



BSI Standards Publication

Electronic displays

Part 2-8: Measurements of optical characteristics — Reflective displays

National foreword

This British Standard is the UK implementation of IEC 62977-2-8:2025.

The UK participation in its preparation was entrusted to Technical Committee EPL/100, Audio-visual equipment.

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INTERNATIONAL STANDARD

**Electronic displays –
Part 2-8: Measurements of optical characteristics – Reflective displays**



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ELECTRONIC DISPLAYS –

**Part-2-8: Measurements of optical characteristics –
Reflective displays**

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Draft	Report on voting
110/1745/FDIS	110/1764/RVD

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

The language used for the development of this International Standard is English.

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INTRODUCTION

All documents published by IEC TC 110 that are written on the measurement for electronic displays refer to a set of methods and procedures that are similar to one another. These measurement methods are sometimes identical. This document is written for reflective displays by referring to IEC 62977-2-2 and is intended to identify these methods and to describe them together with suitable precautions and diagnostics. Therefore, this document can be a reference for forthcoming standards to make the work of the involved experts more efficient and to avoid reduplication of efforts.

Introduction of the common optical measurement methods (COMM) is also related to a structure where each kind of optical measurement finds its unambiguous position for identification of similarities to other methods or for clarification of distinctions. This structural classification together with a general taxonomy is supposed to make the process of standards production easier, faster and thus more effective.

This document describes the common optical measurement methods applicable to the reflective displays. However, the contents overlap with some parts of the existing standards which are developed in TC 110 (IEC 61747-6-2:2011 and IEC 62679-3-1:2014), in which the documents describe the optical measurement methods of the individual display technologies, such as LCD and E-paper. This document is intended to be used as common optical measurement methods for the reflective direct view type and a reference document for future standards. In addition, the present document can be used in the revisions of the existing standards (IEC 61747-6-2:2011 and IEC 62679-3-1:2014) in their maintenance time by referring to this document to the largest extent possible.

The characteristics and the measurement methods of electronic displays in the IEC 62977 series are summarized in Table 1.

Table 1 – Measurement structure from optical quantities, to evaluations and to results (top down)

Variables	Time		Location (x, y)	Direction (θ , φ)	Test pattern, electrical driving, input signal	Illumination conditions	Temperature, humidity
Data sampling condition	Fast	Slow	Slow	Slow^a	Slow^a		
Results	transitions from one optical state to another state	temporal stability (uniformity)	uniformity	uniformity^a	static pattern^a characteristic function (electro-optic transfer function, EOTF) characteristic values (e.g. threshold, saturation),	darkroom indoor^a outdoor^a	standard environmental conditions^a
Evaluations 1 st order	turn-on, turn-off, delay (latency) time periods, temporal modulations				luminance reflectance^a contrast^a chromaticity^a threshold, saturation values, steepness of transitions, etc.		
Evaluations 2 nd order	flicker prediction, moving picture response time, etc.				EOTF from which the exponent gamma is evaluated chromaticity and colour gamut area^a colour gamut volume^a		

^a Indicates the characteristics and measurement methods which are written in this document

ELECTRONIC DISPLAYS –

Part-2-8: Measurements of optical characteristics – Reflective displays

1 Scope

This part of IEC 62977 specifies standard measurement conditions and methods for determining the optical characteristics of reflective direct view displays that render real 2D images on a flat panel. This document applies to flat panel displays operated in a reflective mode with any integrated light sources turned off during measurement. The input signal is unbounded and encodes either monochrome or colour images.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

IEC 62977-2-1:2021, *Electronic displays – Part 2-1: Measurement of optical characteristics – Fundamental measurements*

IEC 62977-2-2:2020, *Electronic displays – Part 2-2: Measurement of optical characteristics – Ambient performance*

ISO/CIE 11664-1, *Colorimetry – Part 1: CIE standard colorimetric observers*

ISO/CIE 11664-2, *Colorimetry – Part 2: CIE standard illuminants*

ISO/CIE 11664-4, *Colorimetry – Part 4: CIE 1976 L*a*b* Colour space*

ISO/CIE 23539, *Photometry – The CIE system of physical photometry*

CIE 015, *Colorimetry*

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1.1

reflective display

electronic display device that modulates the illumination incident from an external source and reflects it back as spatially and spectrally modulated light

Note 1 to entry: Any reflective display consists of at least two basic optical elements. (a) reflector and (b) reflection modulator. The reflector element reflects back the incident ambient light so that the observer can see spatially modulated light. The reflection modulator changes the reflectance either equally for all wavelengths for an achromatic display or in a spectrally selective manner for a colour one.

Note 2 to entry: Ambient illumination is necessary for the recognition of the visual information on a reflective display.

3.1.2

ambient contrast ratio

contrast ratio under ambient illumination

contrast ratio of a display with both hemispherical diffuse and directional illumination incident onto its surface used to simulate real lighting environments

[SOURCE: IEC 62679-1-1:2014, 3.2.1, modified – the admitted term “contrast ratio under ambient illumination” has been added.]

3.1.3

ambient display colour

display colour under ambient illumination

colour of a display with both hemispherical diffuse and directional illumination incident onto its surface at a defined geometry, spectra, and illumination levels that simulate a realistic lighting environment

[SOURCE: IEC 62679-1-1:2014, 3.2.2, modified – the preferred term “daylight display colour” has been replaced with “ambient display colour” and the admitted term “display colour under ambient illumination” has been added.]

3.1.4

viewing direction range

angular span within which a viewer can perceive the visual content displayed on a screen for its intended application

Note 1 to entry: The angle is described with unidirectional angle or bidirectional angle, for example, left and right in horizontal, or up and down in vertical around the display's central axis, i.e. surface normal. See also 8.2.

Note 2 to entry: Viewing direction-dependent performance is often reported as “viewing angle” or “viewing direction range” in the electronic display market, especially when the left/right and up/down characteristics are symmetrical.

3.2 Abbreviated terms

BRDF	bidirectional reflectance distribution function
CIE	Commission Internationale de l'Eclairage (International Commission on Illumination)
CIELAB	CIE 1976 $L^*a^*b^*$
DUT	device (display) under test
LMD	light measuring device
SID	Society for Information Display
VAS	variable aperture source

3.3 Symbols

A list of symbols used in this document is given in Table 2. The other symbols and units used in this document are coherent with IEC 62977-2-2.

Table 2 – Summary of symbols

Symbol	Units	Definition
θ_S	degree	Angle of inclination of light source (relative to the surface normal of the DUT)
θ_R	degree	Angle of inclination of LMD (relative to the surface normal of the DUT)
φ_S	degree	Azimuth angle of light source which is defined by the rotation around the surface normal of the DUT
φ_R	degree	Azimuth angle of the LMD which is defined by the rotation around the surface normal of the DUT
d_S	mm	Distance from the centre of a measurement field on the DUT to the centre of the exit port of a light source
d_R	mm	Distance from the centre of a measurement field on the DUT to the centre of the acceptance aperture of LMD or the front lens of LMD
r	mm	Radius of exit port of an integrating sphere light source Radius of the exit aperture of the light source
ψ	degree	Angle subtended by the exit aperture of the light source to the DUT (Source subtense angle)
ψ_{accept}	degree	Angle subtended by the acceptance aperture of LMD to the DUT (Angular aperture of LMD)
α_{meas}	degree	Angle subtended by the measurement field of LMD to the DUT (Measurement field angle)
E	lx	Illuminance
$E(\lambda)$	$\text{W m}^{-2} \text{ nm}^{-1}$	Spectral irradiance
L	cd m^{-2}	Luminance
$L(\lambda)$	$\text{W m}^{-2} \text{ sr}^{-1} \text{ nm}^{-1}$	Spectral radiance
L^*	-	CIELAB (CIE 1976 $L^*a^*b^*$) lightness
ΔE^*_{ab}	-	CIELAB (CIE 1976 $L^*a^*b^*$) colour difference is the Euclidean distance between two colour coordinates
R	%	Luminous reflectance factor in off-specular directional illumination
$R(\lambda)$	%	Spectral reflectance factor in off-specular directional illumination
R_h	%	Luminous haze reflectance factor in a specular reflection geometry, representing the maximum value of haze component of the DUT
ρ	%	Luminous reflectance factor in hemispherical diffuse illumination
$\rho(\lambda)$	%	Spectral reflectance factor in hemispherical diffuse illumination
ρ_r	%	Luminous specular (regular) reflectance in a specular reflection geometry, representing the specular (regular) reflection contribution of the DUT
$\rho_r(\psi)$	%	Luminous specular (regular) reflectance as a function of the source subtense angle
$\rho_r(\lambda)$	%	Specular (regular) spectral reflectance in a specular reflection geometry, representing the specular (regular) reflection contribution of the DUT
ρ_L	%	Luminous diffuse (Lambertian) reflectance in a specular reflection geometry, representing the diffuse (Lambertian) scatter contribution of the DUT
P_i	-	Measurement position i of 9 points location ($i = 0$ to 8)
CR	-	Contrast ratio
$S(\lambda)$	-	Relative spectrum of CIE Illuminant
X, Y, Z	-	Tristimulus values of CIE 1931 standard colorimetric system
x, y	-	Chromaticity values of CIE 1931 chromaticity coordinates system

Symbol	Units	Definition
A_{xy}	%	Chromaticity gamut area of CIE 1931 chromaticity coordinates system The percentage of area in relation to the entire area encompassed by the monochromatic spectrum locus
VDR_H	degree	Horizontal viewing direction range
VDR_V	degree	Vertical viewing direction range

4 Specifications of illumination

4.1 General

Standard lighting conditions shall comply with IEC 62977-2-2:2020, 4.3.

4.2 Standard illumination spectra

For spectral measurement of reflective displays, a spectrally smooth broadband illumination (e.g. a spectrum range exceeding 380 nm to 780 nm) shall be used. Such illumination can be provided by incandescent lamps, for example, or combinations of LEDs and so on. When using a photometer, such as a luminance meter, to measure reflective display, the spectrum of illumination shall be specified. The absence of fluorescence should be checked by illuminating the display with blue light at a 45° inclination angle and determining if a glow from the illumination area can be observed.

The measured reflection coefficients shall be used to predict the performance of reflective displays when viewed under CIE Standard Illuminants such as Illuminant A, D50, D65, and CIE Illuminant D75. One of the following reference illumination conditions shall be used to simulate indoor and outdoor viewing environments. The CIE Illuminants given in Table 3 shall be used for indoor and outdoor illumination conditions. The optical characteristics of a display under indoor and outdoor illumination conditions are determined using the reflection coefficients from Clause 7. When using a photometer, the illumination spectra should approximate CIE Standard Illuminant A, D50 or D65 and the relative spectral distribution used shall be reported.

NOTE 1 The recommended type of illuminants are referred to in IEC 62977-2-2:2020, 4.3.3.

NOTE 2 CIE Standard Illuminant A is realized by an incandescent lamp. D50 and D65 can be approximated by an incandescent or a halogen lamp with a colour temperature conversion filter such as a light balancing (LB) filter. However, it is difficult to realize D75.

Table 3 – Reference illuminant conditions

CIE Illuminant	Indoor, room illumination			Outdoor, daylight illumination		
	Hemispherical diffuse	Off-specular directional	Specular	Hemispherical diffuse	Off-specular directional	Specular
A	✓	✓	✓			
D50	✓	✓	✓		✓	✓
D65	✓	✓	✓	✓	✓	✓
D75				✓		

NOTE Relative spectral power distribution of the CIE Standard Illuminant A, D50 and D65 are described in ISO/CIE 11664-2 and for the CIE Illuminant D75 in CIE 015.

5 Light measuring devices (LMDs)

5.1 General

For measurement and characterization of reflective displays, spectroradiometers shall be used. When the spectrum of illumination used is specified, luminance meters can be used (see 7.7.1). The employed LMD shall be checked for the following criteria and specified accordingly:

- sensitivity of the measured quantity to polarization of light,
- errors caused by veiling glare and lens flare (i.e. stray-light in optical system),
- timing of data-acquisition, low-pass filtering over time and temporal aliasing-effects,
- linearity of LMD,
- general $V(\lambda)$ mismatch index (f_1') [1]¹ is 6 % or less (for luminance meter).

5.2 LMD conditions

LMD conditions shall comply with IEC 62977-2-2:2020, 4.4.4. The following parameters should be specified:

- 1) The distance between the LMD and the measurement spot on the DUT,
- 2) The measurement field area (angle) on the DUT shall be 2° or less,
- 3) The angular aperture (i.e. acceptance angle and entrance pupil area) of the LMD (refer to Figure A.1).

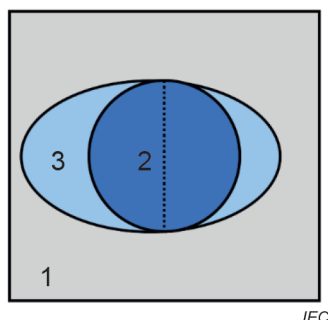
When measuring matrix displays the LMD should be set to the measurement field that includes more than 500 pixels² on the display under normal observation (the standard measurement direction). The angular aperture of the LMD, ψ_{accept} , shall be 5° or less (refer to Annex A). When the number of pixels in the field of measurement is lower than 500, then it should be confirmed and reported that the measurement yields equivalent results. In case of measuring segmented displays, the field of measurement should be set within a single segment only.

5.3 Effects of receiver inclination

The measurement field of most LMDs is circular at the normal measurement direction. With increasing LMD inclination the shape of the measurement area becomes an elongated ellipse with the short axis of the ellipse being perpendicular to the inclination plane of the LMD and the centre of that shape shifted relative to the LMD optical axis (refer to Annex B). In order to avoid measurement errors, it shall be assured that the measurement field remains unchanged with a constant optical state (uniform luminance on the measurement area) for all angles of inclination, as shown in Figure 1. In the case of reflective displays, the display area at and around the measurement field shall be uniformly illuminated. The uniformly illuminated area of the DUT should be at least twice as large (in both horizontal and vertical directions) than the measurement field at the largest used inclination of the LMD. Dimensions and location of the measurement field shall be specified in the measurement report.

¹ Numbers in square brackets refer to the Bibliography.

² Note that the official definition of a pixel can include a multitude of constituent dots.



Key

- 1 Uniform field on the DUT
- 2 Circular measurement field at normal direction
- 3 Measurement field at an angle of inclination with respect to minor diameter of the ellipse

Figure 1 – Shape of measuring spot of LMD

6 Arrangements of illumination source, DUT and LMD

6.1 General

Reflective displays make use of the ambient illumination to visualize information. To achieve the required precision and reproducibility of the measurement results, the cross-coupling between the illumination apparatus and the LMD should be avoided. The geometry of the measurement set should be well defined, in order to avoid trilateral coupling between illumination, DUT and LMD ([2] to [21]).

Clause 6 describes a selection of different geometries suitable for measuring and characterizing reflective displays as a function of the direction of observation (i.e. viewing direction or direction of measurement). A set of parameters provides detailed specification of the conditions that are used for measurement of the electro-optical characteristics indicated in the following paragraph.

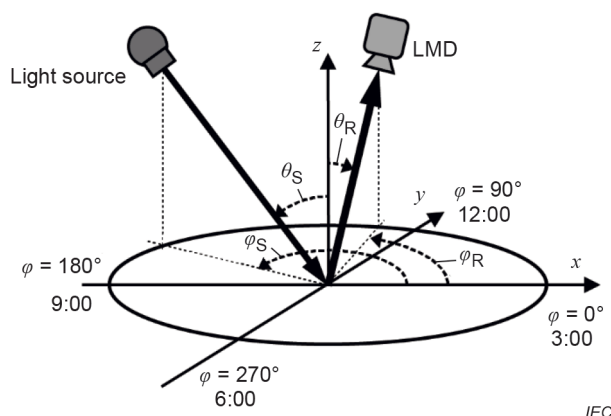
At least one of four types of illumination geometries (see 6.3, 6.4, 6.5 and 6.6) shall be used for determining the performance of the display. Additional illumination geometries can also be used. For specular reflection measurement, the specular illumination geometry specified in 6.7 shall be used. The details of the illumination geometry used for a given measurement shall be reported. Further guidance on the proper implementation of these illumination geometries is given in the Society for Information Display (SID) Information Display Measurements Standard [22]. The standard illumination geometry shall comply with IEC 62977-2-2:2020, 4.2.

NOTE 1 The range of geometries for illumination of the DUT and detection of the light reflected from the DUT is not limited to the examples presented here.

NOTE 2 The purposes of the illumination geometries are described in Annex C.

6.2 Coordinate system for viewing direction and light source position

The viewing direction, which is represented by the optical axis of the LMD, and the light source alignment are specified by angle of inclination, θ , measured relative to surface normal, and the azimuth angle, φ (angle of rotation around the DUT's surface normal, that is, measured with respect to a reference direction) in a spherical coordinate system as illustrated in Figure 2. The angles θ and φ shall be used to specify the direction of light incidence (θ_S , φ_S) and the measurement direction (θ_R , φ_R).

**Key**

- θ_R Inclination angle of LMD
 φ_R Azimuth angle of LMD
 θ_S Inclination angle of light source
 φ_S Azimuth angle of light source

Figure 2 – Illustration of spherical directions θ and φ for the light source and LMD

The optical axis of the light source that crosses the centre of the light source's aperture shall be fixed to the centre of the measurement field area on the DUT surface, that is any direction (θ_S, φ_S). Then, the LMD's optical axis shall be fixed to the centre of the illumination spot (θ_R, φ_R). Finally, the LMD can take any measurement direction (refer to Annex A).

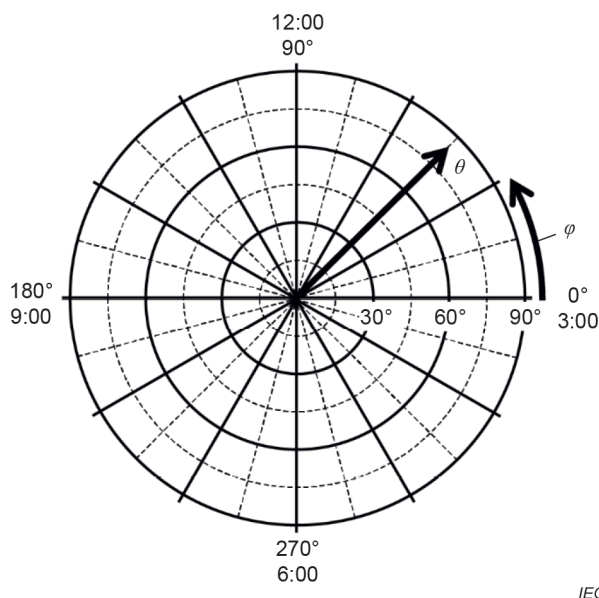


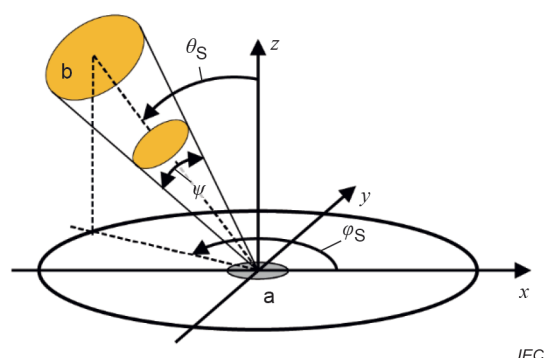
Figure 3 – Polar coordinate system for specification of directions (illumination and measurement)

Each direction specified by the spherical coordinates according to Figure 2 can be represented and illustrated in a polar coordinate system as shown in Figure 3. The angle of inclination, θ , is represented by the length of the radius vector. The azimuth angle (angle of rotation), φ , counted from a reference direction (here the x -axis), corresponds to the directions on a clock (e.g. $\varphi = 90^\circ$ corresponds to twelve o'clock).

Variations of scalar quantities (e.g. luminance, contrast, etc.) with viewing direction or direction of illumination can be represented in polar coordinate systems by lines of constant value (iso-lines). Ranges of directions that meet certain minimum requirements (e.g. contrast is less than 10) can be shown as regions in a polar coordinate system (e.g. refer to Annex D).

6.3 Directional illumination

Directional illumination means illumination of the measurement field from essentially one single specified direction (i.e. unidirectional). It is provided by a lamp bulb or a source device with a small aperture with uniform illumination which is subtending a small angle (5° or less which complies with IEC 62977-2-2:2020, 4.3.4.2) from the centre of the measurement field. The source subtense angle (ψ) from the measurement field and the direction of the cone-axis (θ_S, φ_S) shall be specified.



Key

- a Measurement field
- b Area of uniform illumination

NOTE The types of illumination are classified according to the angle subtended from the measurement field (a). An area of uniform luminance (b) is subtending the angle ψ at the measurement field, illumination is provided within the cone specified by the cone axis (θ, φ) and the source subtense angle, ψ . In the case $\psi = 180^\circ$ and the cone axis at the normal direction, the illumination is provided from within the complete hemisphere (i.e. hemispherical diffuse illumination).

Figure 4 – Illustration of a directional illumination

All conditions comply with IEC 62977-2-2:2020, 4.3.4.2, except the following conditions. The standard conditions are (a) $\theta_S = 30^\circ$ and $\theta_R = 0^\circ$, (b) $\theta_S = 45^\circ$ and $\theta_R = 0^\circ$ or (c) $\theta_S = 0^\circ$ and $\theta_R = 30^\circ$. Alignment accuracy should be within $\pm 0,4^\circ$.

NOTE 1 The definition of directional illumination used here is different from the definition of a directional light source according to CIE TN 010:2019 [23].

NOTE 2 The value of reflectance characteristics generally depends on the angular extent of the incident flux at the field of measurement and the LMD acceptance cone (see CIE 038:1977 [24]).

6.4 Ring light illumination

A ring light provides directional illumination of the field of measurement with a constant angle of inclination, θ , for all azimuth angles, φ (between 0° and 360° azimuth).

All conditions comply with IEC 62977-2-2:2020, 4.3.4.3. The standard conditions are $\theta_R = 0^\circ$ and $\theta_S \pm \Delta = 45^\circ \pm 3^\circ$. The ring light and LMD should have an alignment accuracy of $\pm 0,7^\circ$.

NOTE 1 The figures are drawn in IEC 62977-2-2:2020, 4.3.4.3.

NOTE 2 Ring light illumination is especially useful when the reflected surface exhibits diffractive scatter.

6.5 Conical illumination

Conical illumination provides illumination from a conical-shaped light source of subtense angle, Ψ . The central axis of the light source is centred on the measurement area of the DUT. It can provide the uniform luminance at the centre of the DUT. The direction of the cone axis (θ_S, φ_S) and the source subtense angle, Ψ , shall be specified.

When the source subtense angle is 180° and the cone axis is perpendicular to the plane of the DUT, the illumination is hemispherical. If the hemispherical dome emits light at a constant luminance, the illumination is uniformly hemispherical.

Conical illumination can be realized by, for example, apertures of integrating spheres or internally illuminated hemispheres. Figure 5 shows the examples of conical illumination. The illumination is provided out of a source subtense angle, Ψ , with the apex of this angle fixed to the centre of the measuring spot on the DUT. The variation of the intensity of incident light with direction inside this solid angle shall be specified. The cone of illumination itself is specified by the direction of the axis of the cone and the maximum inclination with respect to the surface normal of the DUT (i.e. the source subtense angle).

A light source centred about the surface normal of the DUT illuminates the DUT from a range of inclination angles, θ_S ($0^\circ < \theta_S < \theta_{S \max}$), for all azimuthal angles, $\varphi_S = 0^\circ$ to 360° . The LMD is aligned to form the angle, θ_R , with respect to the surface normal of the DUT. The measurement field on the DUT is defined by the area element that is imaged on the detector of the LMD.

The distance, d , of the source from the DUT shall be accurate within the radius, r , of the exit port and the direction of the illuminating device shall be aligned within 4° . The LMD shall be aligned within $0,5^\circ$. Means shall be provided for the LMD to look on the DUT through the illuminating device (e.g. slit, aperture). The standard condition is $\theta_R = 0^\circ$ to 8° . The subtense of the source shall be $\theta_{S \max} \geq 70^\circ$. The relationship between the subtense angle Ψ , the distance d and the radius r is as follows.

$$\begin{aligned}\Psi &= 2 \times \theta_{S \max} \\ \theta_{S \max} &= \arctan \frac{r}{d}\end{aligned}\tag{1}$$

where

Ψ is the angle subtended by the source aperture (source subtense angle), expressed in degree;

r is the radius of source aperture, expressed in mm;

d is the distance between source aperture and DUT, expressed in mm.

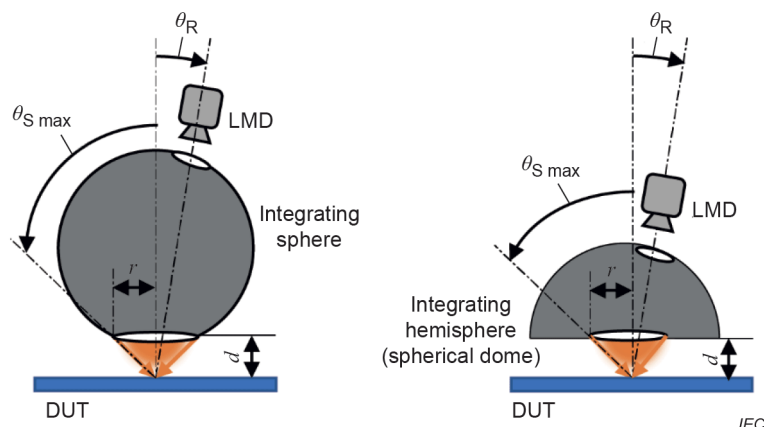


Figure 5 – Examples of conical illumination

When reflectance characteristics shall be measured as a function of the viewing direction, an extended conical illumination may be used which provides illumination for the field of measurement from a wide range of directions. An example of an extended conical illumination device is shown in Figure 6. This example has a slit extending from the equator through the north-pole back to the equator. When such a slit is used in a dark room environment, it acts as a gloss trap, for excluding specular reflection of the DUT from directions corresponding to the regularly reflected optical axis of the LMD. A gloss trap made from highly absorbing material may be used at the opposite side of LMD instead of a slit cover (see Clause A.3, Annex D). For specular included reflection measurement, a slit cover made from the same highly reflecting material as the sphere inner wall should be added at the opposite side of LMD instead of a gloss trap. When using the device like the case in this example, the direction of the LMD optical axis may range from $\theta_R = 0^\circ$ to $\theta_R = 60^\circ$ at $\varphi_R = 0^\circ$ or 180° .