Automotive EMC Workshop
Bench-Top EMC Pre-Compliance Testing

Johnson Controls Automotive Electronics
Automotive Industry Trends

- Increasing complexity of electronics
  - Combining multiple functions on one board
  - New technology such as Bluetooth, GPS, smart keys, and backup cameras

- Unique packaging and mounting conditions (interior/exterior styling trends)
  - Smaller spaces
  - Close proximity to sensitive / noisy modules

- Increased receiver sensitivity
  - Improved performance of RF systems

- Shorter development cycles (<16 months)
  - ‘Get it right the first time’
  - Can no longer iterate the way to compliance
Example Electronics Content in Vehicles

- Mobile Device Gateway
- Information Displays
- HVAC Heads
- HomeLink
- Autovision
- Compass
- eMotion Compass
- Blue Connect
- Clocks
- Cluster
- Intelligent Power Distribution Module
- Tire Pressure Monitoring System
- Access Control System
- Body and Interior Controller
- Immobilizer
- Park Distance Indicator
- Display Solutions for RSE
- Overhead Console Electronic
- PathPoint
Product Development Trends

- Develop and deliver electronic products on-time
  - Delays impact delivery of new technology and introduction of vehicles
  - Vehicle sales are affected

- Meet all requirements (manage design trade-offs)
  - Product must operate correctly
  - Product must not overheat
  - Product must be compatible with its electromagnetic environment
  - Etc…

- Lowest cost
  - Product cost and engineering development costs
  - Low cost country (LCC) alternative manufacturing and design resources

- End-customer satisfaction…must be high quality
  - JD Power Ratings, etc…
Program Development Timeline

- **Proposal** ➔ Prospective business quotation
- **Business Award** ➔ Notification from OEM of awarded contract
- **Requirements** ➔ Define target requirements for product
- **Detailed Design** ➔ Develop initial design and prototypes
- **DV** ➔ Validating the product design
- **PV** ➔ Validating the process of manufacturing the product
- **PPAP** ➔ Production part approval process submission to OEM
- **SOP** ➔ Start of production
EMC Perspective / Point of View

How do we achieve EMC given the industry and product trends?

- Identify potential EMC concerns early
- Derive countermeasures to problems that address the root-cause
- Optimize countermeasures and components for lowest cost
- Evaluate design trade-offs / impact in other areas
  - Adding slewing components can cause thermal issues on switching power supplies
  - Too much series clock termination can add delay to memory BUS and cause timing violations
  - Placing components
- Meet or exceed performance outlined in module/system specification
- Support vehicle level testing and issues
Impact of Trends and Compromise

- Reduced time to do proper simulations/analysis before creating hardware
- Fewer design iterations to improve EMC performance of hardware
- Fewer visits to the compliance laboratories
Historical Approaches to EMC Compliance

Approach #1

1. Design → Build → Compliance Testing → Resolve Issues → Vehicle Integration → Resolve Issues

Approach #2

1. Design → Simulate → Build → Compliance Testing → Resolve Issues → Vehicle Integration → Resolve Issues

Approach #3

1. Design → Simulate → Build → Pre-Compliance Testing → Resolve Issues → Compliance Testing → Resolve Issues → Vehicle Integration → Resolve Issues
Overview of Testing Opportunities

**Pre-Compliance Testing**
- Low cost, quick
- Self-directed
- Considered not to be final
- May include system level
- Flexible test methods
- Can ‘over test’
- Can correlate to vehicle
- Can address unique config.

**Module Compliance Testing**
- Expensive / time consuming
- OEM directed
- Considered not to be final
- Includes system level
- Rigid test methodology
- May not correlate to vehicle

**Vehicle Compliance Testing**
- Very expensive / time consuming
- Completed by OEM
- Considered to be final judge
- Includes many systems
- Includes wiring, mounting, etc.
- May not correlate to module
- Results not accessible to Tier 1

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Initiated by electronic component supplier

Final internal checks

OEM assessment
Bench-top Pre-Compliance Methods

What are pre-compliance tests?
- Tests that are run prior to formal compliance tests
- Tests that typically run faster than compliance tests
- Tests that are cheaper to develop and run than compliance tests

Why run pre-compliance tests? What is the motivation?
- Test with methods that emulate the issues found during historical vehicle integration tests
- Increase confidence in meeting EMC requirements at a lower cost with a more optimal design
- Allows for troubleshooting and fixing issues during testing
- Provides quantitative performance levels (not only pass/fail like compliance tests often provide)
Traditional Implementation of Pre-Compliance Testing

- Emulate existing component level EMC standards
  - Emissions
  - Immunity
  - ESD
  - Transients
- Reduce/replace pieces of equipment
- Make the test run faster
- Run testing at higher levels of immunity and lower levels of emissions limits
Overall Improvement Achieved in Addressing EMC

- Adding both simulation and pre-compliance testing has...

  ...produced fewer issues in both module and vehicle integration testing

- Costs have been driven down due to a proactive approach

- Product delivery timing has improved
Component Testing → PASS, but Vehicle Testing → FAIL??

- New product technology and unique vehicle content and packaging
  - More prolific noise source signatures (GSM, CDMA, SMPS, Lighting, BT, etc.)
  - Greater sensitivity in receivers (FM/AM radio, GPS, PKE, USS, etc.)
  - Increased use of consumer electronics devices (USB, Cell phones etc.) in the vehicle

- Traditional test methods may not detect the potential issues
- Module supplier and OEM must work together to resolve vehicle issues
Impact of Identifying EMC Issues During Vehicle Integration

- Poor reliability → unfavorable component choices, or lack of proper prove-out
- Shift the problem → a solution applied to one module can cause problem in another
- Difficult manufacturing → lack of proper time to engineer a manufacturable solution
- Delay program timing → due to a complex and lengthy ‘prove-out’ scheme
- Higher costs → repeat vehicle testing is expensive
- Lack of information → Tier 1 suppliers have little information about the complete system
Recent Trends in Pre-Compliance Test Methodology

- Existing standards do provide value to the testing process
  - Today's standards were developed for many legitimate reasons
  - They identify real concerns
  - In many cases they are repeatable and use common equipment

- Emulating existing component level standards is not adequate to find issues
  - Standards take time to update
  - Currently the standards do not adequately measure products' performance
  - Configurations that exist in the car are far more complex than the test standards

- Create flexible low cost test methods that emulate 'real' vehicle scenarios
  - Develop methods that are designed to reproduce prior issues at a bench-top level

- Partner with OEMs
  - Suppliers communicate early concerns and develop new ways to test
  - OEMs share information with suppliers about electronic component packaging in the vehicle
Types of Pre-Compliance Testing

- Emulating component level EMC testing to boost confidence before DV & PV
- Failure analysis testing to identify root-cause of EMC issues
  - Use tools to aid in debugging and countermeasure development
- Testing that emulates scenarios found in the vehicle
  - Often involves two or more modules making a system
  - Measure EMC performance under actual configurations found in the vehicle
Vehicle Level Issues Discovered → Create New P.C. Test Methods

- **RF Emissions**
  - FM band interference from compass module
  - AM band interference from compass module
  - Inoperable passive keyless entry and vehicle starting from switching power supply
  - GPS band interference and resulting navigation issues due to digital memory BUS noise
  - FM band noise interference due to harness coupling to nearby digital memory BUS noise

- **Noise Immunity**
  - Noise in car audio system due to GSM (*Groupe Spécial Mobile*) noise
  - Microcontroller interrupt initiated based upon false input detection

- **Voltage Transients**
  - LCD display flickering
  - Power supply protection circuit failure
FM Band Interference from Compass Microcontroller

- Noisy modules mounted on the rear tray package near antennas
- Digital integrated circuit (IC) noise couples into radio band antennas
RF Scanning Test Method

- Formalized in the SAE J1752 – 2 by the SAE Integrated circuit/EMC task force
- Intended to measure the electric and magnetic near-fields of integrated circuits
RF Scanning Results

- Results must be interpreted carefully in order to develop countermeasures.
- Historical data needs to be tracked to form meaningful limits on radiation.
### RF Scan Test – Equipment and Approximate Cost

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-compliant spectrum analyzer</td>
<td>$9,000</td>
</tr>
<tr>
<td>RF cables</td>
<td>$2,500</td>
</tr>
<tr>
<td>Pre-amplifier</td>
<td>$1,200</td>
</tr>
<tr>
<td>Scanning table / machine /controller</td>
<td>$15,000 - $50,000</td>
</tr>
<tr>
<td>Lower cost to build your own</td>
<td></td>
</tr>
<tr>
<td>Computer</td>
<td>$1,500</td>
</tr>
<tr>
<td>Camera</td>
<td>$1,000</td>
</tr>
<tr>
<td>Automation software</td>
<td>$5,000</td>
</tr>
</tbody>
</table>

**Total Cost Estimate**  
~ $50K
GSM: *(Groupe Spécial Mobile)* Noise Issue

- Cell phone causing interference on car audio system

![Diagram showing GSM interference and audible buzzing in speakers](image)
GSM Audio Noise Interference Example

- **GSM** signal is capacitively coupled and demodulated to audio frequencies and passed into the audio system in the vehicle.

  - High Impedance audio circuit is susceptible to capacitive coupling.
  - Capacitance.
  - Noise amplified in head unit and heard over speakers.
  - ~1W source @ 890MHz & 217Hz modulation.
GSM Test Method Details

Two suggested methods

1 – Method according to ISO 11452-9 \( \rightarrow \) using sleeve antennas

- Craig Fanning from Elite Labs (Chicago, IL) presented a paper in IEEE EMC 2007 Titled “Evaluating Cell Phone and Personal Communications Equipment and their EMC Effects on Automotive Audio and In-Cabin Modules”

- Found digital transmitters < 0.1 Watts to be a low risk in the vehicle
- Found digital transmitters > 0.7 Watts to cause compatibility issues

2 – Method according to ISO 11452-4 \( \rightarrow \) BCI method

- Used at JCI to reproduce failures found in vehicle
- Testing done with a range of powers (500mW – 2 Watts) to reproduce issues
- Two forms of applied interference \( \rightarrow \) coupling from probe to DUT and injected current in harness
GSM Interference Test Method

Signal Generator

Amplifier

Forward Power Measurement
Spectrum Analyzer or Power Meter

Directional Coupler

Input

Output (GSM)

Input

Output

Forward Power (2 W)

LISN

Power Source

Sample

Ground

Audio System

DUT

Pulse Gen
217 Hz

SCOPE

Monitor effects on Audio System

Shielded Room

LOAD

Automotive Battery

Ground

Sample

Bill

GROUND

POWER

SIGNAL

PROBE
## GSM Test – Equipment and Approximate Cost

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<tr>
<td>RF Signal generator w/ pulse</td>
<td>$12,000</td>
</tr>
<tr>
<td>RF Cables</td>
<td>$3,500</td>
</tr>
<tr>
<td>HF RF amplifier</td>
<td>$18,000</td>
</tr>
<tr>
<td>Directional coupler</td>
<td>$1,500</td>
</tr>
<tr>
<td>Computer and automation software</td>
<td>$6,500</td>
</tr>
<tr>
<td>Injection probe</td>
<td>$4,000</td>
</tr>
<tr>
<td>RF chamber</td>
<td>$18,000</td>
</tr>
<tr>
<td>Artificial networks and automotive battery</td>
<td>$2,000</td>
</tr>
<tr>
<td>Monitoring equipment</td>
<td>$2,500</td>
</tr>
</tbody>
</table>

## Total Cost Estimate

~ $68K
Passive Keyless Entry / Vehicle Starting System

PKE System

Magnetic Field Sensor

Competing signals at the receiver !!

Electronic Module

Passive Key
Switch-mode Power Supply Interfering with Passive Key System

The source:
- 12 Volt $\rightarrow$ 3.3V buck (step-down) power converter
- Switching inductor generates powerful magnetic field
- Field strength range $\rightarrow$ 4 – 25nT at distance of 10cm

The victim:
- Passive keyless and vehicle start system
- Magnetic transducers located in the vehicle at various locations
- Sensitivity range $\rightarrow$ 1 – 10nT at distance of 10cm
Passive Keyless Entry Magnetic Field Test

- Measures magnetic field emissions from a given module or system
- Quantified field (dBpT or nT) at a given distance
- Developed due to magnetic field interference not detected by module level testing
- Performed correlation in-vehicle measurements (developed a magnetic field limit)
Passive Keyless Entry Test Results
## Passive Keyless Entry Magnetic Field Test – Equipment and Approximate Cost

### Equipment

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<td>$3,500</td>
</tr>
<tr>
<td>Magnetic Loop</td>
<td>$3,500</td>
</tr>
<tr>
<td>Computer and automation software</td>
<td>$2,800</td>
</tr>
</tbody>
</table>

### Total Cost Estimate

~ $20K
GPS Noise Interference In Vehicle Example (Side view of car)
Inside The Noisy Product – Noise Source Details

- Fast rise/fall time from memory bus digital activity
- Very low level harmonics in GPS band
- Enough near field coupling to cause an issue
  - Coupling to harness and GPS antenna / receiver module
CISPR25 1 Meter GPS Test Not Sufficient To Detect Vehicle Issues

- Dynamic range of CISPR25 test is ~ 0 dBuV/M
- Typical signals that cause interference can be much lower in amplitude
GPS Signal Amplitudes

- Pseudo random modulation code is required to restore GPS signal to full amplitude (-100dBm)
- The signal can then be measured by a receiver

![Graph showing GPS Signal Amplitudes]

- Receiver Noise Floor = -105dBm
- GPS Spread Spectrum Level = -150dBm
- De-coded GPS signal = -100dBm
GPS Noise Evaluation Test Method

- Test narrow & broad band emissions from product that may interfere with GPS
- Tested with GPS Antenna, bias and pre-amplifier
- Measure satellite reception and RSSI (received signal strength input)
GPS Noise Test – Equipment and Approximate Cost

**Equipment**

- GPS receiver with RS-232 output → $2,500
- GPS patch antenna and RF cables → $5,500
- Attenuator and retransmit antenna → $2,000
- Non-metallic bench → $1,000
- Computer and automation software → $3,200

**Total Cost Estimate** → ~ $15K
Transient Test Box

Product Assurance Robustness (PAR) Tester

- Development is credited to Arnold Nielson (retired from Visteon)
- PAR tester design and test philosophy is formalized in the SAE J2628
- Low cost solution to simulate vehicle transient events
- Designed to produce random voltage transient events in a systematic way

JCI Version
Parallel Miscellaneous Noise Tester – From FORD EMC RI130/RI150

- Couple inductive and charging system transients to product wiring
- Expose each wire in harness
- Observe product functionality during exposure
Parallel Miscellaneous Noise Fixture + PAR Tester
Parallel Misc. Noise + PAR Test – Equipment and Approx. Costs

- **Equipment**
  - Digital storage oscilloscope → $15,000
  - Probes and cables → $1,500
  - PAR Tester → $5,500 - $15,000
    - Lower cost to build your own according to SAEJ2628
  - Miscellaneous Noise Fixture → $2,500
  - Relays, table, automotive batteries → $1,500

- **Total Cost Estimate** → ~ $30K
Conclusions

- Component level compliance tests are performed according to standards
  - Not updated frequently; requires agreement from many parties
  - May not represent unique vehicle scenarios, rather the more traditional EMC issues

- Pre-Compliance tests are performed according to the need
  - Methods are updated frequently
  - More flexible and can adapt to the scenario in the vehicle
  - Allow for root-cause and countermeasure development while testing
  - Allow for testing to collect quantitative data rather than attribute (PASS/FAIL)
  - Tests are low cost to develop and maintain
  - In partnership with OEMs correlation to vehicle level has been established
Thank you for your attention

Questions?