EURAMET Project 1129: Characterisation of RF diode power sensors v01

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Abstract

This report represents the results of an interlaboratory measurement comparison involving RF diode power sensors. Two national metrology institutes participated in this exercise. The measurands of interest were the calibration factors at 4 different power levels as well as the linearity and the complex input reflection coefficient at different power levels. Today different types of diode power sensors become increasingly important for various applications and set new demands for calibration laboratories. To our knowledge no comparisons have been conducted so far for such devices.

Contents

1. Introduction

Today different types of RF diode power sensors become increasingly important for various applications and set new demands for calibration laboratories. Such sensors offer an increased dynamic range compared to thermal sensors but they require internal linearity corrections. Furthermore properties like linearity and input reflection are frequency dependent. Therefore a calibration system for diode power sensors is more complex compared to a system for thermal power sensors. This first bilateral comparison offers the participants the possibility to verify their measurement procedures and it provides a possibility to find and fix errors.

2. Participants and Schedule

Table 1 lists the participants in this bilateral interlaboratory comparison. Pilot duties were shared among the two national metrology institutes, SP and METAS. SP provided the travelling standard, coordinated the measurements, performed regular control measurements to monitor the stability of the device and analyzed the data whereas METAS acted as coordinator of the Euramet project and wrote this report.

Acronym	Laboratory
SP	Technical Research Institute of Sweden Borås, Sweden contact: Klas Yhland klas.yhland@sp.se
METAS	Federal Office of Metrology Bern-Wabern, Switzerland contact: Jürg Furrer e-mail: juerg.furrer@metas.ch

Table 1: Participants and contacts of the comparison

Table 2 shows the sequence of measurements done by the participants. The last column is the date of measurement in days with respect to the first measurement done by SP. In February 2009, SP informs that their linearity measurements are incorrect due to too high harmonics at the signal generator output and requests to repeat them after the METAS measurements. In October 2009, SP requested to repeat the linearity measurements again, because they found a new algorithm [6] to reduce their uncertainty considerably.

Laboratory	Type of Work	Result	End of measurement	Time line (days)
SP	Measurement 1		31.12.2008	0
METAS	Measurement	Certificate of calibration	2.4.2009	92
SP	Measurement 2	Certificate of calibration 1	10.7.2009	191
SP	Cross Check	See § 3.1 and apendix C	10.7.2009	
SP	Measurement 3	Certificate of calibration 2	19.11.2009	323
SP	Cross Check	See § 3.1 and apendix C	19.11.2009	

Table 2: Sequence of measurements done by participants

3. Travelling Standard and Measurements

The travelling standard was a diode power sensor type NRV-Z1, sn100038 from Rohde & Schwarz with a type N-connector and a frequency range from 10 MHz to 18 GHz and a dynamic range from -67 dBm to + 13 dBm. Included was a power meter, type NRVS, sn100087 from Rohde & Schwarz for the readout of the sensor.

The measurands of this comparison were:

- Calibration factor (relative to the calibration factor at 50 MHz) at the 4 power levels 1 µW, 10 µW, 100 µW and 1 mW (-30 dBm, -20 dBm, -10 dBm and 0 dBm), expressed in W/W. Test frequencies (25): 50, 75, 100, 200, 300, 500, 750 MHz, 1 GHz, 2 GHz … 17 GHz, 18 GHz.

  The calibration factor CF (relative to the calibration factor at 50 MHz) defined as:

  $$CF(f)_{50\,MHz}\ (W/W) = \frac{P_{incident}(f = 50\,MHz)}{P_{incident}(f)} \qquad \text{for the same instrument indication}$$

- Complex input reflection coefficient at the same frequencies at power levels of 10 µW and 1 mW (-20 dBm and 0 dBm), expressed in real and imaginary parts.

- Linearity, related to the value at 10 µW (-20 dBm), in the input power range of 1 µW to 20 mW (- 60 dBm to + 10 dBm in 5 dB steps and + 13 dBm), expressed as a deviation of linearity in dB at the test frequencies of 50 MHz and 1 GHz.

  The Linearity Lin is defined as a level dependent calibration factor, related to the calibration factor at 10 µW (-20 dBm):

  $$Lin(dB) = 10 \cdot \log \frac{CF(P_X)}{CF(10\mu W)}$$

Documentation of the results:

The participants were asked to document their results in the form of a calibration certificate and a GUM [1] compliant measurement uncertainty budget.

Tables and figures of the electronic data submitted by the participants can be found in appendix A. Additional information of the participants, as uncertainty budgets, are shown in appendix B.

3.1 Behaviour of the Travelling Standard

Control and cross check measurements to monitor the stability of the travelling standard were performed by SP two times according to Table 2. The results showed no drift of the device under test (DUT) and therefore no corrections were necessary. Cross check results can be found in appendix C.

4. Data Analysis

The analysis of the data in this report is restricted to the results submitted by the participants in the form of certificates of calibration. These values are listed in appendix A.

The Normalized Error (En) is calculated as a measure of the agreement between the results of the participants. It is defined as the difference between the results normalized with respect to the expanded uncertainty of this difference.
|En| < 1 indicates an agreement between the participants at the 95 % level.

4.1 Results

4.1.1 Normalized Calibration Factor

The results for the calibration factor are shown for each power level (0 dBm, -10 dBm, -20 dBm and -30 dBm) in two graphs and in one table. The following quantities are shown:

CF_{ME}: Calibration Factor from METAS
CF_{SP}: Calibration Factor from SP
$u(CF_{ME})$: standard uncertainty in CF_{ME}
$u(CF_{SP})$: standard uncertainty in CF_{SP}

$$\text{Error} = CF_{SP} - CF_{ME}$$

$$U(\text{Error}) = 2 \cdot \sqrt{u(CF_{ME})^2 + u(CF_{SP})^2}$$

$$En = \text{Error}/U(\text{Error})$$

4.1.2 Normalized Calibration Factor CF at 0 dBm

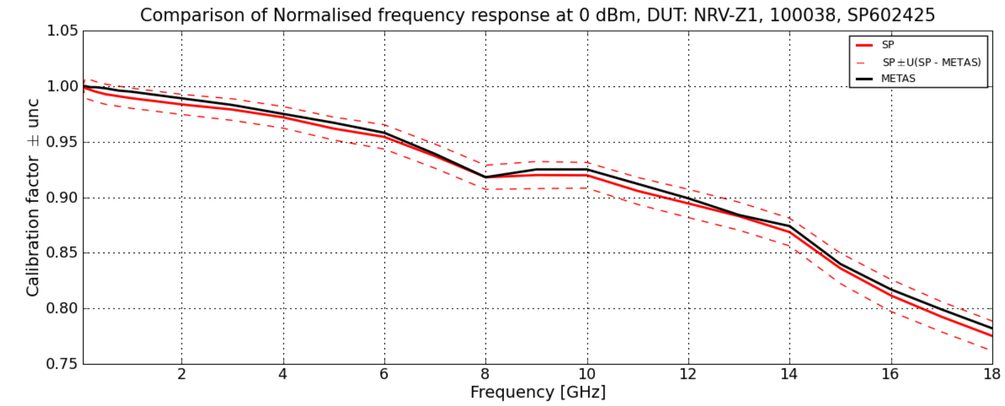

Figure 1:

Calibration Factor ± U(Error) at 0 dBm

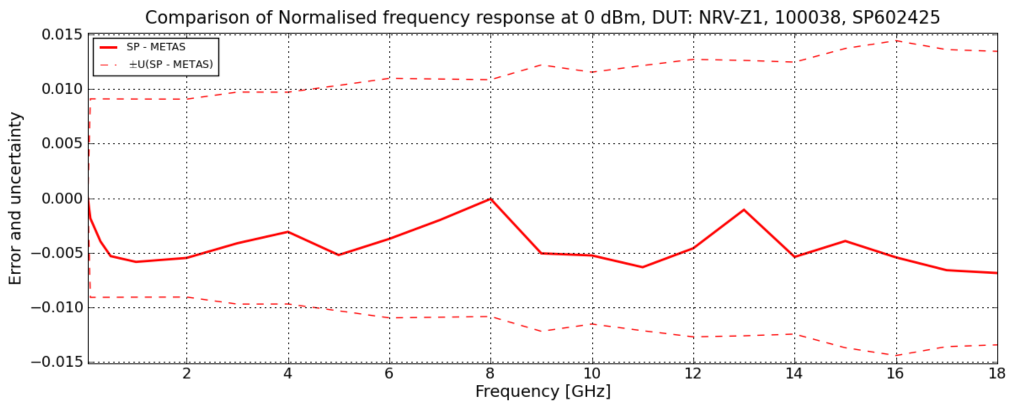

Figure 2:

Error ± U(Error) at 0 dBm

Frequency MHz	En	Error	U(Error)	CF_{ME}	CF_{SP}	$u(CF_{ME})$	$u(CF_{SP})$
50	0	0	0	1	1	0	0
100	-0.20	-0.002	0.009	1.000	0.9981	0.0030	0.0034
300	-0.44	-0.004	0.009	0.999	0.9950	0.0030	0.0034
500	-0.59	-0.005	0.009	0.998	0.9927	0.0030	0.0034
1000	-0.64	-0.006	0.009	0.995	0.9892	0.0030	0.0034
2000	-0.60	-0.005	0.009	0.989	0.9835	0.0030	0.0034
3000	-0.43	-0.004	0.010	0.983	0.9789	0.0030	0.0038
4000	-0.32	-0.003	0.010	0.975	0.9719	0.0030	0.0038
5000	-0.51	-0.005	0.010	0.967	0.9618	0.0035	0.0038
6000	-0.34	-0.004	0.011	0.958	0.9543	0.0035	0.0042
7000	-0.18	-0.002	0.011	0.939	0.9370	0.0035	0.0042
8000	-0.01	0.000	0.011	0.918	0.9179	0.0035	0.0041
9000	-0.42	-0.005	0.012	0.925	0.9199	0.0040	0.0046
10000	-0.46	-0.005	0.012	0.925	0.9197	0.0035	0.0046
11000	-0.52	-0.006	0.012	0.912	0.9057	0.0035	0.0050
12000	-0.36	-0.005	0.013	0.899	0.8944	0.0040	0.0049
13000	-0.09	-0.001	0.013	0.884	0.8829	0.0040	0.0049
14000	-0.43	-0.005	0.013	0.874	0.8686	0.0040	0.0048
15000	-0.29	-0.004	0.014	0.840	0.836	0.0045	0.0052
16000	-0.38	-0.005	0.014	0.817	0.812	0.0050	0.0052
17000	-0.49	-0.007	0.014	0.799	0.792	0.0045	0.0051
18000	-0.51	-0.007	0.013	0.782	0.775	0.0045	0.0050

Table 3:

Normalized Calibration Factor at 0 dBm

4.1.3 Normalized Calibration Factor CF at -10 dBm

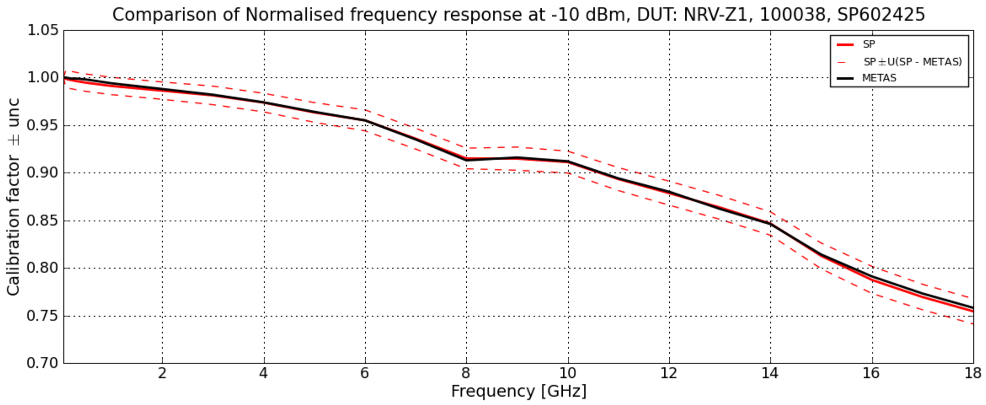

Figure 3:

Calibration Factor ± U(Error) at -10 dBm

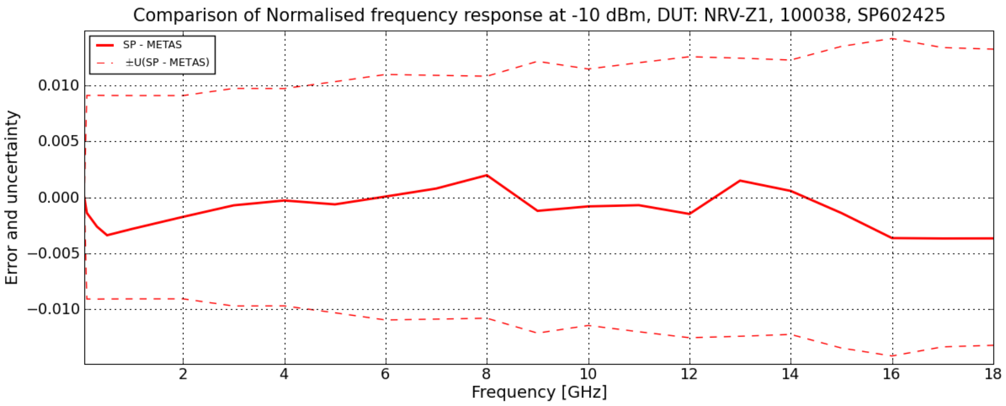

Figure 4:

Error ± U(Error) at -10 dBm

Frequency MHz	En	Error	U(Error)	CF_{ME}	CF_{SP}	$u(CF_{ME})$	$u(CF_{SP})$
50	0	0	0	1	1	0	0
100	-0.15	-0.001	0.009	1.000	0.9986	0.0030	0.0034
300	-0.29	-0.003	0.009	0.999	0.9964	0.0030	0.0034
500	-0.37	-0.003	0.009	0.998	0.9946	0.0030	0.0034
1000	-0.31	-0.003	0.009	0.994	0.9912	0.0030	0.0034
2000	-0.19	-0.002	0.009	0.988	0.9862	0.0030	0.0034
3000	-0.08	-0.001	0.010	0.982	0.9813	0.0030	0.0038
4000	-0.03	0.000	0.010	0.974	0.9737	0.0030	0.0038
5000	-0.06	-0.001	0.010	0.964	0.9634	0.0035	0.0038
6000	0.01	0.000	0.011	0.955	0.9551	0.0035	0.0042
7000	0.07	0.001	0.011	0.935	0.9358	0.0035	0.0042
8000	0.18	0.002	0.011	0.913	0.9150	0.0035	0.0041
9000	-0.10	-0.001	0.012	0.916	0.9148	0.0040	0.0046
10000	-0.07	-0.001	0.012	0.912	0.9112	0.0035	0.0046
11000	-0.06	-0.001	0.012	0.894	0.8933	0.0035	0.0049
12000	-0.12	-0.002	0.013	0.880	0.8785	0.0040	0.0049
13000	0.12	0.002	0.013	0.862	0.8635	0.0040	0.0048
14000	0.05	0.001	0.012	0.846	0.8466	0.0040	0.0047
15000	-0.11	-0.001	0.014	0.814	0.813	0.0045	0.0050
16000	-0.26	-0.004	0.014	0.791	0.787	0.0050	0.0051
17000	-0.28	-0.004	0.013	0.773	0.7693	0.0045	0.0050
18000	-0.28	-0.004	0.013	0.758	0.7543	0.0045	0.0049

Table 4:

Normalized Calibration Factor at -10 dBm

4.1.4 Normalized Calibration Factor CF at -20 dBm

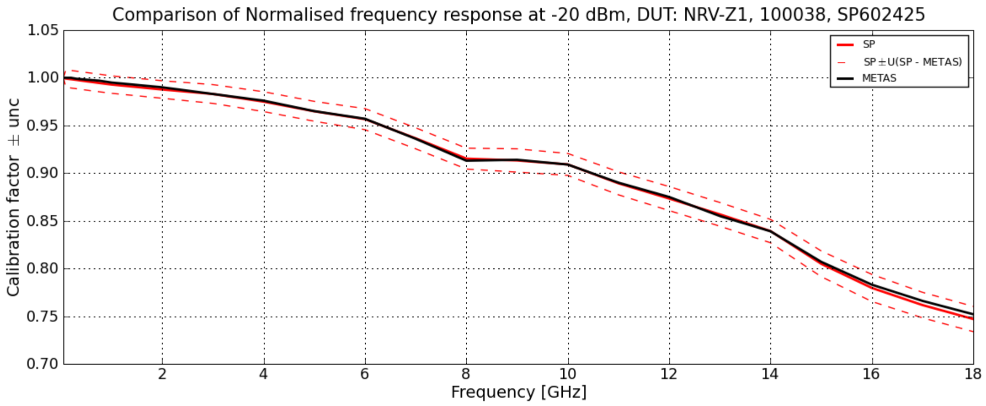

Figure 5:

Calibration Factor ± U(Error) at -20 dBm

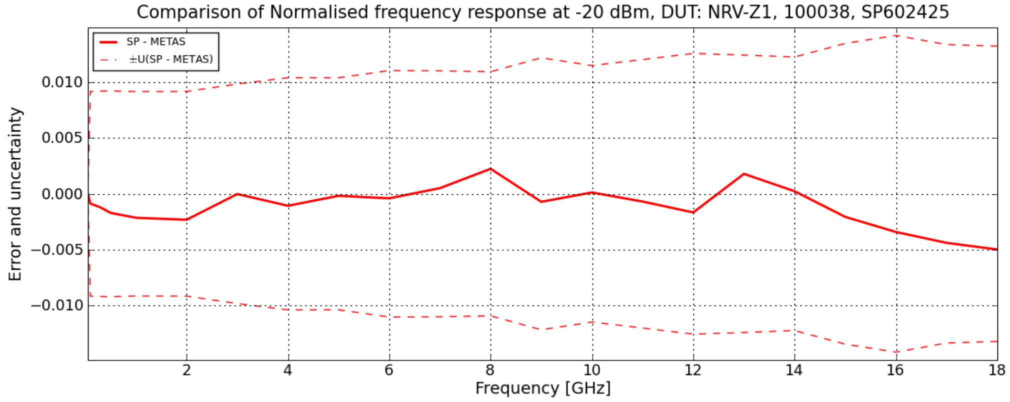

Figure 6:

Error ± U(Error) at -20 dBm

Frequency MHz	En	Error	U(Error)	CF_{ME}	CF_{SP}	$u(CF_{ME})$	$u(CF_{SP})$
50	0	0	0	1	1	0	0
100	-0.10	-0.001	0.009	1.000	0.9991	0.0030	0.0035
300	-0.13	-0.001	0.009	0.999	0.9978	0.0030	0.0035
500	-0.19	-0.002	0.009	0.998	0.9963	0.0030	0.0035
1000	-0.24	-0.002	0.009	0.995	0.9928	0.0030	0.0035
2000	-0.25	-0.002	0.009	0.990	0.9877	0.0030	0.0035
3000	0.00	0.000	0.010	0.983	0.9830	0.0030	0.0039
4000	-0.10	-0.001	0.010	0.976	0.9749	0.0035	0.0039
5000	-0.02	0.000	0.010	0.965	0.9648	0.0035	0.0039
6000	-0.04	0.000	0.011	0.957	0.9566	0.0035	0.0043
7000	0.05	0.001	0.011	0.936	0.9365	0.0035	0.0043
8000	0.21	0.002	0.011	0.913	0.9152	0.0035	0.0042
9000	-0.06	-0.001	0.012	0.914	0.9133	0.0040	0.0046
10000	0.01	0.000	0.012	0.909	0.9091	0.0035	0.0046
11000	-0.06	-0.001	0.012	0.890	0.8893	0.0035	0.0049
12000	-0.13	-0.002	0.013	0.875	0.8733	0.0040	0.0049
13000	0.14	0.002	0.012	0.855	0.8568	0.0040	0.0048
14000	0.02	0.000	0.012	0.839	0.8392	0.0040	0.0047
15000	-0.15	-0.002	0.014	0.807	0.805	0.0045	0.0050
16000	-0.24	-0.003	0.014	0.783	0.780	0.0050	0.0050
17000	-0.33	-0.004	0.013	0.766	0.7616	0.0045	0.0050
18000	-0.38	-0.005	0.013	0.752	0.7470	0.0045	0.0049

Table 5:

Normalized Calibration Factor at -20 dBm

4.1.5 Normalized Calibration Factor CF at -30 dBm

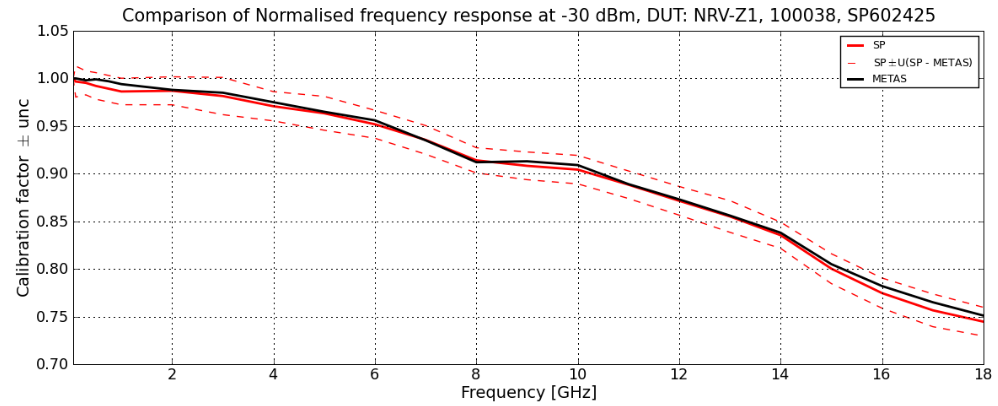

Figure 7:

Calibration Factor ± U(Error) at -30 dBm

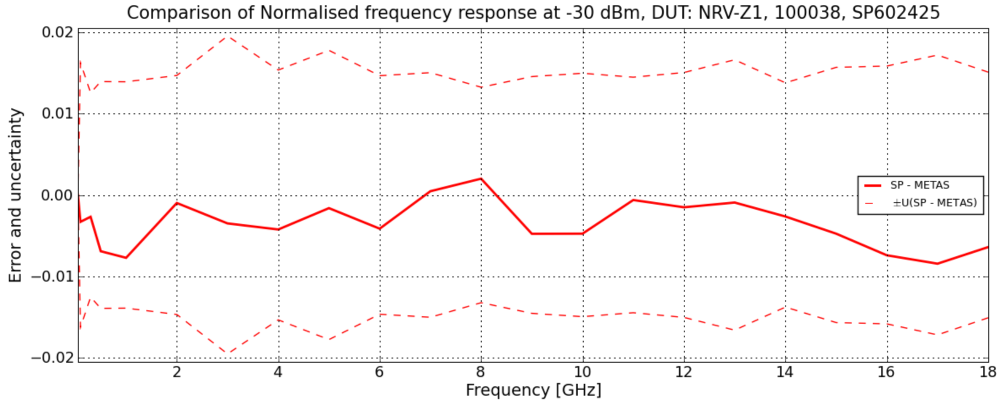

Figure 8:

Error ± U(Error) at -30 dBm

Frequency MHz	En	Error	U(Error)	CF_{ME}	CF_{SP}	$u(CF_{ME})$	$u(CF_{SP})$
50	0	0	0	1	1	0	0
100	-0.20	-0.003	0.016	1.000	0.9967	0.0065	0.0049
300	-0.21	-0.003	0.013	0.998	0.9953	0.0040	0.0048
500	-0.50	-0.007	0.014	0.999	0.9921	0.0050	0.0049
1000	-0.56	-0.008	0.014	0.994	0.9863	0.0050	0.0048
2000	-0.07	-0.001	0.015	0.988	0.9870	0.0055	0.0049
3000	-0.18	-0.004	0.020	0.985	0.982	0.0080	0.0056
4000	-0.28	-0.004	0.015	0.975	0.971	0.0055	0.0054
5000	-0.09	-0.002	0.018	0.965	0.9634	0.0075	0.0048
6000	-0.28	-0.004	0.015	0.956	0.9519	0.0055	0.0048
7000	0.03	0.001	0.015	0.935	0.935	0.0055	0.0051
8000	0.15	0.002	0.013	0.912	0.914	0.0040	0.0053
9000	-0.33	-0.005	0.015	0.913	0.908	0.0045	0.0057
10000	-0.32	-0.005	0.015	0.909	0.904	0.0050	0.0056
11000	-0.04	-0.001	0.015	0.889	0.888	0.0050	0.0052
12000	-0.10	-0.002	0.015	0.873	0.871	0.0050	0.0056
13000	-0.06	-0.001	0.017	0.856	0.855	0.0065	0.0052
14000	-0.19	-0.003	0.014	0.838	0.835	0.0045	0.0052
15000	-0.30	-0.005	0.016	0.805	0.800	0.0055	0.0056
16000	-0.47	-0.007	0.016	0.782	0.775	0.0055	0.0057
17000	-0.49	-0.008	0.017	0.765	0.757	0.0065	0.0056
18000	-0.42	-0.006	0.015	0.751	0.745	0.0055	0.0052

Table 6:

Normalized Calibration Factor at -30 dBm

4.1.6 Normalized Linearity

The results for linearity are shown for the two test frequencies (50 MHz and 1 GHz) in two graphs and in one table. The following quantities are shown:

Lin_{ME}: Normalized Linearity from METAS
Lin_{SP}: Normalized Linearity from SP *)
$u(Lin_{ME})$: standard uncertainty in Lin_{ME}
$u(Lin_{SP})$: standard uncertainty in Lin_{SP}

$$Error = Lin_{SP} - Lin_{ME}$$

$$U(Error) = 2 \cdot \sqrt{u(Lin_{ME})^2 + u(Lin_{SP})^2}$$

$$En = Error / U(Error)$$

*) Data from Certificate of Calibration MTkP900225-K08 MTkHF NRV-Z1 (19th Nov. 2009)

4.1.7 Normalized Linearity Lin at 50 MHz

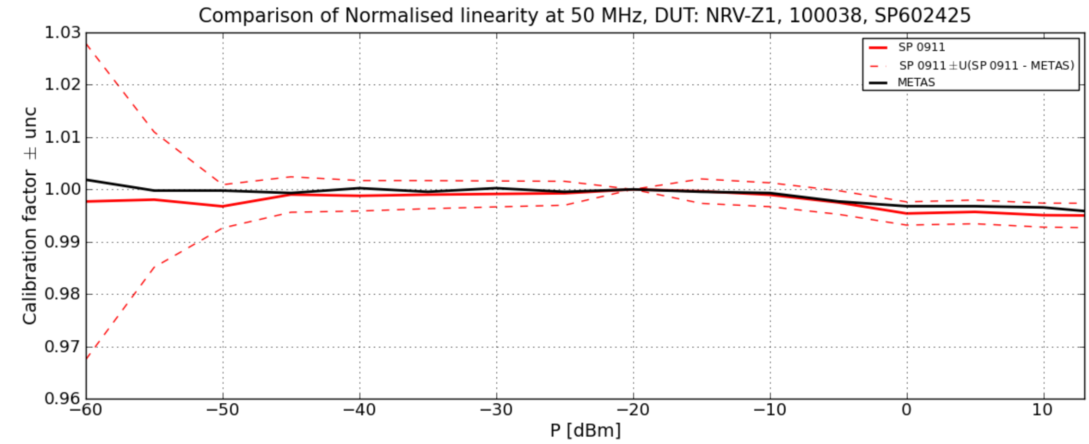

Figure 9: Normalized Linearity ± U(Error) at 50 MHz

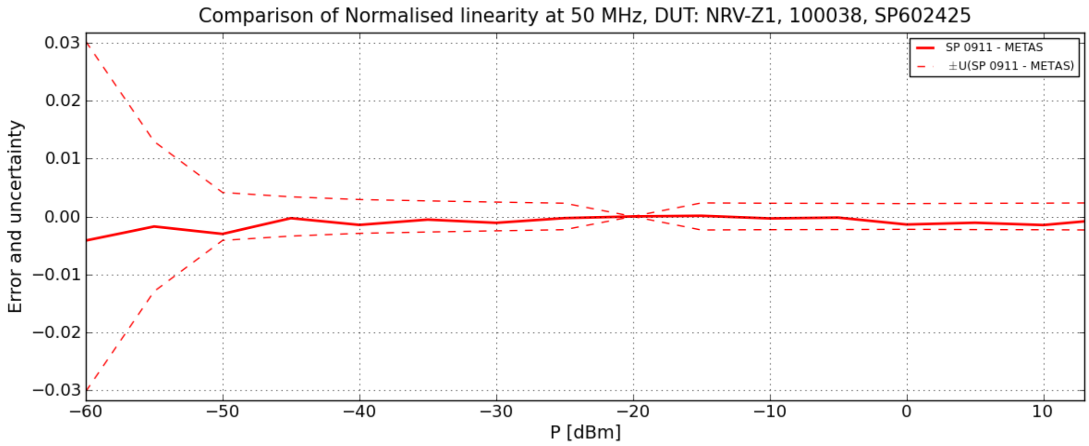

Figure 10: Error ± U(Error) at 50 MHz

Table 7: Normalized Linearity at 50 MHz

$P_{nominal}$ dBm	En	Error	U(Error)	Lin_{ME}	$u(Lin_{ME})$	Lin_{SP}	$u(Lin_{SP})$
-60	-0.14	-0.0042	0.0302	1.0018	0.0138	0.9977	0.0061
-55	-0.13	-0.0017	0.0129	0.9998	0.0058	0.9980	0.0030
-50	-0.73	-0.0030	0.0041	0.9998	0.0017	0.9968	0.0011
-45	-0.09	-0.0003	0.0034	0.9993	0.0015	0.9990	0.0008
-40	-0.50	-0.0015	0.0029	1.0002	0.0013	0.9988	0.0007
-35	-0.20	-0.0006	0.0027	0.9995	0.0012	0.9990	0.0007
-30	-0.45	-0.0011	0.0025	1.0002	0.0010	0.9991	0.0007
-25	-0.12	-0.0003	0.0023	0.9995	0.0009	0.9993	0.0007
-20	0.00	0.0000	0.0000	1.0000	0.0000	1.0000	0.0000
-15	0.05	0.0001	0.0023	0.9995	0.0009	0.9997	0.0007
-10	-0.15	-0.0003	0.0023	0.9993	0.0009	0.9990	0.0007
-5	-0.09	-0.0002	0.0023	0.9977	0.0009	0.9975	0.0007
0	-0.63	-0.0014	0.0022	0.9968	0.0009	0.9954	0.0006
5	-0.48	-0.0011	0.0023	0.9968	0.0009	0.9957	0.0007
10	-0.65	-0.0015	0.0023	0.9966	0.0009	0.9951	0.0007
13	-0.37	-0.0009	0.0023	0.9959	0.0009	0.9950	0.0007

4.1.8 Normalized Linearity Lin at 1 GHz

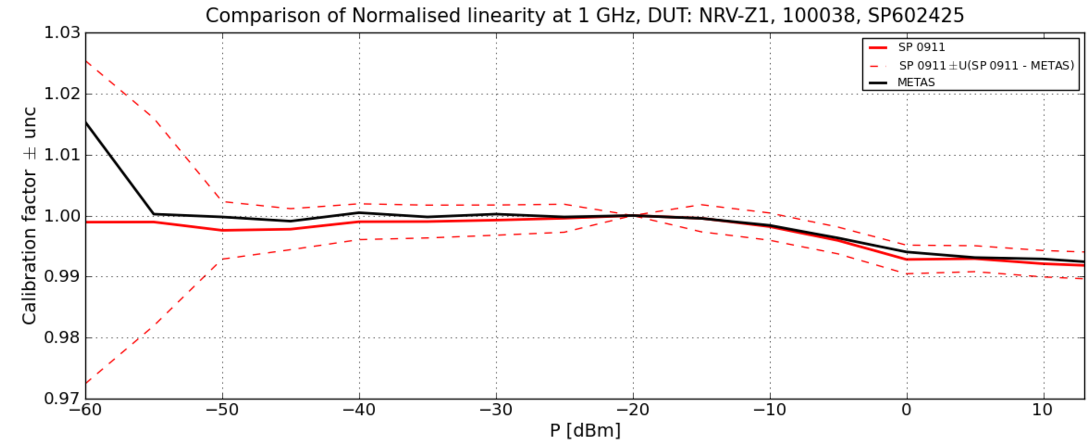

Figure 11: Normalized Linearity ± U(Error) at 1 GHz

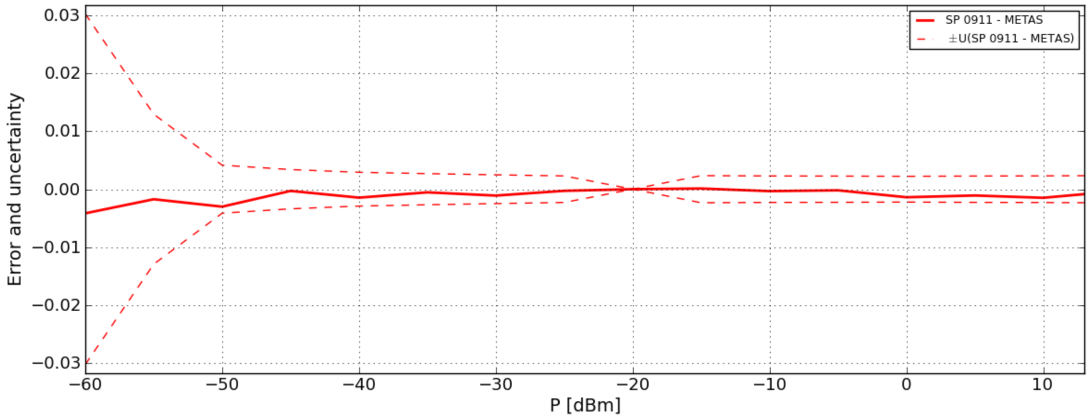

Figure 12: Error ± U(Error) at 1 GHz

Table 8: Normalized Linearity at 1 GHz

$P_{nominal}$ dBm	En	Error	U(Error)	Lin_{ME}	$u(Lin_{ME})$	Lin_{SP}	$u(Lin_{SP})$
-60	-0.62	-0.0164	0.0265	1.0153	0.0117	0.9989	0.0062
-55	-0.08	-0.0013	0.0170	1.0002	0.0081	0.9989	0.0027
-50	-0.47	-0.0022	0.0047	0.9998	0.0021	0.9976	0.0011
-45	-0.39	-0.0013	0.0034	0.9991	0.0015	0.9978	0.0008
-40	-0.50	-0.0015	0.0029	1.0005	0.0013	0.9990	0.0007
-35	-0.28	-0.0008	0.0027	0.9998	0.0012	0.9990	0.0007
-30	-0.40	-0.0010	0.0025	1.0002	0.0010	0.9992	0.0007
-25	-0.09	-0.0002	0.0023	0.9998	0.0009	0.9996	0.0007
-20	0.00	0.0000	0.0000	1.0000	0.0000	1.0000	0.0000
-15	0.01	0.0000	0.0022	0.9995	0.0009	0.9996	0.0006
-10	-0.09	-0.0002	0.0022	0.9984	0.0009	0.9982	0.0006
-5	-0.19	-0.0004	0.0022	0.9963	0.0009	0.9959	0.0006
0	-0.52	-0.0012	0.0024	0.9940	0.0009	0.9928	0.0007
5	-0.09	-0.0002	0.0021	0.9931	0.0009	0.9929	0.0005
10	-0.37	-0.0008	0.0022	0.9929	0.0009	0.9921	0.0006
13	-0.27	-0.0006	0.0022	0.9924	0.0009	0.9918	0.0006

4.1.9 Complex Input Reflection Coefficient at 0 dBm and -20 dBm

The reflection coefficients are measured with a VNA as complex quantities with real and imaginary components. The current VNA uncertainty calculation returns an uncertainty which is equal for both components and the correlation between real and imaginary parts is assumed to be zero.

The following quantities are shown:
Re_{ME}, Im_{ME}, S_{11ME}, $|S_{11ME}|$: Complex Input Reflection Coefficient from METAS
Re_{SP}, Im_{SP}, S_{11SP}, $|S_{11SP}|$: Complex Input Reflection Coefficient from SP
$u(S_{11ME})$: standard uncertainty in S_{11} from METAS
$u(S_{11SP})$: standard uncertainty in S_{11} from SP

$$\text{Error} = |S_{11SP} - S_{11ME}|$$

$$U(\text{Error}) = 2.45 \cdot \sqrt{u(S_{11ME})^2 + u(S_{11SP})^2}$$

$$En = \text{Error}/U(\text{Error})$$

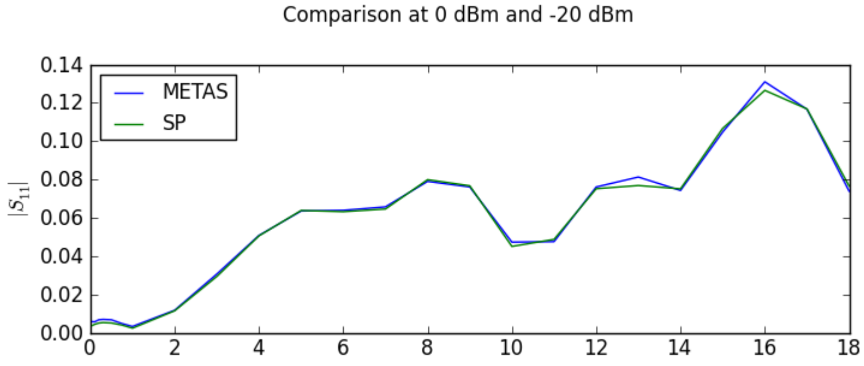

Figure 13:

$|S_{11}|$
at 0 dBm

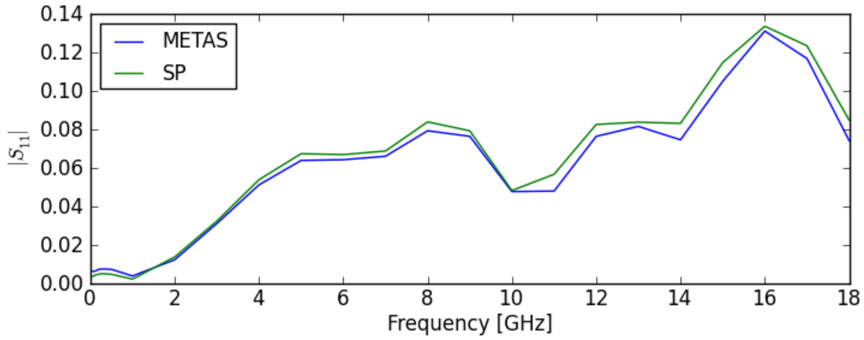

Figure 14:

$|S_{11}|$
at -20 dBm

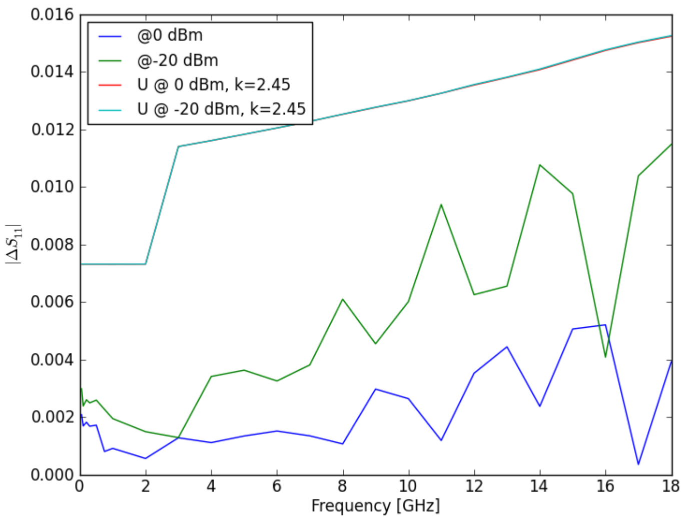

Figure 15:

Error = $|\Delta S_{11}|$
and U(Error)

at 0 dBm and
-20 dBm

Table 9: Complex input reflection coefficient at 0 dBm

Frequency MHz	En	Error	U(Error)	Re_{ME}	Im_{ME}	Re_{SP}	Im_{SP}	$u(S_{11ME})$	$u(S_{11SP})$
50	0.29	0.0021	0.0073	0.006	0.001	0.004	0.001	0.0020	0.0022
100	0.23	0.0017	0.0073	0.006	0.000	0.005	0.001	0.0020	0.0022
300	0.23	0.0017	0.0073	0.007	-0.002	0.005	-0.002	0.0020	0.0022
500	0.23	0.0017	0.0073	0.005	-0.005	0.004	-0.004	0.0020	0.0022
1000	0.12	0.0009	0.0073	-0.002	-0.003	-0.002	-0.002	0.0020	0.0022
2000	0.08	0.0006	0.0073	0.012	-0.001	0.012	-0.001	0.0020	0.0022
3000	0.11	0.0013	0.0114	-0.015	-0.027	-0.014	-0.026	0.0040	0.0024
4000	0.10	0.0011	0.0116	-0.034	0.038	-0.033	0.039	0.0040	0.0025
5000	0.11	0.0013	0.0118	0.059	0.024	0.059	0.025	0.0040	0.0027
6000	0.13	0.0015	0.0120	-0.003	-0.064	-0.002	-0.063	0.0040	0.0029
7000	0.11	0.0013	0.0123	-0.049	0.044	-0.049	0.043	0.0040	0.0030
8000	0.09	0.0011	0.0125	0.074	0.028	0.075	0.029	0.0040	0.0032
9000	0.23	0.0030	0.0128	0.006	-0.076	0.009	-0.076	0.0040	0.0033
10000	0.20	0.0026	0.0130	-0.041	0.024	-0.040	0.022	0.0040	0.0035
11000	0.09	0.0012	0.0133	0.045	-0.016	0.046	-0.016	0.0040	0.0036
12000	0.26	0.0035	0.0135	-0.060	-0.047	-0.057	-0.049	0.0040	0.0038
13000	0.32	0.0044	0.0138	-0.015	0.080	-0.014	0.076	0.0040	0.0040
14000	0.17	0.0024	0.0141	0.060	-0.044	0.059	-0.046	0.0040	0.0041
15000	0.35	0.0051	0.0144	-0.104	-0.013	-0.105	-0.018	0.0040	0.0043
16000	0.35	0.0052	0.0147	0.045	0.123	0.041	0.120	0.0040	0.0045
17000	0.02	0.0004	0.0150	0.083	-0.082	0.083	-0.082	0.0040	0.0046
18000	0.26	0.0039	0.0152	-0.074	0.001	-0.077	-0.002	0.0040	0.0048

Table 10: Complex input reflection coefficient at -20 dBm

Frequency MHz	En	Error	U(Error)	Re_{ME}	Im_{ME}	Re_{SP}	Im_{SP}	$u(S_{11ME})$	$u(S_{11SP})$
50	0.14	0.0010	0.0073	0.004	0.001	0.003	0.001	0.0020	0.0022
100	0.21	0.0015	0.0073	0.005	0.000	0.004	0.001	0.0020	0.0022
300	0.12	0.0009	0.0073	0.005	-0.002	0.005	-0.001	0.0020	0.0022
500	0.16	0.0012	0.0073	0.004	-0.004	0.003	-0.003	0.0020	0.0022
1000	0.16	0.0012	0.0073	-0.001	-0.002	-0.002	-0.001	0.0020	0.0022
2000	0.07	0.0005	0.0073	0.013	-0.001	0.013	-0.001	0.0020	0.0022
3000	0.14	0.0016	0.0114	-0.017	-0.029	-0.016	-0.028	0.0040	0.0024
4000	0.08	0.0009	0.0116	-0.035	0.041	-0.034	0.041	0.0040	0.0025
5000	0.06	0.0007	0.0118	0.062	0.024	0.063	0.024	0.0040	0.0027
6000	0.17	0.0020	0.0120	-0.007	-0.067	-0.005	-0.067	0.0040	0.0029
7000	0.07	0.0009	0.0123	-0.050	0.048	-0.049	0.048	0.0040	0.0030
8000	0.15	0.0018	0.0125	0.078	0.025	0.080	0.026	0.0040	0.0032
9000	0.22	0.0029	0.0128	0.000	-0.078	0.003	-0.079	0.0040	0.0033
10000	0.15	0.0020	0.0130	-0.039	0.031	-0.038	0.029	0.0040	0.0035
11000	0.18	0.0023	0.0133	0.050	-0.021	0.052	-0.022	0.0040	0.0036
12000	0.25	0.0034	0.0136	-0.067	-0.047	-0.065	-0.050	0.0040	0.0038
13000	0.22	0.0030	0.0138	-0.010	0.086	-0.009	0.083	0.0040	0.0040
14000	0.25	0.0035	0.0141	0.063	-0.051	0.063	-0.054	0.0040	0.0041
15000	0.37	0.0053	0.0144	-0.112	-0.010	-0.114	-0.015	0.0040	0.0043
16000	0.28	0.0042	0.0148	0.052	0.127	0.049	0.124	0.0040	0.0045
17000	0.17	0.0026	0.0150	0.083	-0.090	0.082	-0.092	0.0040	0.0047
18000	0.28	0.0042	0.0153	-0.081	0.008	-0.084	0.006	0.0040	0.0048

4.2 Summarizing Results

The analysis of all measured quantities at each individual test frequency and each test level resulted in |En| < 1, which indicates an overall agreement between the participants at the 95 % level.
Control measurements to investigate the behavior of the travelling standard during the whole measurement period showed no drift or stability problems and therefore no corrections were necessary.
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5. Conclusions

The Calibration Factor (Normalized Frequency Response), the Linearity (Level Dependent Calibration Factor) and the Complex Input Reflection Coefficient of a Diode Power Sensor were compared.
Besides the good agreement in all results between the participants the following comments can be made:

This first Diode Power Sensor comparison helped to improve the measurement procedures at both labs.

The measurement of the Calibration Factor was based on the conventional direct comparison method at both laboratories but required additional efforts to create the different power levels and to control the harmonic content of the signal source. With a carefully designed setup it is possible to achieve measurement uncertainties of the same order of magnitude as with thermal power sensors. This is even true for power levels below 1 mW.

The Linearity (Level Dependent Calibration Factor) was evaluated by each participant applying different setups. The results agree and the resulting measurement uncertainties are considerably lower than for the frequency dependent Calibration Factor.

For Calibration Factor and Linearity characterization of Diode Sensors it is important to keep harmonics of the test signal at a low level, otherwise they can contribute considerably to the total measurement uncertainty.

A. Data submitted by participants

A.1 Data submitted by SP (July 2009)

SP MTkP802365-K03 MTkHF NRV-Z1 100038 SP602425.pdf issued 07 July 2009

Table 11: Data submitted by SP (July 2009)

Normalized Calibration Factor CF at 0 dBm		
Frequency MHz	CF (W/W)	U(CF) (W/W)
50	1	0
100	0.9981	0.0068
300	0.9950	0.0068
500	0.9927	0.0068
1000	0.9892	0.0068
2000	0.9835	0.0068
3000	0.9789	0.0076
4000	0.9719	0.0076
5000	0.9618	0.0076
6000	0.9543	0.0084
7000	0.9370	0.0084
8000	0.9179	0.0083
9000	0.9199	0.0092
10000	0.9197	0.0092
11000	0.9057	0.0099
12000	0.8944	0.0099
13000	0.8829	0.0097
14000	0.8686	0.0095
15000	0.836	0.010
16000	0.812	0.010
17000	0.792	0.010
18000	0.775	0.010

Normalized Calibration Factor CF at - 10 dBm		
Frequency MHz	CF (W/W)	U(CF) (W/W)
50	1	0
100	0.9986	0.0069
300	0.9964	0.0069
500	0.9946	0.0069
1000	0.9912	0.0069
2000	0.9862	0.0069
3000	0.9813	0.0077
4000	0.9737	0.0077
5000	0.9634	0.0076
6000	0.9551	0.0085
7000	0.9358	0.0084
8000	0.9150	0.0083
9000	0.9148	0.0092
10000	0.9112	0.0091
11000	0.8933	0.0098
12000	0.8785	0.0097
13000	0.8635	0.0096
14000	0.8466	0.0093

Normalized Calibration Factor CF at - 10 dBm		
Frequency MHz	CF (W/W)	U(CF) (W/W)
15000	0.813	0.010
16000	0.787	0.010
17000	0.7693	0.0099
18000	0.7543	0.0098

Normalized Calibration Factor CF at - 20 dBm		
Frequency MHz	CF (W/W)	U(CF) (W/W)
50	1	0
100	0.9991	0.007
300	0.9978	0.007
500	0.9963	0.007
1000	0.9928	0.0069
2000	0.9877	0.0069
3000	0.9830	0.0078
4000	0.9749	0.0077
5000	0.9648	0.0077
6000	0.9566	0.0085
7000	0.9365	0.0085
8000	0.9152	0.0084
9000	0.9133	0.0092
10000	0.9091	0.0091
11000	0.8893	0.0098
12000	0.8733	0.0097
13000	0.8568	0.0095
14000	0.8392	0.0093
15000	0.805	0.010
16000	0.780	0.010
17000	0.7616	0.0099
18000	0.7470	0.0097

Normalized Calibration Factor CF at - 30 dBm		
Frequency MHz	CF (W/W)	U(CF) (W/W)
50	1	0
100	0.9967	0.0098
300	0.9953	0.0097
500	0.9921	0.0097
1000	0.9863	0.0097
2000	0.9870	0.0097
3000	0.982	0.011
4000	0.971	0.011
5000	0.9634	0.0095
6000	0.9519	0.0097
7000	0.935	0.010
8000	0.914	0.011
9000	0.908	0.011
10000	0.904	0.011
11000	0.888	0.010
12000	0.871	0.011
13000	0.855	0.010

Normalized Calibration Factor CF at - 30 dBm		
Frequency MHz	CF (W/W)	U(CF) (W/W)
14000	0.835	0.010
15000	0.800	0.011
16000	0.775	0.011
17000	0.757	0.011
18000	0.745	0.010

Normalized Linearity Lin at 50 MHz		
P_{DUT} (dBm)	Lin (dB)	U(Lin) (dB)
-59.89	0.087	0.094
-54.961	-0.013	0.067
-49.92	0.011	0.043
-44.955	-0.016	0.038
-39.924	-0.008	0.037
-34.957	-0.005	0.037
-29.93	-0.003	0.025
-24.922	0.0000	0.0099
-19.936	0	0
-14.934	-0.0012	0.0052
-9.883	-0.0057	0.0050
-4.927	-0.0098	0.0050
0.11	-0.0174	0.0051
5.077	-0.0165	0.0051
9.996	-0.0180	0.0051
13.05	-0.0193	0.0050

Normalized Linearity Lin at 1000 MHz		
P_{DUT} (dBm)	Lin (dB)	U(Lin) (dB)
-60.099	-0.11	0.25
-54.988	-0.008	0.081
-49.948	-0.002	0.043
-45.016	0.000	0.041
-39.983	-0.002	0.040
-35	0.000	0.040
-30.017	-0.002	0.015
-24.971	0.001	0.014
-19.911	0	0
-14.991	-0.0058	0.0062
-9.952	-0.0116	0.0056
-4.967	-0.0208	0.0058
0.057	-0.0316	0.0056
4.962	-0.0339	0.0054
10.01	-0.0360	0.0058
13.069	-0.0376	0.0057

Voltage Reflection Coefficient at 0 dBm (1 mW)			
Frequency MHz	Real (MagLin)	Imaginary (MagLin)	U(VRC) (MagLin)
50	0.0039	0.0012	0.0054
100	0.0046	0.0009	0.0054
300	0.0054	-0.0015	0.0054
500	0.0040	-0.0036	0.0054
1000	-0.0015	-0.0022	0.0054
2000	0.0117	-0.0005	0.0054
3000	-0.0143	-0.0259	0.0058
4000	-0.0330	0.0385	0.0062
5000	0.0588	0.0253	0.0066
6000	-0.0016	-0.0633	0.0070
7000	-0.0487	0.0427	0.0074
8000	0.0746	0.0289	0.0078
9000	0.0089	-0.0763	0.0082
10000	-0.0397	0.0217	0.0085
11000	0.0461	-0.0165	0.0089
12000	-0.0571	-0.0491	0.0093
13000	-0.0138	0.0757	0.0097
14000	0.059	-0.046	0.010
15000	-0.105	-0.018	0.011
16000	0.041	0.120	0.011
17000	0.083	-0.082	0.011
18000	-0.077	-0.002	0.012

Voltage Reflection Coefficient at - 20 dBm (10 µW)			
Frequency MHz	Real (MagLin)	Imaginary (MagLin)	U(VRC) (MagLin)
50	0.0030	0.0013	0.0054
100	0.0039	0.0010	0.0054
300	0.0046	-0.0012	0.0054
500	0.0033	-0.0031	0.0054
1000	-0.0017	-0.0011	0.0054
2000	0.0135	-0.0009	0.0054
3000	-0.0158	-0.0280	0.0058
4000	-0.0342	0.0414	0.0062
5000	0.0626	0.0244	0.0066
6000	-0.0050	-0.0665	0.0070
7000	-0.0492	0.0478	0.0074
8000	0.0797	0.0258	0.0078
9000	0.0026	-0.0791	0.0082
10000	-0.0381	0.0293	0.0085
11000	0.0518	-0.0224	0.0089
12000	-0.0654	-0.0501	0.0094
13000	-0.0092	0.0831	0.0097
14000	0.063	-0.054	0.010
15000	-0.114	-0.015	0.011
16000	0.049	0.124	0.011
17000	0.082	-0.092	0.011
18000	-0.084	0.006	0.012

A.2 Data submitted by SP (November 2009)

MTkP900225-K08 MTkHF NRV-Z1 100038 SP602425.pdf issued 19 November 2009

Table 12: Data submitted by SP (November 2009)

Normalized Linearity Lin at 50 MHz		
P_{DUT} (dBm)	Lin (dB)	U(Lin) (dB)
-59.935	-0.010	0.053
-54.913	-0.009	0.026
-49.928	-0.014	0.010
-44.91	-0.0043	0.0069
-39.915	-0.0053	0.0063
-34.901	-0.0044	0.0060
-29.917	-0.0038	0.0059
-24.932	-0.0032	0.0059
-19.895	0	0
-14.888	-0.0015	0.0063
-9.889	-0.0045	0.0059
-4.882	-0.0109	0.0057
0.086	-0.0201	0.0055
5.105	-0.0187	0.0058
10.096	-0.0215	0.0060
13.112	-0.0217	0.0063

Normalized Linearity Lin at 1000 MHz		
P_{DUT} (dBm)	Lin (dB)	U(Lin) (dB)
-59.965	-0.005	0.054
-54.975	-0.005	0.024
-49.95	-0.0105	0.0098
-44.956	-0.0097	0.0067
-39.95	-0.0044	0.0064
-34.953	-0.0043	0.0061
-29.919	-0.0033	0.0059
-24.898	-0.0019	0.0059
-19.909	0	0
-14.93	-0.0019	0.0054
-9.929	-0.0079	0.0055
-4.948	-0.0178	0.0052
0.078	-0.0314	0.0064
6.313	-0.0308	0.0047
10.053	-0.0345	0.0051
13.095	-0.0356	0.0053

A.3 Data submitted by METAS

Metas certificate of calibration 217-00983 issued 07 April 2009

Table 13: Data submitted by METAS (April 2009)

Normalized Calibration Factor CF at 0 dBm		
Frequency MHz	CF (W/W)	U(CF) (W/W)
50	1	0
100	1.000	0.006
300	0.999	0.006
500	0.998	0.006
1000	0.995	0.006
2000	0.989	0.006
3000	0.983	0.006
4000	0.975	0.006
5000	0.967	0.007
6000	0.958	0.007
7000	0.939	0.007
8000	0.918	0.007
9000	0.925	0.008
10000	0.925	0.007
11000	0.912	0.007
12000	0.899	0.008
13000	0.884	0.008
14000	0.874	0.008
15000	0.840	0.009
16000	0.817	0.010
17000	0.799	0.009
18000	0.782	0.009

Normalized Calibration Factor CF at - 10 dBm		
Frequency MHz	CF (W/W)	U(CF) (W/W)
50	1	0
100	1.000	0.006
300	0.999	0.006
500	0.998	0.006
1000	0.994	0.006
2000	0.988	0.006
3000	0.982	0.006
4000	0.974	0.006
5000	0.964	0.007
6000	0.955	0.007
7000	0.935	0.007
8000	0.913	0.007
9000	0.916	0.008
10000	0.912	0.007
11000	0.894	0.007
12000	0.880	0.008
13000	0.862	0.008
14000	0.846	0.008
15000	0.814	0.009
16000	0.791	0.010

Normalized Calibration Factor CF at - 10 dBm		
Frequency MHz	CF (W/W)	U(CF) (W/W)
17000	0.773	0.009
18000	0.758	0.009

Normalized Calibration Factor CF at - 20 dBm		
Frequency MHz	CF (W/W)	U(CF) (W/W)
50	1	0
100	1.000	0.006
300	0.999	0.006
500	0.998	0.006
1000	0.995	0.006
2000	0.990	0.006
3000	0.983	0.006
4000	0.976	0.007
5000	0.965	0.007
6000	0.957	0.007
7000	0.936	0.007
8000	0.913	0.007
9000	0.914	0.008
10000	0.909	0.007
11000	0.890	0.007
12000	0.875	0.008
13000	0.855	0.008
14000	0.839	0.008
15000	0.807	0.009
16000	0.783	0.010
17000	0.766	0.009
18000	0.752	0.009

Normalized Calibration Factor CF at - 30 dBm		
Frequency MHz	CF (W/W)	U(CF) (W/W)
50	1	0
100	1.000	0.013
300	0.998	0.008
500	0.999	0.01
1000	0.994	0.01
2000	0.988	0.011
3000	0.985	0.016
4000	0.975	0.011
5000	0.965	0.015
6000	0.956	0.011
7000	0.935	0.011
8000	0.912	0.008
9000	0.913	0.009
10000	0.909	0.01
11000	0.889	0.01
12000	0.873	0.01
13000	0.856	0.013
14000	0.838	0.009
15000	0.805	0.011

Normalized Calibration Factor CF at - 30 dBm		
Frequency MHz	CF (W/W)	U(CF) (W/W)
16000	0.782	0.011
17000	0.765	0.013
18000	0.751	0.011

Normalized Linearity Lin at 50 MHz		
P_{DUT} (dBm)	Lin (dB)	U(Lin) (dB)
-60	0.008	0.12
-55	-0.001	0.05
-50	-0.001	0.015
-45	-0.003	0.013
-40	0.001	0.011
-35	-0.002	0.01
-30	0.001	0.009
-25	-0.002	0.008
-20	0	0
-15	-0.002	0.008
-10	-0.003	0.008
-5	-0.01	0.008
0	-0.014	0.008
5	-0.014	0.008
10	-0.015	0.008
13	-0.018	0.008

Normalized Linearity Lin at 1000 MHz		
P_{DUT} (dBm)	Lin (dB)	U(Lin) (dB)
-60	0.066	0.10
-55	0.001	0.07
-50	-0.001	0.018
-45	-0.004	0.013
-40	0.002	0.011
-35	-0.001	0.010
-30	0.001	0.009
-25	-0.001	0.008
-20	0	0
-15	-0.002	0.008
-10	-0.007	0.008
-5	-0.016	0.008
0	-0.026	0.008
5	-0.030	0.008
10	-0.031	0.008
13	-0.033	0.008

Voltage Reflection Coefficient at 0 dBm (1 mW)			
Frequency MHz	Real (MagLin)	Imaginary (MagLin)	U(VRC) (MagLin)
50	0.006	0.001	0.004
100	0.006	0	0.004
300	0.007	-0.002	0.004
500	0.005	-0.005	0.004

Voltage Reflection Coefficient at 0 dBm (1 mW)			
Frequency MHz	Real (MagLin)	Imaginary (MagLin)	U(VRC) (MagLin)
1000	-0.002	-0.003	0.004
2000	0.012	-0.001	0.004
3000	-0.015	-0.027	0.008
4000	-0.034	0.038	0.008
5000	0.059	0.024	0.008
6000	-0.003	-0.064	0.008
7000	-0.049	0.044	0.008
8000	0.074	0.028	0.008
9000	0.006	-0.076	0.008
10000	-0.041	0.024	0.008
11000	0.045	-0.016	0.008
12000	-0.06	-0.047	0.008
13000	-0.015	0.08	0.008
14000	0.06	-0.044	0.008
15000	-0.104	-0.013	0.008
16000	0.045	0.123	0.008
17000	0.083	-0.082	0.008
18000	-0.074	0.001	0.008

Voltage Reflection Coefficient at - 20 dBm (10 µW)			
Frequency MHz	Real (MagLin)	Imaginary (MagLin)	U(VRC) (MagLin)
50	0.004	0.001	0.004
100	0.005	0	0.004
300	0.005	-0.002	0.004
500	0.004	-0.004	0.004
1000	-0.001	-0.002	0.004
2000	0.013	-0.001	0.004
3000	-0.017	-0.029	0.008
4000	-0.035	0.041	0.008
5000	0.062	0.024	0.008
6000	-0.007	-0.067	0.008
7000	-0.05	0.048	0.008
8000	0.078	0.025	0.008
9000	0	-0.078	0.008
10000	-0.039	0.031	0.008
11000	0.05	-0.021	0.008
12000	-0.067	-0.047	0.008
13000	-0.01	0.086	0.008
14000	0.063	-0.051	0.008
15000	-0.112	-0.01	0.008
16000	0.052	0.127	0.008
17000	0.083	-0.09	0.008
18000	-0.081	0.008	0.008

B. Additional information by the participants

B.1 SP

SP provided two certificates of calibration
MTkP802365-K03 MTkHF NRV-Z1 100038 SP602425.pdf issued 07 July 2009
MTkP900225-K08 MTkHF NRV-Z1 100038 SP602425.pdf issued 19 November 2009

B.1.1 Method of Calibration

Calibration factor
SP uses the direct calibration setup [2-3] shown in Figure 16. The volt meter, the standard power sensor, and the DUT (device under test) are alternately connected to the power splitter. Their readout is taken simultaneously with the monitoring power sensor. For certificate MTkP802365-K03 the attenuator is used in linearity calibrations below -30 dBm and for certificate MTkP900225-K08 the attenuator is used in linearity calibrations below -20 dBm.

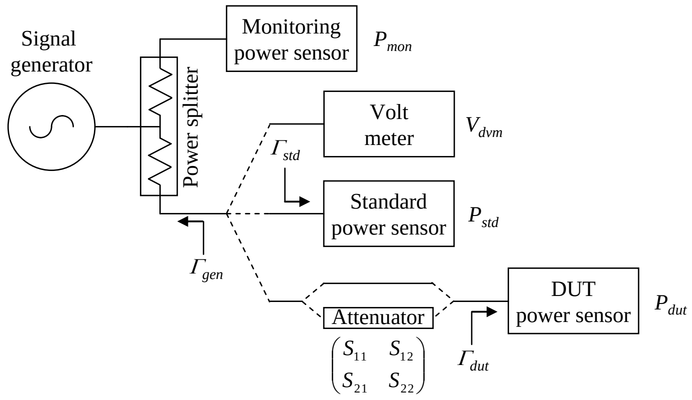

Figure 16: The calibration setup used at SP

The absolute power level in the setup is traced to the volt meter. The frequency dependent calibration factor of the DUT is traced to the standard sensor. The normalized linearity of the DUT is traced to the linearity of the monitoring sensor and the effective attenuation of the attenuator. The effective attenuation is either calculated from the reflection coefficients in the setup and the S-parameters of the attenuator (certificate MTkP802365-K03) or solved from an extra measurement on the monitor and the DUT [6] (certificate MTkP900225-K08).

Reflection Coefficient
The reflection coefficient is measured with an HP8510C vector network analyzer using short-open- load standards which are traced to through-reflect-line standards and additional airlines.

B.1.2 Uncertainty Budget

Table 14 shows the uncertainty contributions and an example uncertainty budget for the frequency dependent calibration factor. All uncertainty contributions are relative. Therefore all sensitivity coefficients are unity and are left out.

Table 14: Example uncertainty budget for frequency dependent calibration factor at 0 dBm

Source of relative uncertainty contribution	Probability distribution	Relative standard uncertainty for the frequency [GHz]		
		0.05	0.1	18
Calibration factor of the standard sensor	Normal	0.00202	0.00254	0.00539
Drift in the standard sensor	Normal	0.00060	0.00075	0.00150
Mismatch	Normal	0.00004	0.00004	0.00231
Monitor linearity, DUT connected	Normal	0.00018	0.00018	0.00018
Monitor linearity, standard connected	Normal	0.00018	0.00018	0.00018
DUT resolution	Uniform	0.00007	0.00007	0.00007
Monitor resolution, DUT connected	Uniform	0.00013	0.00013	0.00013
Monitor resolution, standard connected	Uniform	0.00013	0.00013	0.00013
Standard resolution	Uniform	0.00013	0.00013	0.00013
Root sum square of type B uncertainties		0.00214	0.00267	0.00607
Transfer of uncertainties from the normalising frequency		0	0.00214	0.00214
Random errors	Normal	0	0.00004	0.00017
Combined relative standard uncertainty	Normal	0	0.0034	0.0064
Expanded relative uncertainty	Normal	0	0.0068	0.0129
Calibration factor		1	0.9981	0.775
Expanded uncertainty	Normal	0	0.0068	0.010

Table 15 shows the uncertainty contributions and an example uncertainty budget for the linearity in certificate MTkP802365-K03. All uncertainty contributions are relative. Therefore all sensitivity coefficients are unity and are left out.

Table 15: Example uncertainty budget for linearity at 50 MHz (certificate MTkP802365-K03, July 09)

Source of relative uncertainty contribution	Probability distribution	Relative standard uncertainty for the level [dBm]		
		-40	-20	0
Effective attenuation including mismatch	Normal	0.00416	0.00000	0.00000
Monitor linearity, DUT connected	Normal	0.00029	0.00037	0.00018
DUT resolution	Uniform	0.00007	0.00007	0.00007
Monitor resolution, DUT connected	Uniform	0.00013	0.00013	0.00013
Root sum square of type B uncertainties		0.00418	0.00040	0.00024
Transfer of uncertainties from the normalising level		0.00040	0	0.00040
Random errors	Normal	0.00052	0	0.00036
Combined relative standard uncertainty	Normal	0.00423	0	0.00059
Expanded relative uncertainty	Normal	0.0085	0	0.0012
Calibration factor [dB]		-0.0083	0	-0.0174
Expanded relative uncertainty [dB]	Normal	0.037	0	0.0051

Table 16 shows the uncertainty contributions and an example uncertainty budget for the linearity in certificate MTkP900225-K08. All uncertainty contributions are relative. Therefore all sensitivity coefficients are unity and are left out.

Table 16: Example uncertainty budget for linearity at 50 MHz (certificate MTkP900225-K08, Nov 09)

Source of relative uncertainty contribution	**Probability distribution**	**Relative standard uncertainty for the level [dBm]**		
		-40	-20	0
Effective attenuation including mismatch	Normal	0.00049	0.00000	0.00000
Monitor linearity, DUT connected	Normal	0.00029	0.00037	0.00018
DUT resolution	Uniform	0.00007	0.00007	0.00007
Monitor resolution, DUT connected	Uniform	0.00013	0.00013	0.00013
Drift in the DUT zeroing	Normal	0.00005	0.00000	0.00000
Root sum square of type B uncertainties		0.00059	0.00040	0.00024
Transfer of uncertainties from the normalising level		0.00040	0	0.00040
Random errors	Normal	0.00010	0	0.00042
Combined relative standard uncertainty	Normal	0.00072	0	0.00063
Expanded relative uncertainty	Normal	0.0014	0	0.0013
Calibration factor [dB]		-0.0053	0.0000	-0.0201
Expanded relative uncertainty [dB]	Normal	0.0063	0.0000	0.0055

Note that the drift in the monitor linearity is not yet included in the uncertainty budget. The drift was however monitored from the calibration of the monitor throughout this comparison and it was negligible compared to the uncertainty contributions above.

B.2 METAS

Metas provided a certificate of calibration 217-00983 issued 07 April 2009

B.2.1 Method of Calibration

Calibration Factor: Metas uses the modified direct comparison setup [2], [3] according Figure 17. Harmonics of the synthesized frequency source are supressed by a switchable lowpass filterbank in order to reduce this dominating uncertainy contribution in case of calibrating diode sensors. The standard power sensor REF and the DUT (device under test) are alternately connected to the power splitter. Their readout is taken simultaneously with the monitoring power sensor MON. The fix attenuator is used to improve MON linearity. The frequency dependent calibration factor of the DUT is traced to the power standard.

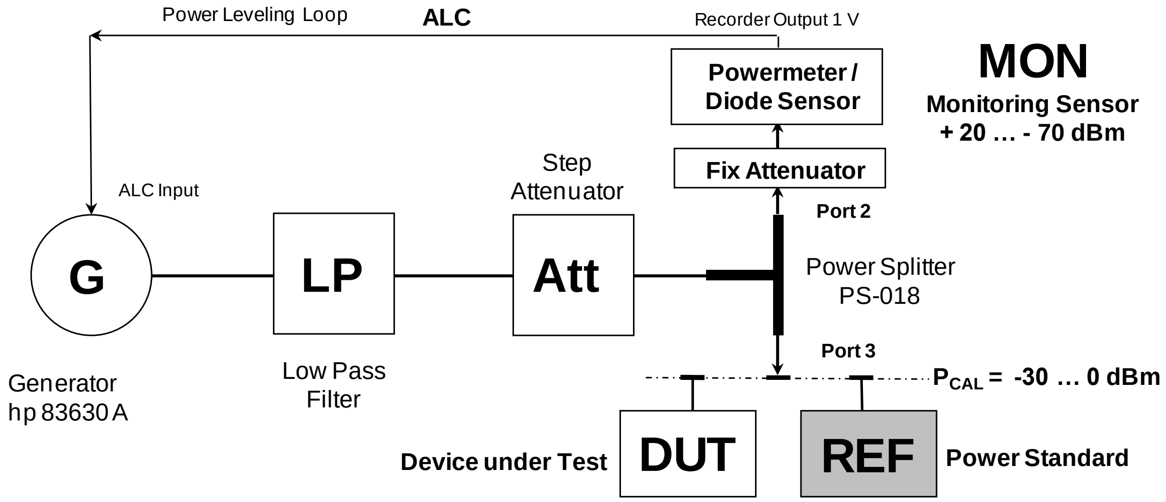

Figure 17: Setup used at Metas to determine the calibration factor vs. frequency

Linearity of the Calibration Factor: Metas uses a setup shown in Figure 18. The linearity [4], [5] of the DUT is traced to the attenuation of the step attenuator which has been calibrated using the Metas WBCO system (Waveguide below cutoff attenuator).

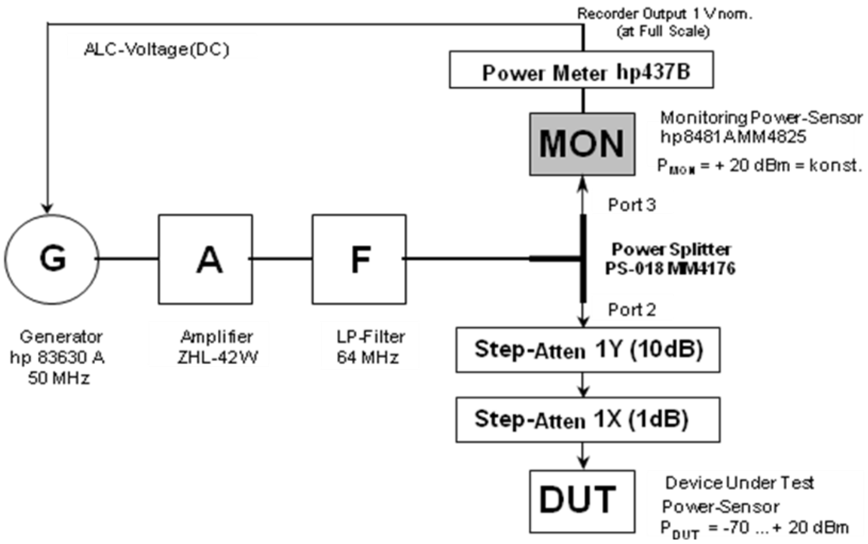

Figure 18: Setup used at Metas to determine the linearity of the calibration factor, f = 50 MHz

Reflection coefficients: The reflection coefficients are measured by means of a HP8510C vector network analyzer (calibration method: open-short-sliding load).

B.2.2 Uncertainty Budget

Calibration Factor:

Table 17: Example uncertainty budget for frequency dependent calibration factor (18 GHz / 1 mW)

Uncertainty Budget f = 18 GHz Calibration power = 1 mW (0 dBm)									
xi	Mesurand Xi	Description	Prob. Distrib	di	Estimate xi	Unit Estimate	Standard-Uncertainty u(xi) [lin]	Sensitivity Coefficient ci	Std-Unc contribution u(xi) [lin]
x1	R_{DUT}	$R = P_{DUT\_Read} / P_{MON\_Read}$	-		0.7722	[lin]	0.00050	0.998	0.00050
x2	R_{REF}	$R = P_{REF\_Read} / P_{MON\_Read}$	-		0.9384	[lin]	0.00034	-0.821	-0.00028
x3	K_{eREF}	Calibration Factor Ke_REF	norm.	0.5	0.9348	[lin]	0.00385	0.824	0.00317
x4	δKe	δKe: Drift & Aging Ke_REF	rect.	0.577	0	[lin]	0.001	0.770	0.00077
x5	D_{MON}	Linearity MON	norm.	0.5	1	[lin]	0.0015	-0.770	-0.00116
x6	D_{REF}	Linearity REF	norm.	0.5	1	[lin]	0.0015	0.770	0.00116
x8	MF	Mismatch-Factor	norm.	1	1.0015	[lin]	0.00106	0.770	0.00082
x11	U_{transf_50MHz}	Unc transfer from $f_{normalizing}$ (50MHz)	-		1	[lin]	0.00150	0.770	0.00116
x15	SRREF	Resolution (Meter) REF	rect.	0.577	1	[lin]	0.00100	-0.770	-0.00077
x16	SRDUT	Resolution (Meter) DUT	rect.	0.577	1	[lin]	0.00100	0.770	0.00077
x17	ZS	Zero Set	rect.	0.577	0	[W]	0.00001	0.770	0.00000
x18	ZD	Zero Drift	rect.	0.577	0	[W]	0.00003	0.770	0.00002
x19	TC	Temperatur Coeff. (System)	rect.	0.577	1	[lin]	0.00100	0.770	0.00077
x20	N	Noise	rect.	0.577	0	[W]	0.00004	0.770	0.00003
x22	H_{REF}	Harmonics, REF (thermal sensor)	U	0.707	60	[dB]	1.00E-06	-0.770	-7.70E-07
x23	H_{DUT}	Harmonics, DUT (diode sensor)	U	0.707	30	[dB]	1.00E-03	0.770	7.70E-04
		Calibration Factor						**K_{e_DUT} =**	**0.782**
		Combined Standard Uncertainty						$u(K_{eDUT})$ =	0.00425
		Expanded Standard Uncertainty						$U(K_{eDUT})$ =	0.085
		Expanded Std Unc (rounded)						**$U(K_{eDUT})$ =**	**0.090**

Linearity of the Calibration Factor:

Table 18: Example uncertainty budget for linearity at 50 MHz

DUT-Level Nom. Value Side B (dBm)	Step-Att nominal Attenuation Side B (dB)	StepAtt Unc k=1 (dB)	StdUnc X1 Mismatch StdUnc Source (-)	StdUnc X2 Mismatch StdUnc Load (-)	StdUnc X3 StepAtt at P DUT StdUnc (-)	StdUnc X4 StepAtt at P REF StdUnc (-)	StdUnc X5 Side A & B Combined Type A StdUnc (-)	Comb StdUnc (-)	Expanded Uncertainty k = 2 (-)	Expanded Uncertainty rounded k = 2 Log (dB)
-60	-70	0.0070	0.00010	0.00009	0.0016	0.0005	0.01278	0.01289	0.02577	0.120
-55	-65	0.0065	0.00010	0.00006	0.0015	0.0005	0.00384	0.00415	0.00829	0.037
-50	-60	0.0060	0.00005	0.00009	0.0014	0.0005	0.00096	0.00175	0.00350	0.016
-45	-55	0.0055	0.00005	0.00006	0.0013	0.0005	0.00069	0.00152	0.00304	0.014
-40	-50	0.0050	0.00010	0.00011	0.0012	0.0005	0.00012	0.00126	0.00251	0.011
-35	-45	0.0045	0.00010	0.00015	0.0010	0.0005	0.00006	0.00115	0.00230	0.011
-30	-40	0.0040	0.00011	0.00010	0.0009	0.0005	0.00005	0.00104	0.00208	0.010
-25	-35	0.0035	0.00016	0.00012	0.0008	0.0005	0.00005	0.00095	0.00190	0.009
-20	-30	0.0030	0.00016	0.00012	0.0007	0.0005	0.00006	0.00086	0.00171	0.008
-15	-25	0.0025	0.00016	0.00012	0.0006	0.0005	0.00005	0.00077	0.00153	0.007
-10	-20	0.0020	0.00016	0.00012	0.0005	0.0005	0.00003	0.00068	0.00137	0.006
-5	-15	0.0015	0.00016	0.00012	0.0003	0.0005	0.00003	0.00061	0.00122	0.006
0	-10	0.0010	0.00016	0.00012	0.0002	0.0005	0.00005	0.00056	0.00111	0.005
5	-5	0.0005	0.00016	0.00012	0.0001	0.0005	0.00005	0.00052	0.00104	0.005
10	0	0.0000	0.00016	0.00012	0.0000	0.0005	0.00002	0.00050	0.00101	0.004

All uncertainty contributions are relative. Therefore all sensitivity coefficients are unity and are left out.

C. Control and Cross Check Measurements of the Travelling Standard

Control and cross check measurements to investigate drift and stability of the travelling standard during the whole measurement period were performed by SP two times according to Table 2. The results showed no significant drift of the device under test (DUT) and therefore no corrections were necessary.

The compared and analyzed calibration factor data is shown for each power level (0 dBm, -10 dBm, -20 dBm and -30 dBm) by two graphs and one table. The following data is given:

CF_{SP_0812}: Calibration Factor measured at SP in December 2008
CF_{SP_0906}: Calibration Factor measured at SP in June 2009
CF_{SP_0911}: Calibration Factor measured at SP in November 2009
$u(CF_{SP\_0812})$: standard uncertainty* in CF_{SP_0812}
$u(CF_{SP\_0906})$: standard uncertainty* in CF_{SP_0906}
$u(CF_{SP\_0911})$: standard uncertainty* in CF_{SP_0911}

$$\mathrm{Error} = CF_{SP\_0906} - CF_{SP\_0812} \quad \text{or} \quad CF_{SP\_0911} - CF_{SP\_0812}$$

$$U(\mathrm{Error}) = 2 \cdot \sqrt{u(CF_{SP\_0906})^2 + u(CF_{SP\_0812})^2} \quad \text{or} \quad 2 \cdot \sqrt{u(CF_{SP\_0911})^2 + u(CF_{SP\_0812})^2}$$

$$En = \mathrm{Error}/U(\mathrm{Error})$$

If En < 1 the measured drift is regarded as not significant and no corrections are made.

* Only uncertainties due to resolution, repeatability and linearity where included in $u(CF_{SP\_xxxx})$ when doing the cross checks.

C.1 Crosscheck of Normalized Frequency Response, SP July09 vs. SP Dec08

C.1.1 Crosscheck of Normalized Frequency Response at 0 dBm

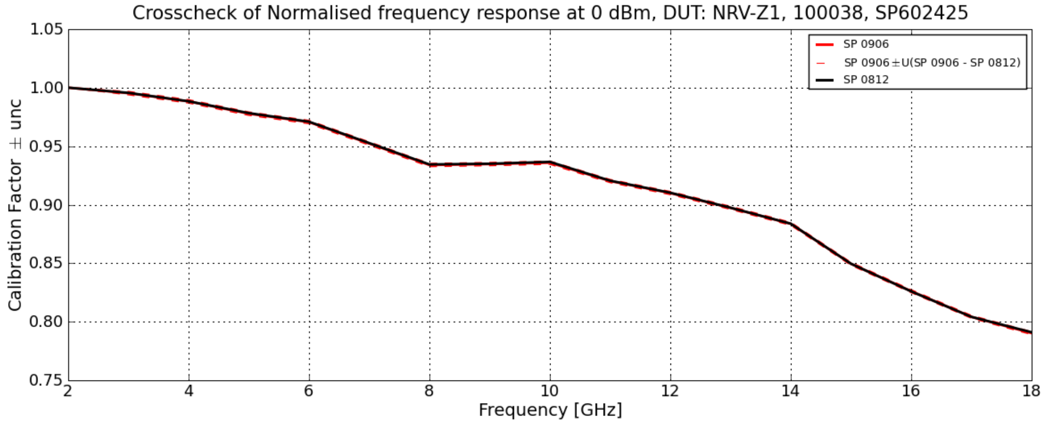

Figure 19:

Calibration Factor ± U(Error) at 0 dBm

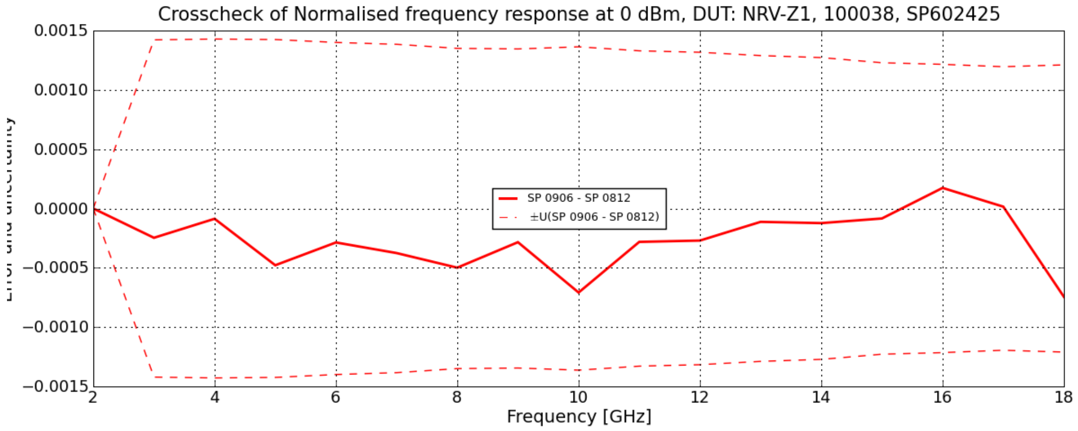

Figure 20:

Error ± U(Error) at 0 dBm

Frequency MHz	En	Error	U(Error)	CF_{SP_0812}	$u(CF_{SP\_0812})$	CF_{SP_0906}	$u(CF_{SP\_0906})$
2000	0	0	0	1	0	1	0
3000	-0.17	-0.00025	0.0014	0.9956	0.00051	0.9953	0.00050
4000	-0.06	-0.00009	0.0014	0.9884	0.00050	0.9883	0.00051
5000	-0.34	-0.00048	0.0014	0.9782	0.00050	0.9778	0.00051
6000	-0.21	-0.00029	0.0014	0.9709	0.00050	0.9706	0.00050
7000	-0.27	-0.00038	0.0014	0.9526	0.00049	0.9523	0.00049
8000	-0.37	-0.0005	0.0014	0.9344	0.00047	0.9339	0.00048
9000	-0.21	-0.00028	0.0014	0.9350	0.00048	0.9347	0.00047
10000	-0.52	-0.00071	0.0014	0.9366	0.00049	0.9359	0.00048
11000	-0.21	-0.00028	0.0013	0.9205	0.00047	0.9202	0.00047
12000	-0.21	-0.00027	0.0013	0.9102	0.00046	0.9099	0.00047
13000	-0.09	-0.00011	0.0013	0.8974	0.00045	0.8973	0.00046
14000	-0.10	-0.00012	0.0013	0.8838	0.00045	0.8837	0.00045
15000	-0.07	-0.00008	0.0012	0.8496	0.00043	0.8495	0.00044
16000	0.14	0.00017	0.0012	0.8259	0.00044	0.8261	0.00042
17000	0.01	0.00002	0.0012	0.8042	0.00044	0.8042	0.00041
18000	-0.62	-0.00075	0.0012	0.7910	0.00045	0.7903	0.00041

Table 19: Crosscheck of normalized frequency response at 0 dBm, SP July09 vs. SP Dec08

C.1.2 Crosscheck of Normalized Frequency Response at -10 dBm

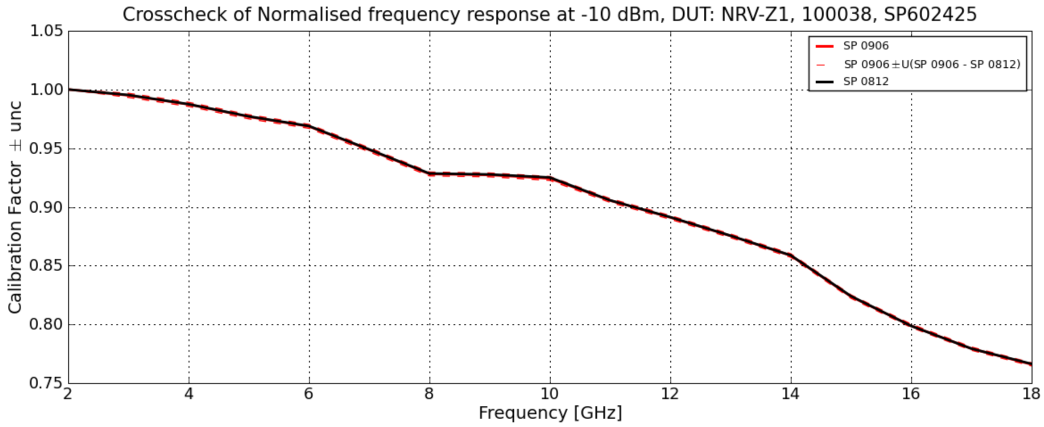

Figure 21:

Calibration Factor ± U(Error) at -10 dBm

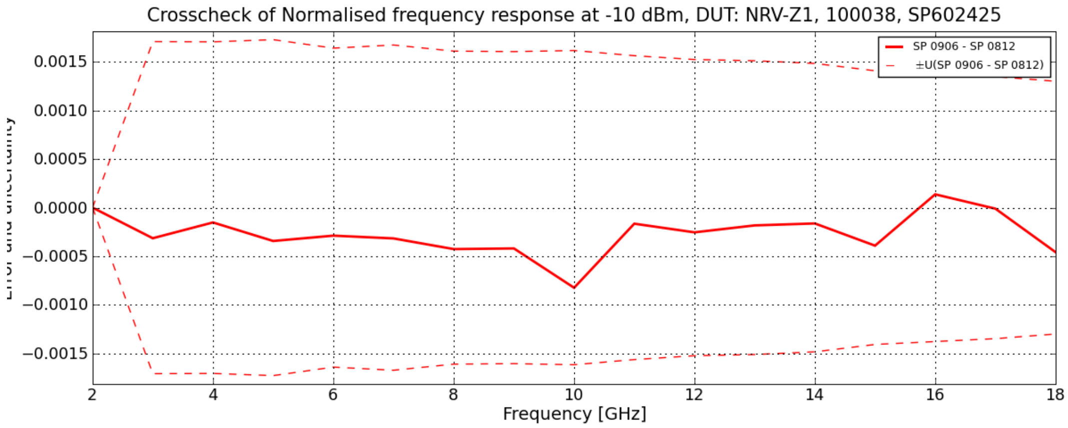

Figure 22:

Error ± U(Error) at -10 dBm

Frequency MHz	En	Error	U(Error)	CF_{SP_0812}	$u(CF_{SP\_0812})$	CF_{SP_0906}	$u(CF_{SP\_0906})$
2000	0	0	0	1	0	1	0
3000	-0.18	-0.00032	0.0017	0.9953	0.00061	0.9950	0.00060
4000	-0.09	-0.00015	0.0017	0.9875	0.00059	0.9873	0.00062
5000	-0.20	-0.00034	0.0017	0.9771	0.00062	0.9767	0.00061
6000	-0.18	-0.00029	0.0016	0.9688	0.00058	0.9686	0.00058
7000	-0.19	-0.00032	0.0017	0.9489	0.00060	0.9486	0.00058
8000	-0.27	-0.00043	0.0016	0.9285	0.00058	0.9280	0.00056
9000	-0.26	-0.00042	0.0016	0.9276	0.00057	0.9272	0.00057
10000	-0.51	-0.00083	0.0016	0.9251	0.00057	0.9242	0.00058
11000	-0.11	-0.00017	0.0016	0.9056	0.00056	0.9054	0.00055
12000	-0.17	-0.00025	0.0015	0.8913	0.00054	0.8910	0.00054
13000	-0.12	-0.00018	0.0015	0.8755	0.00054	0.8753	0.00053
14000	-0.11	-0.00016	0.0015	0.8588	0.00051	0.8586	0.00054
15000	-0.28	-0.00039	0.0014	0.8240	0.00050	0.8237	0.00050
16000	0.10	0.00014	0.0014	0.7986	0.00048	0.7988	0.00049
17000	-0.01	-0.00001	0.0014	0.7793	0.00048	0.7793	0.00047
18000	-0.35	-0.00046	0.0013	0.7663	0.00046	0.7659	0.00046

Table 20: Crosscheck of normalized frequency response at -10 dBm, SP July09 vs. SP Dec08

C.1.3 Crosscheck of Normalized Frequency Response at -20 dBm

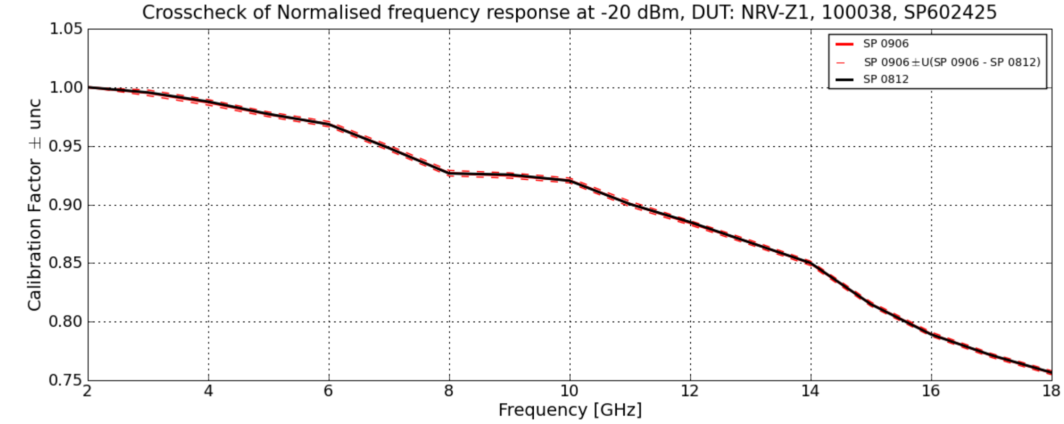

Figure 23:

Calibration Factor ± U(Error) at -20 dBm

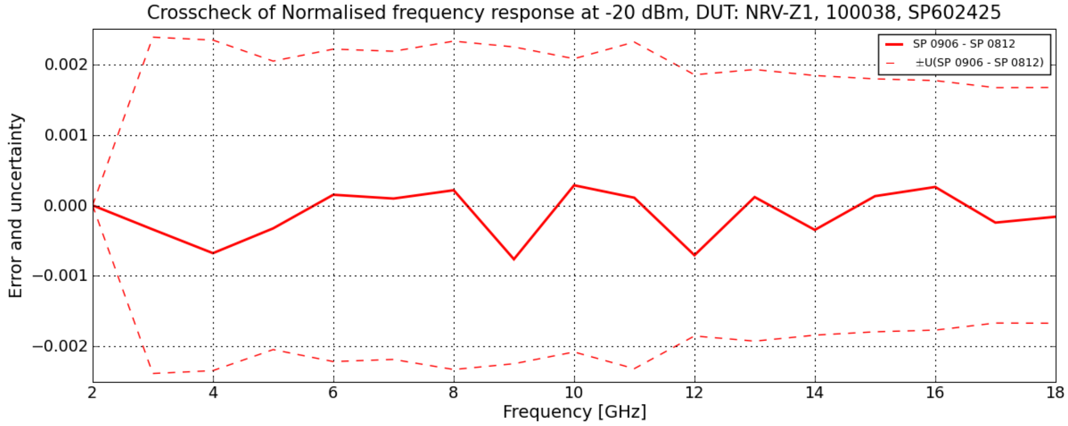

Figure 24:

Error ± U(Error) at -20 dBm

Frequency MHz	En	Error	U(Error)	CF_{SP_0812}	$u(CF_{SP\_0812})$	CF_{SP_0906}	$u(CF_{SP\_0906})$
2000	0	0	0	1	0	1	0
3000	-0.14	-0.00034	0.0024	0.9956	0.00086	0.9952	0.00083
4000	-0.29	-0.00068	0.0024	0.9878	0.00079	0.9871	0.00087
5000	-0.16	-0.00033	0.0021	0.9772	0.00073	0.9769	0.00072
6000	0.07	0.00015	0.0022	0.9684	0.00088	0.9685	0.00069
7000	0.04	0.0001	0.0022	0.9481	0.00082	0.9482	0.00074
8000	0.09	0.00022	0.0023	0.9264	0.00080	0.9267	0.00085
9000	-0.34	-0.00077	0.0023	0.9254	0.00085	0.9247	0.00074
10000	0.14	0.00029	0.0021	0.9202	0.00070	0.9205	0.00077
11000	0.05	0.00011	0.0023	0.9003	0.00083	0.9004	0.00082
12000	-0.38	-0.00071	0.0019	0.8849	0.00070	0.8842	0.00061
13000	0.06	0.00012	0.0019	0.8674	0.00072	0.8675	0.00064
14000	-0.19	-0.00035	0.0019	0.8501	0.00068	0.8497	0.00063
15000	0.07	0.00013	0.0018	0.8148	0.00067	0.8150	0.00060
16000	0.15	0.00026	0.0018	0.7890	0.00064	0.7893	0.00062
17000	-0.15	-0.00025	0.0017	0.7714	0.00063	0.7711	0.00056
18000	-0.10	-0.00016	0.0017	0.7565	0.00065	0.7563	0.00054

Table 21: Crosscheck of normalized frequency response at -20 dBm, SP July09 vs. SP Dec08

C.1.4 Crosscheck of Normalized Frequency Response at - 30 dBm

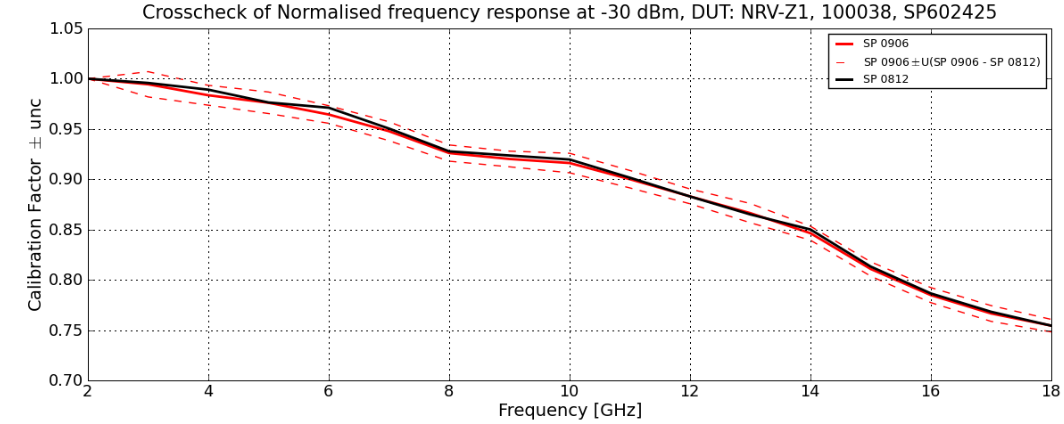

Figure 25:

Calibration Factor ± U(Error) at -30 dBm

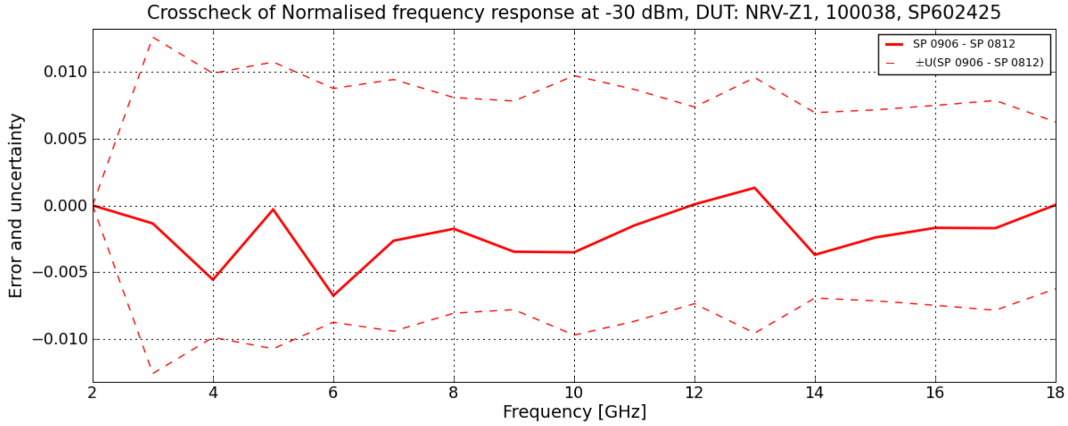

Figure 26:

Error ± U(Error) at -30 dBm

Frequency MHz	En	Error	U(Error)	CF_{SP_0812}	$u(CF_{SP\_0812})$	CF_{SP_0906}	$u(CF_{SP\_0906})$
2000	0	0	0	1	0	1	0
3000	-0.11	-0.0014	0.0126	0.9958	0.00383	0.9945	0.00499
4000	-0.56	-0.00556	0.0099	0.9891	0.00348	0.9835	0.00350
5000	-0.03	-0.0003	0.0107	0.9764	0.00492	0.9761	0.00212
6000	-0.77	-0.00675	0.0087	0.9712	0.00330	0.9644	0.00286
7000	-0.28	-0.00264	0.0094	0.9504	0.00317	0.9478	0.00347
8000	-0.22	-0.00175	0.0081	0.9278	0.00299	0.9260	0.00270
9000	-0.44	-0.00347	0.0078	0.9237	0.00247	0.9202	0.00302
10000	-0.36	-0.00351	0.0097	0.9197	0.00424	0.9162	0.00235
11000	-0.17	-0.0015	0.0087	0.9016	0.00367	0.9001	0.00231
12000	0.01	0.00008	0.0074	0.8829	0.00233	0.8830	0.00284
13000	0.14	0.00131	0.0096	0.8650	0.00299	0.8664	0.00373
14000	-0.53	-0.0037	0.0069	0.8501	0.00250	0.8464	0.00240
15000	-0.34	-0.0024	0.0071	0.8132	0.00250	0.8108	0.00255
16000	-0.23	-0.00168	0.0075	0.7865	0.00336	0.7848	0.00164
17000	-0.22	-0.0017	0.0078	0.7682	0.00220	0.7665	0.00324
18000	0.01	0.00003	0.0062	0.7544	0.00203	0.7544	0.00236

Table 22: Crosscheck of normalized frequency response at -30 dBm, SP July09 vs. SP Dec08

C.2 Crosscheck of Normalized Frequency Response, SP Nov09 vs. SP Dec08

C.2.1 Crosscheck of Normalized Frequency Response at 0 dBm

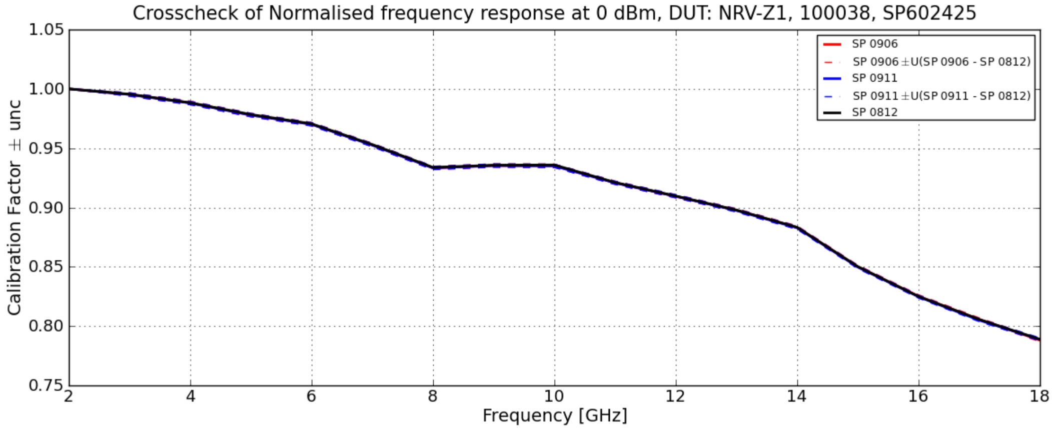

Figure 27:

Calibration Factor ± U(Error) at 0 dBm

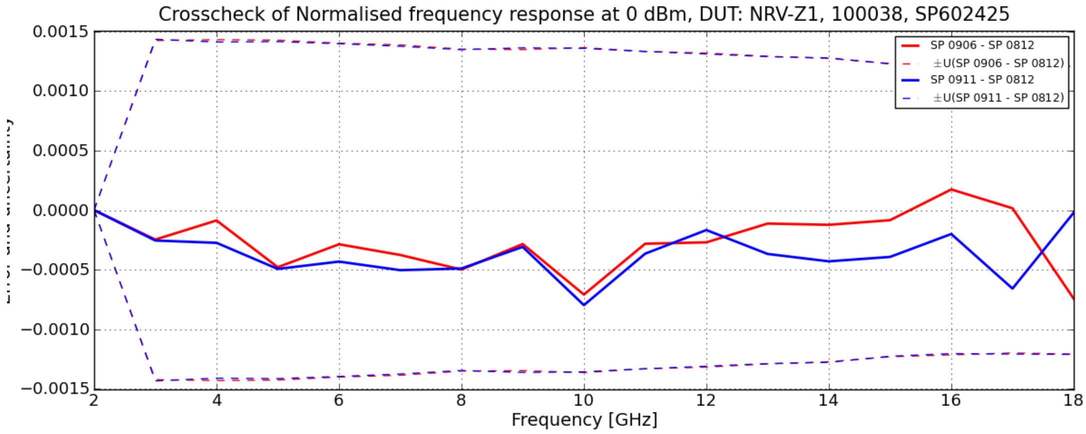

Figure 28:

Error ± U(Error) at 0 dBm

Frequency MHz	En	Error	U(Error)	CF_{SP_0812}	$u(CF_{SP\_0812})$	CF_{SP_0911}	$u(CF_{SP\_0911})$
2000	0	0	0	1	0	1	0
3000	-0.18	-0.00026	0.0014	0.9955	0.00051	0.9953	0.00051
4000	-0.20	-0.00027	0.0014	0.9883	0.00050	0.9880	0.00050
5000	-0.35	-0.00049	0.0014	0.9784	0.00050	0.9779	0.00050
6000	-0.31	-0.00043	0.0014	0.9705	0.00050	0.9701	0.00049
7000	-0.37	-0.0005	0.0014	0.9531	0.00049	0.9526	0.00048
8000	-0.36	-0.00049	0.0014	0.9338	0.00047	0.9333	0.00048
9000	-0.23	-0.00031	0.0014	0.9356	0.00048	0.9353	0.00048
10000	-0.59	-0.0008	0.0014	0.9359	0.00048	0.9351	0.00048
11000	-0.28	-0.00037	0.0013	0.9211	0.00047	0.9208	0.00047
12000	-0.13	-0.00017	0.0013	0.9097	0.00046	0.9095	0.00046
13000	-0.29	-0.00037	0.0013	0.8978	0.00045	0.8975	0.00046
14000	-0.34	-0.00043	0.0013	0.8833	0.00045	0.8829	0.00045
15000	-0.32	-0.00039	0.0012	0.8502	0.00043	0.8498	0.00044
16000	-0.17	-0.0002	0.0012	0.8250	0.00044	0.8248	0.00042
17000	-0.55	-0.00066	0.0012	0.8057	0.00044	0.8050	0.00042
18000	-0.02	-0.00002	0.0012	0.7889	0.00045	0.7888	0.00041

Table 23: Crosscheck of normalized frequency response at 0 dBm, SP Nov09 vs. SP Dec08

C.2.2 Crosscheck of Normalized Frequency Response at -10 dBm

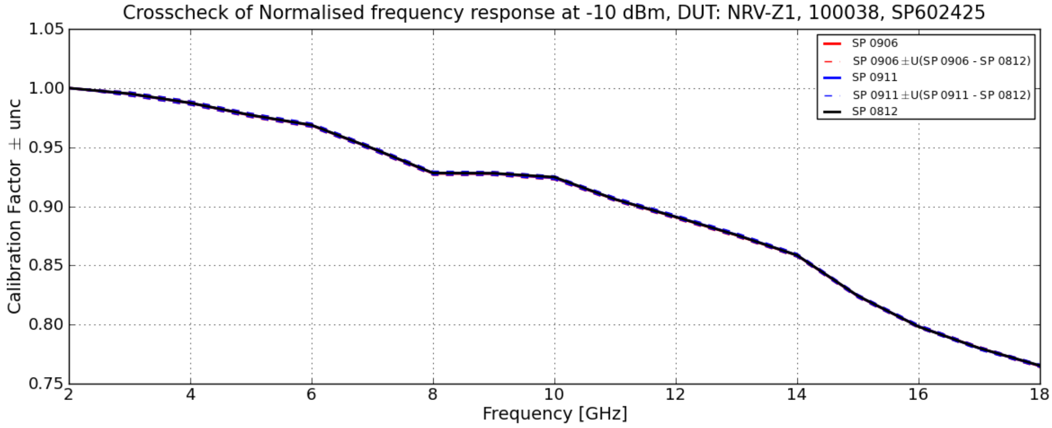

Figure 29:

Calibration Factor ± U(Error) at -10 dBm

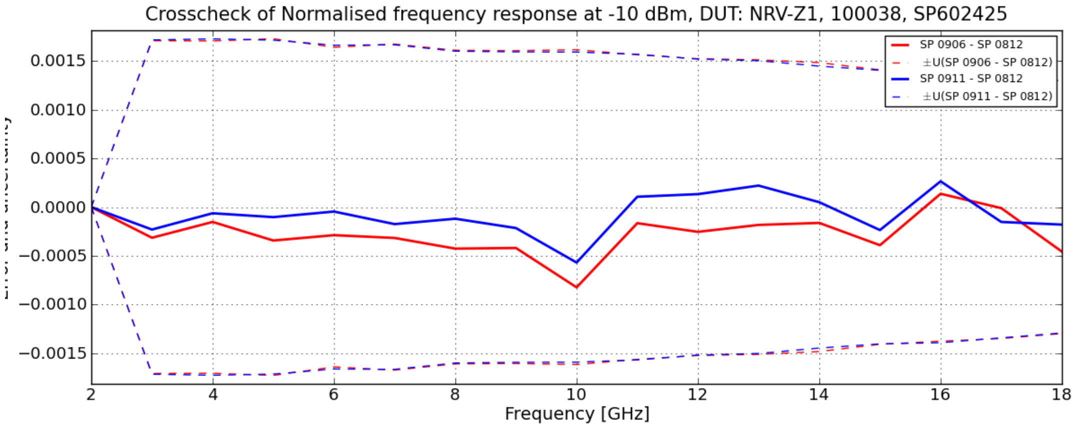

Figure 30:

Error ± U(Error) at -10 dBm

Frequency MHz	En	Error	U(Error)	CF_{SP_0812}	$u(CF_{SP\_0812})$	CF_{SP_0911}	$u(CF_{SP\_0911})$
2000	0	0	0	1	0	1	0
3000	-0.13	-0.00023	0.0017	0.9953	0.00061	0.9950	0.00061
4000	-0.04	-0.00006	0.0017	0.9874	0.00059	0.9874	0.00063
5000	-0.06	-0.0001	0.0017	0.9771	0.00062	0.9770	0.00060
6000	-0.03	-0.00005	0.0017	0.9687	0.00058	0.9686	0.00059
7000	-0.11	-0.00018	0.0017	0.9492	0.00060	0.9490	0.00058
8000	-0.08	-0.00012	0.0016	0.9282	0.00058	0.9280	0.00056
9000	-0.14	-0.00022	0.0016	0.9280	0.00057	0.9277	0.00056
10000	-0.36	-0.00057	0.0016	0.9247	0.00056	0.9241	0.00056
11000	0.07	0.00011	0.0016	0.9059	0.00056	0.9060	0.00055
12000	0.09	0.00013	0.0015	0.8910	0.00054	0.8911	0.00054
13000	0.15	0.00022	0.0015	0.8757	0.00054	0.8759	0.00053
14000	0.04	0.00005	0.0015	0.8585	0.00051	0.8586	0.00051
15000	-0.17	-0.00024	0.0014	0.8243	0.00050	0.8241	0.00050
16000	0.19	0.00026	0.0014	0.7982	0.00048	0.7985	0.00051
17000	-0.11	-0.00015	0.0013	0.7800	0.00048	0.7799	0.00047
18000	-0.14	-0.00018	0.0013	0.7653	0.00046	0.7651	0.00046

Table 24: Crosscheck of normalized frequency response at -10 dBm, SP Nov09 vs. SP Dec08

C.2.3 Crosscheck of Normalized Frequency Response at -20 dBm

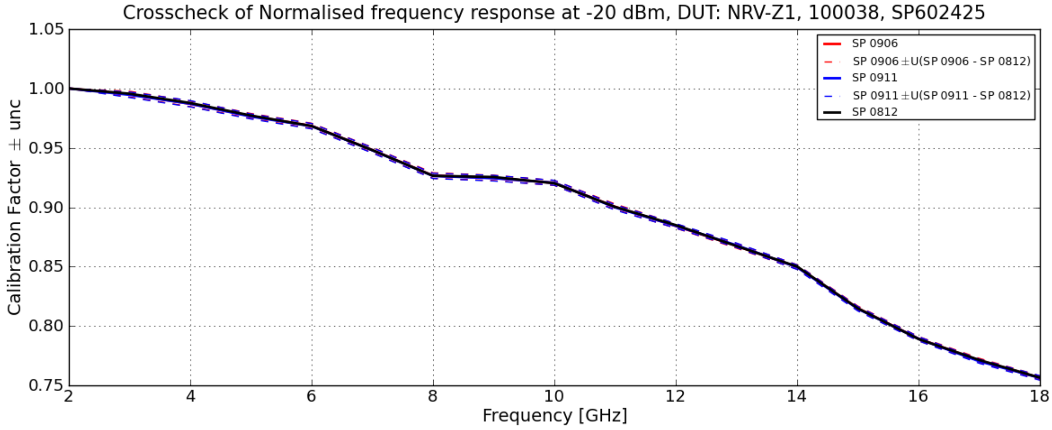

Figure 31:

Calibration Factor ± U(Error) at -20 dBm

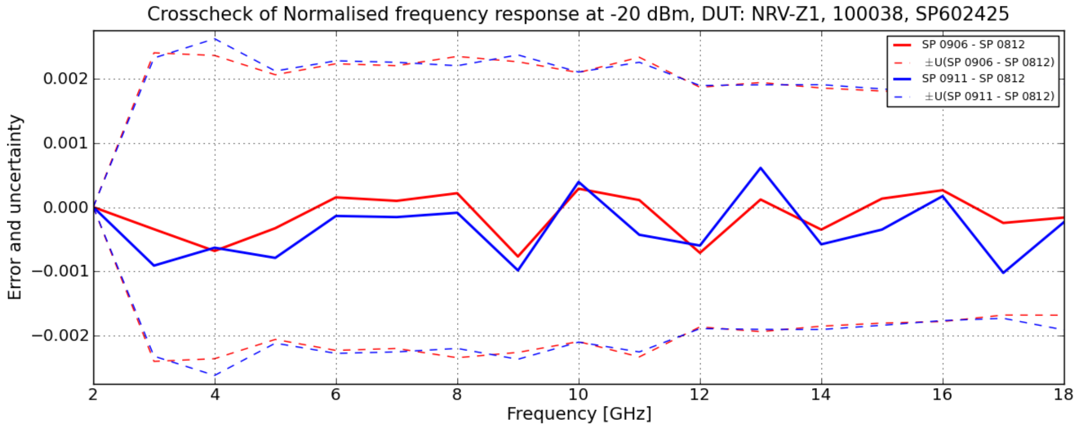

Figure 32:

Error ± U(Error) at -20 dBm

Frequency MHz	En	Error	U(Error)	CF_{SP_0812}	$u(CF_{SP\_0812})$	CF_{SP_0911}	$u(CF_{SP\_0911})$
2000	0	0	0	1	0	1	0
3000	-0.39	-0.00091	0.0023	0.9956	0.00086	0.9947	0.00077
4000	-0.24	-0.00063	0.0026	0.9878	0.00079	0.9872	0.00104
5000	-0.37	-0.00079	0.0021	0.9772	0.00073	0.9764	0.00076
6000	-0.06	-0.00014	0.0023	0.9684	0.00088	0.9682	0.00072
7000	-0.07	-0.00016	0.0023	0.9481	0.00082	0.9479	0.00077
8000	-0.04	-0.00009	0.0022	0.9264	0.00080	0.9264	0.00075
9000	-0.42	-0.00098	0.0024	0.9254	0.00085	0.9245	0.00082
10000	0.19	0.00039	0.0021	0.9202	0.00070	0.9206	0.00078
11000	-0.19	-0.00043	0.0023	0.9003	0.00083	0.8999	0.00076
12000	-0.32	-0.0006	0.0019	0.8849	0.00070	0.8843	0.00063
13000	0.32	0.00061	0.0019	0.8674	0.00072	0.8680	0.00062
14000	-0.30	-0.00058	0.0019	0.8501	0.00068	0.8495	0.00067
15000	-0.19	-0.00035	0.0018	0.8148	0.00067	0.8145	0.00062
16000	0.10	0.00017	0.0018	0.7890	0.00064	0.7892	0.00061
17000	-0.59	-0.00102	0.0017	0.7714	0.00063	0.7703	0.00060
18000	-0.12	-0.00023	0.0019	0.7565	0.00065	0.7563	0.00070

Table 25: Crosscheck of normalized frequency response at -20 dBm, SP Nov09 vs. SP Dec08

C.2.4 Crosscheck of Normalized Frequency Response at -30 dBm

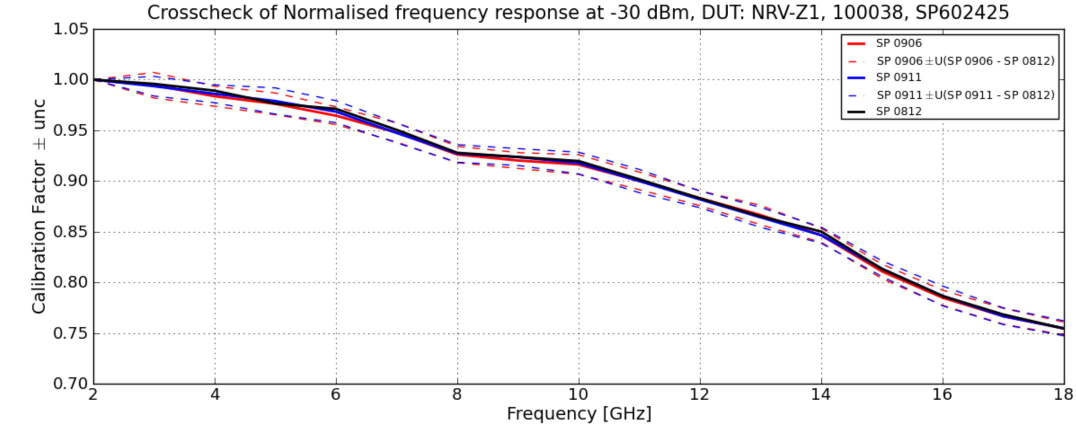

Figure 33:

Calibration Factor ± U(Error) at -30 dBm

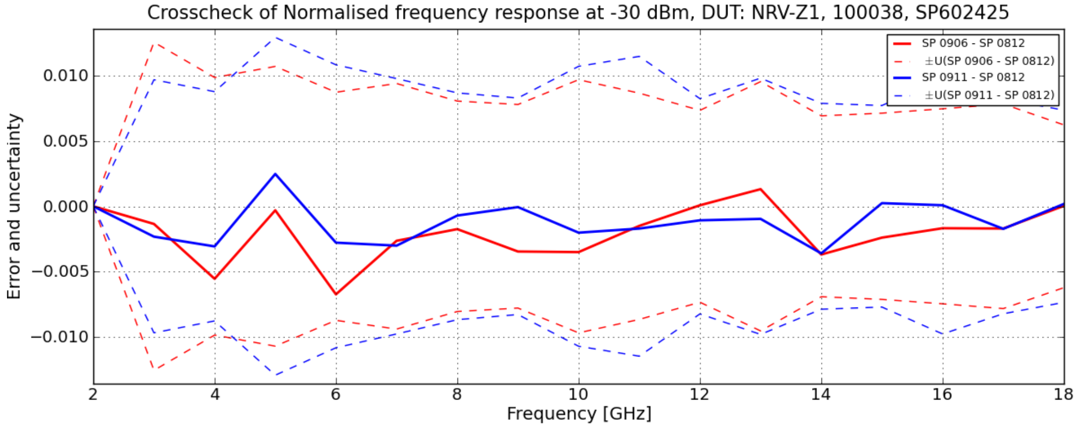

Figure 34:

Error ± U(Error) at -30 dBm

Frequency MHz	En	Error	U(Error)	CF_{SP_0812}	$u(CF_{SP\_0812})$	CF_{SP_0911}	$u(CF_{SP\_0911})$
2000	0	0	0	1	0	1	0
3000	-0.24	-0.00233	0.0097	0.9958	0.00383	0.9935	0.00298
4000	-0.35	-0.00308	0.0088	0.9891	0.00348	0.9860	0.00268
5000	0.19	0.0025	0.0129	0.9764	0.00492	0.9789	0.00420
6000	-0.26	-0.0028	0.0108	0.9712	0.00330	0.9684	0.00430
7000	-0.31	-0.00302	0.0098	0.9504	0.00317	0.9474	0.00372
8000	-0.08	-0.00071	0.0087	0.9278	0.00299	0.9271	0.00315
9000	-0.01	-0.00006	0.0083	0.9237	0.00247	0.9236	0.00333
10000	-0.19	-0.002	0.0107	0.9197	0.00424	0.9176	0.00328
11000	-0.15	-0.0017	0.0115	0.9016	0.00367	0.8999	0.00442
12000	-0.13	-0.00108	0.0083	0.8829	0.00233	0.8818	0.00340
13000	-0.10	-0.00097	0.0098	0.8650	0.00299	0.8641	0.00390
14000	-0.46	-0.00361	0.0079	0.8501	0.00250	0.8465	0.00305
15000	0.03	0.00024	0.0077	0.8132	0.00250	0.8134	0.00294
16000	0.01	0.00008	0.0098	0.7865	0.00336	0.7865	0.00356
17000	-0.21	-0.00173	0.0082	0.7682	0.00220	0.7665	0.00348
18000	0.03	0.00018	0.0074	0.7544	0.00203	0.7546	0.00307

Table 26: Crosscheck of normalized frequency response at -30 dBm, SP Nov09 vs. SP Dec08

D. Technical Protocol

Measurement Comparison:
Characterisation of diode power sensors
Technical Protocol Ver. 10-2009

Foreword

SP and METAS have agreed on a bilateral inter laboratory comparison of a radio frequency (RF) diode power sensor.
The main goal of the comparison is the characterisation of the RF diode power sensor at different power levels, whereas thermal power sensors are normally calibrated only at one RF power level (typically at 1 mW).
This first comparison offers the participants the possibility to verify their measurement procedures including the evaluation of measurement uncertainty and it provides a possibility to find and fix errors.

Participants

Interest in participation have expressed so far:
- SP Swedish National Testing and Research Institute, Box 857, SE-501 15 BORAS, Sweden
- Federal Office of Metrology METAS, CH-3003 Bern-Wabern, Switzerland

SP and METAS share the duties of the pilot laboratory as follows:
SP prepares the device under calibration, adopts the coordination of the measurements, adopts the evaluation of the results and performs the control measurements to record the stability of the device.
METAS acts as a coordinator of the Euramet project, and writes the reports.

Device under calibration

The measurement standard is a diode power sensor type NRV-Z1, sn100038 (R&S) with a frequency range 10 MHz to 18 GHz (type N-connector) and a dynamic range from -67 dBm to + 13 dBm.
Included is a power meter type NRVS, sn100087 (R&S) for the readout of the sensor.
The devices are provided by SP.

Measurands

The measurands of this comparison are:

- Calibration factor (relative to the calibration factor at 50 MHz) at the 4 power levels 1 µW, 10 µW, 100 µW and 1 mW (-30 dBm, -20 dBm, -10 dBm and 0 dBm), expressed in W/W. Test frequencies (25): 50, 75, 100, 200, 300, 500, 750 MHz, 1 GHz, 2 GHz … 18 GHz.
- Complex input reflection coefficient at the same frequencies at a power levels of 10 µW and 1 mW (-20 dBm and 0 dBm), expressed in real and imaginary parts.
- Linearity, related to the value at 10 µW (-20 dBm), in the input power range of 1 nW to 20 mW (- 60 dBm to + 10 dBm in 5 dB steps and + 13 dBm), for the test frequencies 50 MHz and 1 GHz, expressed as a deviation of linearity in dB.

Documentation of the results

The participants are asked to document their results in the form of a calibration certificate and a GUM compliant measurement uncertainty budget.

Analysis and report

The analysis of the comparison will be confidential and the initial report will only be available to the participants. After approval by all participants the final report with the results of the comparison will be published in the Euramet database.

Time table

Date	***Participant***	***transfer to***
December 2008	SP	METAS
February & March 2009	METAS	SP
June 2009	SP, control measurements	
June & July 2009	Analysis by SP and discussion of the results and the report by the participants	
October 2009	Final report to EURAMET	

E. References

[1] International Organization for Standardization, Geneva. Guide to the expression of uncertainty in measurement, 1995.

[2] Juroshek, J. R. NIST: 0.05 - 50 GHz Direct Comparison Power Calibration System; Conference on Precision Electromagnetic Measurements , May 14-19, 2000, Syndey, Australia - May 01, 2000.

[3] John R. Juroschek: „A Direct Calibration Method For Measuring Equivalent Source Mismatch“; Microwave Journal, October 1997.

[4] Holland, K., and Howes, J.: Improvements to the Microwave Mixer and Power Sensor Linearity Measurement Capability at the National Physical Laboratory. IEE Proc.-Scientific Measurement Technology, Nov. 2002.

[5] Agilent: Fundamentals of RF and Microwave Power Measurements (Part 2), Power Sensors and Instrumentation. Agilent AN 1449-2, p.14 ff, 5988-9214EN.

[6] K. Yhland, J. Stenarson, and C. Wingqvist: Power Sensor Linearity Calibration with an Unknown Attenuator. To be presented at Conference on Precision Electromagnetic Measurements, June 2010, Daejeon, Korea