EMC studies for CMS tracker upgrade
Status & Plans

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OUTLINE

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1. Introduction - Motivation

Today

- New FEE requirements forces to install DC-DC converters close to FEE (inside sub-detector modules).
  - The high current demanded by each power channel

- However DC-DC converters are a very noise source
  - It is necessary to minimize the noise coupling between FEE – DC-DC units
  - It is necessary to minimize the total noise inside sub-detector volume

- 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 noise emissions** inside tracker volume
  - GREAT effort form CERN & Aachen

Upgrade
2. EMC project-upgrade

- **EMC immunity studies for CMS tracker upgrade - 9.04**
  - IFCA & ITA – *Approved* by CMS MB on November 2009
    - First stage of the EMC strategy – long term strategy for CMS
- **The project is founded by Spanish agencies and ITA**
  - 3 year project
  - Project members:
    - Instituto de Física de Cantabria (CSIC-UC)
    - Instituto Tecnológico de Aragón (G. Aragón)
    - Centro Nacional de Microelectrónica Barcelona (CSIC)
- The main goal of the project is:
  - To define preliminary rules to ensure the integration of main components (Detector, FEE, Power network and DC-DC)
  - To define design strategies that allow increasing the immunity of the Detector-FEE unit – Robust FEE designs to EMI phenomena
3. Working packages – Status & Plans

- The project has started in 2010

- It is divided in four working packages
  - WP 1: Power network impedance characterization
  - WP 2: Noise propagation effects in power network
  - WP 3: Noise immunity test in FEE prototypes
  - WP 4: Validation of EM immune OFS for temperature, magnetic field and strain: Effect on overall EM noise

- Strong collaborations with other groups is planned
  - FERMILAB – M. Johnson- B. Copper
  - Aachen –K. Klein
  - CERN-F. Faccio
3. Working packages – Status & Plans

• **WP 1: Power network impedance characterization**

  - The aim of WP1 is to define and characterize the impedances connected to the DC-DC power converter
    - *It defines the noise (conducted and radiated) levels emitted by the DC-DC power converters* **AT SYSTEM LEVEL**
    - Characterization of the electromagnetic environment
      - Impedances (FEE & Power Bus)
      - Multiple units
  - Simulation of effect to impedances connected to the DC-DC power converter-TWEP 2010
  - First measurement on ITA facilities with a ITA DC-DC power converter prototype – May 2011
3. Working packages – Status & Plans

- **Simulations**

- **Measurements**
3. Working packages – Status & Plans

• Preliminary results
  – Strong dependence of DM noise emissions respect
    – Input & output Impedance
    – Granularity
  – Strong dependence of CM noise emissions respect
    – Stray capacitance Impedance
    – Input voltage

• A test set up has been developed to estimate noise emissions in real scenario – System Level
  – Previous studies have shown that the impedance connected to the DC-DC has strong impact in noise emission
  – It represents the low impedances connected to the DC-DC
  – It has to be prepared to work between up to 100 MHz.
3. Working packages – Status & Plans

- The impedance effect have more or less impact depending on DC-DC layout & size
- It is planned to repeat these tests with Aachen’s converter
3. Working packages – Status & Plans

**WP 2: Noise propagation effects in power network**

- The aim of WP2 is to define the key points that allow designing the power network to minimize the effects of noise currents generated by DC-DC converter.

  - Effects of noise emission of carbon fiber
  - Shielding effectiveness to carbon fiber
  - DC-DC layout effects (conducted and radiated)
  - Cables – Ability to radiate

- This WP is carrying out in two stages:

  - Simulations models
    - Transmission line models - MATLAB code (finished)
  - Real conducted and radiated test (Anechoic chambers)
    - Radiated noise from DC-DC prototype
    - Noise distribution on DC-DC prototype
3. Working packages – Status & Plans

- **WP 2: Effects of noise emission of carbon fiber**

Results for ITA prototype
They are similar to the ones measured with System test board
3. Working packages – Status & Plans

WP2. Shielding effectiveness test of carbon fiber

• The carbon fiber is used in the development of double-stack structure.
3. Working packages – Status & Plans

**Shielding effectiveness test to carbon fiber**

- Sample 1: Carbon fiber
- Sample 2: copper insertion on carbon fiber

### Shielding Effectiveness Table

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<th>SE dB</th>
<th>ATEN.</th>
<th>%</th>
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<td>10000:1</td>
<td>99.99%</td>
</tr>
<tr>
<td><strong>EXCELENT</strong></td>
<td>100</td>
<td>100000:1</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

- They may be use as DC-DC converter shield
  - More studies are required – Copper ground
3. Working packages – Status & Plans

• **WP 3: Noise immunity test in FEE prototypes**

  – The aim WP3 is to define the FEE immunity on prototypes:
    • Impact of integration strategies in the overall design.
      – Conducted immunity test
      – Radiated immunity test (ITA facilities).
  – Some preliminary work has been done during 2009
    • Analysis of coupling mechanism in old tracker
      – Already presented in TWEPP 2009 & Tracker upgrade meetings (H field at pitch adapter)
  – Future plans – two options
    • Test FEE prototypes of new Tracker system
    • Test old FEE in new topologies
  – These tests are planned for 2012
  – We expect to collaborate with other groups
3. Working packages – Status & Plans

• **WP 4: Validation of EM immune OFS for temperature, magnetic field and strain: Effect on overall EM noise**
  
  - The purpose of WP4 seeks out the implementation of OFS to substitute previous measuring systems based on cooper cables.
    
    - Different methods for attaching the fibres to carbon composites supports
    - Architectures for sensor distribution network
    - EMC factor measurement (Copper Vs FOS)
  
  - Main FOS activities
    
    - Complete the market survey.
    - Proposal of fiber routing for CMS upgraded tracker
    - Testing of standalone fibers (irradiation).
    - CF test structures with bonded or embedded fibers.
    - Mechanical expansion and compression test under several thermal and humidity conditions.
    - Experimental validation of OFS vs. electrical expansion gauges.
    - Comparison with FEA simulations
3. Working packages – Future works

Long & detailed tests campaign planned for next months

1.- Conducted emission test to DC-DC Aachen converter
2.- Radiated emission test (ITA and Aachen)
   – Magnetic emission test to DC-DC converter.
   – Electric emission test to DC-DC converter.
   – Magnetic and electric emission test to DC-DC converter on double-stack carbon fiber developed by FERMILAB:
     • On double-stack carbon fiber
     • Inner double-stack carbon fiber
     • On double-stack structure not grounded, grounded one side, grounded two sides, grounded at the middle of the structure
3.- Multiple DC-DC converter test
   – It is planned to install 4 or 5 DC-DC converters on the CF structure. Radiated and conducted emission test.
3. Working packages – Future works

4.- Radiated emission test

• Radiated emission test will be performed inside of the semi-anechoic chamber.
• Near and far field will be measured.
• The electromagnetic field will be measured using electric antenna (30 MHz to 1 GHz) and magnetic antenna (9kHz to 30 MHz) for near and far field.
• Radiated emissions test to different components to power system distribution, they will carry out with current probe and antenna:
  • Unshielding twisted cables
  • Shielding twisted cables
  • Radiated emissions on power distribution board
4. Conclusions

- EMC Tracker upgrade project is on going.
- This project is well founded by Spanish R&D program and ITA
- The project is divided in 4 WP
- WP1, WP2 & WP4 has started
  - WP1 focused on impedance effects on noise emission is finished
  - WP2 focused on power network issues - on going
  - WP3 is planned
  - WP4 focused on development of high immunity systems is on going