Automotive EMC
Introduction and Overview

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Automotive Systems “Past and Present”

• Today’s vehicles contain three centuries of technology...19th century internal combustion engines...combined with 20th century electrical systems...and 21st century electronics....
Automotive Systems and EMC

- The inclusion of new technologies in automotive systems has resulted in new challenges across the spectrum.
- …and can result in EMC issues from LF to SHF!
Why is EMC Important to the Automotive Industry?

- Today’s electronic systems (including vehicles) contain many more active electronic components than in the past.

- Those components and assemblies may emit RF noise or be exposed to external sources of energy - resulting in unanticipated changes in system operation.
The EMC “Model” (as applied to Automotive Systems)

- The “Source” – near / far field…high magnetic field or electric field?
- The “Path” – radiated or conducted?
- The “Receiver” – intentional or unintentional?
Electromagnetic Environment for Automotive Systems

• May be “off board” and “on board” sources.
• Studies have shown almost “DC to daylight” sources and high field strength levels – both electric and magnetic.
• Typical on board fields of 10 – 100 V/m.
• Some off board fields are 100’s of V/m !
Examples of “Off Board” RF

- New wireless technologies demand more spectrum and more energy
- Many rural areas are now populated
- Vehicle must operate in this new environment
“On Board” Vehicle Sources

- Automobiles can have on board sources of significant emissions.
- High RF levels with common equipment such as mobile radio transmitters.
Automotive Industry EMC Methodology

- Vehicle Original Equipment Manufacturer (OEM) practice is to address EMC in the component and system design phase.

- The resolution of EMC issues must comprehend a high volume, complex manufacturing process AND do not affect program timing.

- *Goal* is to balance EMC requirements with market-based vehicle usage.
“Customer Focused” Automotive EMC Benefit

- Recognition of two-way radio usage.
- Important to understand installation in vehicles to minimize EMC issues.
Development of OEM “Mobile Radio Installation Guidelines”

- Shows “EMC friendly” methods to install two way radios and antenna systems.
- Based on commercially available radios and transmitters.
Automotive EMC Requirements

• “Good” News: Most automotive systems are exempt from FCC Part 15 (see 15.103).
• “Bad” News: OEM requirements typically 10 to 40 dB more stringent than Part 15.
• “Ugly” News: Most OEM requirements are based upon international standards such as CISPR, ISO, SAE (which many international legislated requirements are also based on).
Automotive EMC Case Studies

- Emissions: Microprocessor clock harmonic was on two way radio frequency – rendering radio communication impossible.
- Immunity (the Automotive characterization of susceptibility): An engine and transmission seemed defective due to control system malfunctions – cause was a change from a metal to a non-conductive component package.
Automotive System RF Emissions

• Vehicle systems can be responsible for onboard noise generation as a byproduct of vehicle operation.

• In the automotive industry, this noise has been classified into two categories:
  – Broadband (typically due to electrical arcing)
    » Referred to as “Arc and Spark” noise.
  – Narrowband (typically due to active electronics)
    » All other noise NOT due to “Arc and Spark”.

Representation Of Noise Bandwidth

- Broadband noise is greater than the “width” of receiver of the energy.
- Narrowband noise is less than the “width” of the receiver.
Typical Sources Of Broadband Noise

- Sources include ignition components and similar pulse-type systems.

- Electric motors (both the traditional and the new “brushless”).
EMC / RFI Issues in Power Electronics

• Important to understand the impact of the “slew rate” of high power devices.

• Many are designed for low power dissipation during operation resulting in:
  – Operation at an order of magnitude faster than response of electromechanical devices
  – Causing radiated/conducted emission issues.
Why Ignition Noise Is “Broadband”

- Representative ignition systems used today - all utilize high-voltage discharge.

- Source of noise is spark discharge across gap in plug and/or distributor.
Consequences Of Broadband Noise Sources

• BAD – Due to functions that are required for basic vehicle operation (such as ignition or inductive devices).
• BAD – Can have both conducted AND radiated coupling path.
• GOOD – Energy spread out – may have minimal effect on potential receivers (intentional and unintentional).
Representation of Narrowband Emissions

- Sources are active electronics.
- Result is a spectrum of a “comb-like” appearance.
- Spectrum stays approximately constant over time.
Consequences Of Narrowband Noise Sources

- BAD - May be many sources on a vehicle due to proliferation of active devices.
- BAD - Receivers can appear to function “almost normal”.
- GOOD - Can be addressed in component design process (will be discussed by Todd Hubing).
Immunity Issues Must Be Addressed - Why?

“Good Old Days”

Today's Systems

Complex engine/vehicle control systems require a high degree of robustness to insure proper operation
Vehicle Level Immunity To External Fields

- The goal: to understand the compatibility of the electronic systems with the environment
Today’s Systems Can Have Immunity Issues

- Characteristics of today’s systems are:
  - Electronic modules that radiate energy may also be efficient unintentional receivers of energy.
  - Therefore, RF sources may affect the operation of active devices….with the following implications…
Immunity Issues Can Exist Due To The Following…

- Most of today’s vehicle rely on active devices, microprocessors, and vehicle communication networks for:
  - Control of vehicle functions.
  - Entertainment systems.
  - Legislated requirements (such as tire pressure monitoring).
**Immunity: Industry Practices**

- How to ensure product immunity?
  - Measures should be implemented to “design in” appropriate immunity characteristics.
  - System and component testing can be conducted by simulating “external” sources to ensure immunity characteristics.
**Bulk Current Injection (BCI) Test Method**

- Injection of RF or pulse energy on wiring harness.
- Typical BCI testing is to 400 MHz.
- General rule: 1.5 mA of RF current induced on a cable is equivalent to $\frac{1}{2}$ wavelength cable in a field strength of 1 V/M.
EMC Circuit Design for Immunity

- Add series inductance to sensitive I/O.
- Add parallel capacitance to shunt RF away.
- Buffer or isolate circuits (opto-isolator, transformer).
- Keep circuit gain-bandwidth to minimum required.
- Application of localized shielding on devices.
Wire Routing Impact On EMC

• Even the process of wire routing is can be an important contributor to EMC!
  – Need to comprehend sources and receivers in systems.
  – Wire routing affects EMC “Path”.
  – Critical to recognize that due to parasitic inductance and/or capacitance effects exist.
**Why Wiring Is Contributor To Conducted EMC Issues**

- Early vehicle systems had few electrical components to be connected - when many wiring practices were developed.
- Today’s systems have increased wiring demands and sensitive electronic devices.
- Must be addressed - wiring will still be used for the foreseeable future.

![Diagram of electrical circuit](image-url)
Why Wiring is Important to Automotive EMC

• Early systems (and vehicles) had few components to be connected - Recent systems have increased wiring complexity.
• Many automotive engineers consider it “just a piece of wire” and the chassis is “GROUND”!
• Wiring will still be used for many systems in the future.
• Need to understand relevant physical parameters.
Role Of Wiring In Conducted EMC Issues

• Energy may escape or be brought into/from the modules by conduction with wiring harness.

• Wiring can act as a coupling mechanism.
Automotive Wiring Inductive Coupling

- Coupling from the wiring of system 1 to the wiring of system 2 can occur.
- May be due to “common ground” with many automotive circuits.
- Noise is induced in system 2 by “dI/dt” of system 1:
  - Occurs during period when dI/dt NOT equal to zero
  - Is the source of inductively coupled transients
Automotive Wiring Capacitive Coupling

- Capacitive coupling from system 1 to system 2.
- Due to close proximity of many wires in a harness bundle.
- Noise is induced in system 2 by “dV/dt” of system 1:
  - Occurs during period when dV/dt NOT equal to zero
  - Is the source of capacitive coupled transients
Auto Industry “Best Practices” For Wiring To Minimize EMC

- **Recommendation**
  - Route wiring away from ignition system, spark plug wires, and alternator wiring.

- **Rationale**
  - High energy noise may couple inductively or capacitively into wiring.

- Don’t bundle antenna, speaker, or power wiring with vehicle wiring.

- **Rationale**
  - Low-level signals can be affected by high-power circuits.
Conducted Transients and Automotive Systems

- Can result in voltages about 5–10 times that of vehicle system (e.g. 13.8 volts – 150 volts transient generation).
- Can be results of the many inductive loads used in automotive systems.
Protection is Required to Minimize Effect of Transients

- Circuit provisions for over voltage, load dump, and reverse battery should be made.
- Transient protection should be on all I/O and lines going to vehicle power.
- Realize that all vehicle devices may not have extensive transient suppression needed by sensitive I/O.
Automotive EMC Electrostatic Discharge

- Testing is used to identify sensitivities.
- Simulates natural and human-body induced high voltage (4 - 25 kV) discharges.
- Can cause immediate failure or induce latent defect (such as in manufacturing process or customer use).
Things to Consider Before Vehicle Level Testing Begins

• Meet component requirements.
• Wiring representative of the actual production vehicle.

Why?

– Component level requirements are set at level to prevent any vehicle level interactions from occurring.
– Many time only the power and signal lines are in the harness – and the return conductor is the vehicle chassis.
“Quick” Vehicle Level Help

• For emission diagnostics:
  – AM/FM radio receivers - AM setting useful to trace BB noise - FM useful to trace NB noise.
  – Clamp ferrites on harnesses to eliminate effect of conducted energy.
  – Disconnect fuses until noise stops.

• For immunity – 150 MHz hand held radio can provide local high fields to identify potential issues.
Automotive Component EMC Practices

• “Back in the day”, the emphasis was on vehicle level testing.

• Now the emphasis is on component level requirements and performance due to complexity of vehicles, styles, applications, and extensive use of common components.

• Key to assuring vehicle EMC is the ability to assure component level EMC performance.
“Cost of EMC” and Solutions Available

- Goal should be to identify options to address EMC early in the design stage. Early attention minimizes cost – and maximizes available options.
- Use “Pre-Compliance” methods whenever possible (will be discussed by Scott Mee).

<table>
<thead>
<tr>
<th>Cost of EMC</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMC Solutions</td>
<td>Many</td>
<td>Some</td>
<td>Few</td>
<td>None</td>
</tr>
<tr>
<td>Program Phase</td>
<td>Design</td>
<td>Development</td>
<td>Validation</td>
<td>Production</td>
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The Component’s Role In Automotive EMC

• Incorporate a “Design for EMC” approach.
• Test by simulating component operation as it would function in the complete vehicle.
• If component passes test no action is required. If it does not pass - use the test data to determine corrective action plans.
Component Testing Methods

• Most are based upon CISPR, ISO standards (two of which will be discussed in detail by Vince Rodriguez).
• Defines typical component level test set-up.
• Device under test is configured to function in a manner similar to vehicle application.
What is the Supplier’s Role?

- Obligation to deliver a component that meets-component level EMC without requiring vehicle level corrective actions.
- Depends on crucial supplier-to-OEM cooperation (*will be discussed by Julian Weber*).
- Important to know the program requirements and demonstrate compliance by validation.
Component Level EMC Program Plan

- The process to ensure proper component design, development, and validation prior to vehicle validation.

- The process includes:
  - Definition of test modes, and input signals similar to application usage.
  - Wiring harness definition.
  - Load definition.
  - Methods for monitoring test results.
Next Steps for Automotive EMC

• Develop and improve simulation and modeling to include both DESIGN aspects and impact of manufacturing issues.
• Goal is to develop physics based models and to evaluate anticipated EMC characteristics using circuit simulation and electromagnetic theory (will be discussed by Daryl Beetner).
• Key aspect is understanding the coupling paths, sources and receivers.
Automotive EMC - Overview

- Automotive EMC is concerned with vehicle electrical/electronic system interaction.
- Looks at radiation or conduction.
- Can be addressed by emphasis in the design stage and verified through testing.
Automotive EMC Summary

• The first vehicle EMC issues were primarily limited to reception quality of AM radios.

• Today’s vehicles have many complex systems:
  – Powertrain Control
  – Vehicle Control
  – Communication

• Tomorrow’s vehicle will be even more complex:
  – Hybrid’s
  – Fuel Cells
Automotive EMC – The Future

• The success of our ability to manage the EMC of future systems will depend on:
  
  – How we use our knowledge of the fundamental issues that have been discussed here.
  
  – Our ability to work together using the tools available to us!