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1 SUBJECT

Defining the test equipment and methods for the bench test for verifying the immunity of the electronic devices to magnetic field disturbances.

2 PURPOSE

The purpose of the test is the adjustment of the electronic devices that check the proper operation of the system to be tested subjected to high intensity and low frequency (15 Hz – 30 kHz) magnetic fields, such as those caused by the presence of electric lines or transformer stations in the immediate vicinity or by powerful electric devices such as vehicle engines and inverters (15 Hz – 150 kHz).

3 FIELD OF APPLICATION

This standard is valid for devices installed on vehicles with a 12 V and 24 V electric system and equipped with an ”OTTO” or ”DIESEL”, cng, electric cycle internal combustion engine.

4 TEST CONDITIONS

The tests must be carried out on electric devices that have already passed the function checks referred to in the general procurement specification IVECO STD. 18–2252 and in the specific procurement specifications.

4.1 Test environment

The measurement is taken with the electronic devices installed in the Helmholtz coil with a predetermined layout, in the most precise manner to guarantee result repeatability.

4.1.1 The room must be large enough to contain all of the necessary instrumentation, providing a sufficient distance (at least 2 m) between the magnetic field generation device (Helmholt coil or antenna loop) and the rest of the instrumentation, and no disturbances are permitted that could influence the test results.

The environmental climatic requirements must be as follows;

– Temperature: 23 ± 5 ^{o}C;

– Relative humidity: 45 – 70 %;

– Atmospheric pressure: 860 – 1060 mbar

Edition	Date	Description of modifications	Group
1	06.05.2008	New.	PME
2	04.11.2008	Paragraphs 6.1.1 and 9 corrected.	

4.2 **Test voltage**

Refer to the values shown in **Table I**.

Voltage		
	SYSTEMS	
	12 V	**24 V**
UA	13.5 ± 0.5 V	27 ± 1 V
UB	12 ± 0.2 V	24 ± 0.4 V

Table I

where:

– UA = System voltage (engine on);

– UA = Battery voltage (engine off);

4.3 **Test levels**

The test must be carried out within the below defined frequency range and limits:

– Frequency range: 15 Hz – 150 kHz;

– Field intensity: 1000 A/m decreasing up to 10 A/m from 1 kHz to 10 kHz according to the formula $1000/(f/1000)^2$;

– Type of injected signal: sinusoidal or triangular;

– Magnetic field polarization: x, y, z axes of the test device;

– Frequency variation: logarithmic or linear;

– Points per decade: 50;

– Residence time 5 s or the time necessary for checking the correct operation of the device to be tested.

5 TEST EQUIPMENT

5.1 **Low frequency generator**

It must meet the following minimum requirements:

– Minimum frequency band: 15 Hz – 150 kHz;

– Generable wave forms: sinusoidal and triangular;

– Output signal amplitude: at least 5 Vpp;

– Output impedance: 50 Ω;

– Frequency accuracy: better than 1%;

– Amplitude adjustment: at pitches lower than 0.5 dB.

5.2 **Power amplifier**

It must meet the following minimum requirements:

– Minimum frequency band: 15 Hz – 150 kHz;

– Deliverable current: from 6.33 Arms with 3.6 Ω at 30 Hz up to 6.33 μArms with 3.6 kΩ at 30 kHz with a linear progression between the aforesaid points;

– Harmonic level: at least 15 dB lower than the fundamental frequency, across the entire operation band.

5.3 **Helmholtz coil**

It must be able to guarantee the generation of magnetic fields of at least 170 dBμA/m (310 A/m) at 30 Hz up to 50 dBμA/m (0.31 mA/m) at 150 kHz with a logarithmic variation between the aforesaid points with a test volume of at least 30 x 30 x 30 cm.

It must also have a ”loop sensor” for measuring the magnetic field generated in the frequency band between 15 Hz and 150 kHz.

5.4 **Antenna loop;**

It must meet the following minimum requirements in the range between 15 Hz and 150 kHz:

– diameter: 120 mm;

– Revolutions per minute: 20;

– cable: 2mm (type awg12).

the density of the magnetic flow at a distance of 50mm from the loop surface is given by the equation:

– $B = \mu o H = 9.5 \times 10^{-5} I$ (T = Tesla).

The imperturbability of the magnetic field at a distance of 50 mm from the loop surface is given by the equation:

– $H = 75.6 \text{ x} I$ (A/m).

The non linear characteristics must be considered and determined for calculating the value of the current to apply to the device to be tested.

5.5 **Current measuring instrument**

Current monitoring can occur through the direct use of a clamp on type probe as well as an energized indirect measurement through shunt resistances, as long as it guarantees the true RMS reading of the current within a frequency range of 15 Hz and 150 kHz.

An oscilloscope, a true RMS AC voltmeter or a true RMS AC amperometer can be used.

If a technique with shunts is used, the equipment must contain shunts for a 4 point measurement of the current circulating in the Helmholtz coil, selectable through the capacity commutator, and a switch commutator for commutating the signal source between the amplifier and the generator.

NOTE **:** *the commutation between the amplifier and the generator must be done at a high frequency when the current that is to be injected in the Helmholtz coil is lower than the minimum deliverable by the amplifier.*
In that case, the commutation excludes the amplifier and the coil is directly controlled by the generator.

5.6 **Magnetic field gauge**

It must be able to measure fields of at least 1000 A/m within a frequency range between 15 Hz and 150 kHz.
For measuring the magnetic field using the antenna loop method, it must have the following characteristics:

– diameter: 1.57 in;

– Revolutions per minute: 51;

– cable : 0.071 mm (7 strands 41 awg);

– shielding: electrostatic;

– correction factor: see the manufacturer's data sheet to convert the sensor factor from the energized value to that in the magnetic field.

5.7 **Power supply**

It must supply the voltage and deliver the maximum current necessary for the correct operation of the device to be tested.

It is advisable to use a power supply with voltage that can be adjusted between 0 and 24 V, 40 A, with a buffer battery of 45 Ah, 225 A.

5.8 **Impedance stabilization network (L.I.S.N.)**

It must be implemented according to the wiring diagram shown in **Figure 1**, and have the impedance characteristics upon variation of the frequency as indicated in **Figure 2**.

It must also fulfill the following requirements:

– the resistance between terminals P and A must be lower than 5 mΩ;

– the resistance between terminals P and B, when terminals A and B are closed in a short circuit, must not diverge more than 10% from the theoretical curve shown in **Figure 2**, in the frequency band 100 kHz 20 MHz;

– the resistance between terminals P and B, when terminals A and B are closed in a short circuit, must not diverge more than 10% from the theoretical curve shown in **Figure 2**, in the frequency band 100 kHz 20 MHz;

– capacity C must support a continuous voltage of at least 1500 V;

– inductance L must support the current supply of the device to be tested.

IMPEDANCE STABILIZATION LINE (L.I.S.N.)

Wiring diagram:

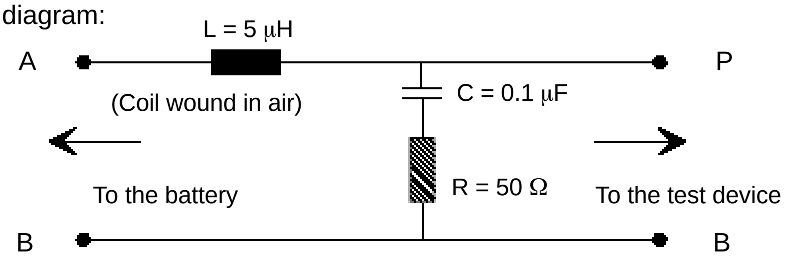

Figure 1

Impedance module:

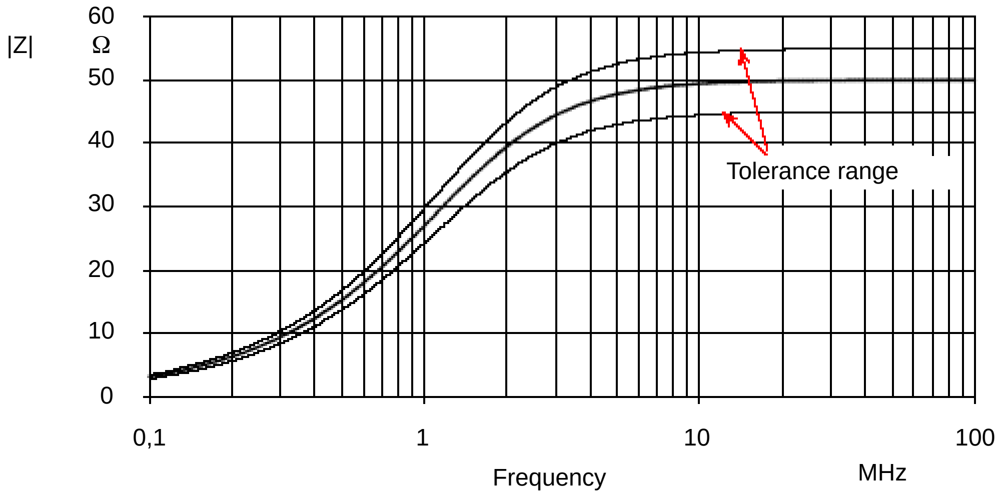

Figure 2

5.9 Stimulus and monitoring system for the device to be tested

– It must permit the device to be tested to operate correctly in normal conditions of use, as foreseen by the relative drawing or procurement specification;

– It must be able to correctly interface with the sensors and actuators of the system to be checked, without excessively changing its electric (impedance) characteristics;

– Any sensors/actuators that are not real (simulated) must not be sensitive to the magnetic field levels generated by the Helmholtz coil or the antenna loop.

It is therefore advisable to use, when possible, stimulus and monitoring systems consisting of the following:

Stimulus system:

– external instrumentation necessary for generating sensor stimulus signals;

– an external unit that transmits the stimulus signals with electric–optic conversion;

– a shielded, self powered unit that receives the signals with optic–electric conversion (to be placed inside the chamber);

– devices that inject the stimulus signals to the sensors (transducers connected to system sensors);

– optical connection fibers between the transmission and reception units.

Monitoring system:

– a shielded and self powered signal transmission unit for monitoring the functional status of the device to be tested with electro–optic conversion (to be positioned near the system to be tested);

– an external reception unit with optic–electric conversion of the signals for monitoring the functional status of the system to be tested;

– optical connection fibers between the transmission and reception units;

– external instrumentation necessary for signal monitoring.

6 TEST BENCH

The test bench used will depend on the check methodology that has been adopted, either with the device inside the Helmholtz coil or with the device 5 cm from the antenna loop

6.1 Device set–up for the Helmholtz test

6.1.1 Place the device inside the Helmholtz coil test volume and turn it toward the magnetic field (coil axis) along one of its 3 axes (x, y and z), and place the cabling and instrumentation necessary for its correct operation (real sensors and actuators and/or stimulus and monitoring system to connect to the device) on a non–magnetic surface (ex. wood table) outside of the coil.

The required set–up is shown in **Figure 3**.

The equipment set–up for the Helmholtz coil method

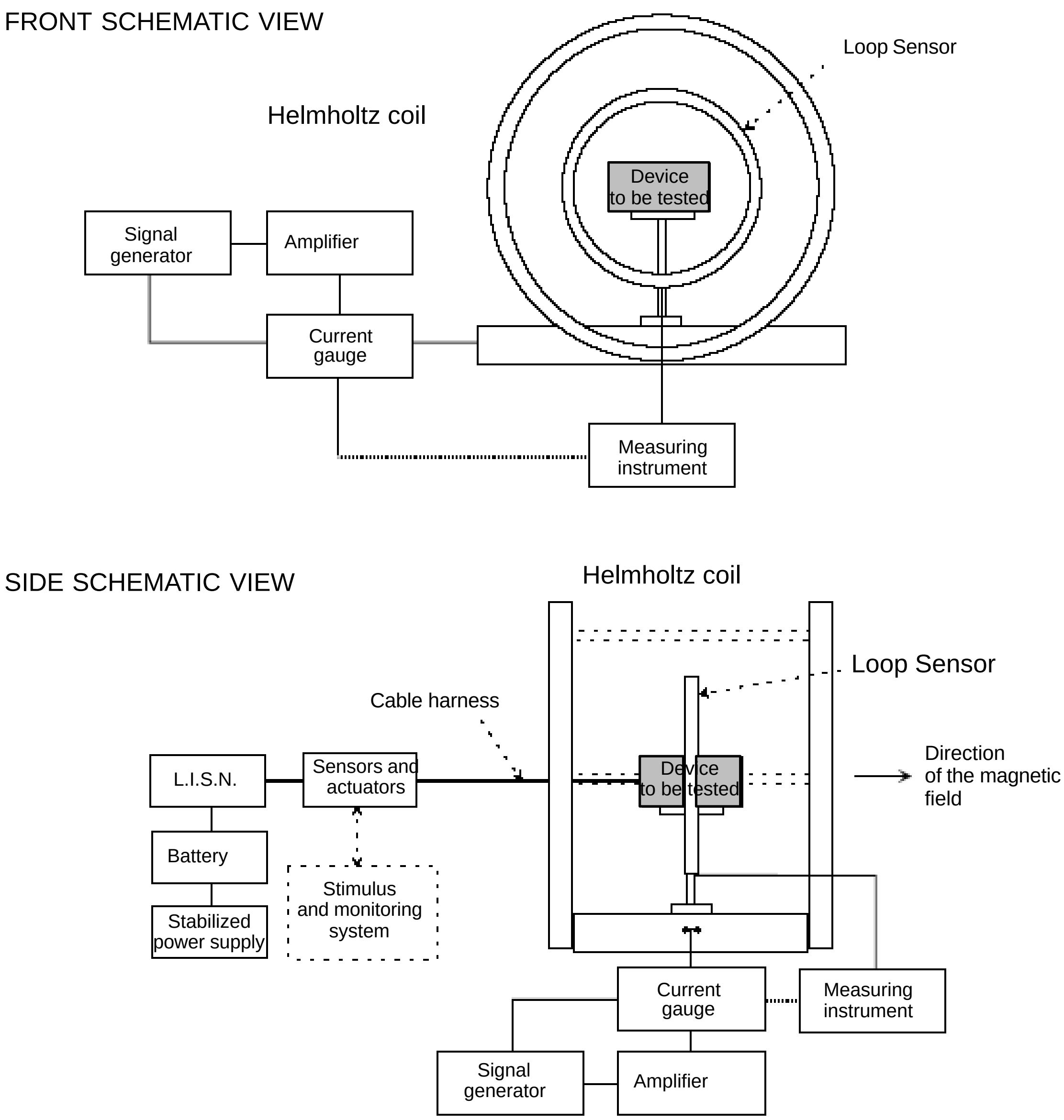

Figure 3

6.1.2 If the ground connection is expressly foreseen on the system frame or on one of the sensors/actuators, this connection must be done using a ground plait or a section cable that is adequate for the closest reference mass (ex. negative pole of the L.I.S.N.).

6.1.3 Arrange the cables so that they lay as parallel as possible to the magnetic field lines, trying to arrange the sensor and actuators outside of the coil.
If the cabling foreseen on the vehicle is used and the power supply lines (positive and negative) do not permit a connection with the impedance stabilization network (L.I.S.N.), keeping it outside of the Helmholtz coil, they must be extended with two cables laid parallel next to each other.
If instead the cabling foreseen on the vehicle is not used, the type of cable harness (section, shielding, twisting, grounding lines, etc...) used must comply with the vehicle's cable harness.

6.2 Magnetic field level adjustment

The magnetic field (H) adjustment may be done in three ways: in closed–loop, precalibrated and theoretical.

6.2.1 Magnetic field level adjustment in closed–loop

Preferably the magnetic field adjustment (H) should be done in closed–loop through a measurement on the magnetic field probe (Helmholtz coil "loop sensor"), as described below:

– The magnetic field level adjustment is done while taking the measurement by means of the field measurement that was measured by a magnetic field probe ("loop sensor") located inside the Helmholtz coil.

– To do the adjustment, carry out these steps in the following order:

6.2.1.1 Acquire the effective value (rms) of the voltage level measured by the measuring instrument (V) at the "loop sensor" ends.

6.2.1.2 Calculate the measured field level (Hm) using the antenna factor (AF=20* Log(H[A/m]/V[V])) of the "loop sensor" by means of the formula:

– Hm[dBμA/m]=V[dBμV]+AF(f) or Hm[dBμA/m]=20*Log(V[V])+120+AF(f) where f is the measurement frequency.

6.2.1.3 increase the generator level by one factor H[A/m]/Hm[A/m] (equivalent to one increment in dB of H[dBμA/m]–Hm[dBμA/m]) and repeat points 6.2.1.1 and 6.2.1.2 until the required field level is reached (Hm=H ± tol.) or until the maximum deliverable current level is reached.

If, due to technical reasons, this type of adjustment cannot be carried out, it must be done using one of the two alternative methods called PRE–CALIBRATION and THEORETICAL.

6.2.2 **Magnetic field level adjustment in PRE–CALIBRATION**

The magnetic field level adjustment is done while taking the measurement by means of the Helmholtz coil control current measurement (measured by a few shunts), using as a reference the current intensity needed to generated the required field without the device to be tested.

A pre–calibration is required in order to carry out this adjustment, without the device to be tested, during which a measurement is taken of the effective value of the coil control current I(f) required to obtain a certain reference field Hr(f) measured by a magnetic field probe in closed–loop.

During the actual test, the field adjustment must be done by following the steps described below:

6.2.2.1 Acquire the effective value (rms) of the voltage level measured by the measuring instrument (V) at the ends of the utilized shunt.

6.2.2.2 Calculate the measured field level (Hm) using one of the following formulas:

– Hm[dBμA/m]=V[dBμV]+20*Log(S[1/Ω])–I(f)[dBμA]+Hr(f)[dBμA/m]

– Hm[dBμA/m]=20*Log(V[V])+120+20*Log(S[1/Ω])–I(f)[dBμA]+Hr(f)[dBμA/m]

– Hm[dBμA/m]=20*Log(V[V]*S[1/Ω]/I(f)[A])+Hr(f)[dBμA/m]

where f is the measurement frequency and S is the current/voltage ratio of the utilized shunt.

6.2.2.3 increase the generator level by one factor H[A/m]/Hm[A/m] (equivalent to one increment in dB of H[dBμA/m]–Hm[dBμA/m]) and repeat points 6.2.2.1 and 6.2.2.2 until the required field level is reached (Hm=H ± tol.) or until the maximum deliverable current level is reached.

6.2.3 **Magnetic field level adjustment with the THEORETICAL method**

The magnetic field level adjustment is done while taking the measurement by means of the Helmholtz coil control current measurement (measured by a few shunts), calculating theoretically the current intensity needed to generated the required field.

To carry out this adjustment, the following steps must be followed:

6.2.3.1 Acquire the effective value (rms) of the voltage level measured by the measuring instrument (V) at the ends of the utilized shunt.

6.2.3.2 Calculate the measured field level (Hm) using the antenna factor (AF=20*Log(H[A/m]/I[A])) of the Helmholtz coil by means of the formula:

Hm[dBμA/m]=V[dBμV]+20*Log(S[1/Ω])+AF(f);

or

Hm[dBμA/m]=20*Log(V[V])+120+20*Log(S[1/Ω])+AF(f).

where f is the measurement frequency and S is the current/voltage ratio of the utilized shunt.

6.2.3.3 increase the generator level by one factor H[A/m]/Hm[A/m] (equivalent to one increment in dB of H[dBμA/m]–Hm[dBμA/m]) and repeat points 6.2.3.1 and 6.2.3.2 until the required field level is reached (Hm=H ± tol.) or until the maximum deliverable current level is reached.

NOTE : *if the manufacturer has closed the "loop sensor" on a low impedance load (50 Ω etc.) it must be done by arranging this load in parallel to the measurement instrument.*

6.3 The equipment set–up with the antenna loop method

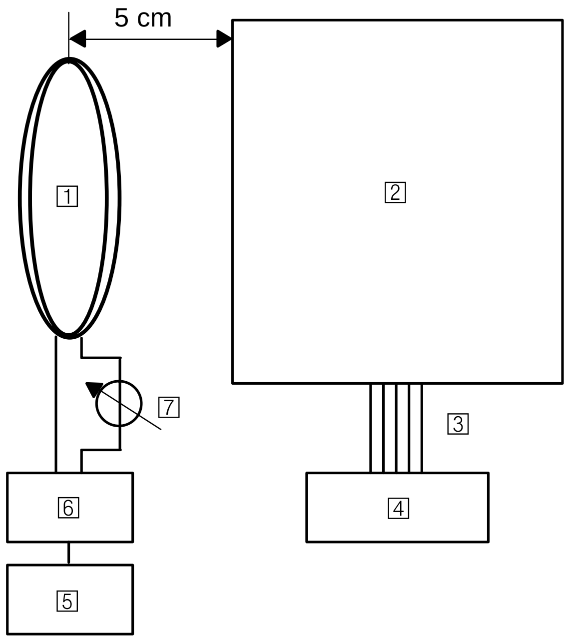

Figure 4

Key

1 Antenna loop;

2 DUT (Dispositivo Under Test);

3 Wiring;

4 Peripheral devices;

5 Low frequency generator;

6 Low frequency amplifier;

7 Current gauge.

7 CHECK METHODOLOGY

The check methodology adopted can be either with the device inside the Helmholtz coil or with the device 5 cm away from the antenna loop.

8 TEST EXECUTION

8.1 Arranging the equipment in the Helmholtz coil

8.1.1 Arrange the instrumentation necessary for carrying out the test (listed in the dedicated module ”INSTRUMENTATION REQUIRED FOR THE TEST”), according to the set–up shown in **Figure 3**.

8.1.2 Place the device to be tested in the the Helmholtz coil test volume.

8.1.3 Place the wiring of the device to be tested and the auxiliary instrumentation required for its correct operation according to the set–up described in point 6.1, trying to minimize the differential couplings intrinsic of the wiring. The wiring length must guarantee immunity between the loads and the power supply. The wiring to be tested must be positioned on a non conductive and low permeability surface.

8.1.4 Connect the sensors and actuators foreseen for the device to be tested, which must be the same as those foreseen on the drawing for installation on the vehicle, if possible, and they must be stressed and monitored by means of the stimulation and monitoring system.

8.1.5 Connect the power supply lines of the system to be tested to the battery and the power supply by means of the impedance stabilization network (L.I.S.N.).

8.2 Activation of the device to be tested

8.2.1 Connect and power the device to be tested as foreseen by the drawing or the relative procurement specification.

8.2.2 Apply the signals necessary for system operation to the electric inputs or physical sensors.

8.2.3 Arrange the system in the particular condition of static operation (absence of variation in the stimulus signals) or dynamic operation (sequence of particular variations in the stimulus signals that purposely change the system state or behavior) that is required according to what is foreseen by the relative drawing or procurement specification to test its correct operation.

8.2.4 Acquire the characteristic parameters of the signals supplied by the actuators to be used as a reference during the test.

8.3 Test set up

8.3.1 The measurement of the susceptibility curve of the system to be tested must be done, for each of the possible positions of the three axes of the device in the direction of the magnetic field (x, y and z axes placed on the Helmholtz coil axis) and for each of the system operation conditions, in the frequency range and in the conditions foreseen by the product specification or IVECO STD. 18–2252.

The frequency steps must be:

– 50 points/decade (4.7 % increase) from 15 Hz to 150 kHz.

NOTE : *The frequency steps can be doubled (25 points/decade) for particular devices that require particularly long test time.*

8.4 Measurement of the device's susceptibility curve

Repeat the following procedure for each frequency point of the susceptibility curve to be measured according to what is described in points 8.4.1 – 8.4.6.

8.4.1 Select the correct current gauge setting in coherence with the frequency and magnetic field level to be generated (switch the Helmholtz coil control source between the generator and amplifier and select the current supply).

8.4.2 Set the wave form (sinusoidal, triangular, etc.) and the frequency required for generating the magnetic field on the signal generator.

8.4.3 Adjust the signal generator output level in order to obtain the current required for realizing the required magnetic field at the output of the amplifier or the generator (the adjustment using the magnetic field level measurement instrument is described in point 6.2).

NOTE : *If it is not possible to reach the required magnetic field intensity, the maximum possible field must be obtained using the maximum current supplied by the amplifier.*

8.4.4 Check the correct operation of the device being tested, in the particular operating conditions being tested, and compare the characteristic parameters of the signals supplied by the sensors with those of reference.

8.4.5 If the device is not operating properly, repeat points 8.4.3 and 8.4.4, starting from a field level that does not cause malfunctioning, to determine the minimum field level at which the system stops operating properly.

8.4.6 Use a graph to indicate the field level reached at the current test frequency, pointing out the points of malfunction of the device being tested in comparison to those of correct operation.

9 FUNCTIONAL CLASS CLASSIFICATION

The functional states of electronic devices during the tests refer to the following classes:

– **CLASS A**: All device functions meet the requirements, both during and after the test.

– **CLASS B**: All device functions meet the requirements both during and after the test; however one or more of them can be out of tolerance within the limits required by the specific procurement specification or by the product specification.
However, these functions return to their characteristic value at the end of the disturbance.

– **CLASS C**: A device function can be in failure, but it goes back automatically to its characteristic value at the end of the disturbance also through an autoreset autoreset function that returns the device to the conditions complying with the present parameters.

– **CLASS D**: A device function can be in failure and it does not go back to its characteristic value at the end of the disturbance, until externally reset.

– **CLASS E**: One or more device functions can be in failure both during and after the test.
These functions do not go back to their characteristic values at the end of the disturbance until the device is repaired or replaced.

NOTE **:** *Irreversible faults on the test devices when subjected to the maximum test level are not accepted (FUNCTIONAL CLASS E).*

10 COMPONENT/SYSTEM DEFECT CLASSIFICATION

10.1 Defect classification

The following defect classification applies in relation to the functions performed on the components/system:

– **P**: Primary defect which affects vehicle control and can be perceived by the driver or other road user, or which can generate functional alterations that could confuse the other road users.

– **NP**: Non–primary defect which does not affect the control of the vehicle or of secondary functions of the system to be tested.

These classifications will be defined on the relative production specifications.

11 TEST LEVELS

The test must be carried out from 15Hz to 150 kHz with magnetic fields of 1000 A/m decreasing with the frequency, applying a sinusoidal or triangular signal and with the magnetic field polarization on the X, Y, Z axes of the device to be tested.

11.1 Allowable limits

The relative functional class reached (A – B – C – D – E) by the product being tested during MAGNETIC field radiance must comply with or be better than what is foreseen for all test levels or according to the relative product specification. In the case of device malfunction, a manual search must be carried out for the minimum electric field levels at which the device starts again to function properly (susceptibility limit determination).

– From 0 to 100 A/m (decreasing with the frequency) no type of defect is accepted.

– From 100 to 300 A/m (decreasing with the frequency) it is accepted that a non–primary device function is out of tolerance, if it goes back to its specification values automatically at the end of the disturbance.

– From 300 to 1000 A/m (decreasing with the frequency) it is also accepted that a primary device function is out of tolerance, if it goes back to its specification values automatically at the end of the disturbance.

12 PRESENTATION OF THE RESULTS REACHED BASED ON THE RELATIVE FUNCTIONAL CLASS

Electric field/frequency diagrams that represent the susceptibility curves and the relative class reached (A – B – C – D – E) must be provided for each system being checked, for each test condition and for each test level. In addition, the types of determined anomalies must be indicated. The functions of the product being tested must comply with what is specified in **Table II**.

Frequency band	Magnetic field intensity	Acceptability level		
	(A/m)	Defect type	Functional Class	
15 Hz – 1000 Hz with	100	No defect	A	No defect, either during or after the disturbance
1 kHz –10 kHz	$100 / (F/1000)^2$			
10 kHz – 150 kHz	1			
15 Hz – 1000 Hz	300	Non–Primary Defect	B	Self resettable at the end of the Radio Frequency
1 kHz – 10 kHz	$300 / (F/1000)^2$			
10 kHz – 150 kHz	3			
15 Hz – 1000 Hz	1000	Primary defect	B	Self resettable at the end of the Radio Frequency
1 kHz – 10 kHz	$1000 / (F/1000)^2$			
10 kHz – 150 kHz	10			

Table II

REFERENCED STANDARDS

IVECO STD.: 16–2108, 18–2252.