<u>TERMS TO BE DEFINED</u> 25 June, 2003

Alphabetical listing (by first word); terms followed by (P) have proposed definitions listed below; those followed by (A) have adopted definitions listed below.

Absolute accuracy (A)
Accuracy (A)
Antenna Gain (A)
Antenna temperature
Attenuation (P)
Attenuation constant (P)
Available power ratio (P)
Bandwidth—See Predetection bandwidth, Effective noise bandwidth, Half-power bandwidth
Bias (A)
Blackbody load (A)
Brightness (A)
Brightness temperature
Boresight (A)
Calibration (A)
Check standard (P)
Close-coupling (P)
Directivity (A)
Drift (A)
Effective noise bandwidth (P)
Efficiency (P)
Emissivity (of a surface) (A)
End-to-end calibration (A)
Equivalent blackbody temperature (P)
Equivalent physical temperature (P)
Error (A)
Error budget (A)
Experimental standard deviation (A)
External (radiometer) calibration (A)
Fractional loss (P)
Gain—See Antenna gain, System gain
Half-power bandwidth (P)
Higher-level data product
Injection calibration method (P)
Internal (radiometer) calibration (A)
Limiting radiometric resolution (A)
Loss factor (P)
Noise equivalent delta T
Noise temperature (P)
Polarization (P)
Predetection bandwidth (P)

Radiance (A)
Radiometer (A)
Radiometric accuracy
Radiometric resolution (A)
Radiometric sensitivity (A)
Random error (A)
Receiver noise temperature (P)
Receiver noise figure (P)
Reference temperature (P)
Relative error (A)
Relative uncertainty (A)
Repeatability (A)
Reproducibility (A)
Resolution (A)
Response time (A)
Sensitivity (A)
Spatial resolution
Spectral brightness (A)
Spectral radiance (A)
Spectral power (P)
Stability (A)
System equation (A)
System gain
System noise figure (P)
System noise temperature (P)
Systematic error (A)
Traceability (A)
True value (A)
Type-A uncertainty (A)
Type-B uncertainty (A)
Uncertainty of measurement (A)
Uncertainty budget (A)
Validation (A)
Verification (A)

PROPOSED DEFINITIONS

Effective noise bandwidth (B_n): the width of an ideal rectangular filter (or other circuit or component) having the same maximum (available) gain as the real filter, and which produces the same output available power (integrated over frequency) as the real one when the input is white noise. In terms of the filter (available) gain G, $B_n = \frac{\int_0^\infty G(f)df}{G_{\max}}$.

Predetection bandwidth (B_{pre}): the effective bandwidth of the predetection section of a radiometer, used in computing the ideal radiometer resolution. In terms of the gain G of the predetection section, $B_{pre} = \frac{\left\{\int_0^\infty G(f)df\right\}^2}{\int_0^\infty G^2(f)df}$.

Reference temperature (T_0): Temperature used in ratios to set a scale, conventionally taken as $T_0 = 290$ K.

Noise temperature (of a waveguide or coaxial noise source, or at a reference plane in a microwave circuit/network, T_n): the available noise power spectral density at the reference plane divided by Boltzmann's constant (k_B); thus $\frac{dP_n^{av}}{df} = k_B T_n$ by definition, where the subscript *n* denotes "noise." For a resistor at physical temperature T_{phys}, the noise temperature is given by $k_B T_n = \frac{hf}{e^{\frac{hf}{k_B T_{phys}}} - 1}$, so that for $\frac{hf}{k_B T_{phys}} << 1$, $T_n \approx T_{phys}$.

Receiver noise temperature (T_R): the equivalent input noise temperature (at the waveguide or coaxial input plane) that would produce the receiver response that would be observed for zero input signal (to the receiver). The receiver noise temperature is a function of frequency, and it is also depends on the location of the input reference plane and on the reflection coefficient of the input source at that reference plane. For a remote-sensing radiometer it is the reflection coefficient at the waveguide (or coaxial) plane of the antenna.

Receiver noise figure (F_R): a measure of the system noise defined as the ratio of the output or measured noise power divided by the corresponding noise power that would result for an identical but noiseless receiver, for the case where the input noise temperature is the reference temperature T_0. It is commonly expressed in dB. It is related to the receiver noise temperature by

$$F_R(dB) = 10\log_{10}\left(\frac{T_S + T_0}{T_0}\right)$$

As with the receiver noise temperature, the receiver noise figure is dependent on the reflection coefficient of the input source.

Injection calibration (of a radiometer): see internal calibration (of a radiometer).

Close-coupling: the technique by which the receiving aperture of a radiometer is coupled to a blackbody load so that the system is closed to stray radiation.

Spectral power: the power per unit frequency interval.

Attenuation (of a two-port): the ratio of input power to output power for matched conditions, *i.e.*, for reflectionless terminations on both ports (not necessarily assuming that S_{11} and S_{22} of the two-port vanish), usually expressed in dB. [6, p. 61], [7, pp. 36&77] Also see Loss factor, Attenuation constant.

Loss factor (of a two-port, *L*): the ratio of input power to output power, $L = p_{in}/p_{out}$; also called the attenuation. The loss factor is usually used assuming matched (reflectionless) conditions; in the presence of mismatch, L should be replaced by the inverse of the available power ratio (or defined in terms of available powers as in [8]), in order to preserve the form of the equation $T_2 = \alpha T_1 + (1-\alpha)T_a$.

Attenuation constant (α): for a wave propagating in a lossy medium, the coefficient governing the exponential decay of the *amplitude* with distance, $|E| = |E_0|e^{-\alpha z}$; also sometimes called the "attenuation."

Available power ratio (of a two port, α): the ratio of output available power to input available power, $\alpha \equiv p_{out}^{avail} / p_{in}^{avail}$. For matched (reflectionless) conditions, the available power ratio is equal to the efficiency.

Fractional loss: the fraction of the power at the input that does not appear at the output, due to both ohmic loss and reflections; equal to one minus the inverse of the loss factor, $(1 - 1/L)$.

Note: The same comments regarding mismatch apply as for the loss factor itself.

Efficiency (of a two-port, η): the ratio of output delivered power to input delivered power, $\eta \equiv p_{out}^{del} / p_{in}^{del}$. [6, p. 49], [7, p. 36] For matched (reflectionless) conditions, the efficiency is equal to the available power ratio and to the inverse of the loss factor, $\eta = \alpha = 1/L$.

Equivalent physical temperature: the physical temperature (T_{phys}) of a passive termination that would produce the observed noise temperature; related to the noise temperature T_n by $kT_n = \dfrac{hf}{e^{hf/kT_{phys}} - 1}$.

Equivalent blackbody temperature: the physical temperature (T_{bb}) of an ideal black body that would produce the observed brightness; related to the brightness B_f by $B_f = \dfrac{2}{\lambda^2}\left(\dfrac{hf}{e^{hf/kT_{bb}} - 1}\right)$.

ADOPTED DEFINITIONS

Radiance (*L*): the radiated power per unit solid angle per unit area normal to the direction defined by the solid angle Ω,

$$L = \frac{dP}{d\Omega dA_\perp}, \text{ where } dA_\perp = \cos\theta dA .$$

Brightness: the radiance, the radiated power per unit solid angle per unit area normal to the direction defined by the solid angle Ω.
Note: Brightness is often used for Spectral brightness [IEEE, Krause]. The meaning is usually clear from the context.

Spectral radiance (L_f): the *radiance* per unit frequency interval, $L_f \equiv \dfrac{dL}{df}$.

Spectral brightness: the brightness per unit frequency, the spectral radiance.

Blackbody load: microwave load with characteristics very close to those of a perfect black body within a certain frequency range.

Emissivity (of a surface): the spectral radiance of the surface relative to the spectral radiance of an ideal black body radiator at the same temperature, $e(\theta,\phi) = \dfrac{L(T,\theta,\phi)}{L_{BB}(T)}$.

Radiometer: a very sensitive receiver, typically with an antenna input, that is used to measure radiated electromagnetic power.

System equation (of a microwave radiometer): equation relating the primary measurand of the radiometer, *e.g.*, the brightness temperature, to subsidiary measurands, such as powers, and to calibration quantities, such as standard values.

Half-power bandwidth (B_{3dB}): the width at which the power response is half the maximum value; also called the 3-dB width.

Boresight: the beam-maximum direction of a highly directive antenna. [3]

Directivity (of an antenna in a given direction): The ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions. [3]
Notes: The average radiation intensity is equal to the total power radiated by the antenna divided by 4π. If the direction is not specified, the direction of maximum radiation is implied.

Antenna gain: The ratio of the radiation intensity in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically. [4]
Note: This is equivalent to the commonly used definition that the antenna gain is the product of the *directivity* and the ohmic efficiency (sometimes called the ohmic loss factor).

Calibration: set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system and the corresponding values realized by standards. The result of a calibration permits either the assignment of values of measurands to the indications or the determination of corrections with respect to indications. [1]

End-to-end calibration (of a radiometer): calibration of entire radiometer system as a unit, achieved by observing the values of output quantities (voltage, power, …) for known values of incident radiance at the antenna aperture.

External calibration (of a radiometer): calibration method that applies reference signals from targets that lie outside the radiometer. In the case that these targets illuminate the antenna of the radiometer, and end-to-end calibration is obtained.

Internal calibration (of a radiometer): calibration of a radiometer by connecting embedded reference noise sources to the receiver chain; also called injection calibration.

Validation: the process of assessing, by independent means, the quality of the data products derived from the system inputs.
Note: In a remote-sensing application, validation is commonly performed by comparing the value of a higher order data product (*e.g.* sea surface temperature) inferred from the measured value of the brightness temperature, with a direct measurement of that quantity.

Verification: validation.

Traceability: property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties. [1]

True value: value consistent with the definition of a given particular quantity. [1,2]
Notes: This is a value that would be obtained by a perfect measurement. True values are by nature indeterminate.

Experimental standard deviation: for a series of n measurements of the same measurand, the quantity s characterizing the dispersion of the results and given by the formula

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

x_i being the result of the ith measurement and $\bar{x}$ being the arithmetic mean of the n results considered. [1,2]
Notes: Considering the series of n values as a sample of a distribution, $\bar{x}$ is an unbiased estimate of the mean μ, and s^2 is an unbiased estimate of the variance σ^2 of that distribution. The expression $s/\sqrt{n}$ is an estimate of the standard deviation of the distribution of $\bar{x}$ and is called the experimental standard deviation of the mean.

Error: result of a measurement minus a true value of the measurand. [1,2]
Notes: Since a true value cannot be determined, in practice a conventional true value is used. When it is necessary to distinguish "error" from "relative error," the former is sometimes called the "absolute error."

Relative error: error of measurement divided by a (conventional) true value of the measurand. [1,2]

Random error: result of a measurement minus the mean that would result from an infinite number of measurements of the same measurand carried out under repeatability conditions. [1,2]
Notes: Random error is equal to error minus systematic error. Because only a finite number of measurements can be made, it is possible to determine only an estimate of random error.

Systematic error: mean that would result from an infinite number of measurements of the same measurand carried out under repeatability conditions minus a true value of the measurand. [1,2]
Notes: Systematic error is equal to error minus random error. Like true value, systematic error and its causes cannot be completely known. For a measuring instrument, see "bias."

Error budget: usually used to mean uncertainty budget.

Uncertainty of measurement: parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand; also a measure of the possible error in the estimated value of the measurand as provided by the result of a measurement. See [2] or [5] for details.

Relative uncertainty: uncertainty of the measurand divided by the nominal value of that measurand.
Note: not defined in [1] or [2], but an obvious extension.

Type-A uncertainty: an uncertainty or component of uncertainty that is evaluated by the statistical analysis of series of observations. (adapted from [2])

Type-B uncertainty: an uncertainty or component of uncertainty that is evaluated by means other than the statistical analysis of series of observations. (adapted from [2])

Uncertainty budget: a detailed tabulation of the sources of uncertainty and their respective contributions to the standard uncertainty in the measurand of interest; sometimes referred to as "error budget."

Accuracy: closeness of the agreement between the result of a measurement and a true value of the measurand. Since the true value cannot be determined exactly, the measured or calculated value of highest available accuracy is typically taken to be the true value. If a value of higher accuracy than the value in question is not available, then the accuracy cannot be assigned a meaningful quantitative value.

Resolution: smallest difference between values of a measurand that can be meaningfully distinguished. (modified from [1])

Sensitivity: change in the response of a measuring instrument divided by the corresponding change in the stimulus. [1,3]

Radiometric (or radiometer) resolution: the smallest change in input brightness temperature or radiance that can be detected in the system output. The radiometric resolution can be measured by computing the Type-A uncertainty, *e.g.*, the standard deviation of the mean of a number of measurements of the same quantity made over a short enough time period that the system can be considered to be stable. It is also often estimated by using the equation $\Delta T_{\min} = \frac{T_{Sys}}{\sqrt{B_{pre}\tau}}$, or the variant of this equation that is appropriate for the particular radiometer in question.

Radiometric sensitivity: often used to mean radiometric resolution, but this use is discouraged in light of the definition of sensitivity.

Limiting radiometric resolution: the radiometric resolution evaluated for input brightness temperature of zero.

Absolute accuracy: commonly used to denote the total uncertainty excluding the radiometric resolution. When the radiometric resolution is evaluated by statistical means (type-A uncertainty) and all other uncertainties are estimated by other means, the absolute accuracy corresponds to the total type-B uncertainty.

Stability: ability of a measuring instrument to maintain constant its metrological characteristics with time. [1]
Notes: Stability may be quantified in several ways, for example: in terms of the time over which a metrological characteristic changes by a stated amount, or in terms of the change in a characteristic over a stated time.

Reproducibility (of results of measurements): closeness of the agreement between the results of measurements of the same measurand carried out under changed conditions of mesurement. [1]
Notes: A valid statement of reproducibility requires specification of the conditions changed. Reproducibility may be expressed quantitatively in terms of the dispersion characteristics of the results.

Repeatability (of results of measurements): closeness of the agreeement between the results of successive measurements of the same measurand carried out under the same conditions of measurement. [1]
Notes: Repeatability conditions include: the same measurement procedure, the same observer, the same measuring instrument used under the same conditions, the same location, and repetition over a short period of time. Repeatability may be expressed quantitatively in terms of the dispersion characteristics of the results.

Bias (of a measuring instrument): systematic error of the indication of a measuring instrument . [1]
Note: The bias of a measuring instrument is normally estimated by averaging the error of indication over an appropriate number of repeated measurements.

Drift: slow change of a metrological characteristic of a measuring instrument. [1]

Response time: time interval between the instant when a stimulus is subjected to a specified abrupt change and the instant when the response reaches and remains within specified limits around its final steady value. [1]

REFERENCES

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[3] IEEE Standard Dictionary of Electrical and Electronics Terms, 4th ed., ANSI/IEEE Std 100-1988.

[4] IEEE Standard 145-1993 (Standard Definitions of Terms for Antennas).

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