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Recommendations for shielded enclosures

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CENELEC

European Committee for Electrotechnical Standardization
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Foreword

This Technical Report was prepared by the Technical Committee CENELEC TC 210, Electromagnetic compatibility (EMC).

The text of the draft was submitted to vote in accordance with the Internal Regulations, Part 2, Subclause 11.4.3.2 (simple majority) and was approved by CENELEC as CLC/TR 50484 on 2009-03-20.

This document supersedes R210-005:1999.

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1 Scope

This Technical Report applies to shielded enclosures used for EMC testing which are to be validated according to the EN 50147 series of standards and the corresponding international standards. The object of this report is to give guidance to the selection of the shielding materials and components. The frequency range for this document is 10 kHz to 40 GHz.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 50147-1:1996, *Anechoic chambers – Part 1: Shield attenuation measurement*

EN 50147-2, *Anechoic chambers – Part 2: Alternative test site suitability with respect to site attenuation*

EN 55011, *Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement* (CISPR 11, mod.)

EN 55022, *Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement* (CISPR 22, mod.)

IEC 60050(161), *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

3 Definitions

Void.

4 General

Depending on the particular circumstances, it may be necessary to shield a room from the electromagnetic environment. Conversely it may be necessary to protect the environment from electromagnetic energy generated within the room. Figure 1 illustrates this.

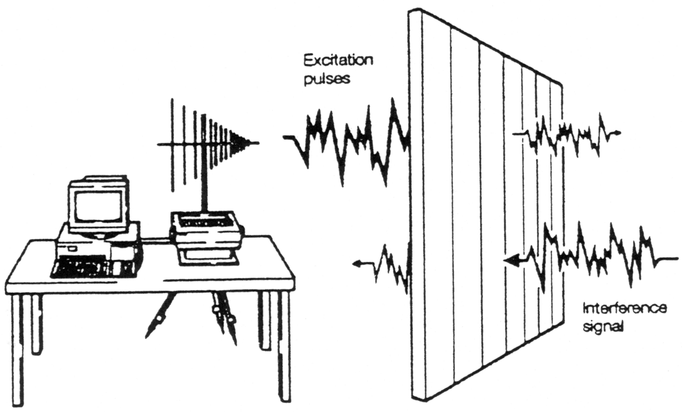


Figure 1 – Illustrated set-up for shielding

5 Shielding

The shielding effectiveness (SE) of a shielded enclosure can be measured, e.g. as described in EN 50147-1, or calculated, e.g. as in 5.1. In general, the SE of a shielded enclosure can only be calculated for simple cases. To do this a number of assumptions are made. The most important of these assumptions is that the envelope formed by the enclosure is homogeneous and consists of material whose properties such as thickness (t), conductivity (σ) and permeability (μ) are well defined. Another assumption is that the shielded enclosure has a simple geometric structure. Normally, steel, copper or aluminium sheets are used to meet the SE requirements.

The SE not only depends on the shield material parameters but also on the wave impedance of the field to be shielded. Consequently, the SE depends on the distance (r) between source and shield, relative to the wavelength λ_0 of the field, normally expressed in the quantity βr = $2\pi r/\lambda_0 = 2\pi f r/c_0$, where f is the frequency and $c_0 = 3 \cdot 10^8 \ m/s$ the propagation velocity of the field. Then, three regions are distinguished:

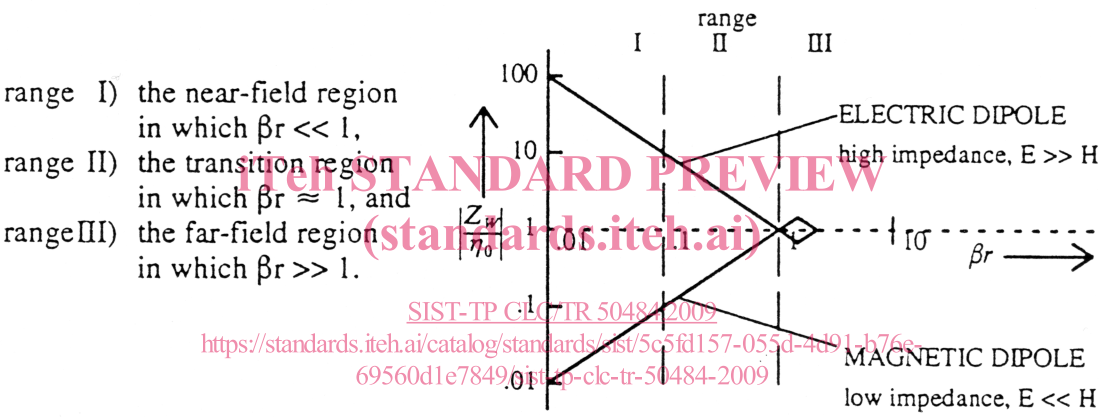


Figure 2 – Wave impedance versus distance of the field source

In the far-field (plane wave, free space) the wave impedance is a constant η_0 = 377 Ω. In the near-field, the wave impedance depends on βr and, consequently, on the type of source. The two most important types of source are:

1) the magnetic dipole having a wave impedance $Z_{wH} \ll \eta_0$, and therefore normally called a 'low-impedance source'. In the near-field Z_{wH} is proportional to βr;

2) the electric dipole having a wave impedance $Z_{wE} \ll \eta_0$, and therefore normally called a 'high-impedance source'. In the near-field Z_{wE} is in inversely proportional to βr.

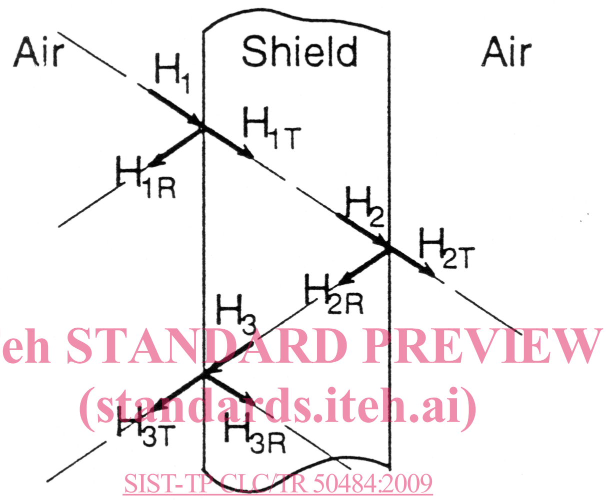
In the near-field region (normally the lower frequency range, say up to 10 MHz) the minimum SE of an enclosure is determined by the SE for the magnetic field component of a low-impedance source. A high SE value is then achieved by using a shield of an adequate thickness with a high value of the relative permeability.

In the higher frequency range (normally f larger than 10 MHz) and in the case that $\beta r \gg$ l a shield with a good conductivity is important. In this range constructional details of the enclosure, such as joints/seems, doors, inserts and resonance effects will limit the final SE of the enclosure, in particular when the largest dimensions of slits and openings in the enclosure are smaller than λ_0. The cable feed-throughs are another source of limitation of the SE .

5.1 Shielding attenuation

In many SE calculations, SE is considered to be equal to the attenuation S of the amplitude of the electric or magnetic component of the EM field as caused by an infinitely large planar shield. In general, this is not correct. For example, in S calculations resonance effects in the field distribution inside a shielded enclosure which will affect the SE are not taken into account. However, S calculations allow a good estimate of SE when considering shielded enclosure requirements. In these calculations the direction of propagation of the EM wave to be shielded is generally taken perpendicular to the shield.

The major basic theories and concepts of shielding were established by Schelkunoff [1] and Kaden [2]. More condensed and detailed practical information can be found in EMC textbooks [3].



The incoming field wave is represented by H_1.

Figure 3 – Schematic diagram of the partial reflections (subscript R) and transmissions (subscript T) at the two surfaces of a shield

According to the Schelkunoff theory, the total attenuation S_T provided by a shield results from three mechanisms, their relation being given by (see Figure 3):

$$S_T = S_A \cdot S_R \cdot S_{MR} = \frac{H_{IT}}{H_2} \cdot \left(\frac{H_1}{H_{IT}} \cdot \frac{H_2}{H_{2T}} \right) \cdot \left(\frac{H_{2R}}{H_3} \cdot \frac{H_3}{H_{3R}} \cdots\cdots \right) \qquad (1)$$

where

H represents the amplitude of the field component to be shielded.

When expressed in dB

$$S_\tau = S_A + S_R + S_{MR} \quad \text{(dB)} \qquad (2)$$

These terms are elucidated in 5.1.1 to 5.1.3, and numerical examples are given in 5.1.4.

5.1.1 The absorption loss term $S_A = H_{1T} / H_2$ i.e. the contribution to S_R as a result of the energy absorption when the field passes once through the shield. S_A can be calculated from

$$S_A = e^{t/\delta} \tag{3}$$

where

δ is the skin depth of the shielding material, given by

$$\delta = \sqrt{\frac{2}{\omega\sigma\mu}} \tag{4}$$

and

$$\omega = 2\pi f .$$

NOTE 1 The conductivity can be written as $\sigma = \sigma_r \cdot \sigma \cdot c_u$, where $\sigma_{cu} = 5{,}8 \cdot 10^7\ S/m$ is the conductivity of copper and σ_r the conductivity of the shield material relative to copper. Similarly, μ can be written as $\mu = \mu_r\mu_o$, where $\mu_0 = 4\pi \cdot 10^{-7}\ S/m$ and μ_r the relative permittivity of the shield. Expressing the frequency in MHz, δ can be written as

$$\delta = \frac{66}{\sqrt{f(MHz)\sigma_r\mu_r}}\ (\mu m) \tag{5}$$

NOTE 2 S_A does not depend on the distance between source and shield, it only depends on the shield material parameters t, υ, μ and the frequency f. From Equation (3) it follows that $S_A \approx 8 \cdot t/\delta$ (dB).

5.1.2 The reflection loss term $S_R = (H_1 / H_{1T})(H_2 / H_{2T})$, i.e. the contributions to S_T as a result of the reflection of the field when entering and leaving the shield. This contribution is proportional to the wave impedance of the field and, hence, in the near field S_R depends on the type of source via the factor βr as indicated in Clause 5.

a) Near field $(\beta r << I)$:

In the case of an electric dipole source, S_R can be estimated from

$$S_R = S_{RE} = \frac{\sigma\delta}{4\sqrt{2}} \cdot \frac{\eta_o}{\beta r} \tag{6}$$

Note that $S_{RE} \rightarrow \infty$ when $\beta r \rightarrow 0$, i.e. when $f \rightarrow 0$ and/or $r \rightarrow 0$.

In the case of a magnetic dipole source, S_R can be estimated from

$$S_R = S_{RH} = \frac{\sigma\delta}{4\sqrt{2}}\eta_0\beta r \quad \text{(see the Note to } S_{MR}\text{)} \tag{7}$$

Note that $S_{RH} \rightarrow 0$ when $\beta r \rightarrow 0$, i.e. when $f \rightarrow 0$ and/or $r \rightarrow 0$.