PRESENTED BY

INTERFERENCE TECHNOLOGY

2018 AUTOMOTIVE EMC GUIDE

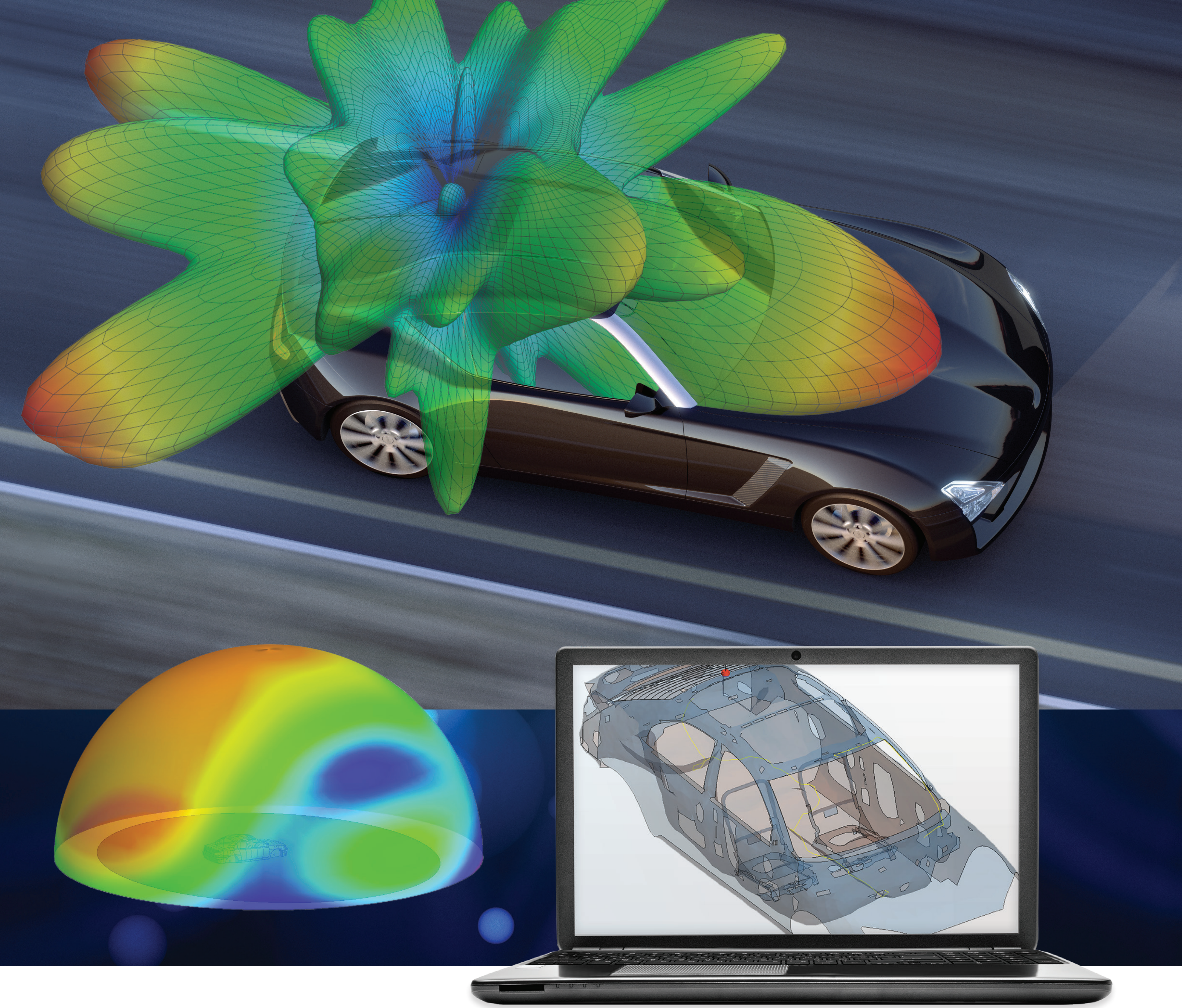
INTERFERENCE TECHNOLOGY GUIDE SERIES | www.interferencetechnology.com

TABLE OF CONTENTS

EMC EQUIPMENT MANUFACTURERS CHART

The following chart is a quick reference guide of test equipment and includes everything you'll need from the bare minimum required for key evaluation testing, probing, and troubleshooting, to setting up a full in-house precompliance or full compliance test lab. The list includes amplifiers, antennas, current probes, ESD simulators, LISNs, near field probes, RF signal generators, spectrum analyzers, EMI receivers, and TEM cells. Equipment rental companies are also listed. The products listed can help you evaluate radiated and conducted emissions, radiated and conducted immunity and a host of other immunity tests, such as ESD and EFT.

EMC Equipment Manufacturers		Type of Product/Service													
Manufacturer	Contact Information - URL	Antennas	Amplifiers	Near Field Probes	Current Probes	Spectrum Analyzers/EMI Receivers	Software Simulation	ESD Simulators	LISNs	Radiated Immunity	Conducted Immunity	Pre-Compliance Test	TEM Cells	Rental Companies	RF Signal Generators
A.H. Systems	http://www.ahsystems.com	X	X		X							X			
Aaronia AG	http://www.aaronia.com	X	X			X						X			
Advanced Test Equipment Rentals	https://www.atecorp.com	X	X			X		X	X	X	X	X		X	X
Altair	https://www.altair.com						X								
Amplifier Research (AR)	https://www.arworld.us/	X	X			X			X	X	X	X			X
Anritsu	http://www.anritsu.com					X						X			X
Beehive Electronics	http://www.beehive-electronics.com			X								X			
Electro Rent	http://www.electrorent.com		X			X		X	X	X	X	X		X	X
CST Computer Simulation Technology GmbH	https://www.cst.com						X								
EM Test	http://www.emtest.com										X	X	X		
EMC Partner	https://www.emc-partner.com							X			X				
Empower RF Systems	http://www.empowerrf.com		X							X					
ETS-Lindgren	http://www.ets-lindgren.com	X	X	X	X				X	X	X	X	X		X
Fischer Custom Communications	http://www.fischercc.com			X	X				X			X			
Gauss Instruments	https://www.gauss-instruments.com					X									
Haefley-Hippotronics	http://www.haefely-hipotronics.com							X			X				
Instrument Rental Labs	http://www.testequip.com		X			X		X	X	X	X	X		X	X
Instruments For Industry (IFI)	http://www.ifi.com		X							X	X				
Keysight Technologies	http://www.keysight.com			X		X			X			X			X
Microlease	https://www.microlease.com		X			X		X	X	X	X	X		X	X
Milmega	http://www.milmega.co.uk		X							X	X				
MVG	http://www.mvg-world.com	X													
Narda/PMM	http://www.narda-sts.it	X	X			X			X	X	X	X			
Noiseken	http://www.noiseken.com							X			X	X			
Ophir RF	http://ophirrf.com		X								X				
Pearson Electronics	http://www.pearsonelectronics.com				X										
Rigol Technologies	https://www.rigolna.com			X	X	X						X			X
Rohde & Schwarz	https://www.rohde-schwarz.com	X	X	X	X	X			X	X	X	X			X
Siglent Technologies	http://siglent.com/			X		X						X			X
Signal Hound	https://signalhound.com			X		X						X			X
TekBox Technologies	https://www.tekbox.net		X	X					X			X	X		
Tektronix	http://www.tek.com			X		X						X			
Teseq	http://www.teseq.com		X		X			X		X	X	X	X		
Test Equity	https://www.testequity.com/leasing/		X			X		X	X	X	X	X		X	X
Thermo Keytek	https://www.thermofisher.com							X			X				
Thurlby Thandar (AIM-TTi)	https://www.aimtti.com					X						X			X
Toyotech (Toyo)	https://toyotechus.com/emc-electromagnetic-compatibility/	X	X			X			X	X		X			
TPI	http://www.rf-consultant.com														X
Transient Specialists	http://www.transientspecialists.com									X	X		X		
TRSRenTelCo	https://www.trsrentelco.com	X	X			X			X	X	X	X		X	X
Vectawave Technology	http://vectawave.com		X												
Windfreak Technologies	https://windfreaktech.com														X



AUTOMOTIVE EMC

By Maurizio Di Paolo Emilio, Ph.D

Introduction

The rapid development of the automotive industry and the trend towards autonomous vehicles and ADAS systems continue to drive the need for more sophisticated EMC design and test scenarios for the automotive industry. Vehicle platforms become increasingly much more complex with electronic devices that need a reliable function without impacting security or communication infrastructure.

The increase of electronics in automotive systems has not just foreseen a radical change in control systems with ECUs, but also in the communication, information, security and mobile entertainment systems in vehicles. It is important that all the electronic devices of a vehicle are electromagnetically compatible and do not interfere with the systems outboard.

The new wireless communication paradigms applied to the automotive sector require high performance electronic systems that operate at high bitrates and, therefore, at high frequencies according to the operating environment. Each of these new sub-systems must comply with the electromagnetic compatibility (EMC) standards. Furthermore, the integrity of the signals, the transmitted and processed data streams are critical aspects. Miniaturization of electronic products is a must and, as a consequence, manufacturing tolerance can be no longer neglected. Variations in nominal design parameters cause irregular behaviours that negatively affect the EMC and signal integrity and power (SI / PI) aspects.

Signal Integrity

Historically, engineers have used signal integrity testing (SI) as a key part of design and development of new systems and for maintaining standard qualifications. With today's increasing demand for higher system throughput and reduced latency in cloud computing, customers are increasingly designing low-loss laminate materials with more stringent design specifications and tolerances for impedance control.

The integrity analysis continues to evolve by combining simulation models with instrumentation to include detailed measurements of non-uniform trace structures, vias, packages and connectors. As the PCBs become more complex, the lines between the different scopes of analysis become blurred. The concepts of signal and power integrity are closely related. Power integrity problems in a project can actually appear as signal integrity problems. That's why performing signal integrity analysis is important for creating reliable designs, as well as for understanding and resolving possible problems encountered in the laboratory.

Digital projects traditionally have not been suffered of problems associated with the loss of a transmission line that can have significant consequences on the transmitted data. At low speeds, the frequency response has low influence on the signal. However, as speed increases, high frequency effects take over and even shorter lines can suffer of interferences such as crosstalk and reflections. In this case, the characteristics of a circuit can be determined as a function of parasitic impedances, which become prevalent along a transmission line.

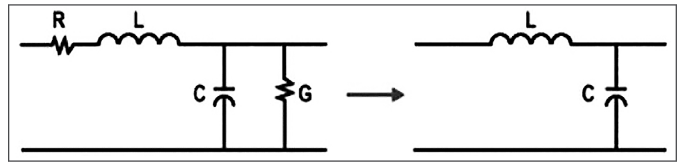


Figure 1: circuit model of a transmission line (on the left) and approximation to the first order (on the right)

An example of circuit model is shown in *Figure 1*. The impedance plays an important role determining a perfect match of the transmission path of the signal and therefore effects on the quality of the signal. A mismatching between the line, source and load impedances determines a reflection of the signal with consequent energy loss and signal degradation. At high data rates this can cause overshoot of the signal, undershoot and stepped waveforms, which produce signal errors.

The mismatch of impedance can be overcome through the use of circuit schemes with simple parallel (see *Figure 2*) and more complex RC terminations in which a resistor-capacitor network provides a high-pass filter to remove low-frequency effects but passes the high-frequency signal.

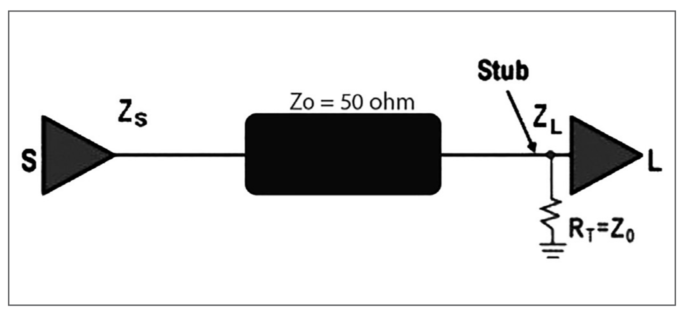


Figure 2: parallel termination circuit diagram

Losses in the high frequency signal transmission line make difficult for the receiver to interpret the information correctly. The following two causes of losses in a transmission line are due to the transmission medium:

- Dielectric absorption: high frequency signals excite the molecules in the insulation, reducing signal level. Dielectric absorption refers to the PCB material.

- Skin effect: high frequency signal current tends to travel on the conductors with an increase in the self-inductance of the material. The effective reduction of the conductive material causes an increase in resistance and, therefore, the attenuation of the signal (*Figure 3*). The density of alternating current J in a conductor decreases exponentially from its value on the surface J_s according to depth d from the surface:

$$\delta = \sqrt{\frac{2\rho}{\omega\mu}}\sqrt{\sqrt{1+(\rho\omega\varepsilon)^2}+\rho\omega\varepsilon}$$

Where ρ is the resistivity of the conductor, ω is the angular frequency, μ is the magnetic permeability, ε is the permittivity of the material.

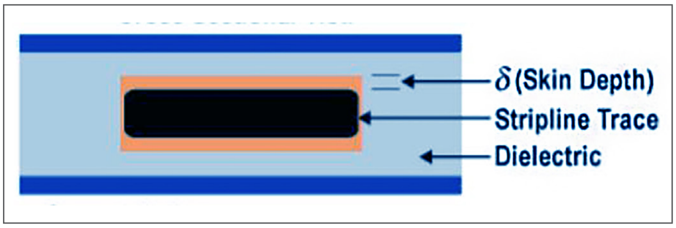


Figure 3: PCB section. The current route is orange. In blue is the ground plane and in celestial is the dielectric of the material. The copper PCB trace is highlighted in black.

CMOS circuits are very popular in many automotive sectors, due to their high speed and very low power dissipation. An ideal CMOS circuit dissipates energy only when it changes state and when the capabilities of the node need to be charged or discharged. In general, a CMOS requires an average of 10 mA and emission limitation techniques are focused on peak voltage and current values rather than average.

The rising current from the power supply on the chips pin is a primary source of emission. By placing a bypass capacitor near each power pin, this problem is limited. Larger capacitors provide strong current peaks, and tend to react badly to high-speed demands. Very small capacitors can react quickly to demand, but their total charge capacity is limited and can quickly run out. The best solution for most circuits is a mix of different sizes of parallel capacitors, perhaps 1-μF and 0.01-μF in parallel.

One area in which automotive designers are interested is in the AM radio band. Most every car is equipped with radios, which has a very sensitive and high gain tuneable amplifier from 500 kHz to 1.5 MHz. Many switching power supplies use switching frequencies within this same band, which leads to problems in automotive applications. As a result, most devices use switching frequencies above this band, often at 2 MHz or higher.

Automotive Standard

The automotive industry and the car manufacturers have the aim of satisfying a variety of requirements regarding electromagnetic compatibility (EMC). For example, two requirements must ensure that electronic devices do not emit excessive electromagnetic interference (EMI) or noise and are immune to noise emitted by other systems.

Automotive systems have several receivers installed around the car. The IEC Commission has formulated international standards to protect them. The international standard for this electromagnetic noise is formulated as CISPR 25, and the power supply on board is required to meet this standard (*Figure 4*).

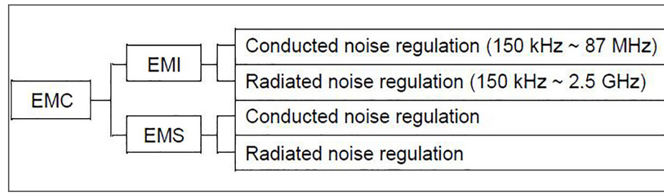


Figure 4: electromagnetic noise

Automotive standards that relate to electromagnetic compatibility (EMC) are mainly developed by CISPR, ISO and SAE. CISPR and ISO are organizations that develop and maintain standards for international use. The CISPR 25 and ISO 11452-2 standards form the basis of most other standards.

CISPR 25 is a standard with different test methods. It requires that the level of test electromagnetic noise is being performed is at least 6 dB lower than the lowest measured levels. Another standard of testing is the ISO 11452-4 Bulk Current Injection (BCI) to check if a component is negatively affected by the narrow band electromagnetic fields. The test is performed by coupling noise directly in the wiring with a current probe.

CISPR 25 contains limits and procedures for measuring radio interference in the frequency range from 150 kHz to 1000 MHz. The standard applies to any electronic / electrical component intended for use on vehicles, trailers and devices. CISPR 25 defines the test configuration as shown in *Figure 5* for measuring the noise of the radiation emitted by the apparatus.

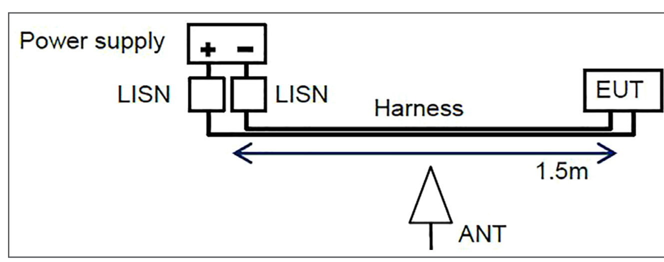


Figure 5: EMI Radiated Noise Test Configuration Example

In the case of irradiated noise measurement of 1 GHz or less, the antenna is placed in the middle of the harness. The wiring current (or voltage) (or LISN) is measured for the conducted noise. The length of the line is different from the test condition for the radiation noise. Therefore, it is important to reduce the noise source level and to prevent noise propagation along the line to reduce EMI noise.

EMC Testing

When a magnetic field is present, a coil of conductive material can act as an antenna and convert the magnetic field into a current flowing around the wire. The small size of these loops minimizes the inductive effects of these materials. An example of this effect is when there is a differential data signal. A loop can be formed between the transmitter and the receiver with the differential lines. Another common loop is when two subsystems share a circuit, for example a display and an ECU device.

When a high-speed signal is sent through a transmission line and encounters a change in the characteristic impedance, part of the signal is reflected back and the other continues along the electrical path. Then, reflection leads to emissions.

Emissions can be caused by an interruption in the signal track or in the ground plane. For this it is necessary to avoid sharp angles on the signal track. To minimize reflections on components, it's important to use small components such as size 0402 and set the width of the track equal to the width of the 0402 component.

A recurring topic when trying to solve EMI problems is to reduce dv/dt or di/dt where possible. In this context, DC-DC converters may seem completely harmless as switching regulators are much more efficient than other linear solutions. One area in which automotive designers are not interested in creating interference is in the AM radio band. The cars are equipped with AM solutions, which have a very sensitive and high-gain tuneable amplifier from 500 kHz to 1.5 MHz. Most automotive switching supplies use the switching frequencies above this band, often at 2 MHz or higher. If the filter is not sufficient to contain this interference, it can trigger an EMI cycle over the whole circuit.

There are several ways to implement EMI noise reduction countermeasures.

Spread Spectrum Clock Generation (SSCG) is a method by which the energy contained in the small band of a clock source is spread on a larger one in a controlled mode, thus reducing the spectral amplitude of the fundamental and harmonics to reduce the emission radiated by the clock. This is obtained by modulating the clock frequency with unique shapes that allow reaching the peak of reduction of the EMI.

By varying the clock frequency on a band in a controlled mode, the time elapsed from the signal at a certain frequency is reduced, and in this way the concentration of energy at any frequency is reduced. So energy is spread on the band of frequencies that reduce the amplitude of the peak.

SSCG provides a way to reach EMC goals. It is an active solution, preserves the integrity of the clock, and can cover a wide range of frequencies. Compared to traditional methods of using passive components such as ferrite beads, RF coils to suppress EMI, SSCG uses an integrated circuit of active components to reduce the EMI peak using frequency modulation (*Figure 6*).

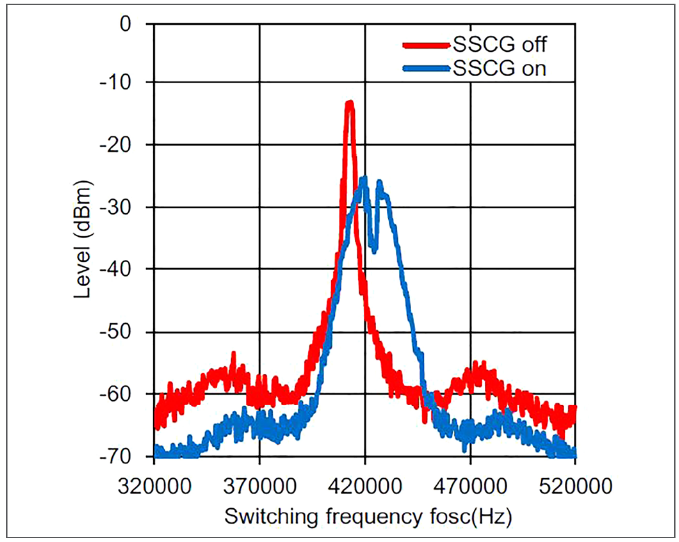


Figure 6: EMI reduction with SSCG

Power Circuits

Various electronic devices are mounted on vehicles with different power sources. Switching circuits help power management solutions but are essentially noise sources. Where it is not possible to increase the switching frequency is necessary to introduce noise suppression measures.

DC-DC switching solutions for automotive systems have a switching frequency of 2 MHz, with the exception of some devices. Therefore, there is almost no problem in the range of AM radio (from 530 kHz to 1.8 MHz) as it is below 2 MHz, but countermeasures could be requested with values above 2 MHz. In particular, high noise frequency above 30 MHz is the most important since it generates cases of interference such as to interrupt the correct functioning of a system. A diagram of the step-down DC-DC converter is shown in the following *Figure 7*.

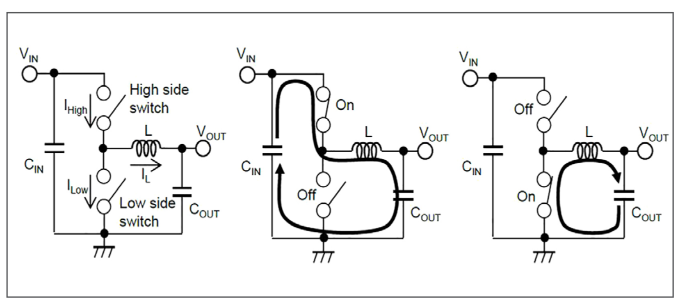


Figure 7: step-down converter with current loop in various cases depending on the switch position

The parasitic inductance of the loop generates a high frequency voltage and therefore noise. To reduce this high frequency, it is necessary to reduce the parasitic inductance and to improve the switching response speed. Noise suppression measures are not limited to vehicles and can also be used with other industrial equipment (*Figures 8* and *9*).

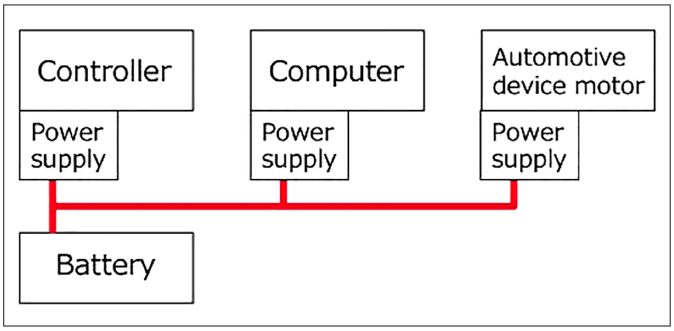


Figure 8: automotive power system

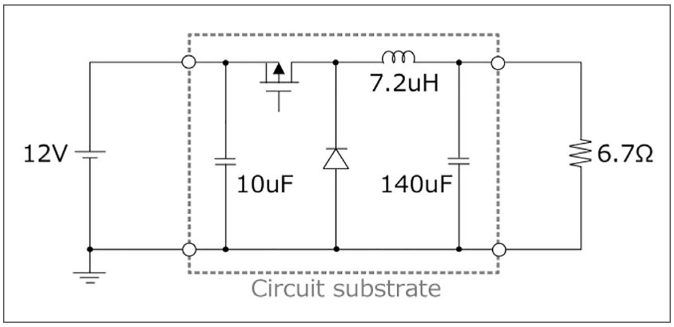


Figure 9: model of IC DC-DC step-down

Some methods consist of using appropriate shields to suppress noise up to 20 MHz. Or insert a common mode stop coil (CMCC) immediately next to the power connector to suppress noise in common mode at 20 MHz or higher, or, an LPF near the power connector to suppress noise in normal mode at 20 MHz or higher. In *Figure 10* an implementation circuit of what has been described.

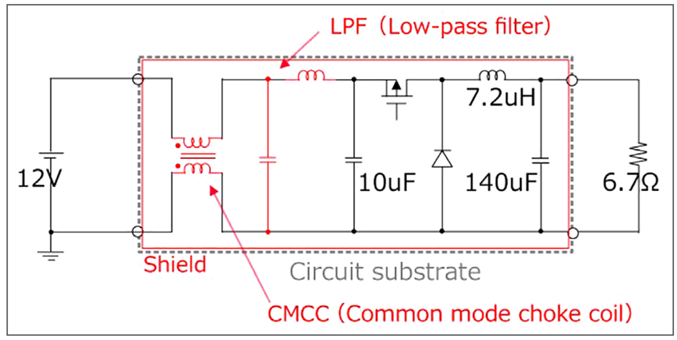
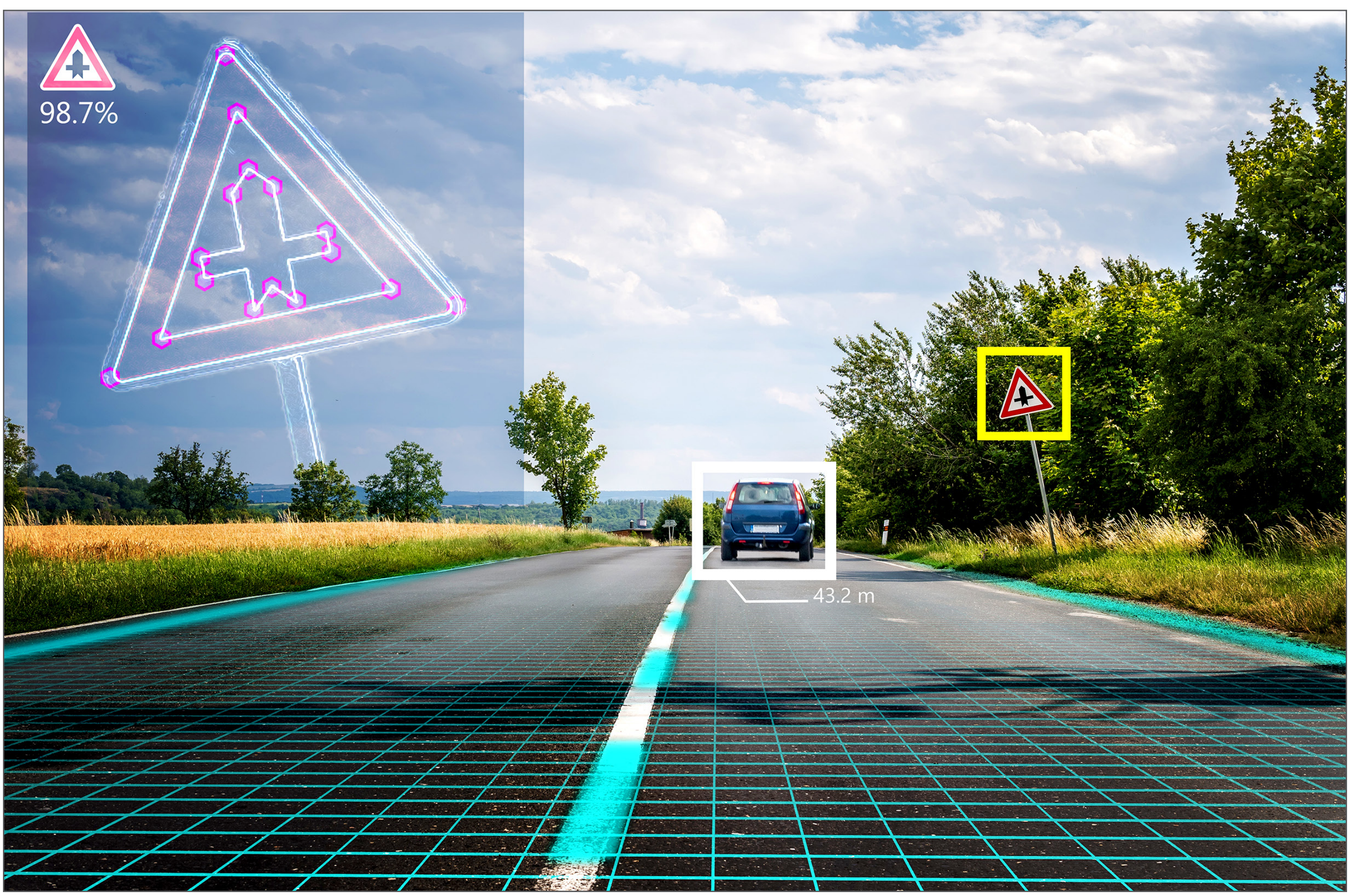


Figure 10: the circuit model of Figure 9 with noise suppression methods

Conclusion

Automobiles rely more on electronics: ADAS systems and self-driving vehicles; in all these there is a growing need to operate without errors without interfering with other systems in the vehicle. Through a selection of the appropriate components, materials and PCB study; engineers are able to design robust systems that enable automotive systems to operate EMI-free reliability.



THE PARADOXICAL NATURE OF AUTOMOTIVE RADIATED EMISSION TEST REQUIREMENTS

By Manish Kothari
electronics.engg@gmail.com

Introduction
This article discusses the paradoxical nature of automotive Radiated Emission (RE) test requirement on components versus vehicle level as per ECE Regulation No. 10 revision 5 (ECE R 10 Rev. 5) / AIS-004 (Part 3) standard. Shown below is a graphical comparison of broadband (BB) and narrowband (NB) limit lines for electronic sub-assembly (ESA) level v/s vehicle level RE test.

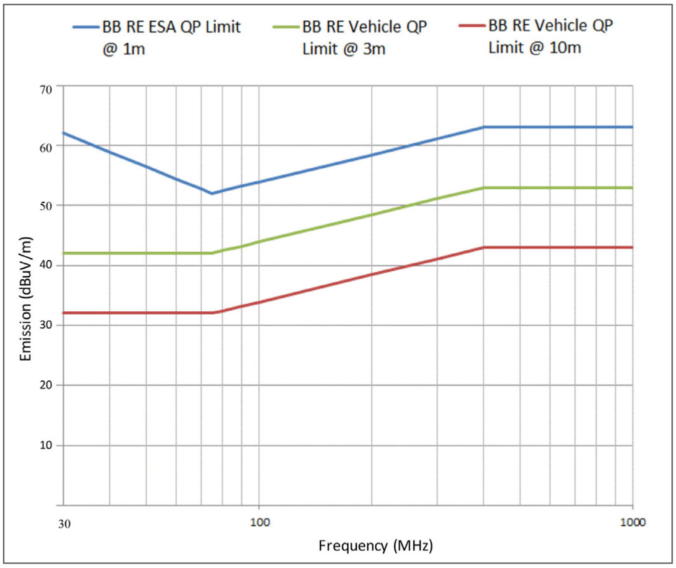


Figure 1: Comparison of BB Quasi-Peak Limit for ESA (@ 1m) V/S Vehicle level (@ 3m &10m)

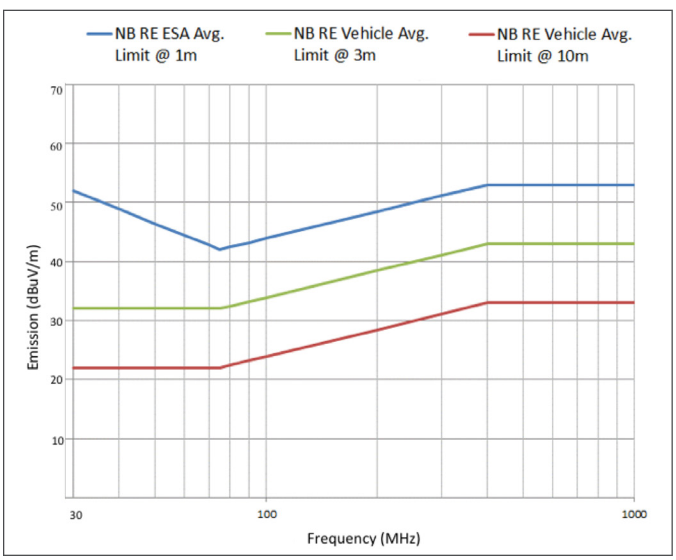


Figure 2: Comparison of NB Abg. Limit for ESA (@ 1m) V/S Vehicle level (@ 3m & 10m)

It is quite apparent that limit lines of component level RE test requirement (Blue line) as per ECE R 10 is less stringent (higher level of limit lines) when compared to vehicle level RE limits (Green and Maroon lines) which is more stringent (lower level of limit lines).

Under such situations, logic dictates that none of the vehicles should meet RE test requirements, since every component fitted on the vehicle is permitted to emit more radiation compared to the vehicle itself. Yet, in almost every case, it is the other way around, i.e. vehicles comply with their standard requirements. This is primarily because the vehicle's metal body acts as a Faraday cage and helps contain the emissions of electrical/electronic components underneath it.

Certainly, we have to consider the Free Space Path Loss (FSPL) too, as vehicle measurements are done at 3m / 10m whereas component level measurement will be performed at 1m.

Everything was going fine until OEMs started replacing metal with plastics and other plastic composites to build the vehicle body. This single phenomenal move resulted in a sizable drop in the weight and cost of the vehicle, leaving everybody happy except EMC engineers.

In their relentless effort for killing two birds with one stone, on the hindsight, they have created a bigger problem for EMC engineers to deal with. The removal of metal body would no longer arrest the emissions of ESAs beneath it!

In this article we are going to discuss about the comparison of component level versus vehicle level RE requirements for broadband and narrowband RE tests. At the same time, we will understand the impact of higher limits of component RE level on vehicle RE behavior.

Discussion
Having established that limit lines of component level RE test requirement as per ECE R 10 is less stringent (higher level of limit lines) when compared to vehicle level RE limits which is more stringent (lower level of limit lines), let us next discuss the similarities and differences between test set-up requirements for component and vehicle level RE test.

Let's start with the commonalities:
In both the cases, broadband and narrowband RE tests need to be performed for the frequency range of 30 MHz ~ 1GHz in vertical and horizontal antenna polarizations. The test set-up will be as per CISPR-25 RE requirement. The BB RE test will be performed with quasi-peak detector (peak detector can be used with correction of 20dB in the limit lines). An average detector will be used for NB RE test.

The major differences:
Distance of antenna from DUT is different for component and vehicle level RE tests. For component level RE test, the distance between DUT (Device Under Test) to antenna shall be 1 ±0.01 m and the orientation of the DUT will be as per CISPR-25, i.e. in front of the antenna. This DUT orientation in front of antenna is fixed i.e. one face of DUT towards antenna.

However, for vehicle level RE test, the distance between vehicle to antenna is 10 ±0.2 m or 3 ±0.05 m and test will be performed on both left and right side of the vehicle. Therefore w.r.t. component level test where only one face of DUT will be facing towards the antenna, on vehicle level RE test two orientation of component (left and right side of vehicle) will be facing the antenna.

Now suppose, a component on which far field RE measurement was performed at 1 m is, fitted on a vehicle (which is made up of plastic composition). As discussed earlier, the vehicle RE measurement will be performed at either 3m or 10 m. The expected behavior of emissions from such a component can be theoretically determined, w.r.t the vehicle emissions, by considering the FSPL (free space path loss) for 2m or 9m distance respectively. The reason to have 2m or 9m FSPL correction is that, the component RE measurement will be performed at 1m whereas vehicle RE measurement need to be performed either 3m or 10m; therefore, the difference of distance i.e. 2m or 9m was considered for correction.

Section 3.1 discusses the comparison of component & vehicle level RE limit lines and their far-field behavior considering the 2m/9m distance FSPL.

Trend of Vehicle level RE BB limits @ 3m / 10m, with FSPL correction on Component level RE BB limits @ 1m

The following graph shows the trend of vehicle level limit lines (for @3m and 10m) if FSPL corrections are applied on component level emission limit lines @1m.

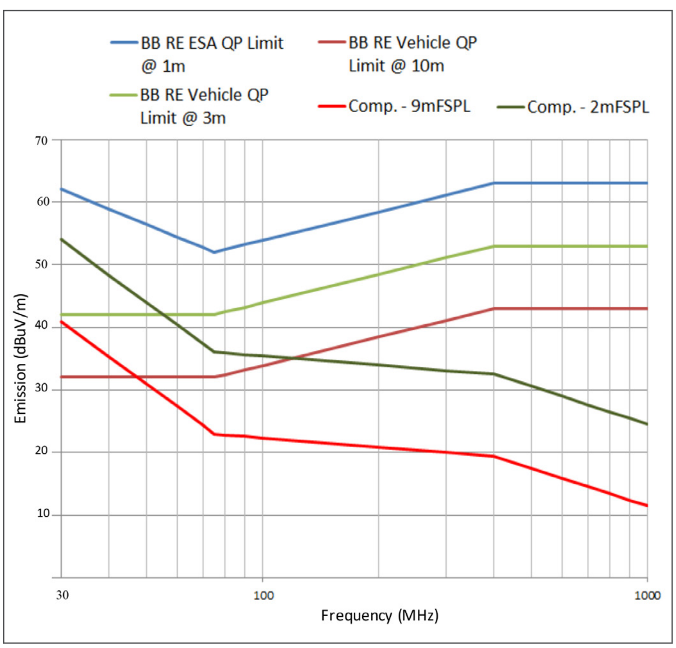


Figure 3: Trend of vehicle level limit lines (@ 3m & 10m) with FSPL correction component level emission limit lines @1m

To reiterate, the component level far field RE will be measured at 1m, whereas, vehicle level far field RE measurement will be performed at either 3m or 10m. Therefore, a correction of 2m and 9m FSPL shall apply on component level limit line (@ 1m); to check the behavior of the same component on vehicle radiated emissions measured at 3m / 10m.

The FSPL correction (in dB) is measured using following formula:

FSPL (in dB) = $20 \log_{10}(f) + 20 \log_{10}(d) + 20 \log_{10}(4\pi/c)$

Here:
f: is frequency in MHz
d: is distance in meter (m)
c: is speed of light (roughly 3×10^8 meter/second)

In *Figure 3*, Let's take an example of a component RE limit. A correction factor of 2m is applied on blue line (Legend: BB RE ESA QP Limit @ 1m) to get the trend of component RE at 3m represented by dark green line (Legend: Comp. – 2mFSPL). Now, compare the component RE trend of dark green line with vehicle level RE limit at 3m represented with light green line (Legend: BB RE Vehicle QP Limit @ 3m). It can be clearly seen that the component RE trend at 3m is higher compare to vehicle level limits at 3m for initial frequencies from 30 MHz to 55 MHz. Therefore, a component which might be meeting component level RE with very less margin may not comply with vehicle level emission requirement for frequency up to 55 MHz.

Similarly, comparison for the component RE trend of the red line (Legend: Comp. – 2mFSPL) can be done with vehicle level RE limits represented by maroon line (Legend: BB RE Vehicle QP Limit @ 10m). In this case the component RE trend @ 10m (Red line) is higher compare to vehicle level limits @ 10m (maroon line) for initial frequencies from 30 MHz to 45 MHz.

This is to highlight the crux of the whole problem. The critical part of the puzzle is to meet the requirements in the lower frequency range up to 55 MHz.

Conclusion
A component which meets the RE test requirement with a narrow margin may meet vehicle level RE requirement comfortably if the body of the vehicle is made of metal.

However, with the recent drift towards the idea of using plastic composites for making the vehicle body, there will be many challenges which have to be addressed to comply with vehicle level RE requirements, especially in the lower frequency band.

In conclusion, the components on a vehicle with a plastic composite body would have to meet component level RE requirements with a higher margin to comply with the vehicle level requirements. It is an extremely challenging task. Let's hope that the world is ready for it!

Have you tried our Common Mode Choke Finder?

There's nothing common about it!

Search and compare hundreds of common mode choke options in four easy steps.

Step 1: Search parts by Impedance, Attenuation or Inductance at your operating frequency.

Step 2: View results in a sortable table with complete performance specifications and select parts for further analysis.

Step 3: Make direct comparisons of up to six components on single impedance and attenuation graphs.

Step 4: Request free samples of the most interesting parts for evaluation and testing.

It's that Simple!

Give it a test drive at
coilcraft.com/CMCfinder.

coilcraftdirect.com
No min order. Next day delivery.

Coilcraft®

WWW.COILCRAFT.COM

THE ÜBERSYSTEM, AUTOMOTIVE ETHERNET: AN INTERVIEW WITH STEPHEN JACKSON

By Candace Suriano,
candacesuriano@gmail.com

With larger bandwidth, lower latency, and lighter weight, this is the Übersystem; it's the OPEN (One-Pair EtherNet) Alliance Ethernet for automotive, aerospace and more! On June 12th, 2018 I talked to Stephen Jackson (Steve) of Keysight's Ixia Solutions Group about why Automotive Ethernet is the best solution for Advanced Driver Assistance Systems, ADAS, power train, body electronics, and Infotainment – and its evolution to be the best with the help of TSN, Time-Sensitive Networking! (Steve was involved with the original IEEE power over Ethernet standard 802.3af; for Automotive Ethernet the limit is about 5 Watts, IEEE 801.3bu.) [1].

Automotive Ethernet is the IEEE standard 802.3bw, often called BroadR-Reach or BRR based in part on its Broadcom roots in the OPEN Alliance Special Interest Group. BRR uses a SINGLE unshielded twisted wire pair instead of the FOUR twisted pairs found in most other Ethernet versions. If all the signal wiring in a vehicle went with the BRR standard, it would save an estimated 80% of the wiring harness weight [1] and a large portion of the labor [2]. This standard allows for multiple vendors to make this ubiquitous across many platforms: security systems, vehicles, industrial equipment, drones, even airplanes. BRR has a limited length, 10m compared to typically 100m for traditional wired Ethernet, but Steve said that is not a problem because a typical vehicle fits within these distances.

Steve said although BRR is applicable for many vehicle systems, the first area for it to be popularly accepted in is infotainment. Legacy technologies are in widespread use for the areas of vehicle control that are mission-critical, even though Automotive Ethernet can ultimately work better and faster! Due to the cost benefits, Automotive Ethernet has now started to move into areas that had been dominated by CAN, LIN, FlexRay and Most. [1]

CAN is an example of a deterministic system. Like FedEx, you know when a message arrives in a deterministic system[1]. A deterministic system, given a certain input, always has a predictable output, i.e. there is a unique input-event, output-event pair [1,3]. With Ethernet standards that implement TSN (Time Sensitive Networking), Ethernet can be made deterministic. TSN is implemented in layer 2 of the OSI, Open Systems Interconnection, model (*Figure 1*) [4-6]. TSN is scalable and can be used for almost any vehicle function [10]! But, there are still millions of lines of code in LIN, CAN, Flexray, Most and others [7]. Industry can't change quickly because of the inertia of coding and the need for deployed systems to be fully vetted for scale production use [1]. Steve said the deterministic technology will whittle away the perceived advantage of the legacy automotive components. This has to happen over time because of the great inertia of the legacy technology in volume manufacturing. Economics will drive implementation of an Ethernet-enabled wiring harness with TSN, Time-Sensitive Networking. [1]

Layer	Task	Brief Explanation of Layer Service
7	Application	Application specific support, service for network software, platform to send and receive data.
6	Presentation	Determines which user connects to which server and keeps track of the paths used. Compresses data.
5	Session	Tracks amount of data sent and received. Retransmits lost data. Virtual connections. Syncs data flow.
4	Transport	Transport among hosts- transport reliability- starts, maintains and ends virtual circuits.
3	Network	Defines data routes, prioritizes data, Quality of Service - QoS
2	Data Link	Defines how information is formatted and how it accesses the system. TSN is here. Media Access Control, MAC layer is here.
1	Physical	The PHY-Hardware, electrical and mechanical parts of system

Figure 1. Open Systems Interconnection Model

Steve Jackson mentioned how TSN is the next evolution from AVB, Audio Visual Bridging, which helps schedule information packets, implement lower latency and determinism in the automotive Ethernet. (The word time in this sense references the worst-case delay or latency, not the average [1,17,18]). Time is very important in a deterministic system. Steve told me that the IEEE AVB group had become the IEEE TSN group in 2012 [8], since AVB does not imply a time aware network. He guided me to some of the articles that Volker Goller of Analog Devices, the IEEE TSN group, the University of New Hampshire Interoperability Lab, Broadcom, and others wrote on TSN [9-18]. TSN is implemented in the second layer of the OSI (*Figure 1*), allowing scheduling of the data so there can be an absence of collisions and the data is received by the correct switch at the right time. There are a set of IEEE 802.1 sub-standards that can be used to implement TSN, but not all have to be implemented [1,12,16].

Data packets can be redundant so the information always arrives (IEEE 802.1CB). Seamless Redundancy insures that the same message is sent by two or more different paths [16-18]. When the second message arrives, the redundant message is discarded. By sending multiple messages, there are less frames that are lost due to congestion and device failures [9,15-18] (*Figure 2*).

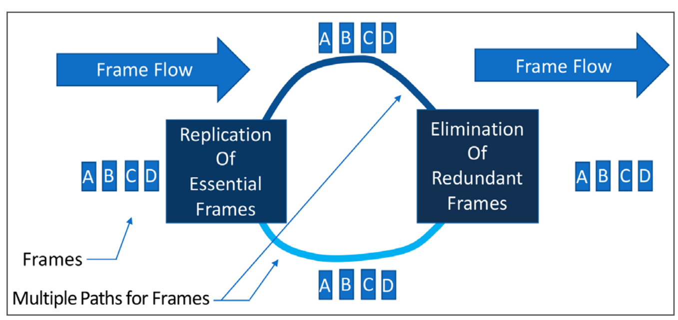


Figure 2. 802.1CB Frame Replication and Elimination for Reliability

TSN allows for a Grand Master Clock and multiple grand master clocks IEEE 802.1AS (REV) a subset of IEEE 1588, Precision Time Protocol, PTP [18]. To select the best Grand Master clock, a Best Master Clock Algorithm is used. One of the ways components become a better value commodity is to reduce the cost of the clock, so having time that is constantly checked across the network is essential [9].

Bob Noseworthy of the University of New Hampshire InterOperability Laboratory when talking about the TSN said, "To achieve the absolute lowest possible latency, IEEE 802.1Qbv defines a Time Aware Shaper, which defines timed traffic gates which act as stop-lights on different priorities of traffic flowing through a switch. "[13]. Volker Goller said that the purpose of the Time Aware Shaper is to avoid traffic interference by dividing Ethernet traffic into separate classes. This makes sure that each traffic class has a set time that it uses the network [9]. Thus, the switches must know what class of traffic can use the network at a given time. Implementing Time Aware Shaper demands highly sophisticated algorithms such as the algorithms used in Siemen's Profitnet [15].

TSN involves scheduling, this is a big part of its time sensitivity, it makes sure express frames are where they need to go before they have to arrive! When the car in front of you stops, the ADAS needs to stop your car, before you hit the stopped vehicle. To allow the stream of data frames to flow smoothly, cyclic queuing and forwarding keeps the frames moving (IEEE 802.1Qch) [17,18]. Each queue has an associated gate. The queue transmits frames according to a set timescale (IEEE 802.1Qbv) [17,18]. Interjecting express messages between preemptible frames is specified by (IEEE 802.1Qbu and 802.3br). The express fames can suspend a preemptible frame in the middle of its transmission as shown in *Figure 3* (IEEE 802.3br) [17,18].

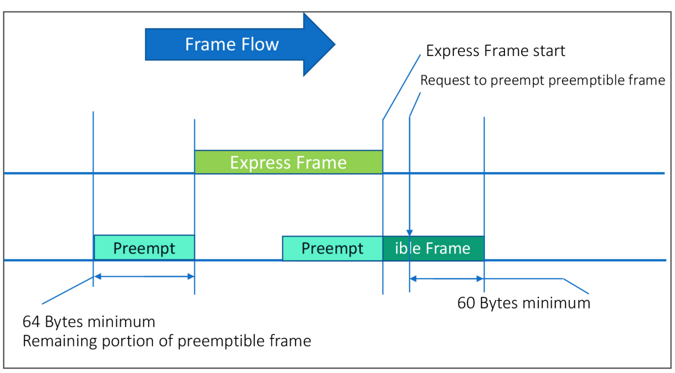


Figure 3. Express Frame Preempting Preemptable Frame IEEE 802.1br

TSN, Time Sensitive Networking has other possible implementations. Just look at all the IEEE 802.1 standards [16-18]. As Steve Jackson said, TSN enables Automotive Ethernet to be dynamic and deterministic. Since the messages always arrive in time sensitive manner, it is by definition reliable. It commands the needed economic benefits that automotive Ethernet may soon replace the entire wiring harness [1]. The conversion will be fun to watch!

The governing bodies for the Automotive Ethernet are the IEEE [19], the OPEN Alliance [20], the AVNU Alliance [21], and the University of New Hampshire Inter-Operability Laboratory [22]. The IEEE standards that pertain to the OPEN Alliance are free. Membership in the OPEN Alliance is gratis as of July 16, 2018. Membership in the AVNU Alliance is not gratis. The University of New Hampshire Interoperability Laboratory, developed the basic tests for the Automotive Ethernet.

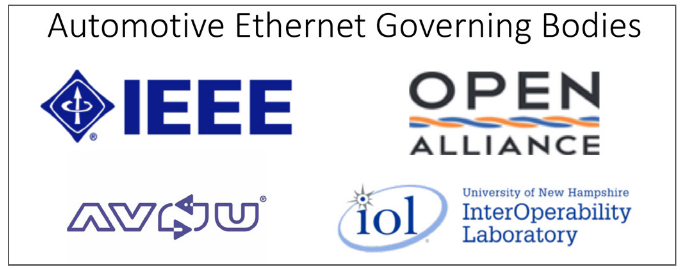


Figure 4. Governing Bodies for Automotive Ethernet

Experts say the Automotive Ethernet 100BASE-T1 is less susceptible to EMI than 10BASE-T and 100BASE-TX [23], but how can it be that an unshielded twisted two-wire pair does so well and is able to pass stringent testing? Texas Instruments Donovan Porter wrote, 'By using the basic principles of superposition and specific encoding and scrambling schemes, 100BASE-T1 reduces electromagnetic interference (EMI), cabling weight, cost and footprint size compared to Ethernet standards 10BASE-T and 100Base-TX.'[23]. Basic test protocols for the Automotive Ethernet have been defined by the University of New Hampshire Interoperability Laboratory and Original Equipment Manufacturers (OEMs), to determine if components will meet the standards. The tests look at how signals can degrade and how injected noise affects the frames. Test manufacturers have developed test packages [24-27] for test protocols and have great decode programs for the Pulse Amplitude Modulation 3 – PAM 3- (*Figure 5*) signals on the Automotive Ethernet [24-27] to help trouble- shoot problems that come up in testing. The Automotive Ethernet uses PAM3 to reduce the bandwidth needed to operate over a twisted pair channel [28], and according to Broadcom, using PAM 3 reduces EMI allowing a more aggressive EMC filtering with lower cost, even over a low-quality transmission line [28].

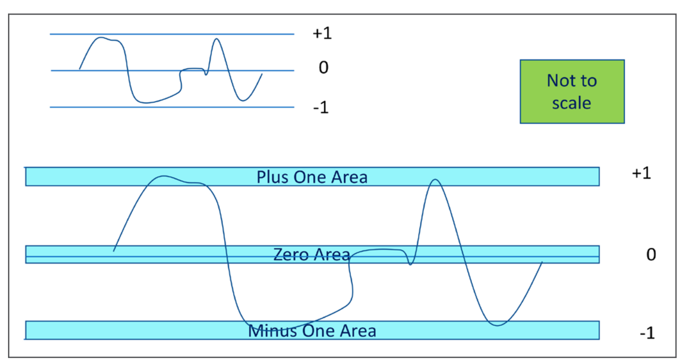


Figure 5. Pulse Amplitude Modulation 3 (PAM 3) signals on the Automotive Ethernet

Please read our next article, where we examine the tests used to stress test Automotive Ethernet and its protocols! There are many people I need to thank for their help in writing this article! I am indebted to Stephen Jackson for spending his time to explain to me how amazing a deterministic Ethernet is to the automotive market. Thank you, Steve. Thank you, David Paul, of Keysight Technologies for making Stephen Jackson available for the interview. Special thanks to Jackie Mancini of Rhode and Schwartz for encouraging me to understand the scope of change the automotive Ethernet involves.

[1] Interview with Stephen Jackson, Solutions Architect Ixia Solutions Group, Keysight Technologies, June 12, 2018, Novi, Michigan.

[2] https://www.wired.com/2012/10/in-car-ethernet/ (Damon Lavrinc 10.16.12 01:00 pm) Retrieved July 1, 2018 9pm ET .

[3] https://en.wikipedia.org/wiki/Deterministic_system Retrieved July 1, 2018 9pm ET .

[4]https://www.cisco.com/c/dam/global/fi_fi/assets/docs/SMB_University_120307_Networking_Fundamentals.pdf Retrieved July 2, 2018 7:50pm ET.

[5] http://ru6.cti.gr/bouras-old/WP_Simoneau_OSIModel.pdf (Paul Simoneau 2006) Retrieved July 9, 2018, 4:15pm ET.

[6] https://www.computernetworkingnotes.com/ccna-study-guide/osi-seven-layers-model-explained-with-examples.html Retrieved July 9, 2018, 4:17pm ET.

[7] Comment by Ali Ranjbar, LHPES, June 12, 2018, Novi Michigan.

[8] http://www.ieee802.org/1/pages/avbridges.html (November 2012) Retrieved July 1, 2018 9pm ET.

[9] http://www.analog.com/media/en/Other/electronica/Time-Sensitive-Networking-for-Industrial-Applications-Volker-Goller.pdf (Volker Goller, Analog Devices, 2016) Retrieved July 1, 2018 9pm ET.

[10] http://www.electronicdesign.com/industrial-automation/what-s-difference-between-ethernet-and-time-sensitive-networking (Volker Goller May 21, 2018) Retrieved July 2, 2018 3pm ET.

[11] http://www.analog.com/ru/technical-articles/a76950-what-role-will-opc-ua-tsn-and-classic-industrial-ethernet-systems-play-in-the-future.html (Volker Goller, Analog Devices) Retrieved July 2, 2018 3:07pm ET.

[12] https://www.electronicsweekly.com/news/embedded-world-video-interview-analog-devices-tsn-real-time-comms-2017-03/ (Volker Goller, Analog Devices, March 15, 2017) Retrieved July 2, 2018 3:11pm ET.

[13] https://www.networkworld.com/article/3189131/lan-wan/the-growing-importance-of-time-sensitive-networks.html (Bob Noseworthy, University of New Hampshire InterOperability Laboratory) Retrieved July 2, 2018 3:20pm ET.

[14] https://www.sensorsmag.com/components/how-emerging-technologies-are-driving-inside-next-gen-cars (Curtis Donahue , University of New Hampshire InterOperability Laboratory, May 31, 2018 12:00am) Retrieved July 2, 2018 3:29pm ET.

[15] https://www.iol.unh.edu/sites/default/files/knowledgebase/UNH-IOL_TSN-Overview.pdf (Bob Noseworthy, University of New Hampshire InterOperability Laboratory, November 24, 2015) Retrieved July 2, 2018 3:50pm ET.

[16] http://www.ieee802.org/1/pages/tsn.html Retrieved July 3, 2018 9:40pm ET.

[17] http://www.ieee802.org/1/files/public/docs2017/tsn-farkas-intro-0517-v01.pdf (Janos Farkas of Ericsson May 15, 2017) Retrieved July 3, 2018 9:50pm ET.

[18] https://drive.google.com/file/d/0B6Xurc4m_PVsZ1lzWWoxS0pTNVE/view (Michael Johas Teener of Broadcom for ISPCS 2015) Retrieved July 15, 2018 10:30pm ET.

[19] www.ieee.org Retrieved July 16, 2018 3:50pm ET.

[20] http://www.opensig.org/ Retrieved July 16, 2018 3:40pm ET.

[21] http://avnu.org/ Retrieved July 16, 2018 7:50pm ET.

[22] https://www.iol.unh.edu/ Retrieved July 16, 2018 8pm ET.

[23] http://www.ti.com/lit/wp/szzy009/szzy009.pdf (Donovan Porter, Systems Engineer ,Texas Instruments 2018) Retrieved July 25, 2018, 4:30pm ET.

[24] Rhode and Schwartz Seminar on Automotive Ethernet Testing presented by Dr. Ernst Flemming, Manager of Oscilloscopes and Alyssa Harder, Oscilloscope Sales Specialist, May 18th, 2018 Southfield, MI.

[25] Teledyne LeCroy Seminar on Automotive Ethernet Testing presented by Mike Hertz, Field Applications Engineer with Teledyne LeCroy May 23, 2018, Farmington Hills, MI.

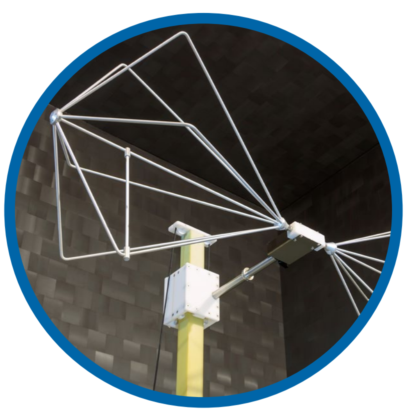
[26] ***Keysight Technologies Tech Day & Open House***, June 12th 2018, Novi, Michigan.

[27] Tektronix Webinar on Automotive Ethernet Testing presented by Darshan Mehta, Product Manager, Tektronix automotive segment with Tektronix Automotive Solutions group.

[28] http://ieee802.org/3/1TPCESG/public/BroadR_Reach_Automotive_Spec_V3.0.pdf Retrieved July 20, 2018, 10pm ET.

Automotive EMC Test Chambers

SFI provides unique automotive EMC test and cyber security solutions for engineers seeking portability, customization, and affordability.



Shielded Fabric Test Chambers:

Size:
Shielded environments designed and built to custom specifications.

Construction:
High attenuation, silver, copper, nickel, conductive fabrics over an aluminum frame.

Portability:
Semi-permanent shielded fabric chambers can be broken down and moved as well as stored away when not in use.

Customizable:
Options include anechoic foam absorber, high-performance IO filter plate and connectors, lighting, ventilation, air conditioning, and more.

Affordability:
Cost-effective alternative to hard wall chambers.

Contact us today for more information:
(585) 393-0650
contactus@select-fabricators.com
www.select-fabricators.com

EMC SIMULATION FOR AUTOMOTIVE ETHERNET

By Matthias Tröscher, SIMULIA, Dassault Systèmes
matthias.troescher@3ds.com

Matthias Tröscher is the Business Development Executive for Transportation & Mobility, focusing on EM simulation in the automotive industry. Tröscher has worked at CST since 2009 and is currently the Business Development Manager for Germany, Austria and Switzerland. Tröscher received his doctorate from the Johannes Kepler University Linz in 2000 for his work on radar warning systems carried out for BMW in Munich. His professional career began with the development of simulation software for analyzing PCBs and cable harnesses.

Tröscher is a member of the IEEE EMC Society and is Vice Chair of the IEEE German EMC Chapter and the IEEE Technical Committees TC-9 for Computational Electronics.

Matthias Tröscher has been involved in the organization of many automotive conferences in Korea, Germany and the USA, and has produced articles for magazines, journals and conferences.

Introduction

The increasing use of electronics in vehicles introduces new risks of interference and crosstalk between components. OEMs and government regulators impose strict limits on electromagnetic interference (EMI) and electromagnetic compatibility (EMC), and redesigning a component that fails to meet these standards can be both expensive and time consuming. This article explains how electromagnetic simulation can be used to design and analyze automotive Ethernet systems to identify and mitigate EMI/EMC problems early in the design process, reducing the risk of problems emerging later.

Background

The number of electronic components in the average car is growing and smart vehicles are a major driver of growth in the automotive market. Designing an electronic system always poses a challenge to the electronic engineer, but there is an additional challenge in the need to connect all of them. To achieve this connection of data between these electronic systems, communication standards are needed.

Modern electronic systems like advanced driver-assistance systems (ADAS) and infotainment have a very high bandwidth requirement, for example for video streaming. The traditional vehicle bus protocols like Controller Area Network (CAN) are not able to provide this bandwidth and there is a need for a new standard with high bandwidth. Automotive Ethernet is a very promising candidate to fill this gap.

Ethernet has been well known for several decades as a connectivity solution in buildings but had not been used in vehicles due to the prohibitive bulk and weight of the cables. Traditional Ethernet cables typically consist of 4 twisted wire pairs (TWPs) that may also be shielded. To develop automotive Ethernet, the physical interface was simplified to one unshielded TWP while keeping the other components of the Ethernet bus the same. These unshielded twisted cables have data rates of 100 Mb/s and are lightweight and cost effective.

Broadcom created the BroadR-Reach standard for automotive Ethernet [1] and to promote its use, the OPEN Alliance (One Pair Ether-Net) was created [2]. Most major players in the automotive market now participate in this alliance. BroadR-Reach® is a point-to-point Ethernet Physical Layer standard for automotive applications, allowing full-duplex communication between two devices over an unshielded twisted wire pair at 100 Mb/s, with plans to further increase it to 1000 Mb/s. However, they make compliance of the BroadR-Reach® Ethernet with automotive EMC requirements a challenging task.

EMC compliance is crucial for releasing products to the market. Regulators such as the FCC and ETSI set EMC limits, and if a product does not comply with them, it cannot be sold in the given country. Furthermore, manufacturers can impose even stricter standards on their suppliers, which can vary from OEM to OEM.

Traditionally, EMC testing has been heavily reliant on measurements with physical prototypes, which can lead to multiple troubleshooting iterations with high corrective costs and a delayed time to market. Identifying potential EMC issues earlier on in the design process can offer significant savings of time and investment. Simulation can be used at any stage of design to model and visualize currents and fields in order to help engineers find and mitigate EMC issues. This can reduce the number of physical prototypes needed, along with reducing the risk of delays, increased costs or embarrassing recalls due to unforeseen interference issues.

PCB Setup

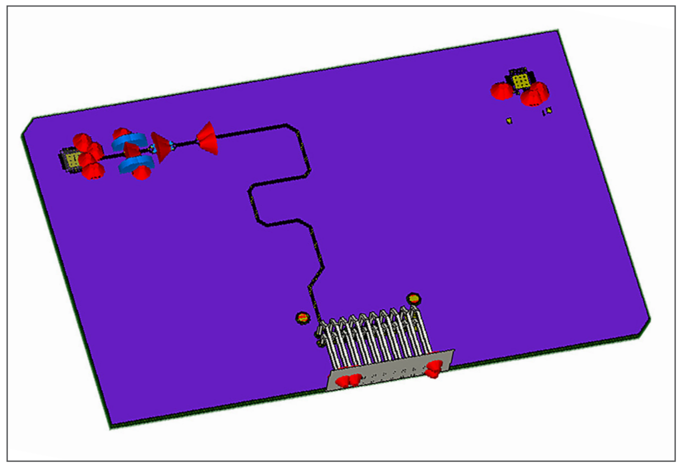


Figure 1: The test PCB, showing the IC, components, traces and connector.

This example (*Figure 1*) uses a typical driver IC for automotive Ethernet (NXP TJA1100) [3]. A PCB stack up was designed using Altium Designer and the Ethernet routed as a differential pair to a simplified connector. The termination on the Ethernet channel is a second PCB, identical to the first one.

A coupled 3D field and circuit simulation was used for this example. This co-simulation is a very common workflow for EMC simulation. The PCB and cable model was analyzed over a frequency range from 0 to 200 MHz, using the Frequency Domain solver in CST Studio Suite® [4], which is based on the finite element method (FEM). An AC frequency domain simulation was used for the circuit.

At frequencies above 1 MHz, the BroadR-Reach automotive Ethernet carries a much higher spectral content than the CAN bus. Designers need to be aware of this and apply the proper techniques to mitigate emissions at these higher frequencies.

Common and Differential Mode

As the automotive Ethernet is run on a differential pair, there are two possible propagation modes: the common mode and the differential mode. While the differential mode is the one used for signaling, the (unintended) common mode will always be created in the system due to asymmetries and is often the source of unwanted electromagnetic emissions. Simulations using multipin waveguide ports can be used to look in detail at the modes and to visualize the electric and magnetic field patterns.

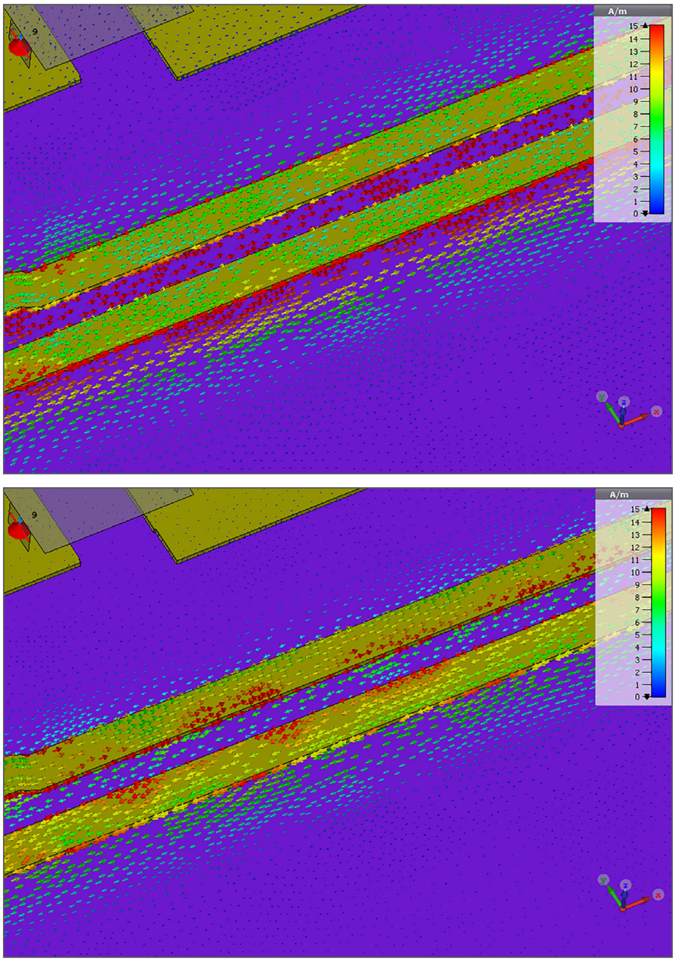


Figure 2: Surface current at 33 MHz, showing common mode (top) and differential mode (bottom)

Figure 2 shows the surface current at 33 MHz. In the differential case the current flows in opposite directions on both lines, while for the common mode the current goes in the same direction and therefore has to flow back to its source in the (common) reference plane. A close look at the bottom image of *Figure 2* shows that there will still be some current on the reference layer in the differential case, albeit with a much smaller amplitude than in the top image.

In the connector, the differential mode is mostly confined to the TWP, while the common mode arises between the TWP and the power (PWR) and ground (GND) wires. If the loop area of the common mode is large, this may lead to higher coupling, higher emissions and to insufficient electromagnetic compatibility (EMC).

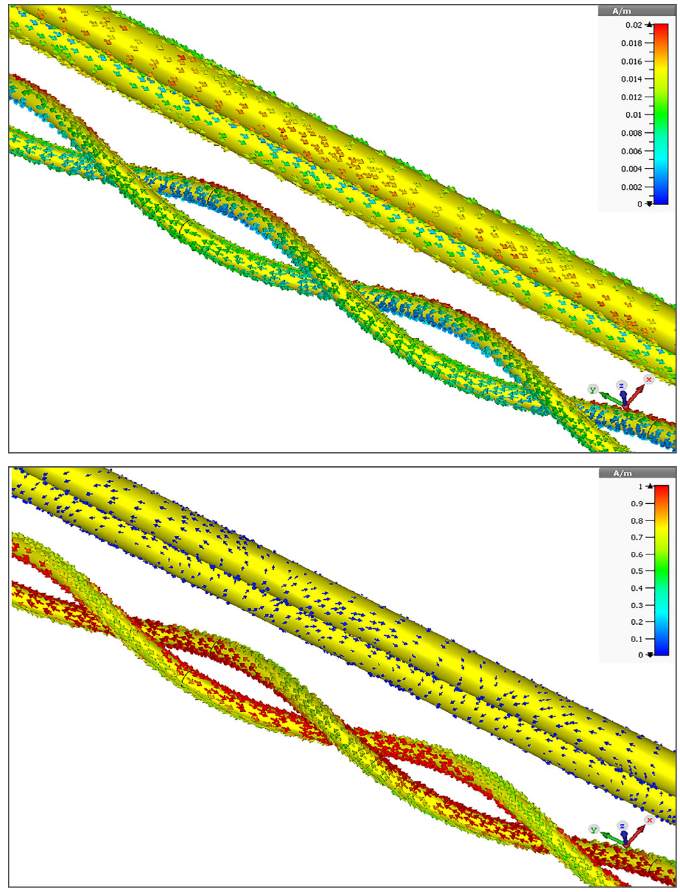


Figure 3: Close-up of surface current on TWP at 33 MHz, showing common mode (top) and differential mode (bottom)

As shown in *Figure 3*, the differential mode flows on the inner section of the TWP, while the common mode flows on the outer side, close to the PWR and GND wires. This plot emphasizes the high accuracy of the full wave 3D solution. Electromagnetic effects can be visualized, and even the position of the mode on the cable is taken into account.

To summarize, the differential to common mode conversion occurs due to non-ideal symmetry in the transmission lines. One cause of these asymmetries can be jitter and skew in the signal generation, which depends on the silicon driver used. Designers may have limited access to models for the driver but can account for this in other ways in the simulation model. Another possible cause is asymmetries in the geometry. These can appear due to routing, connector and cable bonding and other physical discontinuities. We will look at these factors in the next section.

Conducted Emissions

In a typical automotive test set up, the device is connected by cables to a line impedance stabilization network (LISN). The conducted emission is measured at the LISN port. In the first model with just the PCB and the connector, the conducted emission levels are quite low.

However, the real system will have cables connected to them. To account for this, a 1 m long cable is attached to the simulation model. The Ethernet lines are twisted, the PWR/GND are straight. After adding the cables, the emission level increases at the 40 MHz mark by about 20 dB.

Changing the distance between the PWR/GND and the TWP wires causes only little changes in the emission. Even putting the power wires at a 90° angle to the TWP only reduces the emission by a few dB, as shown in *Figure 4* (brown line). The reason is that the emission in this example is dominated by the common mode which is created mainly on the PCB and the connector. As the cables in the simulation are connected to an ideal metallic box with no losses, the common mode can flow very efficiently from the TWP to the PWR/GND pair. The separation of the cables has only a small effect.

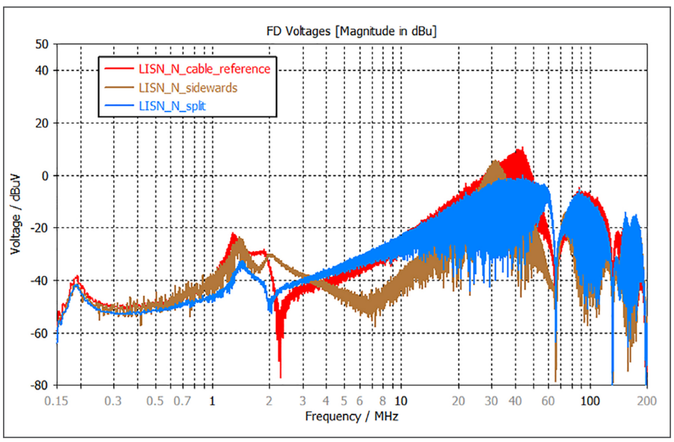


Figure 4: Emissions at LISN-N with different cable configurations.

A much bigger effect is caused by using different references for the TWP and the GND. When the PWR/GND is connected to a different reference from the TWP, the emission drops significantly as shown in *Figure 4* (blue line). The measurement standard prescribes that a common reference needs to be used so this is not a way to mitigate the emission. However, it is important to understand this link because it is a direct effect of this measurement set up.

A way for designers to reduce the emission in practice is by changing the connector pinout. The PWR/GND pair in the simulation was split and put on opposite ends of the connector, creating a wide connection. The emission is significantly increased under this set-up, especially at lower frequencies, due to the fact that the loop created by the PWR/GND is now much bigger.

The effect of untwisting can also be investigated. The TWP is typically untwisted close to the connector in order to bond the wires to the connector pins. Two untwisting scenarios are tested: a short untwist giving a 2.5 cm straight section and a long one giving a 5 cm straight section. We can observe the strong effect of increasing the length of the untwisted wires (*Figure 5*), leading to problematic increases in emission.

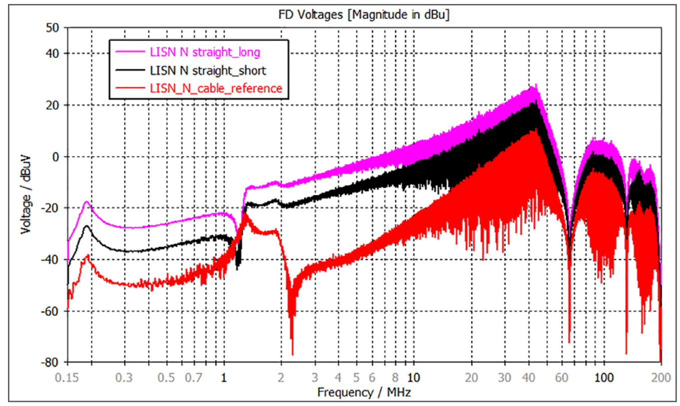


Figure 5: Emission at LISN-N with different untwisting

Finally, a worst-case scenario is considered, in which there is a wide connection across the connector, a long section of untwisted TWP and where the routing on the PCB is not fully symmetric. With all these changes, the emissions increase by approximately 30 dB across the whole frequency range. It is important for the designer to understand what values can be reached with which design changes, and where additional components are needed.

Countermeasures

One of the main countermeasures against emission is common mode choke (CMC). This section will investigate in which cases the CMC is helpful. A CMC is a special coil that has a low impedance for the differential mode and a high impedance for the common mode. Thus, it should block the common mode and let the differential mode pass.

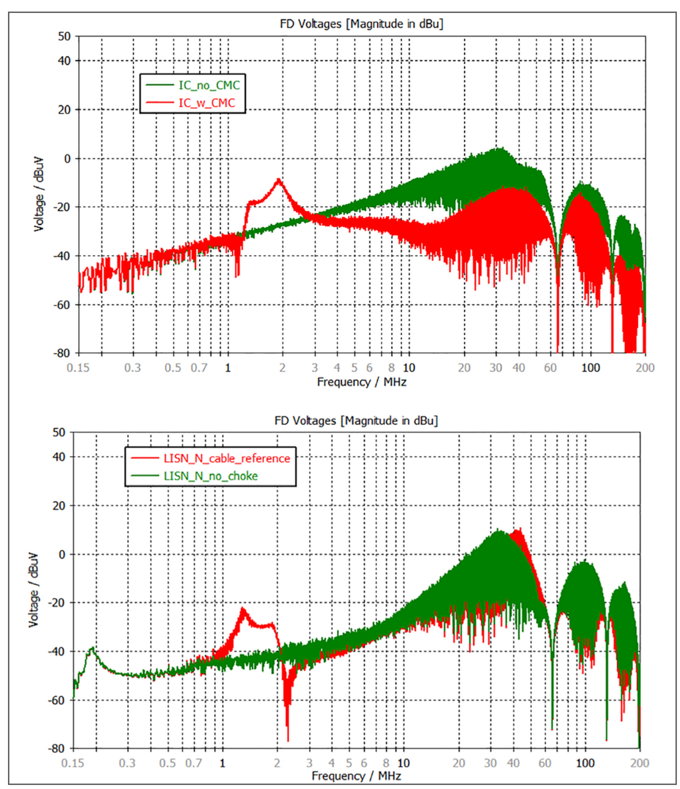


Figure 6: Common mode at Rx IC (top) and emission at LISN-N (bottom) with and without the choke

Figure 6 shows the effect of a common mode choke (CMC) on the EMC performance of the system. At the receiver (upper plot), the choke reduces the common mode as expected. However, at the LISN pin (lower plot), the choke did not have a big effect. There is a difference between the choke effects because there is a difference with how the common mode is created in these two locations.

It has been discussed how common mode emission is caused by asymmetries in time or geometry in the model. In order to simulate the asymmetries in time that cause common mode noise, we need to change from the AC simulation to a transient circuit simulation. We add an asymmetry in the time signal, so there is a skew in the driver: the negative voltage is 0.1 ns later than the positive voltage.

Driving the model including the CMC with the skewed signal reveals that the emission is almost the same for the skewed model as for the model without skew. Removing the choke while the signal has a skew causes emission to drastically increase. Thus, the CMC does an excellent job in suppressing the common mode due to the skew.

However, if we consider the geometry of the setup, one CMC is placed on the reference PCB and the other on the termination PCB, with a long signal path between them. If the common mode is created along this path, it will not be filtered and it can couple to the PWR/GND wire pair. This is why the CMC does not help much to reduce the common mode created by the untwisting.

Another possible way to reduce emission is to use a ferrite clamp. This can be simulated as a ring of high permeability material or with more realistic material models by using the “Ferrite macro” in CST Studio Suite. The ferrite ring may reduce the emission or may move the emission peak to lower frequencies.

An alternative countermeasure is adding shielding. In this case, the bonding of the shield is very important. When an ideal shield is connected to the ground layer of the PCB in a 360° fashion, the shield works excellently and suppresses the emission by about 40 dB.

However, this kind of ideal shielding is not possible in the real connector. Instead, the shield is bonded to a connector pin as shown in the red circle in *Figure 7*. In this more realistic bonding scenario, the effectiveness of the shield drops dramatically: the improvement is now only about 10 dB.

Often in the automotive industry ferrites and shields are not an option because they offer only modest improvements and add too much weight and cost. As the common mode choke is already present in the system, it is important to understand how it functions and what its effect on the emission is.

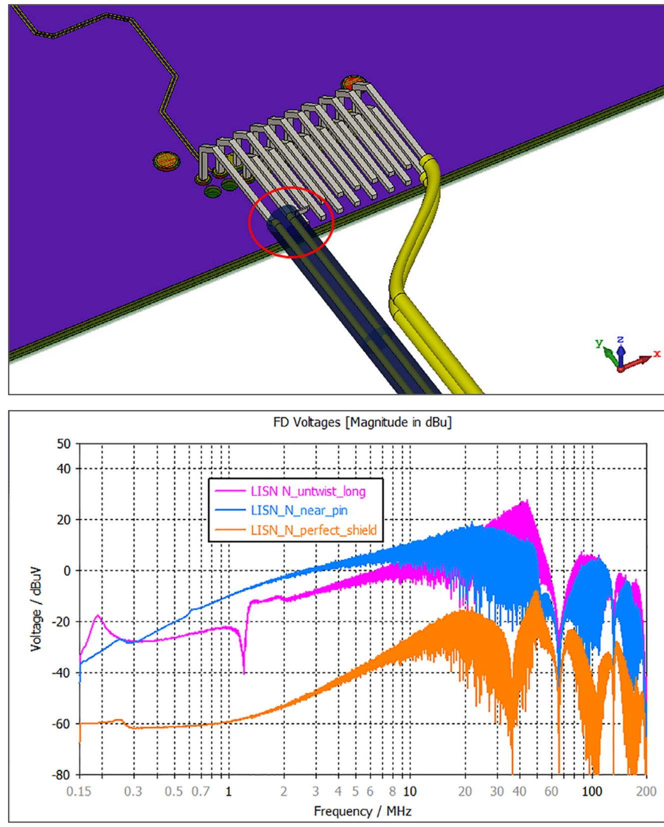


Figure 7: The connector model, showing the cable shield connection (top) and the effect of an imperfect connection (bottom)

Radiated Emissions

Field probes are used to measure the radiated emission in simulation. A sphere of probes is generated with a radius of 1 m from the device under test. Then the emission at all probes is calculated and the worst case envelope is extracted in a post processing step. This is similar to the way a physical measurement is made but, in order to increase speed and efficiency, it does not take into account the real antenna used for the measurement. All these steps can be automated as macros within CST Studio Suite.

Changing the connector layout does seem to be much less critical for radiated emissions than it was in the conducted emission case. On the other hand, untwisting the cables causes similar behavior to the conducted emissions case: The longer the section of untwist is, the higher the emission.

An interesting side note is that by putting the PWR/GND cables at a 90° angle the radiated emission is actually higher, whereas the conducted emission was slightly lower. This is because this set-up produces a much larger loop of the common mode current.

Bulk Current Injection

The bulk current injection (BCI) test is an automotive industry standard for analyzing the susceptibility of electronics and simulation can also be used to access this testing standard.

A BCI clamp model is placed around the cables in the automotive Ethernet simulation. The injection is performed by a 300 mA current, which is a typical testing level in BCI. Disturbance to the actual Ethernet communication will appear in the differential mode that arrives at the receiver. It is the inverse of the emission case: in the emission case, a differential mode is injected and the common mode is typically observed. In the BCI, a common mode is injected and the differential mode is examined.

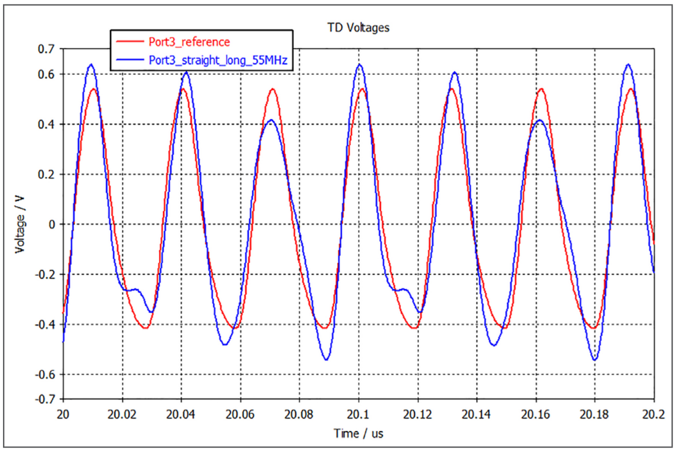


Figure 8: Bulk Current Injection BCI probe used in 3D simulation

It is difficult to judge the impact on the communication by looking at the AC spectrum at the transmitter. A time domain simulation is needed to better understand the effects. The Ethernet channel is excited with a 33 MHz rectangular signal and the transmitted signal at the receiver is recorded. The rectangular pulse has been smoothed at the receiver. This is mainly an effect of the DC caps. However, the high and low levels can still be clearly distinguished in the received pulse. Even after injecting an 88MHz signal at the BCI clamp, which is the frequency at which the coupling is greatest, the signal at the receiver is almost unaffected. This indicates the BCI test will probably be successful.

If the pinout is changed to a wide connection, the coupling to the differential mode is almost the same as in the reference solution, so a changed connector layout will not have a big effect on the BCI test. However, if the wires are now untwisted, the coupling level to the differential mode increases significantly. So, as in both previous examples, the untwisting of the wires has a big effect.

Conclusion

The examples presented are all based on the coupling of the full wave 3D model to a circuit simulation. The effect of the connector & PCB layout on the common mode and also the high impact of the untwist of the TWP at the connector have been demonstrated. The simulation of a BCI susceptibility test was also shown.

The PCB, connector and cable all have a distinct influence on the emission and understanding the creation of the common mode is one of the key steps in successfully designing the system. Several countermeasures to suppress the emission have been discussed. However, all emission and susceptibility scenarios have shown that untwisting of the TWP at the connector has a very adverse effect. The untwisting length needs to be kept as short as possible.

The automotive Ethernet is a next generation signal bus for bandwidth intensive application in vehicles. Because of the speed of the bus, the signals have a much higher frequency than, for example, CAN and designers need to be aware of this. Simulation can be run at an early stage of the design and give valuable answers about the EMC performance of a design.

References

[1] BroadR-Reach® Physical Layer Transceiver Specification For Automotive Applications, Broadcom, http://www.ieee802.org/3/1TPCESG/public/BroadR_Reach_Automotive_Spec_V3.0.pdf

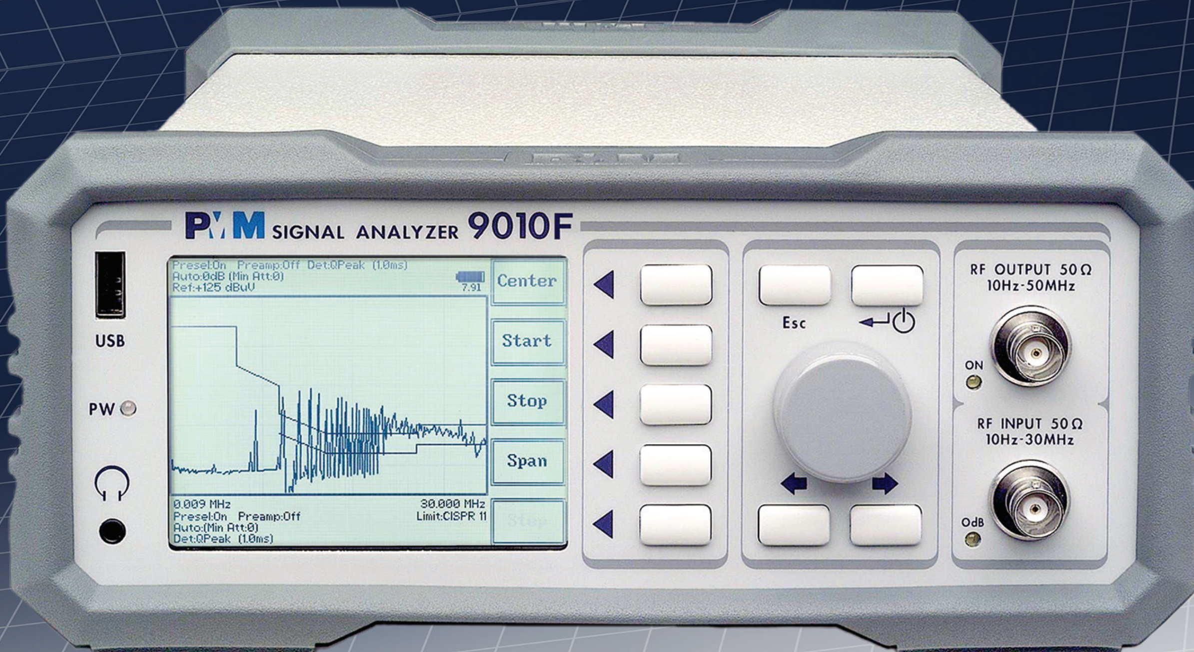
[2] OPEN Alliance, http://www.opensig.org/

[3] TJA1100 data sheet, NXP Semiconductors, https://www.nxp.com/docs/en/data-sheet/TJA1100.pdf

[4] CST Studio Suite, www.cst.com

9010 FAST

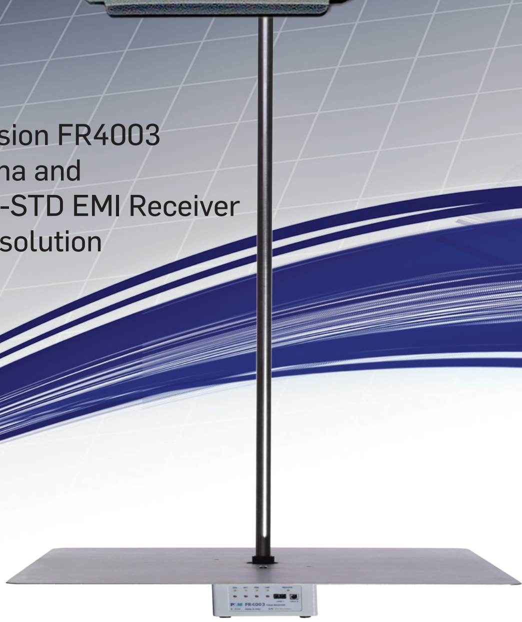
High Speed. Low Uncertainty.



3 Extensions Receiver:

- 30 MHz - 3 GHz
- 30 MHz - 6 GHz
- 6 GHz - 18 GHz

New extension FR4003
Rod Antenna and
CISPR/MIL-STD EMI Receiver
In a single solution



FFT Gapless EMI Receiver

Full compliance to CISPR and MIL-STD

Direct antenna mounting modules

Digital Fiber optic link up to 100m

FIVE STEPS FOR SUCCESSFUL AUTOMOTIVE EMC DESIGN

By Sreevas P Vasudevan
Senior EMI/EMC Engineer

By Praveen S Mohan
Principal EMI EMC Engineer

EMI/EMC behavior of devices has become a major quality benchmark all over the world. The automotive industry follows several standards and stringent limits. Advancements in technology, customer requirements, along with harsher fuel emissions regulations, have resulted in the need to place more electrical and electronic systems into vehicles. In turn these resulted in the need of using electromagnetic compatible systems in the vehicle to avoid cross coupling between the systems and causing non-compliances or customer dissatisfaction.

What makes automotive EMC special?
Electronic systems in automotive involve in safety critical functions which include engine management, braking control, and airbag deployment, to name a few. Also, the automotive industry has seen a new generation of on board electronics for driver assistance devices and entertainment. Having the mobility of automobile, it can be exposed to different electromagnetic environments, from electromagnetically benign locations to electromagnetically harsh environments like airports with high radar fields.

Almost all automobiles today have sensitive AM/FM/DAB radio receivers (or perhaps even a land mobile VHF/UHF radio), so emissions from digital circuits are one of the biggest EMI problems facing today's designer of vehicular electronics. Most of the time the problem is annoying, but in the case of emergency vehicles (police, fire, ambulance), jamming a radio receiver could be life threatening. As a result, most vehicle manufacturers now require suppressing the offending emissions to extremely low levels. In short, automotive emission requirements are aimed at protecting on board receivers (CISPR 25) and immunity requirements are very stringent to protect the safety critical on-board devices. Major Original Equipment Manufacturer (OEMs) had come up with their own standards which are more stringent than regulatory requirements. This make it essential for the suppliers to be fine tuning the EMC design best to suit the market.

EMC control - Vehicle level or Electronic Sub Assembly (ESA)
Understanding the fact that all major OEMs use electronics sub assemblies from more than one supplier for integrating in the vehicle, it is required by all major OEMs that the ESA fulfills the emission and immunity requirements. It can un-doubtfully say that making the ESA compliant to respective standards shall increase compliance possibility at the vehicle level testing, but, over the years it is proved that failure at vehicle levels are not completely avoided by making ESA compliant to EMC.

The article aims to provide a brief understanding for suppliers intended to produce products compliant and acceptable to Tier 1 OEMs.

I. UNDERSTAND THE REQUIREMENT

The automotive industry is a good example of responsible 'EMC regulation'. Country specific legal requirements are limited to generic clauses in the form of directives (for Europe) or FCC – Part 15 (United States). In addition to legal requirements, customer-based requirements are established by OEMs. Requirements of Tier 1 OEMs vary with each other in terms of standard followed, test limits and test type. A standardized test specification that cover major OEMs are far from reality even today [R1]. For radiated and conducted emissions of ESA, OEMs use CISPR25 as guideline and for regulatory purpose at vehicle level emission results, CISPR12 is used. For immunity measurements the ISO 11452-series is referenced for ESA and ISO 11451 series is referenced at the vehicle level. These standards apply to vehicles powered by internal combustion engines, as well as hybrid and electric vehicles. Test distances and methods required to validate a product's performance are detailed in these standards. Some of the OEM specific standards, such as standards issued by General Motors, Ford and Fiat Chrysler requirements are available in the public domain. It is of utmost importance that product manufactures (of ESA) shall be aware of the OEMs they are targeting, and the respective levels of emission and immunity to be achieved.

Vehicle Level		Electronic Sub-Assembly	
Emission Standards	CISPR 12, EN 55012	Emission Standards	CISPR 25, EN 55025
Immunity Standards	ISO 11451-2 (Radiated Immunity)	Immunity Standards	ISO 11452-2 (Radiated Immunity)
	ISO 11451-3 (On Board Transmitter Immunity)		ISO 11452-3 (TEM Cell Method)
	ISO 11451-4 (BCI Method)		ISO 11452-4 (BCI Method)
	ISO 10605 (ESD)		ISO 11452-5 (Stripline)
			ISO 11452-7 (Direct RF Power Injection)
			ISO 11452-9 (Portable transmitter)
			ISO 10605 (ESD)

Table 1 - Automotive EMC Standards Overview

II. INCLUDE EMC IN DESIGN

It is often observed that EMC is taken into consideration at the final phase of the project, either after experiencing a compliance failure or at final sample stage. EMC design from the earliest stages of the project leads to easy implementation and cost-effective design approaches. When designing an electronic circuit, it is necessary to take several precautions to ensure that its EMC performance requirements can be achieved. Methods that can address EMC during the design are optimized as:

- Component selection and frequency selection
- PCB design for minimum radiation
- Cabing & Shielding

A. Component selection and frequency selection
For many automotive electronic systems, the embedded microcontroller is the only high-speed source of EMI on the board. If one can confine the selection of the component having lower emission profile and higher immunity performance, the EMC performance can be improved.

Always ask for EMC compliance data for microcontrollers or passives used in the design. A detailed view EMC performance graphs will help to identify the advantages and shortcomings of the components. Preparing a 'frequency table' (such as shown in Table 2) that list out the fundamental frequency and the dominant harmonics associated with each component would be a handy tool for better understanding of the circuit for design. Better design shall use frequencies that will not interfere constructively.

IC Reference	Radiated Emission Level	Radaiated Immunity Level	Fundamental Frequency	Harmonic Frequency (1st, 3rd, 5th , 7th, 9th , 11th)	EMC Remarks

Table 2 - Component selection - Frequency check

B. PCB design for minimum radiation

Clocks & Harmonics: The primary sources of emissions from microcontroller based automotive systems are the clocks and other highly repetitive signals. A non-sinusoidal periodic waveform is composed of a fundamental frequency plus harmonic frequencies. The harmonics of these signals result in discrete narrowband signals that are typically within the VHF and UHF radio ranges. These harmonics are easily radiated by cables, wiring and printed circuit boards. The amplitude of square wave harmonics in digital systems decreases at the slowest rate (20 dB/decade) as frequency increases, and therefore are a rich sources of high frequency harmonics. Any conductor will act as an efficient antenna when it's physical dimensions exceed a (1/20) fraction of a wavelength. This shows that for a 300 MHz signal, a PCB trace of 5 cm can act as antenna. The design shall take care in avoiding PCB trace length comparable to the wavelength of the signal carried through it.

Spread Spectrum Clocking (SSC): Radiated emissions are typically confined in a narrow band centered around clock frequency harmonics. By uniformly distributing the radiation over a band of a few MHz, regulatory measurement levels (in a 120 kHz bandwidth at frequencies below 1 GHz and in a 1 MHz bandwidth at frequencies above 1 GHz) will be reduced up to 8 dB [R2].

Current Loop: Another key source of emissions is current flow. As processor speeds increase, the current requirement of the processor increases. Current flowing through a loop generates a magnetic field, which is proportional to the area of the loop. Loop area is defined as trace length times the distance to the ground plane. As signals change logic states, an electric field is generated from the voltage transition. Thus, radiation occurs because of this current loop and the voltage transition. The following equation (1) shows the relationship of current, its loop area, and the frequency to EMI (E-field): Since the distance to the ground plane is fixed due to board stack up requirements, minimizing trace length on the board layout is key to decreasing emissions.

$$EMI\ (V/m) = k\ IAf^2 \qquad (1)$$

Where:
k = constant of proportionality
I = current (A)
A = loop area (m^2)
f = frequency (MHz)

Decouple Power Line: Whenever a digital circuit switches, it also consumes current at the switching rate. These pulses of power current will radiate as effectively as pulses of signal current. These switching peak currents cause more radiation since the power levels are usually much higher than those on an individual signal line. For devices with multiple power and ground pins, each pair of pins should be decoupled. High frequency capacitors in the 0.01–0.1 μf range should be installed as close as possible to the device V_{CC}. Also, high frequency capacitors (0.001 μf typical) shall be placed on the input and outputs of all on-board voltage regulators. This will protect these devices against high levels of RF energy and will also help suppress VHF parasitic oscillations from these devices. Keep the capacitors close to the devices, with very short leads.

C. Cabing & Shielding

Radio Frequency Immunity: The design method for better immunity to radio frequency is to avoid unwanted energy reaching vulnerable circuits. This requires high frequency filtering on cables (both power and I/O) which act as antennas and a careful circuit layout and circuit decoupling. To prevent coupling, noise carrying cables shall be placed away from chassis seams. Ferrite beads can be used to attenuate common mode noise on I/O cables. Provide adequate grounding for all cables. Both ends of cables shall be grounded to chassis ground.

The system case acts as shield and reduces EMI by containing EMI radiation. Effectiveness of the shield depends on the material used and the discontinuities in the case. Cable and module shielding are effective but are not popular in vehicular designs due to the costs.

III. REVIEW FOR EMC GUIDELINES

In the above section multiple EMC design methods are mentioned, it is important to suitably select the best possible methods based on the design considerations and cost impact. For better implementation, EMC design reviews shall be conducted at the sample stage. Introduction of front loading enables us to confirm the EMC design effect from the first prototype step and to reduce time for EMC improvement countermeasure at later stages. EMC review, hand in hand with design stage, helps to have a robust EMC design by ensuring major EMC checks are in place.

Structure of EMC design review- The EMC design review shall include the hardware circuit designer, PCB designer, mechanical designer, software designer and persons responsible for cable / interfaces. A detailed check for – Hardware selection, PCB guideline implementations, cable / interface connections must be performed at each review and the potential EMC challenges shall be noted.

EMC design review can look for answers to important question like,

1. How severe are the EMC challenges for the circuit under design?
2. What should be the focus of the EMC design – PCB or at interface cables.
3. Is shielding of cables / critical circuits a possible solution?
4. Do we need an EMC simulation for a cost-effective implementation?
5. A facility for EMC pre-compliance is available or can be developed.

IV. PLAN FOR PRE-COMPLIANCE

Performing pre-compliance EMC testing avoids the risk of product failure and eliminates costly re-testing after design. EMC troubleshooting using near field probes for emission measurement are common nowadays, but for automotive device where the emission requirements are too stringent and immunity levels are too high, an exposure to actual test levels and setups is necessary to understand any pitfalls in design before final compliance testing. There are organizations having in-house equipment capable for automotive emission and immunity measurement, and these organization benefit from easy access and quick fix to EMC threats during design stage itself.

A. Common mode current measurement:
Measuring common-mode currents from cables can give an estimate of the radiated emission values, as radiated emission from cable is directly proportional to the common-mode current in that cable. We can use below equation to find out the amount of E-field emission.

$$\mathrm{E} = \frac{12.6 \times 10^{-7}(f \times l \times \mathrm{Icm})}{r}$$

Where E is the e-field strength in uV/m, Icm is in micro amps, f is in MHz, r (distance from Antenna) & l (Length of the harness) are in meters. Common mode current can be measured with a high frequency clamp-on current probe and a spectrum analyzer / EMI Receiver.

A generic test setup for emission measurement for automotive devices using a LISN, current probe, and spectrum analyzer / EMI receiver is shown below.

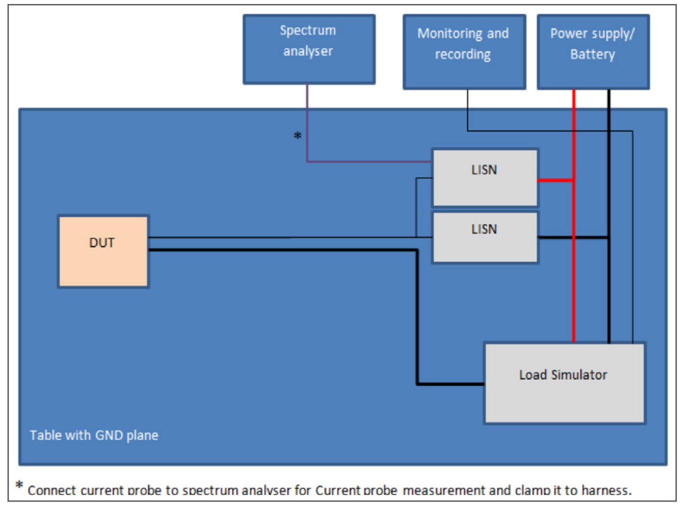


Figure 1 - Conducted emission test setup.

B. 1m Radiated Emission test
Radiated emission testing can be performed as part of pre-compliance measurement with proper calibrated antennas if we can control or reduce the reflection of the emitted field. This can be achieved by keeping the DUT away from reflective surfaces. A lot of trial and error measurement may be required to build this setup in an internal lab. Small broadband antennas are the best choice for 1m EMC testing. A bi-conical antenna (30 – 200 MHz) and a small log periodic antenna (200 – 1000 MHz) are suitable for this kind of measurement. Active antennas are the other option for this kind of test. The antenna needs to be placed 1m from the DUT. Connect the antenna to a spectrum analyzer and take measurements. A reference measurement with an approved lab can give a bench mark for the internal pre-compliance measurement. However at least a 6dB correction factor may be required with respect to an approved lab. Cost effective pre-compliance for radiated emissions can be made by the “Golden Product method” [R4] where the correction factors for the environment and equipment of pre-compliance measurement can be identified by comparing with a Golden sample whose radiated emissions behavior is already available from a test lab.

C. Pre-compliance Immunity testing
Measuring radiated immunity for automotive products without an anechoic chamber will be difficult to do as the fields are very high and it can interfere with the system around and with licensed radio services. Alternative ways to do this are to use hand held radio transmitters and place close to the device under test to check if these can cause any performance degradations. The BCI (ISO 11452-4) test in a small shielded room or shielded box can be used for understanding the immunity performance of the device up to 1 GHz [R3]. This is relatively less expensive than a fully installed antenna measurement.

With these methods, immunity performance of the product at different electromagnetic field levels can be observed and the product can be taken to an approved facility for further investigation and compliance testing.

D. ESD testing

ESD tests can be done in an internal lab with an ESD generator. Various models of ESD generators are available and these can be set up in an internal lab without much space and cost impact. Care should be taken to monitor the temperature and humidity of the area during the test time, as these environmental factors have impact on the static discharge.

V. SYSTEM INTEGRATION

Vehicle manufacturers are required to gain EMC approval for all vehicles. The electronic sub-assemblies, components and separate technical units are operated in full functionality for approval testing. Vehicles must not have electromagnetic emissions above the limits and must be immune to interference levels stated in the appropriate standards. Even though OEMs use sub-assemblies that have sufficient EMC robustness when tested individually, there exist a high chance that electromagnetic robustness for emission and immunity can be affected when different functional modules are integrated. These can be due to sharing of a common power supply or sharing a common communication network.

Inter-system radiated emissions and immunity of ESAs within the vehicle can be improved by proper positioning of the ESA in the vehicle. It is observed that for conventional automobiles with internal combustion engines, EMC sensitive equipment are positioned away from engine section where high power and high frequency switching noise are high. CAN, LIN and FlexRay are major communication networks. When devices are connected to a shared bus network, electromagnetic noise can be controlled by proper impedance matching design.

VI. CONCLUSION

Much advancement is happening in the automotive industry. As automotive systems are more and more occupied with electronic systems and subassemblies, EMI/EMC measurements became crucial for market certification and safety. It is required that automotive suppliers are positioned well in advance for EMC achievement. The above explained the key stages of a successful EMC achievement. Time for required for product development can be reduced if we only had a harmonized method of testing worldwide and with different OEMs. One day, methods and procedures might be unified for test execution that everyone can adopt. For now, by following a common EMC requirement and include EMC in the design strategy, a robust EMC design can more likely be achieved.

VII. REFERENCES

[R1] http://www.autoemc.net/Papers/Test/OHaraGenericEMCStd.pdf

[R2] Intel chip design for EMI - Application Note AP-589

[R3] http://www.ieice.org/proceedings/EMC09/pdf/23R3-4.pdf

[R4] EMC testing part 1- Radiated Emission- Cherry Clough Consultants 5 March 2007

[R5] CISPR 25 Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of on-board receivers

[R6] CISPR 12 Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of off-board receivers

AUTHOR BIOGRAPHY

Mr. Sreevas P Vasudevan is an innovative professional with eight years of functioning in the field of electromagnetic engineering. As a member of IET (MIET), he is an experienced electrical and electronics engineer with specialization in EMI/EMC design, analysis and system electromagnetic compatibility. He is independently involved in Automotive EMI EMC design & validation and acted as consultant for railway electromagnetic assurance for multiple metro projects in Auckland, Doha and London. Mr. Sreevas holds Patent in “ESD capacitor identification tool” registered at Indian patent office. He can be reached at sreevaspv@gmail.com

Mr. Praveen Mohandas is an EMC engineer with 13 years of experience in EMC design, development and validation. Praveen holds a bachelor’s degree in Electronics and Communications and has hands-on experience in the field of EMC design, debugging and validations. He also has in-depth knowledge of EMC standards, legal requirements and various OEM requirements along with vehicle level EMC design reviews and validation process. Mr. Praveen is currently working in UK as a Principal Product Development Engineer in the field of EMC for Electric vehicle products. Praveen holds a patent, “ESD capacitor identification tool”, registered under Indian Patent office. He can be reached at sm.praveen93@gmail.com

REFERENCES
(TEST LABS, GROUPS, PROGRAMS, MAGAZINES, & LINKEDIN GROUPS)

AUTOMOTIVE EMC TEST LABS

Applus Laboratories (Australia)
http://www.appluslaboratories.com/en/

ARAI (India)
https://www.araiindia.com/index.aspx

Cetecom
http://www.cetecom.com/en/products-services/testing.html

CKC Laboratories
http://www.ckc.com/service/emc-testing/automotive-emc-testing/

CMG
http://www.cmgcorp.net/index.shtml

Dayton T. Brown
http://www.dtbtest.com/EMI-Testing-EMC-Testing.aspx

DLS
https://www.dlsemc.com/emc-testing/emc-intro.htm

Element
https://www.element.com/landing/us-emc-emi-testing

Elite Electronic Engineering
http://www.elitetest.com/testing-services/emc-testing/automotive-truck-emc-testing

EMC Technologies
https://www.emctech.com.au/emc-testing/automotive-emc-testing/

Eurofins (UK)
https://etcal.co.uk/automotive-emc-testing/

Horiba Mira
https://www.horiba-mira.com/our-services/emc-vehicle-testing-facilities

Intertek
http://www.intertek.com/automotive/electrical/emc-testing/

Keystone Compliance
https://keystonecompliance.com

Marvell
https://www.marvell.com

MET Laboratories
http://www.metlabs.com/services/emcemi-testing/

National Technical Systems (NTS)
https://www.nts.com/services/industry_specific/automotive

Nemko
https://www.nemko.com/product-testing/emc-testing/automotive

Northwest EMC
http://www.nwemc.com/emc-testing-capabilities/military-aerospace-and-automotive-emc-testing

Seibersdorf Laboratories (Germany)
https://www.seibersdorf-laboratories.at/en/home

TRAC (UK)
http://www.tracglobal.com/content/emc-testing-uk-electromagnetic-compatibility-emc-testing-0

TÜV SÜD America
https://www.tuv-sud-america.com/us-en

Underwriters labs
http://services.ul.com/service/emc-automotive-testing/

Yazaki Testing laboratory
http://www.yazakiemc.com/wp/

If your test lab specializes in automotive EMC testing and is not listed, please contact: info@interferencetechnology.com and we'll include you in the next issue.

REFERENCES (CONTINUED)
(TEST LABS, GROUPS, PROGRAMS, MAGAZINES, & LINKEDIN GROUPS)

AUTOMOTIVE INDUSTRY GROUPS

Auto Alliance
http://www.autoalliance.org

Automotive Industry Action Group
http://www.aiag.org

European Automobile Manufacturers Association
http://www.acea.be

National Automobile Dealers Association
https://www.nada.org

Automotive Council UK
http://www.automotivecouncil.co.uk

Eclipse Automotive Working group
http://www.eclipse.org/org/workinggroups/autowg.php

Automotive Industries Association of Canada
https://www.aiacanada.com

Center for Automotive Research
http://www.cargroup.org

German Association of the Automotive Industry
https://www.vda.de/en

Motor Trades Association of Australia
http://www.mtaa.com.au

Shanghai Automotive Industry Corporation
http://www.chinacsrmap.org/index_CN.asp

UNIVERSITY PROGRAMS

http://www.cvel.clemson.edu/index.html
http://www.cvel.clemson.edu/auto/index.html
http://www.cvel.clemson.edu/emc/index.html

MAGAZINES

Vehicular Technology Magazine, IEEE
IEEE Vehicular Technology Magazine publishes peer-reviewed articles covering advances in areas of interest to the IEEE Vehicular Technology Society: The theoretical, experimental, application and operational aspects of electrical and electronic engineering relevant to motor vehicles and associated land transportation infrastructure.

AUTOMOTIVE INDUSTRY LINKEDIN GROUPS

- Auto OEM Network - World's Largest Automotive Group
- Automotive Industry Professionals Worldwide
- Automotive Management Professionals
- Automotive Industry Professionals
- Automotive OEM Professionals
- Managers of Automotive
- Automotive careers
- Automotive Engineers
- Automotive Electronics and Embedded Software
- The Next Mobility: Automotive & Transportation Industry Innovation
- Automotive PRO Network
- Automotive Infotainment, Telematics & Connectivity
- Automotive Testing
- Automotive Innovation
- Automotive Industry Innovation Group
- ASQ Automotive Division
- Automotive Quality Professionals
- Automotive Systems Engineers
- Center for Automotive Research - CAR
- Automotive Electrical and Electronics Manufacturing
- Automotive Cyber Security
- Automotive active safety / passive safety
- Automotive Electronics Community
- Automotive Sensors and Electronics
- ISO 26262 in Automotive Functional Safety
- Automotive Infotainment Testing
- The Automotive Engineer


EMC LIVE 20 18
BOOTCAMP
November 14, 2018

AUTOMOTIVE EMC CONFERENCES

The following is a partial listing of major automotive electronics conferences planned for 2018 and 2019. If your conference is not listed, please contact: info@interferencetechnology.com

AUTOMOTIVE ELECTRONICS CONFERENCES

EEVConvention (Electric Bus & Trucks)
2019
Location and date TBD
http://www.eevc.eu
The European Electric & Hybrid Vehicle Congress is a global platform to foster exchange of views between the R&D, the industry, the authorities, and end users to develop synergies in the field of e-mobility.

Vehicle Technology Conference (VTC)
Location and date TBD
http://www.ieeevtc.org/
IEEE VTC will bring together individuals from academia, industry and government to discuss and exchange ideas in the fields of mobile, wireless and vehicular technology as well as the applications and services associated with such technology. Features include world-class plenary speakers, panel sessions, tutorials, and both technical and application-based sessions.

Electric & Hybrid Vehicle Technology Show
September 2019 (date TBD)
Novi, MI
http://www.evtechexpo.com
Electric & Hybrid Vehicle Technology Expo is the premier showcase for electric and hybrid vehicle technology and innovation. The show highlights advances right across the powertrain and across a wide range of vehicles from passenger and commercial to off-highway industrial vehicles.

The Battery Show - North America
September 2019 (date TBD)
Novi, MI
https://www.thebatteryshow.com
The Battery Show is the premier showcase of the latest advanced battery technology.

Automotive Test Expo
October 2019 (date TBD)
Novi, MI
http://www.testing-expo.com/usa/
This conference includes the very latest technologies and services that are designed to ensure that the highest standards are met in terms of product quality, reliability, durability and safety.

Applied Power Electronics (APEC)
March 17-21, 2019
Anaheim, CA
http://www.apec-conf.org
APEC focuses on the practical and applied aspects of the power electronics business. This is not just a designer's conference; APEC has something of interest for anyone involved in power electronics:

- Equipment OEMs that use power supplies and dc-dc converters in their equipment
- Designers of power supplies, dc-dc converters, motor drives, uninterruptable power supplies, inverters and any other power electronic circuits, equipment and systems
- Compliance engineers testing and qualifying power electronics equipment or equipment that uses power electronics

Global Automotive Components and Suppliers
May 21-23, 2019
Stuttgart, Germany
www.globalautomotivecomponentsandsuppliersexpo.com/en/
Automotive Component Manufacturers from around the world will be at the expo to display their very latest technologies and products, plus numerous more exhibitors will be on hand to discuss how they can participate in cost reduction within supply chains, and how they can offer new, alternative, cost-effective manufacturing and supply solutions.

Automobil Elektronik Kongress
June 25-26, 2019
Ludwigsburg, Germany
https://www.automobil-elektronik-kongress.de/en/registration/#registrati
The International Congress on Advances in Automotive Electronics once again proved to be a magnet with considerable influence on decision-makers in electrical/electronic system development for the vehicle industry.

AUTOMOTIVE EMC CONFERENCES (CONTINUED)

SAE CONFERENCES

Symposium on International Automotive Technology 2017
January 16-18, 2019
Pune, India
https://siat.araiindia.com
The Symposium on International Automotive Technology (SIAT) is a benchmark event organized by ARAI biennially. SIAT serves as an important forum for exchange of ideas and brainstorming for the automotive industry. Over the years, the event has grown in stature and is now considered as a prestigious automotive event in the global automotive fraternity.

SAE On-Board Diagnostics Symposium - Europe
March 12-14, 2019
Stuttgart, Germany
https://www.sae.org/attend
This event serves as the platform for uniting automotive and commercial vehicle industry experts who need information and insight into CARB, EPA, and EURO IV/V/VI rules and regulations, and SAE standards associated with light- and heavy-duty emissions controls.

SAE Connect to Car
January 8, 2019
Las Vegas, Nevada
http://www.sae.org/events/c2c/
Join us for the SAE International conference track at CES® 2019.

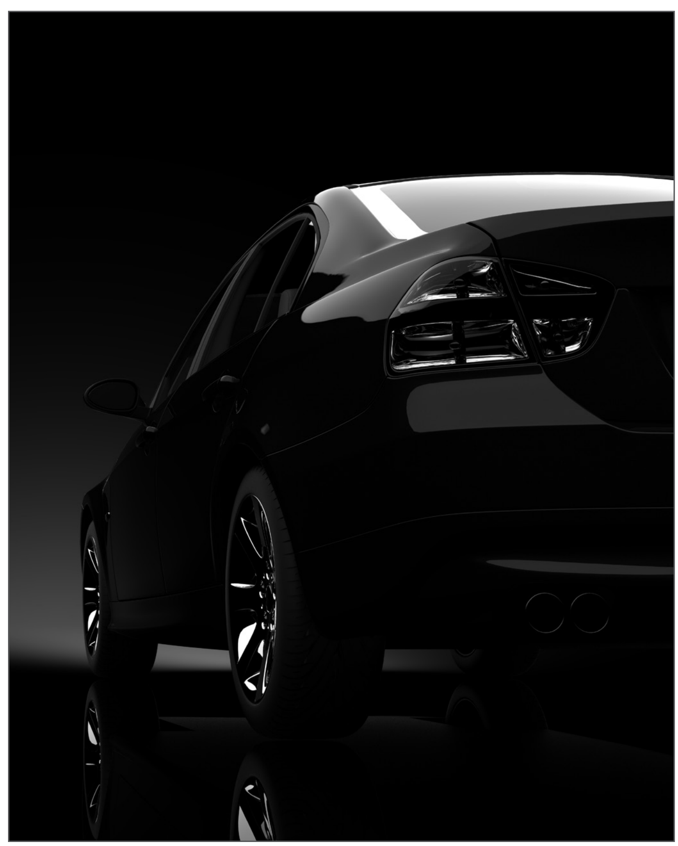
SAE Hybrid and Electric Vehicle Technologies Symposium
February 19-21, 2019
Garden Grove, CA
https://www.sae.org/attend/hybrid
The SAE Hybrid & Electric Vehicle Technologies Symposium is the source for current and forward-looking hybrid and electric vehicle technology advances, providing industry developments from prominent representatives of OEM and supplier companies.

OTHER CONFERENCES THAT INCLUDE AUTOMOTIVE EMC

International Exhibition with Workshops on Electromagnetic Compatibility EMC (EMV 2019)
March 19-21, 2019
Stuttgart, Germany
https://emv.mesago.com/events/en.html
EMV is Europe's leading event on electromagnetic compatibility. Meet the industry's leading companies for EMC-equipment, components and EMC-services. The event offers a wide range of EMC-specific topics. The perfect platform to get the latest information on newest trends and developments!

The 2019 IEEE International Symposium on EMC+SIPI
July 22-26, 2019
New Orleans, LA
http://www.emc2019.emcss.org

2019 Joint IEEE International Symposium on EMC and APEMC
June 3-7, 2019
Sapporo, Japan
http://www.ieice.org/~emc2019/




ITEM MEDIA
Engineered Marketing For The Electronics Industry
Understand your customers' digital footprints to better understand their journey.
Lead Qualification
Lead Generation
Audience Development
Online Events
Content Creation
Technology Implementation
Big Data Translation
...and MORE!
Start your journey today!
please visit
item.media
Additional ITEM Media Brands: Interference Technology | Electronics Cooling | Environmental Test & Design

INDEX OF ADVERTISERS

Altair
1820 E. Big Beaver Rd.
Troy MI 48083, USA

page: 6
t: (248) 614-2400
Contact: www.altair.com/ContactUsForm.aspx
w: www.altair.com

Coilcraft Inc.
1102 Silver Lake Road
Cary, IL 60013, USA

page: 16
t: (800) 322-2645
e: sales@coilcraft.com
w: www.coilcraft.com

CST Computer Simulation Technology GmbH
Bad Nauheimer Straße 19
64289 Darmstadt, Germany

page: 22
t: (508) 665-4400
e: SIMULIA.CST.US.Support@3ds.com
w: www.cst.com | 3DS.com/SIMULIA

EMC LIVE Bootcamp, 2018
Online

page: 38
e: graham@item.media
w: www.emc.live

ETS-LINDGREN
1301 Arrow Point Drive
Cedar Park, TX 78613, USA

page: 12
t: (512) 531-6400
e: sales@ets-lindgren.com
w: www.ets-lindgren.com

HV Technologies, Inc.
8526 Virginia Meadows Dr.
Manassas, VA 20109, USA

page: 35
t: +1 (703) 365-2330
e: emcsales@hvtechnologies.com
w: www.hvtechnologies.com

ITEM Media
1000 Germantown Pike
Plymouth Meeting, PA 19462, USA

page: 41
t: (484) 688-0300
e: info@item.media
w: www.item.media

Narda Safety Test Solutions
435 Moreland Road
Hauppauge, NY, USA

page: 29
t: (631) 231-1700
e: nardasts@l3t.com
w: www.narda-sts.us

Rhode & Schwarz
Muehldorfstrasse 15
81671 Munich, Germany

page: 2
t: Germany: +49 (0) 89 4129 12345
United States: (410) 910-7800
w: www.rohde-schwarz.com
www.rohde-schwarz-usa.com

Select Fabricators
5310 North Street,
Canandaigua, NY 14424, USA

page: 21
t: (585) 393-0650
e: contactus@select-fabricators.com
w: www.select-fabricators.com

2018 AUTOMOTIVE EMC GUIDE

INTERFERENCE TECHNOLOGY GUIDE SERIES
www.interferencetechnology.com