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EMC issues for Tracker upgrade

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OUTLINE

- 1. Introduction.
- 2. EMC strategy
- 3. First stage of EMC analysis for Tracker upgrade.
  - Power network impedance effects in noise emissions.
  - Noise propagation effects in power network.
  - Noise immunity of new SLHC FEE
    - High immunity technologies
- 4. Conclusions

1. Introduction

- CMS SLHC Tracker system will require a new power scheme to bias the FEE.
- DC-DC converter based power distribution system is the option adopted by the CMS Tracker upgrade power task force
  - In terms of noise – less risky
    - Many years of experience 2001-2009
    - HCAL, HF, Pre-shower,TEC and TOB
  - Detailed noise analysis (DC-DC vs Serial)
    - **Talk:** Tracker upgrade meeting Feb. 2009
    - **Poster :** DC-DC Converter vs Serial – TWEPP 2009

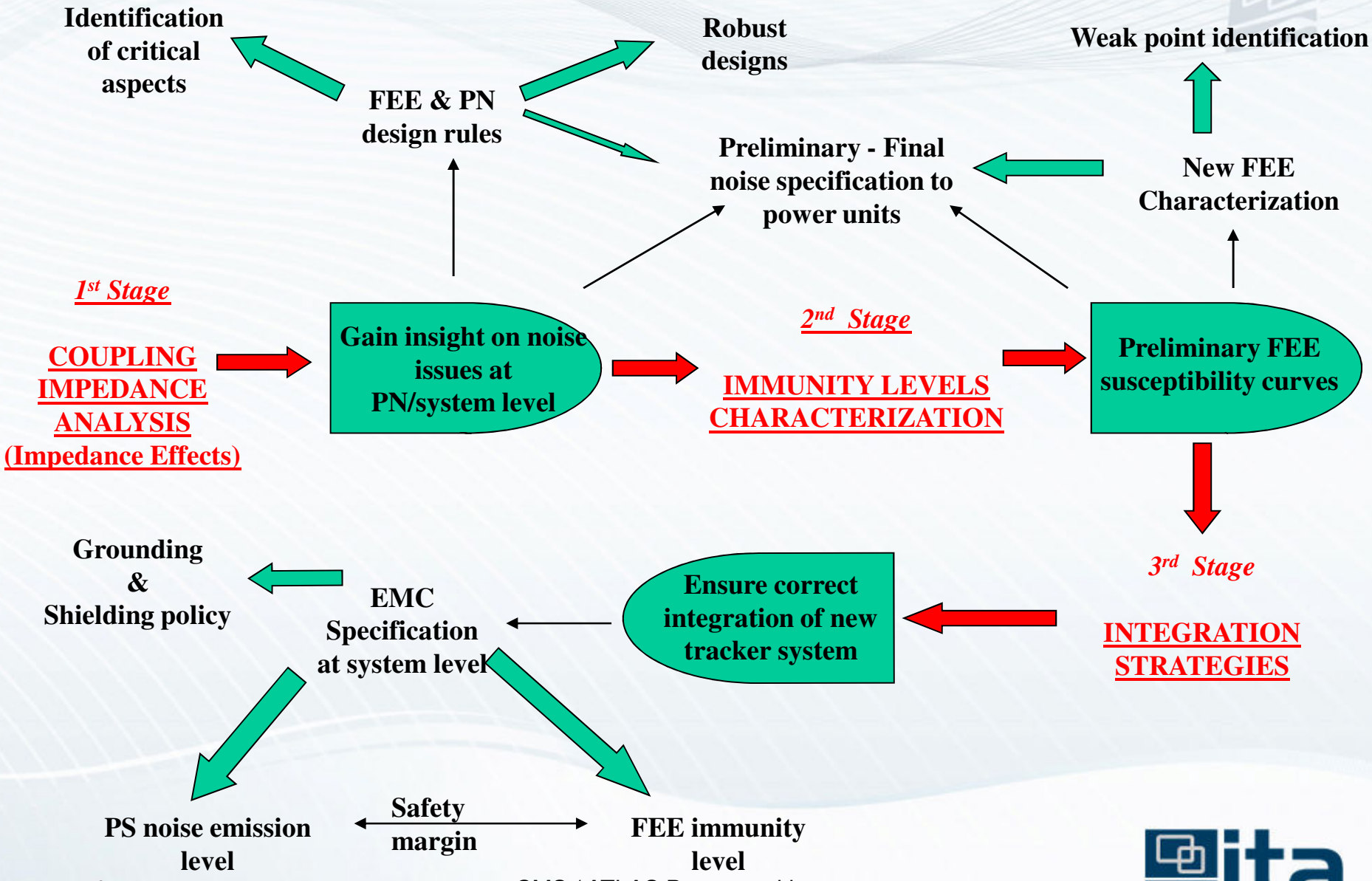
1. Introduction

- Main characteristics of the DC-DC converter powering scheme:
  - Several noise sources close to FEE-Sensor
    - DC-DC power converter, MT & HV line & Structure
  - High magnetic field inside tracker volume
    - No optimal DC-DC power converter design
  - High switching frequency
    - Radiation (Near-field and Far-field)
  - New FEE design
    - Sensitive to sensor & power line connection (LF & HF)
- A large R&D effort is planned and taking place to develop a DC-DC switching converter to operate under high magnetic field with low electromagnetic emissions
- But it is important to have a R&D plan on EMC issues to conduct studies on the tracker detector at the system level
  - To improve FEE immunity
  - To minimize EM noise levels within the tracker volume
  - To ensure the correct integration of SLHC tracker.

2. EMC strategy for CMS Tracker upgrade

- The goal of the EMC studies is to ensure the compatibility of Tracker (CMS) upgrade system
- It will be focused on
  - (Minimize) noise emissions
  - (Maximize) noise immunity
  - (Fix) integration strategies
  - (Ensure) the compatibility between DC-DC converters and FEE
- Experienced gained in the past gives a lot information
  - EMC based design has to be part of the experiment with similar importance that the mechanic / thermal design
    - They have to be tackled and implemented together
    - New environment and the working conditions are very different from previous experiments
  - It requires many EMC studies

2. EMC strategy for CMS Tracker upgrade

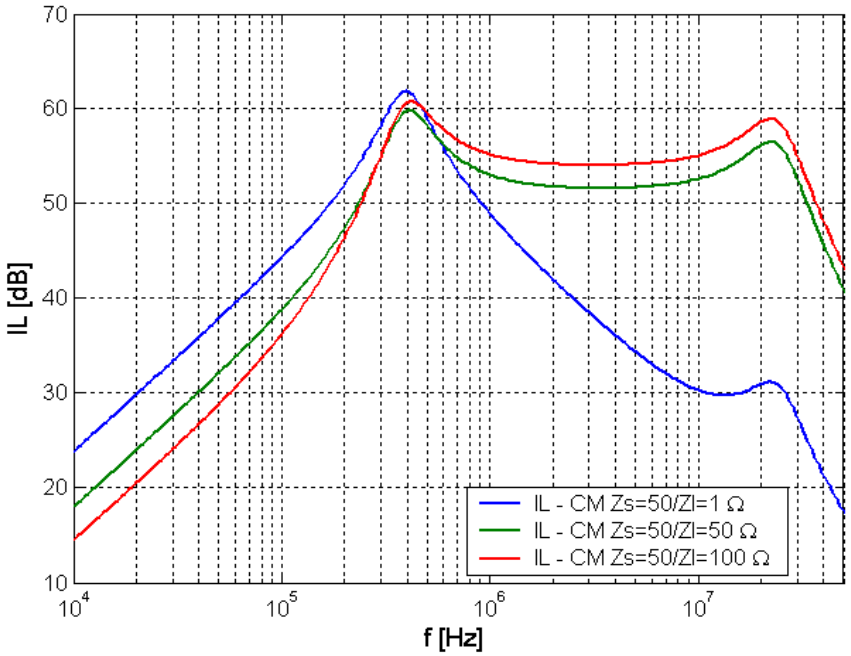


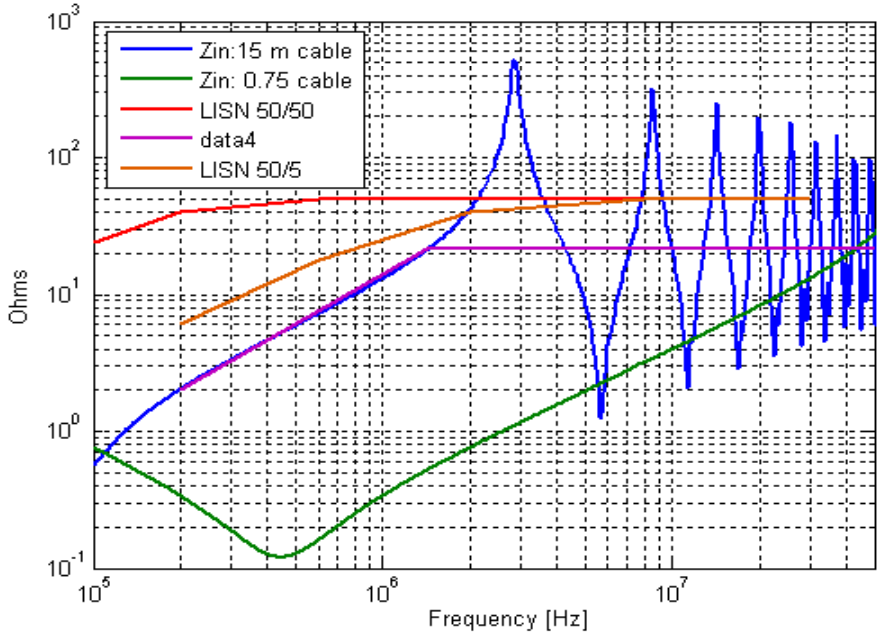
3. First stage of EMC analysis for Tracker upgrade

- The first stage of the EMC analysis plans to study :
  - The coupling impedance characterization
  - The preliminary immunity levels on prototypes (new or old designs)
- It will help to define preliminary rules to ensure the integration of main components (Detector, FEE, Power network and DC-DC power converter)
- It will helps to define design strategies that allow increasing the immunity of the Detector-FEE unit.
- This analysis should be part of the integral design of the tracker detector. It has be considered at the same level as the mechanical and cooling design.
- It can be divided in four parts
  - Power network impedance effects on noise emissions
  - Noise propagations effects in the power network
  - Noise immunity in Detector-FEE prototypes
  - New high immunity systems to electromagnetic noise

3.1 EMC analysis: Noise emissions Vs impedance

- It is very important to define and characterize the impedances connected to the DC-DC power converters
  - It defines the emission (conducted and radiated) levels emitted by the DC-DC power converters compatible with the FEE immunity levels
    - Filters degradation
- It has to be complementary with the decoupling impedances implemented during the immunity test of FEE.
  - Both test has to be complementary



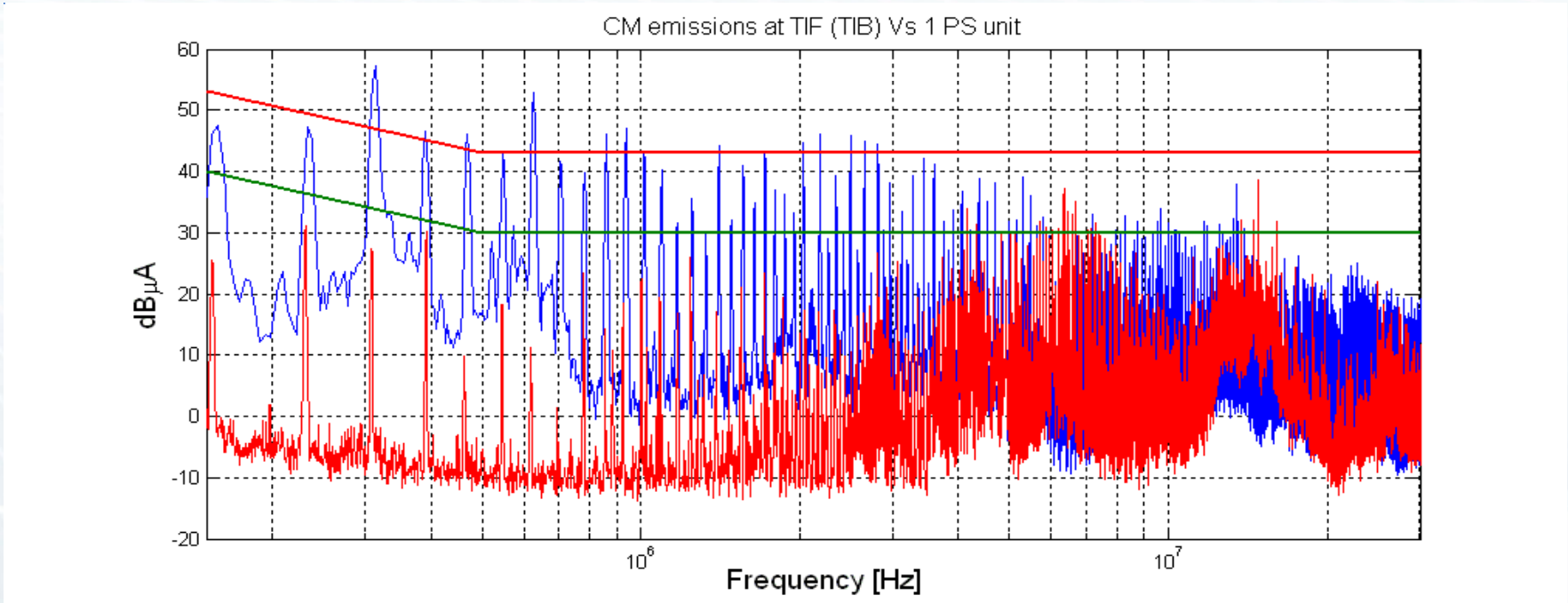


3.1 EMC analysis: Noise emissions vs impedance

- The impedance characterization will define a standard test for integration purpose
  - It has to be valid for conducted and radiation emission test.
- This test characterization will be focused on integration issues at system level and not on DC-DC converter design issues.
  - It is complementary with the work develop by other groups.
- It is probably that the test setup developed in the past has to be redefined.
  - New frequency spectra
    - Old Tracker – (100kHz – 30 MHz)
    - New Tracker – (1 MHz – 100 or 200 MHz)
  - Impedance and cable radiation
  - Radiation emission test
    - This is totally new
    - Near-field and far-field emission is required

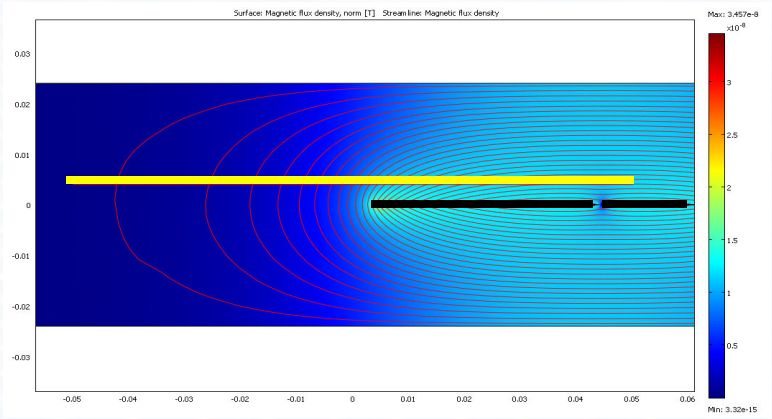
3.2 EMC analysis: Noise propagations

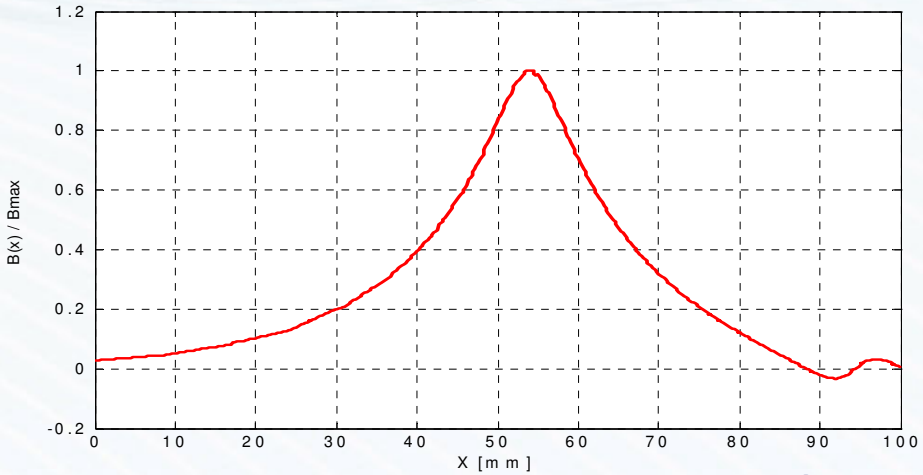
- The goal of this part is to define the key points that allow designing the power network to minimize the effects of the noise generated by the DC-DC power converters and the FEE.
  - Power network radiation
  - Noise exchange between DC-DC power converters
- Experience form previous detectors showed the importance of the EMC based design of the power network.
  - Tracker - PS conducted emissions increased a lot respect to one unit



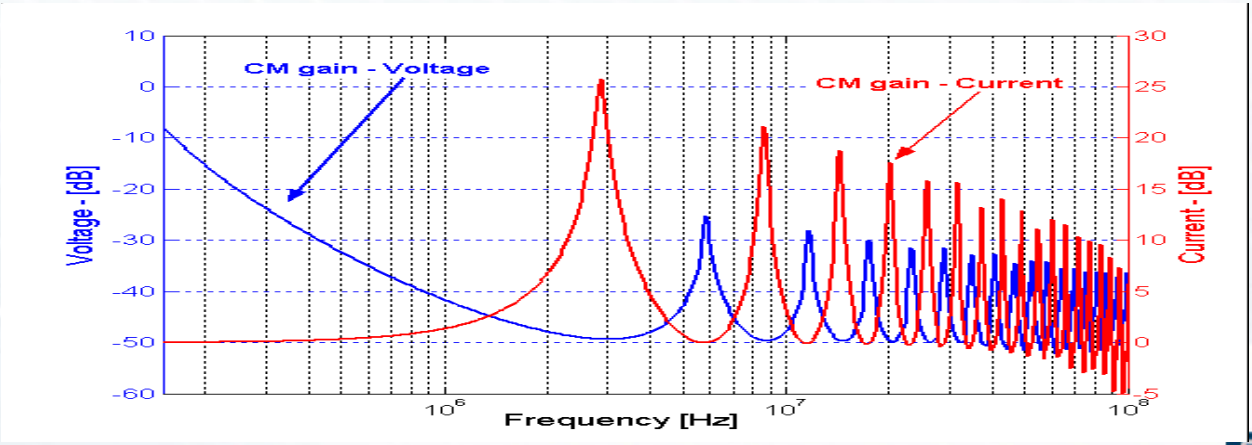
3.2 EMC analysis: Noise propagations

– Tracker “wings” generated by the magnetic field radiated by the power network.





– HCAL- High radiated emissions from power network due to CM currents.



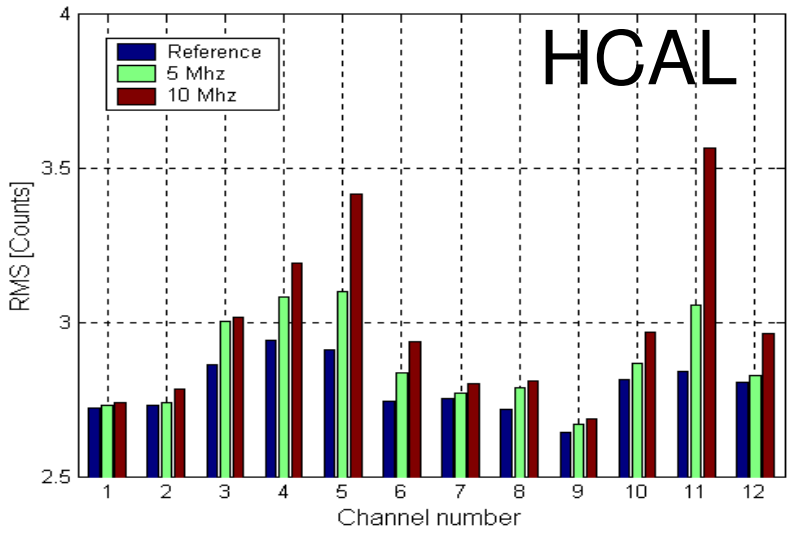
3.2 EMC analysis: Noise propagation

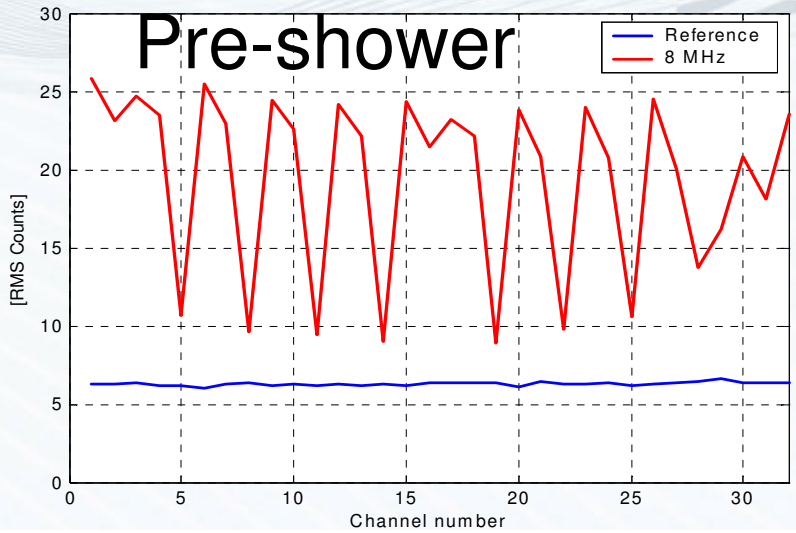
- This part will be divided in four sub-items
  - Development of new methodologies to measure noise in power networks
    - Old methods may not be sufficient
  - Evaluation of power network designs to minimize noise emissions (conducted and radiated)
  - Evaluation and design of EMC filters.
  - Evaluation and design of components layout for noise purposes
- It is planned to study two power networks (methodology is the same)
  - PCB
  - Cables
- It is important to remark the previous experience at Fermilab with KTEV experiment
  - Digital signals / Power distribution based on cables within the detector volume was abandoned because it was mechanical unpractical (2 meter long board – New Tracker will have rods 2 m long)
- This studies has to be conducted in close relation with institutes in charge of DC-DC power converters and Power Network design
  - Include the EMC issues at the same level as power losses, cooling and mechanical constraints.

3.3 EMC analysis: Noise immunity in FEE

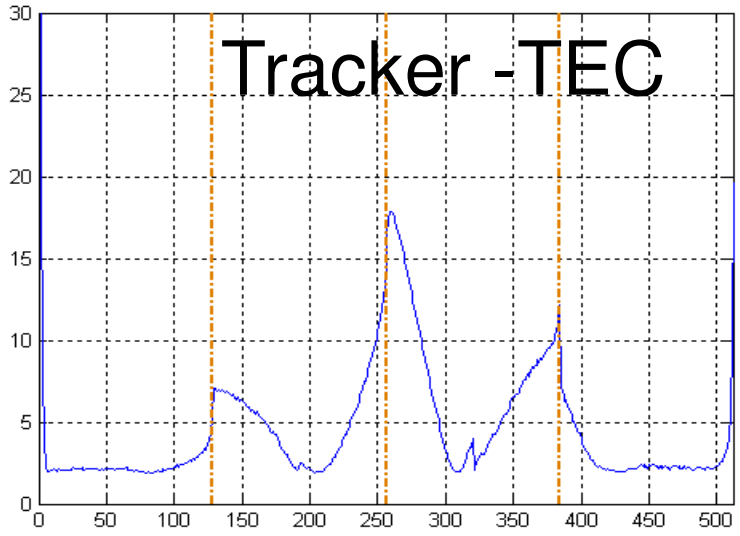
- A set of tests is planned to define the immunity of a prototype of the future generation of FEE.
- These tests will give a lot of information that can be use to improve the immunity of FEE.
  - Corrective actions & new integration strategies.
- Results of immunity tests performed in the past became an excellent and useful tool for:
  - Diagnosis (TEC & TOB, HCAL, Pre-shower)
  - Detection of sensitive areas (HCAL, Pre-shower, TEC, TOB)
  - FEE frequency response to noise (QIE,APV,PACE chips)
  - PS Noise emission specification (HCAL,TEC)
- HCAL and Pre-shower took advantage from these tests and correctives action were implemented in the final design. Others detectors could not due to time constraints
  - HCAL results very useful.
    - Grounding strategy, Filter selection
    - Noise specification to PS units

3.3 EMC analysis: Noise immunity in FEE





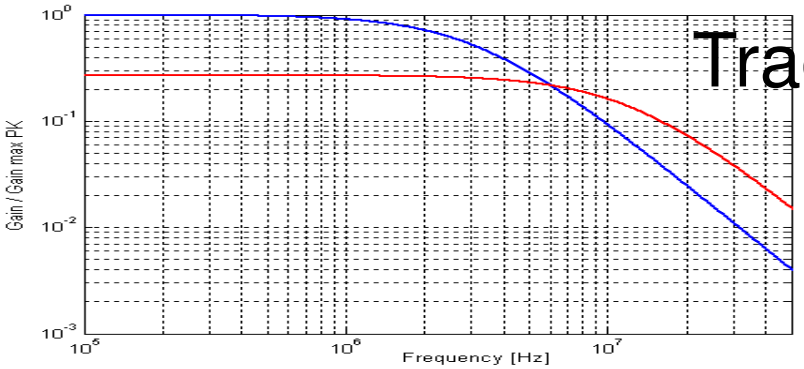
- **Diagnosis & Sensitive areas**
  - HCAL – Ground connection photodiodes-Board
  - Pre-shower - Ground connections between paths
  - Tracker - Noise distribution generated by *By* and CM subtraction

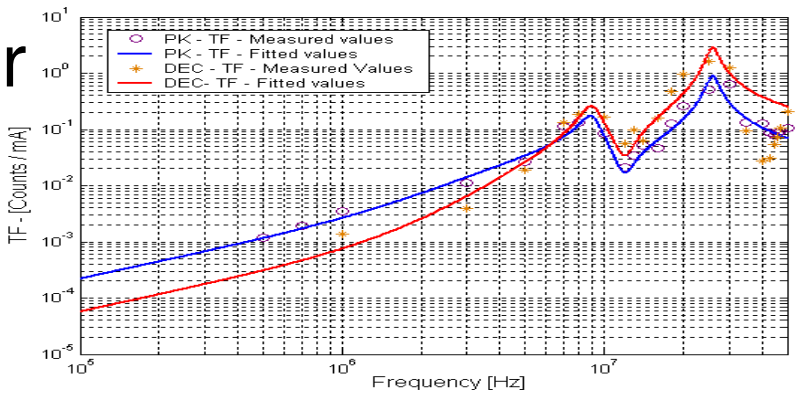


3.3 EMC analysis: Noise immunity in FEE

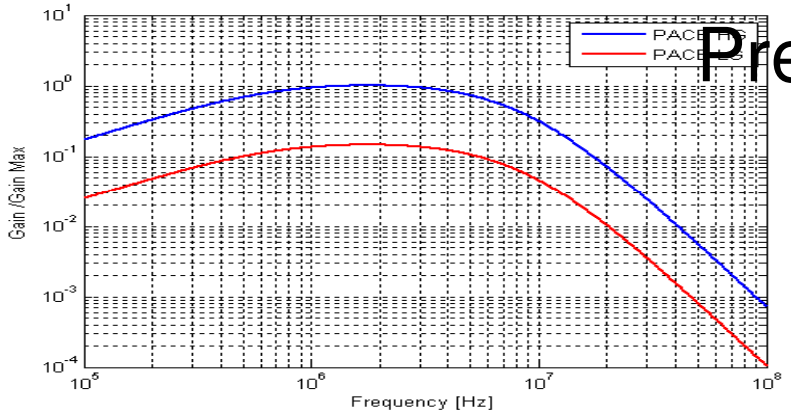
Frequency response

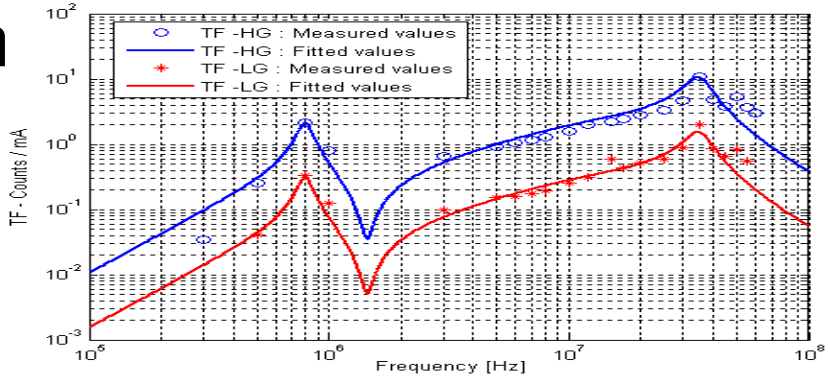
Tracker



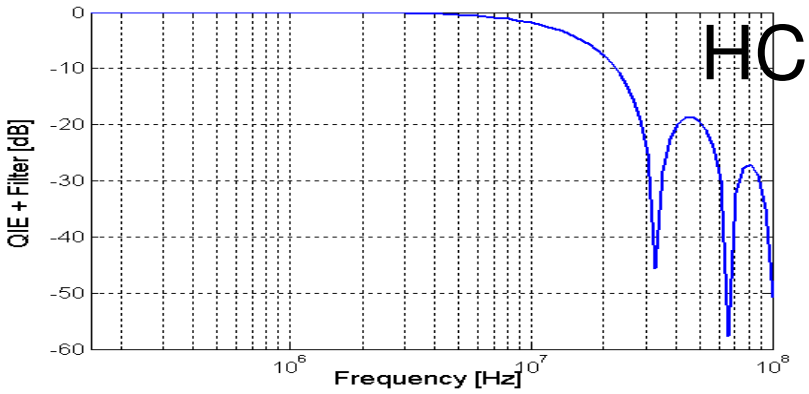


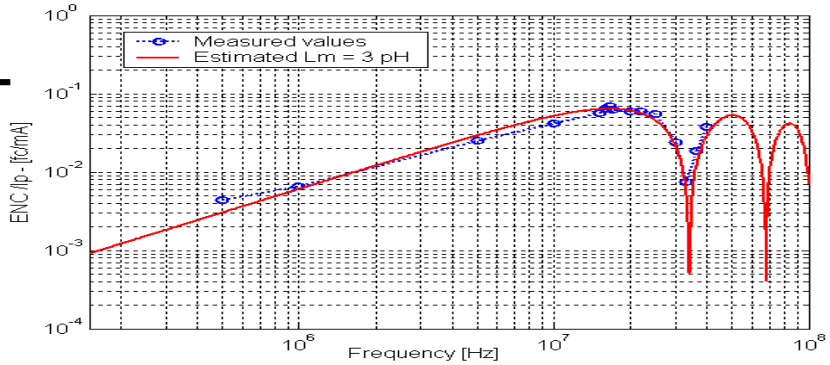
Presh



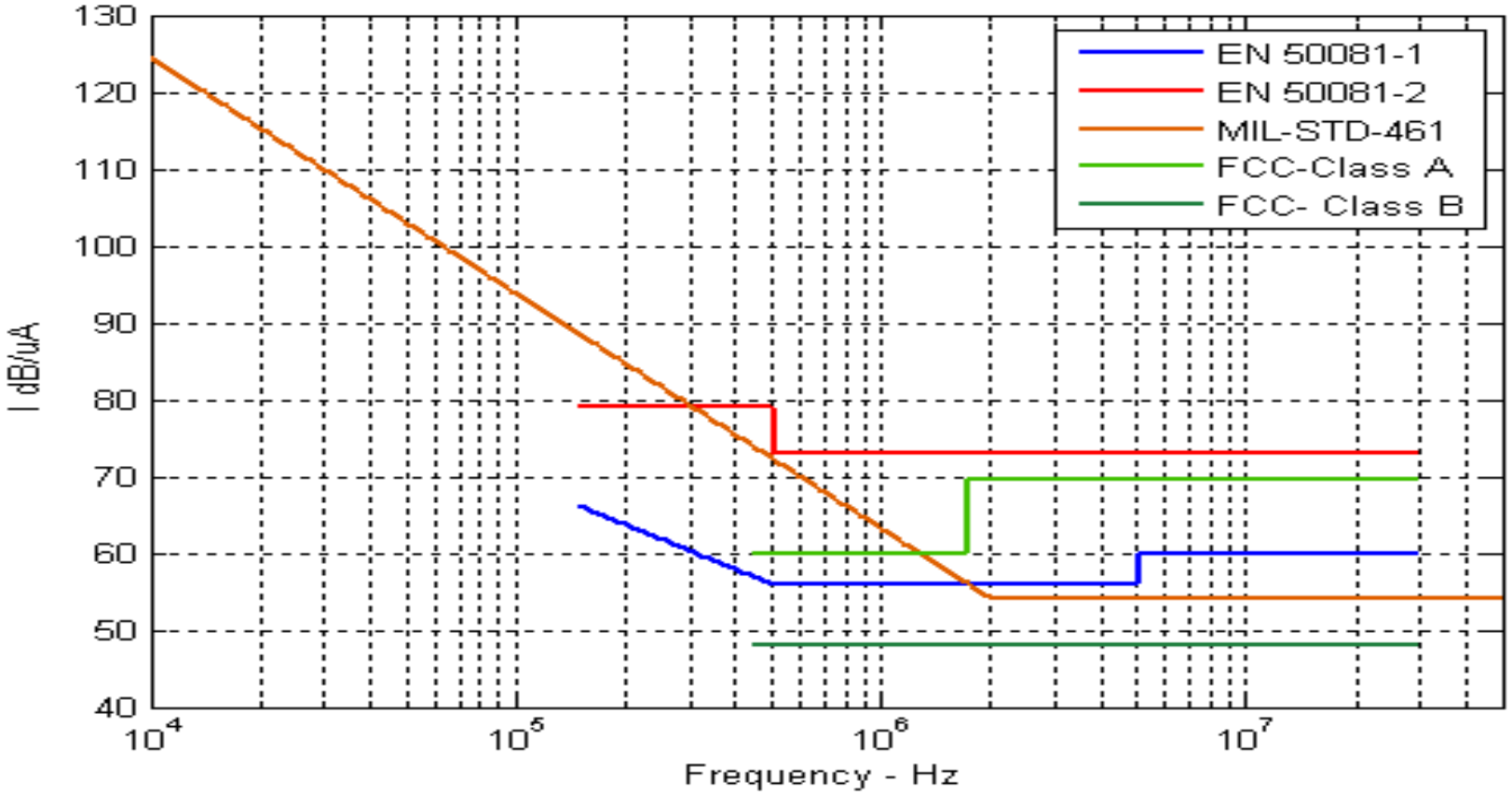


HCAL





3.3 EMC analysis: Noise immunity in FEE



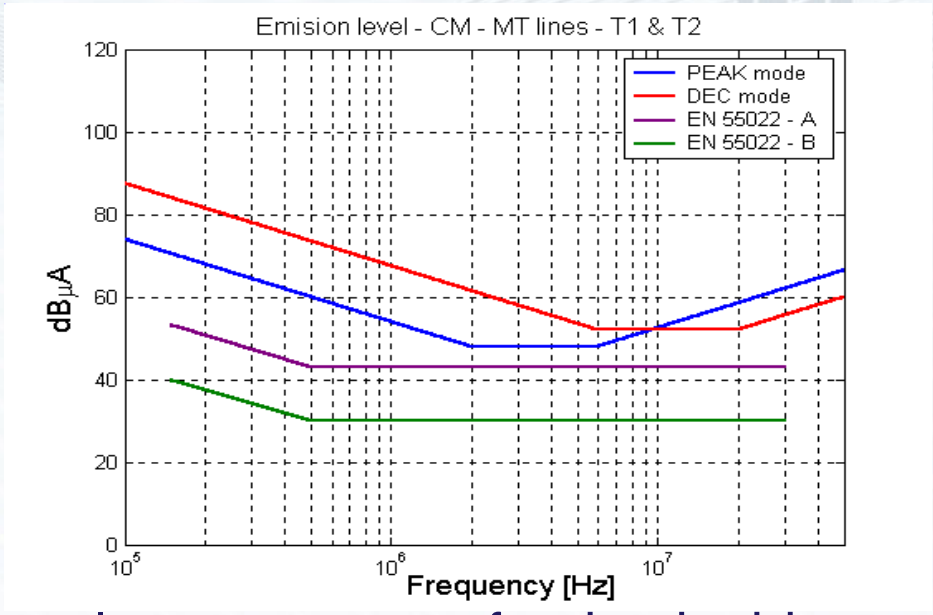
- **Noise emission specification**
  - HCAL – 3 Topologies (GND, FILTER,NO EXTRA)
  - TEC – 2 Topologies (CM FILTER , NO FILTER)
  - Very different from standards

3.3 EMC analysis: Noise immunity in FEE

- It is planned to conduct radiated and conducted immunity tests.
- Test procedures has to be developed because the ones developed for old CMS are not valid.
  - **Conducted noise immunity test**
    - Noise sources are inside the tracker volume
    - Frequency range requires special test set-up (Faraday cage for reference)
  - **Radiation test**
    - It has never been performed before
    - Near-field and far-field (Semi-anechoic chambers)
- Two possibilities are under study
  - Immunity test on improved old prototypes of Tracker system
    - During last year based on modelling and simulations some recommendations has been already presented (See Poster Tracker "wings")
  - Immunity test on CMS or ATLAS upgrade prototypes
    - Collaboration between both experiments

3.4 EMC analysis: High immunity systems to EM noise

- During the immunity tests performed in the CMS tracker system, Temperature sensor lines resulted the weakest element respect to EM susceptibility in the Detector-FEE.
  - But main noise source is located outside (Far way)
    - Filtering is not difficult
    - Coupling path not very good



- New tracker system will generate a large amount of noise inside the tracker volume
  - Easier coupling path
  - Filtering is more complex
- The study or design of new systems insensitive to EM noise to measure temperature, strain or magnetic field will increase the robustness of FEE to EM noise

3.4 EMC analysis: High immunity systems to EM noise

- The use of optical fibre sensors (OFS) to be used as temperature and strain probes will increase the immunity of tracker system.
  - They are very well known in aerospace and aeronautics
- This type of sensor are:
  - Not sensitive to EM fields, HV and transients.
  - Light – weight, miniaturised and flexible
  - Non-interfering , low-loss, long-range signal transmission
- Fibre Bragg Grating (FBG) optical transducer is the most common transducer to measure strain and temperature
  - A light is sent via the optical fibber to the transducer and the diffracted wavelength is measured
  - Diffracted wavelength depends on FBG geometry, that is affected by stress and temperature.

4. CONCLUSIONS

- An EMC strategy to ensure the successful integration of the Tracker upgrade electronics has been presented..
- It is focused on three aspects
  - Study of the Coupling impedances
  - Characterization of FEE Immunity levels
  - Integration strategies
- Experience gained in previous experiments may be used but the new scenario requires:
  - New test methods
  - New emission limits
  - New EMC strategies & designs
    - Make a design with high noise immunity based on electric+mechanic design and not a pure mechanic design.
    - New technologies
- This is a very early stage of the design where EMC studies are very valuable
  - Some solutions may not be implemented at later stages (during integration)

BACKUP SLIDES

2. EMC strategy for CMS Tracker upgrade

Coupling Impedance characterization

- It studies **the effect of the impedances on noise generation, coupling and propagation within the tracker system**
  - Emissions, immunities & propagation.
- It will used to gain insight on noise the distribution near the Detector-FEE and define sensitive areas of system
- It will be used to set EMC designs rules and tests to develop robust designs and improve the immunity of Detector-FEE
  - Immunity and emission tests have to be complementary
  - Noise propagation studies will be used to define safety margin

2. EMC strategy for CMS Tracker upgrade

Immunity levels characterization

- It defines the **immunity levels** for the future tracker system based on preliminary prototypes (old and new)
- It will detect weak points of preliminary and final designs
- It will be used to define the noise emission levels (conducted and radiated) compatible with the Detector-FEE
- Define the preliminary grounding and shielding strategy
- Study high immunity systems to EM noise

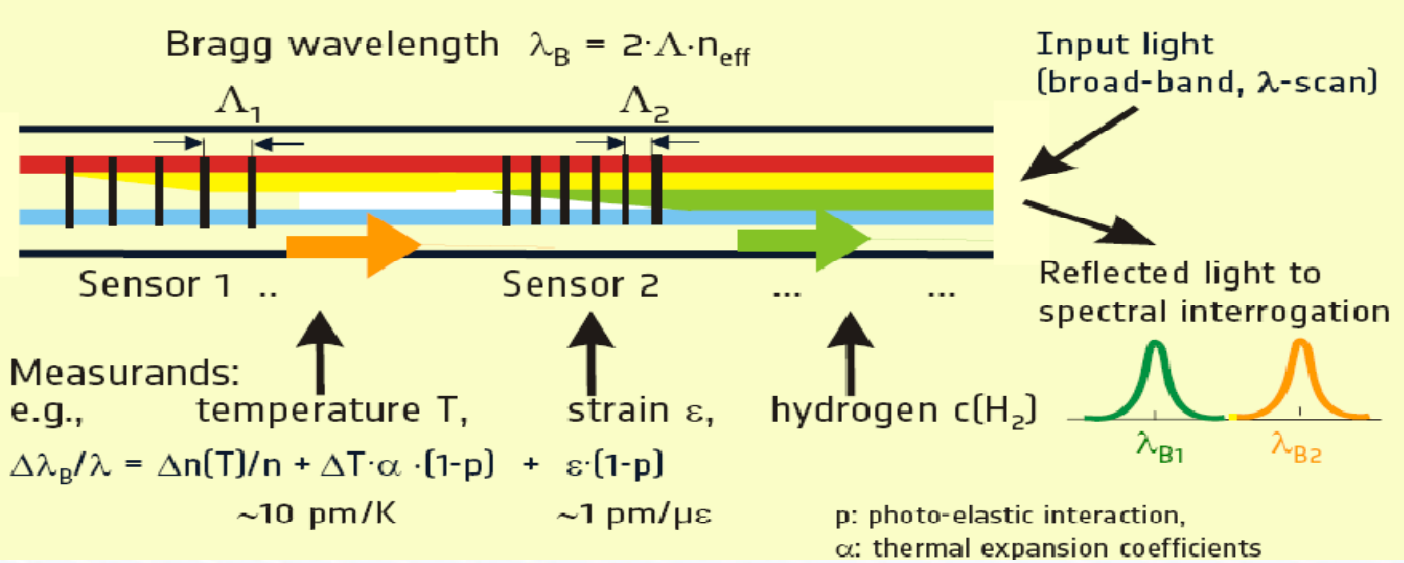
2. EMC strategy for CMS Tracker upgrade

Final integrations aspects

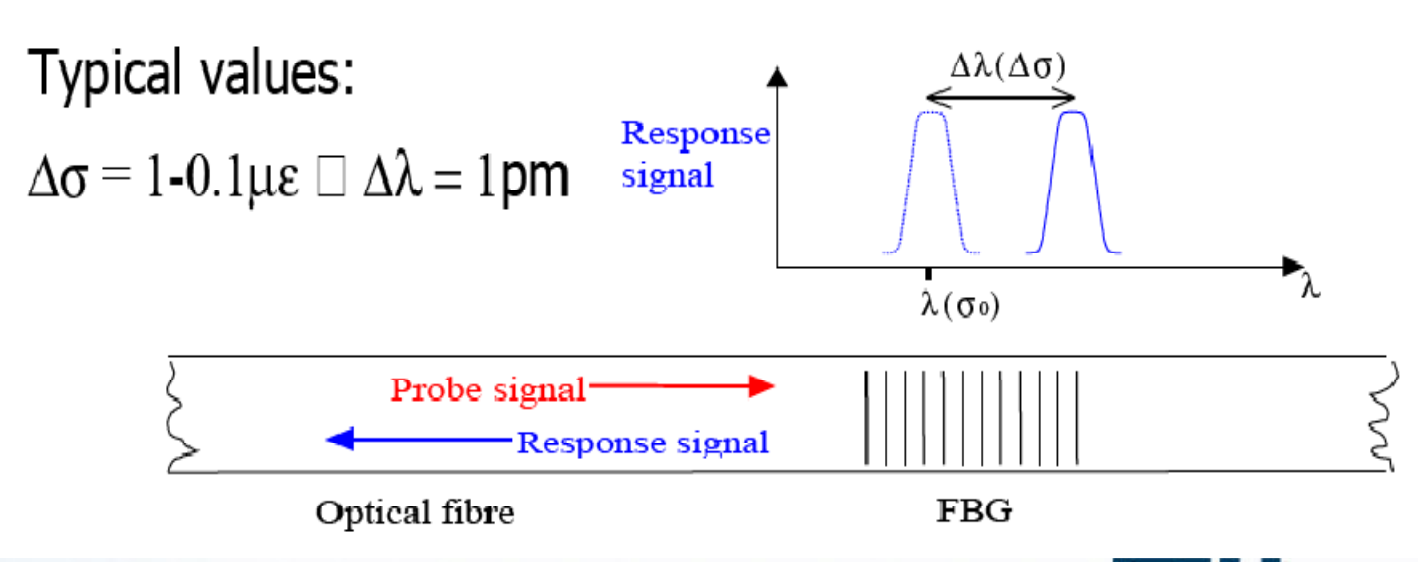
- It defines the final grounding & shielding strategy
- It defines safety margin between the emission and immunity level
  - Contribution from other units
  - Efficiency of coupling mechanism
- It verifies the final emissions and immunity level of PS units.

3.4 EMC strategy: High immunity systems to EM noise

Temp



Stress



3.4 EMC strategy: High immunity systems to EM noise

- The FBG sensors allows:
  - Multiplexing capability – (Sensor Networks)
  - Embedding in composite material –(Smart structures)
  - High and low Temperatures (4 k – 900 ºC).
  - Durable to high strain
- It is plan to study three task :
  - Different methods for attaching the fibres to carbon composites supports
  - Architectures for sensor distribution network
  - EMC factor measurement
    - Noise emissions and immunity with conventional electrical technologies versus Optical Fibre Sensors.