Commercial Articulated Vehicle EMC Testing for Emission Source Identification and Mitigation

Merve Deniz, M. Murat Uysal, and Erdal Usta, OTOKAR Otomotiv ve Savunma Sanayi A. Ş.

Abstract—With development of the industry, automotive industry has also improved. High-tech digital platforms began to be used on from luxury automobiles to commercial vehicles. An important case in the design and development of today's complex vehicles is assuring the electromagnetic compatibility of the electrical system and its numerous subsystems with itself and the environment in which it is used. As a result of these, electromagnetic emission problems have increased. To assure vehicle electromagnetic compatibility, the RF emission and immunity characteristics of vehicles must be controlled. In this paper, electromagnetic compatibility of an articulated vehicle is investigated in a semi anechoic chamber within the scope of homologation tests.

Index Terms—Articulated vehicle, broadband emission, commercial vehicle EMC testing, filter, immunity, narrowband emission.

I. INTRODUCTION

HOMOLOGATION is an approval process that allows a product to enter a market. It starts with initial assessments followed by tests according to standards and directives, up to the preparation of substantiated technical reports to forward to approval authorities in order to obtain the final approval. Under homologation tests, all products must be tested regarding their electromagnetic compatibility. Electromagnetic compatibility (EMC) means that a device/vehicle is compatible with its electromagnetic (EM) environment and also it does not emit EM energy that causes electromagnetic interference (EMI) to the other devices/vehicles. Electromagnetic compatibility tests for commercial vehicles are radiated electromagnetic emission tests and immunity tests to radiated electromagnetic disturbances.

Electromagnetic emissions can be divided in two parts: Broadband emissions and narrowband emissions. "Broadband emission" means an emission, which has a bandwidth greater than that of a particular measuring apparatus or receiver. "Narrowband emission" means an emission which has a bandwidth less than that of a particular measuring apparatus or receiver [1].

Radiated broadband electromagnetic emissions from vehicles are generated by electrical or electronic systems fitted to the vehicle (e.g. ignition system or electric motors). Radiated narrowband electromagnetic emissions from vehicles are such as might emanate from microprocessor-based systems or other narrowband source.

Radiated narrowband and broadband emission limits from vehicles are set by commercial standard called ECE R10-4. [2]. Limits apply throughout the frequency range 30 MHz to 1,000 MHz for measurements performed in a semi anechoic chamber or an outdoor test site.

Radiated broadband measurements shall be performed with either quasi-peak or peak detectors. If measurements are made using a vehicle-to-antenna spacing of 3.0 ± 0.05 m and quasi-peak detector, the limits shall be 42 dB µV/m in the 30 MHz to 75 MHz frequency band and 42 dB µV/m to 53 dB µV/m in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically with frequencies above 75 MHz. In the 400 MHz to 1000 MHz frequency band the limit remains constant at 53 dB µV/m. If peak detectors are used a correction factor of 20 dB as defined in [3] shall be applied.

Radiated narrowband measurements shall be performed with an average detector. If measurements are made using a vehicle-to-antenna spacing of 3.0 ± 0.05 m, the limit shall be 32 dB µV/m in the 30 MHz to 75 MHz frequency band and 32 dB µV/m to 43 dB µV/m in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically with frequencies above 75 MHz. In the 400 MHz to 1000 MHz frequency band the limit remains constant at 43 dB µV/m.

With the horizontal and vertical polarization of the antennas, emission tests must be performed. Multiple antenna positions are required if the length of the vehicle is greater than the 3dB beam-width of the emission antennas.

Besides emission tests, immunity tests are also a must for homologation. These tests are intended to demonstrate the immunity of the vehicle electronic systems.

Immunity test shall be performed using the substitution method, which is based on the use of forward power as the reference parameter used for field calibration and during testing. This method is performed in two phases: field calibration and test of vehicle [4].
The RF power required to achieve the required field strength is determined during the field calibration phase. Calibration is performed without a vehicle in the test location. The specific test level (field) shall be calibrated periodically, using an unmodulated sinusoidal wave, by recording the forward power required to produce a specific field strength (measured with a field probe) for each test frequency. The field strength shall be calibrated for vertical and horizontal polarizations. Place the field generating device at the intended location. For the frequency range 20 MHz or 30 MHz to 2 GHz, the four-field probe calibration method shall be used. Four-field calibration and immunity test on commercial articulated vehicle are shown Fig. 1.

![Image of an articulated vehicle](image1)

In this paper, we investigate narrowband emission of the commercial articulated bus in a semi anechoic room (SAR) in EMC test facility of OTOKAR.

Articulated bus is more complex than the other busses. Generally busses have engine, engine control unit, automatic gearbox, electronic brake system, tachograph, heater, cluster wiper motor, interior lights, flasher etc. But this articulated bus also have articulation control unit, continuous LED type interior lights, day time running lamp, rear/front/interior cameras, monitor, front/side/rear destination boards, height sensor, park sensor, electrical roof hatches, hydrofan, reverse gear buzzer, automatic air conditioner etc. Besides of electronic components, articulated bus has very complex harness. So EMC tests for an articulated bus are more complex than the other commercial vehicles.

II. NARROWBAND EMISSION TESTS

To do an emission test in a SAR, a biconical antenna which is suitable at frequencies 30 MHz to 200 MHz, and a log-periodical antenna; which is suitable for frequencies 200 MHz to 1 GHz are used both vertically and horizontally. It is needed RF cables and an EMI receiver or signal analyzer to observe test results.

At first, vehicle enters the SAR and is positioned as shown in Fig. 2. Measurements are performed from the left and right hand side of the vehicle. Since the vehicle length is 18m; measurements are performed from 6 positions according to antenna 3dB beam-width. Antenna positions are shown at Fig. 3. L shows left side and R shows right side of the vehicle.

![Image of an articulated vehicle](image2)

Fig. 1. An example for immunity test of an articulated vehicle

For narrowband emissions, following steps are performed.
- Ignition switch is ON.
- Dashboard is ON.
- Direction indicator on driver’s side ON.
- Dipped beams are ON.
- Interior lights are ON.
- Destination boards (front, rear, right side) are ON.
- Digital clock is ON.
- Tachograph is ON.
- Day running lights are ON.
- Rear view camera is ON.

Regarding narrowband emission test set up, measurements are performed for both left and right side of the vehicle at six points each.

![Antenna positions diagram](image3)

Fig. 3. Antenna positions

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*Fig. 2. Emission test set up for an articulated vehicle.*
III. EMISSION MITIGATIONS

After emission test results, in order to prevent limit excess and improve electromagnetic compatibility of the vehicles, EMI filters and ferrites are used.

While tests are performing from L6 point, limit excess is observed. It is shown at Fig. 4. To investigate the reason of this limit excess; interior lights are off. When interior lights are off, signal’s levels between 30 MHz and 70 MHz is decreased. It can be seen from Fig. 5.

To prevent the limit excess, according to insertion loss equation given in (1), ferrite impedances are calculated. $Z_A$, and $Z_B$ are system impedances. System impedance for supply voltage lines at about 10Ω.

$$A(dB) = 20 \log \frac{Z_A + Z_F + Z_B}{Z_A + Z_B}$$

(1)

To suppress the interior lamps effect, more than 10 dB attenuation needed for the peaks at frequencies between 30 MHz and 60 MHz’s. From (1), $Z_F$ is found 43.25Ω. It is chosen Mn-Zn ferrite which has minimum 40 Ω ferrite impedance for the frequencies between 30 MHz and 60 MHz’s as shown in Fig. 6. Mn-Zn ferrite core is connected on power leads as shown Fig. 7. Test result can be seen from Fig. 8.

While tests are performing from L1 point, limit excess is observed. It is shown at Fig. 9. Beside the interior lights, to investigate the reason of this limit excess; rear view camera is also off. When rear view camera is off, signal’s levels between 80 MHz and 600 MHz is decreased. It can be seen from Fig. 10.

Fig. 6. Impedance versus frequency graph of Mn-Zn ferrite.

Fig. 7. Mn-Zn ferrite on power leads of interior lights.

Fig. 8. Measurement results from L6 point when all systems are on and Mn-Zn ferrite is on power leads of interior lights.

Fig. 9. Measurement results from L1 point when all systems are on.
To suppress the rear view camera effect, more than 20 dB attenuation needed for the peaks at frequencies between 80 MHz and 500 MHz’s. From (1), $Z_F$ is found $180\Omega$. Because of the rear view camera effect on whole band, it is chosen minimum 200 $\Omega$ ferrite impedance for the frequencies between 80 MHz and 500 MHz’s. Ferrite impedance can be seen from Fig. 11.

To suppress the rear view camera effect an axial ferrite bead are connected serially power leads as shown from Fig. 12. Test result can be seen from Fig. 13.

Then right side of the vehicle at R6 point, emission test is done. Differently from the left side test results, it is observed a limit excess at 30 MHz at R6 point. Then, because of control unit of day running lamps at right side of the vehicle, they are off. Then emission tests are done. It can be seen from Fig. 14 and Fig. 15.

To suppress the day running light effect an EMI filter is connected on power leads as shown from Fig. 16. EMI filter specs are shown on TABLE I. Test result can be seen from Fig. 17.

<table>
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<th>TABLE I</th>
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<tr>
<td>EMI FILTER ATTENUATION LEVELS</td>
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<tr>
<td>Freq. (MHz)</td>
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<tr>
<td>0.15</td>
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<tr>
<td>0.5</td>
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<tr>
<td>1.0</td>
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<td>10</td>
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IV. CONCLUSION

In conclusion, EMC test of commercial articulated bus is more complex than the other commercial vehicles. Because of complexity of electrical and electronics components in vehicle, electromagnetic emission become a major problem. This paper has provided a quick overview of how an EMC test of an articulated bus and narrowband emission mitigation of its. Using suitable ferrite beads and EMI filters, limit excess is compensated.

REFERENCES


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