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Differential calibration of BIPM P3 systems: Long term study

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This memorandum expands the long term study of differential calibration of the BIPM P3 systems, initially provided in section 2 of TM172. Results of a differential calibration are the electrical delays of the calibrated system (receiver + antenna) for each frequency P1/P2 with respect to the delays of the reference system. The reader is directed to TM172 and references therein for details on the quantities involved in calibration exercises.

Several systems have been installed at the BIPM and most have been inter-compared:

- BP0C (Ashtech Z12T) since 2000
- BP0M (Ashtech Z12T) since 2004
- BP0O (Septentrio PolaRx2) between 2004 and 2007 (not considered below)
- BP0R (Septentrio PolaRx2) since 2006
- BP0T (Dicom GTR50) since 2007
- BP0U (Dicom GTR50) since 2008
- BP1C (Septentrio PolaRx3) since 2009
- BP1B (TTS-4) since 2010 (not considered below)

Date	BP0M	BP0C	BP0R	BP1C	BP0T	BP0U
May 2004	☺	☺				
February 2005	☺	☺				
March 2005	☺	☺				
January 2006	☺	☺				
May 2006	☺	☺				
November 2006	☺	☺	(1)			
February 2007	☺	☺				
June 2007	☺	☺				
August 2007	☺	☺				
December 2007	☺	☺	☺		☺	☺
March 2008	☺	☺	☺		☺	☺
December 2008	☺	☺	☺		☺	☺
June 2009	☺	☺	☺		☺	☺
November 2009	☺	☺	☺	☺	☺	☺
December 2009	☺	☺	☺	☺	☺	☺
July 2010	☺	☺	☺	☺	☺	☺ (2)
October 2011	☺	☺	☺	☺	☺	☺

Table 1: List of calibration exercises of BIPM P3 systems. (1) A 2006 measurement of BP0R was off by about 5 ns and is not reported here. (2) Starting 2010, BP0U has a new antenna and is considered as a new system.

Since 2004, when at least two systems were available at the BIPM, these systems have been differentially calibrated, i.e. all measurements have been carried out in the same manner as in a true calibration exercise. Seventeen such exercises have been carried out over close to 8 years (see Table 1 for a list).

The system BP0C (Z12T) at the BIPM since 2000 has been absolutely calibrated and serves as the absolute reference (see TM116). However, since BP0C has been a traveling system for many years and might have suffered from this, the system BP0M (Z12T) has been used as a practical reference for all differential calibrations results. Figure 1 presents the delay differences (BP0M-BP0C), with average values P1=-1.3 ns and P2=1.2 ns. Using the BP0C delay values derived from the absolute calibration (P1=305.6 ns; P2=321.9 ns, see TM116) we derive for BP0M the values (P1=304.3 ns; P2=323.1 ns).The conventional values of the BP0M delays have been chosen in 2009 to be 304.5 ns for P1 and 323.0 ns for P2 (see TM192), i.e. are very close to the updated average values. These conventional values are used as a reference for the differential calibration of the other four systems, which results are presented in Figures 2 to 5 (all figures have the same vertical scale).

We see that the long-term repeatability of a differential calibration exercise involving two P3 systems is at a level of at most 1 ns RMS for both P1 and P2, and slightly below for P1-P2. Peak to peak variations for P1 or P2 are below 4 ns in the worst case (over 8 years, see Figure 1). The repeatability of the P3 linear combination (which is the quantity used in practice for time transfer) is at most 2 ns RMS, with peak to peak variations below 8 ns in the worst case. The available results do not clearly allow identifying one system that could be considered less stable than others over the long term. Unless all systems suffer from some common systematic effect, we may conclude that the level of long-term instability for one system may be at a level of order 0.7 ns RMS for both P1 and P2, and of order 1.5 ns for P3.

Acknowledgements

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References

- Petit G., “Estimation of the values and uncertainties of the BIPM Z12-T receiver and antenna delays, for use in differential calibration exercises”, BIPM TM.116, June 2002.
- Petit G., “Values and uncertainties of the hardware delays of BIPM geodetic systems and estimation of the type B uncertainty of P3/PPP link calibrations”, BIPM TM.172, December 2009.

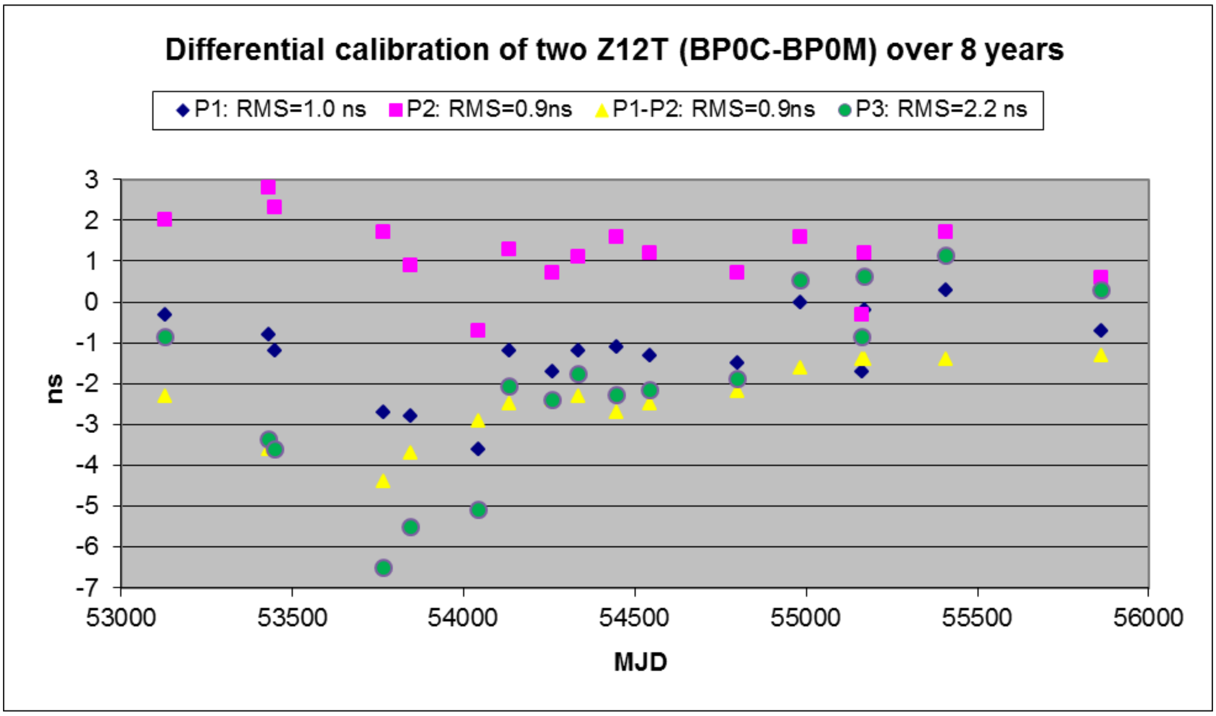


Figure 1: Differential calibration of the Z12T BP0M vs. BP0C. P3 results are offset by 3 ns.

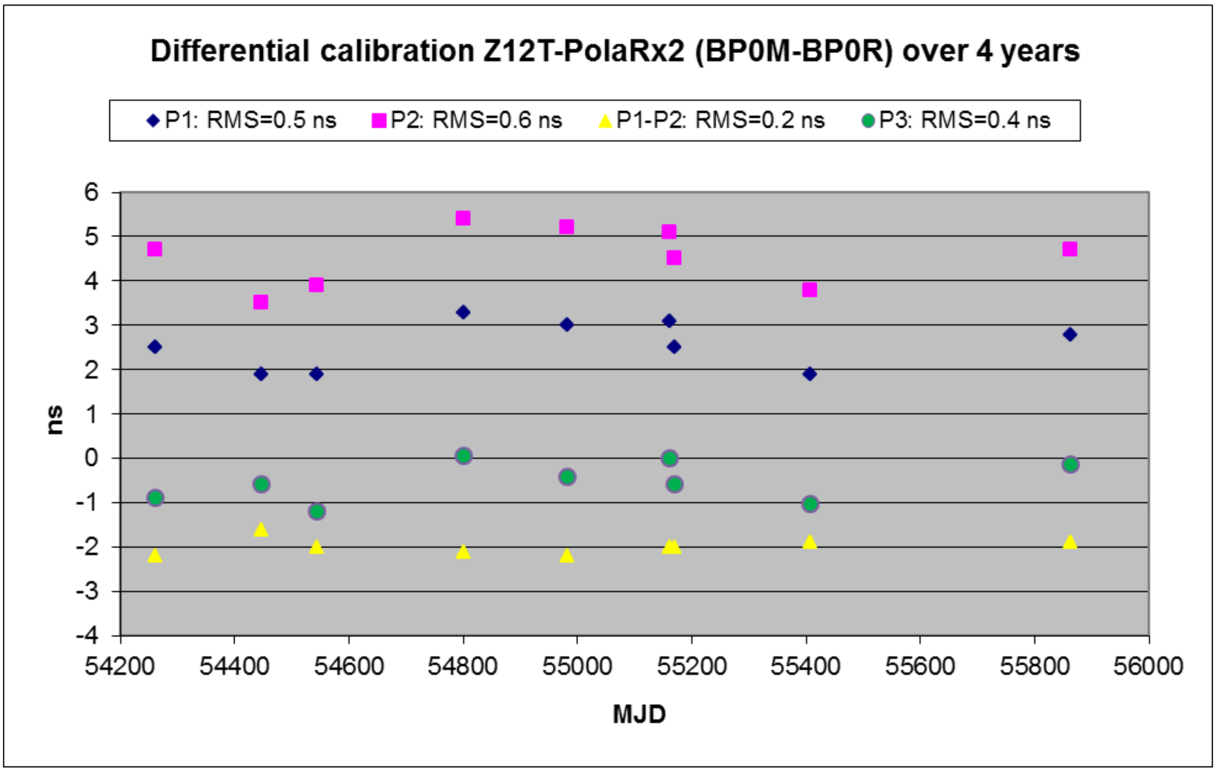


Figure 2: Differential calibration of the PolaRx2 BP0R vs. BP0M. P1, P2 and P3 results are offset by -220 ns.

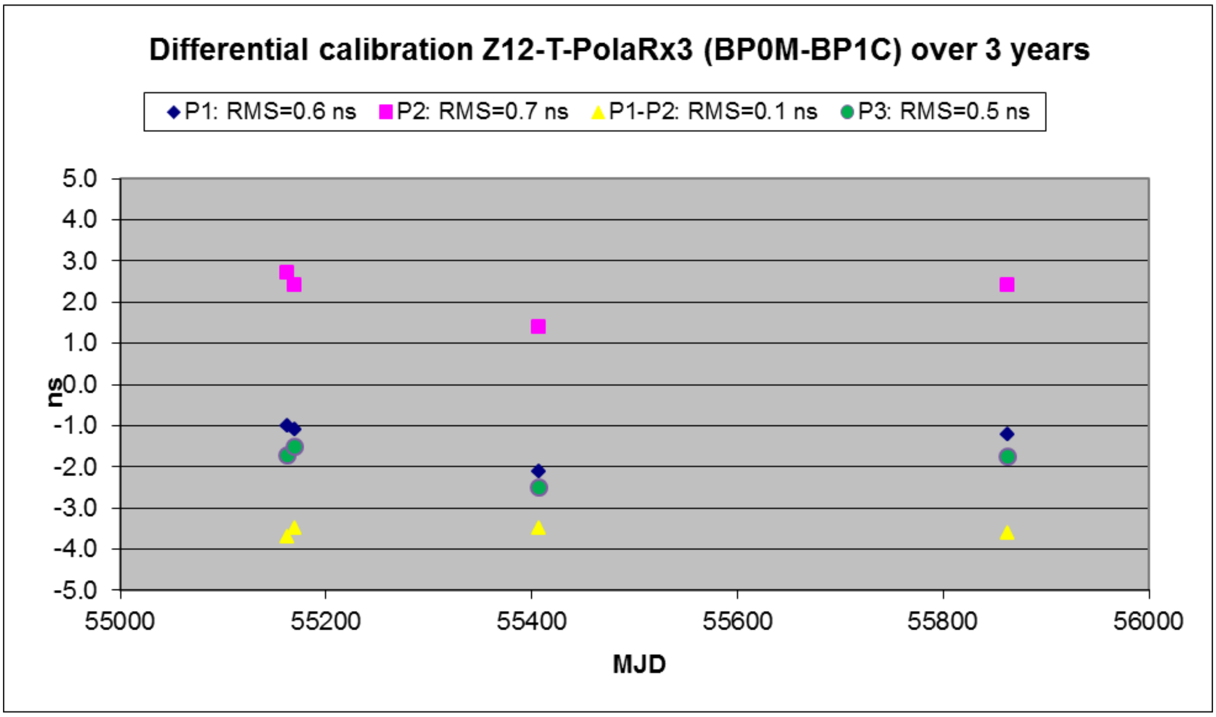


Figure 3: Differential calibration of the PolaRx3 BP1C vs. BP0M. P1/P2 results are offset by -65 ns. P3 results are offset by -60 ns.

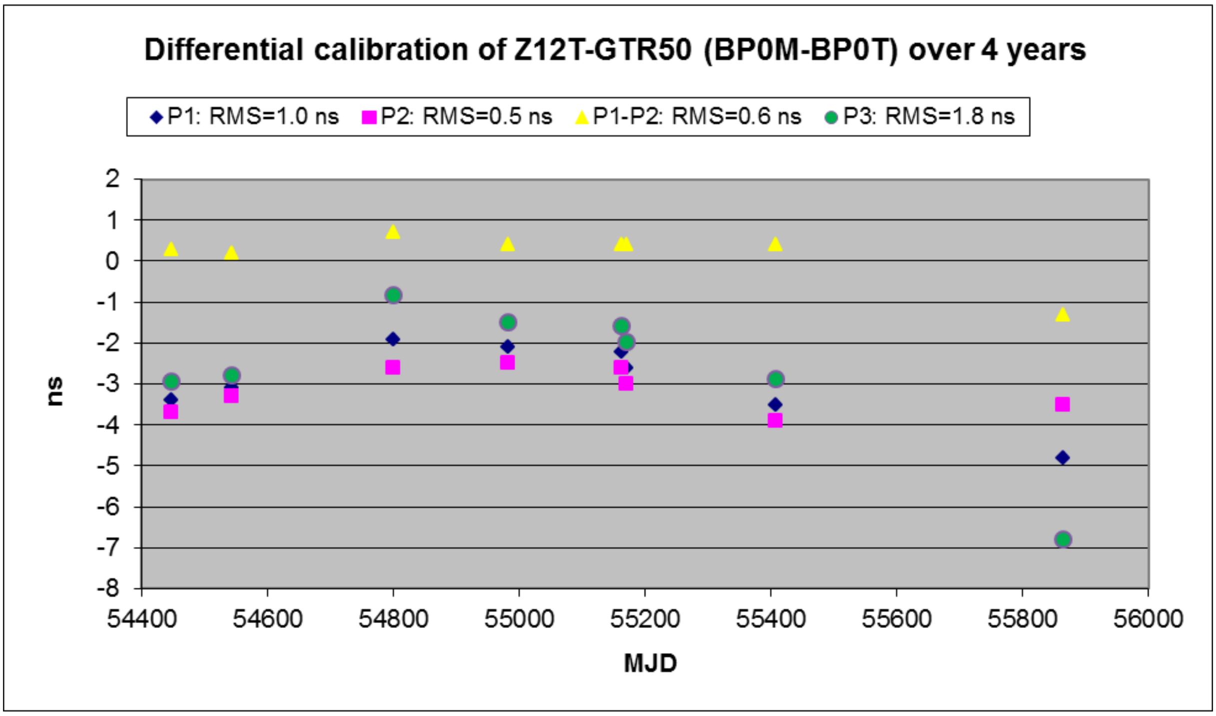
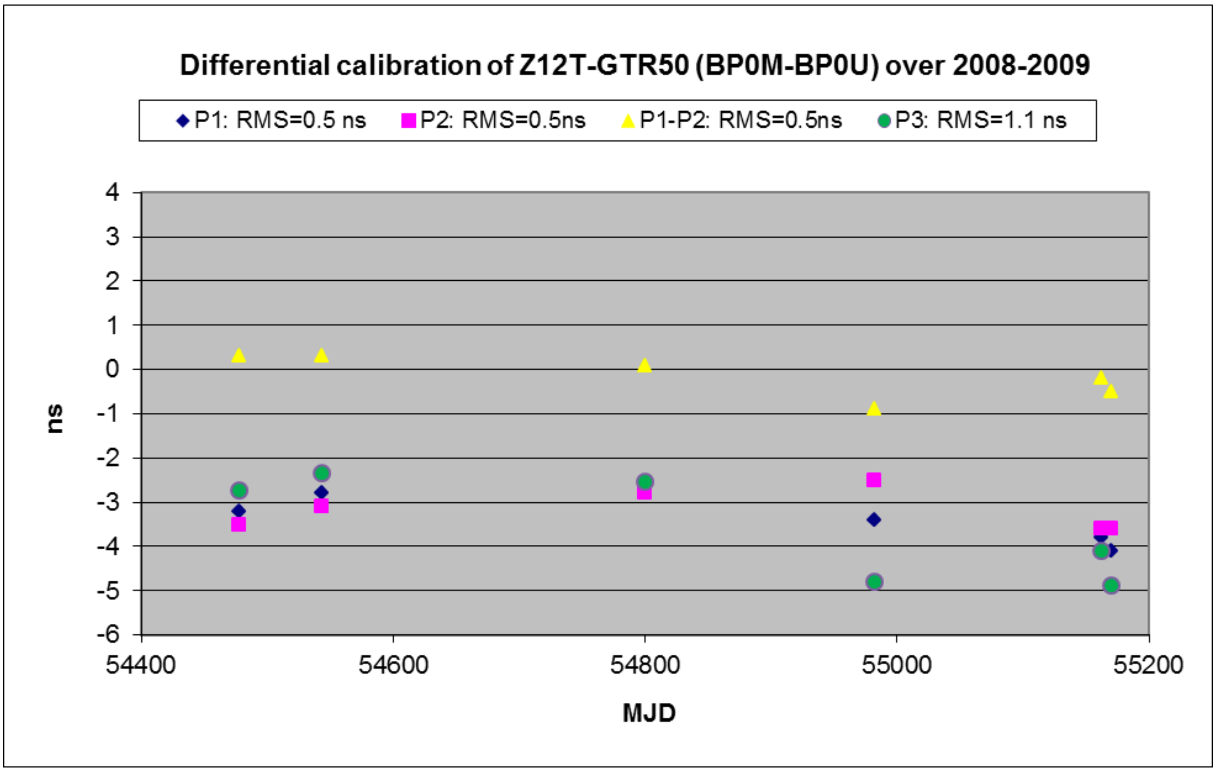


Figure 4: Differential calibration of the GTR50 BP0T vs. BP0M. Results are with respect to the factory calibration.



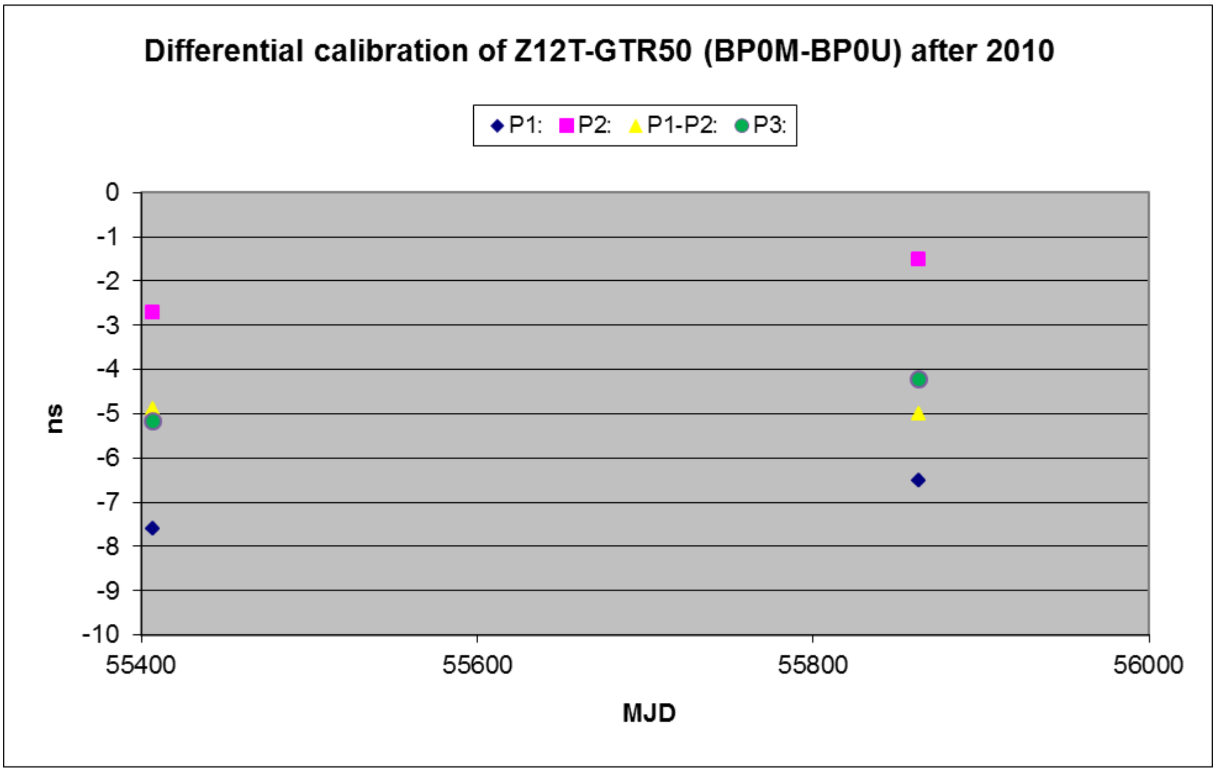


Figure 5: Differential calibration of the GTR50 BP0U vs. BP0M. Results are with respect to the factory calibration. Top plot is before antenna change. Bottom plot is after antenna change, with P3 results offset by 10 ns.