4 - Shielding for EMC - Updated Jan 2021

emc12ms v3.6

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Module 4: Shielding for EMC

(DC to GHz)

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Change Record: v3.4a – v3.6, Jan. 2021
(21 new slides added)

- **Safety note applied to all slides, with some appropriate reformatting**
- ***Three new slides replace slide 4.3.2 – 4.3.2a, 4.3.2b and 4.3.2c***
- **Slide 4.3.3 – graphic improved**
- **Slide 4.5.2 – text improved**
- **Slide 4.5.4 – graphic improved**
- ***New slide 4.9.4a added* – 'Some practical issues with RF-bonding'**
- ***Fifteen new slides added – 4.9.33 to 4.9.47, on 'clamshell' shielding***
- **Slide 4.11.4 – title changed from 'Some displays…' to 'Most displays…'**
- **Slide 4.12.3 – graphic improved**
- **Slide 4.13.4 – another supplier added**
- **Slides 4.13.8 to 4.13.12 – graphics improved**
- ***New slide 4.13.12a added***
- ***New slide 4.14.8 added***

Good Electromagnetic (EM) Engineering…

– is cost-effective SI, PI and EMC engineering: well-proven to save time & money in all lifecycle stages, helping to increase profits & reduce financial risks…

– for PCBs, modules, sub-assemblies, devices, products, equipment, vehicles, sub-systems, systems, installations, etc., etc.; of any size, in all applications

see Module 1 especially 1.15 (also in Webinar 1c) and 1.16 (also in Webinar 1d)

■ This Module contains many EM Engineering guidelines that should *also* be used as an initial design checklist: *any that can't or won't be followed identify a project risk!*

see Module 1, section 1.16 (also in Webinar 1d)

– to adapt any λ-based design guidelines to different EMC standards, *see Module 1, section 1.18* *(also in Webinar 1d)*

Contents

All relevant safety requirements must always be applied – see our training courses on designing for safety compliance

4. Shielding for EMC

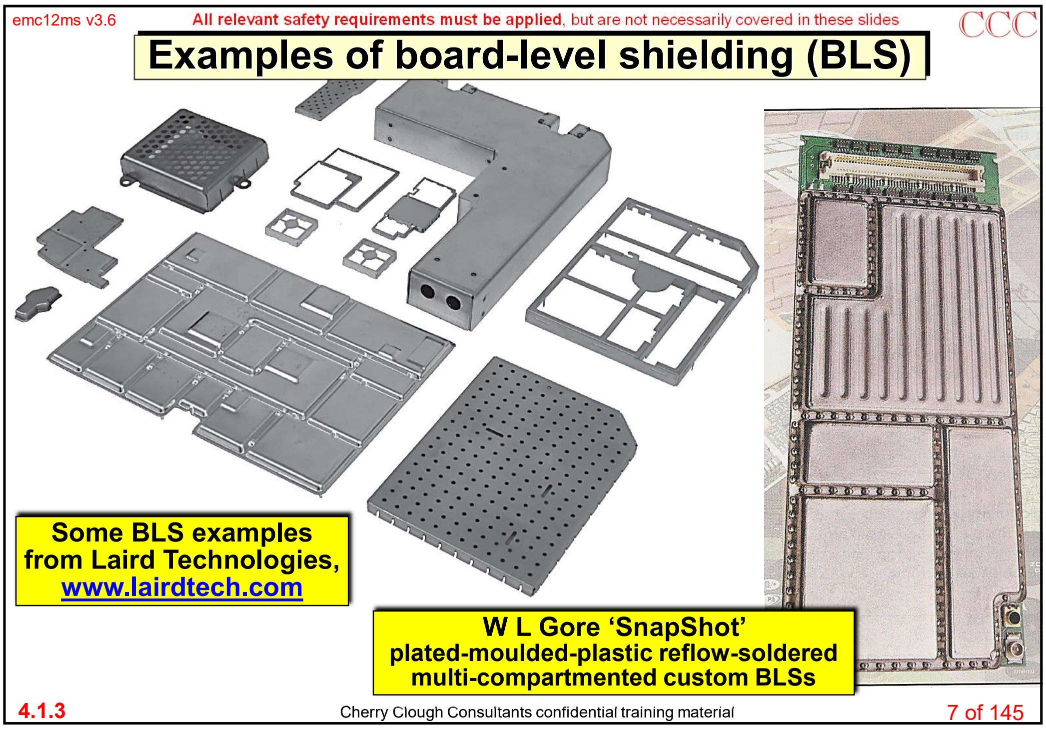
4.1

Economic issues for shielding

Economic issues for shielding
(example costs – for comparisons only)

– Shielding an IC on its own	£ 0.25
– Shielding an area on a PCB	£ 1
– Shielding a whole PCB	£ 10
– Sub-assemblies and modules	£ 15
– Shielding a complete product	£ 100
– Shielding a system (e.g. a rack cabinet)	£ 1000
– Shielding a room	£ 10,000 +
– Shielding a building	£ 100,000 ++

- To save cost, it is best to design products to be able to use shielding at lower levels of assembly (if it turns out to be necessary)


emc12ms v3.6
All relevant safety requirements must be applied, but are not necessarily covered in these slides
CCC
Examples of board-level shielding (BLS)
Some BLS examples from Laird Technologies, www.lairdtech.com
W L Gore 'SnapShot' plated-moulded-plastic reflow-soldered multi-compartmented custom BLSs
4.1.3
Cherry Clough Consultants confidential training material
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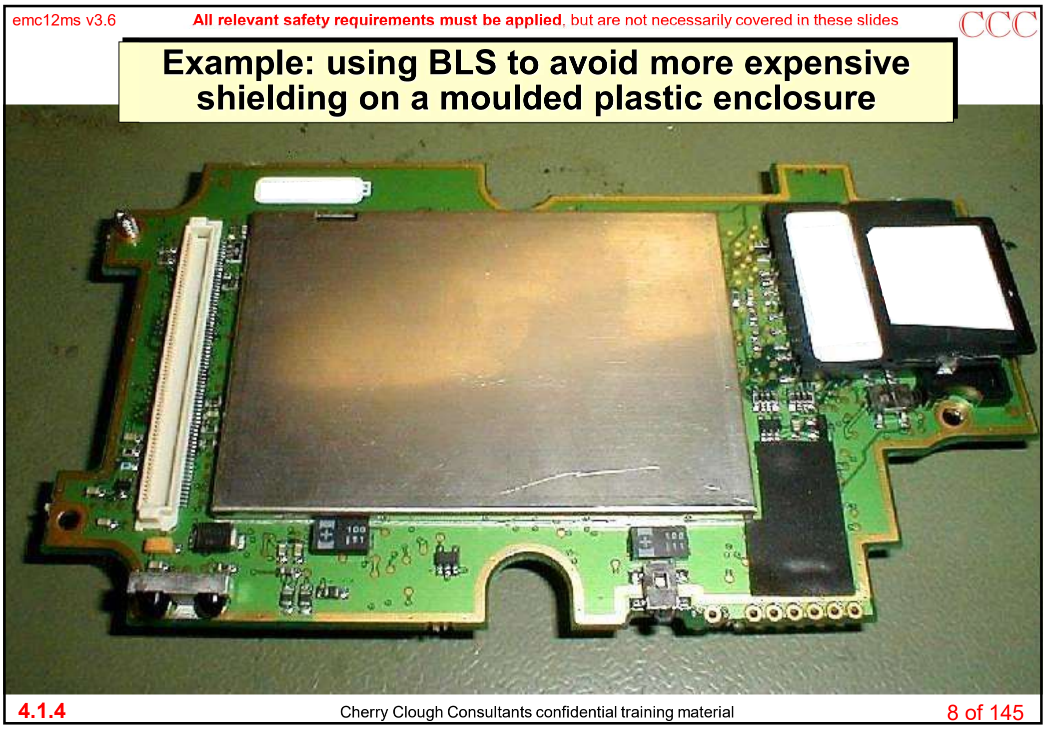
emc12ms v3.6
All relevant safety requirements must be applied, but are not necessarily covered in these slides
CCC
Example: using BLS to avoid more expensive shielding on a moulded plastic enclosure
4.1.4
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4. Shielding for EMC

4.2

Shielding with metal plates (image planes)

Metal plates can give useful shielding

- Ensuring that all components and conductors are close to large metal surfaces can provide some degree of shielding
    - e.g. keeping close to PCB planes, metal chassis, metal enclosures and metal shields (the image plane effect)
  - this might provide enough Shielding Effectiveness (SE) to eliminate the need for a shielded enclosure
    - or at least reduce its SE specifications and its cost
- RF-bonding to the metal surface helps to return stray CM currents locally, helping to improve SE

4. Shielding for EMC

4.3

How shielded enclosures work

How shielded enclosures work (1)

- **A shield places an impedance discontinuity in the path of a propagating wave…**
  - **to Reflect part of the impinging EM waves, giving R dBs of shielding effectiveness (SE)**
  - **and to Absorb some of the remainder of the waves, giving A dBs of SE**
  - **Total SE in dBs = R + A**
    ***Note:* R and A both vary differently with frequency**
- **Actually: SE = R + A + B, where B is caused by multiple reflections inside the shield material itself…**
  which is usually only significant for very thin materials

– see Chapter 15 in Reference [5] (slide 4.16.2) for detail on SE = R + A + B

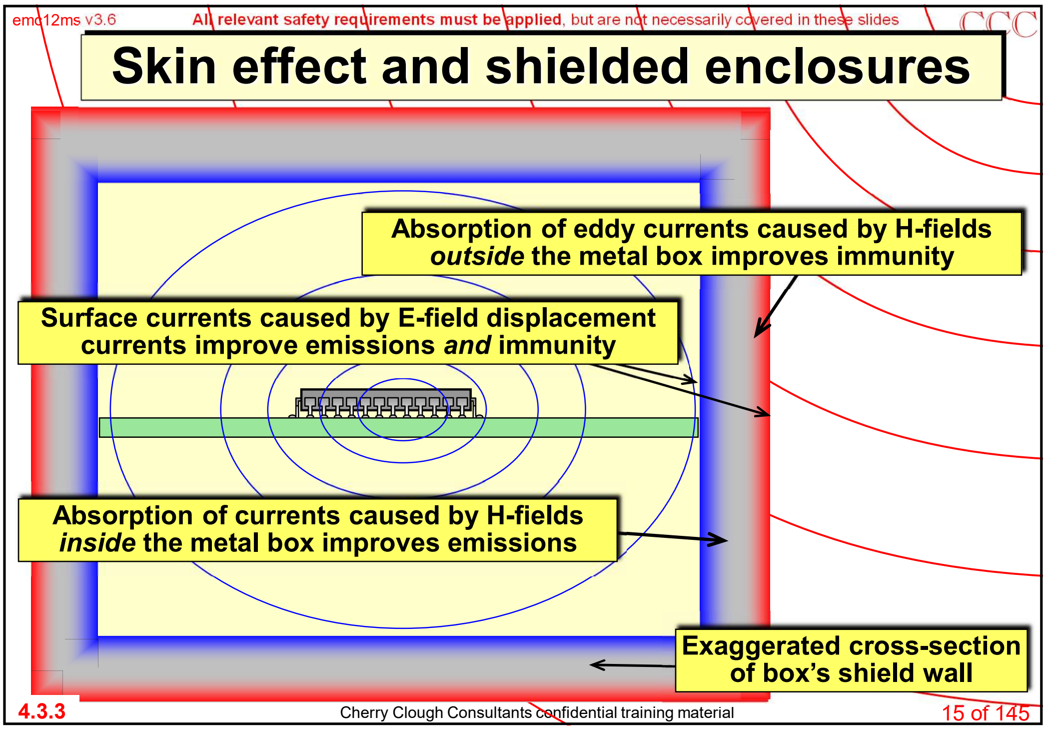
How shielded enclosures work (2)

- **E fields are reflected (R) by the displacement currents they induce in metal *surfaces*…**
  - **higher-conductivity metal surfaces (e.g. gold, copper, chromated aluminium, etc.) increase R because they cause lower losses to the flows of surface currents…**
    - **so, even very thin foils can have good values of R**
- **H field shielding relies on absorption (A) of eddy currents due to resistive losses inside the metal…**
  - **and high values of A need enough thickness of metal to absorb most of the eddy currents…**
    - **the metal needs to be many skin depths thick for a good value of A at the <u>lowest</u> frequency to be shielded**

Skin Effect and its effect on H-field shielding

- **DC currents travel through the *whole* cross-sectional area of a conductor, but eddy currents force RF currents to flow close to the surface…**
  - **this is known as the "skin effect"…**
  - **the higher the frequency, the closer the currents due to the H-fields are forced towards the surface**
- **So, high-frequency currents only penetrate weakly into the *depth* (thickness) of a conductor, increasing the resistance (the lossiness) in their path**

see Module 1, and Reference [4] on slide 4.16.2 for more details on skin effect



emc12ms v3.6 — **All relevant safety requirements must be applied**, but are not necessarily covered in these slides — CCC

We can achieve shielding spec's by controlling the flow of surface currents!

- **There is a 1:1 relationship between surface currents and local near-fields…**
    - **because of quantum electro-dynamics (!)**
  - **so a correctly designed shield, with correct RF-bonding, filtering and/or shielding of any/all conductors that pass through it, of course…**
    - **ensures that enough internal surface currents (internal fields) remain inside *to meet the emissions spec…***
    - **and that enough external surface currents (external fields) remain outside *to meet the immunity spec.***
- **It's hard to visualise fields to control them…**
  - ***but easy to visualise surface currents and control them!***

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4. Shielding for EMC

4.4

Very low frequency (VLF) shielding: DC – 1kHz

Passive VLF shielding

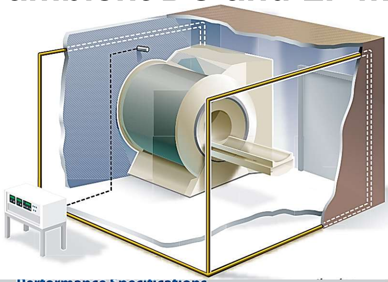
e.g. for: CRTs, photomultiplier tubes, electron microscopes, electron beam welding / additive manufacturing, MRI scanners, EEGs, ECGs, EvPs, etc.

- **H fields < 1kHz are near-field (i.e. low wave impedance) making it difficult to get a good impedance mismatch…**
  - **so reflection is poor, and metal usually isn't thick enough for good absorption (which needs several skin depths)**
- **Very thick mild steel or iron sheets can be used (e.g. several layers of metal plates each 8mm thick)…**
  - **and/or special alloys with a high value of μ_r (e.g. 10,000) used (e.g. "MuMetal")…**
  - **designed to *divert* the LF magnetic flux away from the volume to be shielded (instead of reflecting and absorbing)**

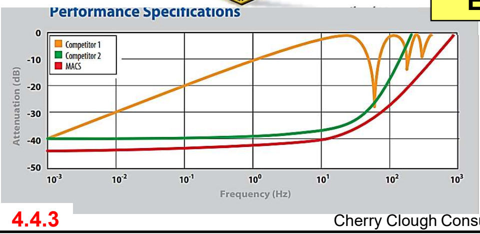
Active VLF shielding

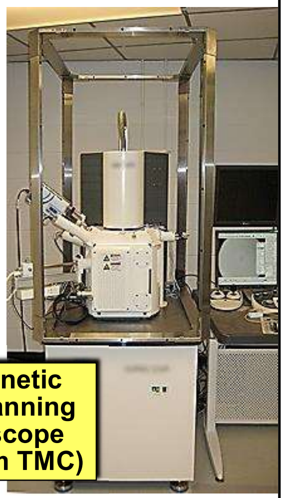
e.g. for: CRTs, photomultiplier tubes, electron microscopes, electron beam welding / additive manufacturing, MRIs, EEGs, ECGs, EvPs, etc.

- **Power amplifiers drive currents in coils to cancel out ambient DC and LF magnetic fields**



E.g. active magnetic shielding for MRI scanner ("MACS" from ETS-Lindgren)





E.g. active magnetic shielding for scanning electron microscope ("Mag-NetX" from TMC)

4. Shielding for EMC

4.5

The problems caused by apertures