INTERNATIONAL STANDARD

ISO 11451-2

First edition
1995-11-23

AMENDMENT 1
1997-08-15

Road vehicles — Electrical disturbances by narrowband radiated electromagnetic energy — Vehicle test methods —

Part 2:
Off-vehicle radiation source

AMENDMENT 1

Véhicules routiers — Perturbations électriques par rayonnement d'énergie électromagnétique à bande étroite — Méthodes d'essai des véhicules —

Partie 2: Source de rayonnement hors du véhicule

AMENDEMENT 1

Reference number
ISO 11451-2:1995/Amd.1:1997(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Amendment 1 to International Standard ISO 11451-2:1995 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 3, *Electrical and electronic equipment*.

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X.400 c=ch; a=400net; p=iso; o=isocs; s=central

Printed in Switzerland

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Page 10

Add the following annex.

Annex B
(informative)

TLS coupling to a device under test and interpretation of test results

B.1 Introduction

A Transmission Line System (TLS) field couples to a device under test in a different mode from the coupling of a radiated electromagnetic wave. These differences are explained in the following clauses, and a method for achieving a realistic correlation between both coupling mechanisms is described.

B.2 Coupling of a TLS to a large object

B.2.1 Model

The vehicle to be tested is positioned longitudinally under the TLS which generates the field. The vehicle is considered as a transmission line which is interacting with the TLS. The mode of coupling is that of coupled transmission lines.

In the case of coupled transmission lines the entire power can be transmitted from the first line to the second one. This is possible if both lines are arranged in parallel over a certain distance, the critical length (l_{cr}). This critical length depends on the geometry of the conductor assembly and the frequency. Along the transmission line the coupled power follows a sine square function (see B.2.3). The shape of this function shows that at half the critical length, half of the power is transferred from the emitting line to the coupled line. Subclause B.2.3 gives a brief description of the theory of coupling.

The character of the coupling under a TLS is that of a line coupling, i.e. the size of the device under test in relation to the TLS strongly influences the coupling. The nature of line coupling is completely different from the radiation coupling with antennas. Antennas are narrowband transmitting and receiving elements with directional patterns.

It can be concluded from these explanations that the TLS coupling is very strong. It differs considerably from the power transmission between two antennas.

Correlations to free field conditions are not to be expected.

B.2.2 Verification

The coupling factors resulting from model calculations vary significantly. The reasons for this are inaccurate estimations of coupling capacitances and mutual inductances in the model. Hence, a verification of the theoretical results by measurements is necessary and for that purpose a transverse electromagnetic mode (TEM) cell is used.

The TEM cell simulates the TLS in the EMC test chamber. A truck is simulated by a stripline arranged at different heights under the septum of the TEM cell. The stripline is terminated at both ends with 50 Ω terminating resistors and the power coupled into the line is measured. For a stripline of length 1 m, maximum power was measured at 112 MHz at a height of 10 cm. The resonance to be expected, according to the $\lambda/2$ coupling (where λ is the wavelength) would be approximately 150 MHz. It is possible to shift this resonance by varying the coupling, i.e. the height of the stripline in the TEM cell. This proves that the critical length depends on the coupling factors. A short description of measurements and their interpretation are given in subclause B.2.3.

It is important to note that measuring results which can be interpreted are only to be expected at frequencies where no chamber resonances occur.

B.2.3 Theoretical considerations and calculation of the critical frequency for TEM coupling

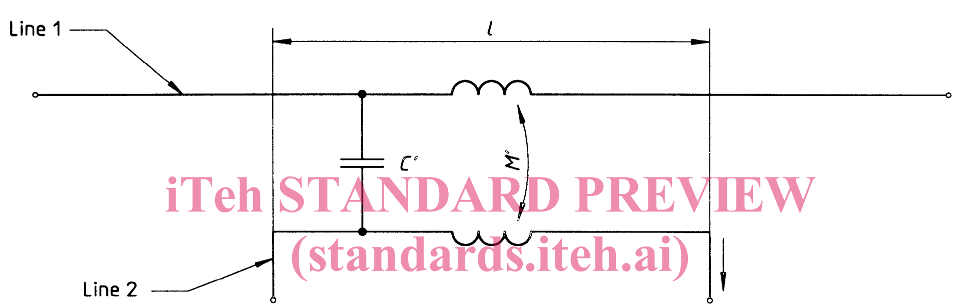


Figure B.1 — Coupling between transmission lines

$$\frac{\partial}{\partial z}\begin{bmatrix} A_1 \\ A_2 \end{bmatrix} = \begin{bmatrix} -\gamma_1 & \kappa_{AB} \\ \kappa_{AB} & -\gamma_2 \end{bmatrix} \cdot \begin{bmatrix} A_1 \\ A_2 \end{bmatrix} \quad \text{... (B.1)}$$

where

A_1 and A_2 are wave amplitudes;

γ_1 and γ_2 are propagation constants;

κ_{AB} is the coupling factor.

The coupled power is dependent on:

— coupling length, l;

— coupling capacitance per unit length, c';

— mutual inductance per unit length, M';

— coupling coefficient, c, expressed in reciprocal metres, calculated from c' and M';

— frequency, f.

For a transmission line which is free of losses the coupling factor is imaginary:

$$\kappa_{AB} = -\mathrm{j}c \ , \ \gamma = \mathrm{j}\beta \quad \text{... (B.2)}$$

The relative power coupled into transmission line 2 along the z-axis follows equation (B.3) (see also figure B.2):

$$P_b = \frac{P_2}{P_1}\left(\frac{c^2}{c^2 + \Delta\beta^2}\right) \cdot \sin^2\left(z\sqrt{c^2 + \Delta\beta^2}\right) \qquad \text{. . . (B.3)}$$

where

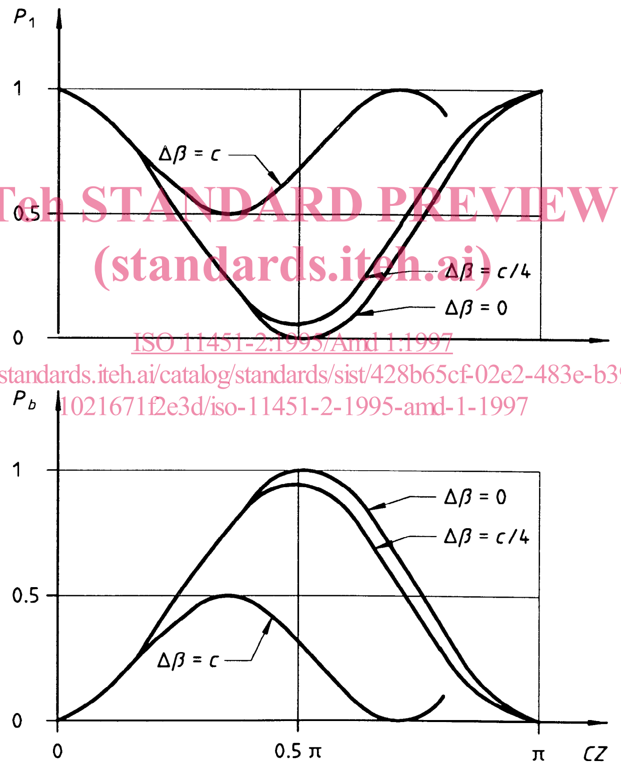
P_b is the relative power normalized to P_1 (i.e. unit is 1);

c is the coupling coefficient, in reciprocal metres;

$\Delta\beta$ is the difference of the phase constants β_1 and β_2, divided by two, in reciprocal metres:

$$\Delta\beta = \frac{\beta_1 - \beta_2}{2}$$

z is the coordinate on the propagation axis, in metres.



[Source: UNGER, H.-G. *Elektromagnetische Theorie für die Hochfrequenztechnik* (Electromagnetic theory for high-frequency techniques)]

Figure B.2 — Power transformation of homogeneously coupled waveguides in longitudinal direction

For $\Delta\beta \approx 0$, equation (B.3) gives $P_b = \sin^2(cz)$. Maxima for P_b are found for $\sin^2(cz) = 1$, i.e. $cz = n(\pi/2)$.

If the coupling length, z, is equal to l_{cr}, the power is completely transferred to line 2. For $n = 1$, this critical coupling length is approximately

$$z = l_{cr} = \pi/(2c) \qquad \text{. . . (B.4)}$$

where c is the coupling coefficient; $c \sim c'/\lambda$ and where λ is the wavelength, in metres.

While the expression $c \sim c'/\lambda$ describes the proportionality of the coupling coefficient c and the quotient of coupling capacitance c' and the wavelength λ, the coupling coefficient c is related to the various capacitances between the conductors themselves and ground as follows:

$$c = (c'/\lambda) \cdot 2\pi/\sqrt{c_1' \cdot c_2'} = c''/\lambda \qquad \text{... (B.5)}$$

where

c' is the coupling capacitance of line 1 and line 2, in farads per metre;

c_1' is the capacitance of line 1 to ground, in farads;

c_2' is the capacitance of line 2 to ground, in farads;

c is the coupling coefficient of the waves in lines 1 and 2, in reciprocal metres;

c'' is the relation of the coupling capacitances adjusted by the impedance of the coupled lines

$$c'' = 2\pi c'/\sqrt{c_1' \cdot c_2'} \qquad \text{... (B.6)}$$

(where c'' has no dimension).

Insertion of equation (B.5) in equation (B.4) gives

$$z = l_{cr} = \pi/(2c) = \pi/(2c''/\lambda) = \pi\lambda/(2c'') \qquad \text{... (B.7)}$$

B.2.4 Example

The example shown in figure B.3 represents a truck under a TLS.

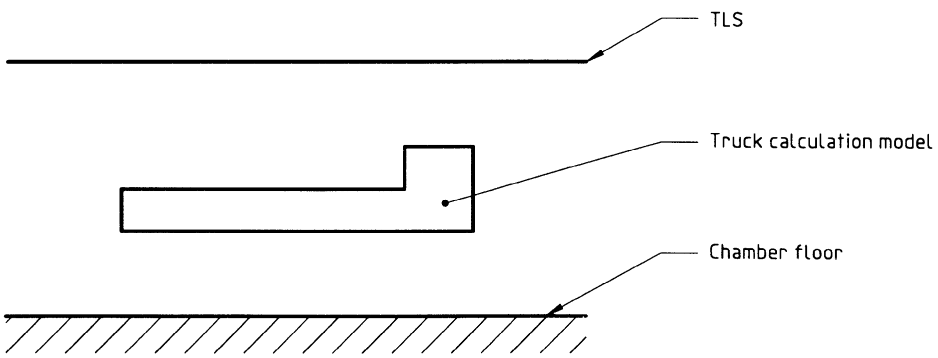


Figure B.3 — Truck model

Using some approximations, the coupling capacitance relation per unit length, c'', between the TLS and the truck model based on real dimensions is found to be in the range

$5{,}6 > c'' > 1{,}7$

Insertion of these values in equation (B.7) gives for the critical length:

$$l_{cr} = \pi\lambda/(2c'') = 300\pi/(2c'' \cdot f) \qquad \text{... (B.8)}$$

values between

$$\frac{84{,}2}{f} < l_{cr} < \frac{277{,}2}{f} \qquad \text{. . . (B.9)}$$

where

f is the frequency in megahertz;

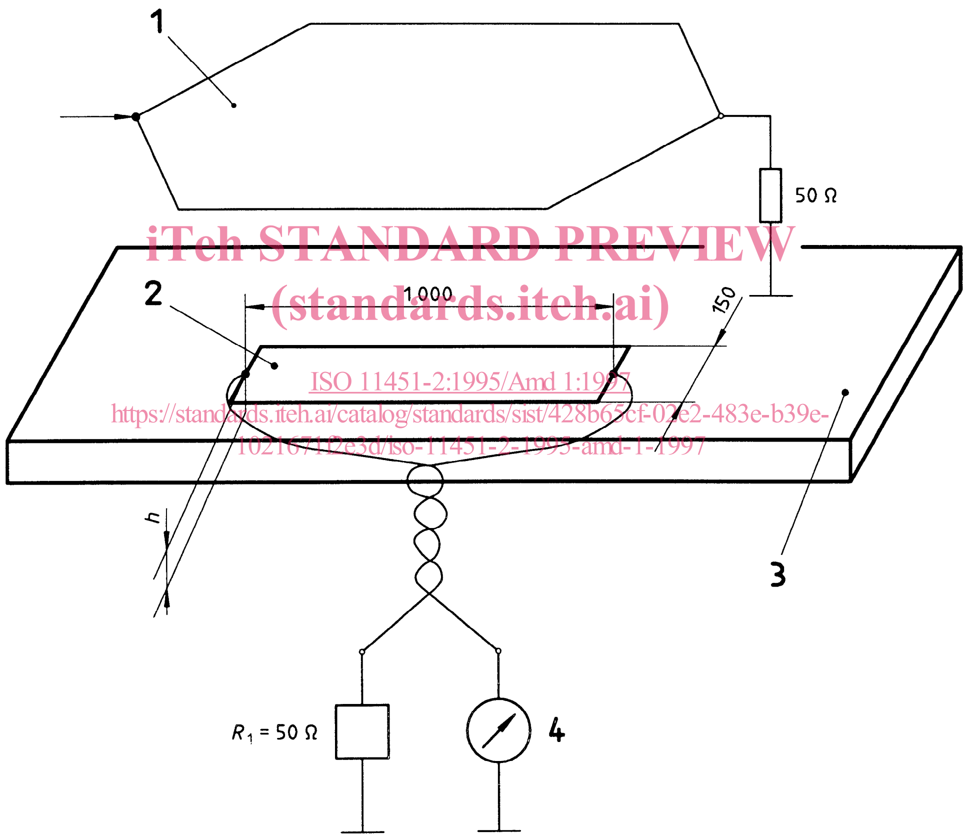
l_{cr} is the critical length in metres.

As an example, for a frequency of 30 MHz, equation (B.9) gives

$2{,}8 \text{ m} < l_{cr} < 9{,}2 \text{ m}$

B.3 Measurement of the coupling of a system in the TEM cell

Dimensions in millimetres



Key

1 Septum
2 Stripline
3 Cell floor
4 Spectrum analyser

Figure B.4 — Schematic arrangement in the TEM cell

B.3.1 Calculated values

For a stripline height h = 0,1 m and with c'' = 2,84 calculated from geometry, for l_{cr} = 1 m, we get:

f_{cr} = 166 MHz

B.3.2 Measured values

For h = 0,1 m (line A in figure B.5), we find

f_{cr} = 112 MHz

With equation (B.8), this results in c'' = 4,2 (recall that c'' carries no dimension).

The method from MEINKE, GUNDLACH, *Textbook of the RF Technics* has been applied to calculate c'' from geometry. A more exact method is known, but it would be extensive with view to mathematics. Taking this into account, the conformity of calculated and measured values is acceptable.

B.4 Use of the TLS in the frequency range up to 30 MHz

When a conductor assembly is used as a field generating device in an absorber lined chamber, cavity resonances may be excited by these conductors and by reflections at the devices under test. Thus, no measurements in the frequency ranges of the chamber resonances shall be made because it is not possible to evaluate the resulting fields.

The frequencies f_{res} of chamber resonances can be calculated according to the following equation:

$$f_{res} = \sqrt{(n_z/a)^2 + (n_x/b)^2 + (n_y/c)^2} \Big/ \left(2 \cdot \sqrt{\varepsilon_0 \cdot \mu_0}\right) \qquad \text{... (B.10)}$$

where

a, b, c are length, width, height respectively, in metres;

n_z are modes 1, 2, 3, ... in the z-direction;

n_x are modes 1, 2, 3, ... in the x-direction;

n_y are modes 1, 2, 3, ... in the y-direction;

ε_0 is the electric constant, in farads per metre;

μ_0 is the magnetic constant, in henrys per metre.

The frequencies can also be measured. For this purpose, a short antenna is used, which generates a field in the chamber. This field is received by a second antenna. At the frequencies of chamber resonances, inhomogenities of the field strength are observed.

B.5 General aspects and results of TLS measurements

In the absence of a device under test (vehicle), for a given height of the TLS above the floor the field strength is nearly constant at any height between the floor and the TLS. The absolute value of the field strength for equal feeding power is a function of the height of the TLS (only valid centrically under the TLS).

If a vehicle is installed in the chamber, the field is partially changed depending on the position of the vehicle and its dimensions. If the height of the device under test is more than half of that of the TLS, the device under test will strongly interact with the field.

It is recommended that the termination impedance Z_a be equal to the wave impedance Z_w. This will result in the smallest ripple on the field along the longitudinal axis of the antenna.

The reference point should be centrically under the antenna. Here the influence of the height is negligible as long as the width of the TLS is not small compared with the width of the vehicle.

B.6 Conclusions

Some physical effects have to be considered regarding the TLS. These effects are discussed above, the conclusions are supported by measurements and calculations.

B.6.1 The TLS is closely interacting with the absorber lined chamber via its room resonances. From measurements and calculations it can be noted that at these resonance frequencies, which are shifted due to the presence of a device under test (vehicle), the influence of the coupling to the vehicle has no correlation to the calibrated field.

Thus, the frequency ranges of the chamber resonances shall be excluded from the measuring ranges in order to ensure reproducible measurements. Taking into account that the presence of the device under test causes a shift of the chamber resonances to lower frequencies, these frequencies shall be excluded.

B.6.2 The TLS in absorber lined chambers also realizes a transmission line coupling of the TEM field to the device under test. In the case of devices under test which are positioned in the longitudinal direction under the TLS, this can lead to an activation with a transmission line wave, which has characteristics completely different from those of a free space wave which would affect this device under test. The power which is transmitted to the device under test depends on the coupling coefficients and the length of the device under test; in the worst case this power can be 100 % of the feeding power of the transmission line. As this power coupling cannot be described in terms of the field strength, the field strength under the TLS is not a suitable parameter. These interrelations are described in B.2 and have also been observed with devices under test as anomalies in the field strength values of their reactions.

B.6.3 Because of the dimensions of large devices under test, e.g. trucks and buses, it is very difficult to realize a TLS with a complete covering of the device under test by a homogenous field in usual absorber lined chambers.

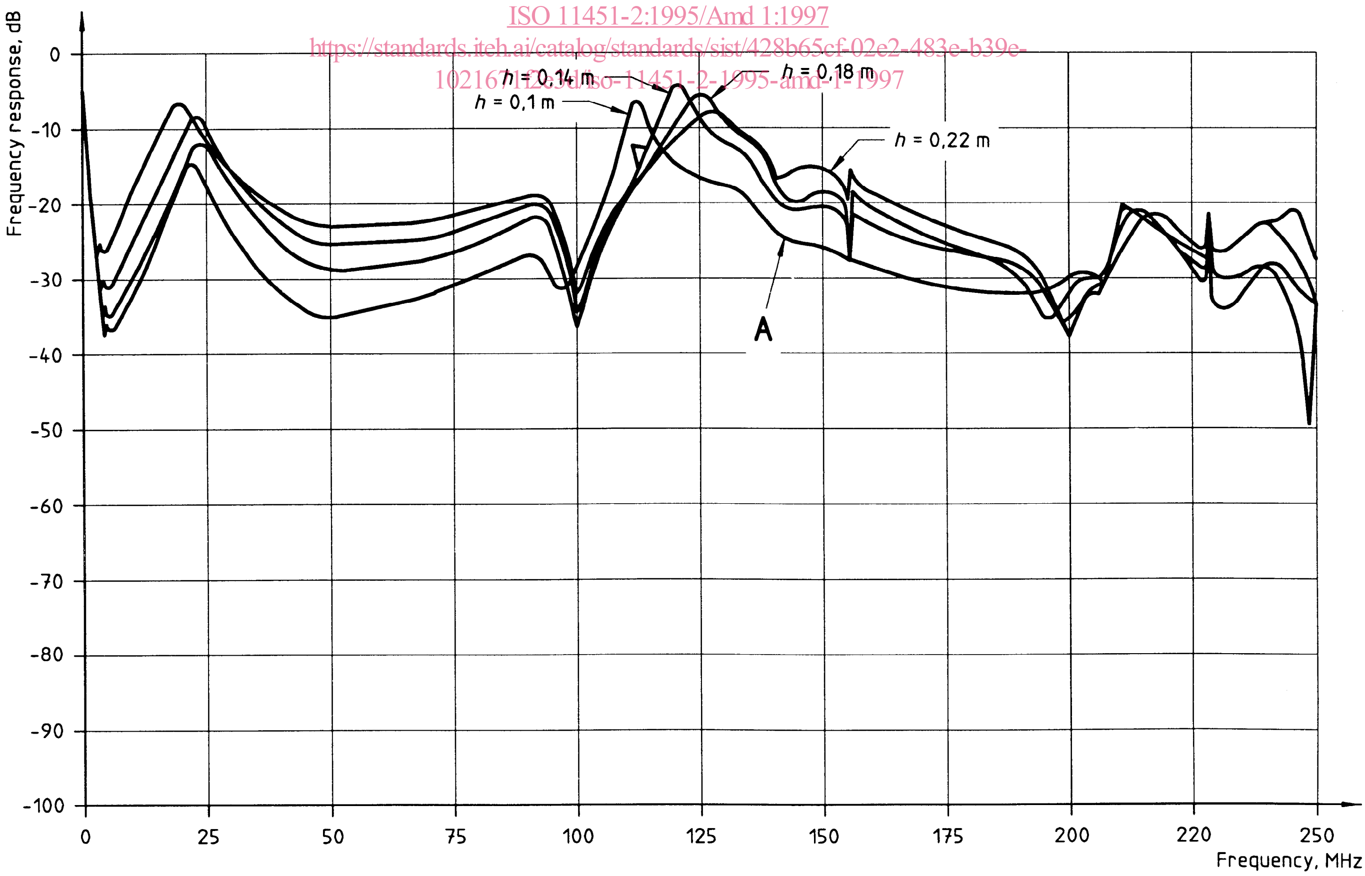


Figure B.5 — Line coupling of a stripline inside a TEM cell for different heights, *h*