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Decorative metallic coatings for radio wave transmissive application products — Designation and characterization method

Revêtements métalliques décoratifs pour les produits d'application transmettant les ondes radio — Désignation et méthode de caractérisation

Reference number
ISO 5154:2023(E)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 107, *Metallic and inorganic coatings*, Subcommittee SC 9, *Physical vapour deposition coatings*.

This second edition cancels and replaces the first edition (ISO 5154:2022), of which it constitutes a minor revision. The changes are as follows:

— updated titles of Table 4 and Table 5;

— updated the position shifts of circles in Figure B.6.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document was developed to provide the designation of the characteristics of the decorative metallic coatings for radio wave transmissive application products, in response to worldwide demand for the standardization of such products. This document was also developed to specify the standard method to quantitatively characterize the decorative parts with the metallic coatings that both have the low transmission loss of radio wave and the metallic appearance.

One of the typical applications of the radio wave transmissive application products is the metallized plastic emblem and other decorative exterior parts for automobiles. These parts are placed in front of the millimetre wave radar transmitter-receivers of the collision prevention system. A typical example of these parts has the low transmission loss of the specific radio wave lower than 2,5 dB and the bright metallic appearance with lightness of 70 or higher. Low transmission loss is consistent with metallic appearance by forming a discontinuous structure of metallic coatings. An example of the discontinuous coating is the sputter-deposited film of low melting point metals such as indium having island structure.

This document specifies the designation and the characterization methods of the decorative metallic coatings of the products for radio wave transmissive application. The designation consists of the transmission loss of the radio wave, the frequency band of the radio wave under consideration, the lightness and hue of the parts, as well as the main material and manufacturing process of metallic coatings. The characterization methods consist of the determination of the transmission loss of radio wave with specific frequency band and the evaluation of lightness and hue which represent the colour and appearance.

Examples of measurement results of the radio wave transmission loss and the colour characteristics are described in Annex A and Annex B, respectively. The information in annexes is for the convenience of users and does not constitute an endorsement by ISO.

Decorative metallic coatings for radio wave transmissive application products — Designation and characterization method

1 Scope

This document specifies the designation and the characterization methods of the decorative metallic coatings of the products for radio wave transmissive application. The designation consists of the transmission loss of the radio wave, the frequency band of the radio wave under consideration, the lightness and hue of the parts, as well as the main material and manufacturing process of metallic coatings. The characterization methods consist of the determination of the transmission loss of radio wave with specific frequency band and the evaluation of lightness and hue which represent the colour and appearance.

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.

ISO 2080, *Metallic and other inorganic coatings — Surface treatment, metallic and other inorganic coatings — Vocabulary*

ISO 4519, *Electrodeposited metallic coatings and related finishes — Sampling procedures for inspection by attributes*

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

ISO 16348, *Metallic and other inorganic coatings — Definitions and conventions concerning appearance*

IEC 60050, *International Electrotechnical Vocabulary (IEV)*

IEC 62431, *Reflectivity of electromagnetic wave absorbers in millimetre wave frequency — Measurement methods*

CIE S 017, *International Lighting Vocabulary*

JIS Z 8721, *Specification of colours according to their three attributes*

ASTM D1535, *Standard Practice for Specifying Color by the Munsell System*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2080, ISO 16348, IEC 60050 and CIE S 017 and the following apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
VNA
vector network analyser
instrument to measure the transfer and/or impedance characteristics, that is, both magnitude and phase changes, of a linear network, device, or material through stimulus response testing over a given frequency range

3.2
TRL calibration method
thru-reflect-line calibration method
one of the calibration methods to fix the systematic errors with the network analyser measurements using a zero-length "thru", a longer "thru" (called “line”), and high-reflect standards

3.3
skin depth
depth at which the current density in a conducting material is reduced to 1/e times the surface current density, at a given frequency

3.4
SCI
specular component include
type of colour measurements including both specular and diffused reflected light

3.5
SCE
specular component exclude
type of colour measurements excluding any specular reflected light

4 Designation

4.1 General

A designation consists of the following:

a) the letters, "StM", as the elementary symbol indicating that the decorative metallic coating has ability for radio wave transmittance and metallic appearance;

b) a letter indicating the frequency band classification;

c) the letter "T" and a number giving the transmission loss followed by a solidus (/);

d) the letter "L" and a number indicating the lightness;

e) letters indicating the hue followed by a solidus (/);

f) an elemental symbol of the main component element of coatings followed by a solidus (/);

g) letters indicting the manufacturing method of coatings.

4.2 Elementary symbol

The elementary symbol, StM, shall indicate that the decorative metallic coating has ability for radio wave transmittance and metallic appearance.

4.3 Transmission loss of radio wave

The following letters and numbers designate the frequency band of the radio wave under consideration and the transmission loss due to reflection and absorption.

4.3.1 Frequency classification

The letters shown in Table 1 designate the frequency bands of the radio wave under consideration.

Table 1 — Designation of frequency bands of radio wave

Designation	Frequency band of the radio wave under consideration[a] Hz	Band name[b]
A	18×10^9 to $26{,}5 \times 10^9$	K
B	$26{,}5 \times 10^9$ to 40×10^9	Ka
C	50×10^9 to75×10^9	V
D	75×10^9 to 110×10^9	W
E	110×10^9 to170×10^9	D
F	170×10^9 to 260×10^9	H
G	300×10^9 to 500×10^9	-

[a] Lower limit exclusive, upper limit inclusive.

[b] The band names of specific frequencies are given in Reference [1].

4.3.2 Transmission loss of radio wave

The letter "T" and a number designate the transmission loss of the radio wave due to reflection and absorption as shown in Table 2.

Table 2 — Designation of transmission loss

Designation	Transmission loss[a] dB
T0,1	0,1 or below
T*x* (x = 0,2 to 2,4)	x
T2,5	2,5 or above

[a] Transmission loss shall be rounded off to one decimal place.

4.4 Lightness and hue

The following letters and numbers designate the lightness and hue angle that specify the colour and appearance.

4.4.1 Lightness

The letter "L" and a number designate the lightness as shown in Table 3.

Table 3 — Designation of lightness

Designation	Lightness[a]
L100	100 or above
L*n* (n = 99 to 41)	n
L40	40 or below

[a] Lightness shall be rounded off to integer.

4.4.2 Hue

The letter(s) shown in Table 4 designate the hue.

Table 4 — Designation of hue

Designation	Hue angle[a] deg	Description of colour name
Chroma of between 3,0 and 5,0		
R	3 - 36	Red
YR	36 - 75	Yellow red
Y	75 - 103	Yellow
GY	103 - 148	Green yellow
G	148 - 186	Green
BG	186 - 225	Blue green
B	225 - 266	Blue
PB	266 - 302	Purple blue
P	302 - 332	Purple
RP	332 - 0	Red purple
RP	0 - 3	Red purple
Chroma of between 0,8 and 3,0		
R	0 - 55	Red
Y	55 to 120	Yellow
G	120 to 205	Green
B	205 to 285	Blue
P	285 to 350	Purple
R	350 to 360	Red
Chroma of 0,8 or below		
N		Achromatic colour

[a] Lower limit exclusive, upper limit inclusive.

4.5 Main component element of coating

An elemental symbol designates the main component element of the decorative metallic coating.

4.6 Manufacturing method

The symbols shown in Table 5 designate the manufacturing methods of the decorative metallic coating.

Table 5 — Designation of manufacturing method

Designation	Manufacturing method
Ve	Vacuum evaporation
Sp	Sputtering
Ep	Electroplating or Electroless plating[a]
OP	Other process

[a] Electroless plating includes autocatalytic plating and immersion coating (see ISO 2080).

4.7 Example of designation

Decorative metallic coatings for radio wave transmissive application products for W band radio wave (75 GHz to 110 GHz) with transmission loss of T0,4 level, having the appearance with the lightness of 90 and the hue of BG (blue green), with the main material of chromium coated by sputtering process would have the following designation:

EXAMPLE StM D T0,4 / L90 BG/ Cr/ Sp+

5 Characterization

5.1 Transmission loss of radio wave

The transmission loss of the specific radio wave frequency band due to the reflection and adsorption shall be determined in accordance with IEC 62431.

5.2 Lightness and hue

The definition of the parameters in CIELAB 1976 colour space, that is, lightness, L^*, chroma, C^*, and chromaticities, a^*, and b^*, are given in ISO/CIE 11664-4. These parameters shall be determined in accordance with ISO/CIE 11664-4. Hue angles shall be calculated from L^*, a^*, and b^* values determined in accordance with ISO/CIE 11664-4.

Colour names shall be determined from hue angles in accordance with Munsell colour system (10 hue) shown in JIS Z 8721 and ASTM D1535 for the products with C^* above 0,8. The colour name of the products with C^* of 0,8 or below shall be defined as achromatic colour.

5.3 Sampling

The sampling shall be carried out in accordance with ISO 4519. The samples of which sizes are fit to the characterization devices may be used. The samples for characterization shall have the same materials and the same coating configurations as the products.

Annex A
(informative)

Transmission loss measurement

A.1 Principle

This annex describes an example of measurement method and some examples of measurement results of the radio wave transmission loss of decorative metallic coatings for radio wave transmissive application products. A free-space measurement method for microwave and millimetre-wave is described. This annex also shows the measurement results of the decorative indium and chromium coatings by the free-space measurement method. These coatings are typically used for the radio wave transmissive applications such as the automobile exterior parts placed in front of the millimetre wave radar transmitter-receivers of the collision prevention system.

A.2 Sample and measurement method

A.2.1 Sample

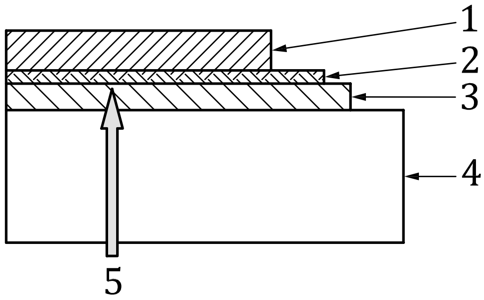
Multi layered structured samples as shown in Figure A.1, of which structure is similar to the decorative metallic coatings of radio wave transmissive parts used in exteriors of automobiles, were prepared. Samples having the same structure were also used in the colour measurements shown in Annex B. Detailed information of metallic coatings in these samples are listed in Table A.1.

Thickness of the metallic coatings was determined on the basis of the skin depth of radio waves in order that small transmission loss due to the absorption can be expected. The calculated skin depths of indium and chromium at 110 GHz are 620 nm and 763 nm, respectively. Discontinuous metallic coatings were also formed to lessen the transmission loss. Discontinuous metallic coatings, that is, island-structured indium or micro-cracked chromium, were prepared by sputtering or vacuum evaporation methods.

The island-structured indium coatings are widely used in the emblem and other decorative exterior parts of automobiles in the market, to obtain both the low transmission loss of radio waves and bright metallic appearance. Micro-cracked chromium coatings are expected to exhibit both the low transmission loss of radio waves and valued appearance similar to the bright electroplated chromium coatings.

Five samples of chromium coatings and four samples of indium coatings shown in Table A.1, which are expected to have different radio wave transmissive characteristics, were manufactured by sputtering or vacuum evaporation with different process parameters.

NOTE Skin depth is a function of electrical conductivity and permeability of the material and radio wave frequency. Skin depth is smaller at higher frequency. Calculated skin depths at 110 GHz, that is, at the highest frequency under consideration, are the smallest ones.



Key

1 top coat: resin
2 metallic coating: In or Cr
3 under coat: resin
4 substrate: polycarbonate, 100 mm × 50 mm × 2 mm
5 incident of millimetre wave

Figure A.1 — Sample

Table A.1 — Detailed Information of metallic coating

No.	Main component element of metallic coating	Morphology of metallic coating	Manufacturing method
1	Cr	micro-crack	Sputtering
2	Cr	micro-crack	Sputtering
3	Cr	micro-crack	Sputtering
4	Cr	micro-crack	Sputtering
5	Cr	micro-crack	Sputtering
6	In	island	Vacuum evaporation
7	In	island	Vacuum evaporation
8	In	island	Sputtering
9	In	island	Vacuum evaporation

A.2.2 Measurement theory

Radio wave transmission loss of the decorative metallic coatings is defined as the ratio of voltage signals received with and without the metallic coating for the same incident power. It is usually expressed by Formula (A.1):

Transmission loss:

$$T_r = 20 \log V_2/V_1 \quad \text{(A.1)}$$

where

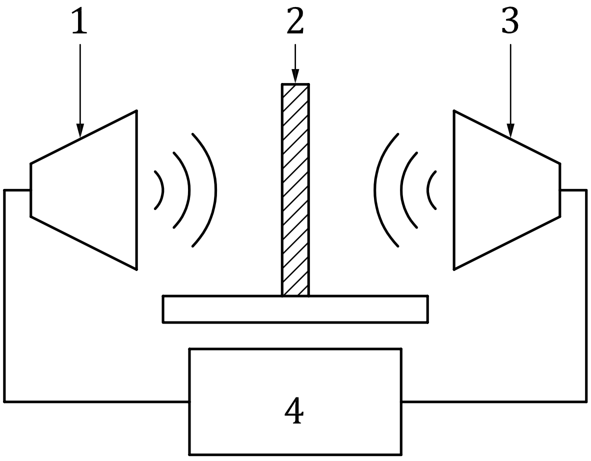
T_r is radio wave transmission loss in dB;

V_1 is received voltage with the material under test with metallic coating;

V_2 is received voltage with the blank material without metallic coating;

NOTE V_1 and V_2 are measured values obtained by vector network analyser (VNA) which is calibrated by thru-reflect-line (TRL) calibration.

A.2.3 Free-space measurement



Key

1 transmitting antenna

2 sample

3 receiving antenna

4 VNA

Figure A.2 — Schematic representation of free-space measurement of radio-wave transmission loss

Electromagnetic signal was focused by antennas in microwave and mm-wave frequencies in order to measure the transmission loss by a VNA (see Figure A.2). Antenna position was adjusted by a micrometre. Free-space measurement method is usually adopted in the frequency bands over 18 GHz, i.e. K, Ka, V, W, D, and H bands and beyond. The band names of specific frequency ranges are given in Reference [1].

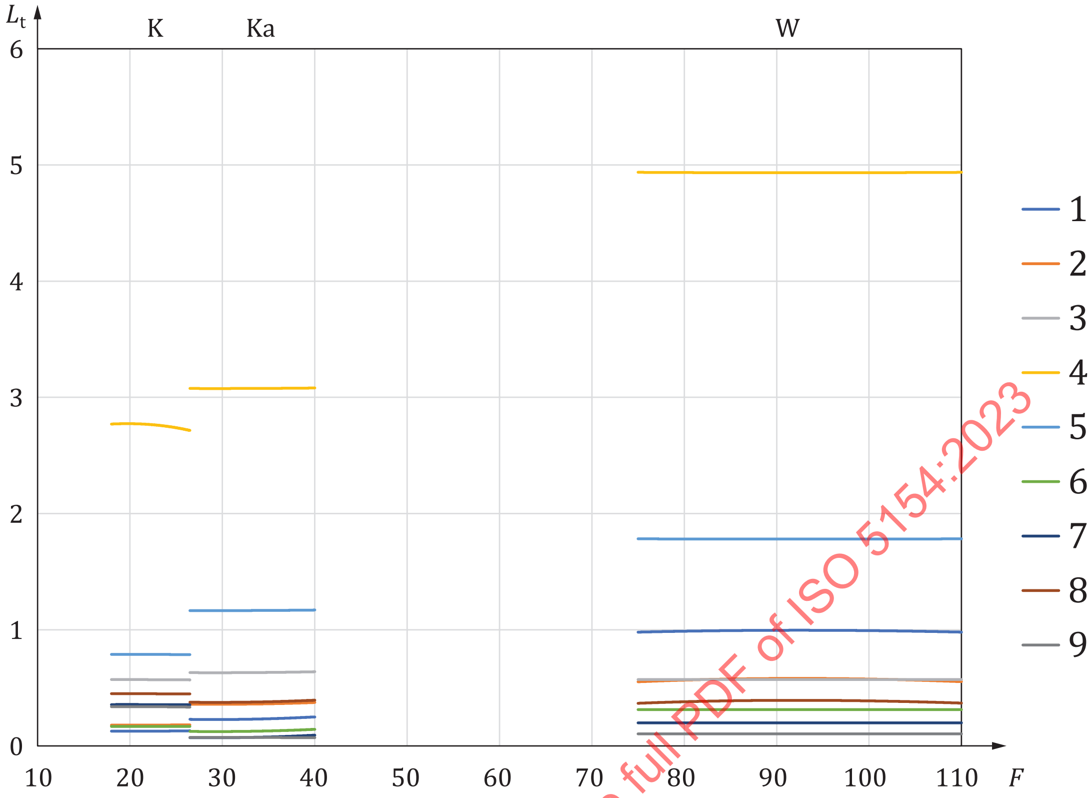
The free-space system connected to VNA was calibrated by TRL calibration method. In TRL calibration, three different types of standards, corresponding to thru, reflect and line, are measured in calibration scheme. After calibration, scattering parameter, i.e. transmission loss, can be measured by the calibrated VNA.

The measurement configuration is similar to the test method described in IEC 62431.

A.3 Measurement results

Transmission losses of 9 samples were measured in the radio-wave frequency ranging between 18 GHz and 110 GHz. The measurements were made for K, Ka and W bands. Their frequency ranges are 18 GHz to 26,5 GHz, 26,5 GHz to 40 GHz, and 75 GHz to 110 GHz, respectively (see Reference [1]).

Measurement results of transmission loss are shown in Figure A.3 and are summarized in Table A.2.



Key

L_t transmission loss in dB

F frequency in GHz

K K band

Ka Ka band

W W band

Figure A.3 — Measurement results of transmission loss for various samples

Table A.2 — Measurement results at several frequency points

Main component element of metallic coating	No.1 Cr	No.2 Cr	No.3 Cr	No.4 Cr	No.5 Cr	No.6 In	No.7 In	No.8 In	No.9 In
K band	0,126 to 0,130	0,179 to 0,181	0,568 to 0,571	2,715 to 2,773	0,785 to 0,788	0,168 to 0,168	0,354 to 0,356	0,448 to 0,449	0,334 to 0,338
Ka band	0,227 to 0,250	0,358 to 0,374	0,630 to 0,638	3,076 to 3,080	1,165 to 1,169	0,124 to 0,143	0,071 to 0,092	0,375 to 0,394	0,070 to 0,073
W band	0,979 to 0,996	0,552 to 0,581	0,572 to 0,672	4,933 to 4,937	1,780 to 1,782	0,312 to 0,312	0,198 to 0,199	0,367 to 0,393	0,103 to 0,103

Table A.3 — Designation of level of transmission loss

Main component element of metallic coating	No.1 Cr	No.2 Cr	No.3 Cr	No.4 Cr	No.5 Cr	No.6 In	No.7 In	No.8 In	No.9 In
K band	T0,1	T0,2	T0,6	T2,8	T0,8	T0,2	T0,4	T0,4	T0,3
Ka band	T0,2 – T0,3	T0,4	T0,6	T3,1	T1,2	T0,1	T0,1	T0,4	T0,1
W band	T1,0	T0,6	T0,6 – T0,7	T4,9	T1,8	T0,3	T0,2	T0,4	T0,1

The typical radio wave transmissive application products for automobiles have the low transmission loss of the specific radio wave lower than 2,5 dB. Samples other than the sample No. 4 showed the transmission loss significantly lower than 2,5 dB for all frequency bands tested (Table A.2, Table A.3). The sample No. 4 had the higher thickness of metallic coating than others had.

The indium and chromium coatings with sufficiently low transmission loss of radio waves were obtained by forming of discontinuous structures using sputtering or vacuum evaporation with appropriate manufacturing parameters.

Designation of the transmission loss for each frequency band is summarized in Table A.3. Designation of the transmission loss is specified in 4.3.2.

Annex B
(informative)

Colour measurement

B.1 Principle

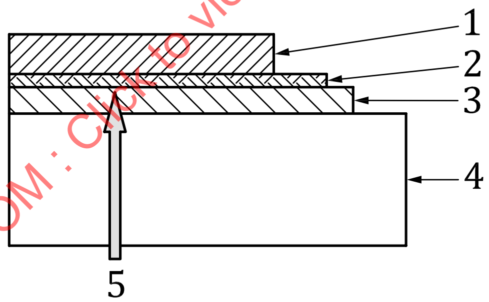
This annex describes an example of measurement method and some examples of measurement results of the colour characteristics of decorative metallic coatings for radio wave transmissive application products.

The decorative coating samples of indium and chromium were used. These coatings are typically used for the radio wave transmissive applications such as the automobile exterior parts placed in front of the millimetre wave radar transmitter-receivers of the collision prevention system.

B.2 Sample and Measurement method

B.2.1 Sample

Multi layered structured samples (see Figure B.1), of which structure was same as that used in the transmission loss measurements shown in Annex A, were prepared. Detailed information of metallic coating in these samples are listed in Table B.1.



Key

1 top coat: resin

2 metallic coating: In or Cr

3 under coat: resin

4 substrate: polycarbonate, 100 mm × 50 mm × 2 mm

5 illumination

Figure B.1 — Multi layer structured sample

Table B.1 — Detailed information of metallic coating

No. of sample	Processing		
	Resin coat	Main component element of metallic coating	Manufacturing method
No.1	Under Coat	Cr	Sputtering
No.2	Under Coat	Cr	Sputtering
No.3	—	Cr	Sputtering
No.4	—	Al/Cr	Sputtering
No.5	—	Al/Cr	Sputtering
No.6	Top Coat	No metal coating	—
No.7	—	In	Vacuum evaporation
No.8	—	In	Vacuum evaporation
No.9	Under Coat	In	Sputtering
No.10	Under Coat	In	Vacuum evaporation

B.2.2 Measurement method

B.2.2.1 Optics geometry

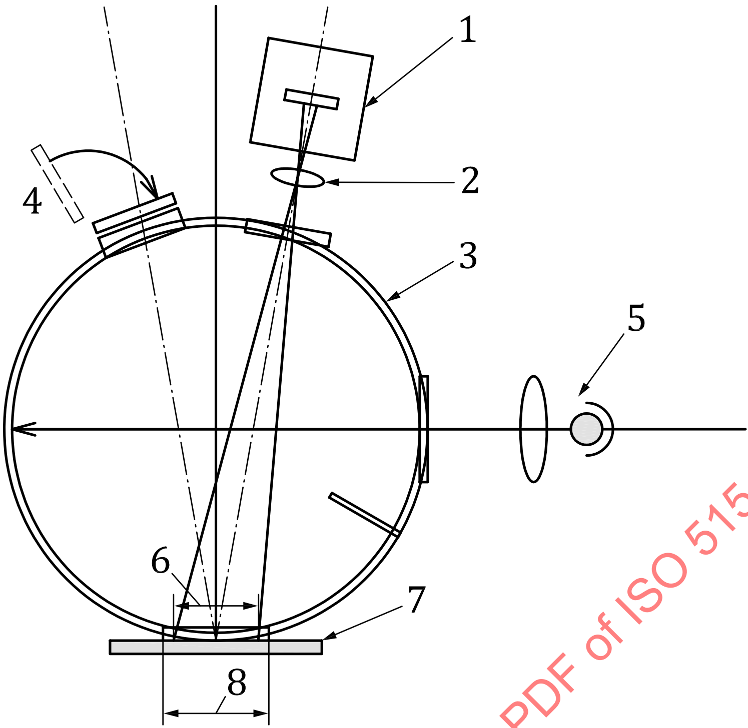
Figure B.2 shows the schematic representation of optics geometry to measure the spectral reflectance. In usual, decorative metallic coatings for radio wave transmissive application products are coated metallic thin film by sputtering or vacuum evaporation, and the optical property is the same as mirror which reflects the light regularly. To measure the optical property of such samples using a commercially available spectrometer, the specular component include (SCI) condition are used to receive mirror reflection. On the other hand, the specular component exclude (SCE) measurement usually gives significantly different results from the visual observation of the subject.

Optical geometry and methods to determine the colour characteristics were as follows:

— Measure the spectral reflectance in the visible range (from 400 nm to 700 nm each 10 nm) with a commercially available *D*/8° integrating sphere illuminator with SCI.

— The diameter of the integrating sphere is preferably large, and therefore a diameter of 150 mm (6 in) was used.

— After measuring the spectral reflectance, calculate the CIELAB value based on D65 light source and CIE 1976 standard colorimetric observer. (See ISO/CIE 11664-4 and References [2], [3] and [4].)



Key

1 detector
2 optics lens
3 integrating sphere
4 light trap (SCI)
5 illumination
6 viewing area
7 sample
8 aperture size

Figure B.2 — Optics geometry

B.2.2.2 Aperture and viewing area size

The aperture was controlled and the illumination diameter and viewing area diameter were variously changed. If the thickness is on the order of the samples, there is effect of the edge loss error. The illumination diameter was changed by changing the applied aperture size, and viewing diameter was changed by changing the focal position of optics lens. Aperture diameters, LA, MA, SA and viewing area diameter, LV, MV, SV were as follows:

— aperture diameter:

LA:30 mm;

MA:11 mm;

SA:7 mm;

— viewing area diameter:

LV:25 mm;

MV:8 mm;

SV:4 mm.

B.2.2.3 Correction of reflectance for low hiding samples

There were some samples in which the metallic coating layer was thin and the transmittance was not neglected due to the discontinuation of metallic coatings. Since the reflectance of such samples are affected by backing, the spectral reflectance were measured by applying white and black backings, and the corrected spectral reflectance, $R(\lambda)$ was obtained using Formula (B.1) and (B.2).

$$P(\lambda)=1 - [R_{mw}(\lambda) - R_{mb}(\lambda)]/[R_w(\lambda) - R_b(\lambda)] \quad (B.1)$$

$$R(\lambda)=[R_{mw}(\lambda) - [1 - P(\lambda)]\cdot R_w(\lambda)]/P(\lambda) \quad (B.2)$$

where

λ	is the wavelength;
$R_w(\lambda)$	is the spectral reflectance of white backing;
$R_b(\lambda)$	is the spectral reflectance of black backing;
$R_{mw}(\lambda)$	is the spectral reflectance of a sample with white backing;
$R_{mb}(\lambda)$	is the spectral reflectance of a sample with black backing.

From the measured or corrected spectral reflectance, the L^*, a^*, b^* values were calculated in CIELAB space under the conditions of D65 light source and CIE 1976 standard colorimetric observer (see ISO/CIE 11664-4), and L^*, C^*_{ab}, h_{ab} are calculated from L^*, a^*, b^* value.

B.3 Measurement results

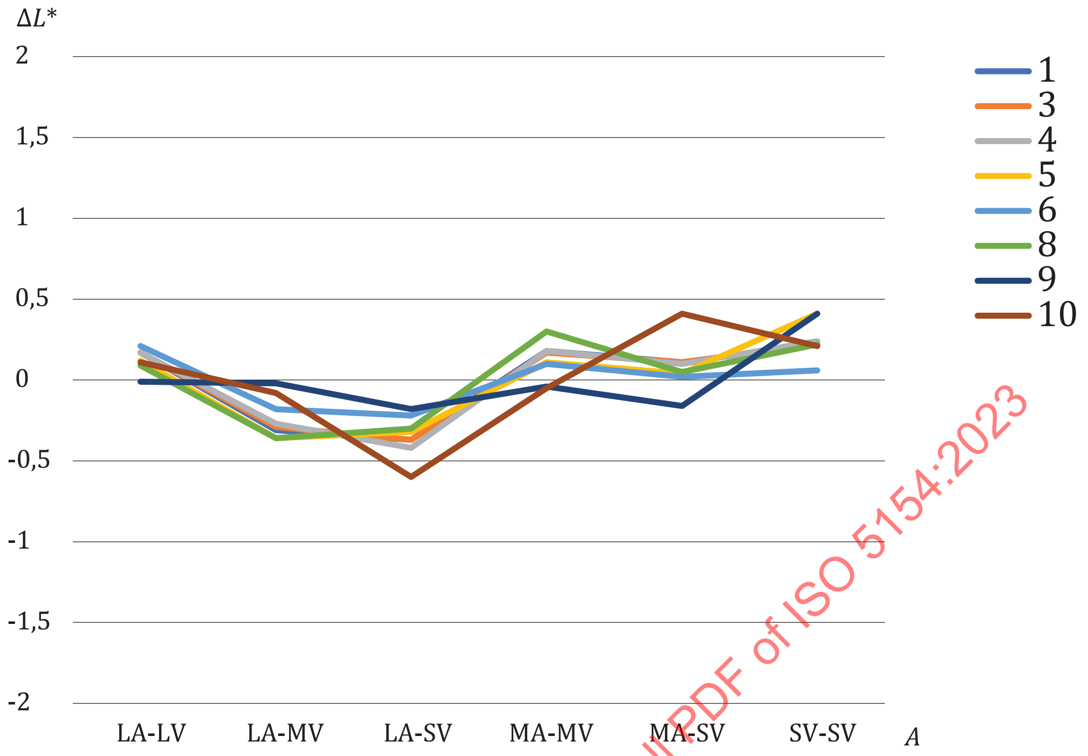
B.3.1 Data Reproducibility: effects of aperture and viewing area

Measurement result of L^* value deviation from average using various aperture and viewing area size are shown in Table B.2 and Figure B.3.

Significant effects of aperture and viewing area diameter on the measurement results were not observed.

Table B.2 — L^* value deviation from average measured with each aperture and viewing area

	LA-LV	LA-MV	LA-SV	MA-MV	MA-SV	SV-SV
No.1	0,17	-0,31	-0,37	0,18	0,11	0,22
No.3	0,17	-0,29	-0,37	0,17	0,11	0,22
No.4	0,17	-0,27	-0,42	0,18	0,10	0,24
No.5	0,12	-0,36	-0,32	0,11	0,04	0,41
No.6	0,21	-0,18	-0,22	0,10	0,02	0,06
No.8	0,09	-0,36	-0,30	0,30	0,05	0,22
No.9	-0,01	-0,02	-0,18	-0,04	-0,16	0,41
No.10	0,11	-0,08	-0,60	-0,05	0,41	0,21

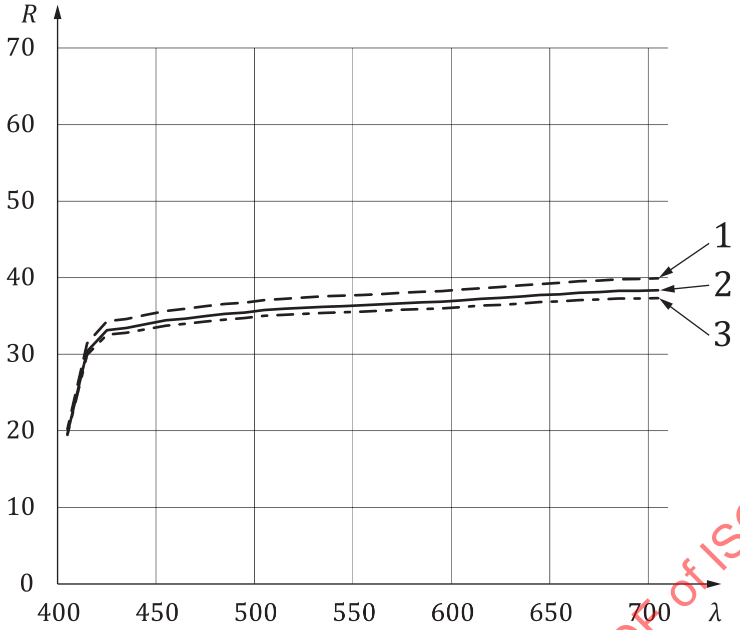


Key

Δ*L**	difference in lightness, *L**
A	aperture-view are size
LA-LV	large aperture – large view area
LA-MV	large aperture – middle view area
LA-SV	large aperture – small view area
MA-MV	middle aperture – middle view area
MA-SV	middle aperture – small view area
SA-SV	small aperture – small view area

Figure B.3 — *L value deviation from average of each aperture and viewing area**

B.3.2 Spectral reflectance of low hiding sample



Key

R	spectral reflectance in %
λ	wavelength in nm
1	white backing
2	corrected
3	black backing

Figure B.4 — Low hiding sample spectrum reflectance measurement result

Measured and corrected spectral reflectances of a low hiding sample (No.9) are shown in Figure B.4. The corrected spectral reflectance was lower than that with a white backing and higher than that with a black backing.

This confirms that the plausible spectral reflectance for L^*, a^*, b^* calculation was obtained by correcting the raw data according to B.2.2.3.

B.3.3 All samples measurement result

Colour characteristics of all samples in Table B.1 were measured using an integrating sphere with the large aperture (diameter: 30 mm) and the large viewing area (diameter: 25 mm).

The values of L^*, a^*, b^*, C^*_{ab} and h_{ab} are shown in Table B.3, the plot of L^* - C^*_{ab} is shown in Figure B.5 and the plot of a^*- b^* is shown in Figure B.6. Although L^*, a^*, b^* or L^*, C^*_{ab}, h_{ab} values in CIELAB space are determined in two decimal places, colour characteristics are represented according to the Munsell colour space to make understand easier. Because the samples No. 7, No. 9 and No. 10 have low hiding power, the white backing and black backing are used in the measurements of these samples. The values corrected from the spectral reflectance using Formula (B.1) and (B.2) are shown.

The designations of colours and corresponding range of C^*_{ab} and the hue angle are shown in 4.4.2 and Table 4. Measurement results of a^*- b^* and the colour designation are shown in Figure B.6.

The L^* values of the samples with chromium coatings (sample No. 1 to 5) ranged from 78,32 to 93,41, and C^*_{ab} ranged from 0,55 to 2,28. The L^* values of the samples with indium coatings (sample No. 7 to 10), L^* ranged from 66,81 to 81,45, and C^*_{ab} ranged from 0,50 to 1,96. The high L^* values represent the bright appearance, and the small C^*_{ab} values show the achromatic or near achromatic colours.