Electromagnetic Interferences from Electric/Hybrid Vehicles

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Abstract

The use of high-power electronics to drive the electrical engines of the new electric and hybrid vehicles produces high-level low-frequency EMI. In hybrid cars, this new emission is added to the ignition system one. In this paper, some EMI measurements including current, near and far electric and magnetic field in two cars and a bus are presented. Some issues in the standards and tests setups must be updated: cars cannot be measured in idle state, new LISNs must be used in the high-power network, magnetic field evaluation for safety is mandatory in some vehicles or to consider radiated transient measurements.

1. Introduction

In the upcoming years, the wide use of electric and hybrid vehicles will produce a new level and type of interferences on the streets and roads [1]. The current combustion engines vehicles usually produce two main types of electromagnetic interference (EMI): the ignition system, the electrical motors and the switches producing broadband EMI and the electronic devices generating narrowband interferences. Electric vehicles use high-power electronics to drive the electrical engine which produces high-level low-frequency EMI. In hybrid cars this new emission is added to the ignition systems one. Plug-in electric vehicles introduce a new device in the mains network and, because their characteristics and the power involved, special considerations must be taken into account.

The standards and test setups must be updated to manage this new EMI source: vehicles cannot be measured in idle state as it is done with combustion ones, the electrical engine must be running and under load; this requirement inside an anechoic chamber represents a new challenge for the test sites. The assessment of the devices connected to the high-voltage network requires the use of new type of LISNs. Due to the high currents involved, magnetic fields inside the vehicle could be large therefore, evaluation for safety is mandatory for certain types of vehicles. Radiated transient signals are a new issue that must be considered in electric and hybrid cars.

In this paper a short description of the architecture of the measured electric/hybrid vehicles is presented. A discussion about new requirements in standards and test setups is developed and several EMI measurements from three different hybrid vehicles are presented.

2. Hybrid vehicles

Different types of hybrid vehicles are being developed nowadays [2]. In this work, the electromagnetic interferences generated by three of these hybrid vehicles have been analyzed. The first one is a commercial parallel-hybrid vehicle (Fig. 1a). In this kind of vehicles the combustion and the electric engines are in parallel, which means that both are allowed, and have the enough power, to move the car. The tested vehicle has a relatively low-capacity high-voltage battery that allows driving the vehicle in full electric mode for few minutes. The electrical engine power is only 60 kW therefore, when high torque is demanded both engines work in parallel. High-voltage batteries are charged when the combustion engine is started and when the regenerative breaking is in operation.

The second vehicle tested is a prototype of a plug-in parallel-hybrid car (Fig. 1b). As the previous one, it has two engines working in parallel but this time the electrical system has larger power (85 kW). Furthermore, it is a plug-in vehicle, which means that the high-voltage batteries could be charged from a mains outlet. Of course, batteries are also recharged when the combustion engine is running and when breaking.

The last vehicle is a series-hybrid bus (Fig. 1c). The combustion engine of this type of vehicles is no longer linked with the wheels. Motion is produced only by the electrical engine while the combustion one is used only to charge the

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accumulative electrical devices, in this case, a set of ultracapacitors. The main advantage of these series-hybrid vehicles is that the combustion engine regime can be optimized in terms of consumption and pollution. Their drawback is that the electrical engine alone must have enough power to drive the bus in all situations.

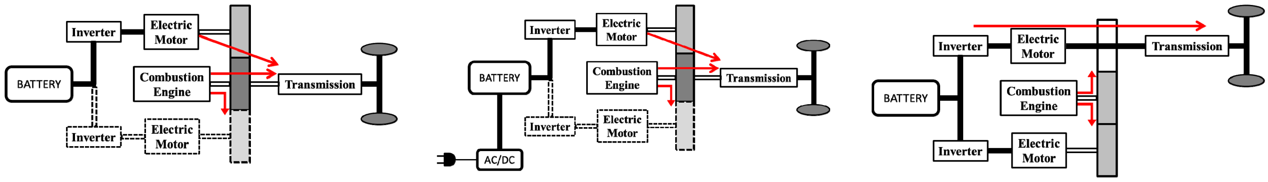

Figure 1. Hybrid vehicle architectures. a) Parallel, b) Parallel plug-in, c) Series

3. Standards and test sites update

EMC standards and test houses are currently focused to measure combustion engines and several modifications must be introduced to make a good assessment of the electrical/hybrid vehicles. Several initiatives are under development in different committees and bodies to define the proper changes. In this work, after performing some EMI measurements of the two cars and the bus defined above, some suggested improvements are listed below.

- Standards and test setups must cover the low frequencies where EMI is produced. Magnetic fields at frequencies as low as 100 kHz must be limited. At that frequency range, only the electric field is currently measured in automotive EMC issues but, because power currents are involved in electrical engines, the magnetic fields are also important. Furthermore, measurements regarding personal safety to magnetic fields are also encouraged in high-power electrical vehicles.

- Plug-in vehicles joint the nowadays separate worlds of automotive and mains network in domestic, commercial and industrial environments (low-power single-phase but also high-power three-phases charging operations are planned). From now on, the car must be considered as another appliance connected to the mains network. Standards must address this issue defining the parameters that must be measured and the limits to apply. Details, like which operation modes are allowed during charging, are important. As an example, if electrical air conditioning is allowed during the charging operation, the power involved and the EMI level will be larger.

- If a component level EMC approach is desired (like now happens with the worldwide used CISRP 25 standard), new test methods must be defined in the high-voltage network. New Line Impedance Stabilization Networks (LISN) able to manage 300 V or larger are needed. Current probes are an alternative to those LISN high-voltage measurements.

- Several details must be solved in the test setups. One main concern is about the vehicle operation when measuring radiated EMI. Up to now, combustion engine vehicles have been measured inside anechoic chambers in the idle estate because ignition system is the major broadband EMI source and no vehicle motion is needed to measure the maximum emission level. Now, the electric vehicles do not have a representative idle mode from the EMI point of view. Power inverters, electric engine and wheels must be in operation and under load when radiated emissions are measured. The chassis dynamometers currently used in test sites to perform immunity vehicle tests are no longer useful to measure radiated EMI because they become themselves a radiated emission source. Fig. 2 shows the radiated EMI from one of this load drum in passive operation. Red line shows the European EMC Automotive Directive limit for radiated emissions. The EMI level generated is larger than the current limit stated in the standards. When the drum is in action, loading the car, the emissions are even larger.

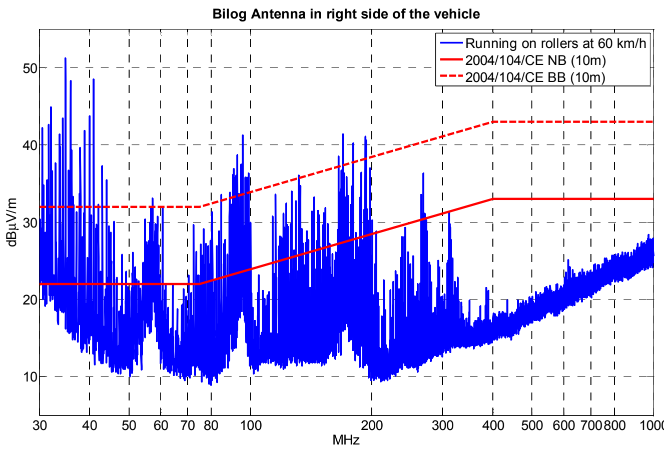

Figure 2. Radiated EMI from a chassis Dynamometer in passive operation.

- Another issue is the reference point to perform the measurements. Up to now the measuring antenna is placed at a certain distance in front of the combustion engine. In electric cars, batteries, power inverters and electric engines are distributed in the vehicle and linked by power cables. Most of the times these cables are the main EMI source; therefore it is not easy to define a specific point in relation with the vehicle to place the measuring antennas. Turning the EUT (Equipment Under Test), as it is done in other products, could be a solution but it is a challenge to combine this requirement with the previous motion and loading one inside an anechoic chamber.

- Radiated transients are a new issue that must be addressed in electric cars. The inverter pulsed power signal, the car motion starting, the regenerative braking or the battery charge connection produce transients signals in the vehicle that can produce radiated interference that can upset wireless devices operating inside and outside the vehicle.

4. EMI measurements in hybrid vehicles

In this section several measurements performed on the different vehicles are presented. Some of the measurements have been made on the road, others in a garage with the vehicle jacked up and also in an anechoic room. Current on the cables up to 100 MHz, radiated fields and magnetic fields outside and inside the vehicles have been considered.

Fig.3 shows the current measured on the unifilar (positive) shielded cable that links the battery and the electrical engine of the hybrid car. Four different plots can be seen in the figure. The first one is the ambient noise, which is very low because the measurement is done with a current probe. When the car electrical mode is turned on, but with the electrical engine stopped, we can see a certain EMI level. This level increases when the car is running and the interference is particularly high at low frequencies up to 50 MHz. Although currently there are no standard limits for EMI currents in the whole car, in Fig.3 the CISPR 25 limit for components is plotted to have a reference. As it can be seen on the plots, some increase is measured above 40 MHz, when the vehicle is under load, running on the road instead of jacked up.

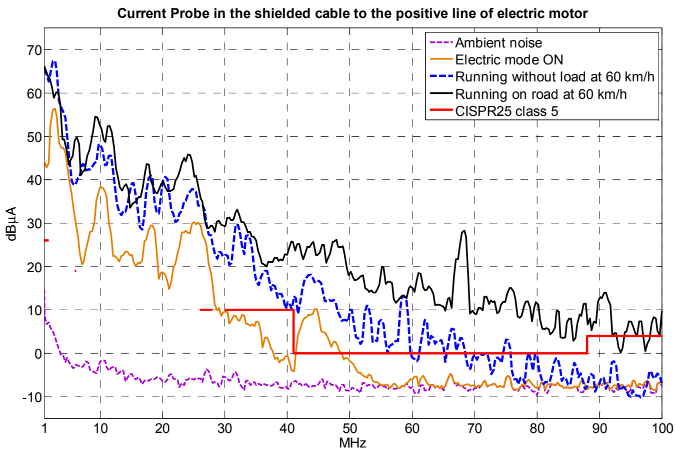

Figure 3. Current measurements on the battery – electrical engine cable.

Next results have been obtained in an anechoic chamber with the vehicle jacked up. Fig 4 shows the electric field measured with and active rod antenna located at 1 m distance from the car. Some radiated emissions can be clearly seen in the 5-30 MHz frequency band. Another time this EMI level is compared with the CISPR 25 limits for components. In this case the emissions of the whole car are below the limits considered.

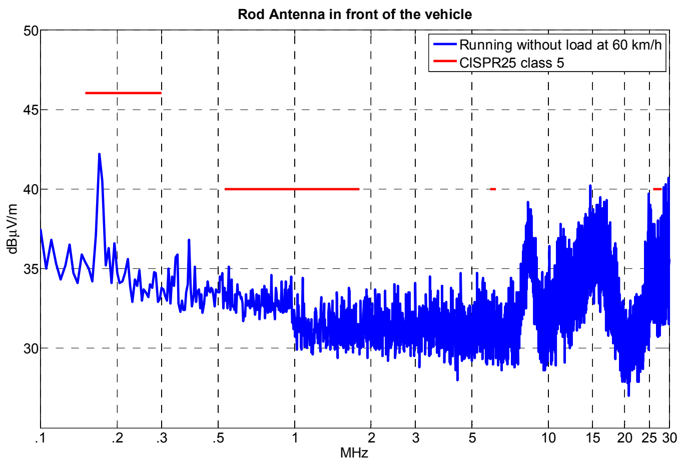

Figure 4. Electric field 1m away the vehicle.

Because high level currents are always involved in hybrid and electric vehicles, some near field magnetic field measurements have been done with an active loop located at 1 m distance from the car. Since there are not mandatory magnetic field measurements in the current standards, the results have been converted to V/m to be compared with the current electric field limits. Far field E/H=120Π Ω condition has been applied as usual, although it is not necessarily true in this near field situation. Fig.5 shows the magnetic field results. The measurement has been performed in a garage, where the EMI produced by the car operation is clearly above the ambient noise level. In this case, the emissions are larger than the limits stated in CISPR 25 for components.

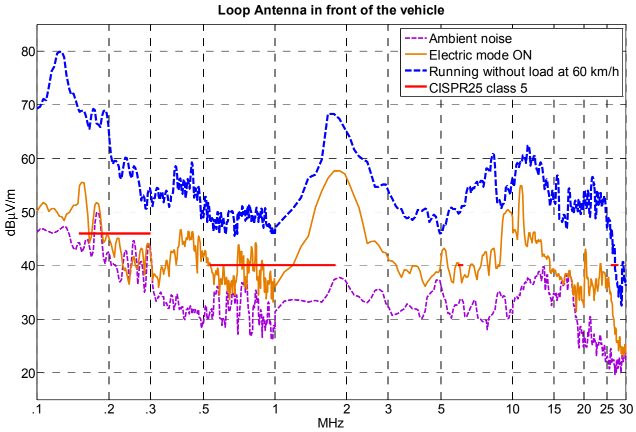

Figure 5. Magnetic field 1m away the vehicle.

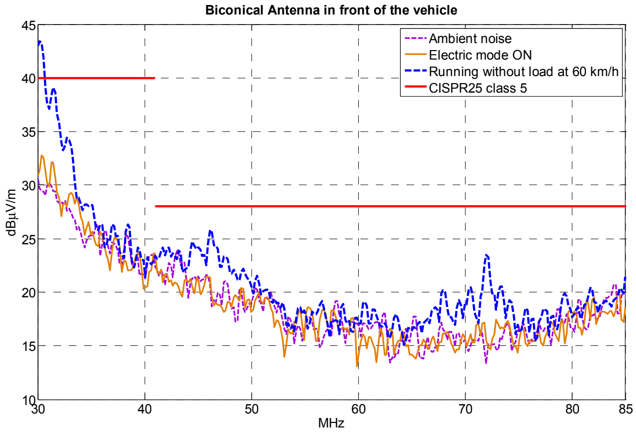

Figure 6. Electric field measured within 30-85 MHz.

Fig.6 shows the measurements recorded with a biconical antenna in the frequency band between 30 and 85 MHz. Measurements above this frequency range produce no significant EMI levels. Even in this lower frequency band, the emissions, although can be detected, are quite low and always under the standard limits. Some further measurements have been performed when the vehicle is starting and in the regenerative breaking mode. When starting, 10 dB increments have been measured in the 40-50 MHz frequency band. When braking, and therefore charging the batteries, no significant increase has been noted.

Last measurements have been done in a hybrid bus running inside a large garage. In this case our interest is the assessment of the electromagnetic fields present inside the vehicle that could affect the passengers. The bus main electric system distribution is depicted in Fig.7a. The electric accumulators and the inverters are on the roof and the electric engine is under the passenger seats with a cable that links them at the rear part of the bus. Fig.7b shows the magnetic field levels measured with a handheld meter in some seats on the vehicle rear part. Although the levels are noticeable, all the values are within the limits established by the standards for personal safety.

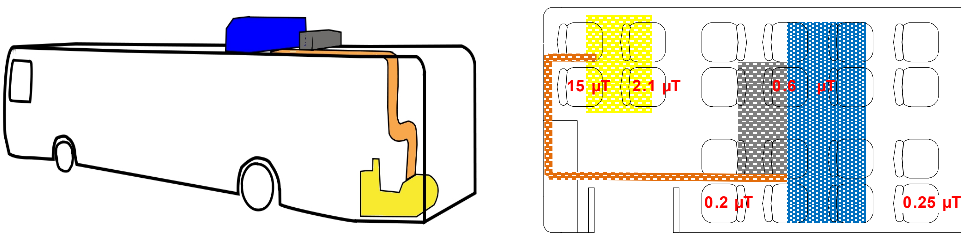

Figure 7. Magnetic field inside a serial hybrid bus.

5. Conclusion

New hybrid /electric vehicles produces new EMI issues that must be addressed in order to perform a correct EMC assessment. Standards, test methods and testing houses must be updated to include the low frequency electromagnetic emissions of the electric engines and the power electronics.

6. Acknowledgments

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7. References

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