Calibration of a power sensor at a frequency of 18 GHz

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This Example is taken from EA 4/02. See EA 4/02 Section S6 for more details.

The measurement involves the calibration of an unknown power sensor with respect to a calibrated power sensor used as a reference by substitution on a stable transfer standard of known small reflection coefficient. The measurement is made in terms of calibration factor, which is defined as the ratio of incident power at the reference frequency of 50 MHz to the incident power at the calibration frequency under the condition that both incident powers give equal power sensor response. At each frequency one determines the (indicated) ratio of the power for the sensor to be calibrated respectively the reference sensor and the internal sensor that forms part of the transfer standard, using a dual power meter with ratio facility.

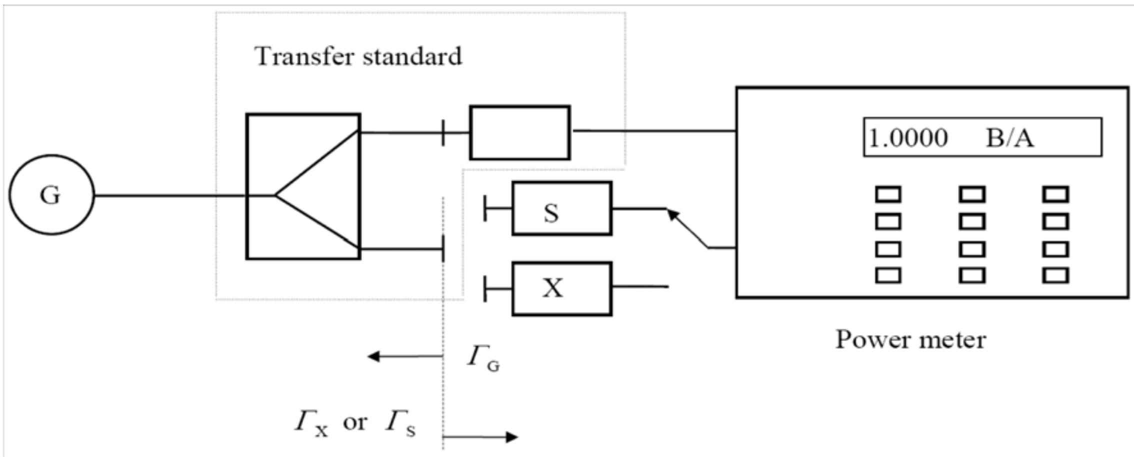

Figure 1: Schematic of the measuring system

Model Equation:

$$K_X = (K_S + \delta K_D) * (M_{Sr} * M_{Xc}) / (M_{Sc} * M_{Xr}) * p_{Cr} * p_{Cc} * p$$

List of Quantities:

Quantity	Unit	Definition
K_X		unknown calibration factor
K_S		calibration factor of the reference power sensor
δK_D		drift of calibration factor of the reference power sensor since its last calibration
M_{Sr}		mismatch factor of the reference power sensor at the reference frequency of 50 MHz
M_{Xc}		mismatch factor of the unknown power sensor at the calibration frequency of 18 GHz
M_{Sc}		mismatch factor of the reference power sensor at the calibration frequency of 18 GHz
M_{Xr}		mismatch factor of the unknown power sensor at the reference frequency of 50 MHz
p_{Cr}		correction of the observed ratio for non-linearity and limited resolution of the power meter at power ratio level of the reference frequency
p_{Cc}		correction of the observed ratio for non-linearity and limited resolution of the power meter at power ratio level of the calibration frequency

Quantity	Unit	Definition
p		$=p_{iX}/p_{iS,}$ ratio of the output power ratios indicated at the power transfer system in realizing equal response for the unknown and the reference power sensor

K_S:
Type B normal distribution
Value: 0.957
Expanded Uncertainty: 0.011
Coverage Factor: 2

REFERENCE SENSOR: The reference sensor was calibrated six months before the calibration of the unknown power sensor. The value of the calibration factor, given in the calibration certificate, is (95,7±1,1)% (coverage factor k=2), which also may be expressed as 0,957±0,011

δK_D:
Type B rectangular distribution
Value: -0.001
Halfwidth of Limits: 0.002

DRIFT OF THE STANDARD: The drift of the calibration factor of the reference standard is estimated from annual calibrations to be -0,002 per year with deviations within ±0,004. From these values the drift of the reference sensor which has been calibrated half a year ago is estimated to be -0.001 with deviations within ±0,002.

M_{Sr}:
Type B U-shaped distribution
Value: 1.0
Halfwidth of Limits: 0.0008

MISMATCH FACTORS: As the transfer standard system is not perfectly matched and the phase of the reflection coefficients of the transfer standard, the unknown and the standard power sensors are not known, there will be an uncertainty due to mismatch for each sensor at the reference frequency and at the calibration frequency. The probability distribution of the contribution is U-shaped and the limits are calculated from the magnitude of the reflection coefficients (see EAL-R2-S1:S6.8).

M_{Xc}:
Type B U-shaped distribution
Value: 1.0
Halfwidth of Limits: 0.0168

M_{Sc}:
Type B U-shaped distribution
Value: 1.0
Halfwidth of Limits: 0.014

M_{Xr}:
Type B U-shaped distribution
Value: 1.0
Halfwidth of Limits: 0.0008

p_{Cr}:
Type B normal distribution
Value: 1.0
Expanded Uncertainty: 0.00142
Coverage Factor: 1.0

LINEARITY AND RESOLUTION OF THE POWER METER: The expanded uncertainty of 0,002 (coverage factor k = 2.0) is assigned to the power meter readings at the power ratio level of the reference frequency and of 0,0002 (coverage factor k = 2.0) at the power ratio level of calibration frequency due to non-linearity of the power meter used. These values have been obtained from previous measurements. Since the same power meter has been used to observe both p_{iX} and p_{iS} the uncertainty contributions at the reference as well at the calibration frequency are correlated. Because power ratios at both frequencies are considered, the effect of the correlations is to reduce the uncertainty. Thus only the relative difference in the readings due to systematic effects must be taken into account resulting in a standard uncertainty of 0,00142 associated with the correction factor p_{Cr} and 0,000142 with the correction factor p_{Cc}.

p_{Cc}: Type B normal distribution
Value: 1.0
Expanded Uncertainty: 0.000142
Coverage Factor: 1.0

p: Type A
Method of observation: Direct
Number of observations: 3

No.	Observation
1	0.9772
2	0.9671
3	0.9836

Arithmetic Mean: 0.975967
Standard Deviation: $8.3\cdot10^{-3}$
Standard Uncertainty: $4.803\cdot10^{-3}$
Degrees of Freedom: 2

MEASUREMENTS: Three separate readings are made which involve disconnection and reconnection of both the reference sensor and the sensor to be calibrated on the transfer standard to take connection repeatability into account. The poer ratio p is precalculated from the powermeter readings (see EAL-R2-S1:S6.10).

Uncertainty Budgets:

K_X: unknown calibration factor

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
K_S	0.957000	$5.500\cdot10^{-3}$	normal	0.98	$5.4\cdot10^{-3}$	11.0 %
δK_D	$-1.000\cdot10^{-3}$	$1.155\cdot10^{-3}$	rectangular	0.98	$1.1\cdot10^{-3}$	0.5 %
M_{Sr}	1.0000000	$565.7\cdot10^{-6}$	U-distr.	0.93	$530\cdot10^{-6}$	0.1 %
M_{Xc}	1.00000	0.01188	U-distr.	0.93	0.011	46.9 %
M_{Sc}	1.000000	$9.899\cdot10^{-3}$	U-distr.	-0.93	$-9.2\cdot10^{-3}$	32.6 %
M_{Xr}	1.0000000	$565.7\cdot10^{-6}$	U-distr.	-0.93	$-530\cdot10^{-6}$	0.1 %
p_{Cr}	1.000000	$1.420\cdot10^{-3}$	normal	0.93	$1.3\cdot10^{-3}$	0.7 %
p_{Cc}	1.0000000	$142.0\cdot10^{-6}$	normal	0.93	$130\cdot10^{-6}$	0.0 %
p	0.975967	$4.803\cdot10^{-3}$	normal	0.96	$4.6\cdot10^{-3}$	8.1 %
K_X	0.93302	0.01618				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
K_X	0.933	0.032	2.00	95% (t-table 95.45%)