RESISTANCE OF ELECTRONIC DEVICES TO THE DISTURBANCES OF IRRADIATED TYPE "TEM CELL" METHOD

ORIGIN:
ISO WD 11452 Part 3

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1 SUBJECT

Defining test equipment and methods to verify at the bench the resistances of electronic devices to irradiated electromagnetic disturbances.

2 PURPOSE

Purpose of the test is the preliminary setup of electronic devices from the point of view of immunity to electromagnetic fields generated in Tem Cell.

3 FIELD OF APPLICATION

The present standard is valid for equipment installed on vehicles with a 12–V and 24–V electric system, fitted with "OTTO" or "DIESEL" cycles internal combustion engines.

4 TEST CONDITIONS

The tests must be carried out on electronic devices that have already passed functional checks recalled in IVECO STD. 18–2252 and in the special specifications.

4.1 Test environment

Measurement is carried out on electronic devices installed in the Tem Cell with a preset layout, in the most precise way in order to guarantee repeatibility of results.

4.1.1 Test chamber whose dimensions are such as to contain Tem Cell, instruments (antennas and related accessories) and bench that has a minimum size of 2 x 1 m.
Test environment must be free from noises that can affect test results.

Edition	Date	Description of modifications	Group
1	30.11.1993		
2	25.08.1999	Modified: points 4.3, 5.1, 5.6.3, 5.6.5, 8.4, 10.1, 10.2, and Figures 2A and 2B.	
3	11.09.2001	Points 11 and 12 modified.	
4	03.03.2006	Supervisor and Manager added. Modified frequencies at points: 4.3, 5.6.1, 5.6.2 and 8.4. Points 11 and 12 modified. Editing modifications.	**PEL**

4.1.2 Environmental climatic requirements:

– Temperature: 23 ± 5 °C
– Relative humidity: 45 – 70 %
– Atmospheric pressure: 860 – 1060 mbar

4.2 Test voltage

Refer to values given in **Table I**:

TABLE I

VOLTAGE	FOR 12 V SYSTEMS (V)	FOR 24 V SYSTEMS (V)
UA	13.5 ± 0.5 V	27 ± 1 V
UB	12 ± 0.2 V	24 ± 0.4 V

Where: UA = System voltage (engine ON)
UB = Battery voltage (engine OFF)

4.3 Test levels

The test must fall within the frequency range and the following limits:

– Frequency range: 10 KHz – 200 MHz
– (*) Modulation type: Amplitude (A.M.)
– (*) Modulation frequency: 400 Hz or 1000 Hz
– (*) Modulation index: 0 – 80 % (**)
– Field intensity: 200 V/m
– Frequency change: Logarithmic or linear
– Points for decade: 100 or 20 MHz a 200 MHz with 1 MHz linear steps
– Permanence time: 3 s or the time necessary to check correct operation of tested device

(*) Only if required

(**) If a test is required, use the module signal in amplitude instead of that in CW conditions; peak to peak value of the electric field must in any case be:

E (CW peak) = E (AM peak)

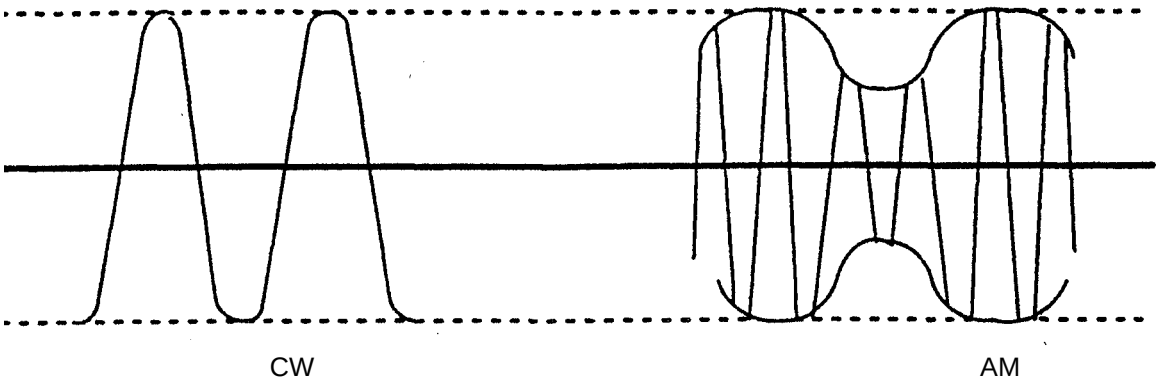


FIGURE 1

Relations between generated powers will be equal to:

$$\frac{P\,(AM)}{P\,(CW)} = \frac{((1 + m^2)E^2)}{2} = \frac{E^2}{2} = \frac{(1 + m^2)}{2} \cdot \frac{E^2}{E^2} = \frac{(1 + m2) : 2}{(1 + m)^2}$$

$$P\,(AM) = \frac{(2 + m^2)E^2)}{(2(1 + m)^2} P\,(CW)$$

for m = 0.8 (AM 1 KHz 80 %) will result:

P (AM) = 0.407 P (CW).

5 TEST EQUIPMENT

5.1 TEM Cell

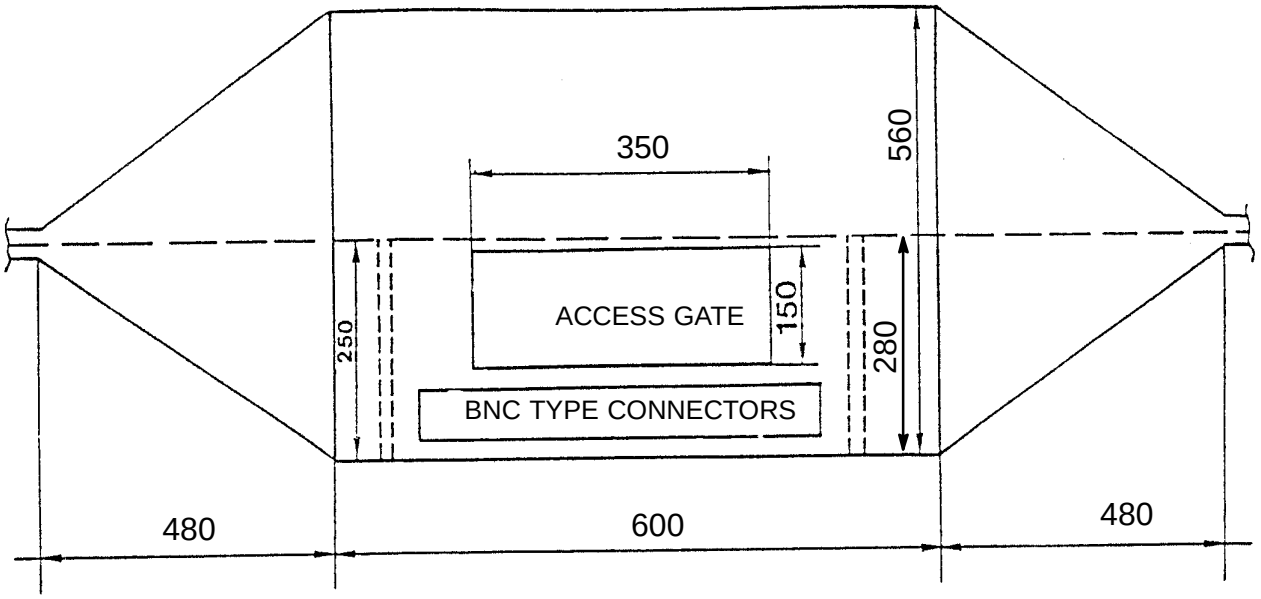
It must be of the closed type, non radiating and with the geometrical characteristics described in **Figure 2A** and **2B**. Cell dimensions are meant as internal.
Mechanical dimensions must be such as to obtain an optimum characteristic impedance for correct interfacing with power amplifier and for allowing radiance of tested electronic system connected to fictitious wiring.
Cell central baffle height must be > 25 cm ± 10%.
The Tem Cell must have an access gate for component positioning, a filter carrier panel where fictitious wiring (inside Tem Cell) can be connected to cables coming from the outside; and must also have, at front wall level, a connector (A1) connected in the shortest way as possible to a series of connectors – type BNC (A2) – according to what described in **Figure 3**.
Tested part dimensions which can be inserted inside Tem Cell must not exceed:

– length: 230 mm;
– depth: 180 mm;
– height: 80 mm.

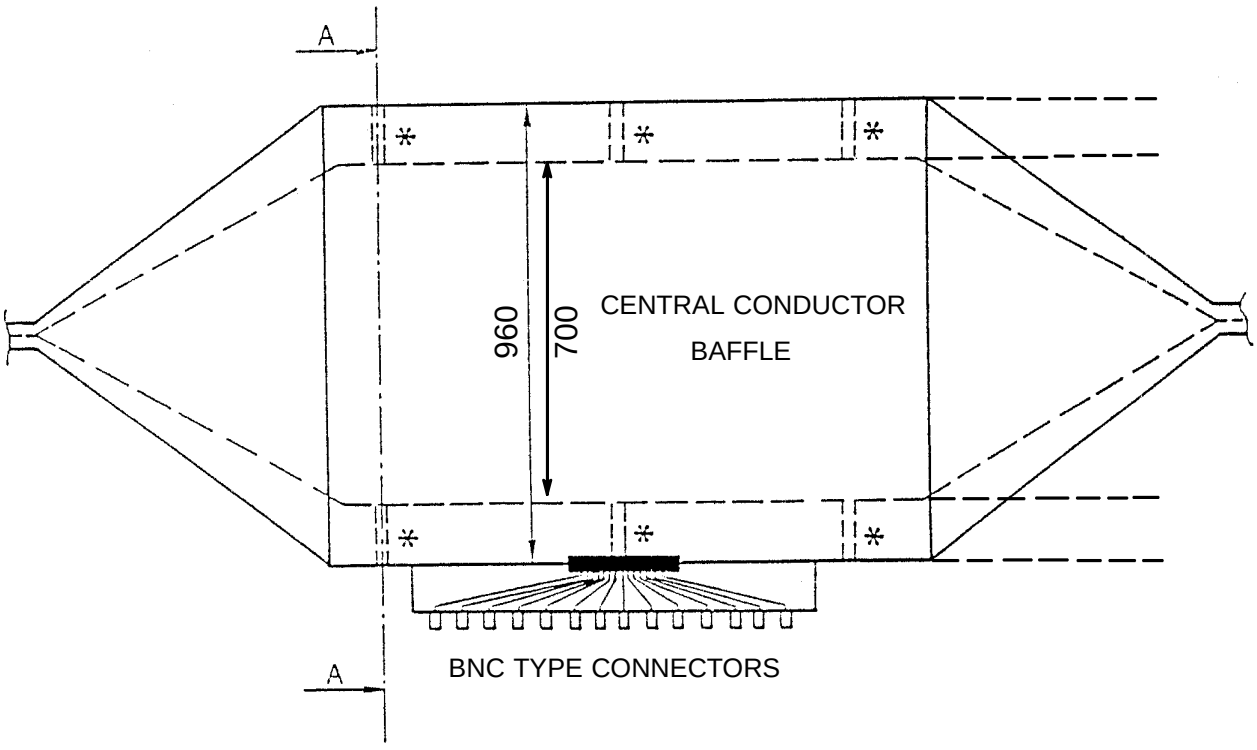
Tem Cell electric characteristics must comply with frequency range and electromagnetic field maximum intensity requirements and also:

– standing wave ratio (R.O.S.), measured at empty Tem Cell input (i.e. absence of tested component and internal connections) closed on 50 Ω, must be < 2 :1 for the whole frequency band;
– electric field radiated from Tem Cell towards the outside, must not exceed intensity E = 1 V/m at 1 m distance from the cell itself, under maximum electric field conditions when it is generated internally and connections are absent.

FIGURE 2A – TEM CELL GEOMETRICAL CHARACTERISTICS



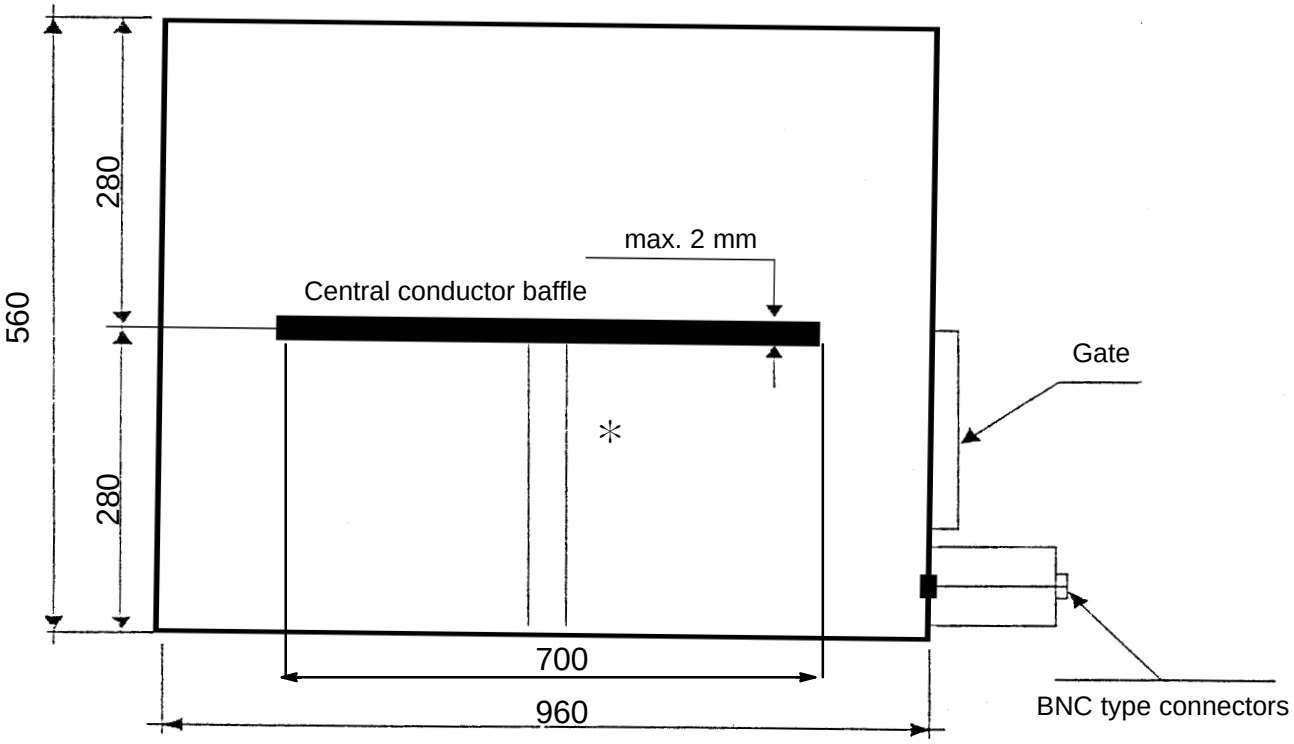
FRONT VIEW



TOP VIEW

⁎ Dielectric material support

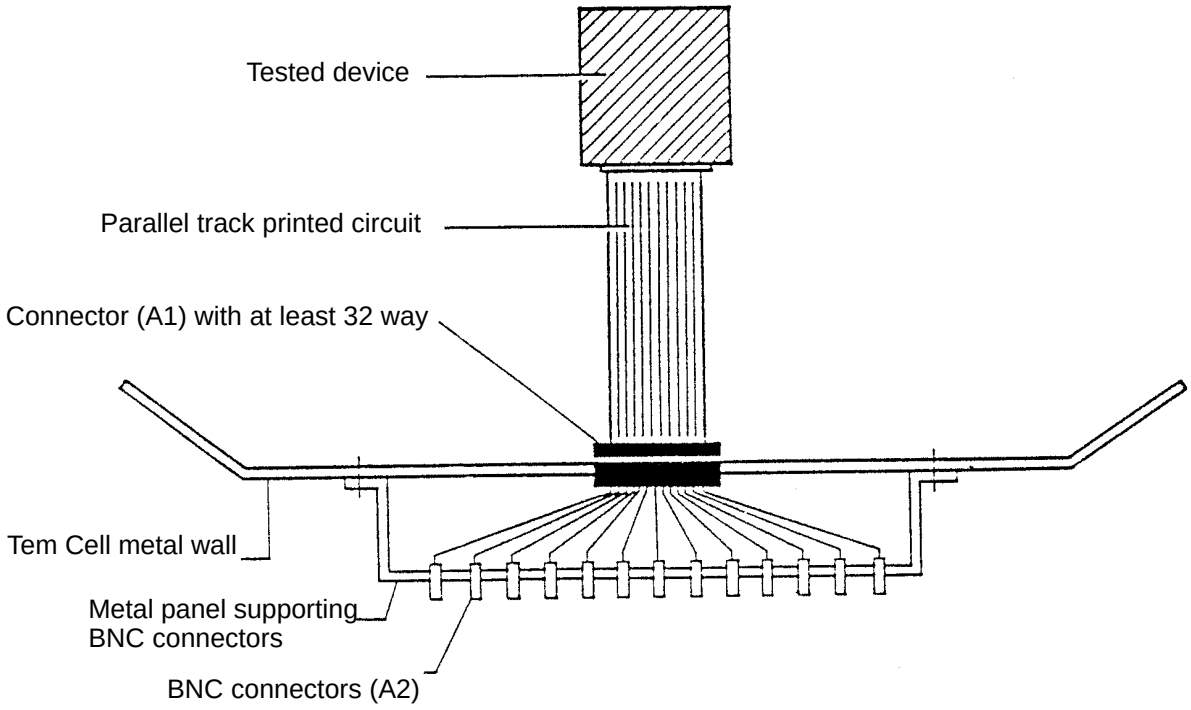
FIGURE 2B – TEM CELL GEOMETRICAL CHARACTERISTICS (SECTION A–A VIEW)



⁎ Dielectric material support

Dimensions in mm.

FIGURE 3 – DETAIL OF CONNECTIONS



5.2 Isotropic electromagnetic field meters

They must carry out electromagnetic field surveys in the frequency range between 10 KHz – 220 MHz and must be fed by internal batteries and fitted with an optical fiber output for remote indication.

5.3 Stimulating and monitoring system for the device being tested

– It must allow the correct operation of the system being tested in normal conditions of use, as provided by the drawing or the related specification.

– It must be capable of correctly interfacing with the system under test sensors and actuators, without altering their functional electric characteristics (impedances).

To comply with the above mentioned requirements, the system must be made up as follows:

5.3.1 *Stimulating system*

– Instrumentation for generating sensor stimulating signals.

– Stimulating signal transmitting unit with electro–optical conversion.

– Signal reception unit with opto–electrical conversion.

– Injection devices of stimulating signals to sensors.

– Optical fibers connecting transmission and reception units.

5.3.2 *Monitoring system*

– Signal transmitting unit for monitoring the operation condition of the system under test with electro–optical conversion.

– Reception unit with signal opto–electrical conversion for monitoring operation condition.

– Optical fibers connecting transmission and reception units.

– Monitoring instruments.

5.4 Power supply

Power supply with adjustable voltage between 0 – 40 V, 80 A, according to IVECO STD. 16–2108, with a 12 V, 70 Ah, 350 A battery as a backup (1 battery for 12 V tests, 2 batteries for 24 V tests).

5.5 Impedance stabilization network (L.I.S.N.)

It must be realized according to the wiring diagram in **Figure 4**, and have the impedance characteristics varying with frequency as indicated in **Figure 5**.
It must also comply with the following requirements:

– the resistance between P and B, when A and B terminals are short–circuited must not deviate by more than 10% from the theoretical curve shown in **Figure 5**, in the 100 KHz – 20 MHz frequency band;

– the C capacity must stand continuous voltages of at least 1500 V;

– the L inductance must stand tested device supply current.

FIGURE 4 – L.I.S.N. WIRING DIAGRAM

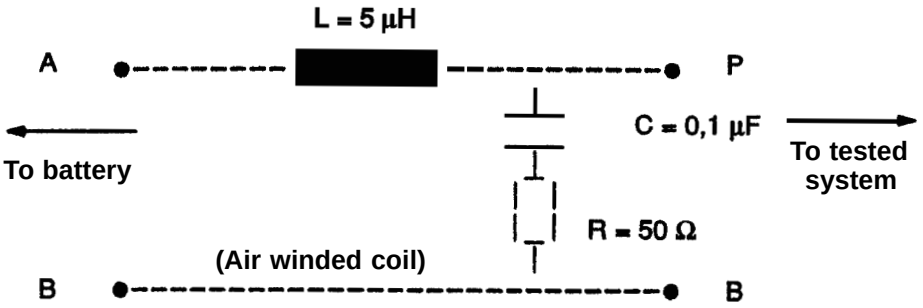
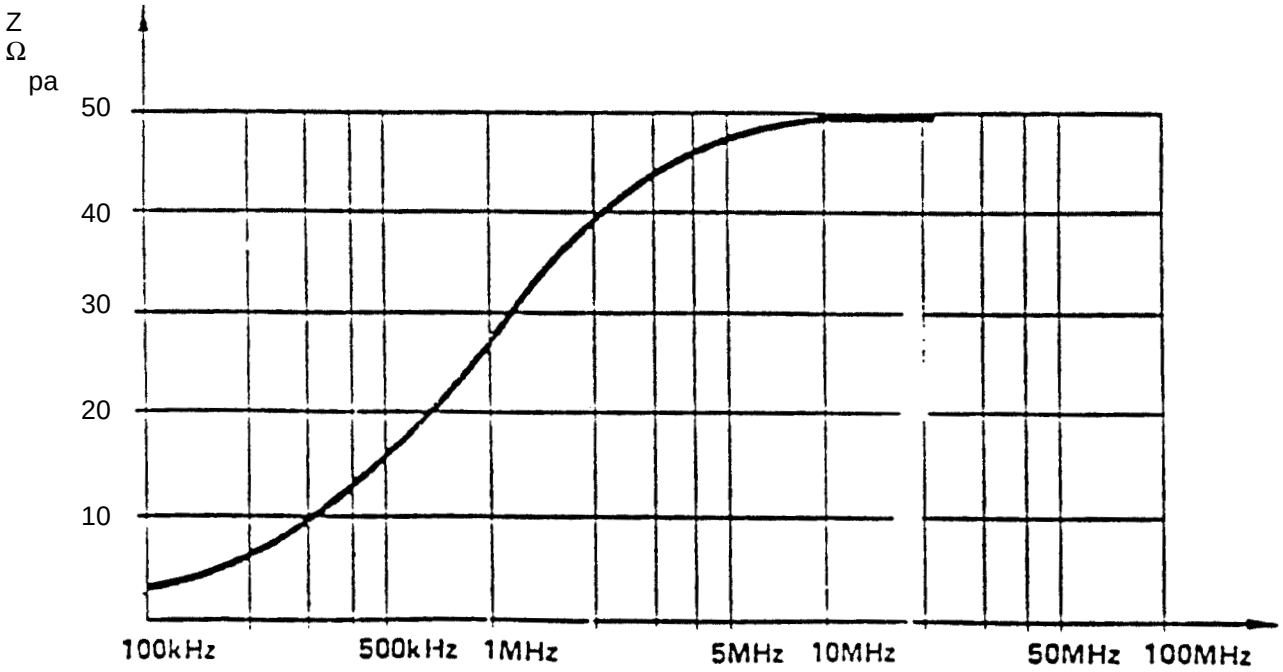


FIGURE 5 – IMPEDANCE MODULE BEHAVIOUR (A and B terminals are short–circuited)



5.6 **Radiofrequency generating/controlling system**

Instrumentation must be situated outside Tem Cell.
It is composed of the following instruments:

5.6.1 ***Signal generator***

It must be able to generate sinusoidal signals in the frequency band from 10 KHz to 200 MHz, amplitude modulated with modulated index varying between 0 (absence of C.W.) and 80%, with modulating frequencies (sinusoidal) of 400 – 1000 Hz.
The accuracy of the carrier frequency must be ± 1% and the harmonics (or other spurious signals) must be at least 25 dB below the fundamental frequency. Amplitude must vary with continuity from 0 to steps below 0.5 dB.

5.6.2 ***Radiofrequency power amplifiers***

They must have the following technical characteristics:

– Minimum frequency band: 10 KHz – 200 MHz;

– Generated power adequate to obtain the electromagnetic field level (E.M.) required in point 4.3;

– Harmonics: at least 15 dB less than the fundamental frequency, for the whole operating band;

– Other non harmonic signals: at least 20 dB less than the fundamental frequency, for the whole operating band;

– Input power to obtain the maximum output power (sensitivity): 1 mW (0 dBm) on a 50 Ω load.

5.6.3 ***Radiofrequency wattmeters***

They must have the following technical characteristics:

– Minimum frequency band: 10 KHz –1 GHz;

– Measurement accuracy in the test frequency band of at least ± 0.5 dB;

– Accepted input power: it must be compatible with the frequency coming out from Tem Cell load resistive attenuator.

5.6.4 ***Load resistive attenuator for Tem Cell***

It must have the following technical requirements on the whole frequency band:

– Impedance: 50 Ω;

– Maximum available power greater than that generated by radiofrequency amplifier;

– Resistive attenuator standing wave ratio (R.O.S.) must be less than 1.2:1;

– Attenuation accuracy in test frequency band must be at least ± 0.5 dB, if this accuracy is not guaranteed, it is necessary to gauge attenuation and take into account gauging values during measurement phase.

5.6.5 ***Directional couplers***

They must have the following technical requirements:

– Direct power measurement (with possibility of optionally measuring also the reflected power);

– Accepted input power: it must be compatible with the maximum power generated by radiofrequency power amplifiers;

– Measurement accuracy: ± 0.5 dB in the respective frequency bands.

5.6.6 ***Control and switching unit***

It must drive signal and power switches and radiofrequency amplifiers, coherently with the required test bands.

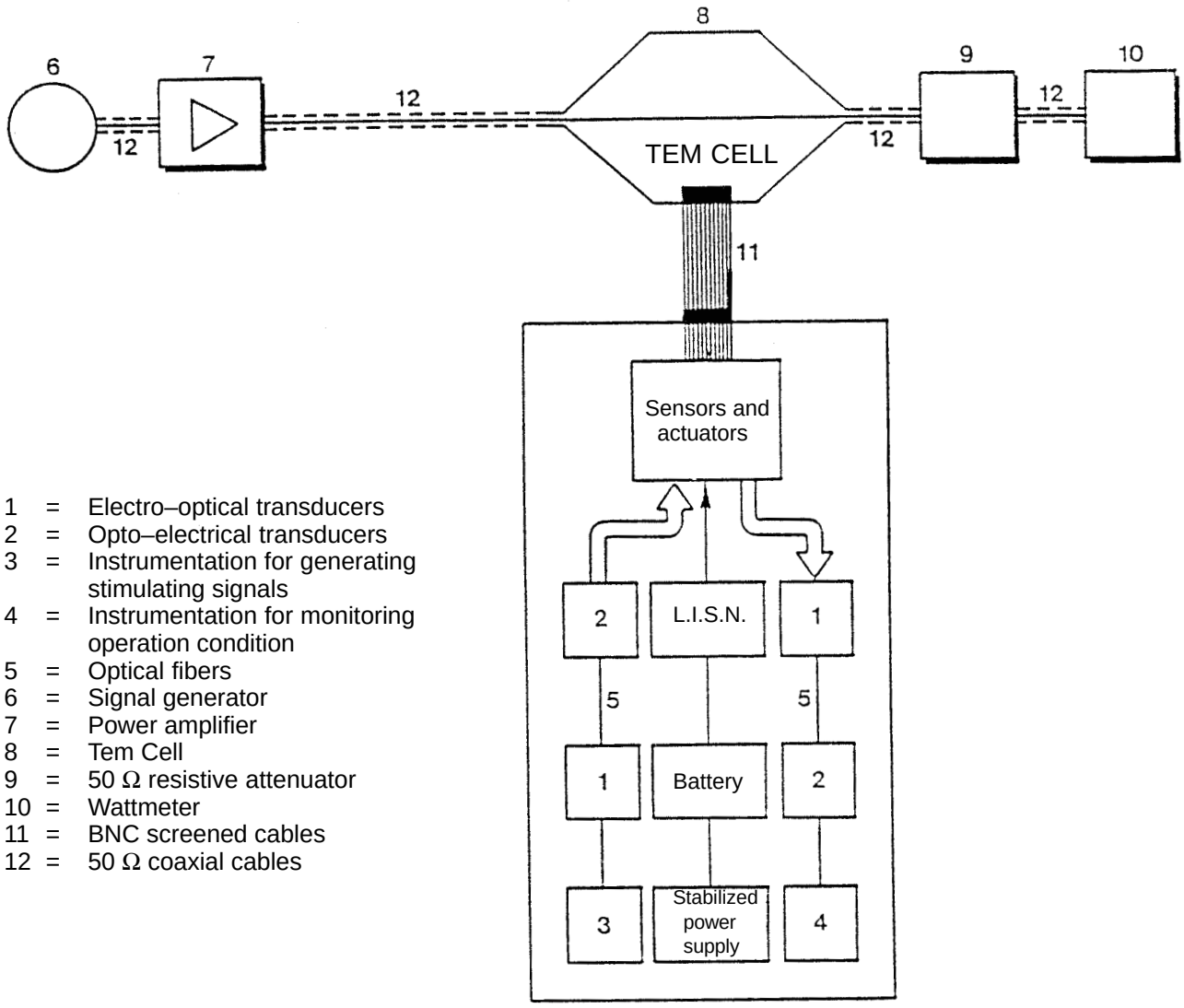
5.6.7 ***Electric field repeaters***

They must be with optical fiber input and indication, through digital or analogue display, of the measured quantity.

6 TEST BENCH

Figure 6 shows the block diagram and **Figure 7** shows the test circuit.

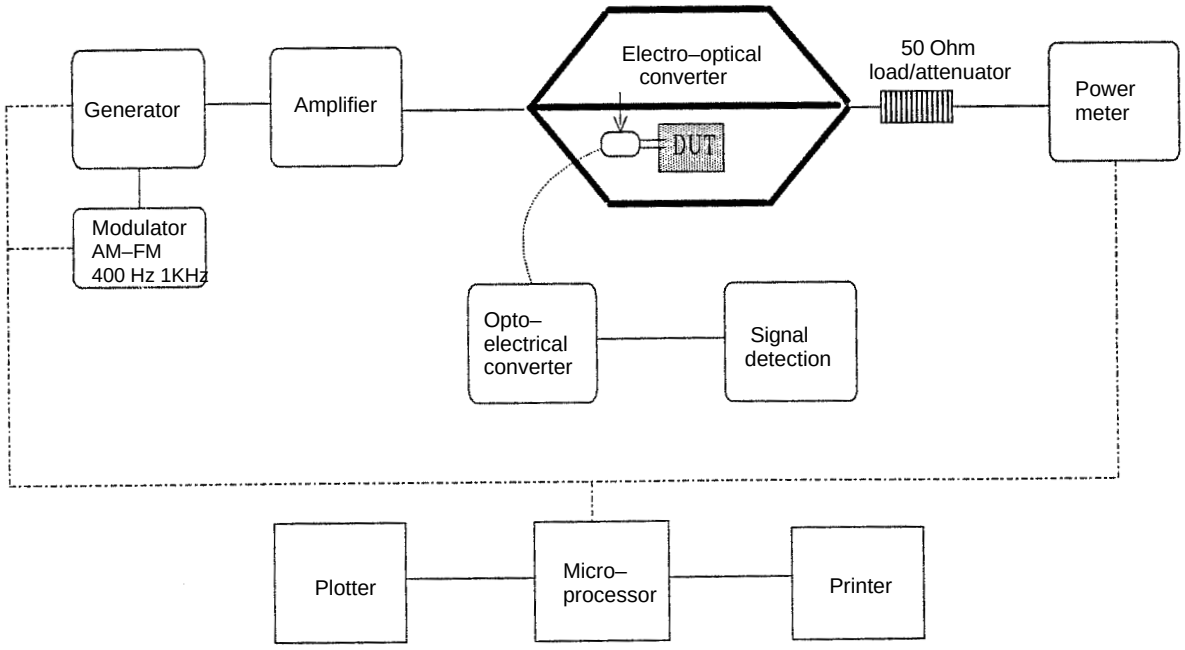
FIGURE 6 – TEST BENCH BLOCK DIAGRAM



1 = Electro–optical transducers
2 = Opto–electrical transducers
3 = Instrumentation for generating stimulating signals
4 = Instrumentation for monitoring operation condition
5 = Optical fibers
6 = Signal generator
7 = Power amplifier
8 = Tem Cell
9 = 50 Ω resistive attenuator
10 = Wattmeter
11 = BNC screened cables
12 = 50 Ω coaxial cables

Stimulating and monitoring system

FIGURE 7 –



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_____ OPTICAL FIBER

6.1 Connect: signal generator, power amplifier, Tem Cell, 50 Ω resistive load attenuator, wattmeter and stimulating and monitoring system with power supply for tested device and impedance stabilizer network, as shown in **Figure 7**.

6.2 Lay down tested device exactly at the volume center of the Tem Cell lower half, insulated from its base by means of a low dielectric constant material layer (e.g. wood, see **Figure 8**).

If the device is connected to vehicle earth, simulate this connection by means of a Bonding (preferably built with copper plait), as short as possible, anchored between tested ECU and Tem Cell lower plane.
The test must be carried out with ECU positioned on both X and Y planes.

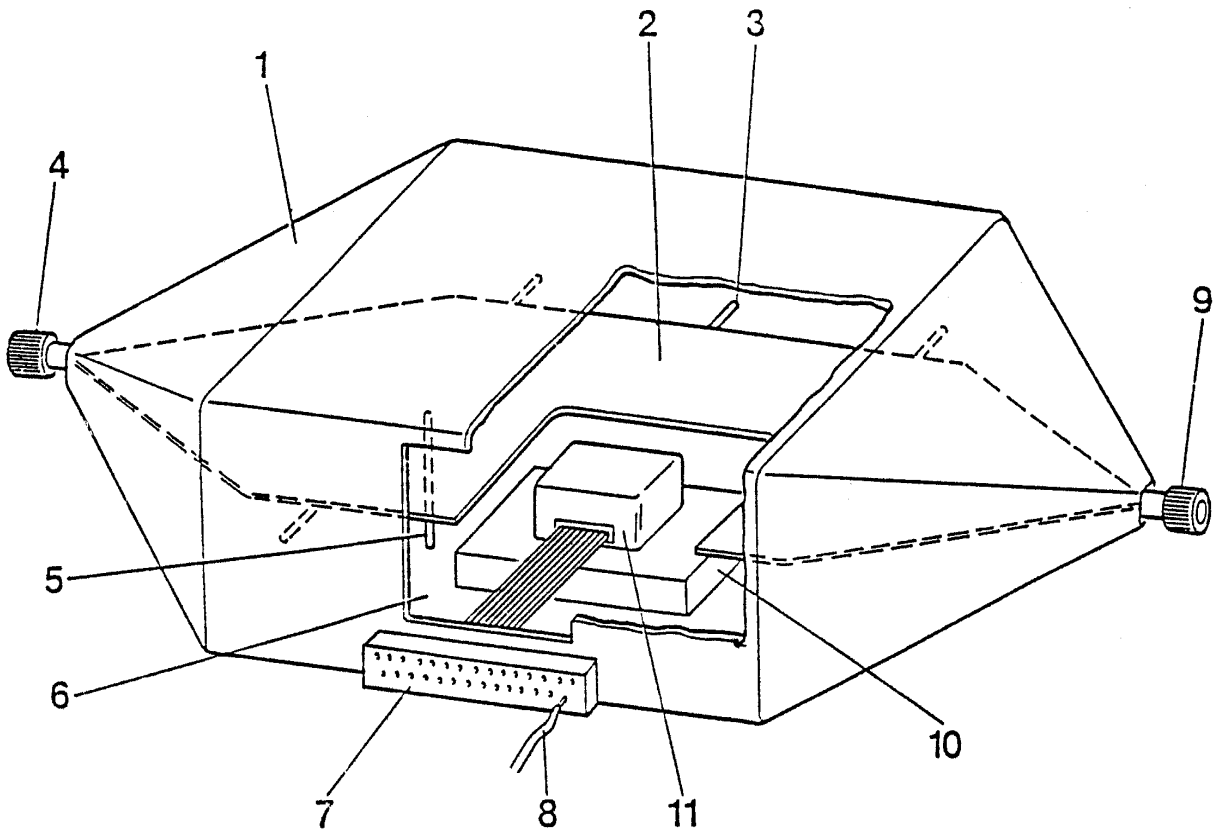
6.3 Connect tested device to connector (A1), present on Tem Cell front wall, by means of a parallel track printed circuit (see **Figure 3**).
Printed circuit tracks must be straight and parallel, correctly dimensioned for the currents they must drive.

When using a cable harness, screen it and place it as near as possible to the cell plane, metal braiding must be connected to Tem structure only on crossing panel, unless actual installation requires screen connections to tested control unit.

6.4 Power supply and all peripheral units (sensors, actuators, etc.) necessary to tested device operation, must be placed outside the Tem Cell and connected to tested device through BNC connectors situated on cell wall (see **Figure 6**).
Cables between these external equipments and BNC connectors must be only of the screened type with length exceeding 2 m.
Cable screening must be connected to Tem Cell external metal structure.
If necessary sensors and actuators must be inserted inside a screened connector to avoid radiations towards operators.

6.5 Sensors must be stressed through stimulating system described in point 5.3.1.
Indicative signals for tested device operating condition must be measured through monitoring system described in point 5.3.2.

FIGURE 8 – TESTED DEVICE LAYOUT



Key:

1	Tem Cell	7	Panel supporting BNC connectors (A2)
2	Tem Cell central conductor baffle	8	Screened connecting cables
3	Dielectric material insulator	9	Output connectors
4	Input connector	10	Insulating support with low dielectric constant for system under test (e.g. wood)
5	Dielectric material insulator	11	System under test (maximum height must be 1/3 of that between central baffle and Tem Cell base wall)
6	Access gate		

7 CHECK METHODS

7.1 Gauging of tested areas when system is absent

It consists in acquiring the power curve irradiated by the Tem Cell necessary to generate, in the chosen measurement point, an electric field whose intensity is known and constant.
This reference curve allows, during checks on the component, and provided it is in the same radiation conditions, to return to the “loadless” value of the electric field through reading only the irradiated power, since the quadratic ratio linking the electric field with Tem Cell power stands always valid.
By the term “power control” it is normally meant the feedback method applied on the gauging curve.

7.2 Gauging procedure

Field meter must be placed at the same point where the wiring center point of the system under check will position after it is installed on Tem Cell test baffle where is situated electromagnetic field sensor, the place must be gauged with a continuous signal (C.W.).
Gauging can be used for all the following checks provided of assuring always the same layout of the device being tested.

8 TEST EXECUTION

8.1 Supply and activate the device under test as specified in drawing or in the related Specification.

8.2 Adjust signal characteristics sent to Tem Cell in order to obtain the electromagnetic field intensity and test frequencies required in the Specification or in the related drawing.

8.3 Radiation of the device under test and automatic frequency scanning at electric field levels, complying with frequency step and preset permanence times; use different types of signal generators and amplifiers consistently with the respective frequency bands.
For every generated frequency adjust amplitude of the signal produced by generator in order to obtain, at amplifier output, the necessary power (defined at gauging stage) for carrying out the required electromagnetic field.
If it is not possible to attain the required electromagnetic field intensity; maximum output power from amplifier must in any case be obtained.

NOTE **:** *Adjust Tem Cell input signal characteristics in order to obtain the specified electric field intensity, test frequencies and modulation type.*
Calculate electric field with the following ratio:

$$E = \frac{\sqrt{P\frac{R}{A}}}{H}$$

Where:

- E = Electric field intensity (in V/m)
- P = Power measured by wattmeter (W)
- R = 50 Ω
- A = Power attenuation value introduced by resistive attenuator (figure less than 1)
  (example of attenuation with 20 dB, A = 0.01)
- H = Distance between ground plane and Tem Cell upper conductor (in meters) = 0.25 m.

8.4 Test summary table

Position of system under test	Exactly at volume center of Tem Cell lower half, insulated from its base by means of a low dielectric constant material layer (wood).
System operation conditions	Normal operation under the operating conditions imposed to vehicle.
Test area gauging	In the absence of system, with field sensor exactly at volume center of Tem Cell lower half.
Frequency bands	BAND 1: 10 KHz – 20 MHz BAND 2: 20 MHz – 200 MHz
Frequency step	Logarithmic with 100 points per decade or for linear band 2 with 1 MHz steps.
Frequency permanence	3 s, or the time necessary to check correct operation of the device being tested.
Required qualification level	BAND 10 KHz – 200 MHz : 200 V/m.
Modulation type	CW or with amplitude modulation with 80% modulation index.
Test methods (for substitution)	Automatic frequency scanning with closed ring check of radiated power on the basis of gauging curve. Manual search of susceptibility limits.
Test methods (calculated)	Adjust Tem Cell input signal characteristics in order to obtain the specified electric field intensity, test frequencies and modulation type. Calculate electric field with the formula shown in the note of point 8.3.

9 FUNCTIONAL CLASS CLASSIFICATION

The functional states of the electronic devices during tests can be referred to the following classes:

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

– *CLASS B*: All device functions meet 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 Specification or by the Product specification.
These functions however reach back their characteristic value at the end of the disturbance.

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

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

– *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 value at the end of the disturbance until the device is repaired or replaced.

NOTE **:** *Irreversible failures (FUNCTIONAL CLASS E) are not admissible on tested devices, subjected to the maximum test level.*

10 FAILURE CLASSIFICATION OF COMPONENTS/SYSTEM AND RELATED TEST LEVELS

10.1 Failure classification

With respect to the functions carried out on the component/system, the following failure classification is provided:

– **P**: Priority failure that affects vehicle control, perceivable by the Driver or other road user, or that generates operation alterations which could cause confusions to other road users.

– **NP**: Non–priority failure that does not affect vehicle control or secondary functions for the examined system.

These classifications will be defined on the relevant product specifications.

11 TEST LEVELS

Carry out the test at 200 V/m from 10 KHz to 200 MHz with amplitude modulation with 1 KHz frequency modulation and 80% modulation index.

11.1 Acceptability limits

The relevant functional class (A – B – C – D – E) achieved by the product being examined during electric field radiation shall be compliant with or higher than what specified for all the test levels or by the related product specification. In case of device malfunctioning, carry out a manual detection of minimum levels electric field at which the device restarts regular operation (susceptibility limit detection).

– From 0 to 100 V/m no defect tolerated.

– From 101 to 150 V/m some non–priority functions can be out of tolerance but they shall return automatically to conformity levels as soon as disturbance disappears.

– From 151 to 200 V/m some priority functions can be out of tolerance but they shall return automatically to conformity levels as soon as disturbance disappears.

12 PRODUCTION OF RESULTS ACCORDING TO THE RELEVANT FUNCTIONAL CLASS ACHIEVED

Types of anomalies found must be shown for every system being verified, for every test condition and for every test level, the electric field/frequency diagrams representing the susceptibility curves and the achieved relevant functional class (A – B – C – D – E). Product functions being examined must comply with the tabulated prescriptions.

LEVEL	CLASS ACHIEVED	RESULTS/REMARKS
0 – 100 V/m	A	No defects, both during and after disturbance
101 – 150 V/m	B	Non–priority function defect that resets automatically as soon as Radio Frequency disappears
151 – 200 V/m	B	Priority function defect that resets automatically as soon as Radio Frequency disappears

STANDARDS QUOTED

IVECO STD.: 16–2108, 18–2252.