

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE

**Letter symbols to be used in electrical technology –  
Part 2: Telecommunications and electronics**

**Symboles littéraux à utiliser en électrotechnique –  
Partie 2: Télécommunications et électronique**



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67 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

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Partie 2: Télécommunications et électronique**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## LETTER SYMBOLS TO BE USED IN ELECTRICAL TECHNOLOGY –

## Part 2: Telecommunications and electronics

## FOREWORD

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International Standard IEC 60027-2 has been prepared by IEC technical committee 25: Quantities and units.

This fourth edition cancels and replaces the third edition published in 2005. This fourth edition constitutes a technical revision.

This edition includes the following significant changes with respect to the previous edition:

- a) former Subclauses 3.8 and 3.9 are cancelled and replaced by IEC 80000-13:2008;
- b) former Subclause 3.10, now 4.8, is revised in accordance with IEC 60050-192:2015;
- c) former Subclause 3.11, now 4.9, is revised in accordance with IEC 60050-561:2014;
- d) former Subclause 3.13, now 4.11, is revised in accordance with ISO 80000-8:2007, IEC 60050-801:1994 and IEC 60050-802:2011;
- e) technical and editorial corrections have been carried out, mainly in Subclause 4.1.
- f) tables are simplified, mainly by deleting useless columns.

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

| FDIS        | Report on voting |
|-------------|------------------|
| 25/635/FDIS | 25/640/RVD       |

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

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60027 series, published under the general title *Letter symbols to be used in electrical technology*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

# LETTER SYMBOLS TO BE USED IN ELECTRICAL TECHNOLOGY –

## Part 2: Telecommunications and electronics

### 1 Scope

This part of IEC 60027 is applicable to telecommunications and electronics. It gives names and symbols for quantities and their units.

### 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 60027-1:1992, *Letter symbols to be used in electrical technology – Part 1: General*

IEC 60027-1:1992/AMD1:1997

IEC 60027-1:1992/AMD2:2005

### 3 Terms and definitions

No terms and definitions are listed in this document.

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

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

### 4 Introduction to tables

In this part of IEC 60027, complex quantities are in general denoted by underlining their symbols. However, this does not constitute a compulsory rule in applications (see IEC 60027-1).

To avoid any ambiguity, some quantity names are followed by a specific use, enclosed in angle brackets "<...>" after a comma.

When several symbols are indicated for a given quantity, the first is the preferred symbol and the others are reserve symbols, unless otherwise stated.

When several units are indicated for a given quantity, the first is the coherent SI unit, unless otherwise stated. For logarithmic ratios, the first mentioned unit is the decibel.

For quantities defined as a logarithm of the ratio of two power quantities or two root-power quantities (also known as field quantities), the submultiple decibel (dB) of the bel (B) is generally used, rather than the neper (Np). The bel is not explicitly mentioned in the tables. See IEC 60027-3 and ISO 80000-1:2009, Annex C.

## 5 Quantities and units

### 5.1 General concepts

| Item number | Quantity                  |                                          |                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Units            |          |                                                                                                               |
|-------------|---------------------------|------------------------------------------|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|----------|---------------------------------------------------------------------------------------------------------------|
|             | Entry number in IEC 60050 | Name                                     | Symbol                    | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Name             | Symbol   | Remarks                                                                                                       |
| 101         | 101-12-02                 | signal                                   | $S$<br>$s$                | A signal is any physical phenomenon whose presence, absence or variation is considered as representing information. In general, a signal is a quantity, one or more parameters of which represent information.<br>In this document, $S_1$ and $S_2$ are used for input and output signals respectively. See IEC 60027-1 for other suitable subscripts.<br>In cases where the type of signal quantity is known, for example, electric current, voltage, pressure, etc., use the appropriate symbol.<br>With respect to capital and lower-case letters, see IEC 60027-1:1992, 2.1. |                  |          | The unit depends on the kind of quantity constituting the signal (electric current, voltage, pressure, etc.). |
| 102         |                           | signal power                             | $P_s$<br>$P_{sig}$        | "s" (lower case, upright) is used as subscript for "signal".<br>In signal theory, the term "instantaneous power" is by convention used for the square of the instantaneous value of a signal. This square is proportional to a physical power if the signal is a root-power quantity (or field quantity) (see Note 1 to entry of IEC 60050-103:2009, 103-09-05).<br>In a physical system, a signal power is always a physical power.                                                                                                                                             | watt             | W        |                                                                                                               |
| 103         |                           | signal level                             | $L$<br>$L_s$<br>$L_{sig}$ | $L = 10 \lg \left  \frac{S}{S_{ref}} \right  \quad \text{dB} = \frac{1}{2} \ln \left  \frac{S}{S_{ref}} \right  \quad \text{Np}$ where $S$ and $S_{ref}$ are two signals of the same kind, $S_{ref}$ being a reference signal.                                                                                                                                                                                                                                                                                                                                                   | decibel<br>neper | dB<br>Np |                                                                                                               |
| 104         | 702-07-04                 | absolute power level;<br>power level     | $L_p$                     | $L_p = 10 \lg \frac{P}{P_{ref}} \quad \text{dB} = \frac{1}{2} \ln \frac{P}{P_{ref}} \quad \text{Np}$ where $P$ is a power and $P_{ref}$ is a reference power.                                                                                                                                                                                                                                                                                                                                                                                                                    | decibel<br>neper | dB<br>Np |                                                                                                               |
| 105         | 702-07-06                 | absolute voltage level;<br>voltage level | $L_U$                     | $L_U = 20 \lg \frac{U}{U_{ref}} \quad \text{dB} = \ln \frac{U}{U_{ref}} \quad \text{Np}$ where $U$ is a voltage and $U_{ref}$ is a reference voltage.<br>The synonym "voltage level" may be used only where there is no ambiguity.                                                                                                                                                                                                                                                                                                                                               | decibel<br>neper | dB<br>Np |                                                                                                               |

| Item number | Quantity                  |                                                    |                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Units            |          |                                                                                                              |
|-------------|---------------------------|----------------------------------------------------|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|----------|--------------------------------------------------------------------------------------------------------------|
|             | Entry number in IEC 60050 | Name                                               | Symbol                       | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Name             | Symbol   | Remarks                                                                                                      |
| 106         | 702-07-05                 | relative power level                               | $L_{r,x}$<br>$L_r$           | $L_{r,x} = L_{p,x} - L_{p,0}$<br>where $L_{p,x}$ and $L_{p,0}$ are the absolute power levels (104) at the measuring point and at a reference point, respectively.                                                                                                                                                                                                                                                                                                                                          | decibel<br>neper | dB<br>Np |                                                                                                              |
| 107         | 702-08-03                 | noise                                              | $N$<br>$n$<br>$S_n$<br>$s_n$ | A noise is any variable physical phenomenon, generally a quantity, apparently not conveying information and which can be superimposed on, or combined with, a wanted signal.<br>Concerning upper and lower-case letters, see IEC 60027-1:1992, 2.1.<br>"n" (lower case, upright) is used as subscript for "noise".<br>In cases where the type of noise quantity is known, use the appropriate symbol (for example, $I$ , $i$ for electric current) with $n$ as subscript (e.g. $I_n$ , $i_n$ ).            |                  |          | The unit depends on the kind of quantity constituting the noise (electric current, voltage, pressure, etc.). |
| 108         | 103-09-05                 | power spectral density,<br><for a signal or noise> | $w(f)$                       | $P = \int_0^{\infty} w(f) df$<br>where $f$ is the frequency and $P$ is the total power.<br>In signal theory, the term "instantaneous power" is by convention used for the square of the instantaneous value of a signal or noise. This square is proportional to a physical power if the signal or the noise is a root-power (or field quantity). See Note 1 to entry of 103-09-05 in IEC 60050-103:2009.<br>In a physical system, the power spectral density is always a physical power spectral density. | watt per hertz   | W/Hz     |                                                                                                              |
| 109         |                           | power spectral density of white noise              | $N_0$                        | The power spectral density (108) is frequency-independent:<br>$w(f) = N_0$                                                                                                                                                                                                                                                                                                                                                                                                                                 | watt per hertz   | W/Hz     |                                                                                                              |
| 110         | 702-08-51                 | equivalent noise voltage                           | $U_n$                        | Applies to a one-port network.<br>$U_n$ is an RMS voltage.                                                                                                                                                                                                                                                                                                                                                                                                                                                 | volt             | V        |                                                                                                              |

| Item number | Quantity                  |                                                              |                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Units  |          |         |
|-------------|---------------------------|--------------------------------------------------------------|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|----------|---------|
|             | Entry number in IEC 60050 | Name                                                         | Symbol            | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Name   | Symbol   | Remarks |
| 111         | 702-08-52                 | equivalent noise resistance;<br>noise resistance             | $R_{eq}$<br>$R_n$ | Applies to a one-port network.<br>$R_{eq} = \frac{U_n^2}{4kT_{ref}\Delta f}$ where $U_n$ is the equivalent noise voltage (110), $k$ is the Boltzmann constant, $T_{ref}$ is a reference temperature and $\Delta f$ is the frequency bandwidth (154) considered.<br>The synonym "noise resistance" may be used only where there is no ambiguity.                                                                                                                          | ohm    | $\Omega$ |         |
| 112         | 702-08-54                 | spot noise temperature                                       | $T(f)$            | Applies to a one-port network.<br>$f$ is frequency.                                                                                                                                                                                                                                                                                                                                                                                                                      | kelvin | K        |         |
| 113         | 702-08-55                 | mean noise temperature                                       | $\bar{T}$         | Applies to a one-port network.                                                                                                                                                                                                                                                                                                                                                                                                                                           | kelvin | K        |         |
| 114         | 702-08-56                 | equivalent spot noise temperature                            | $T_{eq}(f)$       | Applies to a two-port network.<br>$f$ is frequency.                                                                                                                                                                                                                                                                                                                                                                                                                      | kelvin | K        |         |
| 115         | 702-08-58                 | mean equivalent noise temperature;<br>mean noise temperature | $\bar{T}_{eq}$    | Applies to a two-port network.<br>The synonym "mean noise temperature" may be used only where there is no ambiguity.                                                                                                                                                                                                                                                                                                                                                     | kelvin | K        |         |
| 116         | 702-08-57                 | spot noise factor                                            | $F(f)$            | Applies to a two-port network.<br>The noise factor is the ratio of the exchangeable power spectral density (108) of output noise to the power spectral density that would be present at the output if the only source of noise were input thermal noise at a reference temperature $T_{ref}$ :<br>$F(f) = 1 + \frac{T_{eq}(f)}{T_{ref}}$ where $T_{eq}(f)$ is the equivalent spot noise temperature (114).<br>For exchangeable power, see IEC 60050-702:1992, 702-07-11. | one    | 1        |         |

| Item number | Quantity                  |                                    |                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Units            |        |
|-------------|---------------------------|------------------------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|--------|
|             | Entry number in IEC 60050 | Name                               | Symbol          | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Name             | Symbol |
| 117         | 702-08-57                 | spot noise figure                  | $F_n(f)$        | $F_n(f) = 10 \lg F(f) \text{ dB} = \frac{1}{2} \ln F(f) \text{ Np}$ <p>where <math>F(f)</math> is the spot noise factor (116).<br/>           In English, "noise factor" is generally used for the arithmetic expression and "noise figure" is used for the logarithmic expression. See IEC 60050-702:1992, 702-08-57, Note 2.<br/>           In French, "facteur de bruit" is generally used in both cases.</p>                                                                                                                                                              | decibel<br>neper |        |
| 118         | 702-08-59                 | mean noise factor;<br>noise factor | $\bar{F}$       | <p>Applies to a two-port network.</p> $\bar{F} = 1 + \frac{\bar{T}_{\text{eq}}}{T_{\text{ref}}}$ <p>where <math>\bar{T}_{\text{eq}}</math> is the mean equivalent noise temperature (115) and <math>T_{\text{ref}}</math> is a reference temperature.<br/>           The synonym "noise factor" may be used only where there is no ambiguity.</p>                                                                                                                                                                                                                             | one              | 1      |
| 119         | 702-08-59                 | mean noise figure;<br>noise figure | $\bar{F}_n$     | $\bar{F}_n = 10 \lg \bar{F} \text{ dB} = \frac{1}{2} \ln \bar{F} \text{ Np}$ <p>where <math>\bar{F}</math> is the mean noise factor (118).<br/>           In English, "noise factor" is generally used for the arithmetic expression and "noise figure" is used for the logarithmic expression. See IEC 60050-702:1992, 702-08-59, Note 2.<br/>           In French, "facteur de bruit" is generally used in both cases and the adjective "logarithmique" is omitted in practice.<br/>           The synonym "noise figure" may be used only where there is no ambiguity.</p> | decibel<br>neper |        |
| 120         | 702-08-61                 | signal-to-noise ratio;<br>SNR      | $k_{\text{SN}}$ | <p>Signal power (102) divided by noise power.<br/>           In practice, the symbol <math>S/N</math> is generally used.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                  | one              | 1      |

| Item number | Quantity                  |                                                 |                                    |                                                                                                                                                                                                                                                                                | Units                                  |                                                                                                              |
|-------------|---------------------------|-------------------------------------------------|------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|--------------------------------------------------------------------------------------------------------------|
|             | Entry number in IEC 60050 | Name                                            | Symbol                             | Definition and remarks                                                                                                                                                                                                                                                         | Name                                   | Symbol                                                                                                       |
| 121         | 702-08-61                 | signal-to-noise logarithmic ratio               | $K_{\text{SN}}$                    | $K_{\text{SN}} = 10 \lg k_{\text{SN}} \text{ dB} = \frac{1}{2} \ln k_{\text{SN}} \text{ Np}$ <p>where <math>k_{\text{SN}}</math> is the signal-to-noise ratio (120).<br/>In practice, the term "signal-to-noise ratio" and the symbol <math>S/N</math> are generally used.</p> | decibel<br>neper                       | dB<br>Np                                                                                                     |
| 122         | 103-07-17                 | growth coefficient                              | $\sigma$                           | <p>Example:<br/> <math display="block">u(t) = \hat{u} e^{\sigma t} \sin \omega t</math>           where <math>u(t)</math> is a sinusoidal function of time <math>t</math>, with angular frequency <math>\omega</math> and amplitude <math>\hat{u}</math>.</p>                  | decibel per second<br>neper per second | dB/s<br>Np/s                                                                                                 |
| 123         | 103-05-24                 | damping coefficient                             | $\delta$                           | $\delta = -\sigma$ <p>where <math>\sigma</math> is the growth coefficient (122).</p>                                                                                                                                                                                           | decibel per second<br>neper per second | dB/s<br>Np/s                                                                                                 |
| 124         | 103-07-16                 | complex angular frequency;<br>complex frequency | $\underline{s}$<br>$\underline{p}$ | $\underline{s} = \sigma + j\omega = -\delta + j\omega$ <p>where <math>\omega</math> is the angular frequency, <math>\sigma</math> is the growth coefficient (122) and <math>\delta</math> is the damping coefficient (123).</p>                                                | second to the power of minus one       | $\text{s}^{-1}$<br><br>Special units are only used when the real and imaginary parts are treated separately. |

| Item number | Quantity                  |                                  |                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Units            |          |                                                                                                            |
|-------------|---------------------------|----------------------------------|------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|----------|------------------------------------------------------------------------------------------------------------|
|             | Entry number in IEC 60050 | Name                             | Symbol                             | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Name             | Symbol   | Remarks                                                                                                    |
| 125         | 131-15-20                 | transfer function                | $\underline{H}$<br>$\underline{T}$ | $\underline{H}(\underline{s}) = \frac{\underline{S}_2(\underline{s})}{\underline{S}_1(\underline{s})}$ <p>where <math>\underline{S}_1</math> and <math>\underline{S}_2</math>, respectively, are the complex representations of the input and output signals, respectively, as functions of the complex angular frequency <math>\underline{s}</math> (124).</p> <p>The complex quantities are generally the Laplace transforms of the time-varying quantities:</p> $\underline{H} = \frac{\underline{L}_{S_2}(t)}{\underline{L}_{S_1}(t)}$ <p>where <math>\underline{L}_{S_1}(t)</math> and <math>\underline{L}_{S_2}(t)</math> are the Laplace transforms of the signals <math>s_1(t)</math> and <math>s_2(t)</math> and <math>t</math> is time.</p> |                  |          | The unit of the quantity $\underline{H}$ is the quotient of the unit of $s_2(t)$ by the unit of $s_1(t)$ . |
| 126         |                           | transfer gain                    | $G(\omega)$                        | $G(\omega) =  H(j\omega) $ <p>where <math>H(\sigma + j\omega)</math> is the transfer function (125).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                  |          | The unit is the same as for $\underline{H}$ .                                                              |
| 127         |                           | transfer attenuation             | $A(\omega)$                        | $A(\omega) = 1 / G(\omega)$ <p>where <math>G(\omega)</math> is the transfer gain (126).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                  |          | The unit is the reciprocal of the unit of $\underline{H}$ .                                                |
| 128         |                           | transfer exponent                | $\underline{I}$                    | <p>If the transfer function <math>\underline{H}</math> (125) is of dimension one (see IEC 60050-112:2010, 112-01-13):</p> $\underline{H}(j\omega) = G(\omega)\exp[-jB(\omega)] = \exp[\underline{I}(\omega)]$ $\underline{I} = A - jB \quad (\text{see 129 and 130}).$ <p>See also image transfer coefficient (IEC 60050-131:2002, 131-15-25).</p>                                                                                                                                                                                                                                                                                                                                                                                                    | one              | 1        | Special units are only used when the real and imaginary parts are treated separately.                      |
| 129         |                           | logarithmic transfer attenuation | $A$                                | $A = 20 (\lg e) \operatorname{Re}(\underline{I}) \quad \text{dB} = \operatorname{Re}(\underline{I}) \quad \text{Np}$ <p>where <math>\underline{I}</math> is the transfer exponent (128) and <math>e</math> is the base of the natural logarithm.</p> <p>In practice, "transfer attenuation" is used.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                              | decibel<br>neper | dB<br>Np |                                                                                                            |

| Item number | Quantity                  |                                 |               |                                                                                                                                                                                                                                                                                                                         | Units            |          |                                           |
|-------------|---------------------------|---------------------------------|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|----------|-------------------------------------------|
|             | Entry number in IEC 60050 | Name                            | Symbol        | Definition and remarks                                                                                                                                                                                                                                                                                                  | Name             | Symbol   | Remarks                                   |
| 130         |                           | phase change;<br>phase shift    | $B_{\varphi}$ | $B(\omega) = \text{Im}(\underline{I}) = -\arg \underline{H}(j\omega)$<br>where $\underline{H}(\sigma + j\omega)$ is the transfer function (125) and $\underline{I}$ is the transfer exponent (128).                                                                                                                     | radian degree    | rad<br>° | $1^{\circ} = \frac{\pi}{180} \text{ rad}$ |
| 131         |                           | voltage attenuation factor      | $a_U$         | $a_U = \frac{U_1}{U_2}$<br>where $U_1$ and $U_2$ are two voltages. Subscripts 1 and 2 can for example designate the input port and the output port, respectively, of a two-port network. The inverse of the voltage attenuation factor is the voltage gain factor (133).<br>In practice, "voltage attenuation" is used. | one              | 1        |                                           |
| 132         |                           | logarithmic voltage attenuation | $A_U$         | $A_U = 20 \lg a_U$ dB = $\ln a_U$ Np<br>where $a_U$ is voltage attenuation factor (131). When the logarithmic voltage attenuation is negative, its absolute value is the logarithmic voltage gain (134).<br>In practice, "voltage attenuation" is used.                                                                 | decibel<br>neper | dB<br>Np |                                           |
| 133         |                           | voltage gain factor             | $g_U$         | $g_U = \frac{U_2}{U_1}$<br>where $U_1$ and $U_2$ are two voltages. Subscripts 1 and 2 can, for example, designate the input port and the output port, respectively, of a two-port network. The inverse of the voltage gain factor is the voltage attenuation factor (131).<br>In practice, "voltage gain" is used.      | one              | 1        |                                           |
| 134         |                           | logarithmic voltage gain        | $G_U$         | $G_U = 20 \lg g_U$ dB = $\ln g_U$ Np<br>where $g_U$ is the voltage gain factor (133). When the logarithmic voltage gain is negative, its absolute value is the logarithmic voltage attenuation (132).<br>In practice, "voltage gain" is used.                                                                           | decibel<br>neper | dB<br>Np |                                           |

| Item number | Quantity                  |                                                                                   |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Units            |          |         |
|-------------|---------------------------|-----------------------------------------------------------------------------------|--------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|----------|---------|
|             | Entry number in IEC 60050 | Name                                                                              | Symbol | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Name             | Symbol   | Remarks |
| 135         | 702-02-10                 | power loss factor;<br>power attenuation factor                                    | $a_p$  | Use subscript $S$ instead of $P$ in the case of apparent powers.<br>$a_p = \frac{P_1}{P_2}$<br>Subscripts 1 and 2 are used to designate the power of a signal at two points, for example, input and output of a two-port network, or the power of a signal in two specified conditions, for example, for defining insertion attenuation or insertion loss (IEC 60050-131:2002, 131-15-30).<br>The inverse of the power loss factor is the power gain factor (137).<br>In practice, "power loss" or "power attenuation" are used. | one              | 1        |         |
| 136         | 702-02-10                 | logarithmic power loss;<br>logarithmic power attenuation;<br>loss;<br>attenuation | $A_p$  | Use subscript $S$ instead of $P$ in the case of apparent powers.<br>$A_p = 10 \lg a_p \text{ dB} = \frac{1}{2} \ln a_p \text{ Np}$<br>where $a_p$ is the power loss factor (135).<br>When the logarithmic power loss is negative, its absolute value is the logarithmic power gain (138).<br>In practice, "logarithmic" is omitted in the terms.                                                                                                                                                                                 | decibel<br>neper | dB<br>Np |         |
| 137         | 702-02-11                 | power gain factor;<br>gain factor                                                 | $g_p$  | Use subscript $S$ instead of $P$ in the case of apparent powers.<br>$g_p = \frac{P_2}{P_1}$<br>Subscripts 1 and 2 are used to designate the power of a signal at two points, for example, input and output of a two-port network, or the power of a signal in two specified conditions, for example, for defining available power gain (IEC 60050-702:1992, 702-07-12).<br>The inverse of the power gain factor is the power loss factor (135).<br>In practice, "factor" is omitted in the terms.                                | one              | 1        |         |

| Item number | Quantity                  |                                             |                      |                                                                                                                                                                                                                                                                                                                                                                                      | Units                                |                 |
|-------------|---------------------------|---------------------------------------------|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|-----------------|
|             | Entry number in IEC 60050 | Name                                        | Symbol               | Definition and remarks                                                                                                                                                                                                                                                                                                                                                               | Name                                 | Symbol          |
| 138         | 702-02-11                 | logarithmic power gain;<br>logarithmic gain | $G_P$                | Use subscript S instead of P in the case of apparent powers.<br>$G_P = 10 \lg g_P \text{ dB} = \frac{1}{2} \ln g_P \text{ Np}$<br>where $g_P$ is the power gain factor (137). When the logarithmic power gain is negative, its absolute value is the logarithmic power loss (136).<br>In practice, "logarithmic" is omitted in the terms.                                            | decibel<br>neper                     | dB<br>Np        |
| 139         | 702-08-60                 | effective noise bandwidth                   | $B_n$                | Applies to a two-port network.<br>$B_n = \frac{1}{g_{\max}} \int_0^\infty  g(f) ^2 df$<br>where $g(f)$ is the available power gain (IEC 60050-702:1992, 702-07-12) as a function of frequency $f$ and $g_{\max}$ is the maximum available power gain.                                                                                                                                | hertz                                | Hz              |
| 140         | 103-10-18                 | propagation coefficient                     | $\underline{\gamma}$ | Coefficient of the distance in the complex representation of a wave<br>$A_0 \exp(-\underline{\gamma}x + j\omega t + j\vartheta_0)$<br>where $x$ is the distance in the direction of propagation, $\omega$ is the angular frequency, $t$ is time and $\vartheta_0$ is the initial phase (IEC 60050-103:2009, 103-07-05).<br>$\underline{\gamma} = \alpha + j\beta$ (see 141 and 142). | metre to the power of minus one      | $\text{m}^{-1}$ |
| 141         | 103-10-19                 | attenuation coefficient                     | $\alpha$             | $\alpha = \text{Re} \underline{\gamma}$<br>where $\underline{\gamma}$ is the propagation coefficient (140).                                                                                                                                                                                                                                                                          | neper per metre<br>decibel per metre | Np/m<br>dB/m    |

| Item number | Quantity                  |                                                |                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Units                                |              |         |
|-------------|---------------------------|------------------------------------------------|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|--------------|---------|
|             | Entry number in IEC 60050 | Name                                           | Symbol                             | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                               | Name                                 | Symbol       | Remarks |
| 142         | 103-10-20                 | phase change coefficient;<br>phase coefficient | $\beta$                            | $\beta = \text{Im } \underline{\gamma}$<br>where $\underline{\gamma}$ is the propagation coefficient (140).                                                                                                                                                                                                                                                                                                                                          | radian per metre<br>degree per metre | rad/m<br>°/m |         |
| 143         | 702-02-16                 | phase delay                                    | $t_\phi$<br>$\tau_\phi$            |                                                                                                                                                                                                                                                                                                                                                                                                                                                      | second                               | s            |         |
| 144         | 702-02-20                 | group delay                                    | $t_g$<br>$\tau_g$                  | See also 608.                                                                                                                                                                                                                                                                                                                                                                                                                                        | second                               | s            |         |
| 145         | 103-10-13                 | phase velocity                                 | $c_\phi$<br>$v_\phi$<br>$c$<br>$v$ | Phase velocity is defined for waves only. If both waves and moving particles are involved, use $c$ for the former and $v$ for the latter.<br>The phase velocity is a vector quantity with magnitude<br>$ c_\phi  = f \lambda = \frac{\omega}{k}$<br>where $f$ is the frequency, $\lambda$ is the wavelength (147), $\omega$ is the angular frequency (IEC 60050-103:2009, 103-07-03), and $k$ is angular wavenumber (IEC 60050-103:2009, 103-10-12). | metre per second                     | m/s          |         |

| Item number | Quantity                  |                                                 |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Units            |        |
|-------------|---------------------------|-------------------------------------------------|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|--------|
|             | Entry number in IEC 60050 | Name                                            | Symbol         | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Name             | Symbol |
| 146         | 103-10-15                 | group velocity                                  | $c_g$<br>$v_g$ | Group velocity is defined for waves only.<br>The group velocity is a vector quantity with magnitude<br>$ c_g  = \frac{df}{d\frac{1}{\lambda}} = \frac{d\omega}{dk}$ where $f$ is the frequency, $\lambda$ is the wavelength (147), $\omega$ is the angular frequency (IEC 60050-103:2009, 103-07-03), and $k$ is the angular wavenumber (IEC 60050-103:2009, 103-10-12).<br>See also 607, where the group velocity is defined as the speed of light in vacuum divided by the group index (606). | metre per second | m/s    |
| 147         | 103-10-10                 | wavelength                                      | $\lambda$      | $\lambda = \frac{ c_\phi }{f}$ where $c_\phi$ is the phase velocity (145) and $f$ is the frequency.<br>See also 602.                                                                                                                                                                                                                                                                                                                                                                            | metre            | m      |
| 148         | 702-07-24                 | complex reflection factor;<br>reflection factor | $r_-$          | $r_- = \frac{S_r}{S_i}$ where $S_i$ and $S_r$ are the complex amplitudes (IEC 60050-103:2009, 103-07-13) of the incident and reflected wave, respectively.<br>$r_- = \frac{Z_2 - Z_1}{Z_2 + Z_1}$ where $Z_1$ is the characteristic impedance (307, 407) of a transmission line ahead of a discontinuity or the impedance of a source; and $Z_2$ is the impedance after the discontinuity or the load impedance seen from the junction between the source and the load.                         | one              | 1      |

| Item number | Quantity                  |                                                     |                            |                                                                                                                                                                                                                                                                   | Units |        |         |
|-------------|---------------------------|-----------------------------------------------------|----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|--------|---------|
|             | Entry number in IEC 60050 | Name                                                | Symbol                     | Definition and remarks                                                                                                                                                                                                                                            | Name  | Symbol | Remarks |
| 149         | 726-07-09                 | standing wave ratio                                 | $s$                        | $s = \frac{S_{\max}}{S_{\min}} = \frac{1+ r }{1- r }$ <p>where <math>S_{\max}</math> and <math>S_{\min}</math> are the maximum and minimum amplitudes, respectively, of the superposition of two waves and <math>r</math> is complex reflection factor (148).</p> | one   | 1      |         |
| 150         | 726-07-07                 | complex transmission factor;<br>transmission factor | $\underline{z}$            | $\underline{z} = \frac{S_{\underline{t}}}{S_{\underline{i}}}$ <p>where <math>S_{\underline{i}}</math> and <math>S_{\underline{t}}</math> are the complex amplitudes (IEC 60050-103:2009, 103-07-13) of the incident and transmitted wave, respectively.</p>       | one   | 1      |         |
| 151         |                           | reference frequency                                 | $f_{\text{ref}}$<br>$f_o$  | Frequency used as a reference.                                                                                                                                                                                                                                    | hertz | Hz     |         |
| 152         |                           | resonance frequency                                 | $f_r$<br>$f_{\text{sn}}$   | Frequency of a forced oscillation at resonance (see IEC 60050-103:2009, 103-05-07).                                                                                                                                                                               | hertz | Hz     |         |
| 153         | 151-13-54                 | cut-off frequency                                   | $f_c$                      | See also 402.                                                                                                                                                                                                                                                     | hertz | Hz     |         |
| 154         | 103-09-02                 | frequency bandwidth;<br>bandwidth                   | $f_B$<br>$B$<br>$\Delta f$ | The bandwidth of the frequency interval ( $f_1, f_2$ ) is $f_B = f_2 - f_1$ .                                                                                                                                                                                     | hertz | Hz     |         |
| 155         | 702-06-19                 | modulation factor,<br><in amplitude modulation>     | $m$                        | $s(t) = \hat{s}(1+m\sin\omega t)\sin\Omega t$ <p>where <math>\Omega</math> is the angular frequency of the carrier oscillation and <math>\omega</math> is the angular frequency of the modulation oscillation.</p>                                                | one   | 1      |         |

| Item number | Quantity                  |                                                        |                                   |                                                                                                                                                                                                                                                                                  | Units         |          |                                                                                                                            |
|-------------|---------------------------|--------------------------------------------------------|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|----------|----------------------------------------------------------------------------------------------------------------------------|
|             | Entry number in IEC 60050 | Name                                                   | Symbol                            | Definition and remarks                                                                                                                                                                                                                                                           | Name          | Symbol   | Remarks                                                                                                                    |
| 156         | 702-04-54                 | amplitude, <of a signal>                               | $A(t)$                            | $\underline{S}(t) = A(t)e^{j\vartheta(t)}$<br>where $\underline{S}(t)$ is the analytic signal associated with the given real signal (see IEC 60050-702:1992, 702-04-52).                                                                                                         |               |          | The unit depends on the kind of the quantity constituting the signal or noise (electric current, voltage, pressure, etc.). |
| 157         | 702-04-55                 | phase, <of a signal>                                   | $\vartheta(t)$<br>$\psi(t)$       | $\underline{S}(t) = A(t)e^{j\vartheta(t)}$<br>where $\underline{S}(t)$ is the analytic signal associated with the given real signal (see IEC 60050-702:1992, 702-04-52).                                                                                                         | radian degree | rad<br>° | $1^\circ = \frac{\pi}{180}$ rad                                                                                            |
| 158         | 702-04-56                 | instantaneous frequency                                | $f(t)$                            | $f(t) = \frac{1}{2\pi} \frac{d\vartheta(t)}{dt}$<br>where $\vartheta(t)$ is the phase (157) of the signal.                                                                                                                                                                       | hertz         | Hz       |                                                                                                                            |
| 159         | 702-06-33                 | instantaneous frequency deviation; frequency deviation | $\Delta f(t)$                     | $\Delta f(t) = f(t) - Q$<br>where $f(t)$ is the instantaneous frequency (158) and $Q$ is the angular frequency of the carrier oscillation.                                                                                                                                       | hertz         | Hz       |                                                                                                                            |
| 160         | 702-06-34                 | peak frequency deviation; peak deviation               | $(\Delta f)_{\text{mm}}$<br>$f_0$ | $(\Delta f)_{\text{mm}} = \max \Delta f(t)$<br>where $\Delta f(t)$ is the instantaneous frequency deviation (159).<br>The synonym "peak deviation" may be used only where there is no ambiguity.                                                                                 | hertz         | Hz       |                                                                                                                            |
| 161         | 702-06-38                 | frequency deviation ratio; deviation ratio             | $\delta$<br>$\eta$                | $\delta = \frac{2\pi(\Delta f)_{\text{mm}}}{\omega}$<br>where $(\Delta f)_{\text{mm}}$ is the peak frequency deviation (160) and $\omega$ is the angular frequency of the modulating oscillation.<br>The synonym "deviation ratio" may be used only where there is no ambiguity. | one           | 1        |                                                                                                                            |

| Item number | Quantity                  |                                                   |                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Units         |          |                                         |
|-------------|---------------------------|---------------------------------------------------|---------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|----------|-----------------------------------------|
|             | Entry number in IEC 60050 | Name                                              | Symbol                                      | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Name          | Symbol   | Remarks                                 |
| 162         | 702-06-31                 | instantaneous phase deviation;<br>phase deviation | $\Delta g(t)$                               | In angular modulation, difference between the phase of the modulated signal and the phase of the carrier in the absence of modulation:<br>$s(t) = \hat{s} \sin(\Omega t + \Delta g(t))$<br>where $s(t)$ is an angular modulated signal with peak value $\hat{s}$ and $\Omega$ is the angular frequency of the carrier oscillation.                                                                                                                                                                                                                                   | radian degree | rad<br>° | $1^\circ = \frac{\pi}{180} \text{ rad}$ |
| 163         | 702-06-32                 | peak phase deviation;<br>peak deviation           | $(\Delta g)_{\text{pm}}$<br>$\mathcal{S}_d$ | $(\Delta g)_{\text{pm}} = \max \Delta g(t)$<br>where $\Delta g(t)$ is the instantaneous phase deviation (162).<br>The synonym "peak deviation" may be used only where there is no ambiguity.                                                                                                                                                                                                                                                                                                                                                                         | radian degree | rad<br>° | $1^\circ = \frac{\pi}{180} \text{ rad}$ |
| 164         | 103-07-32                 | total harmonic factor                             | $d_k$                                       | $d = \frac{\sqrt{(U^2 - U_1^2)}}{U}$<br>where $U$ is the RMS value of a periodic quantity and $U_1$ is the RMS value of its fundamental component.<br>The given symbols are also recommended for quantities characterizing distortion in general without regard to the cause or the kind of the distortion considered. In special cases, it shall be mentioned explicitly which kind of distortion is meant, using the given symbols with suitable subscripts if necessary. Example: total harmonic distortion $d_h$ (or $k_h$ ), see IEC 60050-702:1992, 702-07-62. | one           | 1        |                                         |

## 5.2 Linear time-independent networks under sinusoidal conditions

### 5.2.1 General

Subclause 5.2 applies to networks consisting of linear time-invariant elements and not containing voltage or current sources. Quantities considered are defined under sinusoidal conditions and are functions of the frequency. They are generally complex; however, they are not underlined.

For indicating the matrix character of a quantity, bold face italic type for letter symbols is recommended, for example  $\mathbf{Z}$ . Parentheses may also be placed around the letter symbol, for example  $(\mathbf{Z}_{ij})$ .

Only upper-case letters are indicated for the quantity symbols, but lower-case letters may also be used if necessary.

### 5.2.2 Two-port networks

To determine the signs of matrix elements, the convention indicated in Figure 1 below is used.



**Figure 1 – Conventions concerning signs in electric circuits**

For the representation of two-port matrices, capital letter symbols are preferred in the general case. If a two-port network contains internal two-ports (such as electronic devices), preference is given to lower-case symbols for the internal two-ports. See also IEC 60747-1.

| Item number | Quantity                  |                              |                            |                                                                                                                                                                                        | Units   |          |         |
|-------------|---------------------------|------------------------------|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|----------|---------|
|             | Entry number in IEC 60050 | Name                         | Symbol                     | Definition and remarks                                                                                                                                                                 | Name    | Symbol   | Remarks |
| 201.1       | 131-14-08                 | input impedance              | $Z_1$                      | $Z_1$ is the input impedance at port 1. When 1 and 2 are not suitable subscripts for input and output, other subscripts are "in" and "ex", or "i" and "o", respectively.               | ohm     | $\Omega$ |         |
| 201.2       | 131-14-11                 | output impedance             | $Z_2$                      | $Z_2$ is the input impedance at port 2. When 1 and 2 are not suitable subscripts for input and output, other subscripts are "in" and "ex", or "i" and "o", respectively.               | ohm     | $\Omega$ |         |
| 202.1       | 131-14-09                 | input admittance             | $Y_1$                      | $Y_1$ is the input admittance at port 1. When 1 and 2 are not suitable subscripts for input and output, other subscripts are "in" and "ex", or "i" and "o", respectively.              | siemens | S        |         |
| 202.2       | 131-14-12                 | output admittance            | $Y_2$                      | $Y_2$ is the input admittance at port 2. When 1 and 2 are not suitable subscripts for input and output, other subscripts are "in" and "ex", or "i" and "o", respectively.              | siemens | S        |         |
| 203         | 131-15-28                 | characteristic impedance     | $Z_0$<br>$Z_c$<br>$Z_{ch}$ | The symbol for the corresponding admittance has the same subscript (see 408, 412, 418).<br>See also 307, 407, 411, 417, 501, 502.                                                      | ohm     | $\Omega$ |         |
| 204         | 131-15-23                 | image impedance              | $Z_i$<br>$Z_{im}$          | The symbol for the corresponding admittance has the same subscript.                                                                                                                    | ohm     | $\Omega$ |         |
| 205         | 131-15-24                 | iterative impedance          | $Z_k$<br>$Z_{it}$          | The symbol for the corresponding admittance has the same subscript.                                                                                                                    | ohm     | $\Omega$ |         |
| 206         | 131-14-24                 | impedance matrix             | $\mathbf{z}$               | $\begin{bmatrix} U_1 \\ U_2 \end{bmatrix} = \mathbf{Z} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$ where $\mathbf{Z} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$ | ohm     | $\Omega$ |         |
| 206.1       |                           | open-circuit input impedance | $Z_{11}$                   | $Z_{11} = \left( \frac{U_1}{I_1} \right)_{I_2=0}$                                                                                                                                      | ohm     | $\Omega$ |         |

| Item number | Quantity                  |                                                  |              |                                                                                                                                                                                        | Units   |          |         |
|-------------|---------------------------|--------------------------------------------------|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|----------|---------|
|             | Entry number in IEC 60050 | Name                                             | Symbol       | Definition and remarks                                                                                                                                                                 | Name    | Symbol   | Remarks |
| 206.2       |                           | open-circuit input reverse transfer impedance    | $Z_{12}$     | $Z_{12} = \left( \frac{U_1}{I_2} \right)_{I_1=0}$<br>See also "reverse transfer impedance" (IEC 60050-131:2002, 131-14-14).                                                            | ohm     | $\Omega$ |         |
| 206.3       |                           | open-circuit input forward transfer impedance;   | $Z_{21}$     | $Z_{21} = \left( \frac{U_2}{I_1} \right)_{I_2=0}$<br>See also "forward transfer impedance" (IEC 60050-131:2002, 131-14-13).                                                            | ohm     | $\Omega$ |         |
| 206.4       |                           | open-circuit output impedance                    | $Z_{22}$     | $Z_{22} = \left( \frac{U_2}{I_2} \right)_{I_1=0}$                                                                                                                                      | ohm     | $\Omega$ |         |
| 207         | 131-14-25                 | admittance matrix                                | $\mathbf{Y}$ | $\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \mathbf{Y} \begin{bmatrix} U_1 \\ U_2 \end{bmatrix}$ where $\mathbf{Y} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix}$ | siemens | S        |         |
| 207.1       |                           | short-circuit input admittance                   | $Y_{11}$     | $Y_{11} = \left( \frac{I_1}{U_1} \right)_{U_2=0}$                                                                                                                                      | siemens | S        |         |
| 207.2       |                           | short-circuit reverse transfer admittance        | $Y_{12}$     | $Y_{12} = \left( \frac{I_1}{U_2} \right)_{U_1=0}$<br>See also "reverse transfer admittance" (IEC 60050-131:2002, 131-14-16).                                                           | siemens | S        |         |
| 207.3       |                           | short-circuit input forward transfer admittance; | $Y_{21}$     | $Y_{21} = \left( \frac{I_2}{U_1} \right)_{U_2=0}$                                                                                                                                      | siemens | S        |         |
|             |                           | short-circuit input transfer admittance          |              | See also "forward transfer admittance" (IEC 60050-131:2002, 131-14-15).                                                                                                                |         |          |         |
| 207.4       |                           | short-circuit output admittance                  | $Y_{22}$     | $Y_{22} = \left( \frac{I_2}{U_2} \right)_{U_1=0}$                                                                                                                                      | siemens | S        |         |

| Item number | Quantity                  |                                                                                       |          |                                                                                                                                                                                        | Units   |          |                                                                                                                                                     |
|-------------|---------------------------|---------------------------------------------------------------------------------------|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
|             | Entry number in IEC 60050 | Name                                                                                  | Symbol   | Definition and remarks                                                                                                                                                                 | Name    | Symbol   | Remarks                                                                                                                                             |
| 208         | 131-14-29                 | H-matrix<br>hybrid matrix                                                             | <b>H</b> | $\begin{bmatrix} U_1 \\ I_2 \end{bmatrix} = \mathbf{H} \begin{bmatrix} I_1 \\ U_2 \end{bmatrix}$ where $\mathbf{H} = \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix}$ |         |          | The elements of the matrix are quantities which are not all of the same dimension. When they are of different dimension, they have different units. |
| 208.1       |                           | short-circuit input impedance                                                         | $H_{11}$ | $H_{11} = \left( \frac{U_1}{I_1} \right)_{U_2=0}$                                                                                                                                      | ohm     | $\Omega$ |                                                                                                                                                     |
| 208.2       |                           | open-circuit reverse voltage transfer ratio                                           | $H_{12}$ | $H_{12} = \left( \frac{U_1}{U_2} \right)_{I_1=0}$<br>See also "reverse transfer ratio" (IEC 60050-131:2002, 131-14-19).                                                                | one     | 1        |                                                                                                                                                     |
| 208.3       |                           | short-circuit forward current transfer ratio;<br>short-circuit current transfer ratio | $H_{21}$ | $H_{21} = \left( \frac{I_2}{I_1} \right)_{U_2=0}$<br>See also "forward transfer ratio" (IEC 60050-131:2002, 131-14-18).                                                                | one     | 1        |                                                                                                                                                     |
| 208.4       |                           | open-circuit output admittance                                                        | $H_{22}$ | $H_{22} = \left( \frac{I_2}{U_2} \right)_{I_1=0}$                                                                                                                                      | siemens | S        |                                                                                                                                                     |
| 209         | 131-14-30                 | K-matrix;<br>inverse hybrid matrix                                                    | <b>K</b> | $\begin{bmatrix} I_1 \\ U_2 \end{bmatrix} = \mathbf{K} \begin{bmatrix} U_1 \\ I_2 \end{bmatrix}$ where $\mathbf{K} = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix}$ |         |          | The elements of the matrix are quantities which are not all of the same dimension. When they are of different dimension, they have different units. |
| 209.1       |                           | open-circuit input admittance                                                         | $K_{11}$ | $K_{11} = \left( \frac{I_1}{U_1} \right)_{I_2=0}$                                                                                                                                      | siemens | S        |                                                                                                                                                     |

| Item number | Quantity                  |                                                                                                                                     |                 |                                                                                                                                                                                                                                                                                 | Units |          |                                                                                                                                                     |
|-------------|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
|             | Entry number in IEC 60050 | Name                                                                                                                                | Symbol          | Definition and remarks                                                                                                                                                                                                                                                          | Name  | Symbol   | Remarks                                                                                                                                             |
| 209.2       |                           | short-circuit reverse current transfer ratio                                                                                        | $K_{12}$        | $K_{12} = \left( \frac{I_1}{I_2} \right)_{U_1=0}$<br>See also "reverse transfer ratio" (IEC 60050-131:2002, 131-14-19).                                                                                                                                                         | one   | 1        |                                                                                                                                                     |
| 209.3       |                           | open-circuit forward voltage transfer ratio;<br>open-circuit voltage transfer ratio                                                 | $K_{21}$        | $K_{21} = \left( \frac{U_2}{U_1} \right)_{I_2=0}$<br>See also forward transfer ratio in IEC 60050-131:2002, 131-14-18.                                                                                                                                                          | one   | 1        |                                                                                                                                                     |
| 209.4       |                           | short-circuit output impedance                                                                                                      | $K_{22}$        | $K_{22} = \left( \frac{U_2}{I_2} \right)_{U_1=0}$                                                                                                                                                                                                                               | ohm   | $\Omega$ |                                                                                                                                                     |
| 210         | 131-14-31                 | chain matrix                                                                                                                        | $A$             | $\begin{bmatrix} U_1 \\ I_1 \end{bmatrix} = A \begin{bmatrix} U_2 \\ -I_2 \end{bmatrix}$ where $A = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}$<br>$A$ , $B$ , $C$ , $D$ are sometimes used for $A_{11}$ , $A_{12}$ , $A_{21}$ , $A_{22}$ , respectively. |       |          | The elements of the matrix are quantities which are not all of the same dimension. When they are of different dimension, they have different units. |
| 210.1       |                           | reciprocal of open-circuit forward voltage transfer ratio;<br>reciprocal of open-circuit voltage transfer ratio                     | $A_{11}$<br>$A$ | $A_{11} = \left( \frac{U_1}{U_2} \right)_{I_2=0}$                                                                                                                                                                                                                               | one   | 1        |                                                                                                                                                     |
| 210.2       |                           | negative of reciprocal of short-circuit forward transfer admittance;<br>negative of reciprocal of short-circuit transfer admittance | $A_{12}$<br>$B$ | $A_{12} = \left( \frac{U_1}{-I_2} \right)_{U_2=0}$                                                                                                                                                                                                                              | ohm   | $\Omega$ |                                                                                                                                                     |

| Item number | Quantity                  |                                                                                                                                           |                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Units   |          |                                                                                                                                                     |
|-------------|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
|             | Entry number in IEC 60050 | Name                                                                                                                                      | Symbol          | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Name    | Symbol   | Remarks                                                                                                                                             |
| 210.3       |                           | reciprocal of open-circuit forward transfer impedance;<br>reciprocal of open-circuit transfer impedance                                   | $A_{21}$<br>$C$ | $A_{21} = \left( \frac{I_1}{U_2} \right)_{I_2=0}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | siemens | S        |                                                                                                                                                     |
| 210.4       |                           | negative of reciprocal of short-circuit forward current transfer ratio;<br>negative of reciprocal of short-circuit current transfer ratio | $A_{22}$<br>$D$ | $A_{22} = \left( \frac{I_1}{-I_2} \right)_{U_2=0}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | one     | 1        |                                                                                                                                                     |
| 211         | 131-14-32                 | reverse chain matrix                                                                                                                      | $B$             | $\begin{bmatrix} U_2 \\ I_2 \end{bmatrix} = B \begin{bmatrix} U_1 \\ -I_1 \end{bmatrix}$ where $B = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix}$<br>The reverse chain matrix $B$ is not the inverse of the forward chain matrix $A$ . When using the inverse $A^{-1}$ of $A$ , the following matrix equation will hold: $\begin{pmatrix} U_2 \\ -I_2 \end{pmatrix} = A^{-1} \begin{pmatrix} U_1 \\ I_1 \end{pmatrix}$ . The inverse $A^{-1}$ is sometimes called "forward transfer matrix" or "transfer matrix". |         |          | The elements of the matrix are quantities which are not all of the same dimension. When they are of different dimension, they have different units. |
| 211.1       |                           | reciprocal of open-circuit reverse voltage transfer ratio                                                                                 | $B_{11}$        | $B_{11} = \left( \frac{U_2}{U_1} \right)_{I_1=0}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | one     | 1        |                                                                                                                                                     |
| 211.2       |                           | negative of reciprocal of short-circuit reverse transfer admittance                                                                       | $B_{12}$        | $B_{12} = \left( \frac{U_2}{-I_1} \right)_{U_1=0}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | ohm     | $\Omega$ |                                                                                                                                                     |
| 211.3       |                           | reciprocal of open-circuit reverse transfer impedance                                                                                     | $B_{21}$        | $B_{21} = \left( \frac{I_2}{U_1} \right)_{I_1=0}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | siemens | S        |                                                                                                                                                     |
| 211.4       |                           | negative of reciprocal of short-circuit reverse current transfer ratio                                                                    | $B_{22}$        | $B_{22} = \left( \frac{I_2}{-I_1} \right)_{U_1=0}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | one     | 1        |                                                                                                                                                     |

| Item number | Quantity                  |                                                                                     |          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Units |        |         |
|-------------|---------------------------|-------------------------------------------------------------------------------------|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|--------|---------|
|             | Entry number in IEC 60050 | Name                                                                                | Symbol   | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Name  | Symbol | Remarks |
| 212         | 131-14-35                 | scattering matrix                                                                   | <b>S</b> | $\begin{bmatrix} N_1 \\ N_2 \end{bmatrix} = \mathbf{S} \begin{bmatrix} M_1 \\ M_2 \end{bmatrix} \text{ where } \mathbf{S} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix}$ <p><math>M_1</math> and <math>M_2</math> represent quantities associated with incident waves at port 1 and port 2, respectively (see IEC 60050-131:2002, 131-14-33). <math>N_1</math> and <math>N_2</math> represent quantities associated with output waves at port 1 and port 2, respectively (see IEC 60050-131:2002, 131-14-34). The wave quantities are also represented by <math>a</math> and <math>b</math>. They refer to certain terminal impedances (reference impedances) at each port. See, for example, 217.1.</p> <p>The elements of the scattering matrix are the scattering parameters or scattering coefficients (IEC 60050-131:2002, 131-14-36).</p> | one   | 1      |         |
| 212.1       |                           | input reflection factor;<br>reflection factor at port 1                             | $S_{11}$ | Scattering parameter<br>$S_{11} = \left( \frac{N_1}{M_1} \right)_{M_2=0}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | one   | 1      |         |
| 212.2       |                           | backward wave transfer factor;<br>backward scattering factor                        | $S_{12}$ | Scattering parameter<br>$S_{12} = \left( \frac{N_1}{M_2} \right)_{M_1=0}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | one   | 1      |         |
| 212.3       |                           | forward wave transfer factor;<br>wave transfer factor;<br>forward scattering factor | $S_{21}$ | Scattering parameter<br>$S_{21} = \left( \frac{N_2}{M_1} \right)_{M_2=0}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | one   | 1      |         |
| 212.4       |                           | output reflection factor;<br>reflection factor at port 2                            | $S_{22}$ | Scattering parameter<br>$S_{22} = \left( \frac{N_2}{M_2} \right)_{M_1=0}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | one   | 1      |         |

| Item number | Quantity                  |                   |          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Units |        |         |
|-------------|---------------------------|-------------------|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|--------|---------|
|             | Entry number in IEC 60050 | Name              | Symbol   | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Name  | Symbol | Remarks |
| 213         | 131-14-38                 | wave chain matrix | $T$      | $\begin{bmatrix} N_1 \\ M_1 \end{bmatrix} = T \begin{bmatrix} M_2 \\ N_2 \end{bmatrix}$ where $T = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix}$<br>$M_1$ and $M_2$ represent quantities associated with incident waves at port 1 and port 2, respectively (see IEC 60050-131:2002, 131-14-33). $N_1$ and $N_2$ represent quantities associated with output waves at port 1 and port 2, respectively (see IEC 60050-131:2002, 131-14-34). The wave quantities are also represented by $a$ and $b$ . They refer to certain terminal impedances (reference impedances) at each port. See, for example, 217.1. | one   | 1      |         |
| 213.1       |                           |                   | $T_{11}$ | $T_{11} = \left( \frac{N_1}{M_2} \right)_{N_2=0}$ No special name exists for this quantity.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | one   | 1      |         |
| 213.2       |                           |                   | $T_{12}$ | $T_{12} = \left( \frac{N_1}{N_2} \right)_{M_2=0}$ No special name exists for this quantity.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | one   | 1      |         |
| 213.3       |                           |                   | $T_{21}$ | $T_{21} = \left( \frac{M_1}{M_2} \right)_{N_2=0}$ No special name exists for this quantity.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | one   | 1      |         |
| 213.4       |                           |                   | $T_{22}$ | $T_{22} = \left( \frac{M_1}{N_2} \right)_{M_2=0}$ No special name exists for this quantity.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | one   | 1      |         |

### 5.2.3 $n$ -port networks

To determine the signs of matrix elements, the conventions indicated in Figure 2 are used.

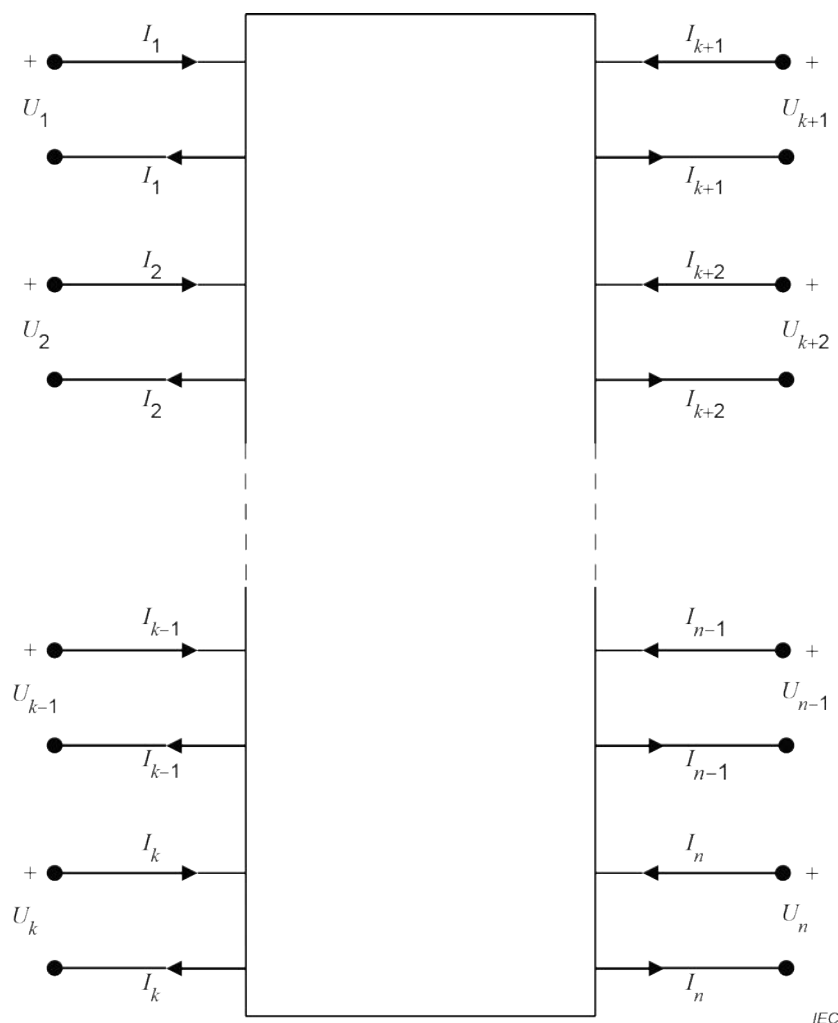


**Figure 2 – Conventions for  $n$ -port linear networks**

Figure 2 can represent either a general  $n$ -port network where all ports are equivalent, or an  $n$ -port network with  $k$  input ports and  $n-k$  output ports.

| Item number | Quantity                  |                                               |              |                                                                                                                                                                                                                                                                                                                                                                                                 | Units   |          |         |
|-------------|---------------------------|-----------------------------------------------|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|----------|---------|
|             | Entry number in IEC 60050 | Name                                          | Symbol       | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                          | Name    | Symbol   | Remarks |
| 214         | 131-14-24                 | impedance matrix                              | $\mathbf{Z}$ | $\begin{bmatrix} U_1 \\ U_2 \\ \dots \\ U_n \end{bmatrix} = \mathbf{Z} \begin{bmatrix} I_1 \\ I_2 \\ \dots \\ I_n \end{bmatrix}$ <p>where <math>\mathbf{Z} = \begin{bmatrix} Z_{11} &amp; Z_{12} &amp; \dots &amp; Z_{1n} \\ Z_{21} &amp; Z_{22} &amp; \dots &amp; Z_{2n} \\ \dots &amp; \dots &amp; \dots &amp; \dots \\ Z_{n1} &amp; Z_{n2} &amp; \dots &amp; Z_{nn} \end{bmatrix}</math></p> | ohm     | $\Omega$ |         |
| 214.1       | 131-14-13                 | transfer impedance from port $j$ to port $i$  | $Z_{ij}$     | $i \neq j$<br>All ports except port $j$ are open.<br>If $Z_{ij} = Z_{ji}$ then the $n$ -port is reciprocal.                                                                                                                                                                                                                                                                                     | ohm     | $\Omega$ |         |
| 214.2       |                           | open-circuit impedance at port $i$            | $Z_{ii}$     | All other ports are open-circuited.                                                                                                                                                                                                                                                                                                                                                             | ohm     | $\Omega$ |         |
| 215         | 131-14-25                 | admittance matrix                             | $\mathbf{Y}$ | $\begin{bmatrix} I_1 \\ I_2 \\ \dots \\ I_n \end{bmatrix} = \mathbf{Y} \begin{bmatrix} U_1 \\ U_2 \\ \dots \\ U_n \end{bmatrix}$ <p>where <math>\mathbf{Y} = \begin{bmatrix} Y_{11} &amp; Y_{12} &amp; \dots &amp; Y_{1n} \\ Y_{21} &amp; Y_{22} &amp; \dots &amp; Y_{2n} \\ \dots &amp; \dots &amp; \dots &amp; \dots \\ Y_{n1} &amp; Y_{n2} &amp; \dots &amp; Y_{nn} \end{bmatrix}</math></p> | siemens | S        |         |
| 215.1       | 131-14-15                 | transfer admittance from port $j$ to port $i$ | $Y_{ij}$     | $i \neq j$<br>All ports except port $j$ are short-circuited<br>If $Y_{ij} = Y_{ji}$ then the $n$ -port is reciprocal.                                                                                                                                                                                                                                                                           | siemens | S        |         |
| 215.2       |                           | short-circuit admittance at port $i$          | $Y_{ii}$     | All other ports short-circuited.                                                                                                                                                                                                                                                                                                                                                                | siemens | S        |         |

| Item number | Quantity                  |              |              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Units   |          |                                                                                                                                                  |
|-------------|---------------------------|--------------|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|----------|--------------------------------------------------------------------------------------------------------------------------------------------------|
|             | Entry number in IEC 60050 | Name         | Symbol       | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Name    | Symbol   | Remarks                                                                                                                                          |
| 216         | 131-14-31                 | chain matrix | $\mathbf{A}$ | $\begin{bmatrix} U_1 \\ \vdots \\ U_k \\ I_1 \\ \vdots \\ I_k \end{bmatrix} = \mathbf{A} \begin{bmatrix} U_{k+1} \\ \vdots \\ U_n \\ -I_{k+1} \\ \vdots \\ -I_n \end{bmatrix}$ <p>where</p> $\mathbf{A} = \begin{bmatrix} A_{11} & \dots & A_{1k} & A_{1(k+1)} & \dots & A_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ A_{k1} & \dots & A_{kk} & A_{k(k+1)} & \dots & A_{kn} \\ A_{(k+1)1} & \dots & A_{(k+1)k} & A_{(k+1)(k+1)} & \dots & A_{(k+1)n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ A_{n1} & \dots & A_{nk} & A_{n(k+1)} & \dots & A_{nn} \end{bmatrix}$ <p>The chain matrix is only defined in the symmetrical case (see Figure 2) with <math>n=2k</math>.</p> |         |          | The elements of the matrix are quantities which are not all the same dimension. When they are of different dimension, they have different units. |
| 216.1       |                           |              | $A_{ij}$     | $i = 1, \dots, k, j = 1, \dots, k$<br>No special name exists for this quantity.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | one     | 1        |                                                                                                                                                  |
| 216.2       |                           |              | $A_{ij}$     | $i = k + 1, \dots, n, j = k + 1, \dots, n$<br>No special name exists for this quantity.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | one     | 1        |                                                                                                                                                  |
| 216.3       |                           |              | $A_{ij}$     | $i = 1, \dots, k, j = k + 1, \dots, n$<br>No special name exists for this quantity.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | ohm     | $\Omega$ |                                                                                                                                                  |
| 216.4       |                           |              | $A_{ij}$     | $i = k + 1, \dots, n, j = 1, \dots, k$<br>No special name exists for this quantity.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | siemens | S        |                                                                                                                                                  |

| Item number | Quantity                  |                   |          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Units |        |
|-------------|---------------------------|-------------------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|--------|
|             | Entry number in IEC 60050 | Name              | Symbol   | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Name  | Symbol |
| 217         | 131-14-35                 | scattering matrix | <b>S</b> | $\begin{bmatrix} N_1 \\ N_2 \\ \dots \\ N_n \end{bmatrix} = \mathbf{S} \begin{bmatrix} M_1 \\ M_2 \\ \dots \\ M_n \end{bmatrix} \quad \text{where } \mathbf{S} = \begin{bmatrix} S_{11} & S_{12} & \dots & S_{1n} \\ S_{21} & S_{22} & \dots & S_{2n} \\ \dots & \dots & \dots & \dots \\ S_{1n} & S_{2n} & \dots & S_{nn} \end{bmatrix}$ <p>Input quantities <math>M_1, M_2, \dots, M_n</math> are associated with incident waves at ports 1, 2, ..., <math>n</math>, respectively (see 217.1). Output quantities <math>N_1, N_2, \dots, N_n</math> are associated with output waves at ports 1, 2, ..., <math>n</math>, respectively (see 217.2). These quantities are, for example, the transversal electric field strength or the voltage, according to the wave type under consideration. They refer to certain terminal impedances (reference impedances) at each port. See, for example, 217.1.</p> | one   | 1      |

| Item number | Quantity                  |                                                         |          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Units                         |           |
|-------------|---------------------------|---------------------------------------------------------|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|-----------|
|             | Entry number in IEC 60050 | Name                                                    | Symbol   | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Name                          | Symbol    |
| 217.1       | 131-14-33                 | incident scattering variable;<br>incident wave quantity | $M_a$    | <p>The incident and output scattering variables <math>M_i</math> and <math>N_i</math> at port <math>i</math> are, for example, formed as linear combinations of the phasors of the voltage <math>U_i</math> and the electric current <math>I_i</math>. An arbitrary number of such linear combinations can be formed. Among them the following two pairs, where the modulus of each phasor is the RMS value of the corresponding sinusoidal quantity, are especially useful (reference directions of currents and sign conventions of voltages as in Figure 2 are assumed):</p> $M_i = \frac{U_i + Z_{\text{ref } i} I_i}{2\sqrt{Z_{\text{ref } i}}} \quad \text{and} \quad N_i = \frac{U_i - Z_{\text{ref } i} I_i}{2\sqrt{Z_{\text{ref } i}}} \quad (1)$ <p>or, if <math>\text{Re}(Z_{\text{ref } i}) &gt; 0</math>,</p> $M_i = \frac{U_i + Z_{\text{ref } i} I_i}{2\sqrt{\text{Re}(Z_{\text{ref } i})}} \quad \text{and} \quad N_i = \frac{U_i - Z_{\text{ref } i}^* I_i}{2\sqrt{\text{Re}(Z_{\text{ref } i})}} \quad (2)$ <p>where <math>Z_{\text{ref } i}</math> is a reference impedance which is generally complex and can, in principle, arbitrarily be chosen and where <math>\sqrt{Z_{\text{ref } i}}</math> is one of the square roots of this impedance.</p> <p>In case (1), <math>M_i^2 - N_i^2 = U_i I_i = S_{-i}</math> is the complex alternating power at port <math>i</math> (see IEC 60050-131:2002, 131-11-40).</p> <p>In case (2), <math> M_i ^2 -  N_i ^2 = \text{Re}(U_i I_i^*) = P_i</math> is the active power at port <math>i</math>. If the reference impedance is real, equations (1) and (2) are identical.</p> <p>See 217.1.</p> | watt to the power of one-half | $W^{1/2}$ |
| 217.2       | 131-14-34                 | output scattering variable;<br>output wave quantity     | $N_b$    | See 217.1.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | watt to the power of one-half | $W^{1/2}$ |
| 217.3       |                           | reflection factor at port $i$                           | $S_{ii}$ | Diagonal element of the scattering matrix.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | one                           | 1         |

| Item number | Quantity                  |                                                |          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Units |        |         |
|-------------|---------------------------|------------------------------------------------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|--------|---------|
|             | Entry number in IEC 60050 | Name                                           | Symbol   | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Name  | Symbol | Remarks |
| 217.4       |                           | wave transfer factor from port $j$ to port $i$ | $S_{ij}$ | Element of the scattering matrix with $i \neq j$ .<br>The $n$ -port is reciprocal if, and only if, $S_{ij} = S_{ji}$ for all pairs $(i, j)$ .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | one   | 1      |         |
| 218         | 131-14-38                 | wave chain matrix                              | $T$      | $k = \frac{n}{2}$<br>input ports with subscripts $1, \dots, k$<br>output ports with subscripts $k+1, \dots, n$<br>$\begin{bmatrix} N_1 \\ \vdots \\ N_k \\ M_1 \\ \vdots \\ M_k \end{bmatrix} = T \begin{bmatrix} M_{k+1} \\ \vdots \\ M_n \\ N_{k+1} \\ \vdots \\ N_n \end{bmatrix} \quad \text{where } T = \begin{bmatrix} T_{11} & \dots & T_{1k} & T_{1(k+1)} & \dots & T_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ T_{k1} & \dots & T_{kk} & T_{k(k+1)} & \dots & T_{kn} \\ T_{(k+1)1} & \dots & T_{(k+1)k} & T_{(k+1)(k+1)} & \dots & T_{(k+1)n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ T_{n1} & \dots & T_{nk} & T_{n(k+1)} & \dots & T_{nn} \end{bmatrix}$ | one   | 1      |         |

### 5.3 Line transmission of signals and telephony

#### 5.3.1 Quantities and units in line transmission

| Item number | Quantity                  |                                           |                                                          |                                                                                                                                                                                            | Units             |                   |         |
|-------------|---------------------------|-------------------------------------------|----------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-------------------|---------|
|             | Entry number in IEC 60050 | Name                                      | Symbol                                                   | Definition and remarks                                                                                                                                                                     | Name              | Symbol            | Remarks |
| 301         |                           | linear impedance;<br>lineic impedance     | $\underline{Z}'$<br>$\underline{Z}$<br>$\underline{Z}_l$ | Series impedance per length<br>$\underline{Z}' = R' + j\omega L'$ .<br><br>The adjectives "linear" and "lineic" are defined in IEC 60050-112:2010, 112-03-14.                              | ohm per metre     | $\Omega/\text{m}$ |         |
| 302         |                           | linear admittance;<br>lineic admittance   | $\underline{Y}'$<br>$\underline{Y}$<br>$\underline{Y}_l$ | Shunt admittance per length<br>$\underline{Y}' = G' + j\omega C'$ .<br><br>See also 301.                                                                                                   | siemens per metre | S/m               |         |
| 303         |                           | linear resistance;<br>lineic resistance   | $R'$<br>$r$<br>$R_l$                                     | Series resistance per length.<br><br>See also 301.                                                                                                                                         | ohm per metre     | $\Omega/\text{m}$ |         |
| 304         |                           | linear inductance;<br>lineic inductance   | $L'$<br>$l$<br>$L_l$                                     | Series inductance per length.<br><br>See also 301.                                                                                                                                         | henry per metre   | H/m               |         |
| 305         |                           | linear conductance;<br>lineic conductance | $G'$<br>$g$<br>$G_l$                                     | Shunt conductance per length.<br><br>See also 301.                                                                                                                                         | siemens per metre | S/m               |         |
| 306         |                           | linear capacitance;<br>lineic capacitance | $C'$<br>$c$<br>$C_l$                                     | Shunt capacitance per length.<br><br>See also 301.                                                                                                                                         | farad per metre   | F/m               |         |
| 307         | 131-15-28<br>726-07-01    | characteristic impedance                  | $\underline{Z}_0$<br>$\underline{Z}_c$                   | $\underline{Z}_0 = \sqrt{\underline{Z}'/\underline{Y}'}$<br><br>where $\underline{Z}'$ is the linear impedance (301) and $\underline{Y}'$ is the linear admittance (302).<br>See also 203. | ohm               | $\Omega$          |         |
| 308         |                           | impedance transformation ratio            | $q_z$                                                    | $q_z =  \underline{Z}_2 / \underline{Z}_1 $ where $\underline{Z}_1$ is the impedance at the input port and $\underline{Z}_2$ is the impedance at the output port.                          | one               | 1                 |         |

**5.3.2 Subscripts for line transmission**

| Item number | Meaning        | Symbol       | Examples of use                                                                                                        | Remarks |
|-------------|----------------|--------------|------------------------------------------------------------------------------------------------------------------------|---------|
| 309         | characteristic | 0<br>c<br>ch | Characteristic impedance (307).                                                                                        |         |
| 310         | image          | i<br>im      | Image impedance (204).                                                                                                 |         |
| 311         | iterative      | k<br>it      | Iterative impedance (205).                                                                                             |         |
| 312         | insertion      | in<br>ins    | Insertion transfer function (IEC 60050-131:2002, 131-15-29),<br>insertion attenuation (IEC 60050-131:2002, 131-15-30). |         |
| 313         | composite      | cp<br>m      | Composite loss (IEC 60050-702:1992, 702-07-18).                                                                        |         |
| 314         | transmission   | t            | Transmission loss (IEC 60050-702:1992, 702-07-07).                                                                     |         |
| 315         | reflection     | r            | Reflection factor (148),<br>reflection loss (IEC 60050-702:1992, 702-07-15).                                           |         |
| 316         | interaction    | rr           |                                                                                                                        |         |

### 5.3.3 Quantities and units in telephony

| Item number | Quantity                  |                                       |                         |                                                                                             | Units            |          |         |
|-------------|---------------------------|---------------------------------------|-------------------------|---------------------------------------------------------------------------------------------|------------------|----------|---------|
|             | Entry number in IEC 60050 | Name                                  | Symbol                  | Definition and remarks                                                                      | Name             | Symbol   | Remarks |
| 317         | 702-07-25                 | logarithmic return loss               | $A_Z$                   | $A_Z = -20 \lg  r $ dB = $-\ln  r $ Np<br>where $r$ is the complex reflection factor (148). | decibel<br>neper | dB<br>Np |         |
| 318         | 722-15-10                 | logarithmic crosstalk attenuation     | $A_x$                   |                                                                                             | decibel<br>neper | dB<br>Np |         |
| 319         | 722-15-09                 | logarithmic signal to crosstalk ratio | $A_{x0}$<br>$A_{d0}$    |                                                                                             | decibel<br>neper | dB<br>Np |         |
| 320         | 722-17-14                 | reference equivalent                  | $A_e$<br>$A_q$          |                                                                                             | decibel<br>neper | dB<br>Np |         |
| 321         | 722-17-05                 | articulation                          | $\eta$<br>$N$           | The first symbol is lower-case Greek letter eta.                                            | one              | 1        |         |
| 322         | 722-17-08                 | logatom articulation                  | $\eta_L$<br>$N_L$       |                                                                                             | one              | 1        |         |
| 323         | 722-17-09                 | sound articulation                    | $\eta_a$<br>$N_a$       | "a" denotes acoustic.                                                                       | one              | 1        |         |
| 324         | 722-17-06                 | word articulation                     | $\eta_v$<br>$N_v$       | "v" denotes verbum.                                                                         | one              | 1        |         |
| 325         | 722-17-10                 | sentence articulation                 | $\eta_{ph}$<br>$N_{ph}$ |                                                                                             | one              | 1        |         |

### 5.3.4 Subscripts for telephony

| Item number | Meaning            | Symbol   | Example of use                                                  | Remarks                                                                                                                                                                                                                                       |
|-------------|--------------------|----------|-----------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 326         | psophometric       | p<br>ps  | IEC 60050-702:1992, 702-08-42, psophometrically weighted noise. | "p" is used to indicate psophometrically weighted values associated with telephone-type circuits.<br>"ps" is used to indicate psophometrically weighted values associated with sound transmissions, usually for broadcast programme purposes. |
| 327         | crosstalk          | x<br>d   | IEC 60050-722:1992, 722-15-09, signal-to-crosstalk ratio.       |                                                                                                                                                                                                                                               |
| 328         | near-end crosstalk | xn<br>dp | IEC 60050-722:1992, 722-15-11, near-end crosstalk attenuation.  |                                                                                                                                                                                                                                               |
| 329         | far-end crosstalk  | xt<br>dt | IEC 60050-722:1992, 722-15-12, far-end crosstalk attenuation.   |                                                                                                                                                                                                                                               |

## 5.4 Waveguide propagation

### 5.4.1 Frequency and wavelength in a waveguide

| Item number | Quantity                  |                       |                                                       |                                                                                                                                                                    | Units |        |         |
|-------------|---------------------------|-----------------------|-------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|--------|---------|
|             | Entry number in IEC 60050 | Name                  | Symbol                                                | Definition and remarks                                                                                                                                             | Name  | Symbol | Remarks |
| 401         | 726-05-03                 | critical frequency    | $f_{\text{crit}}$<br>$f_k$                            | <sup>a</sup>                                                                                                                                                       | hertz | Hz     |         |
| 402         | 726-05-05                 | cut-off frequency     | $f_c$                                                 | <sup>a</sup><br>See also 153.                                                                                                                                      | hertz | Hz     |         |
| 403         | 726-05-04                 | critical wavelength   | $\lambda_c$<br>$\lambda_{\text{crit}}$<br>$\lambda_k$ | <sup>a</sup>                                                                                                                                                       | metre | m      |         |
| 404         |                           | cut-off wavelength    | $\lambda_c$                                           |                                                                                                                                                                    | metre | m      |         |
| 405         | 726-05-01                 | waveguide wavelength  | $\lambda_g$                                           |                                                                                                                                                                    | metre | m      |         |
| 406         |                           | normalized wavelength | $\lambda_r$<br>$\nu$<br>$\lambda_*$                   | $\lambda_r = \frac{\lambda}{\lambda_c} = \frac{f_c}{f}$<br><br>where $\lambda_c$ and $f_c$ are cut-off wavelength (404) and cut-off frequency (402), respectively. | one   | 1      |         |

<sup>a</sup> These quantities concern a particular mode of oscillation. Reference to the mode in question should be added as a subscript, e.g.  $f_{c\text{TEM}}$ . Abbreviated terms denoting different modes of oscillation are given in IEC 60050-726.

#### 5.4.2 Characteristic and normalized impedance and admittance in general

| Item number | Quantity                  |                           |                       |                                                                                                  | Units   |          |         |
|-------------|---------------------------|---------------------------|-----------------------|--------------------------------------------------------------------------------------------------|---------|----------|---------|
|             | Entry number in IEC 60050 | Name                      | Symbol                | Definition and remarks                                                                           | Name    | Symbol   | Remarks |
| 407         | 131-15-28                 | characteristic impedance  | $Z_c$<br>$Z_{ch}$     | The subscript 0 used for vacuum (see 417) is not usable here for "characteristic". See also 203. | ohm     | $\Omega$ |         |
| 408         |                           | characteristic admittance | $Y_c$<br>$Y_{ch}$     | The subscript 0 used for vacuum (see 418) is not usable here for "characteristic".               | siemens | S        |         |
| 409         | 726-07-03                 | normalized impedance      | $z$<br>$Z_r$<br>$Z_*$ | $z = Z / Z_c$<br>where $z$ is an impedance and $Z_c$ is the characteristic impedance (407).      | one     | 1        |         |
| 410         | 726-07-04                 | normalized admittance     | $y$<br>$Y_r$<br>$Y_*$ | $y = Y / Y_c$<br>where $y$ is an admittance and $Y_c$ is the characteristic admittance (408).    | one     | 1        |         |

### 5.4.3 Impedance and admittance at a point in a substance

| Item number | Quantity                  |                                              |                                      |                                                                                                                       | Units   |          |         |
|-------------|---------------------------|----------------------------------------------|--------------------------------------|-----------------------------------------------------------------------------------------------------------------------|---------|----------|---------|
|             | Entry number in IEC 60050 | Name                                         | Symbol                               | Definition and remarks                                                                                                | Name    | Symbol   | Remarks |
| 411         | 705-03-23                 | characteristic impedance, <of a substance>   | $Z_s$<br>$\eta$<br>$Z_{cs}$<br>$Z_i$ | 2 <sup>nd</sup> symbol is lower-case Greek letter eta.<br>See also 501.                                               | ohm     | $\Omega$ |         |
| 412         |                           | characteristic admittance, <of a substance>  | $Y_s$<br>$Y_{cs}$                    |                                                                                                                       | siemens | S        |         |
| 413         | 705-03-22                 | wave impedance, <in a substance>             | $Z_{st}$<br>$\zeta$                  | 2 <sup>nd</sup> symbol is lower-case Greek letter zeta.                                                               | ohm     | $\Omega$ |         |
| 414         |                           | wave admittance, <in a substance>            | $Y_{st}$                             |                                                                                                                       | siemens | S        |         |
| 415         |                           | normalized wave impedance, <in a substance>  | $z_s$<br>$Z_{sr}$<br>$Z_{s*}$        | $z_s = Z_{st} / Z_s$<br>where $Z_{st}$ is the wave impedance (413) and $Z_s$ is the characteristic impedance (411).   | one     | 1        |         |
| 416         |                           | normalized wave admittance, <in a substance> | $y_s$<br>$Y_{sr}$<br>$Y_{s*}$        | $y_s = Y_{st} / Y_s$<br>where $Y_{st}$ is the wave admittance (414) and $Y_s$ is the characteristic admittance (412). | one     | 1        |         |

#### 5.4.4 Impedance and admittance at a point in vacuum

| Item number | Quantity                  |                                                                   |        |                                                                                                                                                                                                                            | Units   |          |         |
|-------------|---------------------------|-------------------------------------------------------------------|--------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|----------|---------|
|             | Entry number in IEC 60050 | Name                                                              | Symbol | Definition and remarks                                                                                                                                                                                                     | Name    | Symbol   | Remarks |
| 417         | 705-03-24                 | characteristic impedance of vacuum;<br>wave impedance of vacuum   | $Z_0$  | $Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} \approx 377 \, \Omega$ <p>where<br/> <math>\mu_0</math> is the magnetic constant,<br/> <math>\epsilon_0</math> is the electric constant.<br/>                     See also 502.</p> | ohm     | $\Omega$ |         |
| 418         |                           | characteristic admittance of vacuum;<br>wave admittance of vacuum | $Y_0$  | $Y_0 = \sqrt{\frac{\epsilon_0}{\mu_0}} \approx 2,66 \, \text{mS}$ <p>where<br/> <math>\epsilon_0</math> is the electric constant and<br/> <math>\mu_0</math> is the magnetic constant.</p>                                 | siemens | S        |         |

### 5.4.5 Impedance and admittance of a waveguide

| Item number | Quantity                  |                                             |                               |                                                                                                 | Units   |          |         |
|-------------|---------------------------|---------------------------------------------|-------------------------------|-------------------------------------------------------------------------------------------------|---------|----------|---------|
|             | Entry number in IEC 60050 | Name                                        | Symbol                        | Definition and remarks                                                                          | Name    | Symbol   | Remarks |
| 419         | 726-07-01                 | characteristic impedance, <of a waveguide>  | $Z_g$<br>$\eta_g$<br>$Z_{cg}$ |                                                                                                 | ohm     | $\Omega$ |         |
| 420         |                           | characteristic admittance, <of a waveguide> | $Y_g$<br>$Y_{cg}$             | $Y_g = 1 / Z_g$<br>where $Z_g$ is the characteristic impedance (419) of the waveguide.          | siemens | S        |         |
| 421         | 726-07-02                 | characteristic wave impedance               | $Z_{gt}$<br>$\zeta_g$         |                                                                                                 | ohm     | $\Omega$ |         |
| 422         |                           | characteristic wave admittance              | $Y_{gt}$                      | $Y_{gt} = 1 / Z_{gt}$<br>where $Z_{gt}$ is the characteristic wave impedance (421).             | siemens | S        |         |
| 423         | 726-07-03                 | normalized impedance, <of a waveguide>      | $z_g$<br>$Z_{gr}$<br>$Z_{g*}$ | $z_g = Z / Z_g$<br>where $z$ is an impedance and $Z_g$ is the characteristic impedance (419).   | one     | 1        |         |
| 424         | 726-07-04                 | normalized admittance, <of a waveguide>     | $y_g$<br>$Y_{gr}$<br>$Y_{g*}$ | $y_g = Y / Y_g$<br>where $y$ is an admittance and $Y_g$ is the characteristic admittance (420). | one     | 1        |         |

## 5.5 Radiocommunications

### 5.5.1 General and tropospheric propagation

| Item number | Quantity                  |                                      |                                        | Units                                                                                                                                                                                                                                                                                                                                                                                                                                             |                  |          |
|-------------|---------------------------|--------------------------------------|----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|----------|
|             | Entry number in IEC 60050 | Name                                 | Symbol                                 | Definition and remarks                                                                                                                                                                                                                                                                                                                                                                                                                            | Name             | Symbol   |
| 501         | 705-03-23                 | characteristic impedance of a medium | $\underline{Z}_i$<br>$\underline{Z}_c$ | $\underline{Z}_i = \sqrt{\frac{\mu_0 \underline{\mu}}{\varepsilon_0 \underline{\varepsilon}_r}}$ <p>where <math>\mu_0</math> is the magnetic constant, <math>\underline{\mu}</math> is the relative complex permeability (IEC 60050-121:1998, 121-12-30), <math>\varepsilon_0</math> is the electric constant, <math>\underline{\varepsilon}_r</math> is the relative complex permittivity (IEC 60050-121:1998, 121-12-14).<br/>See also 411.</p> | ohm              | $\Omega$ |
| 502         | 705-03-24                 | characteristic impedance of vacuum   | $Z_0$                                  | $Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} \approx 377 \Omega$ <p>where <math>\mu_0</math> is the magnetic constant, and <math>\varepsilon_0</math> is the electric constant.<br/>See also 419.</p>                                                                                                                                                                                                                                                | ohm              | $\Omega$ |
| 503         |                           | electric field strength level        | $L_E$                                  | $L_E = 20 \lg \frac{E}{E_{\text{ref}}} \text{ dB} = \ln \frac{E}{E_{\text{ref}}} \text{ Np}$ <p>where <math>E</math> is the electric field strength and <math>E_{\text{ref}} = 1 \text{ mV/m}</math>.</p>                                                                                                                                                                                                                                         | decibel<br>neper | dB<br>Np |
| 504         |                           | free space electric field strength   | $E_0$                                  | Free space is a homogeneous ideal dielectric medium which can be considered of infinite extent in all directions (see IEC 60050-705:1995, 705-02-27).                                                                                                                                                                                                                                                                                             | volt per metre   | V/m      |

| Item number | Quantity                  |                                             |                        |                                                                                                                                                                                       | Units                 |                |                                         |
|-------------|---------------------------|---------------------------------------------|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|----------------|-----------------------------------------|
|             | Entry number in IEC 60050 | Name                                        | Symbol                 | Definition and remarks                                                                                                                                                                | Name                  | Symbol         | Remarks                                 |
| 505         |                           | level of free space electric field strength | $L_{E0}$               | $L_{E0} = 20 \lg \frac{E_0}{E_{ref}} \text{ dB} = \ln \frac{E_0}{E_{ref}} \text{ Np}$<br>where $E_0$ is the free space electric field strength (504) and $E_{ref} = 1 \text{ mV/m}$ . | decibel<br>neper      | dB<br>Np       |                                         |
| 506         | 705-02-03                 | power flux density;<br>radiant flux density | $S$                    |                                                                                                                                                                                       | watt per square metre | $\text{W/m}^2$ |                                         |
| 507         | 102-03-24                 | distance                                    | $d$                    |                                                                                                                                                                                       | metre                 | m              |                                         |
| 508         | 113-01-21                 | height                                      | $h$                    | $h$ is frequently used for the height above sea-level, or for the height of an antenna over ground.                                                                                   | metre                 | m              |                                         |
| 509         | 705-04-03                 | angle of incidence                          | $i$                    |                                                                                                                                                                                       | radian<br>degree      | rad<br>°       | $1^\circ = \frac{\pi}{180} \text{ rad}$ |
| 510         | 705-04-04                 | grazing angle                               | $\psi$<br>$\delta$     | Complement of the angle of incidence (509)<br>$\psi = \frac{\pi}{2} - i$ .                                                                                                            | radian<br>degree      | rad<br>°       | $1^\circ = \frac{\pi}{180} \text{ rad}$ |
| 511         | 705-04-26                 | divergence factor                           | $D$                    |                                                                                                                                                                                       | one                   | 1              |                                         |
| 512         |                           | earth conductivity;<br>ground conductivity  | $\sigma$<br>$\sigma_t$ | "t" denotes "terra".                                                                                                                                                                  | siemens per metre     | S/m            |                                         |
| 513         |                           | actual Earth radius;<br>Earth radius        | $a$<br>$r_t$           | "t" denotes "terra".                                                                                                                                                                  | metre                 | m              |                                         |
| 514         | 705-05-41                 | effective Earth-radius factor               | $k$                    | $k = \frac{1}{1 + a \frac{dn}{dh}}$<br>where $a$ is the actual Earth radius (513), $n$ is the refractive index (601) of the atmosphere, and $h$ is the height above sea-level.        | one                   | 1              |                                         |

| Item number | Quantity                  |                                                        |                 |                                                                                                                                                                     | Units                                  |                |                                                                                        |
|-------------|---------------------------|--------------------------------------------------------|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|----------------|----------------------------------------------------------------------------------------|
|             | Entry number in IEC 60050 | Name                                                   | Symbol          | Definition and remarks                                                                                                                                              | Name                                   | Symbol         | Remarks                                                                                |
| 515         | 705-05-40                 | effective radius of the Earth                          | $a_{\text{ef}}$ | $a_{\text{ef}} = ka$<br>where $k$ is the effective Earth-radius factor (514) and $a$ is the actual Earth radius (513).<br>$ka$ is also used to denote the quantity. | metre                                  | m              |                                                                                        |
| 516         | 705-05-08                 | mixing ratio;<br>mass ratio of water vapour to dry air | $x$             | Ratio of the mass of water vapour to the mass of dry air in a given volume of air.                                                                                  | one<br>gram per<br>kilogram<br>per mil | 1<br>g/kg<br>‰ |                                                                                        |
| 517         | 705-05-09                 | relative humidity                                      | $\varphi$       | Ratio of the partial pressure of water vapour to the partial pressure at saturation.                                                                                | one<br>percent                         | 1<br>%         |                                                                                        |
| 518         | 705-05-10                 | atmospheric refractivity                               | $N$             | $N = 10^6(n-1)$<br>where $n$ is the refractive index (601) of the atmosphere.                                                                                       | $N$ -unit                              |                | Non-SI unit.<br>For $n = 1,000\ 001$ the atmospheric refractivity is $N = 1\ N$ -unit. |
| 519         | 705-05-12                 | modified refractive index                              | $n'$            | $n' = n + \frac{h}{a}$<br>where $h$ is the height above sea-level and $a$ is the actual Earth radius (513).                                                         | one                                    | 1              |                                                                                        |
| 520         | 705-05-13                 | refractive modulus                                     | $M$             | $M = 10^6(n + \frac{h}{a} - 1) = 10^6(n' - 1) = N + 10^6 \frac{h}{a}$<br>where $h$ is the height above sea-level and $a$ is the actual Earth radius (513).          | $M$ -unit                              |                | Non-SI unit.<br>For $n = 1,000\ 001$ the refractive modulus is $M = 1\ M$ -unit.       |

## 5.5.2 Ionospheric propagation

| Item number | Quantity                  |                                       |                                              |                                                                                                                                                                                                                                                                                                                              | Units                                                  |          |         |
|-------------|---------------------------|---------------------------------------|----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|----------|---------|
|             | Entry number in IEC 60050 | Name                                  | Symbol                                       | Definition and remarks                                                                                                                                                                                                                                                                                                       | Name                                                   | Symbol   | Remarks |
| 521         | 705-06-05                 | electron density                      | $n$<br>$n_e$<br>$N$                          |                                                                                                                                                                                                                                                                                                                              | metre to the power of minus three, one per cubic metre | $m^{-3}$ |         |
| 522         | 705-06-08                 | collision frequency                   | $\nu$<br>$\nu_{col}$                         | The symbol $\nu$ is lower-case Greek letter nu.<br>A subscript can be added to identify the particle, e.g. $\nu_e$ for electrons.                                                                                                                                                                                            | second to the power of minus one                       | $s^{-1}$ |         |
| 523         |                           | recombination coefficient             | $\alpha$                                     |                                                                                                                                                                                                                                                                                                                              | cubic metre per second                                 | $m^3/s$  |         |
| 524         | 705-06-09                 | gyrofrequency;<br>cyclotron frequency | $f_c$<br>$\nu_c$<br>$f_{cyc}$<br>$\nu_{cyc}$ | The symbol $\nu$ is lower-case Greek letter nu.<br>$f_c = \frac{1}{2\pi} \frac{ q B}{m}$ where<br>$B$ is the magnetic flux density,<br>$m$ is the mass of the particle,<br>$q$ is the electric charge of the particle.<br>A subscript can be added to identify the particle, e.g. $f_{ce}$ for electron gyrofrequency (525). | hertz                                                  | Hz       |         |
| 525         | 705-07-35                 | electron gyrofrequency                | $f_{ce}$<br>$f_B$                            | $B$ denotes the magnetic flux density.                                                                                                                                                                                                                                                                                       | hertz                                                  | Hz       |         |
| 526         | 705-06-10                 | plasma frequency                      | $f_p$<br>$\nu_p$                             | The symbol $\nu$ is lower-case Greek letter nu.                                                                                                                                                                                                                                                                              | hertz                                                  | Hz       |         |