TECHNICAL REPORT

IEC TR 62064

First edition
1999-07

**Radio-frequency cables –
Relationship between surface transfer impedance and screening attenuation
(A background to the recommended limits contained in IEC 61196-1, clause 14)**

*Câblages pour fréquences radioélectriques –
Relation entre l'impédance de transfert en surface et l'affaiblissement d'écran*

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

RADIO-FREQUENCY CABLES – RELATIONSHIP BETWEEN SURFACE TRANSFER IMPEDANCE AND SCREENING ATTENUATION

(A background to the recommended limits contained in IEC 61196-1, clause 14)

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IEC 62064, which is a technical report, 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 technical report is based on the following documents:

Enquiry draft	Report on voting
46A/330/CDV	46A/348/RVC

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

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RADIO-FREQUENCY CABLES – RELATIONSHIP BETWEEN SURFACE TRANSFER IMPEDANCE AND SCREENING ATTENUATION
(A background to the recommended limits contained in IEC 61196-1, clause 14)

1 Scope

This technical report describes the valuable background material used during the revision of IEC 61196-1, clause 14, guidance for surface transfer impedance and screening attenuation limits for flexible r.f. cables.

In this report the relationship between surface transfer impedance (Z_T) and screening attenuation (a_s) is given, also measurements of Z_T and a_s are provided to show the correlation of mean scanning attenuation between 200 MHz and 500 MHz and Z_T at both 30 MHz and 300 MHz.

The sensitivity of a_s and the relative velocity difference between the inner and outer system is shown, also the need for the cable data sheet to show the a_s values in a standardized form – $\Delta v/v$ = 10 % and the characteristic impedance of the outer system is 150 Ω. It is also shown that a relative velocity difference change from 10 % to 40 % gives an improvement of 12 dB in screening attenuation.

2 General

At high frequencies when the surface transfer impedance Z_T and effective transfer impedance $Z_{TE_{n,f}} = \left| Z_F \pm Z_T \right|$, and increases 6 dB per octave, its relation to the screening attenuation a_s is frequency independent and can be written as (see also figure 1):

$$a_{s_{\genfrac{}{}{0pt}{}{n}{f}}} = -20 \times \log_{10} \left| T_{\genfrac{}{}{0pt}{}{n}{f}} \right| \tag{1}$$

$$= -20 \times \log_{10} \frac{Z_T}{\sqrt{Z_1 Z_2}\, \omega \left| \frac{l}{v_2} \pm \frac{l}{v_1} \right|} = -20 \times \log_{10} \frac{Z_T\, c_o}{\sqrt{Z_1 Z_2}\, \omega \left| \sqrt{\varepsilon_{r2}} \pm \sqrt{\varepsilon_{r1}} \right|} \tag{2}$$

and $$T_{\genfrac{}{}{0pt}{}{n}{f}} = \frac{U_{2\genfrac{}{}{0pt}{}{n}{f}} / \sqrt{Z_2}}{U_1 / \sqrt{Z_1}}$$

where

l is the length of the cable under test;

$T_{n,f}$ are the coupling transfer functions;

‘n’ for the near end and ‘f’ for the far end;

Z_1 is the characteristic impedance of the cable;

Z_2 is the impedance of the outer circuit;

ε_{r1} is the cable dielectric permittivity;

ε_{r2} is the permittivity of the outer circuit;

c_o is the velocity of light in vacuum;

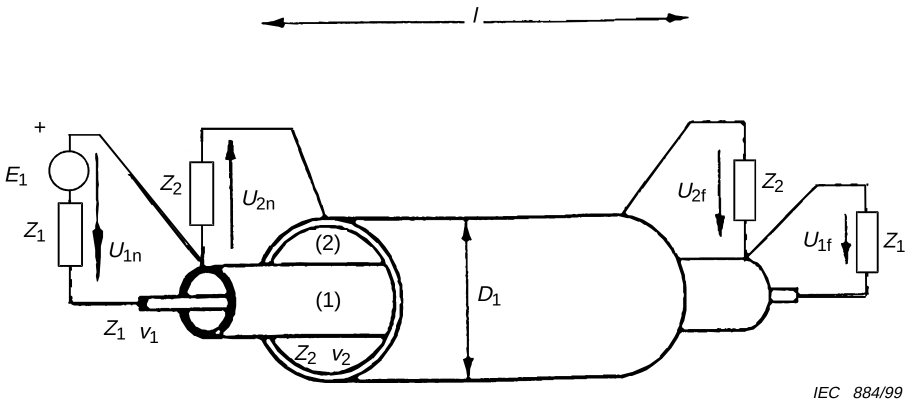
v_1 is the propagation velocity of the inner circuit;

v_2 is the propagation velocity of the outer circuit;

Z_F is the capacitive coupling impedance;

Z_T is the surface transfer impedance;

$Z_{TE_{n,f}}$ is the effective transfer impedance.



(1) The inner circuit, cable under test.

(2) The outer circuit, formed by test line or cylinder or the outer environment as in the absorbing clamp method.

Figure 1 – Concept of screening measurement set-ups

When the capacitive coupling impedance Z_F is present (spaces in the outer conductor), Z_T shall be substituted by Z_{TE}.

"+" sign is for the near end and "–" sign for the far end. Z_1 and Z_2 are the impedances of the inner and outer system and v_1 and v_2 the corresponding velocities.

Screening attenuation a_s is a reliable measure of screening efficiency when the frequency is constant. This is true when Z_T or Z_{TE} increases 6 dB/octave and the following criterion is fulfilled:

$$l_{\substack{n\\f}} \geq \frac{\lambda_o}{\pi\left|\sqrt{\varepsilon_{r1}} \pm \sqrt{\varepsilon_{r2}}\right|} \tag{4}$$

where λ_o is the wave length in free space.

At lower frequencies when l is smaller than that found from (4) the coupling attenuation is:

$$A_{s_{\substack{n\\f}}} = -20 \times \log_{10}\left|T_{\substack{n\\f}}\right| = -20 \times \log_{10}\left|\frac{(Z_F \pm Z_T)\times l}{2\sqrt{Z_1 Z_2}}\right| \tag{5}$$

More detailed information on the above equations is given in the IEC 61917.

3 Correlation between measured screening attenuation a_s and measured surface transfer impedances at 30 MHz and 300 MHz

Z_T and a_s were measured using the same cable construction. Figures 2, 3 and 4 show the correlation between a_s (mean value between 200 MHz and 500 MHz) and the Z_T values correspondingly at 30 MHz and 300 MHz.

In figure 5, typical Z_T curves are shown. For single and double braided outer conductors the 6 dB/octave increase is reached at 30 MHz but for foil-braid constructions at 30 MHz the Z_T can still be decreasing. The effect of this can be clearly seen when comparing the test results in figures 2, 3 and 4 for the foil-braid cables. The correlation between a_s and Z_T (30 MHz) is poor, but much better between a_s and Z_T (300 MHz). For single and double braided cables the correlation is equally good for 30 MHz and 300 MHz. The increase in the values of Z_T which should have been 10 fold (20 dB) is somewhat lower. The full 6 dB/octave increase in Z_T between 30 MHz and 300 MHz has not been reached for all single and double braided cables.

The $Z_T(a_s)$ correlation line slope from equations (1) and (2) is –20 dB/decade.

One reason for the spread in correlation is the strong effect of the velocity differences $v_2 - v_1$ on the a_s value. To demonstrate this, two lines are shown for 40 % and one for 10 % relative velocity difference ($|v_2 - v_1|/v_1$). Also, the outer circuit impedance has been altered from 300 Ω to 150 Ω.

Other reasons for the widespread of the correlation points are that only the cable construction has been kept the same, but the tested samples are different. It is impossible to use the same samples in Z_T and a_s measurements because of the required difference in length of the cable under test (CUT). Even if the samples had been the same, a difference of ±6 dB would exist when the CUT is removed from the test fixture and then remounted.

As shown above, the screening attenuation a_s is dependent on the outer circuit propagation velocity and to a lesser extent on the impedance, and decreases rapidly when the velocities v_2 and v_1 approach each other. For these reasons it has been recommended that a_s shall also be given in standardized conditions a_{sn} where the outer circuit velocity differs by 10 % from the inner circuit velocity, and the outer circuit impedance is 150 Ω.

It can be seen from figures 2 and 3 that the difference is about 10 dB. A drop in relative velocity difference from 40 % to 10 % causes a decrease of 12 dB in a_s. A decrease in impedance of 50 % causes an increase in a_s of 3 dB.

The values of the standardized condition 10 % relative velocity difference / 150 Ω have been shown to be that of a typical cable tray surrounding. Normally the measurement conditions of the absorbing clamp set-up gives approximately a 10 dB improvement value for a_s.

Figures 5 and 6 show typical test results for single braided, double braided and foil-braid outer conductor constructions.

4 Recommended limits for surface transfer impedance and screening attenuation

In clause 14 of IEC 61196-1, table 5 provides the recommended limits. To reach the limit of 100 mΩ/m at 30 MHz for single braided cables some optimization is needed, but even values below 50 mΩ/m are not difficult to obtain. A guide for optimization of single braided outer conductors is in preparation by the IEC. Some older cable design standards have requirements for too great a screen coverage, for example, too much copper in the braid. They are so heavily overbraided that a Z_T of 300 mΩ/m at 30 MHz is common.

To reach an a_s by an absorbing clamp measured screening attenuation of 90 dB for double braided cables some optimization is needed. In CATV networks an a_s higher than 85 dB is under discussion and an optimized double braided construction may fulfil the requirement.

When good screening is needed below 30 MHz the so-called superscreened construction is available, i.e. µ-metal tape sandwiched between two braids.

The most commonly used cable construction, when good screening at relatively high frequencies is needed, is the foil-braid type. A minimum 40 µm Cu-foil is recommended.

At frequencies below 30 MHz the screening properties should be defined at an upper limit of the transfer impedance.

For foil-braid constructions a $Z_T \leq 6$ mΩ/m at 5 MHz and ≤ 8 mΩ/m at d.c. is recommended.

As it is becoming more common to utilize the 5 MHz to 30 MHz return path of the CATV systems, it is important to specify the screening properties below 30 MHz. The relevant values should be calculated in cooperation between TC 46 and SC 100D.

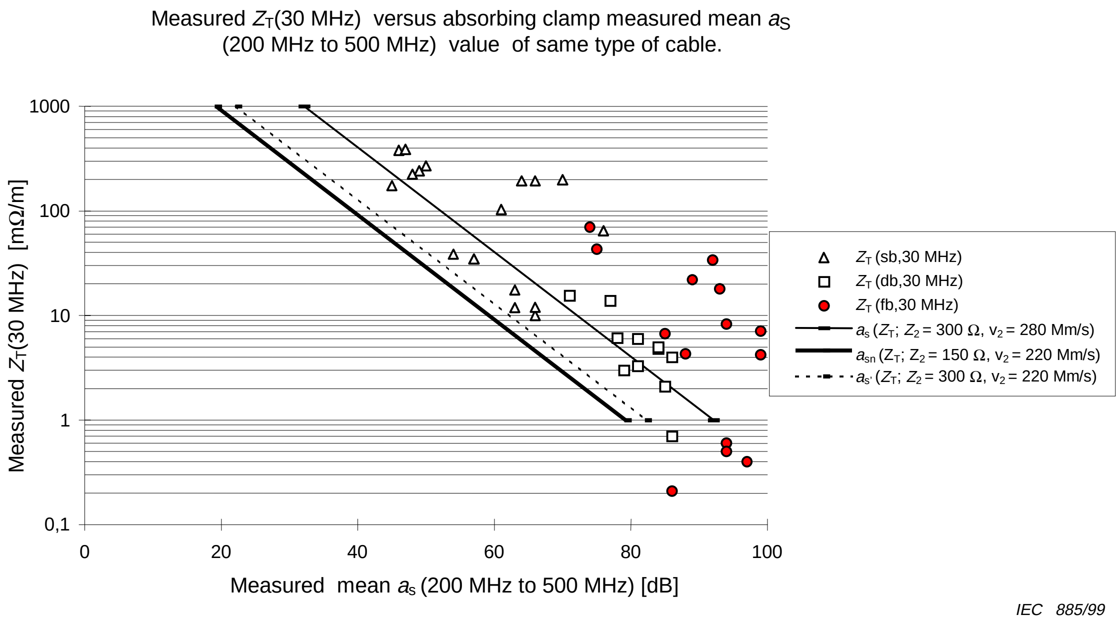


Figure 2 – Measured surface transfer impedance Z_T (30 MHz) versus measured mean screening attenuation a_s values for different outer conductor constructions (sb = single braid; db = double braid; fb = foil + braid) and the calculated relation between Z_T and a_s when Z_T is directly proportional to frequency at high frequencies:

$$a_s = -20 \times \log_{10} \frac{Z_T}{\sqrt{Z_1 Z_2}\,\omega \left| \dfrac{1}{v_2} - \dfrac{1}{v_1} \right|} = -20 \times \log_{10} \frac{Z_T c_o}{\sqrt{Z_1 Z_2}\,\omega \left| \sqrt{\varepsilon_{r2}} - \sqrt{\varepsilon_{r1}} \right|} \qquad (6)$$

when

Z_1 =75 Ω;

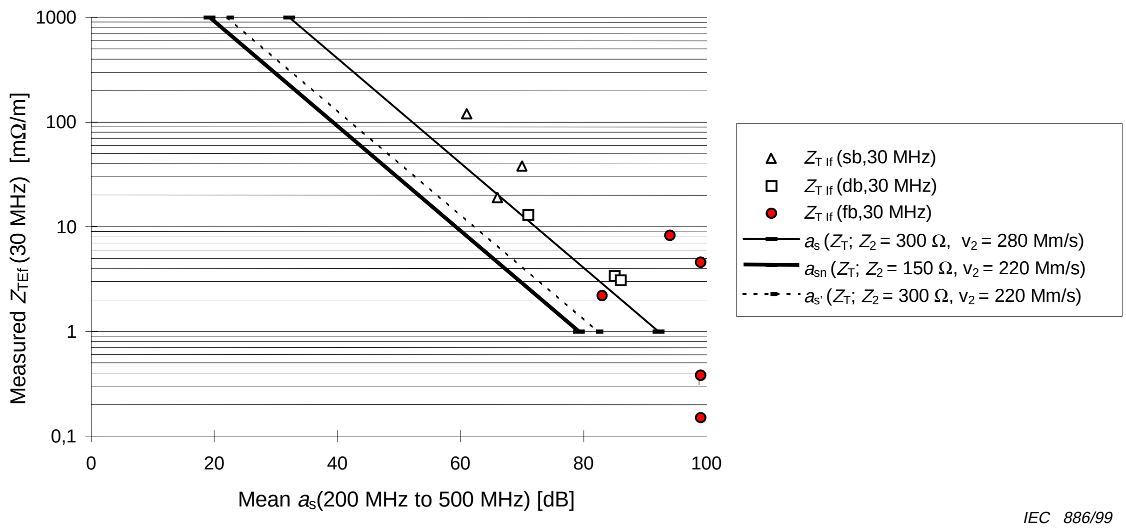
v_1 = 200 Mm/s, assumed for the cable under test;

Z_2 = 300 Ω or 150 Ω;

v_2 = 220 Mm/s ($\Delta v/v_1$ = 10 %) or 280 Mm/s (ε_{r2} =1,15 ; $\Delta v/v_1$ = 40 %);

c_o = 300 Mm/s.

Measured Z_{TEf} (30 MHz) line injection results versus absorbing clamp measured mean a_s (200 MHz to 500 MHz)



IEC 886/99

Figure 3 – Z_{TEf} (30 MHz) line-injection measurement versus absorption clamp-measurement of mean screening attenuation a_s from the same cable sample for different outer conductor constructions (sb = single braid; db = double braid; fb = foil + braid) and the calculated relation between Z_{TEf} and a_s when Z_{TEf} is directly proportional to frequency at high frequencies

$$a_s = -20 \times \log_{10} \frac{Z_{TEf}}{\sqrt{Z_1 Z_2}\,\omega \left| \frac{1}{v_2} - \frac{1}{v_1} \right|} = -20 \times \log_{10} \frac{Z_{TEf}\, c_o}{\sqrt{Z_1 Z_2}\,\omega \left| \sqrt{\varepsilon_{r2}} - \sqrt{\varepsilon_{r1}} \right|} \qquad (7)$$

when

Z_1 = 75 Ω;

v_1 = 200 Mm/s assumed for the cable under test;

Z_2 = 300 Ω or 150 Ω;

v_2 = 220 Mm/s ($\Delta v/v_1$ = 10 %) or 280 Mm/s (ε_{r2} = 1,15; $\Delta v/v_1$ = 40 %);

c_o = 300 Mm/s.

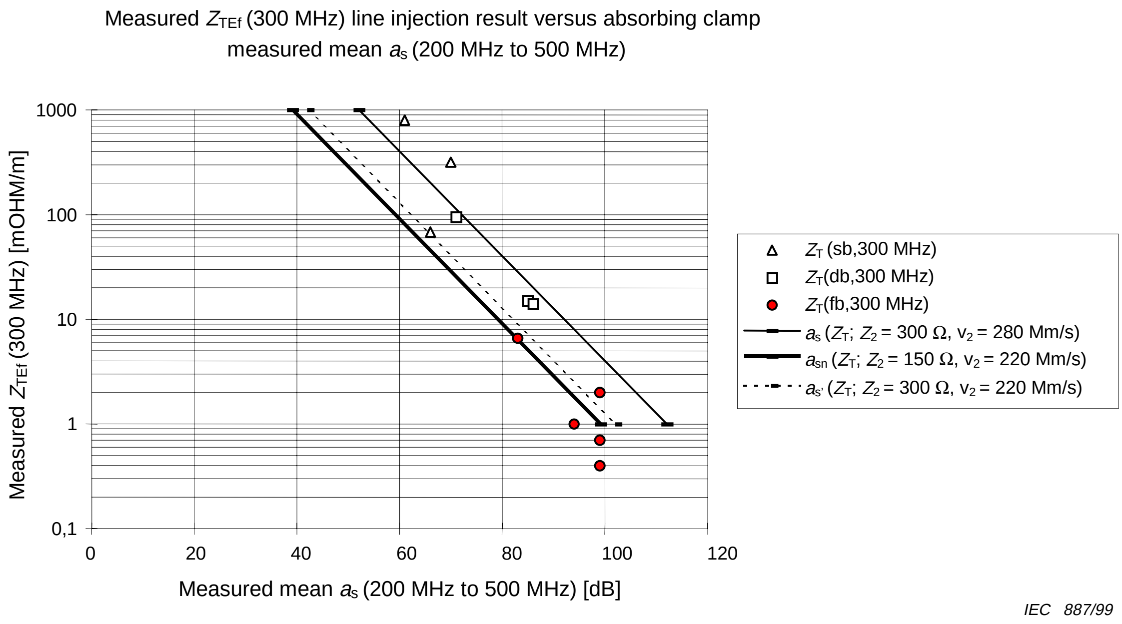


Figure 4 – Z_{TEf} (300 MHz) line-injection measurement versus absorption clamp-measurement of mean screening attenuation a_s from the same cable sample for different outer conductor constructions (sb = single braid; db = double braid; fb = foil + braid) and the calculated relation between Z_{TEf} and a_s when Z_{TEf} is directly proportional to frequency at high frequencies

$$a_s = -20 \times \log_{10} \frac{Z_{TEf}}{\sqrt{Z_1 Z_2}\,\omega \left| \frac{1}{v_2} - \frac{1}{v_1} \right|} = -20 \times \log_{10} \frac{Z_{TEf}\, c_o}{\sqrt{Z_1 Z_2}\,\omega \left| \sqrt{\varepsilon_{r2}} - \sqrt{\varepsilon_{r1}} \right|} \qquad (8)$$

when

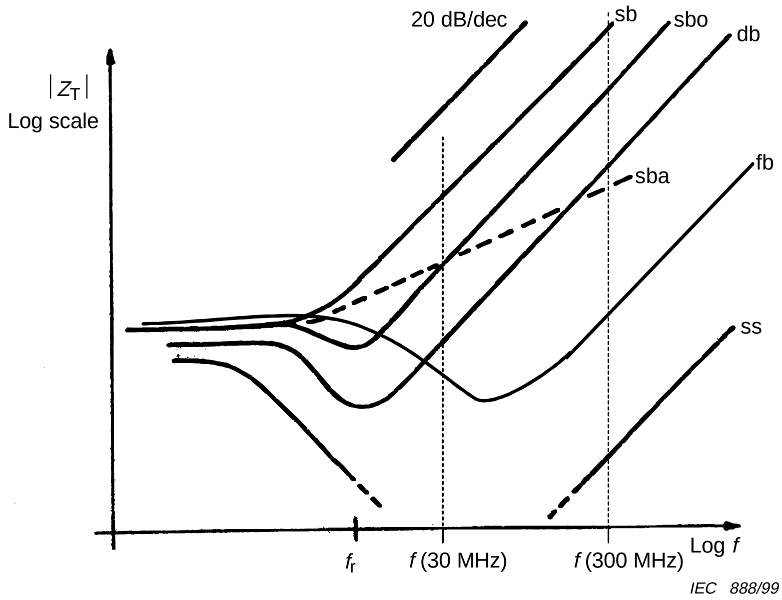
Z_1 = 75 Ω;

v_1 = 200 Mm/s assumed for the cable under test;

Z_2 = 300 Ω or 150 Ω;

v_2 = 220 Mm/s($\Delta v/v_1$ = 10 %) or 280 Mm/s (ε_{r2} =1,15; $\Delta v/v_1$ = 40 %);

c_o = 300 Mm/s.



Key

f_r	typically 1....10 MHz
sb	single braid
sbo	single braid optimized
sba	single braid "irregular"
db	double braid
ss	superscreen
fb	foil+braid

Figure 5 – Surface transfer impedance of typical cables

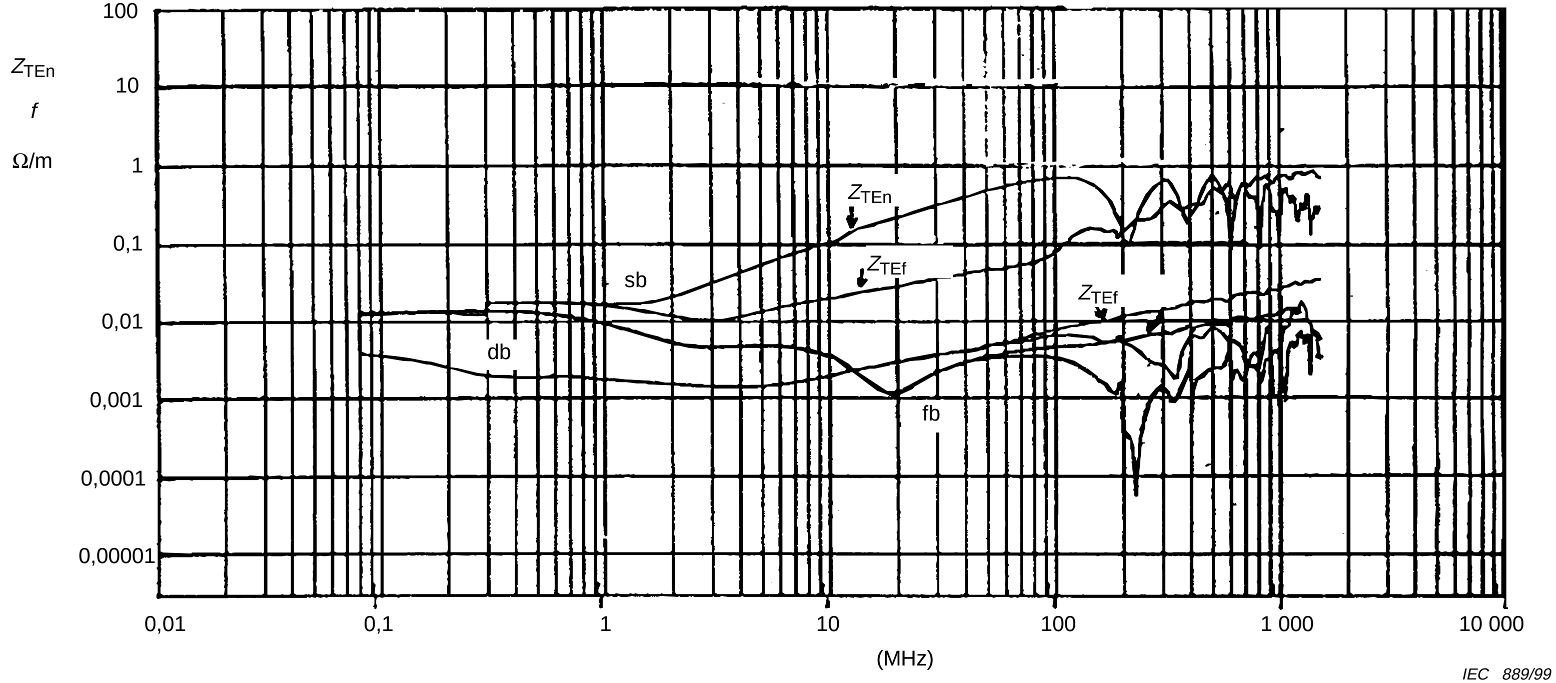


Figure 6 – Typical effective transfer impedance values measured with the line-injection method, (sb = single braid, db = double braid and fb = foil + braid)

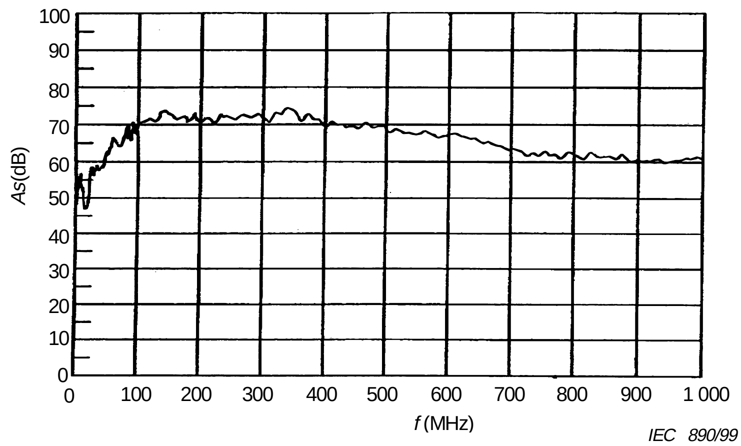


Figure 7a – sb: single braid

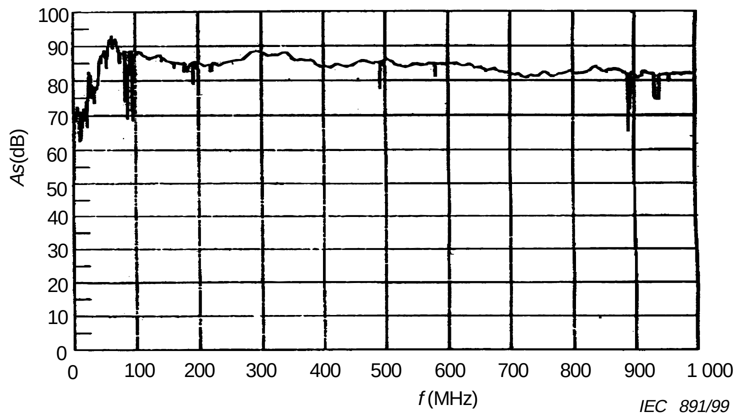


Figure 7b – db: double braid

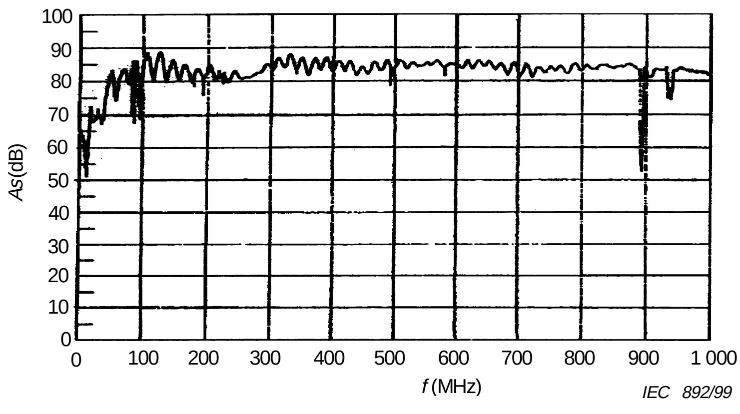


Figure 7c – fb: foil + braid

Figure 7 – Measured screening attenuation (a_s / dB) of the cables in figure 6

5 Reference documents

IEC 61196-1:1995, *Radio-frequency cables – Part 1: Generic specification – General, definitions, requirements and test methods*

IEC 61917:1998, *Cables, cable assemblies and connectors – Introduction to electromagnetic (EMC) screening measurements*

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