Electromagnetic Compatibility and Power Electronics for Railway Systems

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One–day Conference on Power Supply, EMC and Signaling, in Railway Systems
Outline

- Our Centre
- Source of EMI
- HSR – High Speed Railway
- EMC in HSR
- **EMC in Railway is so Challenging**
  - EMI Sources in HSR
- Magnetic Shielding
- **EMC/EMI Standard related to Railway**
  - Discussion and Future work
  - Acknowledgement
Electromagnetic Coupling
Effect of Levitation
Magnetic levitation (maglev)

- Speed:
  - 110km/h to 550km/h
  - For 220km/h
- Guidance force: 2300N
- Levitation force: 8500N
  - Per electromagnet unit
- Airgap 10mm
- Current: 35A
- Number of turns: 190/300
Electromagnetic field

- Gap field 0.8 Tesla
- Max field 1.5 Tesla
- Adopt Linear induction motor for propulsion and
- Electromagnetic suspension for levitation

Analysis and Control of Electromagnetic Coupling Effect of Levitation and Guidance Systems for Semi–High-Speed Maglev Train Considering Current Direction
Jae–Hoon Jeong; Chang–Wan Ha; Jaewon Lim; Jang–Young Choi
IEEE Transactions on Magnetics Year: 2017
Interference between DC and AC

- 50Hz and DC
  - 50Hz voltage is induced on DC due to capacitive field coupling
  - 50Hz electromagnetic force (emf) induced to magnetic coupling

- EMF induces on any coils
- This may affect:
  - Pacemaker
  - Some sensitive devices with longer wiring and loop

- For High speed rail 200km/h,
- Emf induced by static field due to electronics on the train
Induced EMF at high speed

- $\oint H \, dl = Ni$
- Any loop of conductor under change of magnetic field
- A small loop or wire in a high speed train with environment of field may therefore induced voltage in the wire and that due affect the operation of the electronics related to the wire.
Pantograph surge voltage

- Rising of Pantograph induces surge current
- Couple to shielding layer
- Cause other electromagnetic interference
- Caused induction heating effect
Induced voltage

- When pantograph and catenary contact
- Surge voltage reach 5kV and
- Oscillate for few us
- Couple to other part or car body, through high voltage cable shielding layer, voltage transformer

Influence of grounding mode on surge voltage in the process of pantograph rising for high speed train
Wan Yusu; Liu Yaoyin; Gao Guoqiang; Wu Guangning
2016 IEEE International Conference on High Voltage Engineering and Application (ICHVE)
Year: 2016
Pantograph arcing

- The radiated frequency in GSM (876 to 925MHz) that is affected
- The arcing frequency could be high, up to 100Hz.
- Transient frequency is much higher
- The emitted power could be high
EMI Source- Track

- Usage of the rail for both current return and signalling (same conductor for high voltage and low voltage applications)
- Depending on soil characteristics for long track sections the return currents could find its path either through the rail or through the soil
- The Emf, both conductive and radiative mat affect all these signalling system near the track

False signaling in track circuit due to DC component of the arcing.
EMI Source- Pantograph arcing

- Usage of sliding contact to draw high power to the rolling stock through a contact area of few square mm, which causes
  1. **Distorted** supply voltage and current **waveforms**
  2. Generation of a net DC components, **harmonics**, including even harmonics, and interharmonics
  3. Wideband electromagnetic noise emissions
  4. Transients and surges
Pantograph arcing and associated frequency spectrum

• Distorts the regular waveform of the supply voltage and current and generates transients
• Propagate along the railway system, including tracks, track circuits, other locomotives on the same track, substation
• Causes interference voltages and currents in the frequency range from DC to several MHz and radio frequency emissions up to GHz.
• Net DC currents can cause interference to track circuits operating on DC supply voltage.

https://www.kth.se/en/ees/omskolan/organisation/avdelningar/etk/research/topics/emc/2.18951/emc-of-railways-pantograph-arcing-1.47295

Frequency spectrum of the conducted and radiated emission from pantograph arcing and associated railway systems with their frequency bands
Arcing damage

- Contact wire can enhance the **wear and tear**, resulting in poor sliding contact
- That affect the age and the safety
- High voltage and current transient has high $dv/dt$ and the $di/dt$

Wear in contact wire
Techniques For The Reduction of Interference Effects

- Adopting an **earthing/bonding strategy** and ensuring that an adequate RF path is provided to earth via earth braids rather than multi-core cable which may be sufficient for a Safety earth
- Using **filters** at the point of entry of power, signal and control cables
- Addressing screening as part of overall earthing/bonding strategy, eg should the screen be terminated at both ends?
Research on arcing

- Develop the **model of the arcing**
- Under high voltage and high current
- Examine the emission and all transients and all associated effects
- Examine the reduction method
Super–capacitor and arcing

- The transient could propagate through the pantograph
- **High power** super–capacitor have high transient current and low impedance
Research on High Power Management (HPM)

- Study on ultra-capacitors and its high transient bypass
- Design and building of monitoring systems and super-capacitor energy storage system
- Reduction of the high transient and reduce the coupling to other parts
Designed Super-capacitor compensator for arcing
HSR – High Speed Railway
高鐵
Features of a high speed railway

- Greater gradients are allowed on high speed lines than conventional railways.
  - modern high speed trains are extremely powerful, TGVs generate as much as 12,000hp, steam engines were nowhere near as powerful (about 1,000hp) in the era when conventional railways were built.
- The faster a train travels the less it will slow down for the same rise in height.
- High Speed induces higher EMI
- Even static field under high speed will induce EMI
Features of a high speed railway

- **Rolling stock**
  - Articulated multiple units, Steel or aluminium
  - Power cars and a number of carriages, including a **powered bogie** in each of the carriages adjacent to the power cars.
  - Power output of several MW under 25 kV.
  - Pantographs, suspensions, distributed power trains, overhead lines

**How does it stop?**

- **Dynamic brakes**, brake shoes for emergency stops.
- Trailers are equipped with four disks per axle, and backup brake shoes.
- **Magnetic induction track brakes** are planned for the next models.
- Maglevs are slowed down in the same way it is propelled, by **superconducting magnets**.
- All induce emissions
EMC/EMI in HSR
高速列车中的电磁兼容
和电磁干扰
Why EMC in Railway is so Challenging

Modern developments within the railway bring great benefit meanwhile bring great challenge in EMC.

- Usage of sliding contact to draw high power to the rolling stock through a contact area of few square mm, which causes
  1. Distorted supply voltage and current waveforms
  2. Generation of a net DC components, harmonics, including even harmonics, and interharmonics
  3. Wideband electromagnetic noise emissions
  4. Transients and surges
Why EMC in Railway is so Challenging

- Wide variations in the power supply configurations, layout and system topologies between different trains and at different sections of the railway infrastructure.
- High Speed Trains are bulk dynamic loads and their speeds, electrical loads, currents etc. vary in a wide range.
- Usage of the rail for both current return and signalling (same conductor for high voltage and low voltage applications).
- Depending on soil characteristics for long track sections the return currents could find its path either through the rail or through the soil.
Why EMC in Railway is so Challenging

- All these DC components and harmonics propagates in the entire traction power and signalling system causing EMI issues:
  - Saturation of different Transformers used, i.e., booster transformers, auto transformer, substation transformer, vehicle transformers etc.
  - Saturated transformers are a source of even harmonics and interharmonics
  - Radiated EM fields cause interference to wireless services, like GSM-R communication, other radio and wireless based services
  - DC components cause corrosion of bearings
  - Even harmonics and interharmonics affect the control systems of the drives and power electronics
  - Different levels of inrush current, wide band frequency content of transients and surges due to switching in the traction power system, raising and lowering the pantograph UP and DOWN etc.
Why EMC in Railway is so Challenging

With the recent development trends in the propulsion system, where IGBT based drive system are prevailing over GTO based systems. On the other hand more and more sensitive equipment and sensors are being used for control and signalling purposes.

- Higher frequency switching higher order harmonics 高频高次谐波
- Electromagnetic environment is complicate because: 电磁环境复杂原因
  - Difficulties in simulating the high frequency behaviour of the power electronic devices and the complete drive systems 模拟功率电子器件和完整驱动系统的高频性能方面的困难
  - Schematic details and layout of the complete system vary widely 完整系统的示意图细节和布局各不相同
  - Difficulties in performing test: due to cost, inaccessibility of the system 测试困难：成本，系统的不可访问性
  - System topologies vary widely and changes 系统拓扑不同
  - High complexity as well as high sensitivity makes it difficult to predict the associated EM environment 高复杂性及高灵敏度使得难以预测相关的电磁环境
Sources of Electromagnetic Emissions
高铁的干扰源
Infrastructure:

- Substation, rail and catenary have **interfacing**.
- **High frequency harmonic and low frequency harmonics**
- **High speed increases** the change of induction
- **High frequency conduction and low frequency conduction in a cable** has different distributions.
- **Harmonic path has conductive and magnetic coupling to other location, through connection and evening or air.**

Current flow evenly through a conductor when DC or low frequency

The tendency of current to flow near the surface of a conductor when high frequency

Power cable.
On board sources _ Power electronics: 电力电子设备

- **Fast switching** of the power electronics, harmonics from ac/dc converters, ac/ac or dc/ac inverters and dc Choppers 快速放电
- **Broadband interference** from dc commutator motors and drives of the propulsion systems. 电机及驱动系统
- **Emission from discharges in the power**, display units and rotating machineries etc. 电源放电
Power Electronics Components in Traction system

- Component examples for HST & VHST Trains
  - Asynchronous & PMM motor
  - 3 Phase Vacuum contactors for PMM isolation & protection
  - VHST auxiliary inverter case
  - Traction converter with integrated auxiliary converter
  - High performance power module
  - Control electronics
Reduction of Interference Effects
Techniques For The Reduction of Interference Effects

- Adopting an earthing/bonding strategy and ensuring that an adequate RF path is provided to earth via earth braids rather than multi-core cable which may be sufficient for a Safety earth.
- Providing EMI gasketting around panel doors.
- Using filters at the point of entry of power, signal and control cables.
- Categorization and segregation of high and low speed electronics; power electronics.
- Segregation of cables: separation of power and control cables, ensuring power and control cables cross at right angles.
Techniques For The Reduction of Interference Effects
减少干扰的措施

- Twisted wire pairs (TWP) and Screened cables – ensuring screens are given a 360 degree termination.
- Addressing screening as part of overall earthing/bonding strategy, eg should the screen be terminated at both ends? Yes for RF, but what about dc leakage currents?
- RFI from electric trains with inverter drives can be minimized by optimizing the device conduction strategies.
- Use soft-switching for power conversion
- Use multi-level inverter to reduce the switching loss, emission and frequency.
Soft-switching

- All switching devices are under zero-voltage switching
Multi-level inverter

- Reduce switching frequency
- Reduce switching loss
- Reduce voltage stress
- Sharing if the components

Front end Switched Capacitor DC – DC converter

H – bridge inverter
Techniques For The Reduction of Interference Effects

- Earthing impedance
- Active filtering and harmonics compensation
- New polymer bonded magnetic materials
- Combination of active compensation and line filtering
- New magnetic topology design
- Packaging of magnetic components
- Cable techniques
Magnetic Shielding
电磁隔离
Magnetic Shielding

- Electromagnetic interference is now the key safety issue in transportation and in the city. 城市及交通中的电磁辐射成为安全隐患

- High frequency power operation in traction system is now very common. For high-speed rail, the power level is in 10 MW and voltage is in 27.5 kV. 牵引系统高频电力转换尤其是高压大功率 情况下电磁辐射严重

- The motor is electric and the switching frequency or the carrier frequency is high 5kHz. The switching action of the transistors in the motor inverter generates high frequency radiation. 电机驱动器的开关产生高频辐射

- The radiation will have penetration to the control electronics, signal system and vehicle computer. 辐射会干扰到控制系统信号系统以及车辆计算机
## Raw materials engaged

### Composition

<table>
<thead>
<tr>
<th>Naming</th>
<th>Fe₂O₃</th>
<th>NiO</th>
<th>ZnO</th>
</tr>
</thead>
<tbody>
<tr>
<td>NiZn(50:50:0)</td>
<td>50</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>NiZn(50:45:5)</td>
<td>50</td>
<td>45</td>
<td>5</td>
</tr>
<tr>
<td>NiZn(50:40:10)</td>
<td>50</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>NiZn(50:35:15)</td>
<td>50</td>
<td>35</td>
<td>15</td>
</tr>
<tr>
<td>NiZn(50:30:20)</td>
<td>50</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>NiZn(50:25:25)</td>
<td>50</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>NiZn(50:20:30)</td>
<td>50</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>NiZn(50:15:35)</td>
<td>50</td>
<td>15</td>
<td>35</td>
</tr>
</tbody>
</table>

### Preparation of Mn Zn Ferrite

<table>
<thead>
<tr>
<th>Name</th>
<th>Molecular formula</th>
<th>Molecular weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron(III) oxide</td>
<td>Fe₂O₃</td>
<td>159.69</td>
</tr>
<tr>
<td>Manganese(II) oxide</td>
<td>MnO</td>
<td>90.94</td>
</tr>
<tr>
<td>Zinc oxide</td>
<td>ZnO</td>
<td>81.39</td>
</tr>
</tbody>
</table>
# Size of micro-ferromagnetic materials used

The composition and physical properties of the cobalt powder

<table>
<thead>
<tr>
<th>Type</th>
<th>Co (≥ %)</th>
<th>Ni</th>
<th>Fe</th>
<th>Cu</th>
<th>C</th>
<th>Si</th>
<th>O</th>
<th>Bulk density (g/cm³)</th>
<th>Particle size (μm)</th>
<th>Particle size (Mesh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co</td>
<td>99.6</td>
<td>0.10</td>
<td>0.04</td>
<td>0.01</td>
<td>0.02</td>
<td>0.25</td>
<td>0.60</td>
<td>0.6–3.0</td>
<td>300–400</td>
<td></td>
</tr>
</tbody>
</table>

The composition and physical properties of the nickel powder

<table>
<thead>
<tr>
<th>Type</th>
<th>Ni (≥ %)</th>
<th>Mn</th>
<th>Ca</th>
<th>Cu</th>
<th>As</th>
<th>Mg</th>
<th>Si</th>
<th>Fe</th>
<th>Al</th>
<th>O</th>
<th>Bulk density (g/cm³)</th>
<th>Particle size (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni</td>
<td>99.7</td>
<td>0.002</td>
<td>0.015</td>
<td>0.050</td>
<td>0.001</td>
<td>0.002</td>
<td>0.005</td>
<td>0.006</td>
<td>0.250</td>
<td>0.50</td>
<td>2–3</td>
<td></td>
</tr>
</tbody>
</table>
Typical photos for NiZn Ferrite materials (1300°C, 950 minutes, $\delta = \text{ZnO/Fe}_2\text{O}_3$)

Typical images of the extrusive composites

EMC L (a) PMMA—Co(30% : 70%), (b) PMMA—Ni(30% : 70%), (c) PMMA—NiZn(50:50:0) (40% : 60%).
Classical shielding materials

- Solid metal and the frequency range is not very wide
- Frequency response, especially at high frequency is poor 高频频率响应差
- Ferrite 铁氧体
  - High frequency response is good 高频响应好
  - It is difficult to use ferrite thickness of a few mm because the material is brittle 由于材料易碎，很难采用几mm的厚度
  - Relative permeability of over 2000. That is the magnetic flux conductivity in ferrite is 2000 times of air. In practice, a lower value may be good enough.
    - 相对磁导率超过2000，实际上低磁导率足够

New screening material

- Micro-ferromagnetic
- \( \mu_r = 50, 100 \text{ and } 200 \)
- plastic mixed with magnetic materials with micrometer size 细小磁材料和塑胶材料混合而成
Different Micro-ferromagnetic developed

<table>
<thead>
<tr>
<th></th>
<th>5 kHz</th>
<th>50 kHz</th>
<th>100 kHz</th>
<th>500 kHz</th>
<th>1 MHz</th>
<th>2 MHz</th>
<th>10 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>10%PE 90%NiZn(50:20:30 mol) (1100 °C, 20 hours)</strong></td>
<td>L (μH)</td>
<td>43.98</td>
<td>42.55</td>
<td>42.40</td>
<td>42.03</td>
<td>41.98</td>
<td>42.29</td>
</tr>
<tr>
<td></td>
<td>µr(new)</td>
<td>33.12</td>
<td>32.04</td>
<td>31.93</td>
<td>31.65</td>
<td>31.61</td>
<td>31.84</td>
</tr>
<tr>
<td><strong>10%PE 90%NiZn(50:20:30 mol) (1300 °C, 950 minutes)</strong></td>
<td>L (μH)</td>
<td>56.00</td>
<td>55.45</td>
<td>55.26</td>
<td>54.86</td>
<td>55.01</td>
<td>55.59</td>
</tr>
<tr>
<td></td>
<td>µr(new)</td>
<td>42.17</td>
<td>41.75</td>
<td>41.61</td>
<td>41.31</td>
<td>41.42</td>
<td>41.86</td>
</tr>
<tr>
<td><strong>10%PE 90%NiZn(50:30:20 mol) (1300 °C, 950 minutes)</strong></td>
<td>L (μH)</td>
<td>50.49</td>
<td>49.38</td>
<td>49.27</td>
<td>48.98</td>
<td>49.06</td>
<td>49.77</td>
</tr>
<tr>
<td></td>
<td>µr(new)</td>
<td>38.02</td>
<td>37.18</td>
<td>37.10</td>
<td>36.88</td>
<td>31.19</td>
<td>37.48</td>
</tr>
<tr>
<td><strong>10%PE 90%NiZn(50:40:10 mol) (1300 °C, 950 minutes)</strong></td>
<td>L (μH)</td>
<td>38.30</td>
<td>37.94</td>
<td>37.84</td>
<td>37.53</td>
<td>37.47</td>
<td>37.61</td>
</tr>
</tbody>
</table>

The hysteresis loops of the extrusive composites
Test against Direct current (DC) excited field

- Nearly infinite is exposed to a magnetic field with a constant B value
- Thickness of the shield = 3 mm
- One side of the shield nearly equal to 1 T
- Relative permeability is “new screening material“ $\mu_r$
  - 200 to 50

Reduction of Field with different $\mu_r$ materials

$\mu_r = 200$

$\mu_r = 100$

$\mu_r = 50$
Screening effect Alternative current excited magnetic field 10kHz

• It is obvious from (a) and (b) that the shield with higher relative permeability can hold more flux lines, suggesting it can prevent more flux lines outside the shield. (a)比(b)隔离效果好

• The relative permeability is adjusted to 50, the flux line distribution from Fig.4 (c) varies a little, compared with 4 (b). (c)的磁力线分布与(b)相近

• Conclusion: Only small $\mu_r$ is enough for screening 低磁导率材料足够做隔离措施
EMI screening Test
新材科的隔离测试
EMI Screening Test Result
新材料的隔离测试结果

Figure 129: EMI test result for metal sheet with polymer (NiZn60% Materials 1) 聚合物磁性材料板

Figure 130: EMI test result for metal sheet 金属板
EMI/EMC Test equipment and projects
Amplifier
AR (Amplifier Research)
Model 500A100A
500 watts
10 kHz-100 MHz

Antenna
ETS-Lindgren
Model 3117
1-8 GHz

Antenna
ETS-Lindgren
Model 3142c
26 MHz-3 GHz
ESCI-EMI Test Receiver
ROHDE&SCHWARZ
9kHz-3GHz

Signal Generator
Agilent
Model 8648C
9kHz-3200MHz
EMI Test 电磁干扰测试
Calibration Test of Antenna 3117, ETS-Lindgren, Measurement at 3m distance

Photo of the measurement
EMC Test 电磁兼容测试

![EMC Test Diagram](image)

- **Amplifier**
- **Antenna Driver**
- **Signal Generator**
- **Object under test**
- **Antenna**
- **EUT**
- **Electric x,y,z Field Probe**
- **Antenna**
- **1.5m**
- **Date and Time: 2015-04-02 17:49**
Appendix

EMC/EMI Standard related to Railway

与铁路相关的电磁兼容电磁干扰标准
The maximum level of radiated and conductive EMI of any apparatus shall not exceed the levels specified in the European Standard EN50081-1 updated to BS EN61000-6-1 2007.

Table 1 summarized the maximum radiated emissions at a distance 0.5m from any component of the railway equipment for the frequency bands.

Typical maximum allowable quasi-peak radiated emission

根据以上标准距离设备0.5m处最大辐射值

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Frequency range (MHz)</th>
<th>Max. Electric Field</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>uV/m</td>
</tr>
<tr>
<td>Portable radio</td>
<td>166-171</td>
<td>4.2</td>
</tr>
<tr>
<td>CID Radio</td>
<td>440-470</td>
<td>11.1</td>
</tr>
<tr>
<td>Pager</td>
<td>279-281</td>
<td>7.1</td>
</tr>
<tr>
<td>Fire Services Department</td>
<td>147-151</td>
<td>3.7</td>
</tr>
<tr>
<td>Police Radio</td>
<td>440-446</td>
<td>11.1</td>
</tr>
<tr>
<td>Mobile phone</td>
<td>824-960</td>
<td>37.1</td>
</tr>
<tr>
<td>Mobile phone</td>
<td>1700-1900</td>
<td>76.6</td>
</tr>
<tr>
<td>Pacemaker</td>
<td>20Hz-30MHz</td>
<td>-</td>
</tr>
</tbody>
</table>
**Immunity （电磁抗干扰）**

Table 2: Conductive emission for Railway equipment based on EN 60555 (up to 40th harmonics), EN55022, EN55014 (high frequency harmonics)

基于以上标准车上的设备的传导干扰限值

<table>
<thead>
<tr>
<th>Frequency range</th>
<th>Limits (dBuV)</th>
<th>Relevant standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2kHz</td>
<td>Different limits for each harmonics</td>
<td>EN60555</td>
</tr>
<tr>
<td>0.15-0.5MHz</td>
<td>66-56, decrease linearly with log. Freq.</td>
<td>EN55022 or EN55014</td>
</tr>
<tr>
<td>0.5-5MHz</td>
<td>56</td>
<td>EN55022 or EN55014</td>
</tr>
<tr>
<td>5-30MHz</td>
<td>60</td>
<td>EN55022 or EN55014</td>
</tr>
</tbody>
</table>
**Immunity（抗干扰）**

Table 3: Immunity and test requirement in Railway environment  基于表格标准的抗干扰限值及测试要求

<table>
<thead>
<tr>
<th>Environment</th>
<th>Limits and test specification</th>
<th>Limit standard</th>
<th>Test standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiated Electromagnetic field</td>
<td>80-1000MHz, 10V/m 80% AM (1kHz)</td>
<td>ENV50140</td>
<td>IEC-6 1000-4-3</td>
</tr>
<tr>
<td>Conducted radio frequency</td>
<td>0.165-80MHz 10V</td>
<td>ENV 50141</td>
<td>IEC-6 1000-4-6</td>
</tr>
<tr>
<td>Power frequency magnetic field</td>
<td>100A/m DC or 50Hz</td>
<td>IEC 6 1000-4-8</td>
<td>IEC 61000-4-8</td>
</tr>
<tr>
<td>Electrostatic discharge</td>
<td>6kV contact discharge or 8kV air charge</td>
<td>IEC 6 1000-4-2</td>
<td>IEC 6 1000-4-2</td>
</tr>
<tr>
<td>Fast transients</td>
<td>2kV</td>
<td>EN61000-6-2</td>
<td>IEC 6 1000-4-4</td>
</tr>
<tr>
<td>Electrical surges</td>
<td>1kV for differential mode 2kV for common mode</td>
<td>EN 550 14-2</td>
<td>IEC 6 1000-4-5</td>
</tr>
<tr>
<td>DC magnetic field immunity</td>
<td>0.3mT for 2 minutes</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
## Table 4: Commonly quoted EMC standard for railway

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN12015</td>
<td>EMC-Product family standard for lifts &amp; escalators - Emission</td>
</tr>
<tr>
<td>EN12016</td>
<td>EMC-Product family standard for lifts &amp; escalators - Immunity</td>
</tr>
<tr>
<td>BS EN61000-6-1 2007 (EN50081-1)</td>
<td>EMC Generic Emission Standard-Part 1 Domestic environment</td>
</tr>
<tr>
<td>BS EN61000-6-2 2005 (EN50082-2)</td>
<td>EMC Generic Immunity Standard-Part 2 Industrial environment</td>
</tr>
<tr>
<td>EN55022</td>
<td>Limits and methods of measurement of Radio Interference of IT</td>
</tr>
<tr>
<td>EN50061</td>
<td>EMC Standard for Cardiac Pacemaker</td>
</tr>
</tbody>
</table>
### Table 4: Commonly quoted EMC standard for railway

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENV50121-1</td>
<td>Railways Applications - EMC General</td>
</tr>
<tr>
<td>ENV50121-2</td>
<td>Railways Applications - EMC Emission of the whole railway system to outside world</td>
</tr>
<tr>
<td>ENV50121-3-1</td>
<td>Railways Applications - EMC Train and complete vehicle</td>
</tr>
<tr>
<td>ENV50121-3-2</td>
<td>Railways Applications - EMC Rolling stock-apparatus</td>
</tr>
<tr>
<td>ENV50121-4</td>
<td>Railways Applications - EMC-Emission and immunity of the signalling and Telecommunications apparatus</td>
</tr>
<tr>
<td>ENV50121-5</td>
<td>Railways Applications - EMC-Fixed power supply installations</td>
</tr>
</tbody>
</table>
Table 4: Commonly quoted EMC standard for railway

<table>
<thead>
<tr>
<th>IEC6 1000-4-1</th>
<th>EMC-Testing measuring techniques-General</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC6 1000-4-2</td>
<td>EMC-Testing and measuring techniques-Electrostatic discharge requirement</td>
</tr>
<tr>
<td>IEC6 1000-4-3</td>
<td>EMC-Testing and measuring techniques-Radio frequency electromagnetic field-immunity tests</td>
</tr>
<tr>
<td>IEC6 1000-4-4</td>
<td>EMC-Testing and measuring techniques — Electrical fast transient/burst requirements</td>
</tr>
<tr>
<td>IEC6 1000-4-5</td>
<td>EMC-Testing and measuring techniques-Surges immunity tests</td>
</tr>
<tr>
<td>IEC6 1000-4-6</td>
<td>EMC-Testing and measuring techniques — Conducted if disturbances above 9kHz immunity tests</td>
</tr>
<tr>
<td>IEC6 1000-4-8</td>
<td>EMC-Testing and measuring techniques-Power frequency magnetic field immunity tests</td>
</tr>
<tr>
<td>IEC6 1000-4-11</td>
<td>EMC-Testing and measuring techniques-Voltage dips, short interruptions and voltage variations immunity tests</td>
</tr>
<tr>
<td>IEC6 1000-5-2</td>
<td>Installation and mitigation guidelines-Earthing and cabling</td>
</tr>
<tr>
<td>NRPB-GS11</td>
<td>Guidance as to restriction on exposures to time varying EM field</td>
</tr>
</tbody>
</table>
**Table 5: Unpreferred locations of equipment**

<table>
<thead>
<tr>
<th>Standard</th>
<th>Equipment</th>
<th>Unpreferred location</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC61000-4-3</td>
<td>Telecom Equipment, Fire Services Department equipment</td>
<td>Near to Power transmission line</td>
</tr>
<tr>
<td>EN12015</td>
<td>Lifts, Escalators</td>
<td>Near to Platform Screen Doors control room, Battery room</td>
</tr>
<tr>
<td>ENV50121-4</td>
<td>Signalling and telecommunication Apparatus</td>
<td>Near to high power RF transmission system and transformer room</td>
</tr>
<tr>
<td>EN50061 BS6902-1:S1</td>
<td>Implantable pacemaker</td>
<td>Near to high power RF transmission system and switchgear room</td>
</tr>
<tr>
<td>IEC 6 1000-4-6</td>
<td>UPS</td>
<td>Near to Transformer room or switchgear room</td>
</tr>
<tr>
<td>EN55022</td>
<td>Computer /IT equipment</td>
<td>Overhead line</td>
</tr>
<tr>
<td>RIA13</td>
<td>Electronic Control Panel</td>
<td>Near to transformer room and switchgear room</td>
</tr>
</tbody>
</table>
Table 6: Exposure limits to electromagnetic fields advised by INIR board.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Electric field V/m</th>
<th>Magnetic field A/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;100Hz</td>
<td>614000/f</td>
<td>1630</td>
</tr>
<tr>
<td>0.1-lkHz</td>
<td>614/f(kHz)</td>
<td>163/f(kHz)</td>
</tr>
<tr>
<td>1 -30kHz</td>
<td>614</td>
<td>163</td>
</tr>
<tr>
<td>0.03-1 MHz</td>
<td>614</td>
<td>4.89/f(MHz)</td>
</tr>
<tr>
<td>1-10MHz</td>
<td>614/f(MHz)</td>
<td>4.89/f(MHz)</td>
</tr>
<tr>
<td>10-30MHz</td>
<td>61.4</td>
<td>4.89/f(MHz)</td>
</tr>
<tr>
<td>30-400MHz</td>
<td>61.4</td>
<td>0.163</td>
</tr>
<tr>
<td>0.4-2GHz</td>
<td>97.1/f(GHz)</td>
<td>0.258/f(GHz)</td>
</tr>
<tr>
<td>2-300GHz</td>
<td>137</td>
<td>0.364</td>
</tr>
</tbody>
</table>
Discussion and Future work 讨论和未来工作方向

• The EMI suppression and energy recycling technology for pentagraph arcing
• The development of multi power sources based and its EMI in HSR
• EMI shielding material development
• EMI shielding technology in HSR
• New power electronics for power conversion to reduce EMI
• Prepare for High speed system versus increased in EMI
**Power Electronics Research Centre (PERC)**

Fully supported from the industry and government. Research in fundamental study as well as applied research. Aims - to help local industry and the region.

**电力电子研究中心 (PERC)**

得到了工业界和政府支持。基础研究和应用研究同时进行。目标 - 提升本地区及其工业界的竞争力。

**Contact:** 郑家伟 教授 Prof. Eric Cheng,

香港理工大学，电机工程学系 Dept. of EE, HK PolyU

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....Power the future
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  国家轨道交通电气与自动工程技术研究中心 香港分中心
- the National Rail Transit Electrification and Automation Engineering Technology Research Centre
  国家轨道交通电气与自动工程技术研究中心
- South West Jiao Tong University
- 西南交通大学
Thank you!