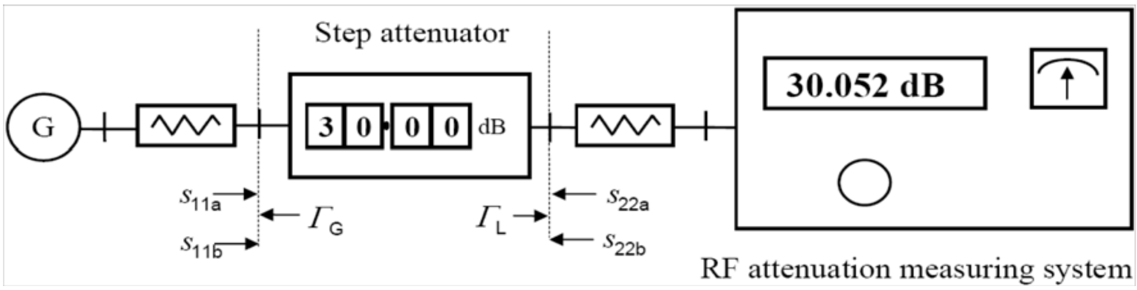
Calibration of a coaxial step attenuator at a setting of 30 dB (incremental loss)

Author: EA

This Example is taken from EA 4/02. See EA 4/02 Section S7 for more details.

The measurement involves the calibration of a coaxial step attenuator at 10 GHz using an attenuation measuring system containing a calibrated step attenuator which acts as the attenuation reference. The method of measurement involves the determination of the attenuation between a matched source and matched load. In this case the unknown attenuator can be switched between a setting of 0 dB and 30 dB and it is this change (called incremental loss) that is determined in the calibration process. The attenuation measuring system has a digital readout and an analogue null detector which is used to indicate the balance condition.



Model Equation:

$$L_X = L_S + \delta L_S + \delta L_D + \delta L_M + \delta L_K + \delta L_{ib} - \delta L_{ia} + \delta L_{0b} - \delta L_{0a}$$

List of Quantities:

Quantity	Unit	Definition
L_X	dB	attenuation of the attenuator to becalibrated
L_S	dB	$=L_{ib} - L_{ia}$ attenuation difference of reference attenuator at 30 dB and 0 dB
δL_S	dB	correction obtained from the calibration of the reference attentuator
δL_D	dB	change of the attenuation of the reference attenuator since its last calibration due to drift
δL_M	dB	correction due to mismatch loss
δL_K	dB	correction for leakage signals between input and output of the attenuator to be calibrated due to imperfect isolation
δL_{ib}	dB	correction due to the limited resolution of the reference detector at 30 dB
δL_{ia}	dB	correction due to the limited resolution of the reference detector at 0 dB
δL_{0b}	dB	correction due to the limited resolution of the null detector at 30 dB
δL_{0a}	dB	correction due to the limited resolution of the null detector at 0 dB

L_S:

Type A
Method of observation: Direct
Number of observations: 4

No.	Observation
1	30.033 dB
2	30.058 dB
3	30.018 dB
4	30.052 dB

Arithmetic Mean: 30.040250 dB
Standard Deviation: 0.018 dB
Standard Uncertainty: $9.132 \cdot 10^{-3}$ dB
Degrees of Freedom: 3

MEASUREMENTS: Four observations are made of the incremental loss of the attenuator to be calibrated between settings of 0 dB and 30 dB. (see EAL-R2-S1:S7.11)

δL_S:

Type B normal distribution
Value: 0.003 dB
Expanded Uncertainty: 0.005 dB
Coverage Factor: 2

REFERENCE ATTENUATOR: The calibration certificate for the reference attenuator gives a value of attenuation for the 30,000 dB setting at 10 GHz of 30,003 dB with an associated expanded uncertainty of 0,005 dB (coverage factor k=2). The correction of +0,003 dB with the associated expanded uncertainty of 0,005 dB (coverage factor k=2) is considered to be valid for attenuation settings of the reference attenuator which differ not more ±0,1 dB from the calibrated setting of 30,000 dB.

δL_D:

Type B rectangular distribution
Value: 0.0 dB
Halfwidth of Limits: 0.002 dB

DRIFT OF THE REFERENCE: The drift of the attenuation of the reference attenuator is estimated from its calibration history to be zero with limits ±0,002 dB.

δL_M:

Type B U-shaped distribution
Value: 0.0 dB
Halfwidth of Limits: 0.0283 dB

MISMATCH LOSS: (see EAL-R2-S1:S7.6)

δL_K:

Type B rectangular distribution
Value: 0.0 dB
Halfwidth of Limits: 0.003 dB

LEAKAGE CORRECTION: Leakage signals through the attenuator to be calibrated have been estimated from the measurements at 0 dB setting to be at least 100 dB below the measurement signal. The correction for leakage signals is estimated from these findings to be within ±0,003 dB at the 30 dB setting.

δL_{ib}:

Type B rectangular distribution
Value: 0.0 dB
Halfwidth of Limits: 0.0005 dB

RESOLUTION OF THE REFERENCE ATTENUATOR SETTING: The digital readout of the reference attenuator has a resolution of 0,001 dB from which the correction for resolution is estimated to be within ±0.0005 dB.

δL_{ia}: Type B rectangular distribution
Value: 0.0 dB
Halfwidth of Limits: 0.0005 dB

RESOLUTION OF THE REFERENCE ATTENUATOR SETTING: The digital readout of the reference attenuator has a resolution of 0,001 dB from which the correction for resolution is estimated to be within ±0.0005 dB.

δL_{0b}: Type B normal distribution
Value: 0.0 dB
Expanded Uncertainty: 0.002 dB
Coverage Factor: 1.0

RESOLUTION OF THE NULL DETECTOR: The detector resolution was determined from a previous evaluation to have a standard deviation of 0,002 dB at each reading with assumed normal probability distribution.

δL_{0a}: Type B normal distribution
Value: 0.0 dB
Expanded Uncertainty: 0.002 dB
Coverage Factor: 1

RESOLUTION OF THE NULL DETECTOR: The detector resolution was determined from a previous evaluation to have a standard deviation of 0,002 dB at each reading with assumed normal probability distribution.

Uncertainty Budgets:

L_X: **attenuation of the attenuator to becalibrated**

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
L_S	30.040250 dB	$9.132\cdot10^{-3}$ dB	normal	1.0	$9.1\cdot10^{-3}$ dB	16.6 %
δL_S	$3.000\cdot10^{-3}$ dB	$2.500\cdot10^{-3}$ dB	normal	1.0	$2.5\cdot10^{-3}$ dB	1.2 %
δL_D	0.0 dB	$1.155\cdot10^{-3}$ dB	rectangular	1.0	$1.2\cdot10^{-3}$ dB	0.3 %
δL_M	0.0 dB	0.02001 dB	U-distr.	1.0	0.020 dB	79.7 %
δL_K	0.0 dB	$1.732\cdot10^{-3}$ dB	rectangular	1.0	$1.7\cdot10^{-3}$ dB	0.6 %
δL_{ib}	0.0 dB	$288.7\cdot10^{-6}$ dB	rectangular	1.0	$290\cdot10^{-6}$ dB	0.0 %
δL_{ia}	0.0 dB	$288.7\cdot10^{-6}$ dB	rectangular	-1.0	$-290\cdot10^{-6}$ dB	0.0 %
δL_{0b}	0.0 dB	$2.000\cdot10^{-3}$ dB	normal	1.0	$2.0\cdot10^{-3}$ dB	0.8 %
δL_{0a}	0.0 dB	$2.000\cdot10^{-3}$ dB	normal	-1.0	$-2.0\cdot10^{-3}$ dB	0.8 %
L_X	30.04325 dB	0.02242 dB				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
L_X	30.043 dB	0.045 dB	2.00	95% (t-table 95.45%)