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AMENDMENT 1
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Amendment 1

Radio-frequency cables –

Part 1:
Generic specification – General, definitions, requirements and test methods

Amendement 1

Câbles pour fréquences radioélectriques –

Partie 1:
Spécification générique – Généralités, définitions, prescriptions et méthodes d'essai

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FOREWORD

This amendment has been prepared by subcommittee 46A: Coaxial cables, of IEC technical committee 46: Cables, wires, waveguides, r.f. connectors, and accessories for communication and signalling.

The text of this amendment is based on the following documents:

FDIS	Report on voting
46A/349/FDIS	46A/355/RVD

Full information on the voting for approval of this amendment can be found in the report on voting indicated in the above table.

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Page 15

3.2.3 Braiding formulae

In table 1, against Variable *W*, in the description column, *replace* "N_d" *by* "$N \times d$".

Page 17

3.2.3.2 Lay factor, K_L

Replace the existing equation by the following new equation:

$$K_L = \sqrt{1+\pi^2 \times \frac{D_m{}^2}{L^2}} = \frac{1}{\cos \beta}$$

3.2.3.3 Filling factor, *q*

Replace the existing equation by the following new equation:

$$q = \frac{n \times W}{2\pi \times D_m} \times \sqrt{1+\pi^2 \times \frac{D_m{}^2}{L^2}}$$

Page 35

7.1.1 Sheath marking

Example:

In the first line of the example, replace "50 Ωm" *by* "50 Ω".

Page 41

9.1.5 Expression of results

Replace equation (1) by the following new equation:

$$\text{ovality}\ (\%) = \frac{2(D_1 - D_2)}{D_1 + D_2} \times 100 \qquad (1)$$

Page 43

9.2.5 Expression of results

Replace equation (2) by the following new equation:

$$\text{eccentricity}\ (\%) = \frac{(T_{\text{max}} - T_{\text{min}})}{D} \times 100 \qquad (2)$$

Page 47

10.1.2 Preparation of test specimen

In figures 1a, 1b and 1c, on page 49, replace the tolerance "± 10 mm" *by* "± 2 mm".

Page 49

10.1.3 Procedure

Replace, in the second line of the third paragraph, "10 mm/min" *by* "100 mm/min".

Replace, in figure 2c, on page 53, "Centre conductor" *by* "Outer conductor".

Page 55

10.2.4 Requirement

Replace the second sentence by the following:

The cable shall meet the electrical requirements specified in the relevant cable specification.

10.3.3 Procedure

Replace, in the first line of the first paragraph "...in accordance with test A of IEC 68-2-1..." *by* "...in accordance with IEC 60068-2-1, test Aa, ...".

Page 59

10.6.3 Procedure

Replace, in the third line of the first paragraph "...in accordance with test B of IEC 68-2-2..." *by* "...in accordance with IEC 60068-2-2, test Ba/Bb,...".

Page 61

10.7.3 Procedure

Replace, in the first line of the first paragraph "...in accordance with test B of IEC 68-2-2..." *by* "...in accordance with IEC 60068-2-2, test Ba,...".

Page 63

10.9.3 Procedure

Replace, in the first line of the first paragraph "...in accordance with test B of IEC 68-2-2..." *by* "...in accordance with IEC 60068-2-2, test Bb,..." .

Page 69

11.1.5 Expression of results

Replace equation (3) by the following new equation:

$$R = \frac{R_m}{l \times \{1 + \rho \times (t - 20)\}} \text{ in } \Omega/\text{km} \qquad (3)$$

Page 71

11.2.5 Expression of results

Replace, in equation (4), "in MΩ/km" *by* "in MΩ•km".

11.3.3 Preparation of test specimen

Replace the equations in the note by the following new equation:

$$C = \frac{C_m \times \beta \times l}{\tan(\beta \times l)} \quad \text{with} \quad \beta \times l = 2\pi \times \frac{l \times f}{3 \times 10^5 \times v_r}$$

Page 73

11.3.4.2 Screened twin cable (two terminal method)

Replace equation (5) by the following new equation:

$$\text{capacitance} = \frac{C_a + C_b}{2} - \frac{C_c}{4} \qquad (5)$$

11.3.4.3 Screened twin cable (three terminal method)

Replace equation (6) by the following new equation:

$$\text{capacitance} = \frac{C_e \times C_f}{C_e + C_f} \qquad (6)$$

Page 75

11.3.4.5 Capacitance unbalance of screened twin cables (three terminal method)

Replace equation (8) by the following new equation:

$$\text{capacitance unbalance} = \frac{100\,(C_e - C_f)}{C_d\left[\dfrac{C_e \times C_f}{C_e + C_f}\right]} \quad \text{in \% (corrected)} \qquad (8)$$

11.4.4 Procedure

Replace, in the first paragraph, "...in accordance with test Na and Nb of IEC 68-2-14", *by* "...in accordance with IEC 60068-2-14, test Nb".

Replace, in the third line of the second paragraph, "...at the end of each step" *by* "...at the end of each cycle".

Page 93

11.10.5.2 Procedure

Replace, after equation (17), "where l is in metres, $l \leq n \leq 10$" *by* "where l is in metres".

Page 99

11.10.7 Electrical length and phase delay

Replace equation (24) by the following new equation:

$$\frac{\Delta L_e}{L_e} \approx \frac{4}{D_{3,e} \times \sqrt{f}} \leq 10^{-3} \qquad (24)$$

Page 101

11.11.2.2 Temperature coefficient of phase constant

In equation (26), replace "CT" *by* "t_c".

Page 103

11.11.5.1 Layout

In figure 11, item 3, attenuator, replace "≥ 10 dBm" *by* "≥ 10 dB".

Page 105

11.11.5.3 Expression of results

Replace, in the penultimate paragraph, "The sign of $\delta b_{tot} / b$ or TC is positive..." *by* "The sign of $\delta b_{tot} / b$ or t_c is positive...".

Page 109

11.11.6.3 Expression of results

In equation (30), replace "*TC*" *by* "t_c".

Page 111

11.11.7.3 Expression of results

In equation (32), replace "*CT*" *by* "t_c".

Page 115

11.12.3 Layout

In figure 14, item 1, sweep generator, delete "30 MHz to 1 000 MHz".

Page 117

11.12.5.3 Accuracy of measurement

In the third sentence of the second paragraph, on page 119, replace "...over as wide a frequency range as possible" *by* "...over a frequency range as wide as possible".

Page 119

11.12.6 Procedure

Replace, on page 121, equation (42) by the following new equation:

$$n \geq \frac{3\,(f_2 - f_1)\,l}{150 \times v_r} \qquad (42)$$

Page 133

11.13.7.2 Procedure

In the first line, delete the word "when".

Replace the second line by "for an open-circuited test specimen when".

Replace the fourth line by "for a short-circuited test specimen when".

Page 135

11.13.7.3 Expression of results

Replace equation (52) by the following new equation:

$$\Delta f = (f_{n,2} - f_{n,1}) \,/\, (n_2 - n_1) \tag{52}$$

Replace equation (53) by the following new equation:

$$\alpha = \frac{8{,}686 \times \delta f \times \pi}{2 \times \Delta f \times (1 + 0{,}002 \times (t - 20))} \times \frac{100}{l} \quad \text{in dB/100 m at 20 °C} \tag{53}$$

Replace equation (54) by the following new equation:

$$l = \frac{150 \times v_r}{\Delta f} \quad \text{in metres} \tag{54}$$

where Δf is in megahertz (MHz).

Replace, on page 137, equation (57) by the following new equation:

$$\alpha = \frac{868{,}6}{l \times (1 + 0{,}002 \times (t - 20))} \times \ln\left(\sqrt{1 + \sin(b) + \sin^2(b)}\right) \tag{57}$$

Page 141

11.16.2 Definitions

Replace, in the first line of the second paragraph, "...at the cable end plus the pulse attenuation..." *by* "...at the cable end minus the pulse attenuation...".

Page 143

11.16.4.1 Approximately sine squared pulse

Replace, in the second paragraph, "is the velocity ratio..." *by* "is the nominal relative velocity ..."

Page 149

11.19.2 Definition

Replace equation (67) by the following new equation:

$$P_{u,max} \approx U_0^2 \,/\, Z \tag{67}$$

Page 151

11.19.4.3 Test methods

In figure 28, on page 159, replace, in both the title and the X axis, "Power gain P_3/P_1 dB" *by* "Power gain P_R/P_1 dB".

Replace "$a_k - a_{k,opt}$" *by* "$a_k = a_{k,opt}$".

Replace "$a_k = a_{k,opt}$ + 3 dB" *by* "$a_k = a_{k,opt} \pm$ 3 dB".

Replace "$a_k = a_{k,opt}$ + 6 dB" *by* "$a_k = a_{k,opt} \pm$ 6 dB".

Page 161

After equations (73) and (74), under "where", *add* "L is the series inductance".

Replace equation (75) by the following new equation:

$$U = \frac{U_0 \times Z}{(b \times Z_0) + Z(\tan \delta_L + \frac{a}{b})} \quad (75)$$

Page 163

Replace the line above equation (76) by the following:

"When at resonance $\omega^2 LC = 1$, with ω as the radian frequency, then the test voltage U is defined as:"

Under equation (76), delete the two lines "and when at resonance $\omega^2 LC = 1$" *and* "with ω as the radian frequency".

Replace, in equation (77), "$Z_0 = Z$ et $L/C = Z^2 / a$" *by* "$Z_0 = Z$ and $L/C = Z^2/a$".

Page 165

Replace equation (79), including the text "The maximum test current, I is defined as:" *and the explanatory text under* "where" *by the following:*

When at resonance $$1/\omega C = \omega L \quad (79)$$

where

ω is the radian frequency;

C is the parallel capacitance;

L is the inductance of the test specimen.

Page 167

Replace equations (80), (81) and (82), including the text "At resonance", *by the following:*

$$1/\omega C = Z\,(2\pi\, l_e/\lambda_o) \tag{80}$$

$$1/\omega C = Z \times b \tag{81}$$

then, the maximum test current I is defined as:

$$I = \frac{U_o}{(b \times Z) + Z_o(\tan\delta_c + \frac{a}{b})} \tag{82}$$

Replace the explanatory text under "where" by the following:

l_e is the electrical length of the test specimen;

λ_o is the wavelength in free space at the test frequency;

U_o is the open-circuit voltage of the generator;

Z is the nominal characteristic impedance of the test specimen;

b is the phase shift of the test specimen, in radians;

a is the attenuation of the test specimen, in nepers;

δ_c is the loss angle of the parallel capacitance;

Z_o is the internal impedance of the generator.

Page 169

Replace, after equation (85), "v_r is the velocity ratio of the test specimen" *by* "v_r is the nominal relative velocity of the test specimen".

Page 171

Replace equation (89) by the following new equation:

$$\frac{P_{d3}}{P_{d1}} = \frac{\alpha_3(1+0{,}002\times(T_{1,max}-T_a))+0{,}5\times\alpha_2}{\alpha_1(1+0{,}002\times(T_{1,max}-T_a))+0{,}5\times\alpha_2} \tag{89}$$

Under the equation, delete "η_3 is the temperature coefficient of the outer conductor material".

Page 173

Replace equation (92) by the following new equation:

$$\alpha_T = \alpha_1(1+0{,}002\times(T_{1,max}-T_a))+\alpha_2+\alpha_3(1+0{,}002\times(T_{1,max}-T_a)) \tag{92}$$

11.19.5.2 Conversion formula for power rating versus frequency

Replace, on page 175, equation (97) by the following new equation:

$$Y = \frac{\alpha_T(f_1)}{\alpha_T(f_2)} \times \frac{\alpha_{1T}(f_2) + 0{,}5 \times \alpha_2(f_2)}{\alpha_{1T}(f_1) + 0{,}5 \times \alpha_2(f_1)} \qquad (97)$$

Under the equation, replace "T" *by* "T_a".

Page 177

12.1.2.1 Electrically short cable lengths

In the note, replace "(λ is 300/$\sqrt{\varepsilon_r}$)" *by* "($\lambda = \frac{300}{\sqrt{\varepsilon_r} \times f}$)".

12.1.2.2 Electrically long cable lengths

In figure 34, on page 179, replace "Test section $l \alpha D$" *by* "Test section L".

Replace equation (100) by the following new equation:

$$Z_{TE} = \max |Z_F \pm Z_T| \qquad (100)$$

Replace equation (101) by the following new equation:

$$T_n = \frac{U_{2n} / \sqrt{Z_{02}}}{U_1 / \sqrt{Z_{01}}} = \frac{I_{2n} \times \sqrt{Z_{02}}}{I_1 \times \sqrt{Z_{01}}} \qquad (101)$$

Replace equation (102) by the following new equation:

$$T_f = \frac{U_{2f} / \sqrt{Z_{02}}}{U_1 / \sqrt{Z_{01}}} = \frac{I_{2f} \times \sqrt{Z_{02}}}{I_1 \times \sqrt{Z_{01}}} \qquad (102)$$

Page 181

12.1.4 Test set-up

Replace, on page 193, the second sentence of the third paragraph by the following:

For measurements in the range >1 GHz, the reflection factor of the feeding circuit including the launcher should be ≤0,1.

12.1.5 Preparation of the test specimen (cable under test)

In the first line of the second paragraph, replace "(N, SKA)" *by* "(N, SMA)".

Page 195

12.1.6.2 Uncontrolled currents

In the first sentence, replace “Special care in required...” *by* “Special care is required...”.

Page 199

12.1.8 Expression of results

Replace “Under consideration.” *by the following new text*:

From the test results above, both the effective transfer impedance Z_{TE} and screening attenuation a_s can be calculated:

as defined: $Z_{TEn_f} = |Z_F \pm Z_T| \rightarrow Z_{TE} = \max(Z_{TEn}; Z_{TEf})$

a) $$Z_{TEn_f} \approx \frac{2}{L} \times \sqrt{Z_{01} \times Z_{02}} \times Env(T_{n_f}) \times \left(1 + \frac{\pi \times f \times L}{v_{\pm}}\right) \quad (121)$$

where

$Env(T_{n_f})$ is the envelope of the near-end/far-end coupling function;

L is the length of the cable under test (CUT).

$$T_{n_f} = 10^{-A_T/20} \quad (122)$$

$$v_{\pm} = \frac{v_1 \times v_2}{|v_2 \pm v_1|} \quad (123)$$

where

+ = near end and – = far end;

v_1 is the phase velocity in the primary circuit;

v_2 is the phase velocity in the secondary circuit.

$A_T = A_S - (A_c/2) - (A_i/2)$ (see figure 58)

NOTE – When $Z_T >> Z_F$, then $Z_T \approx Z_{TE}$, either near-end (T_n, v_+) or far-end (T_f, v_-) data may be used.

For practical purposes, it is preferable to use near-end measurement data for frequencies less than 30 MHz.

If $Z_T >> Z_F$ then Z_T can be calculated by using the simplified procedure shown in figure 58, equation (131).

b) $$a_s = -20\log_{10}\left(\max\left[Env\{T_n\}; Env\{T_f\}\right]\right) \quad (124)$$

The screening attenuation a_s shall also be presented in the normalized conditions $|\Delta v / v_1|$ = 10 % and Z_2 = 150 Ω:

$$a_s(10\,\%/150\,\Omega) \approx -20\log_{10}\left(\frac{Z_{TE} \times 11 \times v_1}{2\pi f \times \sqrt{Z_{01} \times 150\,\Omega}}\right) \quad (125)$$

The screening attenuation is only valid for frequencies higher than the critical frequency.

$$f_c = \frac{v_1 \times v_2}{|v_2 - v_1| \times \pi \times L} \qquad (126)$$

1 Input: – frequency range – impedance of CUT – injection circuit	 Z_{02} Z_{01}	
2 Measure reference data A_o	 (dB)	
3 Measure insertion loss of injection circuit $A_i = A'_i - A_o$	 (dB)	 (127)
4 Measure insertion loss of CUT $A_c = A'_c - A_o$	 (dB)	 (128)
5 Measure transfer function $A_s = A'_s - A_o$	 (dB)	 (129)
6 $A_T = A_s - (A_c/2) - (A_i/2)$ $Z_T = (2/L) \times \sqrt{(Z_{01} \times Z_{02})} \times 10^{-A_T/20}$	(dB) (Ω m^{-1})	(130) (131)
7 Data output		

Figure 58 – Computer flow chart, valid when $Z_T >> Z_F$

Page 201

12.2.2 Definition

In the second line of the first paragraph, replace “(Z_T/m^{-1})” *by* “(Z_T in mΩ/m)”.

12.2.3 Test equipment

In the third line of the third paragraph, replace “...open end in soldered...” *by* “...open end is soldered...”.

12.2.4.1 Method 1: Feeding through a resistance

Replace, on page 205, equation (104) by the following new equation:

$$F' = \frac{\left|(1-n^2)\right| x\sqrt{(\cos^2 x + m^2 \times \sin^2 x)}}{\sqrt{n^2\{\cos x - \cos(nx)\}^2 + \{\sin x - n\sin(nx)\}^2}} \qquad (104)$$

Page 207

12.2.4.2 Method 2: Direct feeding

Replace equation (106) by the following new equation:

$$F'' = \frac{\left|(1-n^2)\sin x\right|}{\sqrt{n^2\{\cos x - \cos(nx)\}^2 + \{\sin x - n\sin(nx)\}^2}} \qquad (106)$$

Page 211

12.3.3.2 Pulse method

Replace, in the heading of the second column of the table, "Oscillator" *by* "Oscilloscope".

Page 221

12.3.7 Determination of capacitance transfer impedance, Z_F

In the fourth line of the first paragraph, delete the word "reflector".

12.4.1 Principle

In the third paragraph, replace "1 000 MHz" *by* "2 500 MHz".

Add the following text after the third paragraph:

Absorbing clamps are commercially available for measurements from 30 MHz to 1 000 MHz and from 300 MHz to 2 500 MHz.

Page 227

12.4.5.1 Method 1: Direct measurement

In figure 51, replace "5 = matching network if $Z_0 = Z_1$..." by "5 = matching network if $Z_0 \neq Z_1$...".

Page 231

12.4.6.1 Insertion loss of the measuring set-up

On page 233, under equation (114), insert "λ" *before* "is the free space wavelength".

Page 235

12.4.7 Expression of results

Replace the title of this subclause by the following new title.

12.4.7 Expression of test results and requirements

Replace the existing text by the following two new subclauses:

12.4.7.1 Expression of results

The screening attenuation a_s is defined as

$$a_s = 10\log_{10}\left(\frac{P_1}{\max(P_{2n};P_{2f})}\right) \quad (115)$$

Where

P_1 is the input power of the inner circuit of the test specimen;

P_{2n} is the near-end cross-talk power of the matched outer circuit;

P_{2f} is the maximum far-end cross-talk power of the matched outer circuit;

max (P_{2n}; P_{2f}) is the maximum power envelope to the near end or far end of the matched outer circuit;

and

$$\frac{P_1}{P_{2n_f}} = \left(\frac{\omega^2 \times Z_1 \times Z_2 \times (v_1 \pm v_2)^2}{|Z_F \pm Z_T|^2 \times (v_1 \times v_2)^2}\right)$$

where

Z_T is the surface transfer impedance;

Z_F is the capacitive coupling impedance;

v_1 is the propagation velocity of the inner circuit;

v_2 is the propagation velocity of the outer circuit.

The test results are substantially dependent on the velocity difference between the inner and outer circuit (v_1 – v_2). Therefore, the results shall also be presented in the standardized condition where Z_2 = 150 Ω and the velocity difference is 10 %. Normally, the standardized condition gives a value of a_s that is 10 dB worse than the test results (see also table 5).

The measured powers indicated by the measuring receiver are P_{4n} and P_{4f} respectively.

Hence

$$a_s = 10\log_{10}\left(\frac{P_0}{\max(P_{4n};P_{4f})}\right) - a_M \qquad (116)$$

where

P_0 is the power of the r.f. generator;

a_M is the insertion loss of the measuring set-up, according to 12.4.6;

$\max(P_{4n};\ P_{4f})$ is the maximum power envelope to the near end or far end indicated by the measuring receiver.

NOTE – $P_{2,max} = P_{2n} + P_{2f}$.

12.4.7.2 Requirements

See table 5. Note that the surrounding conditions of the cable installation affect the clamp measured a_s normally up to 10 dB, which should be subtracted from a_s.

Page 237

12.5 Cable microphony charge level

Replace the title and "Under consideration." *by the following:*

12.5 Cable microphony charge level (mechanically induced noise)

12.5.1 General

Coaxial cables, which are subjected to mechanical stresses such as shock, pulling force, physical pressure or torsion, generate electrical charges which are noticeable as disturbing currents or voltages on the cable.

These disturbances, referred to as "mechanically induced noises" or "cable microphony", are superimposed on the signals which the cable carries and become significant in the case of low level signals.

The frequency range of these electro-mechanical transformations reaches up to about 20 kHz. (In published literature, fast pulses up to the 1 GHz range are described, but they are not included here.)

The advantage of the described measuring procedure is the precisely defined and controlled excitation of the cable sample under test and the reproducibility of the measuring results.

For a simplified classification of cables with different noise behaviour, the cable microphony charge level in dB micro-coulombs/metre (dB(µC/m)) is introduced as a unit of measure, where 0 dB is 1 µC/m.

Specially designed cables have a microphony charge level of about –60 dB(µC/m), whereas standard cables have a microphony charge level of about 0 dB(µC/m).

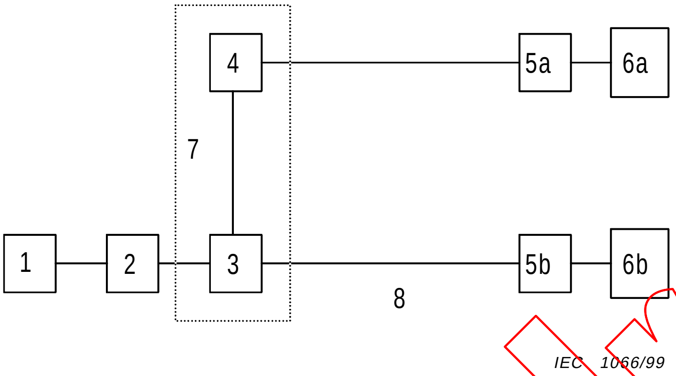
12.5.2 Principle

The purpose of the test is to determine the charge which is generated in a cable when the cable is subjected to mechanical stress.

12.5.3 Definition

cable microphony charge level: the logarithmic [20 log()] value of the ratio of the measured charge related to the elongation ΔL (m) to 1 µC/m

12.5.4 Test equipment



Key

1 Generator, 0 kHz to 20 kHz
2 Power amplifier
3 Vibrator
4 Accelerometer
5a Charge amplifier with extra double integrating
5b Charge amplifier
6a Oscilloscope, elongation measurement
6b Oscilloscope, microphony charge (level) measurement
7 Test rig
8 Cable under test (CUT)

Figure 59 – Measurement set-up

12.5.5 Preparation of the test specimen

Three samples should be taken from a 10 m length of finished cable, at least 1 m apart from each other. One end of each sample shall be provided with a suitable connector.

The other end of each sample shall be prepared to provide a closed screen against disturbing noises from the environment. About 25 mm of the jacket shall be removed, leaving the braid intact. The braid shall then be pushed back and a piece of the insulation shall be cut squarely. The braid shall be stripped back and soldered without contact to the inner conductor.

12.5.6 Procedure

The cable under test is fixed at one end to the membrane of a vibrator and stretched with a defined weight using special clamping jaws similar to a collet chuck (see 12.5.7.1). The free end of the cable is connected to a charge amplifier.

The vibrator, which is fed with a sinusoidal signal, varies the stress on the cable under test along its longitudinal axis. In this way both effects, the piezoelectric effect by strain in the dielectric and the triboelectric effect by relative movement of the cable braid and dielectric are stimulated and can be measured by only one measuring procedure.

The extension of the cable is measured and controlled by measuring the displacement of the vibrator with an accelerometer. The accelerometer is fixed to the vibrator plate and connected to one of the charge amplifiers. The output of the charge amplifier provides a voltage which is proportional to the elongation of the cable by double integration of the accelerometer signal.

The cable under test is connected to an additional charge amplifier. The output of this charge amplifier provides a voltage which is proportional to the charge in the cable under test and may be connected to an oscilloscope or to a PC.

12.5.7 Measurement precautions

12.5.7.1 Fixing and mechanical pre-loading of the cable

The cable sample shall be fixed using special clamping jaws similar to a collet chuck. Care shall be taken when fixing the sample so that induced torsion and undefined mechanical pre-loading are avoided. Depending on torsion and/or pre-loading, different results of cable microphony will be obtained. The sample may become compressed, which will cause errors in the test results, therefore a defined mechanical pre-loading is required for repeatable results.

The defined mechanical pre-loading is obtained by using a guide pulley and a weight in combination with the clamping jaws. Unless otherwise specified in the relevant cable specification, a weight of 500 g is useful for cables with outer diameters up to 5 mm and a weight of 1 kg for cables up to 10 mm outer diameters.

In order to avoid the cable sample hanging slack in the test rig with undefined mechanical pre-loading, it is recommended that the test rig be so designed that the cable sample is mounted vertically.

12.5.7.2 Elongation

The maximum relative elongation $\Delta L/L$ of the cable under test shall be within the dynamic range of the cable in order to imitate a practical application, so that the cable is not destroyed during the test procedure. In this dynamic range of relative elongation $\Delta L/L$, of about 0,4 ‰ maximum the measured values show a linear increase with increasing relative elongation $\Delta L/L$.

12.5.7.3 Mechanical resonances

Under ideal conditions, the measured charge shows linear behaviour against frequency up to approximately 20 kHz in the dynamic range of relative elongation $\Delta L/L$ of the cable sample.

Depending on the individual measuring set-up, at some frequencies, mechanical resonances may occur, which are superimposed on the measured cable microphony and will corrupt the results.

These mechanical resonances will be visible as peaks in the measured curve against frequency. At these frequencies, the measured values are not valid.

To avoid mechanical resonances, attention should be paid to the rigid mounting of the vibrator, and to the fixing points of the cable sample using only a few components having short lever arms.

A ground plate of solid steel, mounted on a solid base, is recommended.

The preferred frequency range of excitation is 50 Hz to 200 Hz.

12.5.7.4 Reproducibility

As cable microphony varies along the length of the cable, reproducibility within reach of the given measurement procedure is about factor 2 resp. within 6 dB. Where higher reproducibility is required, the number of samples under test should be increased and statistical procedures should be applied.

12.5.7.5 Earth loops

In order to avoid unwanted earth loops, the charge amplifiers may be battery powered.

The frame of the test rig should act as a static screen to prevent the cable under test from disturbing environmental LF noises.

12.5.8 Measurement conditions

The relative elongation $\Delta L/L$ of the cable sample shall be in the range of 0,1 ‰ to 0,5 ‰, unless otherwise stated in the relevant cable specification.

Measurements shall be performed in a temperature range from 18 °C to 23 °C unless otherwise stated in the relevant cable specification.

The frequency range of excitation shall be 50 Hz to 200 Hz, unless otherwise stated in the relevant cable specification.

The variation coefficient, caused by mechanical resonances, shall be ≤10 % over the whole measured frequency range.

Three measurements shall be taken with each of three different cable samples.

12.5.9 Expression of results

The correlation between acceleration a and distance s of the relative elongation $\Delta L/L$ of the cable sample is given by:

$$s = s_0 \times \sin(\omega t + \theta) \qquad (132)$$

$$a = \frac{d^2 s}{dt^2} = -s_0 \times \omega^2 \times \sin(\omega t + \theta) \qquad (133)$$

$$a_0 = (2\pi \times f)^2 \times s_0 \qquad (134)$$

The quotient of charge Q_R can be obtained as:

$$Q_R = Q_{meas}/(L \bullet \Delta L/L) = Q_{meas}/\Delta L \qquad (135)$$

where

Q_{meas} is the measured charge, in micro coulombs (µC);

ΔL is the elongation of the cable sample in metres (m);

L is the length of excitation, in metres (m);

$\Delta L/L$ is the relative elongation of the cable sample.

The mean value of the quotient of charge Q_{Rm} shall be the mean value of the three measured quotients of charge Q_R.

For a simplified classification of low noise cables, this mean quotient of charge Q_{Rm} is converted to a logarithmic value defined as the cable microphony charge level where 0 dB is 1 µC/m with:

$$Q = -20\log\,(Q_{Rm}/(1\ \mu C/m))\ \ (dB(\mu C/m)) \qquad (136)$$

12.5.10 Requirements

The measured value of the cable microphony charge level shall not exceed the value which is indicated in the relevant cable specification.

12.5.11 Measurement on delivered length

To determine the distribution of the cable microphony charge level over the cable length, it is possible to make measurements on delivered lengths of cable.

Cable lengths up to 1 000 m are of negligible influence to the test results if the input impedance of the charge amplifier is significantly lower than the total capacitive impedance of the cable under test. The section of the cable under test may be at the beginning, in the middle or at the end of the total cable length. A suitable test rig to measure the cable microphony charge level on delivered lengths is shown in figure 60.

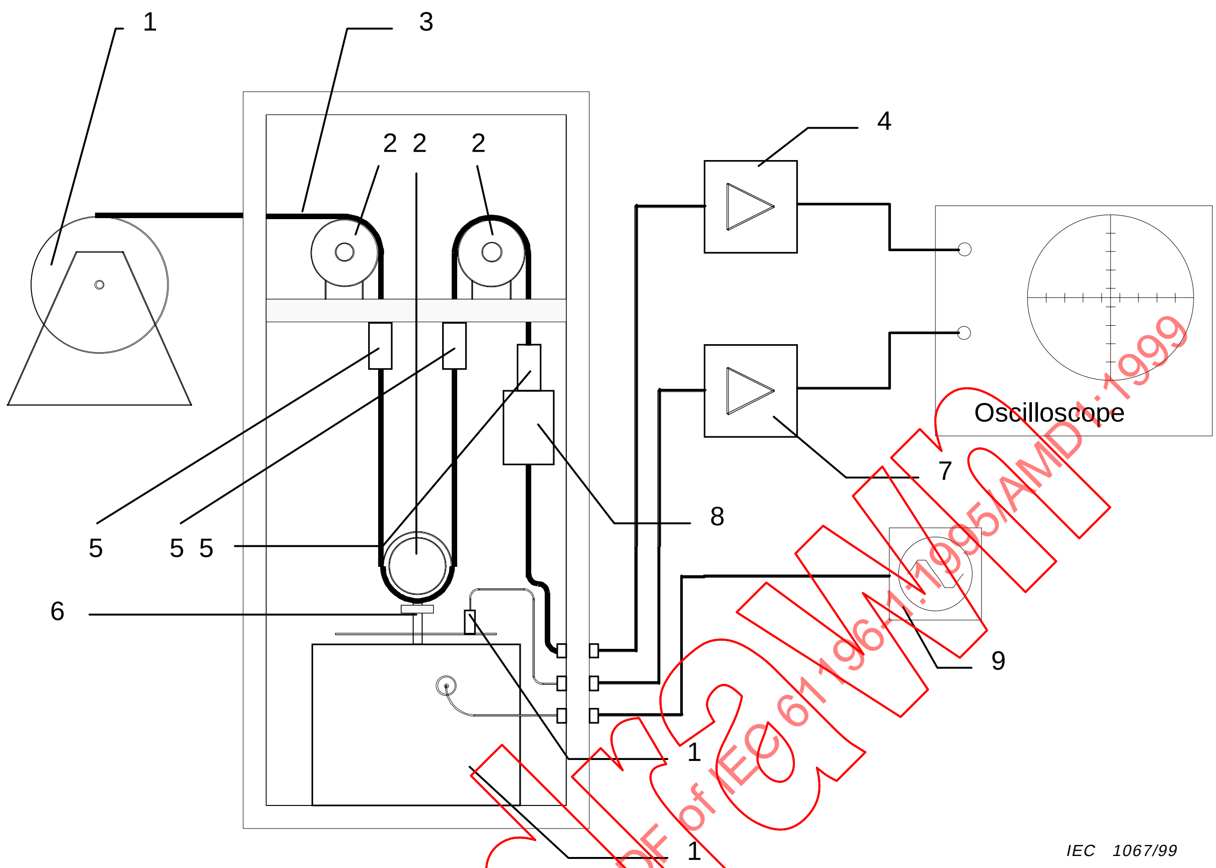
The test rig consists of three pulleys (2) to guide the cable. Two of them are fixed to the frame of the rig and one is fixed to the vibrator. The cable in the test rig may then be pulled forwards and backwards.

During the test, the cable shall be fixed with the clamping jaws (5) and the clamp on the vibrator pulley (6). To straighten the cable length under test and to obtain a defined pre-loading, first the cable in the left clamping jaw (5) is fixed, then the pre-loading weight (8) is attached and the second clamping jaw (5) is fixed.

Pre-loading shall be achieved in such a way that the cable is straightened but the vibrator is still in its rest position.

Finally, the clamp of the vibrator pulley (6) is fixed. If the cable is not fixed on the vibrator pulley (6), the length under test cannot be compressed during the test while the vibrator is running.

The cable length of excitation *L* is the length between the two clamping jaws.



IEC 1067/99

Key

1	Cable drum	7	Charge amplifier with double integration
2	Guide pulleys	8	Pre-loading weight
3	Cable under test	9	Generator
4	Charge amplifier	10	Accelerometer
5	Clamping jaws	11	Vibrator
6	Clamp		

Figure 60 – Measurement on delivery length

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Add, after clause 12.5, the following new subclauses:

12.6 Shielded screening attenuation, test method for measuring the screening attenuation a_S up to and above 3 GHz

12.6.1 General

This triaxial method is suitable to determine the screening attenuation a_S and the surface transfer impedance Z_T of r.f. coaxial cable screens. Due to the concentric outer tube, measurements are independent of irregularities on the circumference and outer electromagnetic field.

A wide dynamic and frequency range can be applied to test even super screened cables with normal instrumentation, from low frequencies up to the limit of defined transversal waves in the outer circuit at approximately 4 GHz.

12.6.2 Principles of measuring method (figure 61)

The disturbing or primary circuit is the matched cable under test. The disturbed or secondary circuit consists of the outer conductor (or the outermost layer in the case of multiscreen cables) of the cable under test and a solid metallic tube having the cable under test in its axis.

The voltage peaks at the far end of the secondary circuit have to be measured. The near end of the secondary circuit is short-circuited. For this measurement, a matched receiver is not necessary. The expected voltage peaks at the far end are not dependent on the input impedance of the receiver, provided that it is lower than the characteristic impedance of the secondary circuit. However, it is an advantage to have a low mismatch, for example by selecting a range of tube diameters for several sizes of coaxial cables.

12.6.3 Definitions and theoretical background

12.6.3.1 Electrical symbols

Z_1	is the characteristic impedance of the primary circuit (cable under test);
Z_2	is the characteristic impedance of the secondary circuit;
Z_S	is a normalized value of the characteristic impedance of the environment of the cable under test (150 Ω outer circuit impedance Z_2);
R	is the input impedance of the receiver;
Z_T	is the transfer impedance of the cable under test (Ω/m);
$Z_F = Z_1 \times Z_2 \times j\omega \times C_T$	is the capacitive coupling impedance of the cable under test (Ω/m);
f	is the frequency (Hz);
C_T	is the through capacitance of the outer conductor per unit length (F/m);
ε_{r1}	is the relative dielectric permittivity of the cable under test;
ε_{r2}	is the relative dielectric permittivity of the secondary circuit;
$\varepsilon_{r2,n}$	is a normalized value of the relative dielectric permittivity of the environment of the cable;
l	is the effective coupling length;
λ_o	is the vacuum wavelength;
c_o	is the vacuum velocity;
a_S	is the screening attenuation which is comparable to the results of the absorbing clamp method (see 12.4);
a_{sn}	is the normalized screening attenuation (Z_S = 150 Ω and $\lvert\Delta v/v_1\rvert$ = 10 %);
P_1	is the feeding power of the primary circuit;
P_2	is the measured power received on the input impedance R of the receiver in the secondary circuit;
P_r	is the radiated power in the environment of the cable, which is comparable to $P_{2n} + P_{2f}$ of the absorbing clamp method of 12.4;
P_S	is the radiated power in the normalized environment of the cable under test (Z_S = 150 Ω and $\lvert\Delta v/v_1\rvert$ = 10 %).

$$\varphi_1 = 2\pi\left(\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}}\right) l / \lambda_0 \tag{137}$$

$$\varphi_2 = 2\pi\left(\sqrt{\varepsilon_{r1}} + \sqrt{\varepsilon_{r2}}\right) l / \lambda_0 \tag{138}$$

$$\varphi_3 = \varphi_2 - \varphi_1 = 4\pi\sqrt{\varepsilon_{r2}}\, l / \lambda_0 \tag{139}$$

12.6.3.2 Theoretical background

For exact calculation, if feedback from the secondary to the primary circuit is negligible, the ratio of the far end voltages U_1 and U_2 are given by:

$$\left|\frac{U_2}{U_1}\right| \approx \left|\frac{Z_T - Z_F}{\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}}} \times \left[1 - e^{-j\varphi_1}\right] + \frac{Z_T + Z_F}{\sqrt{\varepsilon_{r1}} + \sqrt{\varepsilon_{r2}}} \times \left[1 - e^{-j\varphi_2}\right]\right| \times \left|\frac{1}{\omega \times Z_1}\right| \times \left|\frac{c_0}{2 + (Z_2 / R - 1) \times (1 - e^{-j\varphi_3})}\right| \tag{140}$$

i.e. formally |A + B| × C × D, where AC is the far end cross-talk, BC is the reflected near end cross-talk and D is the mismatch factor.

The total oscillations of D are

<2 dB, if 1 < Z_2/R < 1,25,

3 dB, if Z_2/R = 1,4,

10 dB and more, if Z_2/R > 3.

The maximum values of AC and BC are given, if

$\varphi_{1,2}$ = (2N + 1) × π and N is an integer.

12.6.3.3 Screening attenuation

The logarithmic ratio of the feeding power P_1 and the periodic maximum values of the power $P_{r,max}$ which may be radiated due to the peaks of voltage U_2 in the outer circuit are termed screening attenuation a_s.

$$a_s = -10\log_{10}\left(\text{Env}\left|\frac{P_{r,max}}{P_1}\right|\right) \tag{141}$$

The relationship of the radiated power P_r to the measured power P_2 received on the input impedance R is

$$\frac{P_r}{P_2} = \frac{P_{r,max}}{P_{2,max}} = \frac{R}{2 \times Z_S} \tag{142}$$

There will be a variation of the voltage U_2 on the far end, caused by the electromagnetic coupling through the screen and superimposition of the partial waves caused by the surface transfer impedance Z_T, the capacitive coupling impedance Z_F (travelling to the far and near end) and the totally reflected waves from the near end.

At high frequencies and when the cable under test is electrically long (see equation 140):

$$\sqrt{\left|\frac{P_{2,max}}{P_1}\right|} \approx \frac{c_o}{\omega\sqrt{Z_1 \times R}} \times \left|\frac{Z_T - Z_F}{\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}}} + \frac{Z_T + Z_F}{\sqrt{\varepsilon_{r1}} + \sqrt{\varepsilon_{r2}}}\right| \qquad (143)$$

12.6.3.4 Relationship between length and surface transfer impedance Z_T

The relationship between the effective coupling length of the cable under test and the electrical wavelength is important for the characteristic curve of the screening attenuation. In the frequency range of electrically short coupling lengths (see equation 139), the measured attenuation decreases with increasing length. Therefore, it is necessary to define the related length.

With electrically long lengths (see equation 140), the screening attenuation formed by the maximum envelope curve to the coupling voltage ratio is constant for a 6 dB/octave increasing transfer impedance (see figure 62). Therefore, the screening attenuation is defined only at high frequencies.

The coupling length is electrically short, if

$$\lambda_o / l > 10 \times \sqrt{\varepsilon_{r1}} \quad \text{or} \quad f < \frac{c_o}{10 \times l \times \sqrt{\varepsilon_{r1}}} \qquad (144)$$

or electrically long, if

$$\lambda_o / l \le 2 \times \left|\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}}\right| \quad \text{or} \quad f > \frac{c_o}{2 \times l \times \left|\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}}\right|} \qquad (145)$$

where

l is the effective coupling length, in metres (approximately 2 m in figure 61);

λ_o is the free space wavelength, in metres;

ε_{r1} is the resulting relative permittivity of the dielectric of the cable;

ε_{r2} is the resulting relative permittivity of the dielectric of the secondary circuit;

f is the frequency, in hertz.

The measured voltage ratio is related to the transfer impedance Z_T for electrically short coupling length by:

$$Z_T \times l \approx Z_1 \times \left|\frac{U_2}{U_1}\right| \qquad (148)$$

A more detailed description for this case is given in 12.2.

Also, at high frequencies, Z_T can be calculated if Z_F is negligible:

$$Z_T \approx \left|\frac{\omega \times \sqrt{Z_1 \times R} \times \left|\varepsilon_{r1} - \varepsilon_{r2}\right|}{2 \times c_o \times \sqrt{\varepsilon_{r1}}}\right| \times \sqrt{\left|\frac{P_{2max}}{P_1}\right|} \qquad (149)$$

therefore

$$\sqrt{\left|\frac{P_{2,max}}{P_1}\right|} \approx \left|\frac{Z_T \times 2 \times c_o \times \sqrt{\varepsilon_{r1}}}{\omega \times \sqrt{Z_1 \times R} \times |\varepsilon_{r1} - \varepsilon_{r2}|}\right| \qquad (150)$$

12.6.4 Measurement

12.6.4.1 Equipment

The measuring set-up is shown in figure 61 and consists of the following:

- An apparatus of a triple coaxial form with a length sufficient to produce a superimposition of waves in narrow frequency bands which enable the envelope curve to be drawn.
- Commonly a coupling length of 2 m is preferable to determine the screening attenuation from less than 50 MHz upwards. The cylindrical cable screen forms both the outer conductor of the energized coaxial system and the inner conductor of the outer system. The outer conductor of the outer system is a tube of about 50 mm inner diameter with a short circuit to the screen on the fed side of the cable. The ratio of the inner diameter of the tube to the outer diameter of the screen shall be sufficient to ensure that the characteristic impedance is larger than the input resistance of the receiver. The value of the relative dielectric permittivity of the outer circuit shall be approximately one, irrespective of the enclosing cable sheath.
- A signal generator with the same characteristic impedance as the cable under test or with an impedance adapter completed by a power amplifier, if necessary, for very high screening attenuation.
- A receiver with a calibrated step attenuator or network analyser.

12.6.4.2 Cable under test

The cable sample is terminated at the far end by a well screened resistance equal to the nominal value of the characteristic impedance. The connections between the terminating resistance, the screening cap and the cable screen shall be made with care so that the contact resistance can be neglected when interpreting the results. Special care has to be taken in preparing the foil screens in order to avoid cracks in the foil which may introduce errors in the test results.

On the fed side, the cable screen is connected to the short-circuit disk of the outer tube, and care must be taken so that the contact resistance is small and does not influence the results.

The cable under test shall be positioned as nearly concentric as possible in the outer tube to obtain homogeneous wave propagation.

12.6.4.3 Procedure

The quotient of the voltages at the output of the outer circuit and the input of the cable is measured, either directly by a network analyser or with a calibrated step attenuator (assuming that the receiver has the same input impedance as the output impedance of the signal generator ($R = Z_1$)), which is inserted as an alternative to the triaxial apparatus.

Only the peak values of the maximum of the voltage ratio or the minimum of the attenuation shall be measured and recorded as a function of the frequency, in order to determine the envelope curve.

The attenuation introduced by the inclusion of adapters, instead of direct connection, shall be taken into account when calibrating the triaxial apparatus.

The voltage ratio measured is not dependent on the diameter of the outer tube of the triaxial test set-up or on the characteristic impedance Z_2 of the outer system, provided that Z_2 is larger than the input impedance of the receiver.

12.6.4.4 Expression of results

The screening attenuation a_s which is comparable to the results of the absorbing clamp method (see 12.4) has to be calculated with the normalized value Z_S = 150 Ω:

$$a_s = 10\log_{10}\left|\frac{P_1}{P_{r,max}}\right| = 10\log_{10}\left|\frac{P_1}{P_{2,max}} \times \frac{2Z_S}{R}\right|$$

$$= 20\log_{10}\left|\frac{U_1}{U_{2,max}}\right| + 10\log_{10}\left|\frac{300\,\Omega}{Z_1}\right|$$

$$= a_{m,min} - a_z + 10\log_{10}\left|\frac{300\,\Omega}{Z_1}\right| \qquad (151)$$

where

a_s is the screening attenuation related to the radiating impedance of 150 Ω, in decibels (dB);

$a_{m,min}$ is the attenuation recorded as the minimum envelope curve of the measured values, in decibels (dB);

a_z is the additional attenuation of an eventually inserted adapter, if not otherwise eliminated e.g. by the calibration, in decibels (dB);

U_1 is the input voltage of the primary circuit formed by the cable, in volts (V);

U_2 is the output voltage of the secondary circuit, in volts (V);

Z_1 is the characteristic impedance of the cable under test, in ohms (Ω).

At frequencies lower than the limit of the electrically long coupling length, the measurement will be similar to that for surface transfer impedance.

12.6.5 Requirement

The results of the minimum screening attenuation shall comply with the value indicated in the relevant cable specification.

If a limiting value of the radiating power is specified for a cable system operated with a defined power level, the difference between the power level and the limit of the radiating power shall not be greater than the screening attenuation of the cable provided for the system.

12.6.6 Normalized screening attenuation

The screening attenuation is dependent on the velocity difference between the inner and outer circuit. Therefore, the test results may also be presented in normalized conditions where Z_S = 150 Ω and the velocity difference is 10 %.

$$a_{s,n} = a_s + \Delta a \qquad (152)$$

where

$a_{s,n}$ is the normalized screening attenuation.

$$a_{s,n} = 20\log_{10}\left|\frac{\omega \times \sqrt{Z_1 \times Z_S} \times \left|\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2,n}}\right|}{Z_T \times c_0}\right| \qquad (153)$$

where

a_s is the screening attenuation according to equation (144);

Z_1 is the characteristic impedance of the primary circuit;

Z_S is a normalized value of the characteristic impedance of the environment of the cable under test, Z_S = 150 Ω;

Z_T is the transfer impedance of the cable under test;

ε_{r1} is the relative dielectric permittivity of the cable under test;

$\varepsilon_{r2,n}$ is a normalized value of the relative dielectric permittivity of the environment of the cable.

With equations (142), (143), (144), (145) and (146), the difference between the normalized screening attenuation and the measured screening attenuation is calculated by:

$$\Delta a = 20\log_{10}\left(\sqrt{2} \times \frac{\left|1-\sqrt{\frac{\varepsilon_{r2,n}}{\varepsilon_{r1}}}\right|}{\left|1-\frac{\varepsilon_{r2,t}}{\varepsilon_{r1}}\right|}\right) \qquad (154)$$

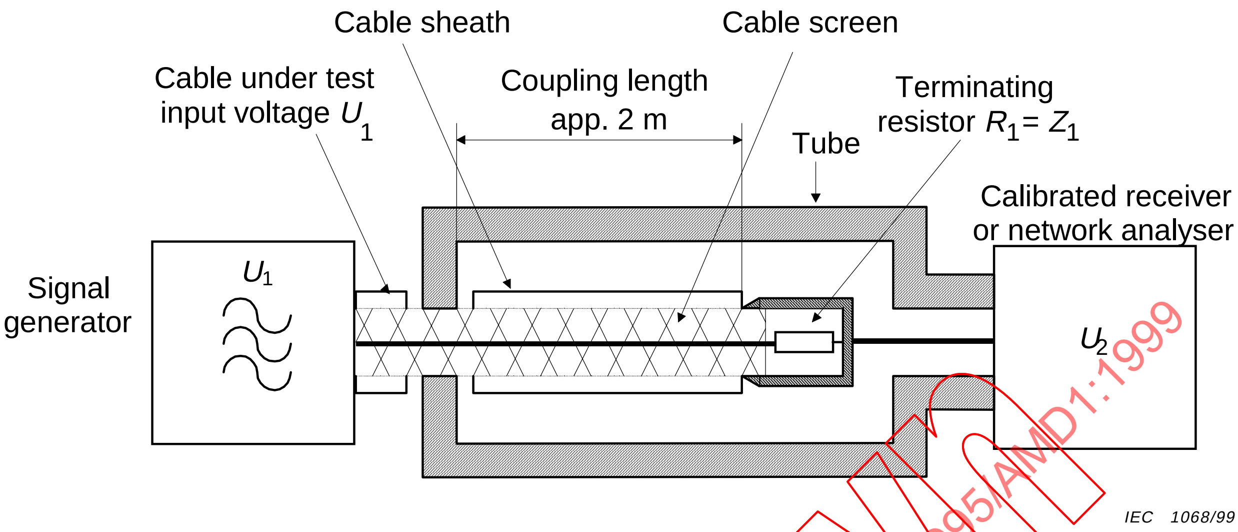
where

$\varepsilon_{r2,t} \approx 1{,}1$ is the relative dielectric permittivity of the outer circuit (tube) during the measurement, with respect to the velocity difference $\Delta v/v_1$ =10 %, the relation between $\varepsilon_{r2,n}$ and ε_{r1} is

$$\sqrt{\frac{\varepsilon_{r1}}{\varepsilon_{r2,n}}} = 1{,}1$$

Therefore, for both solid and foamed polyethylene dielectric cable with $\varepsilon_{r1} \approx 2{,}3$ and $\varepsilon_{r1} \approx 1{,}6$ respectively,

$\Delta a \approx -10$ dB



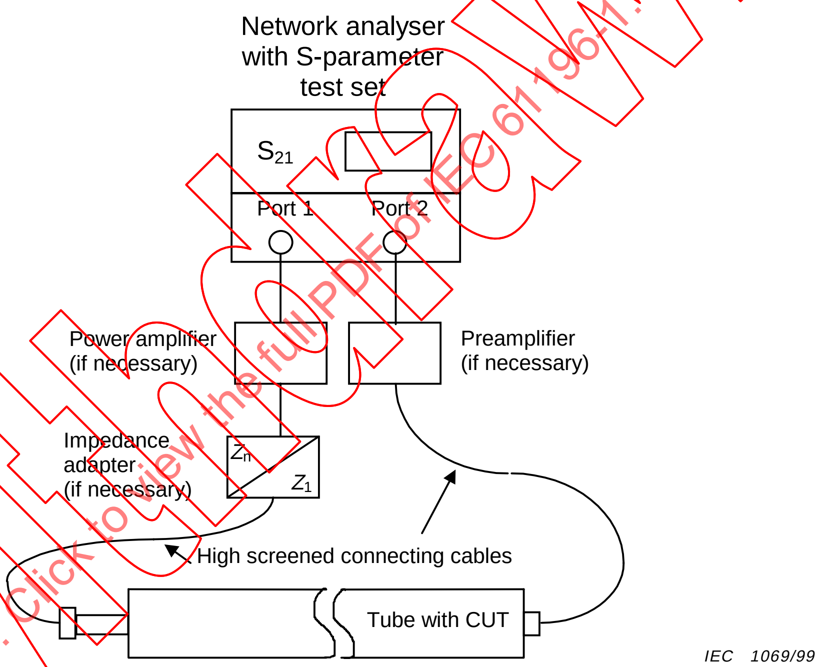


Figure 61 – Triaxial measuring set-up

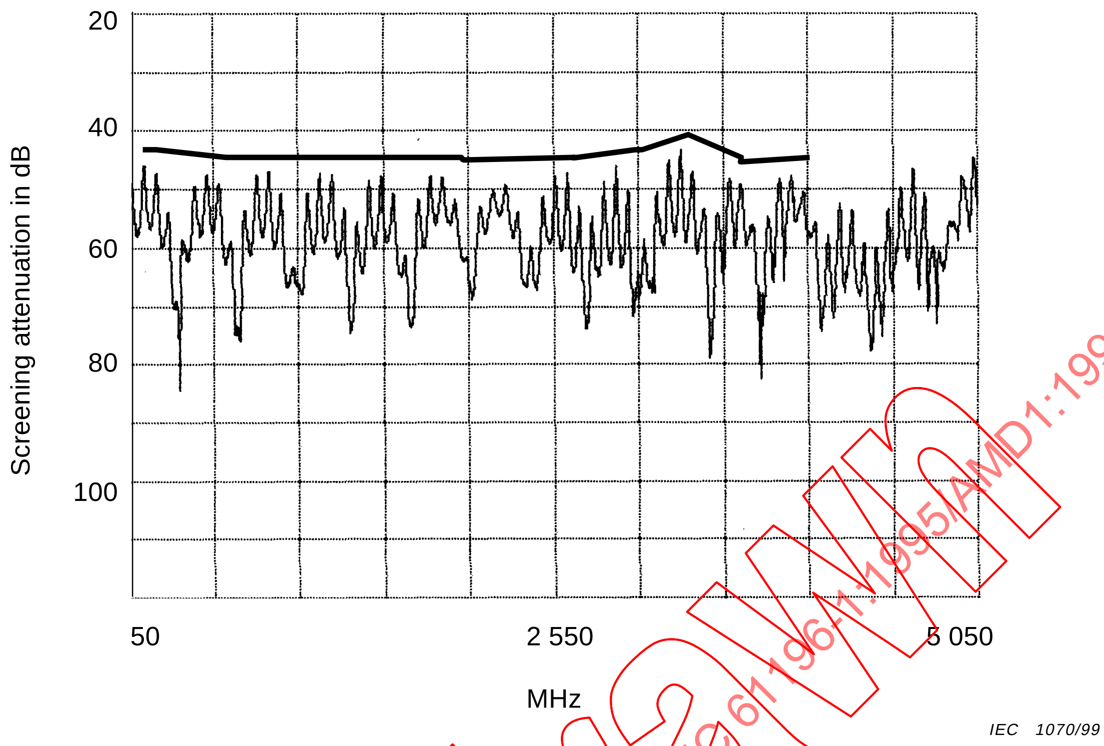


Figure 62 – Measured screening attenuation a_s formed by the maximum envelope curve to the measured coupling voltage ratio U_2/U_1 of a single-braid cable

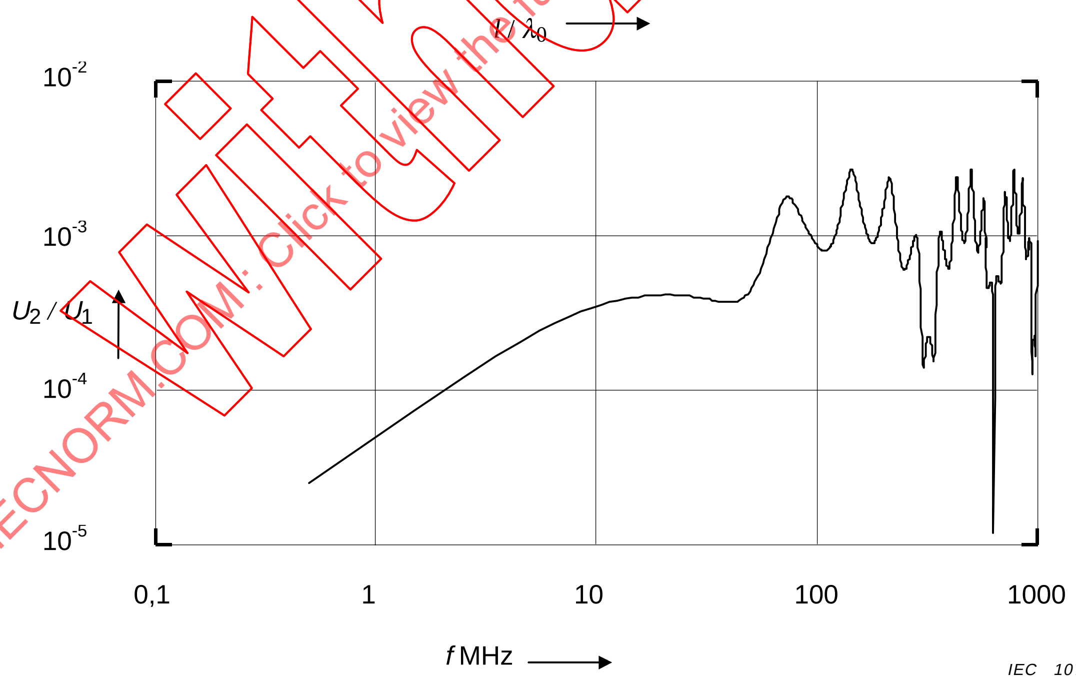


Figure 63 – Relationship of U_2/U_1 on a log(f) scale for a single-braid cable