CCEM.RF-K9.1

Bilateral Comparison

Thermal Noise Standards at 12.4, 13.5, 15 and 17.5 GHz
Supplement of International comparison of thermal noise standards
between 12.4 GHz and 18 GHz (CCEM.RF-K9)

Final Report

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Introduction

A bilateral comparison subsequent upon key comparison CCEM.RF-K9 was decided between VNIIFTRI and PTB. It was registered into the BIPM KCDB under the identifier CCEM.RF-K9.1. The results of this comparison were gathered by the pilot laboratory of comparison CCEM.RF-K9 (LNE).

Organisation of the comparison

Time slots of 3 months were planned for measurements and transportation to the next participant. One supplementary month was allocated for preparation and sending of the measurement report to the pilot laboratory.

Travelling standard

The travelling standard is a waveguide gas discharge noise generator with 16×8 output flange associated to 16×8/R140 adapter, with a power supply. Two reserve gas discharge tubes (maximum difference of noise levels of 0.02 dB) were also supplied.
The specifications of the travelling standard are:
ENR (approx): 18 dB
Gas discharge tube current: 150 ± 0.5 mA
Max SWR: 1.2

Method of measurement

PTB used an RF-switching Dicke-type radiometer for the waveguide band R140 with RF attenuator at the input. The measurement input and the noise source output are separately tuned for $|\Gamma| = 0$. The unknown sources are calibrated against a working standard of about 10000 K, which is calibrated referred to PTB's hot primary standard (650 K).

VNIIFTRI followed the same measurement method used in CCEM.RF-K9.

As follows from CCEM.RF-K9 KEY COMPARISON Final Report, the most appreciable outliers have been received at 12.4 and 17.5 GHz for traveling standards, having noise level about 15 dB. It turned out that the reason of such results was a calibration defect of the basic measuring device on the radiometer input – rotary vane attenuator (RVA) which provided at comparison decrease on 10 dB of measured noise levels. The attempts of elimination of the defect were interfered by the problems which have arisen from the equipment for attenuators verification and from the RVA. Finally RVA was replaced by an attenuator of the same type graduated by the simplified technique with uncertainty 0.03 dB (was 0.01 dB earlier).
Another problem – instability of equipment for low loss measurements in waveguides – has been found at Cryogenic Standard (CS) attestation. To eliminate this problem, hardness of VHF components assembling has been increased and measurements method corrected (to take into consideration the sliding shorts wear).
The relative uncertainty increase caused by mismatch factors at frequency 17.5 GHz can be explained by broadband mismatch of the CS's tuner.
The correction factor on losses in the additional adapter was not taken into account because calculated value of the return loss at 12,4-18,0 GHz was not less than 44 dB and measured attenuation was not more than 10-3 dB.

Measurement results and uncertainty budgets

The parameters to be measured are the magnitude of the reflection coefficient |Γ|, in linear units, the available noise temperature T (K) and the excess noise ratio ENR (dB). These parameters have been measured at the following frequencies: 12.4, 13.5, 15.0 and 17.5 GHz.
Measurements results are reported in tables 1.1 and 2.1.
Uncertainty budgets are reported in tables 1.2 and 2.2.
Uncertainties are given as one standard deviation uncertainties.

The measurement results are plotted in Figures 1 and 2 for available noise temperature and excess noise ratio respectively. Combined type A and type B uncertainties have been plotted as one standard deviation uncertainties.

The Comparison reference value, *CRV*, is calculated as the unweighted mean of the participants' results and its uncertainty, u_{CRV}, is calculated as the experimental standard deviation of the mean.

The Degree of equivalence of each laboratory with respect to Comparison reference value is given by $\Delta_i = x_i - CRV$, and its uncertainty is given by $u_{\Delta i} = \left(u^2(x_i) - u^2_{CRV}\right)^{0.5}$, where x_i is the measurement result of laboratory *i*, for available noise temperature or excess noise ratio.

Presentation of the results relative to the Comparison reference value is given in Figures 3 and 4 for available noise temperature (Δ_T) and excess noise ratio (Δ_{ENR}) respectively.
Uncertainties for the Comparison reference value and the Degrees of equivalence have been plotted as two standard deviation uncertainties.

Conclusion

A bilateral comparison subsequent upon key comparison CCEM.RF-K9 has been organised between PTB and VNIIFTRI. A very good agreement is found between both participants.

PTB measurements
Date of calibration: 08.12.2003-16.12.2003
Room Temperature: 23 °C

F (GHz)	|Γ|	T (K)	ΔT (K)	ENR (dB)	ΔENR (dB)
12.4	0.02	18187	105	17.904	0.025
13.5	0.02	18298	122	17.931	0.029
15.0	0.01	18290	135	17.929	0.032
17.5	0.01	18192	147	17.905	0.036

Table 1.1: PTB measurements

PTB uncertainties

f(GHz)	12.4	13.5	15	17.5
Standard*	97.2	117	130	142
Ambient*	-0.358	-0.361	-0.363	-0.364
Mismatch after Tuning*	17.5	5.44	2.05	2.44
Attenuation with Standard*	2.06	2.07	2.07	2.06
Attenuation with unknown*	-2.06	-2.07	-2.07	-2.06
Tuner Attenuation Variation*	0	3.85	0	12.6
Source Power*	23.8	23.9	23.9	23.8
Resolution*	23.8	23.9	23.9	23.8
Null Detector (Type A)	7.48	3.95	7.17	9.22
Total	105	122	135	147

* Type B

Table 1.2: PTB uncertainties

VNIIFTRI measurements
Date of calibration: 11.02.2007-16.04.2007
Room Temperature: (22±3) °C, Room Humidity: <70 %

F (GHz)	|Γ|	T (K)	ΔT (K)	ENR (dB)	ΔENR (dB)
12.4	0.03	18370	134	17.948	0.032
13.5	0.03	18387	158	17.952	0.038
15.0	0.03	18196	145	17.906	0.035
17.5	0.02	18378	190	17.950	0.046

Table 2.1: VNIIFTRI measurements

VNIIFTRI Uncertainties

F(GHz)	12.4	13.5	15	17.5
Cryogenic Standard	37	21	19	21
Ambient Standard	17	17	17	17
Mismatch factors	36	28	7	146
Attenuation 10 dB Meas.	71	71	70	71
Nonlinearity	50	100	103	50
Resistive divider	83	79	62	62
Adapter	0	0	0	0
Type A	23	46	33	50
Total	134	158	145	190

Table 2.2: VNIIFTRI uncertainties

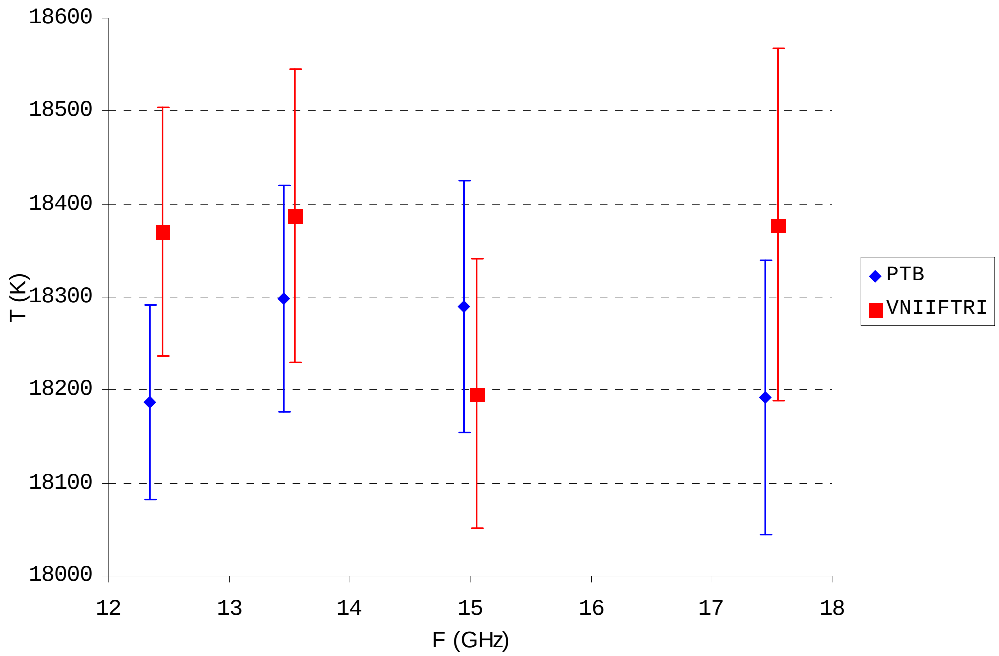

Figure 1: Available noise temperature at 12.4, 13.5, 15 and 17.5 GHz

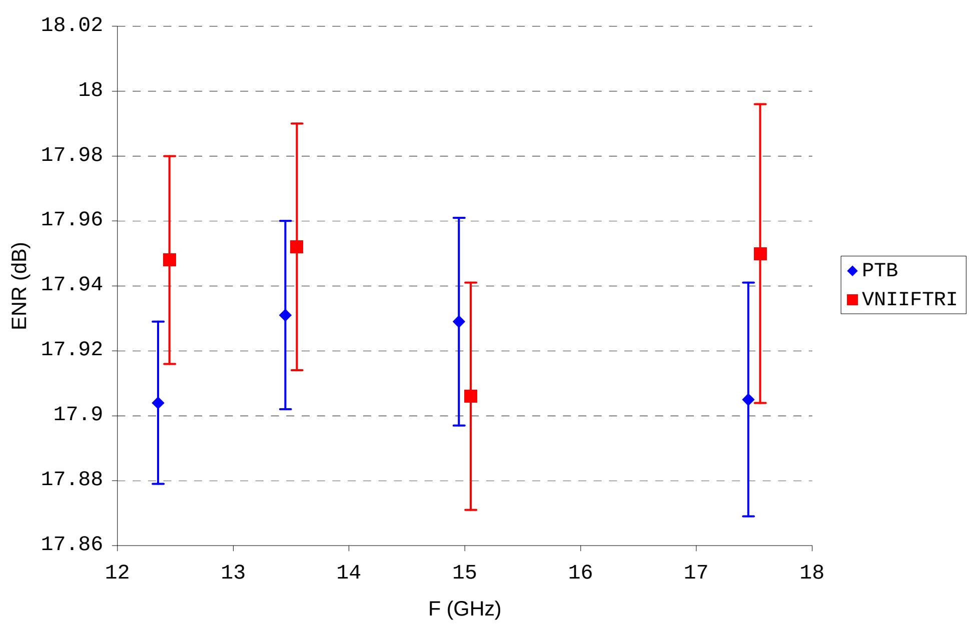

Figure 2: Excess noise ratio at 12.4, 13.5, 15 and 17.5 GHz

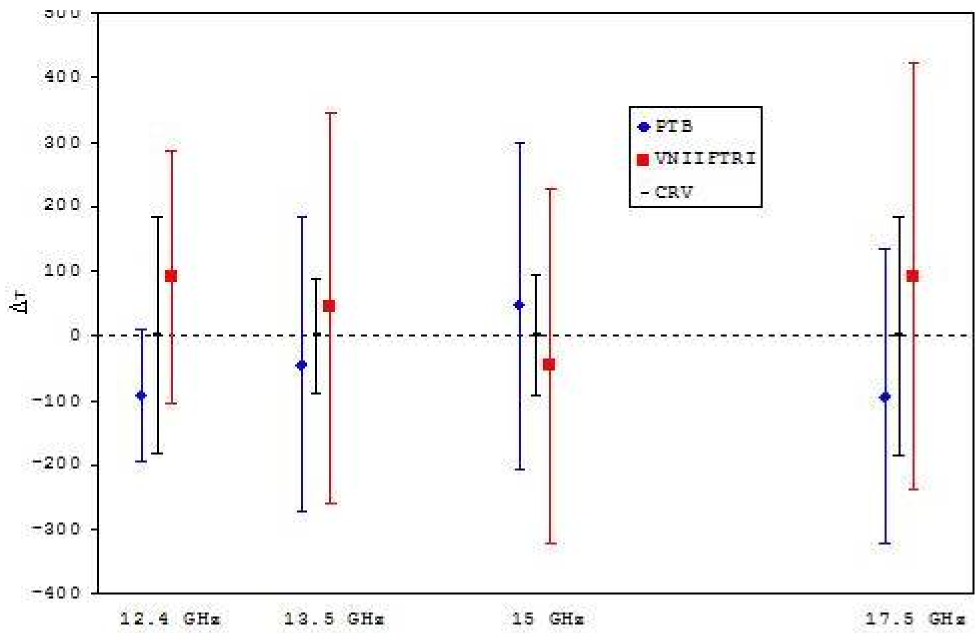

Figure 3: Degree of equivalence for the available noise temperature
at 12.4, 13.5, 15 and 17.5 GHz

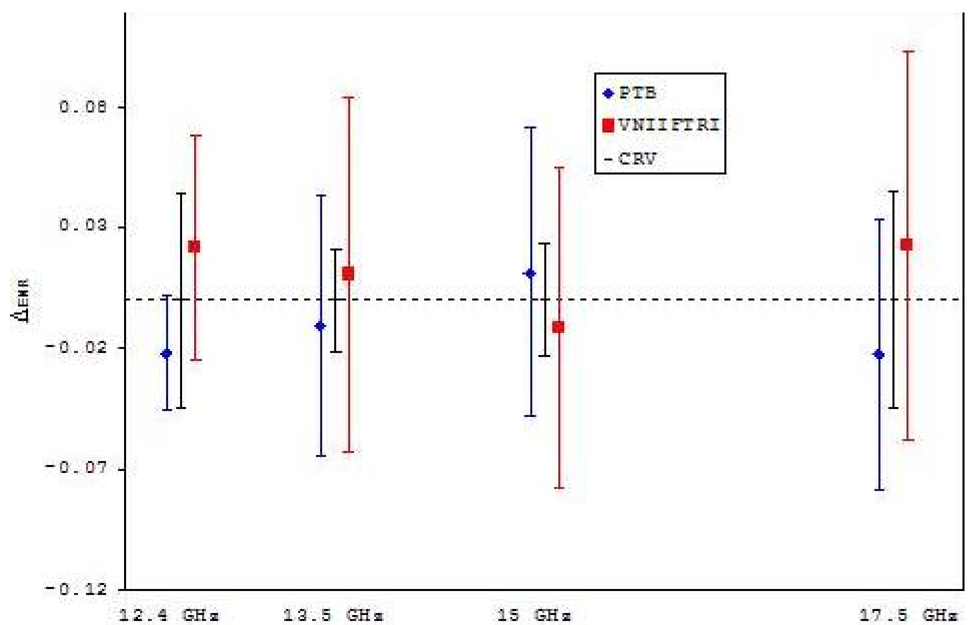

Figure 4: Degree of equivalence for the excess noise ratio
at 12.4, 13.5, 15 and 17.5 GHz