

INVESTIGATIONS OF ELECTRIC FIELD STRENGTH (IN EMC CONTEXT) IN CHOSEN VEHICLES EXPOSED TO ELECTROMAGNETIC FIELD

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Abstract

Fast development of electronics in recent years causes that the number of various kind electronic systems is still growing. This causes also that requirements concerning tests of electromagnetic compatibility (EMC) of whole vehicles as well as their electric/electronic subassemblies become more significant. In this paper, the most important requirements of international regulations in the range of EMC, i.e., ECE UN Regulation No.10 and EU Directive 2004/104/EC, have been outlined. Moreover, results of investigations of electric field strength inside of three chosen vehicles have been presented. The tests have been performed, according to Directive 2004/104/EC, in an absorber-lined shielded chamber in the frequency band 20MHz to 2000MHz and at the electric field strength in the reference point equal to 30V/m. The most important results of these investigations have been presented in the form of graphs of electric field strength distribution in various points of tested vehicles.

Individual electric/electronic devices of a vehicle are exposed to electromagnetic field with a very wide range of values of electric field strength – depending upon a device position in a vehicle, vehicle type and antenna polarization. Values of electric field strength inside of a vehicle may essentially exceed the values recommended by standards for immunity tests of electric/electronic subassemblies.

Keywords: *transport, vehicles, electrical/electronic equipment, electrical/electronic requirements, electric/electronic standards*

1. Introduction

The question of testing of vehicles and their subassemblies, especially in the range of electrical and electronic equipment, is very extensive. The scope of the relevant tests becomes wider and the requirements, especially in the range of safety, reliability and comfort, become higher. Of particular significance are, in recent years, tests concerning electromagnetic compatibility (EMC) of vehicles.

Analyzing features of vehicles electrical and electronic equipment as well as phenomena occurring in the wiring harness of vehicles, in particular, possibility of appearing of large current or voltage pulses, long cables in the wiring harness and a large number of electrical connections, we can state that there exist real possibilities of disturbing interactions between individual electrical and electronic subassemblies – by means of galvanic conduction, inductive and capacitive couplings or by means of radiated emissions.

Electromagnetic disturbances can be placed inside of an extensive group of undesired (or useless) signals that, in real systems, are always accompanying with useful signals following from normal operation of these systems.

The most essential sources of electromagnetic disturbances are:

- temporary and random variations of supply voltage,
- sufficiently fast variations of currents and voltages in electric circuits in presence of lumped or distributed capacities and/or inductances,
- penetration of signals from one circuit to other one; it takes place, in particular, between transmission lines,
- couplings in electric circuits,
- faults in electric circuits and resulting damages of elements or systems,

- noise generated by passive and/or active elements,
- instabilities of electrical connections, temperature variations,
- nonlinear characteristics of elements and systems, including nonlinear loads.

The wiring harness of a vehicle (including appliances) are exposed also to outdoor disturbing signals, i.e., signals generated by other vehicles, road infrastructure, industrial infrastructure, radio transmission etc. Disturbing signals have different levels and occur in a wide range of frequency. Therefore, reliable tests of a whole vehicle in the context of electromagnetic compatibility are very important. They are necessary for conformity assessment of a vehicle with regard to requirements designed for safety and quality.

The tendency to reducing sensitivity to electromagnetic disturbances of electronic elements fitted to motor vehicles as well as a considerable increase, in the environment, in the number of devices being sources of electromagnetic disturbances and simultaneously exposed to such disturbances, caused that undertaking of an international legislative activity, coordinating national regulations in the area of electromagnetic compatibility, has become necessary. The results of such activity can be found in ECE UN Regulations and EU Directives concerning the approval of vehicles and their equipment with regard to electromagnetic compatibility. Among most important standards concerning EMC of vehicles are: ECE UN Regulation No. 10 [1] and EU Directive 2004/104/EC [2].

2. EMC requirements for vehicles and electrical/electronic automotive devices

2.1. EMC requirements for vehicles

EMC requirements for vehicles concern:

- limits for broadband and narrowband electromagnetic disturbances emitted by vehicles
- vehicles (i.e., electrical and electronic devices fitted to a vehicle) immunity to electromagnetic radiation emitted by other objects (broadcasting radio and TV stations, radar stations, radio-communication transmitters etc.).

Limits for radiated electromagnetic emissions from vehicles are specified in EU Directive 2004/104/EC (Annexes: 2, 3, 4, 5) for the frequency range 30MHz to 1000MHz. Measurements of radiated emissions from vehicles shall be performed according to standards CISPR 12 [3] or CISPR 25 [4] in an open-area test site (OATS) or in an absorber-lined shielded enclosure (ALSE). During measurements the engine shall be in operation at the rotational speed 1500/2500 rpm. All devices, capable of producing broadband emissions which may be switched on permanently by the driver or passenger, e.g. wiper motors or fans, should be in operation in maximum load.

The vehicle immunity to electromagnetic radiation is tested at the electric field strength 30 V/m in the reference point (Fig. 1) for the frequency range 20 MHz to 2000 MHz. The test shall be performed according to the standard ISO 11451-2 [5]. The vehicle shall be in an unladen condition (except for necessary test equipment). The engine shall turn the driving wheels at the steady speed of 50 km/h (if the vehicle is equipped with the *cruise control system*, it should be in operation).

Directive 2004/104/EC determines the most important functions related to vehicle safety preservation that are to be checked during tests of vehicles immunity to electromagnetic radiation. The immunity-related functions are as follows:

- a) functions related to the direct steering of the vehicle:
 - by degradation or change in engine, gear box, brake system, suspension system, active steering, speed limitation devices,
 - by affecting the driver's position; e.g., driver's seat or steering wheel positioning,
 - by affecting driver's visibility; e.g., dipped beam, windscreen wiper,
- b) functions related to driver, passenger or other road-user protection:
 - e.g., airbag and safety restraint systems,
- c) functions which, when disturbed, cause confusion to the driver or other road users:
 - optical disturbances: e.g., incorrect operation of direction indicators, stop lamps, end outline

marker lamps, rear position lamps, light bars for emergency system, wrong information from warning indicators, lamps or displays related to functions in points a) or b) which might be observed in the direct view of the driver,

- acoustic disturbances: e.g., incorrect operation of anti-theft alarm or horn,
- d) functions related to vehicle data bus functionality:
 - by blocking data transmission on vehicle data bus-systems, which are used to transmit data, required to ensure the correct operation of other immunity-related functions,
- e) functions which, when disturbed, affect vehicle statutory data: e.g., tachograph, odometer.

2.2. EMC requirements for electrical/electronic automotive devices

EMC requirements for electrical/electronic automotive devices concern:

- limits for broadband and narrowband electromagnetic disturbances emitted by a device under test,
- the immunity of electrical/electronic devices to electromagnetic radiation,
- the immunity of electrical/electronic devices to transient disturbances conducted along supply lines,
- electrical disturbances emitted by a device under test to supply lines.

Limits for radiated electromagnetic emissions from electrical/electronic devices are specified in EU Directive 2004/104/EC (Annexes: 6, 7). Measurements of radiated emissions shall be performed according to the standard CISPR 25 in the frequency range 30 MHz to 1000 MHz. During measurements the device under test shall be in its normal operation mode.

Differences between ECE UN Regulation No. 10 and Directive 2004/104/EC concern the frequency band for immunity tests as well as immunity test methods. Directive 2004/104/EC determines wider frequency band (up to 2000 MHz) as well describes test methods for individual vehicle immunity-related functions.

3. EMC test methods

There is a series of EMC test methods worked out or accepted by CISPR (International Special Committee on Radio Interference). These methods are cited and recommended in standards concerning tests of vehicles and their parts. There are also test methods alternative to standardized methods. On the basis of analysis carried out by the authors, EMC test methods of vehicles and their electrical/electronic subassemblies can be divided into three groups:

- antenna methods,
- hybrid methods,
- antenna-less methods.

This division can be applied to measurements of emitted electromagnetic disturbances as well as to measurements of immunity to electromagnetic radiation. In the antenna method only antennas are used: receiving antennas – for measurements of emitted disturbances, and transmitting antennas – for generating an electromagnetic field when immunity tests are performed. In the hybrid method, antennas as well as other test equipment can be used – in dependence upon the frequency range – e.g., for low frequencies, where high power and large antennas are needed, a TEM transmission line can be used, whereas for higher frequencies – antennas can be employed. Antenna – fewer methods are applied for electrical/electronic subassembly tests where specialist test equipment have to be used.

4. Investigations of electric field strength inside of chosen vehicles

4.1. Investigations objective

EMC immunity tests of vehicles are usually performed in shielded absorber-lined chambers, where electromagnetic wave reflections are essentially reduced and field homogeneity in the test

area is ensured. According to ECE UN Regulation No. 10 and EU Directive 2004/104/EC recommendations the vehicle under test shall be positioned in front of the antenna while electric field calibration is made, before main test measurements, with the aid of a field sensor which shall be positioned in the reference point (Fig. 1).

The following questions arise. The first question concerns values of the electric field strength in places where electrical/electronic devices controlling safety-related functions are positioned. The second question concerns places in which electrical/electronic devices shall be positioned from the point of view of minimal exposure of these devices to external electromagnetic radiation. Finally, the third question concerns more detailed recommendations with regard to vehicle immunity test methods and required values of the electric field strength.

In the present paper the authors undertake an attempt to answer the above questions taking into account the results of the performed electric field strength investigations in chosen vehicles.

4.2. Objects of investigations

The objects of investigations were the following vehicles: Daewoo Lanos, Skoda Octavia, Citroen Berlingo. Basic technical data of these vehicles are presented in Tab. 1.

Tab. 1. Technical data of vehicles under investigations

Parameters/vehicle	Daewoo Lanos	Skoda Octavia	Citroen Berlingo
Engine:			
- type	1.6 DOHC gasoline	AUM gasoline	1.9 diesel
- capacity [cm ³]	1598	1781	1868
- arrangement of cylinders/valves	in line 4/16	in line 4/16	in line 4/8
- maximum power [HP]	106	150	69
- maximum torque [Nm]	145	210	125
- speed at maximum torque [1/min.]	3400	1750	2500
- speed at maximum power [1/min.]	6000	5700	4600
Gear box:			
- type	manual	manual	manual
- number of gears	5+R	5+R	5+R
Wheels driven	front drive	front drive	front drive
Net weight [kg]	1040	1260	1200
Total weight [kg]	1595	1845	184
Body type/seating capacity	hatchback/5	sedan/5	mini van/5
Axle base [m]	2.52	2.50	2.69
Overall dimensions:			
- length [m]	4.07	4.51	4.14
- width [m]	1.68	1.73	1.72
- height [m]	1.43	1.43	1.80
Electronic equipment:			
- ABS/ESC	-/-	+/-	-/-
- front/side airbags	1/-	2/2	1
- dashboard computer	-	+	-
- air-conditioning	+	+	-
- electrically lifted windows front/side	+/-	+/-	-/-
- electric mirror	+	+	-
- parking sensor	-	+	-

4.3. Method and course of investigations

The investigations have been performed, according to recommendations of EU Directive 2004/104/EC, in a shielded absorber-lined chamber in Centralne Laboratorium Badań Technicznych UKE in Borucza near Warsaw:

- antenna (electromagnetic field transmitter) height: 1.5 m,

- electric field strength in the reference point: 30 V/m,
- reference point – antenna distance: 3 m,
- electric field polarization: vertical and horizontal,
- frequency range: 20 MHz to 2000 MHz.

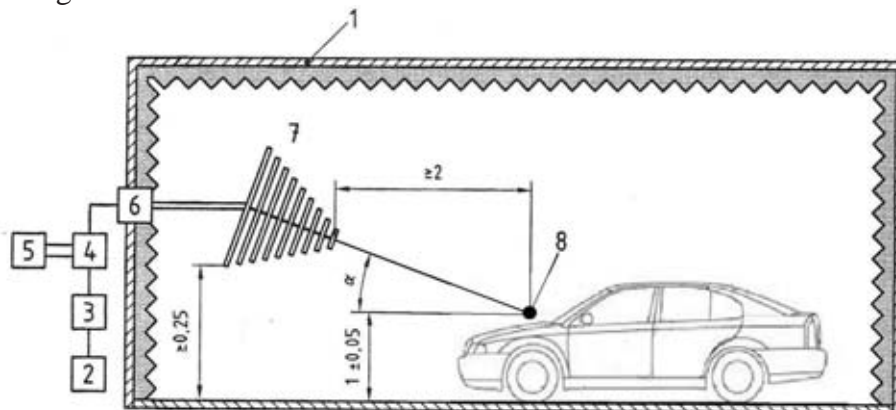


Fig. 1. Vehicle-immunity test in ALSE (ISO 11451-2); α – antenna inclination angle, 1-ALSE, 2- signal generator, 3-power amplifier, 4- dual directional coupler, 5- power meter, 6 coaxial feedthrough, 7-antenna, 8-vehicle reference point

The electric field sensor was positioned in turn in eight chosen points of a vehicle under investigations (Fig. 2):

- under bonnet: in the following five points – behind the right and left headlight (1, 2), on the engine(3), and behind the right and left shock absorber (4, 5),
- in the glove compartment (6),
- under the dashboard (7),
- behind the driver's seat (near the floor) (8).

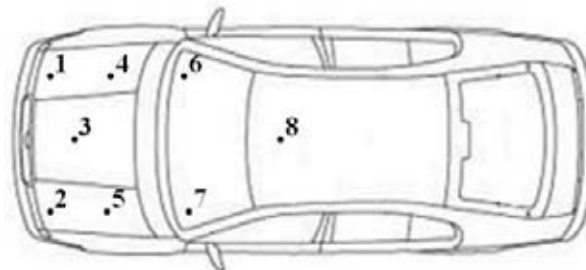


Fig. 2. Positioning of electric field sensors in a vehicle

4.4. Main results

The results of measurements are presented in the form of graphs: electric field strength versus frequency (Fig. 3-10), where vertical polarization of the antenna was taken into account. The reference value of the electric field strength, measured, during calibration, in the reference point with the aid of the electric field sensor, was equal to 30 ± 3 V/m.

The obtained results of measurements show that:

- in the range of low frequencies (up to 300 MHz) in almost all measured points of all vehicles there appear resonances (it causes an essential increase of the electric field strength – even over the reference value),
- these resonances can occur in a narrow frequency interval and then the electric field strength takes very large values (even over 150 V/m),
- the type of antenna polarization essentially affects the resonance frequencies and the corresponding values of the electric field strength, e.g., for the horizontal polarization, behind the left headlight of Berlingo, the electric field strength was 345 V/m at the frequency 46.5 MHz,

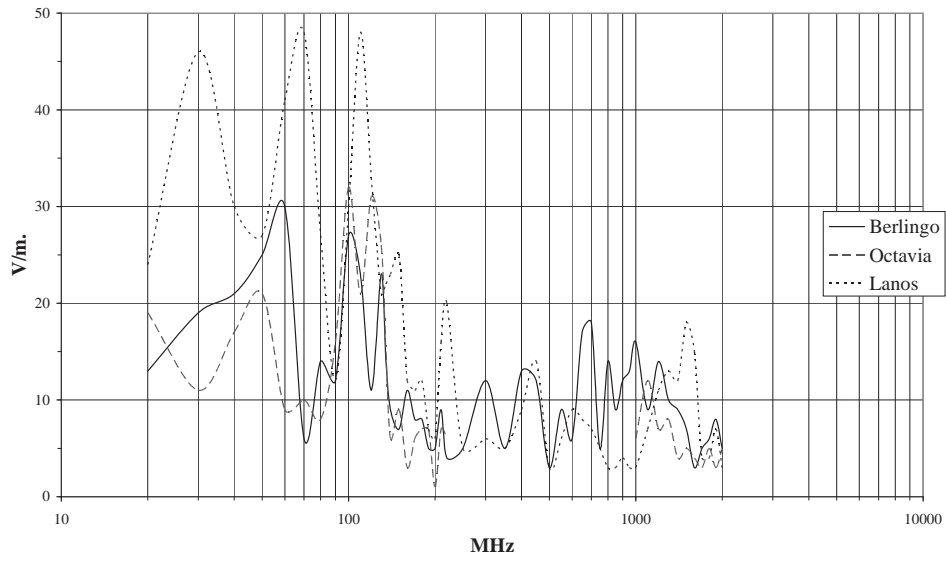


Fig. 3. Electric field strength versus frequency – electric field sensor on the engine

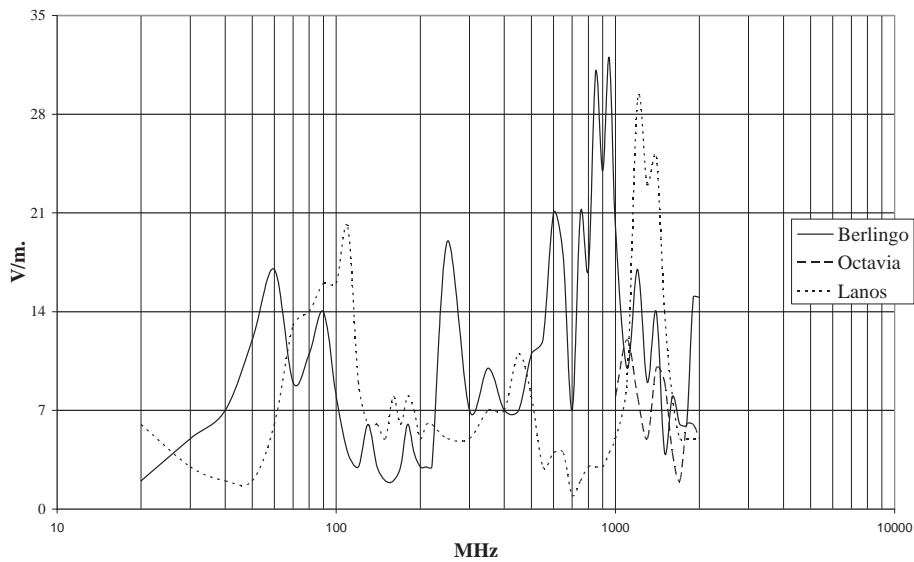


Fig. 4. Electric field strength versus frequency- electric field sensor behind left shock absorber

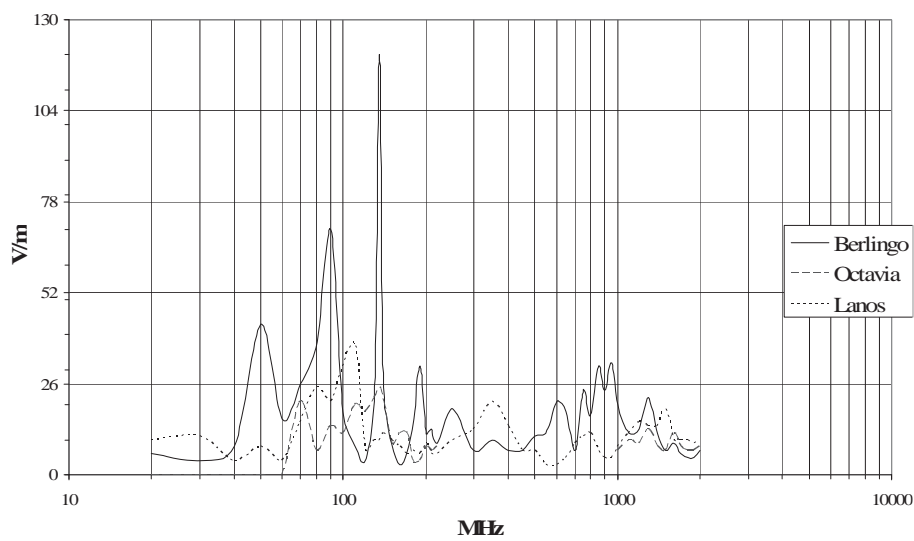


Fig. 5. Electric field strength versus frequency – electric field sensor behind left headlight

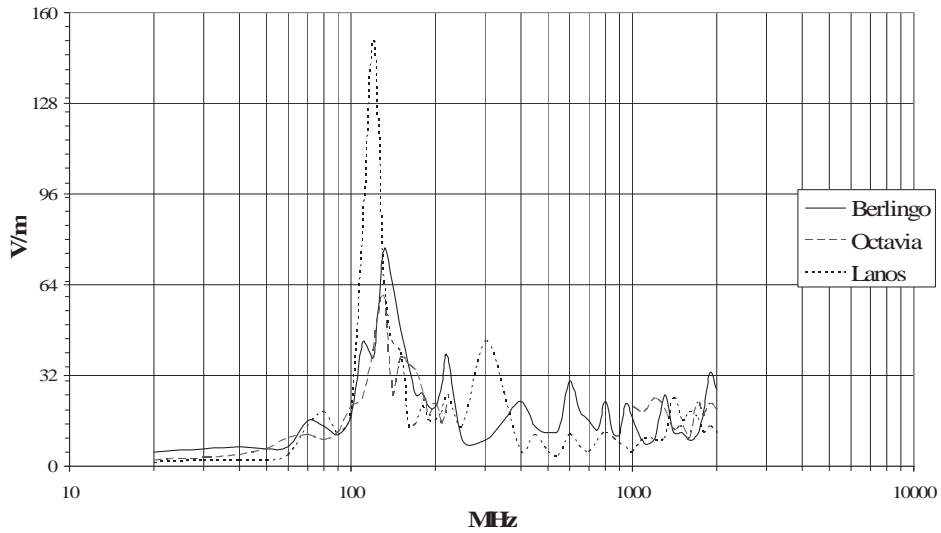


Fig. 6. Electric field strength versus frequency – electric field sensor behind right headlight

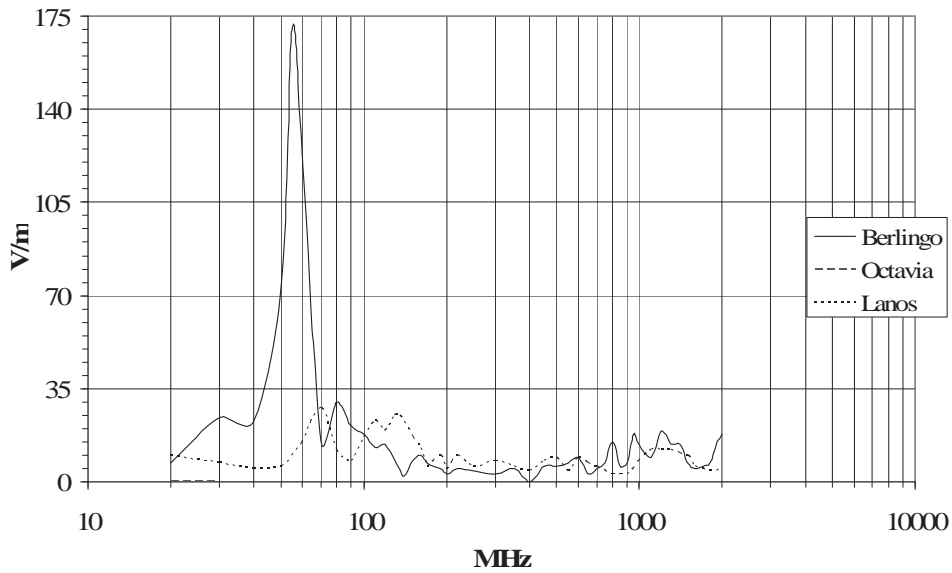


Fig. 7. Electric field strength versus frequency – electric field sensor behind right shock absorber

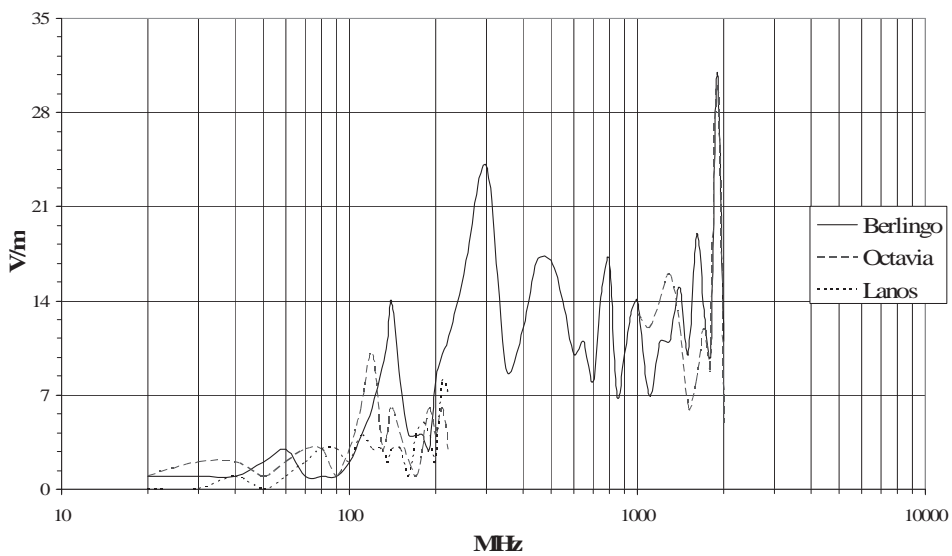


Fig. 8. Electric field strength versus frequency – electric field sensor behind the driver's seat

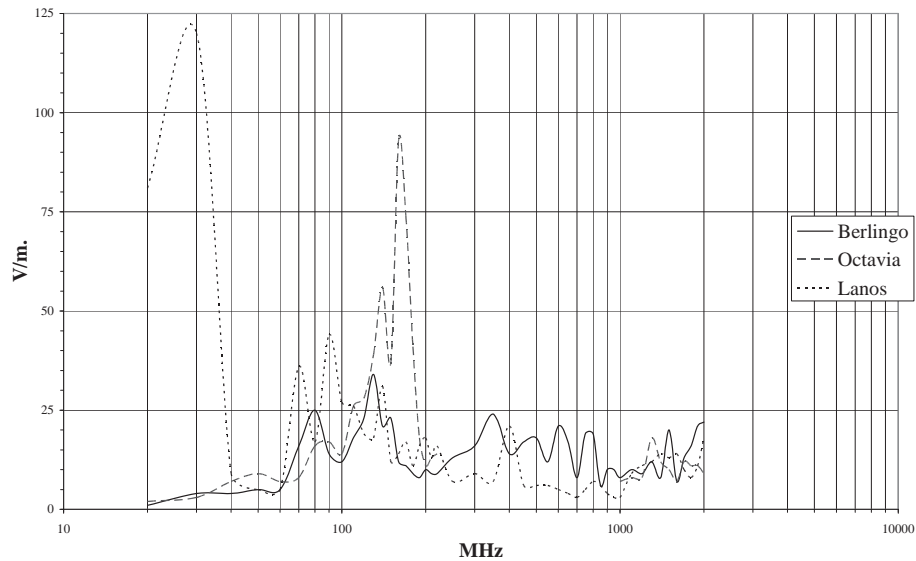


Fig. 9. Electric field strength versus frequency – electric field sensor under dashboard

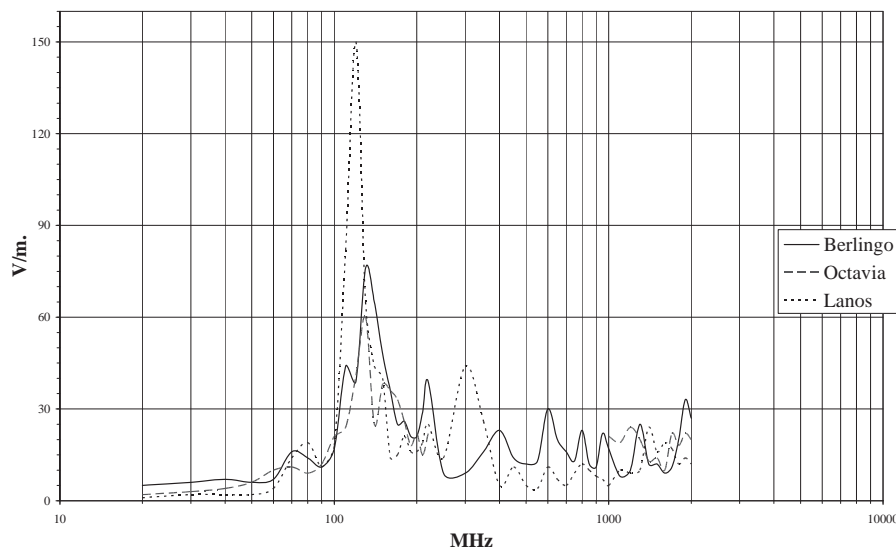


Fig. 10. Electric field strength versus frequency – electric field sensor in the glove compartment

- the electric field strength in the rear part of each vehicle (i.e., behind the driver’s and passenger’s seat as well as in the boot) was essentially lower than in the front part of the vehicle (especially for low frequencies),
- for frequencies above 500 MHz measured values of the electric field strength are smaller than 30 v/m.

5. Conclusions

On the basis of the performed measurements the following general conclusions, which partially answer the questions stated in subchapter 4.1, can be formulated:

- a) it may be observed that individual electric/electronic devices of a vehicle are exposed to electromagnetic field with a very wide range of values of electric field strength – depending upon a device position in a vehicle, vehicle type and antenna polarization,
- b) values of electric field strength inside of a vehicle may essentially exceed the values recommended by standards for immunity tests of electric/electronic subassemblies,
- c) extreme values of electric field strength occur usually at low frequencies (up to 300 MHz),
- d) from the point of view of maximal immunity to electromagnetic radiation, places of installing

- electric/electronic subassemblies in a vehicle should be carefully chosen,
- e) methods of testing vehicles immunity to electromagnetic radiation should take into account the antenna location on four sides of the vehicle as well as horizontal and vertical polarization of the antenna,
 - f) in preliminary tests the range of frequencies 20 MHz to 500 MHz can be enough (since above 500 Mhz the electric field strength above 30 V/m has not been observed).

6. References

- [1] *EU Directive 2004/104/EC*
- [2] *ECE UN Regulation No. 10*
- [3] *IEC CISPR 12 –Vehicles, boats and internal combustion engines – radio disturbance characteristics – limits and methods of measurement for the protection of off-board receivers.*
- [4] *IEC CISPR 25 (2008) - Vehicles, boats and internal combustion engines – radio disturbance characteristics – limits and methods of measurement for the protection of off-board receivers, 2009.*
- [5] *ISO 11451-2: 2005- Road vehicles – Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy- Part 2: Off-vehicle radiation sources, 2005.*

