Overview of the ATLAS Electromagnetic Compatibility Policy

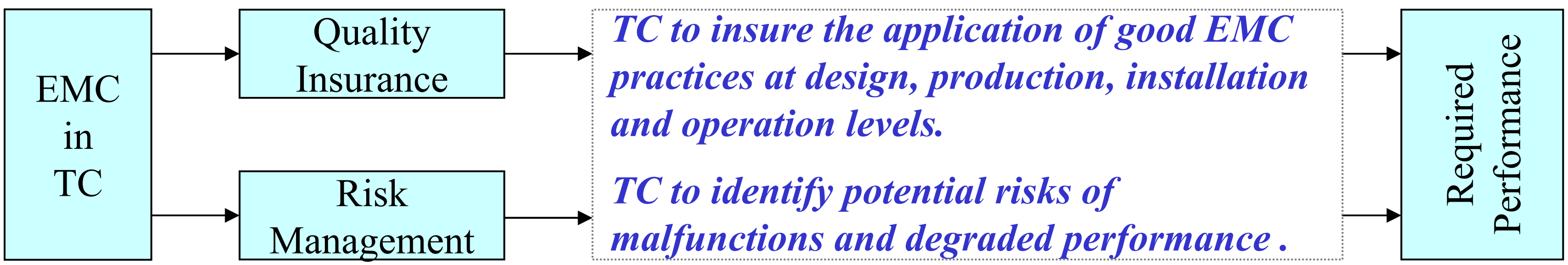
10th Workshop on Electronics for LHC and future Experiments

13 - 17 September 2004, BOSTON, USA

G. BLANCHOT
CERN, CH-1211 Geneva 23, Switzerland
Georges.Blanchot@cern.ch

ATLAS EMC Policy

Reference document is available at: https://edms.cern.ch/file/476490/1/ATLAS-EMC-POLICY.pdf
Additional Information is available at: http://atlas.web.cern.ch/Atlas/GROUPS/FRONTEND/EMC/



Addressed issues:

1. Compliance to CERN electrical safety rules.
2. Immunity against conducted and radiated electromagnetic interferences.
3. Control of interferences down to a level compatible with the required performance of ATLAS.

EMC Implementation in ATLAS

1

Setup definition:

Contact person for safety and EMC.
How the system must be installed and connected to be operated safely.
Fault conditions and protections.
Neighbors and the routing of cables.

2

EMC Conformance:

Compatibility Limits.
Key parameters: clock frequency, bandwidth, thresholds, intrinsic noise, etc…
Conducted noise in cables.
CM susceptibility via LVPS cabling.
Cable shields requirements.

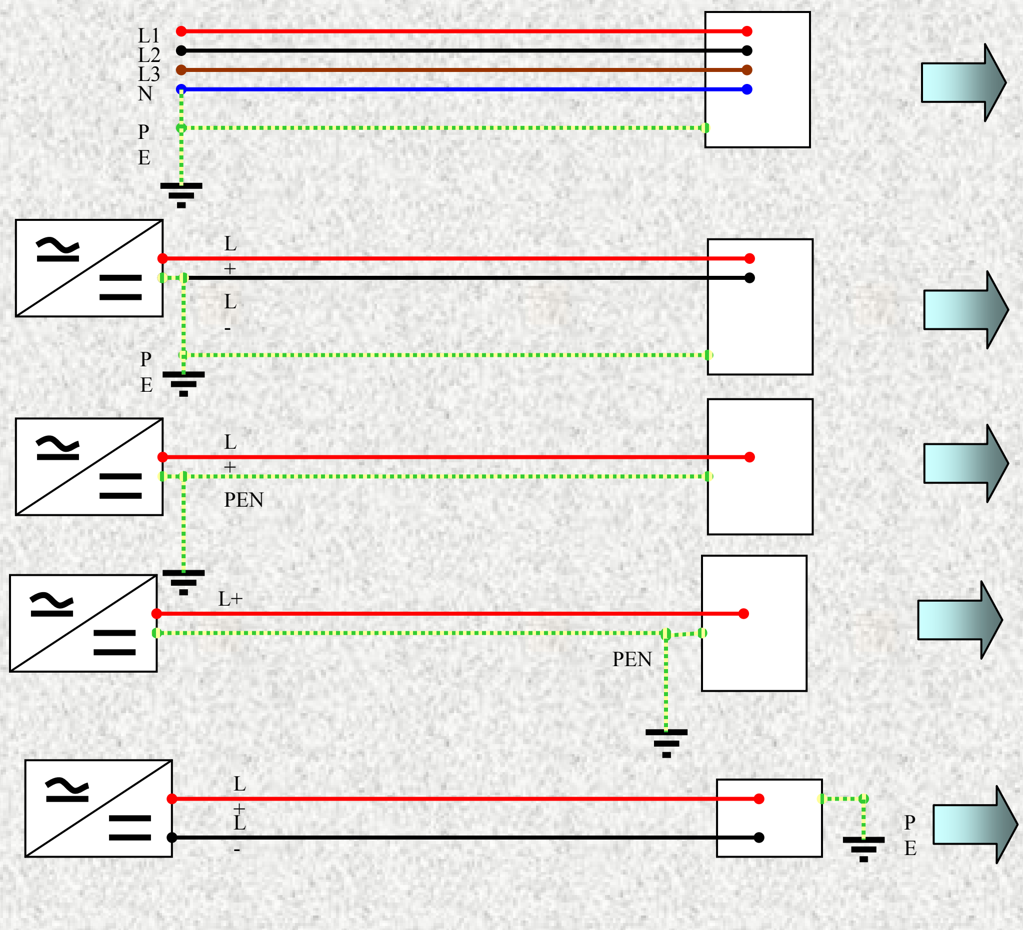
3

Commissioning:

Cross check compliance to safety rule.
Cross check conducted noise levels.

Grounding Configurations

In compliance with the CERN electrical codes



TN-S AC Scheme: separation of neutral and PE. Requires ground fault interruptor.

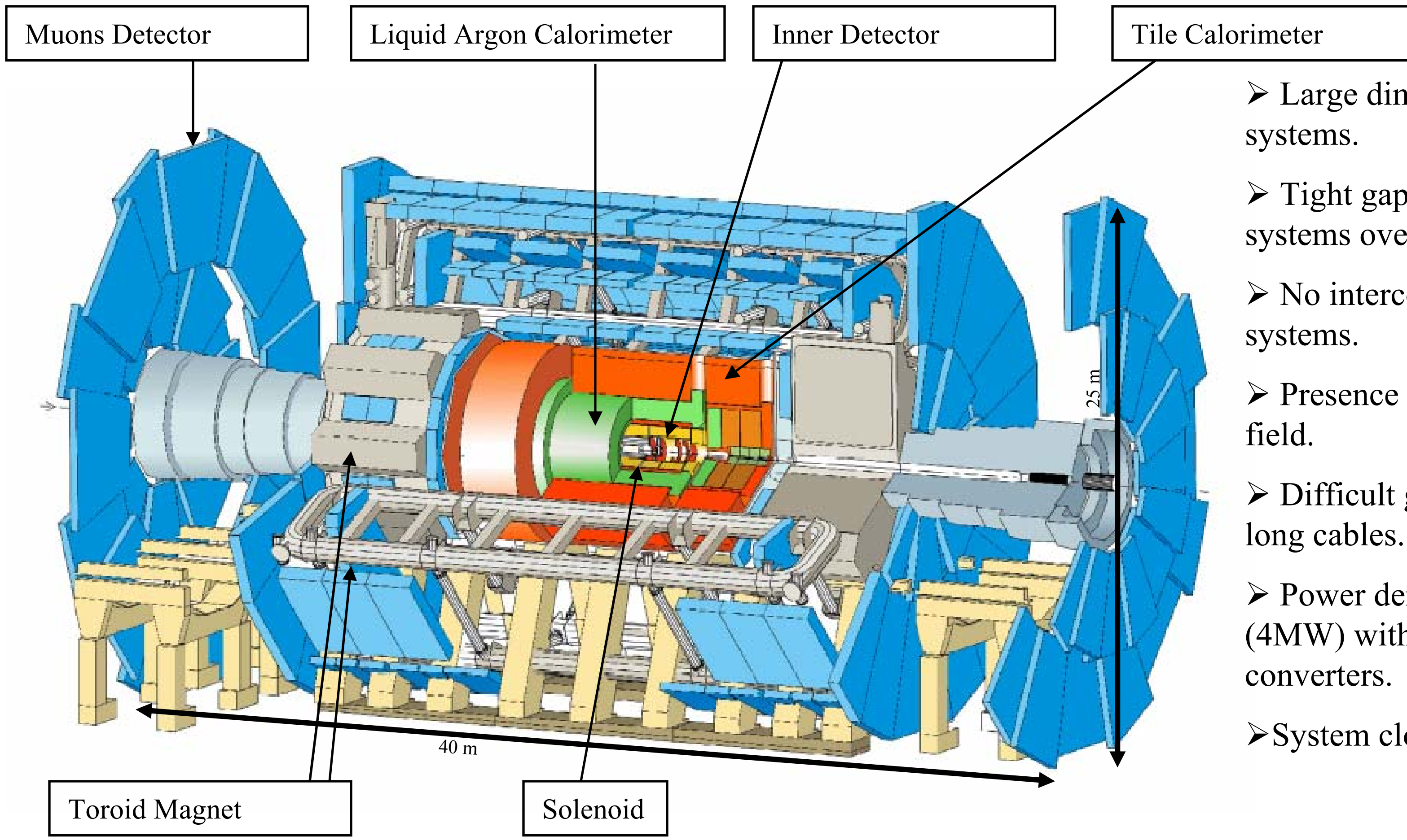
TN-S DC Scheme: separation of return and PE. Requires over current protection.

TN-C DC Scheme: return and PE are common at source. Requires over current protection.

TN-C DC Scheme: return and PE are common at load. Requires over current protection.

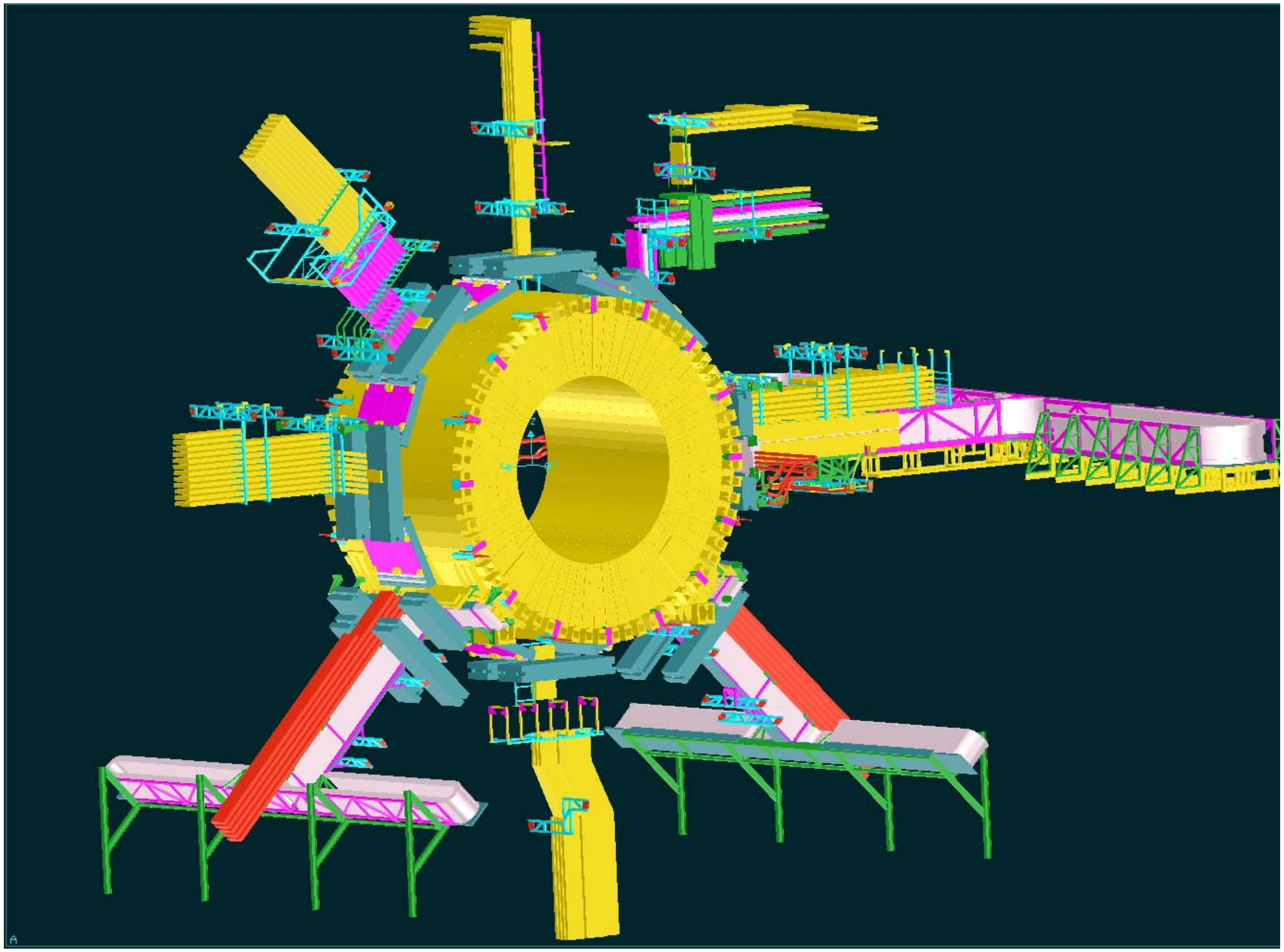
IT DC Scheme: floating. Permanent isolation controller (CPI) and over current protection.

Electromagnetic Environment Systems



- Large dimension shielded systems.
- Tight gaps between systems over large surfaces.
- No interconnect between systems.
- Presence of magnetic field.
- Difficult grounding with long cables.
- Power demanding (4MW) with DC/DC converters.
- System clock 40 MHz.

Electromagnetic Environment Cabling

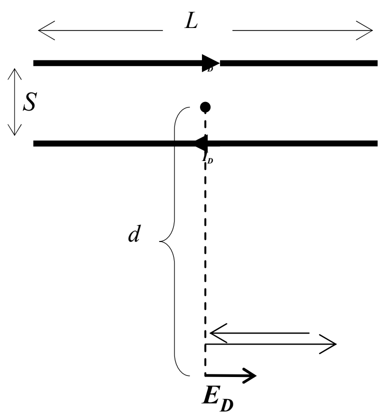


- Very dense cabling into grounded cable trays.
- High density of trays.
- Long cables (> 100 m).
- Trays contain power and data cables, not always possible to separate them.

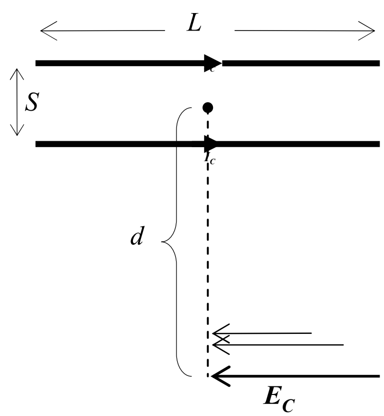
Electromagnetic Compatibility
EMI sources

- Radiated Noise from system is small because at f=40MHz λ=7.5m that is easily shielded by the system faraday cages and enclosures.

- Radiated Noise from cables comes mainly from CM noise (*far field** from electrically short cables).



Differential Mode: the far fields are opposed and cancel each other



Common Mode: the far fields add up.

The contribution of CM current to EMI is typically more than 3 orders of magnitude stronger than the contribution of the same DM current.

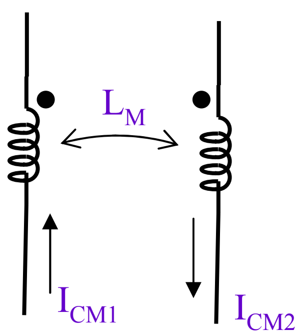
Need to control the sources of CM noise in ATLAS:

- Switched power circuits and converters.
- Digital circuitry.
- CM coupling across cables.

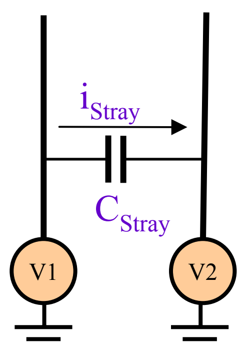
* Far field region starts at a distance $d = \lambda/6$, i.e. 1 m at 40 MHz.

Electromagnetic Compatibility
Near Field in Cable Trays

- The near field is mainly contributed by the CM noise.
- Coupling across cables happens inside cable trays in the *near field* region.
- The near field dominant component is function of the *wave impedance.*
  - ✓ H field dominates for low impedance loads and decreases at rate $1/d^3$.
    Power circuits, DC/DC converters, 50Ω and 120Ω terminated lines, CANBus.
  - ✓ E field dominates for high impedance loads and decreases at rate $1/d^3$.
    Unterminated lines, sensors and TTL signals.
  - ✓ Non dominant field decreases at rate $1/d^2$.



H fields couple through mutual inductance



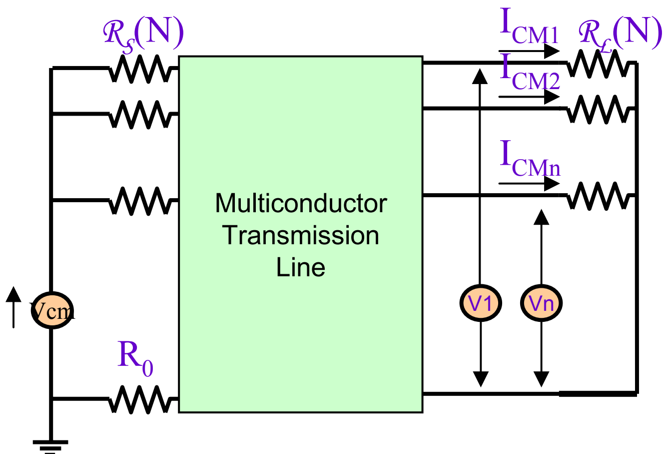
E fields couple through stray capacitance

<u>Need to shield the cables to contain the EMI fields and to provide some level of protection against it.</u>

<u>Need to provide separation between cables to reduce their exposure to EMI fields</u>

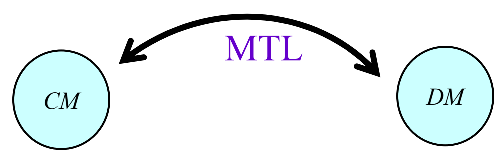
Electromagnetic Compatibility
Long Cables

- The cables in ATLAS are electrically long: L >> λ.
  - ✓ They behave as antennas for wavelengths above λ/10 (>300 kHz for 100 m cables)
- Cables to be modelized as Multiconductor Transmission Lines (MTL).
  - ✓ Current and voltage depend of the per unit length parameters.
  - ✓ Noise and current get amplified or attenuated at the load for given frequencies.
  - ✓ CM turn into DM and vice versa.
- Power loads usually are unmatched to their power cable.



$$V_1 \neq V_n \neq V_{CM}$$

$$I_{CM1} \neq I_{CM2} \neq I_{CMn}$$

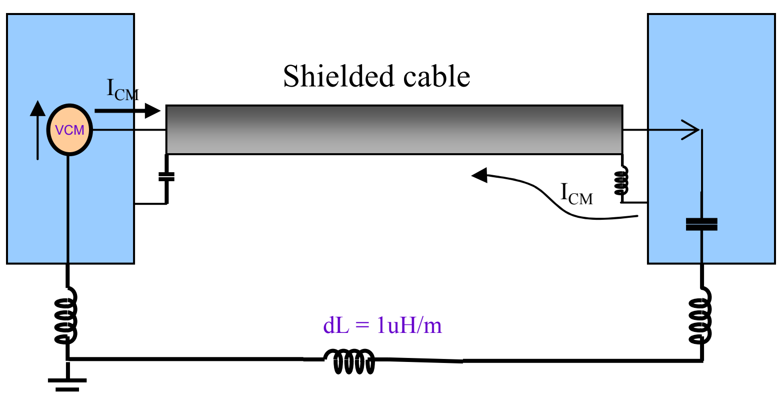


Need to measure the system sensibility to CM currents in a systematic way.

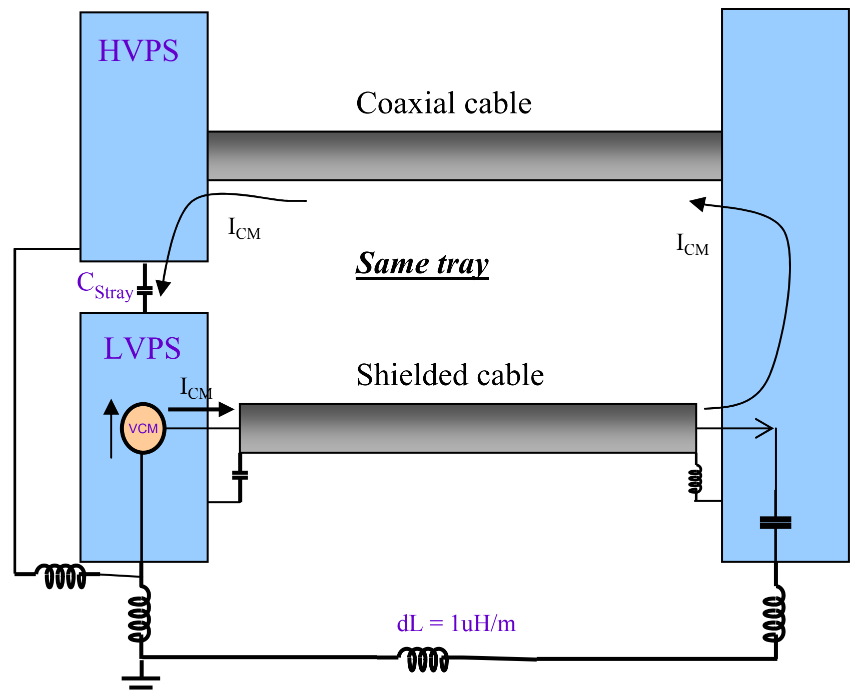
Electromagnetic Compatibility
Common Mode Return Paths

On large systems, beyond few MHz, the equipotentiallity cannot exist.

CM currents return to less inductive path: stray capacitances, shields, ground straps.



CM currents can return through other cables shields.



CM currents can return through other systems, capacitively coupled, in particular if cables lack of shields to provide the return path.

Electromagnetic Compatibility
Routing paths

- Systems must be designed so that:
  - ✓ They emit as low CM as possible.
  - ✓ They tolerate CM from couplings.
- Cables must be routed so that:
  - ✓ The coupling between systems is minimized.
    - Systems that are sensitive to CM must have their cables away from near magnetic field sources (power): separation of power and data inside a tray.
  - ✓ The circuit loop follows the same path.
    - Cables must contain the return conductor: separation of power and data inside a tray.
    - Even DC conductors carry high frequency noise, whose emissions must be minimized.
  - ✓ The circuit loops are contained inside a grounded tray.
    - Preferred with covers.

Electromagnetic Compatibility
Shields

- Cables are closely packed inside trays:
  - ✓ Shield required to minimize emissions.
  - ✓ Shield required as a protection against EMI.
- Shields in ATLAS: effective up to 10 MHz maximum.
  - ✓ Aluminium foil.
    - Poor mechanical strength , difficult to connect, high DC resistance: addition of *drain wire.*
    - Typical transfer impedance = 100 mΩ/m. Good at high frequencies.
  - ✓ Copper braid.
    - Mechanically strong, easy to terminate, sometimes combined with Al foil.
    - Typical transfer impedance = 10 mΩ/m. Good at low frequencies.
- How to connect:
  - ✓ One end to ground: Electric field shielding.
  - ✓ Both ends to ground: Magnetic and electric field shielding.

    Allowing cuurent to flow in the shield cancels out the H field inside the affected cable.

Electromagnetic Compatibility
Compatibility limit

CM Noise

Current [mA] at a given frequency

System
S(f)

System Noise

System dependent parameter.

System noise limit sets the input CM noise limit.

The correlation between CM and system noise must be evaluated.

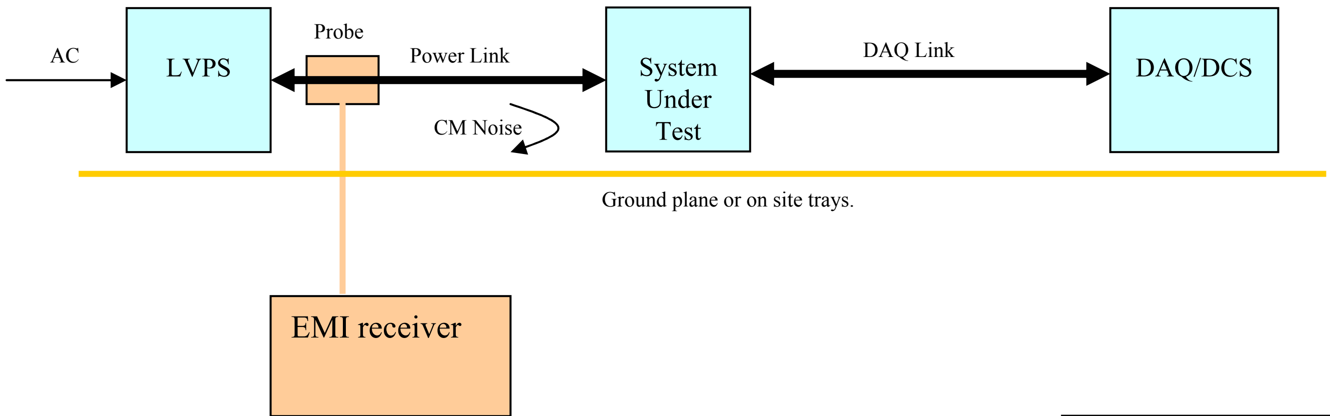
Injected by means of a calibrated injection probe.

RF Generator, injection probe, current probe, EMI receiver.

Note that the system is *also* a source of CM noise sent outwards.

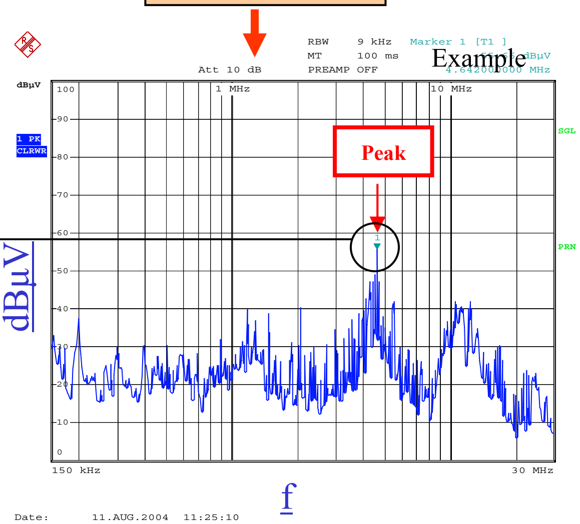
Measured by physics DAQ.

Measurements: emissions



10kHz-100MHz

Voltage computed back to CM current with the current probe calibration curve. Typical values sit in few tens of µA.

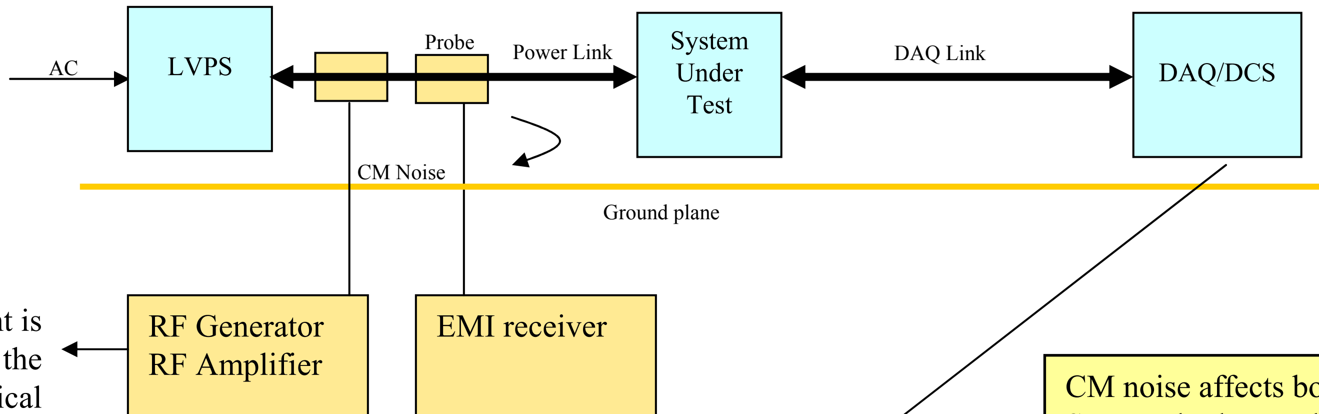


CM noise is contributed by the LVPS ***and*** the System under test. Both must configure the ATLAS real setup (no lab devices).

In lab, a ground plane substitutes the structures and trays that provide the CM return path in ATLAS.

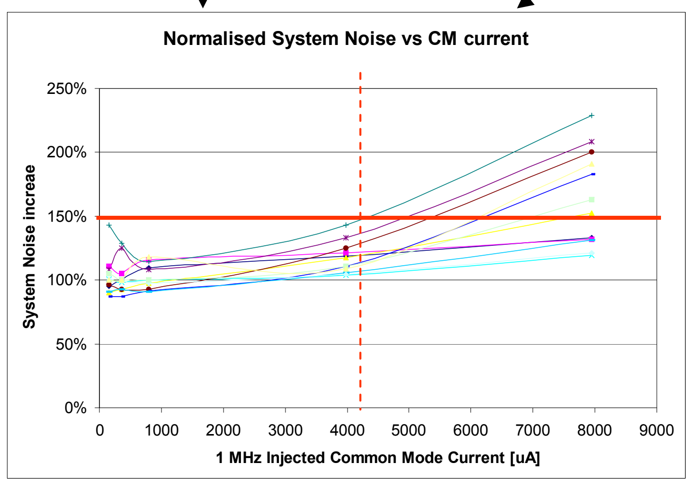
Measurements shall strictly be done with appropriate equipment as described in the policy.

Measurements: Immunity



Injected current is monitored with the current probe.Typical values up to few tens of mA (up to system failure).

Example



Sweep frequency to find worst case peaks.
At worst case peaks, modulate amplification up to reach compatibility limit.

CM noise affects both LVPS and System: both must be representative of the ATLAS setup and appropriate cabling must be used.

In lab, a ground plane substitutes the structures and trays that provide the CM return path in ATLAS.

Measurements shall strictly be done with appropriate equipment as described in the policy.

Conclusion

- ATLAS EMC Policy:
  - ✓ Quality and risk management issue.
  - ✓ Establishes methods and procedures to insure the systems electromagnetic compatibility in the experiment environment.
  - ✓ Compliance requirements specific to the ATLAS and CERN environments.
- Procedures:
  - ✓ Clear description of the setup:
    - ✓ To insuire compliance with safety rules.
    - ✓ To define the valid configuration for EMC measurements.
  - ✓ EMC Measurements:
    - Specific for each system.
    - Aims to understand how noise couples into a system and affects its performance, within the established compatibility limit.
- Guidelines: On cgrounding configurations, coupling modes, cable shields, shield terminations routing paths, test methods, tools.