WHITE PAPER

INSIGHTS FROM CONNECTED MOBILITY:

INTRODUCTION TO ELECTRO-MAGNETIC INTERFERENCE (EMI) IN THE AUTOMOTIVE ENVIRONMENT

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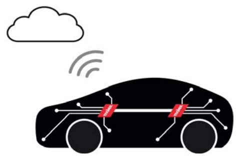
INTRODUCTION TO ELECTRO-MAGNETIC INTERFERENCE (EMI) IN THE AUTOMOTIVE ENVIRONMENT



INTERNAL SOURCES OF EMI

- Collision avoidance radar
- Console applications
- Navigation-radio combination
- Power steering module
- Infotainment head unit
- Airbag inflator
- ECU and other module connectors
- Tire pressure monitoring
- CAN bus
- DC motors
- Ignition systems
- Engine control module
- Electronic Braking Systems (EBS)
- Fuel Control Systems
- Adaptive cruise control

EXTERNAL SOURCES OF EMI

- Garage door opener
- Remote entry
- Cell phone
- Bluetooth devices
- MP3 players with Wi-Fi
- Gaming systems with Wi-Fi
- Third-party navigation systems
- High-power transmitters (i.e., TV and radio towers)

One of the key challenges for those working to develop the automobile of the future is one that has existed for more than 100 years: electromagnetic compatibility. All electronic devices have electromagnetic emissions and some of those emissions are intentional (i.e., Wi-Fi transmitter frequencies) while some emissions are unintentional (i.e., energy generated by various electrical components of the vehicle). Together, they make up the "EMI profile" of a device; and, electromagnetic compatibility (EMC) is the ability of these electronic devices to coexist with EMI without disruptions, interference or other unwanted and undesirable outcomes.

Since some of the earliest days of radio, we have had to work to mitigate traffic caused by signals (then radio, now wireless) crossing paths and bumping into one another. In the early days, there weren't many electronics in an automobile and AM radio was considered high-end technology. It was important for automotive engineers to avoid systems that might unintentionally generate frequencies in the same range as the AM radio (525KHz – 1705KHz). A device with an "EMI profile" that includes high emissions in this frequency range could interfere with the AM radio channel and could result in buzzing or static noises on the radio speakers.

Carmakers have long faced issues with EMI and—as more and more electronic devices have been introduced into the vehicle, including GPS, Wi-Fi, Bluetooth, infotainment systems, AM/FM/satellite radio, power inverters, USB data, USB chargers, wireless chargers, CAN/LIN busses, cameras, radar and Ethernet backbone/gateways — the challenges to manage EMI have increased exponentially.

Add to that the fact that consumers are also adding external and portable devices to the vehicle and the danger of those devices' EMI profiles and their spectrums overlapping only exacerbates the need to mitigate interference.

RADIATED EMISSIONS

Electromagnetic energy dispelled into the air and that energy is classified as being intentional or unintentional.

CONDUCTED EMISSIONS

Electromagnetic energy emitted on wiring

EMI and the Impact to Connected and Autonomous Vehicles

Placing a myriad of electrical and electronic systems into a confined space such as a vehicle means that the EMI reduction is more important than ever as automakers develop intelligent and autonomous vehicles that require the highest level of safety and performance. Car manufacturers must carefully define and enforce electromagnetic compatibility specifications in order to ensure that electronic devices don't interfere with one other, resulting in undesirable equipment or system performance or, worse yet, dangerous outcomes.

Understanding the totality of the EMI profiles and potential compatibility issues within a given automotive network is not a simple task, yet doing so is especially important when it relates to safety. For example, interference that manifests as noise on an AM radio station is certainly not ideal; however, the risks are of far greater concern if a device causes interference that interrupts the expected performance of an autonomous steering and braking system and threatens passenger safety.

In this paper, we will discuss some of the basic types of electromagnetic compatibility (EMC) tests, as well as specific tests required to qualify an electronic device for automotive applications.

Radiated and Conducted Emissions

To begin, it's important that one understand the various types of emissions that must be accounted for and mitigated. Electronic devices radiate electromagnetic energy into the air and that energy is classified as being intentional or unintentional. A cell phone, for example, radiates intentional noise. It's intentional because the phone must connect through the air to a cell phone tower. Power limits and spectrum profiles are imposed on the intentional transmitter for reasons of electromagnetic compatibility.

But some electronic devices also radiate unintentional noise, which — unlike intentional noise — can often be reduced in intensity and controlled. There are a variety of effective methods for reducing unintentional radiated noise, including adding metal shields, improving the layout of the printed circuit board (PCB) or strategically adding filtering devices such as common mode chokes, ferrite, resistors and capacitors, etc.

Additionally, electronic devices can emit noise, called conducted emissions, on the wiring that connects to the device itself. Common connected wiring examples include the power harness, USB cable and Ethernet cable, among others. In some cases, the conducted noise on the cable (conducted emissions) can convert to noise in the air (radiated emissions), making it a "noisy" cable, which can act as an antenna and convert the conducted emissions to radiated emissions.

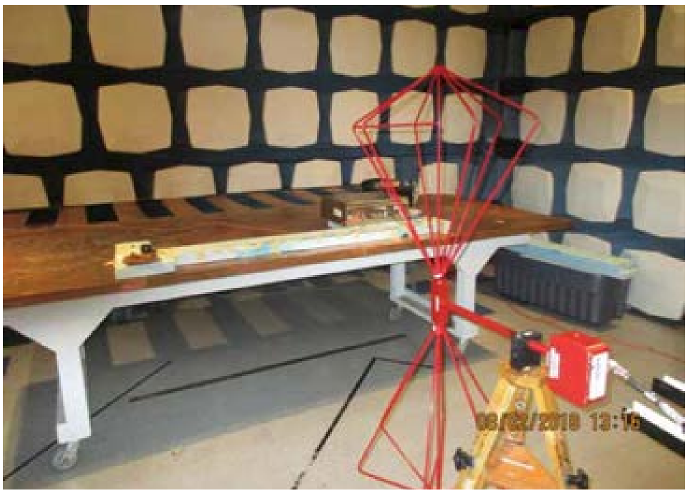
Testing Methods and Parameters

Because vehicles are mobile and can go virtually anywhere, automakers must assume and design for the worst-case scenario, while also creating solutions capable of extremely high reliability at the lowest possible cost. The answer: optimal electromagnetic compliance (EMC) design and selection of the best EMI shielding materials, which requires precision not only in the design, but in the testing and simulation phases.

Since radiated emissions transmit through the air, they can be measured with calibrated antenna set-ups. Multiple antenna types, arranged in various orientations (vertical, horizontal, etc.), must be used in order to capture the full frequency range.

Automakers have specific and stringent requirements when it comes to the test setups, power limits and frequency ranges for radiated and conducted emissions, and they must ensure the measurement techniques and pass/fail criteria meet their requirements. Too stringent of criteria could mean excessive costs to mitigate the noise, while criteria that are too lenient could mean unintentionally interfering with another electronic device resulting in EMI related problems.

The radiated emissions testing range is typically 100KHz – 2GHz and requires three different antennas to cover the entire frequency. Setup includes the DUT, DUT cabling, GND copper plane, pre-amplifiers, computers, power supplies, fiber optic data converters and spectrum analyzer.



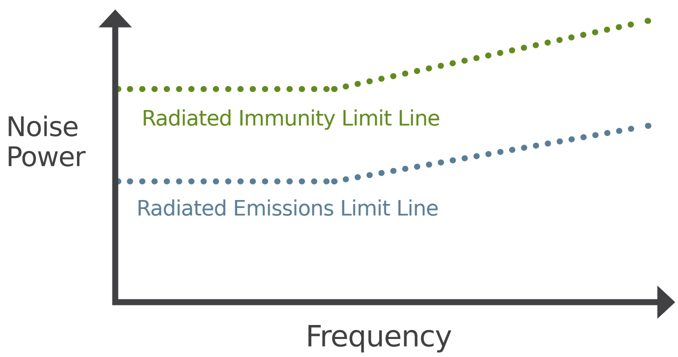
Radiated emission set-up
(Vertical BICON test in a single DUT mode)

Conducted emission set-up on the power conductor.

Automakers must also specify multiple modes of DUT (device under test) operation that must be tested. For example, a USB port mode of operation might only include reading and writing to a thumb drive, while another mode of operation might be require maximum charging current from the USB port, while yet another mode of operation might include connecting a phone to the USB port in order to launch Apple Carplay or Android Auto. The testing phase, then, must account for all of those variables.

Radiated and Conducted Immunity Testing

The purpose of radiated and conducted immunity testing is to determine how well the DUT performs in the presence of noisy disturbances. Pass/fail limits for radiated and conducted emissions must always be below the pass/fail limits for radiated and conducted immunity. The radiated emissions from one device must be lower than the radiated immunity tolerance of the neighboring device, otherwise undesirable operation will occur.



Radiated immunity tests determine how well the DUT performs with electromagnetic disturbers traveling through the air. It must be tested by using a calibrated noise source and transmitting antenna aimed at the DUT.

Conducted immunity tests determine how well the DUT performs with disturbers injected into the cables — i.e. a power harness, USB or Ethernet cables — that connect to the DUT. Automakers usually specify multiple modes of DUT operation be tested, and will also specify expected status level responses. For example:

- Status 1 response - may be "no response." This means that during the immunity testing, the device must work as advertised in the various modes of operation with no noticeable degradation.
- Status 2 response - may be that a noticeable response can occur but must recover automatically after the disturber is removed.
- Status 3 response - could be that a noticeable response occurs and that user intervention is required after the disturbance is removed to return to normal operation (ignition cycle).

Example: A USB port on a DUT operating mode is specified to be playing music from a thumb drive. A specification of a Status 1 means that during the test music must continue to play with no noticeable degradation (no static, no interruptions, etc).

There are numerous types of test set-ups for EMC including:

- Portable transmitter
- Bulk current injector
- Coupled immunity

Portable transmitter test setup:

A specific type of radiated immunity test is referred to as "portable transmitters." This tests the DUT's immunity to devices like cell phones and handheld two-way radios.

Bulk current injection test setup:

A specific type of conducted immunity test is called "bulk current injection" (BCI). This method routes user cables and harnesses through a magnetic field to simulate narrowband radiated electromagnetic energy.

Coupled immunity test setup:

Another type of conducted immunity test is called "Coupled Immunity." This test simulates DUT cables routed in the same bundle or adjacent bundles to disturbing wires. The DUT wire/cable under test is routed next to the disturbing signal for a length of one meter.

Other immunity tests mimic the harsh electrical environment in the vehicle. Some of these tests include:

- **Electrostatic discharge (ESD)** - one of the important electromagnetic compatibility (EMC) tests. The IEC standard IEC61000-4-2 is the widely used standard to test the ESD immunity for electronic equipment. *(Source: https://ieeexplore.ieee.org/document/1282319)*
- **Power line disturbance** - Momentary Voltage Dropouts (vibration and connectors), Start/Stop Battery Droop, Warm Crank Voltage Droop
- **Transient disturbance** - Relay Chatter Coupling, Power Door Locks Inductive Load, Contact Arcing, Contact Bounce
- **Power cycling** - Ignition cycle voltage fluctuations during starting of vehicle engine.
- **Voltage overstress** - Load Dump (battery disconnected while the alternator is generating charging current and with other electrical loads connected), Jump Start, Runaway Alternator, Reverse Polarity

Conclusion

Placing a large amount of electrical and electronic systems into a very confined space poses the problem of keeping the electromagnetic interference of these automotive systems from interfering with each other through radiated and conducted emissions. If not properly controlled, the resulting interference can cause the system to malfunction or even fail in some cases.

The experienced connected automotive team at Molex brings a proven portfolio of automotive solutions, approaches and methods for controlling electromagnetic emissions and techniques to harden an electronic device to withstand electromagnetic interference.

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