METHODS OF INVESTIGATION OF ROAD VEHICLES IN CONTEXT OF IMMUNITY TO ELECTROMAGNETIC FIELD

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Abstract

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 whole vehicles and their subassemblies. A survey of basic standardized EMC test methods is presented in the paper. Moreover, an alternative test method of vehicle immunity worked out by authors is proposed. The method has been verified by using the open-area partially shielded test site (OAPSTS) model and compared with standardized methods contained in ECE UN Regulation No. 10 and EU Directive 2004/104/EC. Tests of vehicle immunity to electromagnetic field have been performed using the model of OAPSTS and the vehicles: Citroen-Berlingo, Skoda-Octavia and Daewoo-Lanos. Estimation of basic statistical parameters has also been worked out. The obtained results show that the proposed method is reliable and, on the other hand, it is more accessible and less expensive than the standardized methods in which employing of very expensive absorber-lined shielded test chambers is necessary. The present paper extends the results obtained in [6, 7].

Keywords: *transport, road vehicles, EMC immunity tests, open-area partially shielded test site model*

1. Introduction

Fast development of electrical and electronic equipment in road vehicles in recent years causes that requirements concerning EMC tests of whole vehicles and their electric/electronic subas-semblies become more significant. The most important requirements are contained in the inter-national regulations ECE UN Regulation No.10 and EU Directive 2004/104/EC. On the other hand, there is a series of EMC test methods worked out or accepted by CISPR (International Special Committee on Radio Interferences). These methods are cited or recommended in standards related to 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 (see Fig.1):

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

Each one of these methods can be applied to measurements of emitted electromagnetic disturbances as well as to measurements of immunity to electromagnetic radiation.

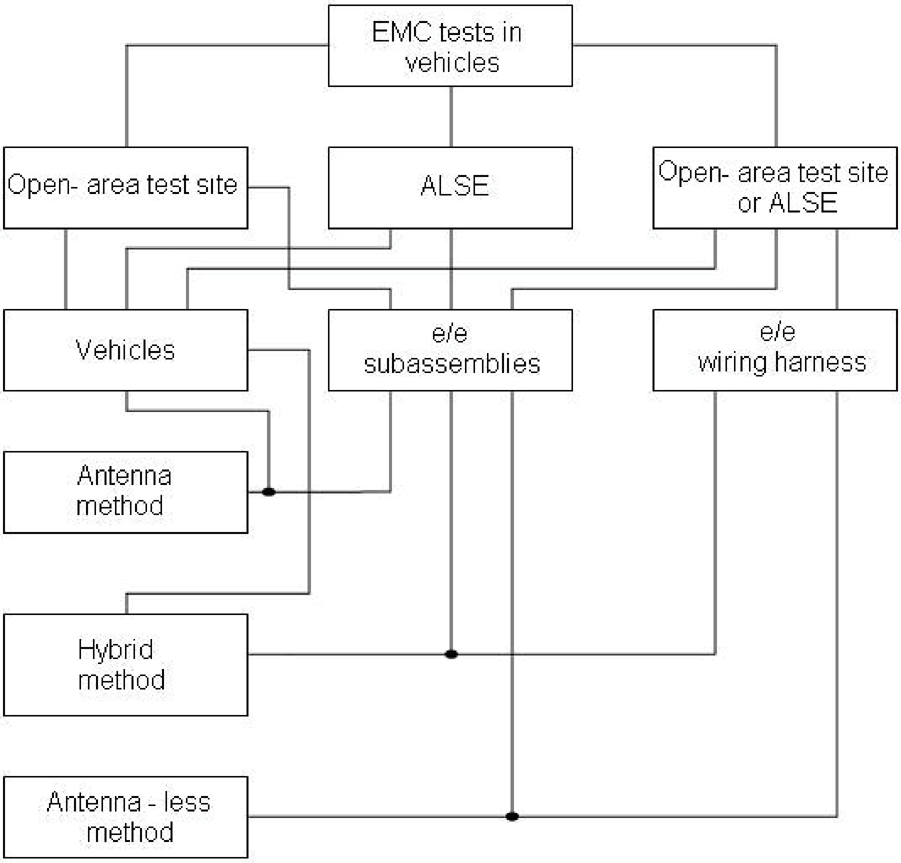

Fig. 1. Classification and applicability range of EMC test methods

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 view of the wide frequency band (20-1000MHz or 2000MHz) a number of switched antennas with optimal characteristics can be used. The most recommended for the measurements are absorber-lined shielded enclosures (ALSE) (see Fig. 2). The main advantages of ALSE's are: essential reducing of electromagnetic wave reflections, ensuring field homogeneity in the test area and lack of external disturbances, while the main disadvantage is the ALSE cost.

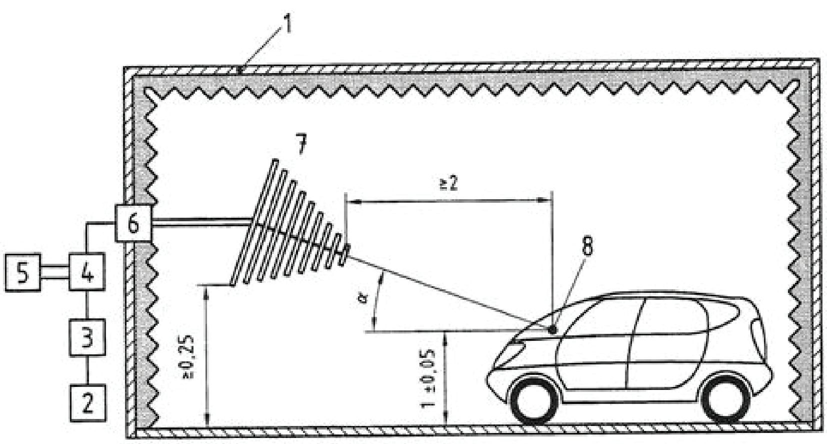

Fig. 2. Vehicle immunity test in ALSE (ISO 11451-2); α -antenna inclination angle, 1-ALSE, 2-signal generator, 3-power amplifier, 4-dual directional coupler,5-power meter, 6-coaxial feed through, 7-antenna, 8-vehicle reference point

Vehicle EMC tests in an open area test site are essentially less expensive compared to the tests in ALSE, however possible external disturbances constitute the main disadvantage.

In the hybrid method, in dependence upon frequency range, antennas and other test equipment can be used. In the range of low frequencies, where relatively high power and antenna large dimensions are required, a transmission line (TLS) can be applied (see Fig. 3). When the immunity tests are considered, the method of current injection (BCI) can also be used (see Fig. 4).

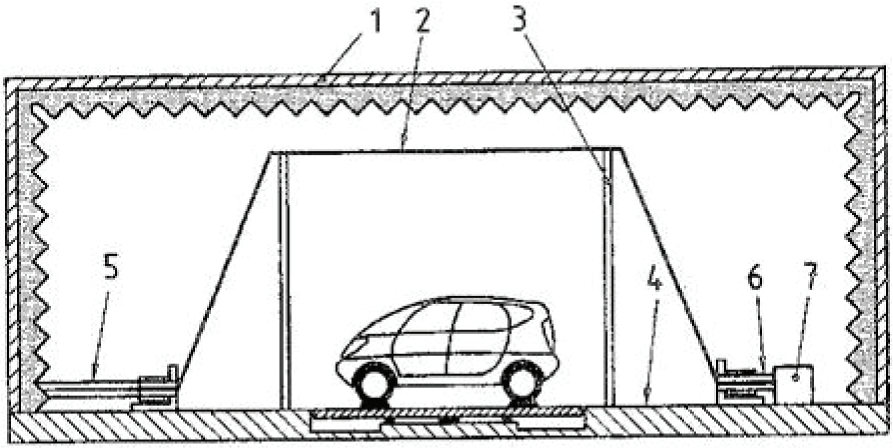

Fig. 3. Transmission line (TLS) in vehicle EMC tests: 1-ALSE, 2-transmission lines, 3-insulators, 4-ALSE floor, 5-supply line,6-coaxial line, 7-load

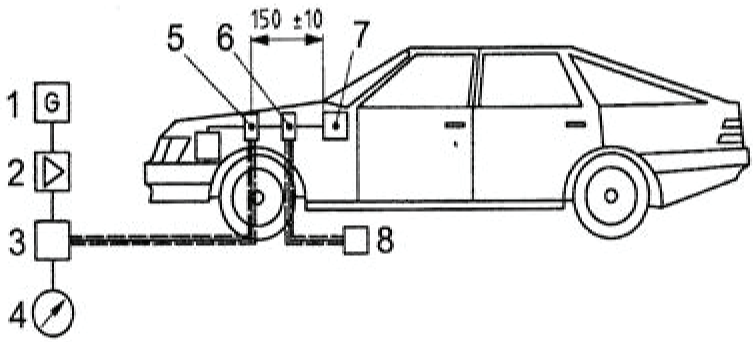

Fig. 4. BCI method in a vehicle subassembly immunity test: 1-signal generator, 2-broadband amplifier, 3-directional coupler, 4-power meter, 5-current injector, 6-measurement probe, 7-equipment under test, 8-spectrum analyzer

The antenna-less methods enable us e.g., to perform immunity tests of all those electrical/ electronics subassemblies which can affect vehicle safety. These methods employ GTEM chambers or strip lines (TEM).

In comparative tests some other EMC test methods, which do not appear in CISPR recommendations, can be used. The comparison of different EMC test methods related to requirements of UN ECE Regulation No.10 (ed. 02) and EU Directive 2004/104/EC can be found in Tab. 1.

2. The proposed antenna method of EMC tests

The proposed method concerns immunity tests of vehicles in open area test site conditions. In the method a number of electromagnetic shields around the tested vehicle are employed. The shields form at least three walls. Two shields are parallel to the longitudinal axis of the vehicle; each of them is placed in the distance at least 3m from the axis. The third shield is placed at least 1.5 m behind the vehicle back. In front of the vehicle an antenna is placed (in the longitudinal axis of the vehicle). The minimal height of the walls should not be less than the vehicle height plus 1m. At the

Tab. 1. Comparison of EMC test methods

Test method: - vehicle (v) - device (d)	Emission tests			Immunity tests		
	Frequency range (MHz)	Covering of the frequency range (%)		Electric field strength (V/m)	Covering of the frequency range (%)	
		R-10	Directive		R-10	Directive
Open – area test site (v + d)	30 - 1000	100	100	30	100	100
ALSE (v + d)	30 - 1000	100	100	30	100	100
BCI (v + d)	–	–	–	Current up to 60 mA	40 (for f)	20 (for f)
TEM Chamber (d)	30 - 300	30	30	75	30 (for f)	15 (for f)
Strip line 150 mm (d)	30 - 1000	100	100	60	100	50 (for f)
GTEM chamber (d)	30 - 2000	100	100	30	100	100

rear wall an additional panel of absorbers should be placed. Determining of the vehicle reference point, the electric field calibration as well as antenna positioning should be done according to standardized requirements. The electric field sensor should be placed inside the engine compartment over the front wheels axle. It is convenient to decompose the whole frequency band into three intervals, e.g., “1” – (20-80)MHz, “2” - (80-1000)MHz, “3” – (1000-2000)MHz. The tested vehicle is placed on rollers and its operation is monitored. During preliminary measurements the vehicle is exposed to low values of electric field strength - about (25-35)% of its nominal standardized value. We conduct the exposure in a discrete manner, e.g., the step of discretization for band “1” is 2MHz, for band “2” – 5MHz and for band “3” – 10MHz. During these preliminary measurements frequency values at which essential peaks of the field strength appear are registered (in the whole frequency range). The main measurements, at the standardized value of the electric field strength (i.e., 30V/m at the reference point), are then conducted only at the registered frequencies. The vehicle shall be in an unladen condition and the engine shall turn the wheels at the steady speed of 50km/h. If during the test, the operation of the vehicle (in the range of the standardized safety related functions) is not worsened, we conclude that the vehicle satisfies the EMC requirements concerning the immunity to electromagnetic radiation.

The method can also be applied in the immunity tests conducted in an absorber-lined shielded chamber.

3. EMC tests in the model of OAPSTS

The model of OAPSTS (see Fig. 5) is designed for conducting immunity tests of vehicles to electromagnetic radiation. The aim of the present research is to determine the possibility of applying the model in the immunity tests conducted with the aid of antenna methods including the method described in Section 2. The model of OAPSTS consists of absorbing shields (made of multilayer textile material containing conductive fibbers) and absorbers (made of polyurethane foam saturated with carbon). The objects of investigations were the vehicles: 1) Citroen Berlingo, diesel, 1.9l, 75KM, 2) Skoda Octavia, gasoline, 1.8l, 150KM, 3) Daewoo Lanos, gasoline, 1.6l, 106KM. The frequency range: 20-2000MHz. Antennas: 3 antennas for the following frequency bands: 25-80MHz, 80-1000MHz, 1000-2000MHz. Electric field strength in the reference point: up to 30V/m. Reference point – antenna distance: 2.0-2.8m. Electric field strength sensors – measurement range: 0.1-100V/m. Calibration of the measurement field has been performed according to UN ECE Regulation No.10: the nominal value of the field strength - 30V/m; the reference point: in the middle of the front wheels axle, 1m –height; antenna – reference point distance: 2m; antenna height: 1.5 -2.0m. The calibration has been made for vertical and horizontal polarization.

The tests included the electric field strength measurements inside and outside the model of OAPSTS, with vehicle and without vehicle as well as inside the vehicle. The vehicle under tests was positioned in front of the antenna. Measurements have been performed in the following points (see Fig. 5): point 0 – the reference point; point 1 – in the front wheels axle on the left wall of OAPSTS; point 2 – in the longitudinal vehicle axis on the back wall of OAPSTS; point 3 – in the front wheels axle on the right wall of OAPSTS.

The tests have been performed for the following measurement versions: version (a) – points 1, 2, 3 – height of probe: 1.5m; measurements in the open area (with vehicle); version (b) – point S in the engine compartment, point P near the glove compartment and point T in the luggage compartment.

The measurements according to version (a) enabled us to confirm the desired attenuating properties of the absorbing shields. The measurements according to version (b) enabled us to determine the courses of the electric field strength in dependence upon the sensors placement.

In order to confirm the validity of the proposed in Section 2 antenna method the results of the electric field strength measurements in the engine compartment (point S) have been employed (see Fig. 6). The comparative assessment of the tests features has been based on statistical estimation. To this end the following estimators have been calculated: mean value ($\mathrm{X} = \frac{1}{n}\sum_{i=1}^{n} \mathrm{x}_i$), mean square value ($\mathrm{X}^2 = \frac{1}{n}\sum_{i=1}^{n} x_i^2$), variance ($\mathrm{W}^2 = \frac{1}{n-1}\sum_{i=1}^{n} (\mathrm{x}_i - \mathrm{X})^2$), root mean square value ($\mathrm{RMS} = \sqrt{\mathrm{X}^2}$), standard deviation ($\mathrm{S} = \sqrt{\mathrm{W}}$), amplitude ($\mathrm{A} = \mathrm{X} + \mathrm{S}$). These estimators were calculated for the following three methods of the immunity assessment: 1. assessment according to Directive 2004/104; 2. assessment according to measurement points (R10.02), 3. assessment according to the antenna method. Recall that the assessment as in 1. requires a large number of the discretization points in the whole frequency range. The results of the estimation are shown in Tab. 2 and 3. The results contained in Tab. 3 show that the antenna method seems to be more useful than the method of R10.02.

Tab. 2. Immunity to radiation parameters estimation for tests of vehicles Berlingo, Octavia, Lanos

estimator	Directive 2004/104/WE			Measurement points (R10.02)			Antenna method		
	Berlingo	Octavia	Lanos	Berlingo	Octavia	Lanos	Berlingo	Octavia	Lanos
mean value	12.45	15.47	16.68	11.18	13.83	20.28	12.23	15.57	18.71
mean square value	200.50	309.95	457.37	152.16	217.94	615.17	202.14	331.07	589.41
variance	46.79	72.42	183.84	29.29	28.15	215.98	55.14	91.88	254.47
root mean square value	14.16	17.61	21.39	12.34	14.76	24.80	14.22	18.20	24.28
standard deviation	6.84	8.51	13.56	5.41	5.31	14.70	7.43	9.59	15.95
amplitude	19.29	23.98	30.24	16.59	19.14	34.98	19.66	25.16	34.66

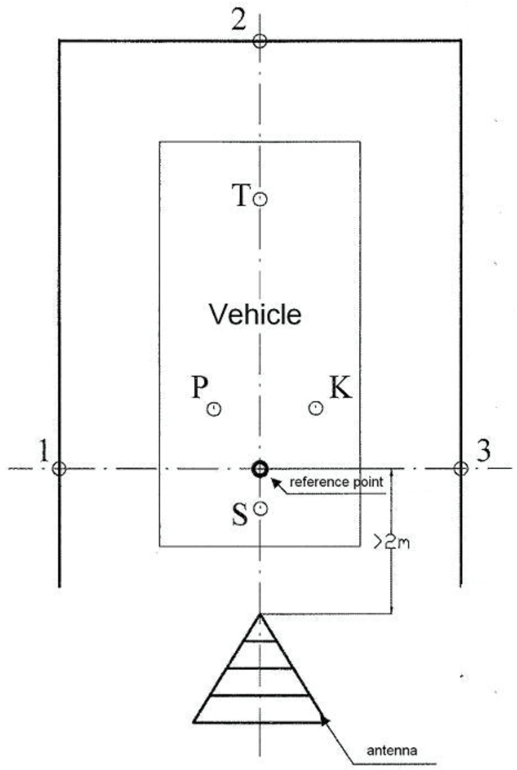

Fig. 5. Positioning of shields, antenna, measurement points and the tested vehicle in OAPSTS

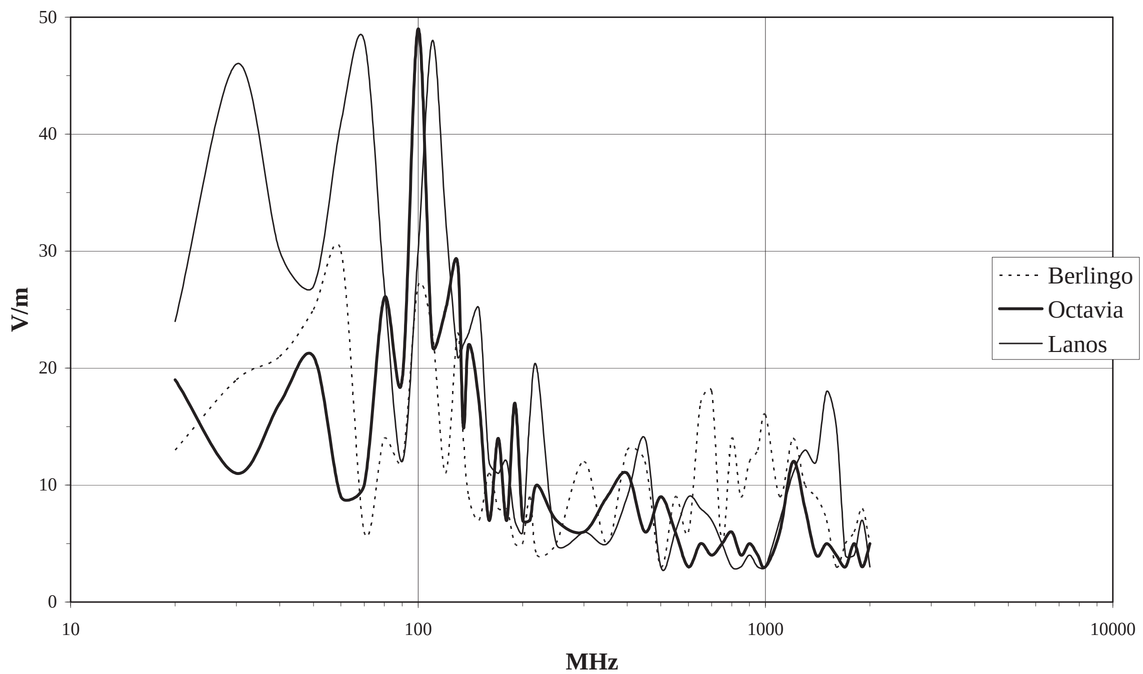

Fig. 6. Electric field strength (in the engine compartment) versus frequency for vehicles Berlingo, Octavia, Lanos (nominal value 30V/m)

4. Conclusion

The methods of immunity tests of vehicles have been discussed. The proposed antenna method has been verified with the use of the model of OAPSTS. A comparative assessment of the discussed methods has also been presented. The main advantage of the antenna method is its time and cost efficiency.

Tab. 3. Parameters estimation results for immunity tests (according to R10.02 and antenna method) for vehicles Berlingo, Octavia, Lanos

tested vehicles	estimation parameter	assessment method	
		measurement points according to R10.02 [dB]	measurement points according to antenna method [dB]
Citroen Berlingo	x	1.73	0.98
	rms	1.36	1.14
	s	0.67	1.44
	a	1.44	1.14
Skoda Octavia	x	1.90	0.09
	rms	1.85	0.25
	s	1.58	1.36
	a	1.81	0.42
Daewoo Lanos	x	1.91	1.98
	rms	1.88	0
	x	1.79	0.75
	a	1.78	0.17

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