SLOVENSKI STANDARD
SIST EN 50289-1-6:2002

01-september-2002

Communication cables - Specifications for test methods - Part 1-6: Electrical test methods - Electromagnetic performance (Note: Applies in conjunction with EN 50289-1-1)

Communication cables - Specifications for test methods -- Part 1-6: Electrical test methods - Electromagnetic performance

Kommunikationskabel - Spezifikationen für Prüfverfahren -- Teil 1-6: Elektrische Prüfverfahren - Elektromagnetisches Verhalten

Câbles de communication - Spécifications des méthodes d'essai -- Partie 1-6: Méthodes d'essais électriques - Performance électromagnétique

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EN 50289-1-6

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ICS 33.120.10

English version

Communication cables -
Specifications for test methods
Part 1-6: Electrical test methods -
Electromagnetic performance

Câbles de communication -
Spécifications des méthodes d'essai
Partie 1-6: Méthodes d'essais électriques -
Performance électromagnétique

Grundnorm für Kommunikationskabel -
Spezifikationen für Prüfverfahren
Teil 1-6: Elektrische Prüfverfahren -
Elektromagnetisches Verhalten

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CENELEC
European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Ref. No. EN 50289-1-6:2002 E

Foreword

This European Standard was prepared by the Technical Committee CENELEC TC 46X, Communication cables.

The text of the draft was submitted to the formal vote and was approved by CENELEC as EN 50289-1-6 on 2000-11-01.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2002-10-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2003-11-01

This European Standard has been prepared under the European Mandate M/212 given to CENELEC by the European Commission and the European Free Trade Association.

Contents

1 Scope

This EN 50289-1-6 details four different test methods to determine the electromagnetic performance characteristics of cables used in analogue and digital communication systems. The four methods are detailed in clauses 6 to 9.

This document discusses test methods aiming to facilitate a selection of the applicable electromagnetic test method.

It is to be read in conjunction with Part 1-1 of EN 50289, which contains essential provisions for its application.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 50289-1-1	2001	Communication cables - Specifications for tests methods - Part 1-1: Electrical test methods - General requirements
EN 50289-1-9	2001	Communication cables - Specifications for tests methods - Part 1-9: Electrical test methods - Unbalance attenuation (longitudinal conversion loss, longitudinal conversion transfer loss)
EN 50290-1-2	[1]	Communication cables - Part 1-2: Definitions
IEC 61196-1	1995	Radio-frequency cables Part 1: Generic specification - General, definitions, requirements and test methods
CISPR 16-1 + A1	1993 1997	Specification for radio disturbance and immunity measuring apparatus and methods Part 1: Radio disturbance and immunity measuring apparatus
ITU-T Recommendation O.9	1988	Series O - Specifications of measuring equipment - General - O.9: Measuring arrangements to assess the degree of unbalance about earth
ITU-T Recommendation G.117	1996	Series G - Transmission systems and media, digital systems and networks - International telephone connections and circuits - General recommendations on the transmission

3 Definitions

For the purposes of this European Standard, the definitions of EN 50290-1-2 apply.

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[1] At draft stage.

4 Survey of electromagnetic test methods

4.1 General

The electromagnetic performance of unbalanced cables (e.g. coaxial RF-cables) is determined only by the quality of the screen. In the case of balanced cables the electromagnetic performance is determined by the combined result of both unbalance attenuation and the effect of screen(s), if any.

The quality of the screen may be evaluated by the measurement of transfer impedance (clauses 6 and 7) or screening attenuation (clauses 8 and 9). The combined result of the unbalance attenuation and the screening attenuation (if applicable) may be evaluated using the coupling attenuation test method (clause 9).

4.2 Transfer impedance Z_T and capacitive coupling impedance Z_F

Two important properties in characterising screening effectiveness of cables are transfer impedance Z_T and capacitive coupling admittance Y_C respectively capacitive coupling impedance Z_F. These properties can be used to calculate the normalised screening attenuation in dB (see 4.4)

The transfer impedance Z_T of an electrically short uniform cable is defined as the quotient of the longitudinal voltage induced in the outer circuit (environment) to the current in the inner circuit (cable) or vice versa, related to unit length (see IEC 61196-1, 12.1.2.1).

$$Z_T = \frac{U_2}{I_1 \cdot L} \qquad (1)$$

where

L coupling length

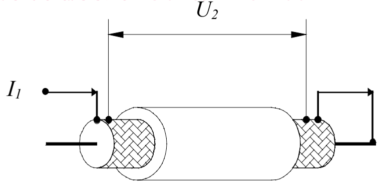


Figure 1 - Definition of transfer impedance Z_T

The capacitive coupling admittance Y_C of an electrically short uniform cable is defined as the quotient of the current in the inner circuit caused by the capacitive coupling to the voltage in the outer circuit, related to unit length (see IEC 61196-1, 12.1.2.1).

$$Y_C = \frac{I_1}{U_2 \cdot L} = j\omega C_T \qquad (2)$$

where

C_T through capacitance

L coupling length

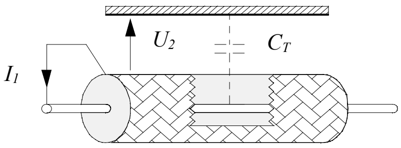


Figure 2 - Definition of coupling admittance

The through capacitance C_T and thus the capacitive coupling admittance Y_C are dependent on the permittivity and geometry of the outer circuit. In order to have a quantity which is invariant on the permittivity and the geometry of the outer circuit and is also comparable to the transfer impedance Z_T we introduce the capacitive coupling impedance Z_F.

$$Z_F = Z_1 \cdot Z_2 \cdot Y_C \tag{3}$$

where

Z_1	characteristic impedance of inner circuit
Z_2	characteristic impedance of outer circuit
Y_C	capacitive coupling admittance

If there are no holes in the screen C_T and Z_F are zero. This is the case for a foil and for double braided screen construction. But in a single braided construction Z_T and Z_F are about the same and Z_F must be taken into consideration.

With electrically short cables, where wave propagation can be neglected, the transfer impedance can be simply obtained as measuring current and voltage.

Therefore the transfer impedance is a suitable criteria to describe the screening effectiveness of electrically short uniform cables.

IEC 61196-1 contains two methods - the triaxial and line injection methods - describing how to measure the transfer impedance of coaxial RF-cables. Clauses 6 and 7 of this standard extend these methods for symmetrical and multi conductor cables as well. In addition this standard provides guidance on impedance matching circuits to be used if the cable impedance is different from the impedance of the test equipment.

The triaxial method only allows measurements at low frequencies (max. 100 MHz) while the line injection method applies for higher frequencies.

4.3 Screening attenuation

With electrically short cables, where wave propagation can be neglected, the screening quantities related to unit length can be obtained as measurement values and directly used to calculate an induced disturbing voltage. In the higher frequency range the transmission characteristics are dependent on the impedance and admittance per unit length as well as on the terminating resistors.

The screening attenuation is a suitable criteria to describe the screening effectiveness of electrically long cables. The screening attenuation is defined as the logarithmic ratio of the power fed into the cable and the radiated maximum peak power:

$$a_S = 10 \cdot \log_{10} \left| \frac{P_{feed}}{P_{rad,max}} \right| \tag{4}$$

For electrically long cables - in a frequency range where the transfer impedance of the cable screen is proportional to frequency - the screening attenuation is length and frequency independent.

The screening attenuation is related to the transfer impedance in one of the following ways:

a) for a matched outer circuit (cable environment) for example in the absorbing clamp method (see clause 9 or IEC 61196-1, 12.4);

$$a_{\mathrm{s,matched}_{\substack{\text{far end}\\ \text{near end}}}} = 20 \cdot \log_{10}\left\{\frac{\omega \cdot \sqrt{Z_1 \cdot Z_2}}{c \cdot |Z_{TE}|} \cdot \left|\sqrt{\varepsilon_{r1}} \pm \sqrt{\varepsilon_{r2}}\right|\right\} \qquad (5)$$

$$|Z_{TE}| = \max|Z_F \pm Z_T| \qquad (6)$$

where

"+"	applies for the near end
"-"	applies for the far end
Z_T	transfer impedance
Z_F	capacitive coupling impedance
Z_{TE}	effective transfer impedance when the capacitive coupling is present (single braided screen)

or

b) for a mismatched outer circuit (cable environment) - with a short circuit at the near end - for example in the shielded screening attenuation method (see clause 8 or IEC 61196-1, 12.6):

$$a_{\mathrm{s,\ mismatched}} = -20 \cdot \log\left\{\frac{c}{\omega\sqrt{Z_1 \cdot 2Z_2}} \cdot \left|\frac{Z_T - Z_F}{\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}}} + \frac{Z_T + Z_F}{\sqrt{\varepsilon_{r1}} + \sqrt{\varepsilon_{r2}}}\right|\right\} \qquad (7)$$

Respectively neglecting of the capacitive coupling

$$a_{\mathrm{s,\ mismatched}} = 20 \cdot \log_{10}\left\{\frac{\omega \cdot \sqrt{Z_1 \cdot Z_2}}{c \cdot |Z_T|} \cdot \frac{|\varepsilon_{r1} - \varepsilon_{r2}|}{\sqrt{2\varepsilon_{r1}}}\right\} \qquad (8)$$

In many cases the capacitive coupling can be neglected. In this case also the near end coupling in a matched outer circuit can be neglected (equation 5). Then the difference between these equations is:

$$\Delta a_s = a_{\mathrm{s,\ mismatched}} - a_{\mathrm{s,\ matched}_{\text{far end}}} \approx 20 \cdot \log_{10}\left(1 + \sqrt{\frac{\varepsilon_{r2}}{\varepsilon_{r1}}}\right) - 4dB \qquad (9)$$

for ε_{r1} = 1,6 and ε_{r2} = 1,1 this difference is $\Delta a_s \approx$ 1,5 dB.

where

Z_T	transfer impedance of cable screen
Z_1	characteristic impedance of cable (inner circuit)
Z_2	characteristic impedance of outer circuit (environment)
c	velocity of light, $3 \cdot 10^8$ m/s
ε_{r1}	resulting relative permittivity of the dielectric of the cable
ε_{r2}	resulting relative permittivity of the environment

4.4 Normalised screening attenuation

The screening attenuation is highly dependent on the velocity difference between the inner and outer circuit. Therefore the test results of the screening attenuation may also be presented in normalised conditions. The normalised conditions are $\Delta v/v_1$ = 10% or $\sqrt{\varepsilon_{r1}/\varepsilon_{r2,n}} = 1{,}1$ and Z_2 becomes the normalised impedance Z_s = 150 Ω.

The difference between the normalised screening attenuation and the measured screening attenuation is calculated by:

$$a_{s,n} = a_s + \Delta a \qquad (10)$$

where

$a_{s,n}$ is the normalised screening attenuation

$$a_{s,n} = 20 \cdot \log_{10} \left| \frac{\omega \cdot \sqrt{Z_1 \cdot Z_S} \cdot \left| \sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2,n}} \right|}{Z_{TE} \cdot c} \right| \qquad (11)$$

$$a_{s,n} = 20 \cdot \log_{10} \left| \frac{\omega \cdot \sqrt{Z_1} \cdot 150 \cdot {}^{1}\!/_{11} \cdot \sqrt{\varepsilon_{r1}}}{Z_{TE} \cdot c} \right| \qquad (12)$$

$$\Delta a = 20 \cdot \log \left(\sqrt{2} \cdot \frac{{}^{1}\!/_{11}}{1 - \dfrac{\varepsilon_{r2,t}}{\varepsilon_{r1}}} \right) \qquad (13)$$

where

$a_{s,n}$	normalised screening attenuation
a_s	measured screening attenuation
ε_{r1}	relative dielectric permittivity of the cable under test
$\varepsilon_{r2,t}$	relative dielectric permittivity of the outer circuit (tube) during the measurement (equals 1,1)
Z_{TE}	equivalent transfer impedance of the cable under test
Z_s	normalised value of the characteristic impedance of the outer circuit of the cable under test, Z_s = 150 Ω
$\varepsilon_{r2,n}$	normalised value of the relative dielectric permittivity of the environment of the cable
Z_1	characteristic impedance of the cable under test

Therefore we have for both solid PE and foamed PE dielectric of the cable (with $\varepsilon_{r1} \approx 2{,}3$ respectively $\varepsilon_{r1} \approx 1{,}6$):

$$\Delta a \approx -10 \text{ dB}$$

The equations (8) and (9) shall be taken to calculate the normalised screening attenuation with a measured transfer impedance.

4.5 Coupling attenuation

The cable (for unbalanced cables) or one cable pair (for symmetrical cables) is fed with the power P_1. Due to the electromagnetic coupling between the cable or pair and the environment surface waves are exited which propagate in both directions along the screen surface (or the cable surface waves where there is not a screen). A surface current transformer is used for picking up the power of the surface waves with an absorber (usually a ferrite tube) to suppress unwanted common mode currents. These kinds of combinations are known as absorbing clamps. On the basis of the peak values of the measured surface currents it is possible to calculate the maximum peak power, P_2 max, in the secondary system formed by the screen of the cable (or the cable itself) and the environment.

The logarithmic ratio of the powers P_1 and P_2 max is termed coupling attenuation, expressed in dB.

For unbalanced cables the coupling attenuation equals the screening attenuation. For symmetrical cables the coupling attenuation is the combined result of both unbalance attenuation and screening attenuation.

The surface current is measured on a swept-frequency basis with a stationary clamp.

Taking into account the effect of both near and far end surface waves, the coupling attenuation a_c is specified by

$$a_c = 10 \log_{10}\left(\frac{P_1}{\max\left[P_{2,n};P_{2,f}\right]}\right) \quad (14)$$

where

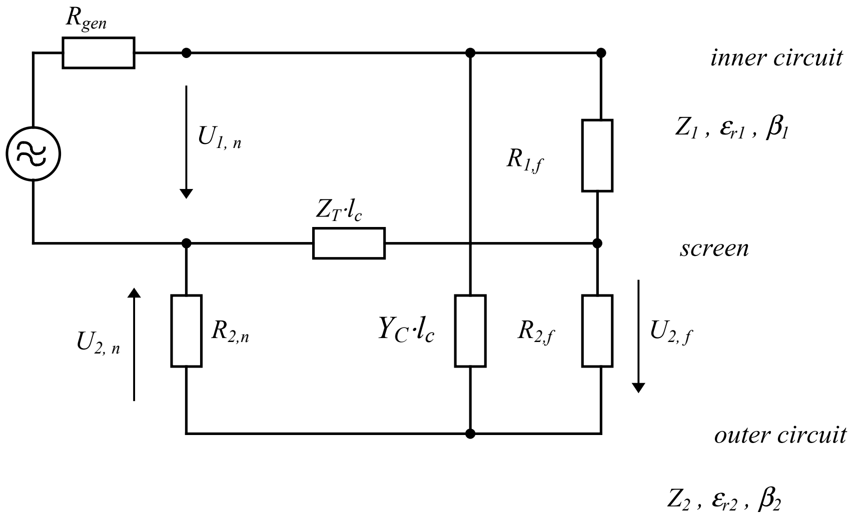
P_1	input power of inner circuit of the sample
$P_{2,n}$	maximum near end coupling peak power
$P_{2,f}$	maximum far end coupling peak power

The advantage of coupling attenuation measurements is that they can be directly used to give information about EMC performance of both screened and unscreened cables.

5 Theoretical background

5.1 General

The three methods (clauses 6, 7 and 8) to measure the screening effectiveness of a cable screen all have the same equivalent circuit.



Key

β_1	phase constant of inner circuit
β_2	phase constant of outer circuit
ε_{r1}	relative dielectric permittivity of the inner circuit
ε_{r2}	relative dielectric permittivity of the outer circuit
L_c	coupling length
M_T	effective mutual inductance per unit length For braided screens $M_T = M'_{12} - M''_{12}$ where M'_{12} relates to the direct leakage of the magnetic flux and M''_{12} relates to the magnetic flux in the braid
R_{gen}	output resistance of generator
$R_{1,\,f}$	load resistance of inner circuit at the far end
$R_{2,\,f}$	load resistance of outer circuit at the far end
$R_{2,\,n}$	load resistance of outer circuit at the near end
R_T	screen resistance per unit length
$U_{1,\,n}$	voltage fed into the inner circuit at the near end
$U_{2,\,f}$	voltage coupled into the outer circuit at the far end
$U_{2,\,n}$	voltage coupled into the outer circuit at the near end
Y_C	capacitive transfer admittance per unit length $= j\omega C_T$
Z_F	capacitive coupling impedance per unit length $= Z_1 Z_2 Y_C$
Z_1	characteristic impedance of the inner circuit
Z_2	characteristic impedance of the outer circuit
Z_T	transfer impedance per unit length $= R_T + j\omega M_T$

Figure 3 - Definitions

5.2 Matched inner and outer circuit

In the line injection method (clause 7) both the inner and outer circuit are matched ($Z_1 = R_{gen} = R_{1,f}$; $Z_2 = R_{2,n} = R_{2,f}$). In that case the coupling through the cable screen, if feedback from the secondary to the primary circuit and the losses are negligible, can be calculated by:

$$\frac{U_{2,\substack{n\\f}}}{U_{1,n}} = \frac{Z_F \pm Z_T}{2Z_1} L_c \cdot S_{\substack{n\\f}} \qquad (15)$$

$$S_n = \frac{1 - e^{-j(\beta_1 + \beta_2).L_c}}{j(\beta_1 + \beta_2).L_c} \qquad (16)$$

$$S_f = \frac{1 - e^{-j(\beta_1 - \beta_2).L_c}}{j(\beta_1 - \beta_2).L_c} e^{-j\beta_2 .L_c} \qquad (17)$$

$$\left| S_{\substack{n\\f}} \right| = \frac{\left| 2 \sin\left(\frac{(\beta_1 \pm \beta_2).L_c}{2} \right) \right|}{(\beta_1 \pm \beta_2).L_c} \qquad (18)$$

$$\beta \cdot L = 2\pi \cdot \sqrt{\varepsilon_r} \cdot \frac{L}{\lambda_0} = \frac{2\pi \cdot L \cdot f}{c} \qquad (19)$$

The first factor in equation (15) relates to the screen parameter and the summing function S to the set-up parameter. Figure 4 shows an example for the summing function S.

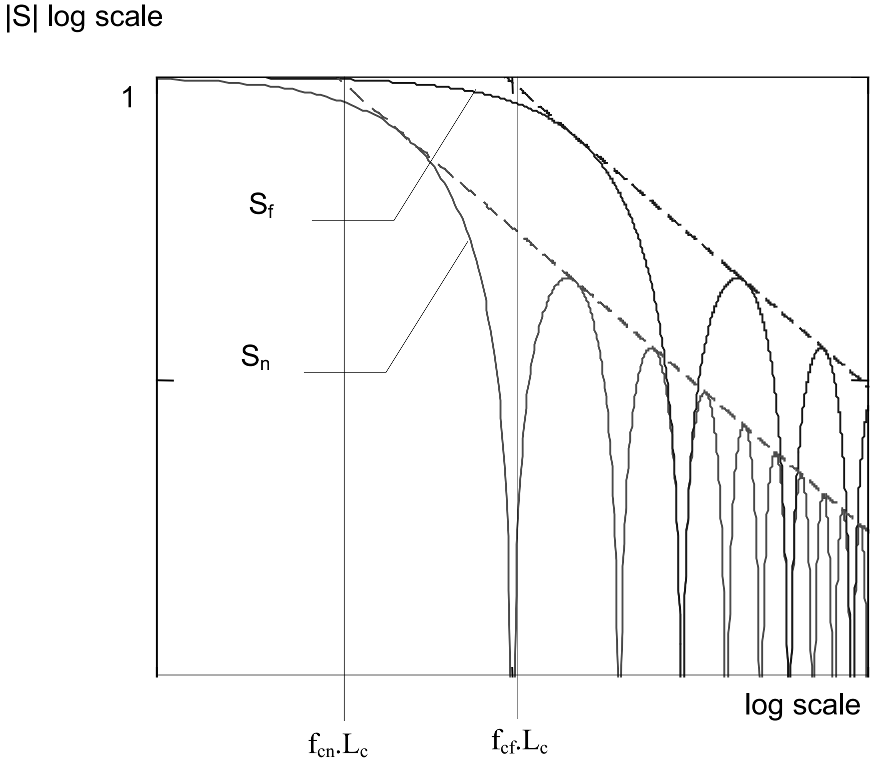


Figure 4 - Calculated summing function S

For high frequencies the asymptotic value becomes

$$\left|S_{\substack{n\\f}}\right| \to \frac{2}{(\beta_1 \pm \beta_2).L_c} \qquad (20)$$

And for low frequencies the summing function becomes

$$\left|S_{\substack{n\\f}}\right| \to 1 \qquad (21)$$

The point of intersection between the asymptotic values for low and high frequencies is the so-called cut-off frequency f_c:

$$f_{\substack{c,n\\f}} \cdot L_c = \frac{c}{\pi \cdot \left|\sqrt{\varepsilon_{r1}} \pm \sqrt{\varepsilon_{r2}}\right|} \qquad (22)$$

With equation (22) we have the condition for electrical short or long cables.

The cable is electrical short if

$$f_{\substack{n\\f}} \cdot L_c \le \frac{c}{\pi \cdot \left|\sqrt{\varepsilon_{r1}} \pm \sqrt{\varepsilon_{r2}}\right|} \qquad (23)$$

or electrical long if

$$f_{\substack{n\\f}} \cdot L_c > \frac{c}{\pi \cdot \left|\sqrt{\varepsilon_{r1}} \pm \sqrt{\varepsilon_{r2}}\right|} \qquad (24)$$

The frequencies where the periodic maxima of S occur are given by

$$f_{\substack{\text{max ima},n\\f}} \cdot L_c = \frac{(1+2m) \cdot c}{2 \cdot \left|\sqrt{\varepsilon_{r1}} \pm \sqrt{\varepsilon_{r2}}\right|} \qquad (25)$$

where m is an integer.

5.3 Matched inner and mismatched outer circuit

In the triaxial methods (clauses 6 and 8) the inner circuit is matched (Z_1 = R_{gen} = $R_{1,f}$) and the outer circuit is mismatched ($R_{2,n}$ = 0, $Z_2 \neq R_{2,f}$). In this case the coupling through the cable screen, if feedback from the secondary to the primary circuit and the losses are negligible, can be calculated by:

$$\begin{aligned} \left|\frac{U_{2,f}}{U_{1,n}}\right| \approx & \left|\frac{Z_T - Z_F}{\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}}} \cdot \left[1 - e^{-j\varphi_1}\right] + \frac{Z_T + Z_F}{\sqrt{\varepsilon_{r1}} + \sqrt{\varepsilon_{r2}}} \cdot \left[1 - e^{-j\varphi_2}\right]\right| \cdot \left|\frac{1}{\omega \cdot Z_1}\right| \cdot \\ & \left|\frac{c}{2 + (Z_2 / R_{2,f} - 1) \cdot (1 - e^{-j\varphi_3})}\right| \end{aligned} \qquad (26)$$