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Bilateral Comparison of 1 Ω Standards
(ongoing BIPM key comparison BIPM.EM-K13.a)
between the NML (Ireland) and the BIPM, June 2004

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A comparison of the 1 Ω reference standards of the BIPM and the National Metrology Laboratory (NML, Dublin, Ireland) was carried out from March to July 2004. Two BIPM 1 Ω travelling standards, BIV193 and BIV207, were shipped to the NML by air courier. The BIPM measurements were carried out by comparison with a 100 Ω reference resistor whose value is known with respect to the BIPM quantized Hall resistance (QHR) standard. The current in the 1 Ω resistors during the measurements was 50 mA. The NML carried out measurements of the travelling standards by a substitution method using a current comparator resistance bridge. The NML resistance standard is maintained with respect to R_{K-90} by means of periodic calibrations and comparisons with the BIPM and by extrapolation of the secular behaviour of its reference group. The measuring current used was also 50 mA. The reference temperature is 23 °C. Both NML and BIPM measurements were carried out at temperatures close to the reference temperature, to within 0.02 °C. The results are referred to the reference temperature. The pressure coefficients of the traveling standards are negligible.

Figures 1 and 2 show the measured values obtained for the two standards by the two laboratories. The BIPM values and uncertainties are calculated for the reference date, the mean date of the NML measurements (28 April 2004), from linear least-squares fits. Those of the NML are calculated from the mean of the measured values.

Table 1 lists the results and the component uncertainty contributions for the comparison NML/BIPM. Table 2 lists the uncertainties associated with maintenance and measuring equipment at the BIPM and Table 3 lists the uncertainties associated with maintenance and measuring equipment at the NML.

The following elements are listed in Table 1:

(1) the mean resistance value R_{NML} of each resistor measured by the NML;
(2) the Type A uncertainty due to the instability of the resistors and the measuring equipment, computed as the standard uncertainty of the mean value;

(3) the Type B uncertainty component due to the measuring equipment of the NML. This uncertainty is partially correlated between the different travelling standards used for a comparison and the contributions that are completely or at least partially correlated are indicated by asterisks (*) in Table 3;

(4-6) the corresponding quantities for the BIPM;

(7) the difference ($R_{\mathrm{NML}} - R_{\mathrm{BIPM}}$) for each resistor, and (8) the clearly uncorrelated (Type A) part of the uncertainty;

(9) the result of the comparison, which is the mean of the differences of the calibration results for the different standards;

the uncertainty of the transfer, estimated by two methods:

(10) the standard deviation of the mean value of the results, from the different resistors, counting only the Type A uncertainties of the individual results;

(11) the *a posteriori* uncertainty, which is the standard deviation of the mean of the two different results, s_{M};

(12) the total uncertainty of the comparison, which is the root-sum-square of the Type A and Type B uncertainties.

In Table 1, the Type A uncertainties are negligible compared with the estimated Type B uncertainties. As usual, the larger of the two estimates in (10) and (11) is adopted as the Type A uncertainty.

The final results of the comparison are presented as the difference between the value assigned to a 1 Ω standard by each laboratory. The difference between the value assigned by the NML at the NML, R_{NML}, and that assigned by the BIPM, at the BIPM, R_{BIPM}, for the reference date is

$$R_{\mathrm{NML}} - R_{\mathrm{BIPM}} = -0.071\ \mu\Omega\ ;\ u_{\mathrm{c}} = 0.23\ \mu\Omega \text{ on } 2004/04/28,$$

where u_{c} is the combined Type A and Type B standard uncertainty from both laboratories.

This is a most satisfactory result. The difference between the values assigned to the travelling standards by the two laboratories is less than the standard uncertainty associated with the difference.

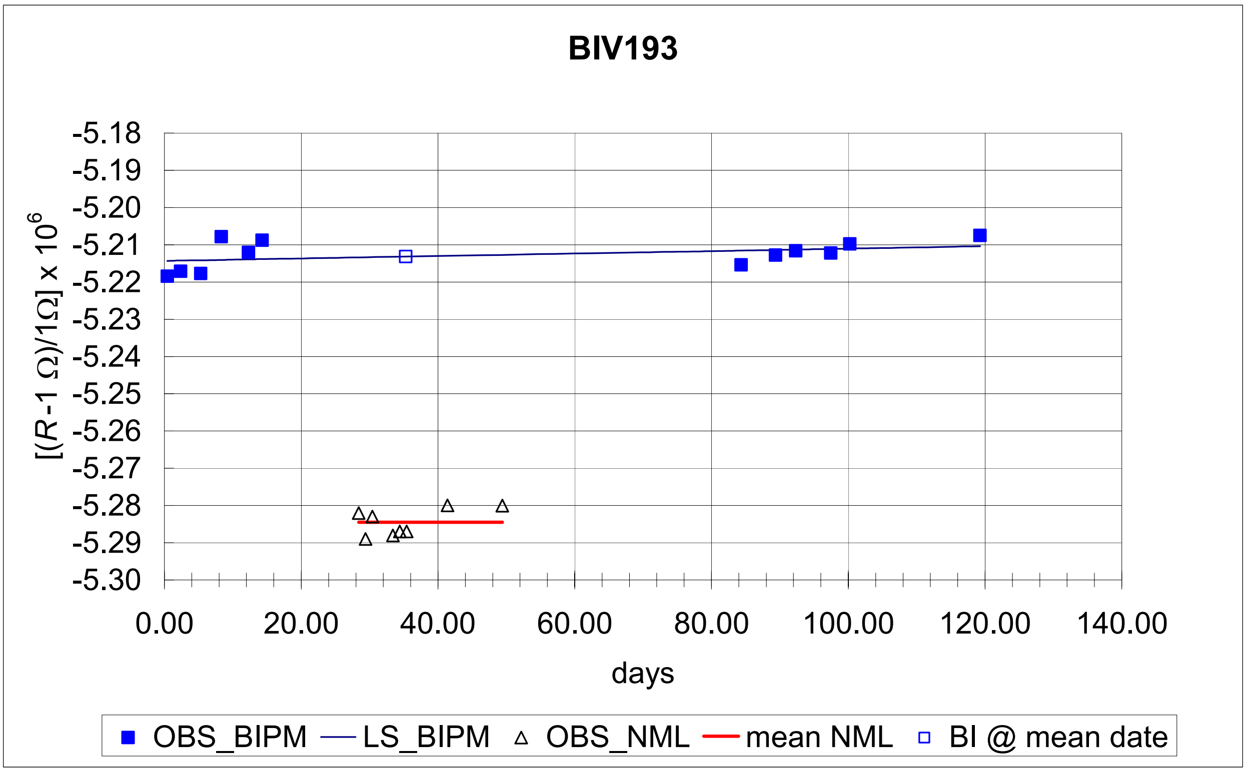

Figure 1. Relative deviation from the nominal 1 Ω value of the resistance of BIV193 vs time: a linear least-squares fit (LS) to the BIPM measurements and the mean of the NML measurements.

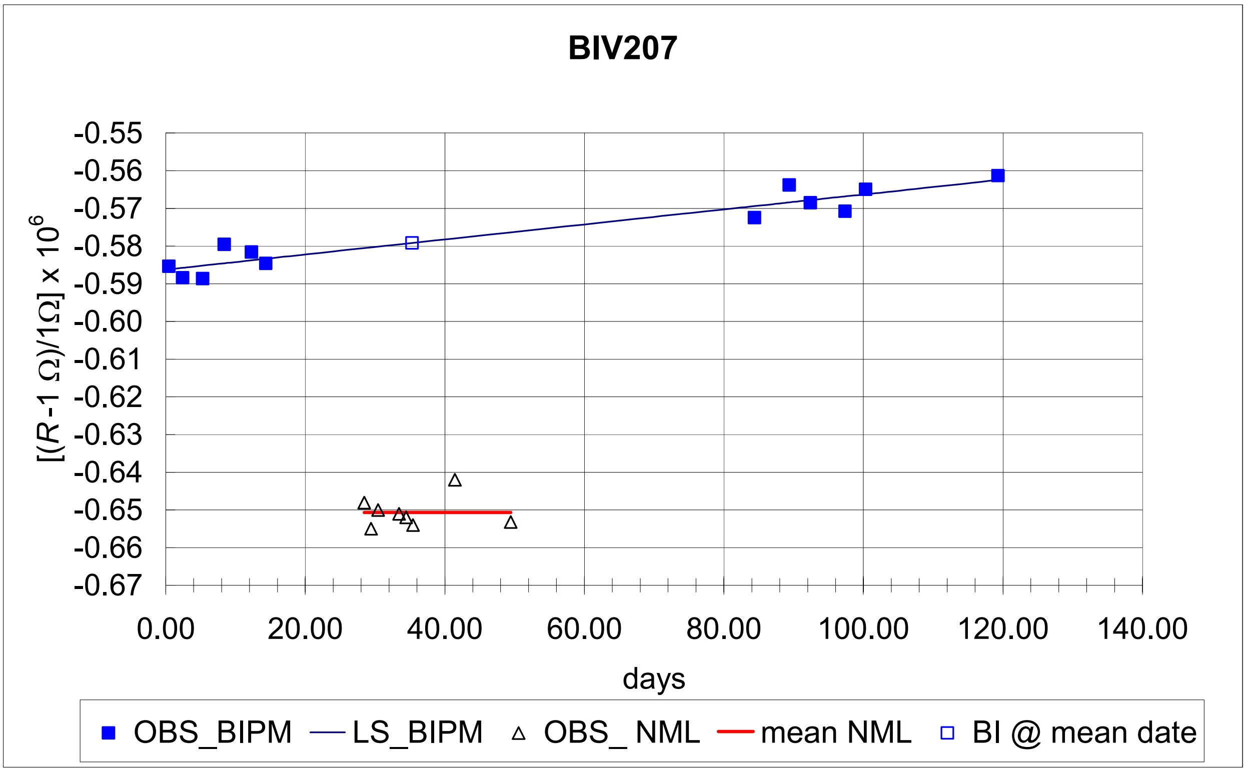

Figure 2. Relative deviation from the nominal 1 Ω value of the resistance of BIV207 vs time: a linear least-squares fit (LS) to the BIPM measurements and the mean of the NML measurements.

Table 1. Results of the NML/BIPM bilateral comparison of 1 Ω standards using two BIPM travelling standards: mean date 28 April 2004. Uncertainties are 1 σ estimates.
The combined Type A uncertainty is $w = [r^2 + t^2]^{1/2}$, the expected transfer uncertainty is $x = [w_{193}^2 + w_{207}^2]^{1/2}/2$ and the total combined uncertainty is $y = [s^2 + u^2 + x^2]^{1/2}$.

			BIV193	BIV207	
1	NML	$(R - 1\ \Omega)/\ \mu\Omega$	−5.2845	−0.6506	
2		type-A uncertainty/ μΩ	0.001	0.001	r
3		type-B uncertainty/ μΩ	0.23		s
4	BIPM	$(R - 1\ \Omega)/\ \mu\Omega$	−5.2132	−0.5792	
5		type-A uncertainty/ μΩ	0.001	0.001	t
6		type-B uncertainty/ μΩ	0.016		u
7		$(R_{NML} - R_{BIPM})/\ \mu\Omega$	−0.0713	−0.0715	
8		combined type-A uncertainty/ μΩ	0.002	0.002	w
9		$< R_{NML} - R_{BIPM} >/\ \mu\Omega$	−0.0714		
10		expected type-A transfer uncertainty/ μΩ	0.001		x
11		s_M of difference for 2 resistors/ μΩ	0.000		
12		total uncertainty in comparison/ μΩ	0.23		y

Table 2. Estimated Type B standard uncertainties, relative to the nominal value, for 1 Ω calibrations with the BIPM equipment. A relative uncertainty of 1×10^{-9} corresponds to 0.001 μΩ.

Realization of $R_H(2)$	2×10^{-9}
Ratio of resistance of 100 Ω reference resistor to $R_H(2)$	3×10^{-9}
Imprecision in the values of the reference resistors (including uncertainties in extrapolated resistance values and residual power, temperature and pressure effects)	13×10^{-9}
Comparison of the travelling standards to the reference resistor (ratio 1 Ω/100 Ω)	9×10^{-9}
Uncertainty in the temperature correction for the travelling standard	1×10^{-9}
Uncertainty in the pressure correction for the travelling standard	1×10^{-9}
rss total	16×10^{-9}

Table 3. Estimated standard uncertainties, relative to the nominal value, for 1 Ω calibrations with the NML equipment. A relative uncertainty of 1×10^{-8} corresponds to 0.01 μΩ. Asterisks (*) indicate components that are either completely correlated or probably significantly correlated when measuring different travelling standards.

Calibrated value of the 1 Ω reference standard*	15×10^{-8}
Bridge ratio	17×10^{-8}
Effects of temperature	0×10^{-8}
rss total	23×10^{-8}