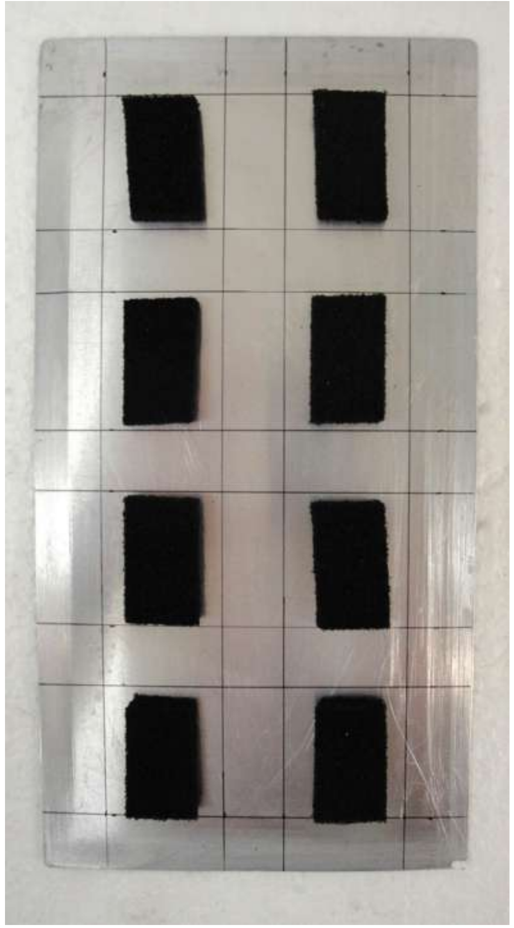


When the *components* close to chamber wall:

- **The ACS is reduced by 10% to 50%**

Surrogate PCB Design

The surrogate PCB is fabricated from a conducting sheet with tailored blocks of carbon loaded polyurethane foam to replicate the absorption of the PCB components. The conducting sheet replicates the PCB ground plane structure. This prototype is single sided.



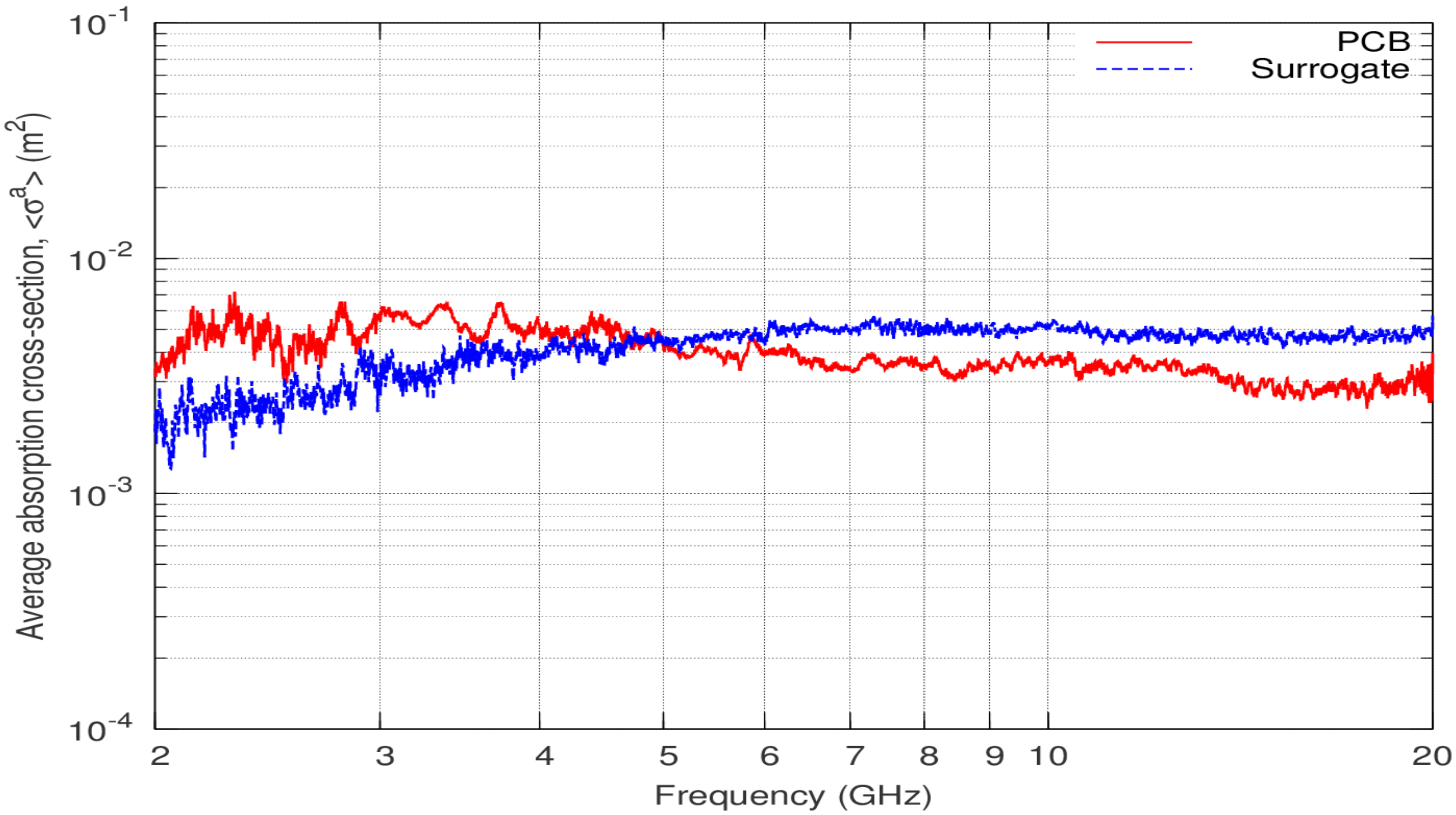
Future work

- **Power balance models**
  - **PCB and other component models**
  - **Dealing with proximity effects**
- **Implications for immunity**
  - **Where does the absorbed energy go?**
  - **How does this affect/predict immunity?**
- **Standardisation**
  - **Inclusion of the effect of absorption in shielding standards?**

Other work

- STSM to UGR
  - Numerical modelling of thin layers
  - Limitations of staircased meshing
  - Leading to
    - Journal paper (MTT) in submission
    - Agreement for further collaboration on FDTD modelling (RS@York)
- PRACE proposals (UPVM,UGR,UoN,UoY)

Surrogate – PCB ACS Comparison



Published Papers

Measured average absorption cross-sections of printed circuit boards from 2 to 20 GHz
Flintoft, I. D., Parker, S., Bale, S. J., Marvin, A., Dawson, J. F. & Robinson, M. P. Apr 2016Article in IEEE Transactions on Electromagnetic Compatibility
DOI: 10.1109/TEMC.2015.2499841

Predicting Shielding Effectiveness of Populated Enclosures Using Absorption Cross Section of PCBs
Parker, S. L., Flintoft, I. D., Marvin, A. C., Dawson, J. F., Bale, S. J., Robinson, M. P., Ye, M., Wan, C. & Zhang, M. 18 Apr 2016 *Electromagnetic Compatibility (EMC EUROPE), 2016 International Symposium*.

Changes in a Printed Circuit Board's Absorption Cross Section Due to Proximity to Walls in a Reverberant Environment
Parker, S., Flintoft, I., Marvin, A., Dawson, J., Bale, S., Robinson, M., Ye, M., Wan, C. & Zhang, M. 19 Apr 2016 *Electromagnetic Compatibility (EMC), 2013 IEEE International Symposium.*

On the measureable range of absorption cross-section in a reverberation chamber
Flintoft, I. D., Bale, S. J., Parker, S., Marvin, A., Dawson, J. F. & Robinson, M. P. Feb 2016Article in IEEE Transactions on Electromagnetic Compatibility

Absorption cross section measurement of stacked PCBs in a reverberation chamber
Parker, S., Flintoft, I. D., Marvin, A., Dawson, J. F., Bale, S. J., Robinson, M. P., Ye, M., Wan, C. & Zhang, M. 29 Jan 2016 *2016 Asia-Pacific Symposium on Electromagnetic Compatibility (APEMC2016).* Shenzhen, China.

Enclosure shielding assessment using surrogate contents fabricated from radio absorbing material
Marvin, A., Flintoft, I. D., Dawson, J. F., Robinson, M. P., Bale, S. J., Parker, S., Ye, M., Wan, C. & Zhang, M. 29 Jan 2016 *2016 Asia-Pacific Symposium on Electromagnetic Compatibility (APEMC2016).* Shenzhen, China.