Test Report

U.S. Department of Commerce
National Institute of Standards and Technology
325 Broadway
Boulder, CO 80305
USA

TEST 76120S
Test Folder Number: 288073-16
Test performed for EndRun Technologies

Instrument being characterized:	Meridian II precision TimeBase
Model Number:	Meridian II
Serial Number:	16040082

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1 TEST CONDITIONS

The Meridian II Precision GPS Time Base (from here onward called GPSDO) was operated in a laboratory environment at the National Institute of Standards and Technology (NIST) for about 30 days from May 6, 2016 through June 6, 2016. The laboratory temperature was stable at 21°C with a fluctuation of $\sim$ 2°C and the relative humidity was maintained between 25 and 45% over this period. The GPSDO was powered with uninterrupted 110 VAC supply. The GPS antenna was mounted on the roof of the NIST building, see Figure 1, using the cable shipped with the test equipment. During the first 24 hours of operation the GPSDO was allowed to self-survey the antenna position. The self-surveyed position as determined by the GPSDO differed from previously surveyed NIST position by less than 2.3 meters, see Table 1, along any direction. The exact coordinates that are used for computing common-view difference are obtained using NRCAN precise point positioning (PPP) algorithm using at least a day of RINEX data sampled every 30s. Continuous measurements were made on both 1 PPS and 10 MHz outputs every second over the duration of the test. 1 PPS signal from the GPSDO was measured relative to a delayed version of UTC(NIST) with a GuideTech GT200[4] time interval counter board installed in a computer using custom software. The GPSDO supplied the start pulse and the delayed UTC(NIST) provided the stop pulse. Figure 2 shows a block diagram of the 1 PPS and 10 Mhz measurement setup. For sampling time τ in the range of 10 to 100 s, the 1 PPS measurement noise ($\sim$40 ps) is comparable to that of the GPSDO but for larger values of τ the measurement noise is negligible.

Table 1: Comparing antenna coordinates obtained using different methods

Method	x(m)	y(m)	z(m)
Meridian II	-1288333.192	-4721658.867	4078683.637
NRCAN-PPP	-1288333.969	-4721660.860	4078684.444

The 10 MHz low phase noise output from the GPSDO was compared to a 10 MHz signal from UTC(NIST) for frequency stability tests. UTC(NIST) is derived from an ensemble of 5 hydrogen masers and 4 cesium standards. The stability of UTC(NIST) is better than the instrument under test for all averaging times at or above 0.1 s. Below 0.1 s the NIST reference may corrupt the measurements by a small amount. The 10 MHz time domain stability (Allan deviation and time deviation) measurements were made using a Timing Solutions Corporation(TSC), now Microsemi [5], 5110A Time Interval Analyzer. The measurement noise floor of TSC 5110A is well below the stability level of the GPSDO being tested. Repeated tests at

NIST have confirmed the accuracy of TSC 5110A for making Allan deviation measurements. Measurements were made using the instantaneous mode with a nominal bandwidth of 500 Hz.

A plot of Meridian II – UTC(NIST) 1PPS delay measurements over the test period is given in Figure 3 with a mean of 241.1 ns and standard deviation of 2.6 ns. A daily average for Meridian II – UTC(USNO), with UTC(USNO) computed from common-view difference between NIST and USNO is given in Figure 4.

2 TEST RESULTS

2.1 ALLAN DEVIATION AND TIME DEVIATION

Figure 5 shows the Allan deviation(ADEV) plots for PPS and 10 MHz data for τ ranging from 1 to $\sim 10^6$ s. Computing the time deviation(TDEV) for large values of τ are computationally expensive. As a compromise, we have sampled the above data set with $\tau_0 = 60$ s in the plots presented in Figure 6, with values of τ as large as ~ 500000 s. The time deviation for $\tau_0 = 1$ s are given in Tables 2 and 3 for 1PPS and 10Mhz data for smaller values of τ than that were considered in Figure 6. The data are not smoothed or averaged for generating the plots and tables for ADEV and TDEV.

Table 2: Time deviation for 1PPS for smaller τ

τ (s)	Time deviation (ns)	Uncertainty (10^{-6} ns)
1	0.088354	57.000
2	0.071767	44.072
4	0.053260	32.554
8	0.041943	25.636
16	0.039205	23.963
32	0.045640	27.896
64	0.061346	37.497

Time deviation is computed using the formula

$$\sigma^2(\tau) = \frac{\tau^2}{3}\sigma^2_{\mathrm{Mod}}(\tau), \tag{1}$$

where $\sigma_{\mathrm{Mod}}(\tau)$ is the modified and overlapping Allan deviation and $\sigma(\tau)$ is the time deviation(TDEV).

Table 3: Time deviation for 10 MHz for smaller τ

τ (s)	Time deviation (ns)	Uncertainty (10^{-6} ns)
1	0.0049994	3.0600
2	0.010754	6.5822
4	0.013964	8.5469
8	0.014063	8.6076
16	0.016721	10.235
32	0.024438	14.957
64	0.041703	25.525

2.2 Antenna and receiver delay

It is assumed that the GPSDO is tracking UTC(USNO) as broadcast by the GPS signals. The mean time difference between UTC(NIST) and UTC(USNO) during the test period, determined from the ionosphere-free(P3) common view measurements, was UTC(NIST) − UTC(USNO) = −0.5 ns with an uncertainty of 2.3 ns, see Figure 7. From Figure 3,

$$\langle \text{Meridian II} - \text{UTC(NIST)} \rangle = 241.1\text{ns}, \tag{2}$$

From Figure 7,

$$\langle \text{UTC(NIST)} - \text{UTC(USNO)} \rangle = -0.5\text{ns}. \tag{3}$$

Adding equations (2) and (3) we obtain

$$\langle \text{Meridian II} - \text{UTC(USNO)} \rangle = 240.6\text{ns}. \tag{4}$$

The cable delay from the UTC(NIST) source to the local reference point has been measured to be 438.3 ns (with an uncertainty $\sim$ 0.5 ns). Subtracting the antenna cable delay of 188.9 ns and the corrected PPS output of Meridian II (see equation 4) from the cable delay, the combined antenna and receiver delay for the Meridian II Precision GPS Time Base is estimated to be 8.8 ns with an uncertainty $\sim$ 2.6 ns.

Figure 1: Meridian II Precision GPS antenna attached to antenna mounts on the fiber glass platform atop NIST, Boulder, Bldg. 1 roof.

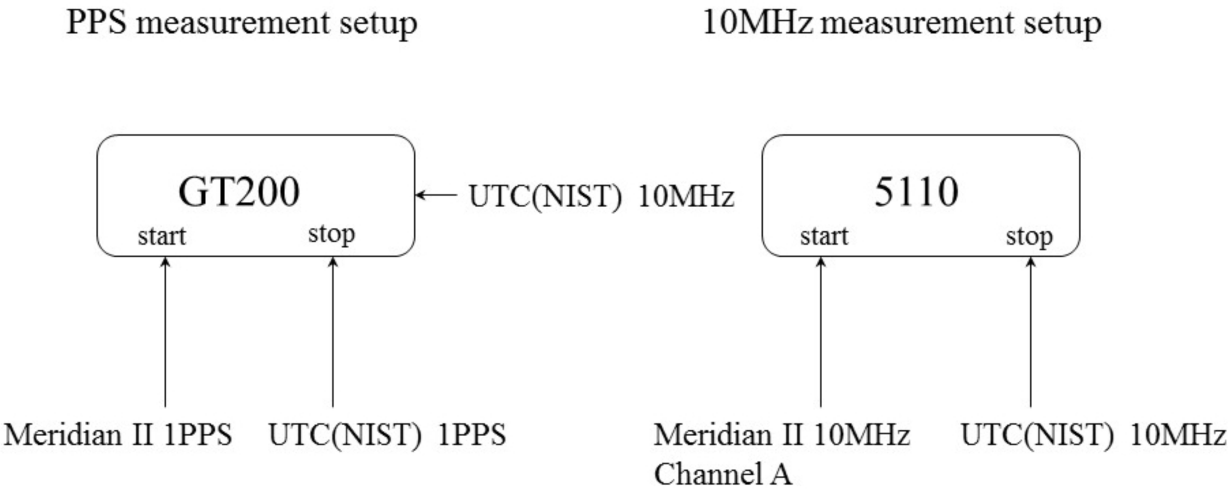

Figure 2: In both setups, start and stop measurements are performed with cables that are identical in length. The local reference point from UTC(NIST) is 438.3 ns and the reported antenna cable delay is 188.9 ns.

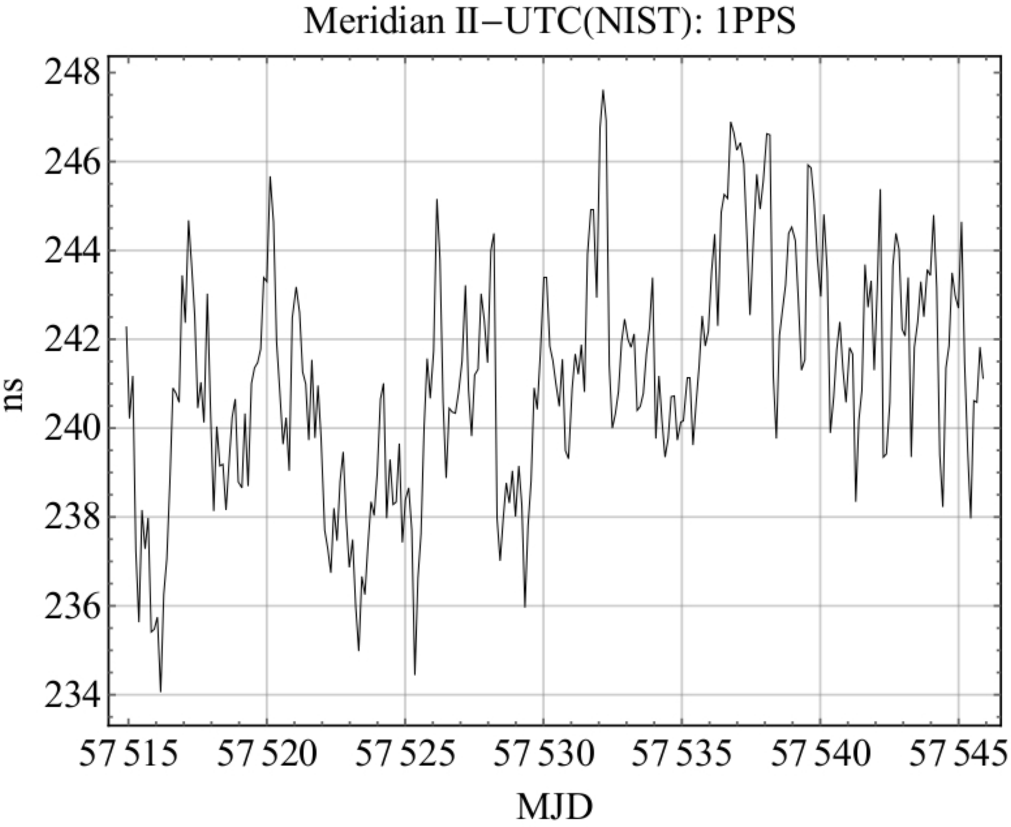

Figure 3: Meridian II − UTC(NIST) 1PPS delay measurements starting with MJD 57514.92358 sampled every 600 s until MJD 57545.91964. MJD 57514 is May 6, 2016. The mean and standard deviation of this measurement every second over the duration of the test is 241.1 ns and 2.6 ns.

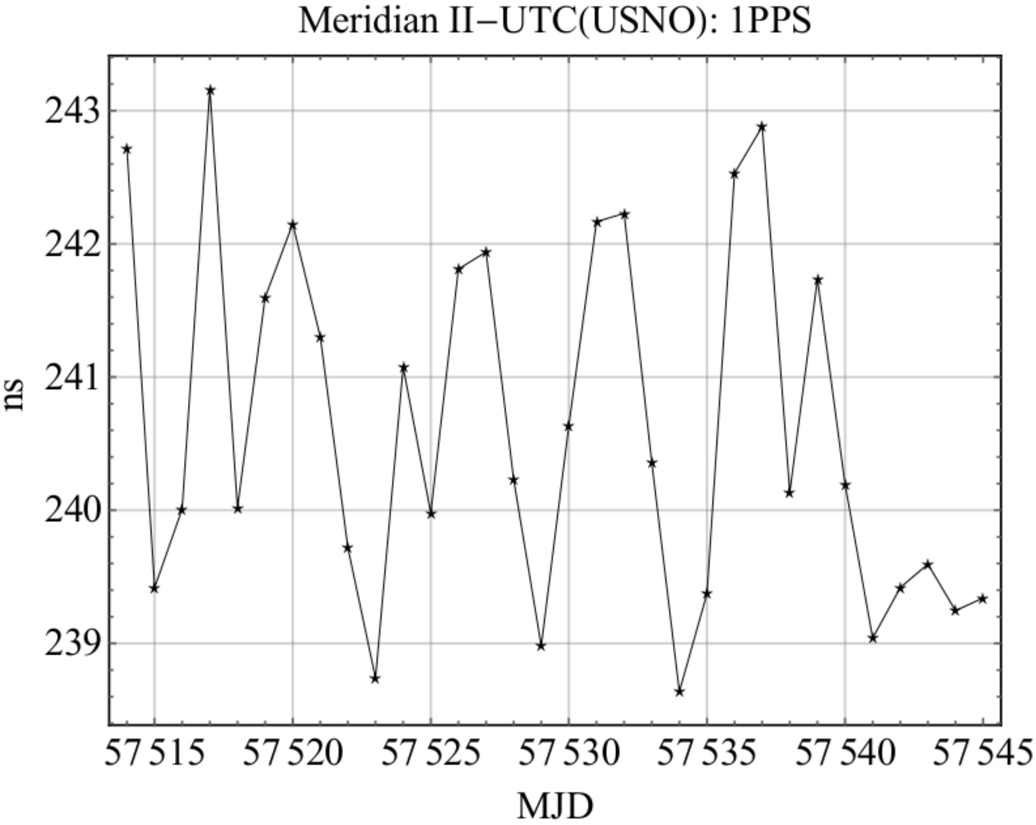

Figure 4: Meridian II − UTC(USNO) daily average for 1PPS delay measurements synchronized with UTC(USNO) obtained from common-view. The mean and standard deviation are 240.6 ns and 1.3 ns. MJD 57514 is May 6, 2016.

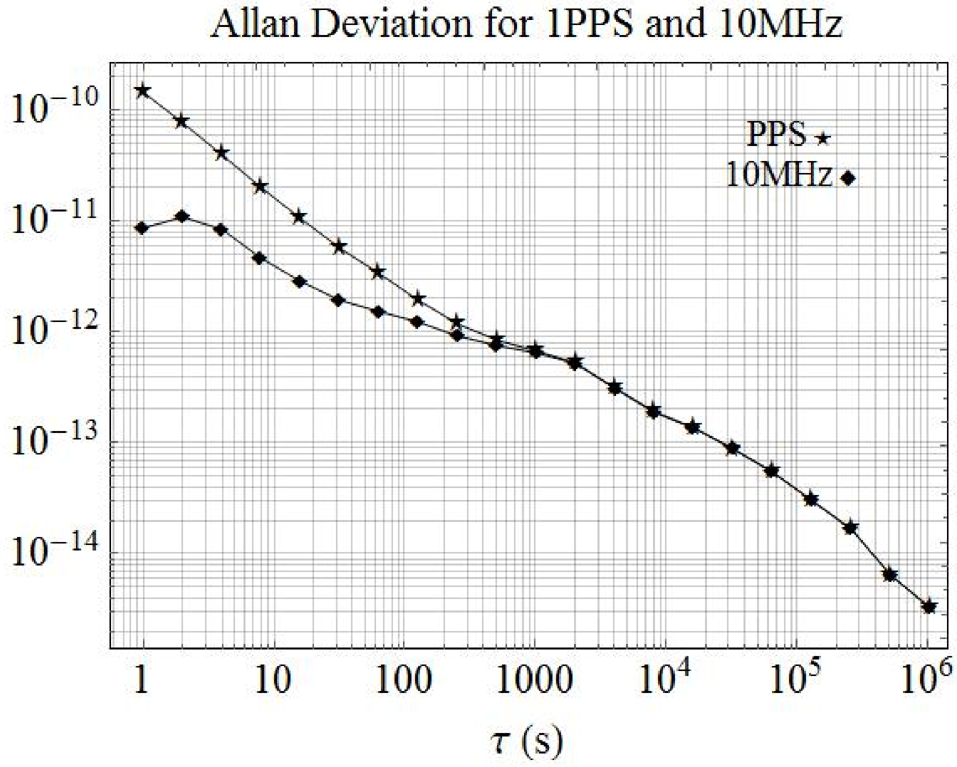

Figure 5: Allan deviation for the 1PPS and 10 MHz measurements for Meridian II-NIST as a function of sampling interval τ. $\tau_0 = 1$ s.

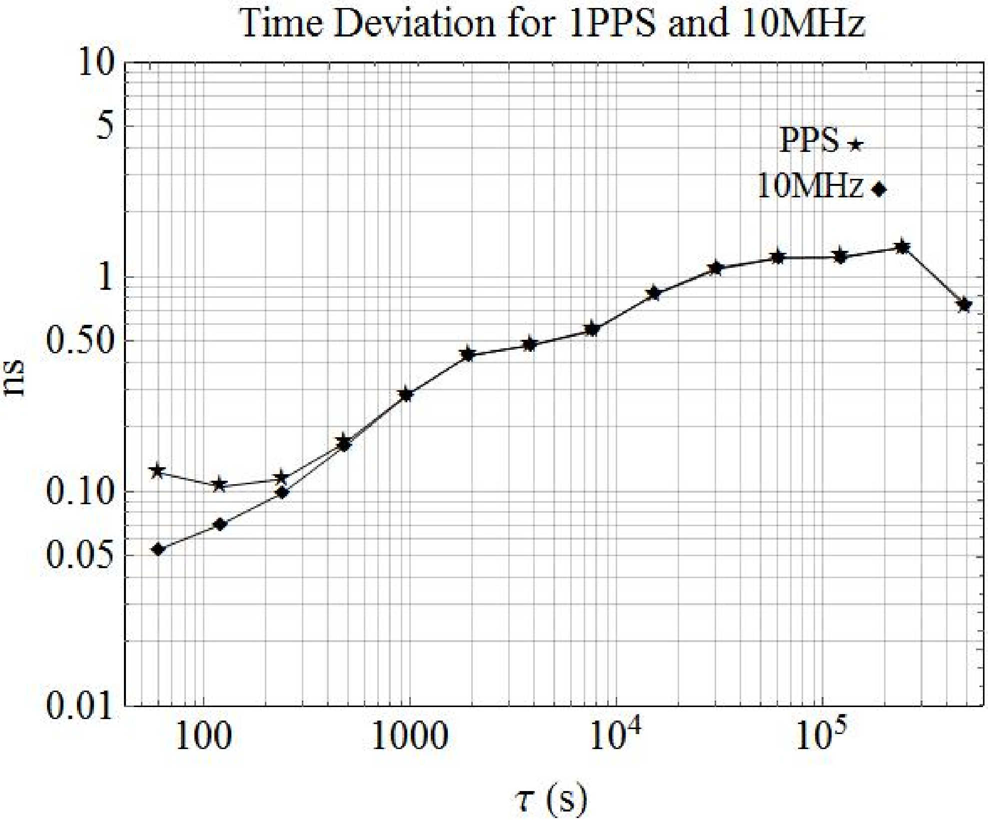

Figure 6: Time deviation for the 1PPS and 10 MHz measurements for Meridian II-NIST as a function of sampling interval τ. $\tau_0 = 60$ s.

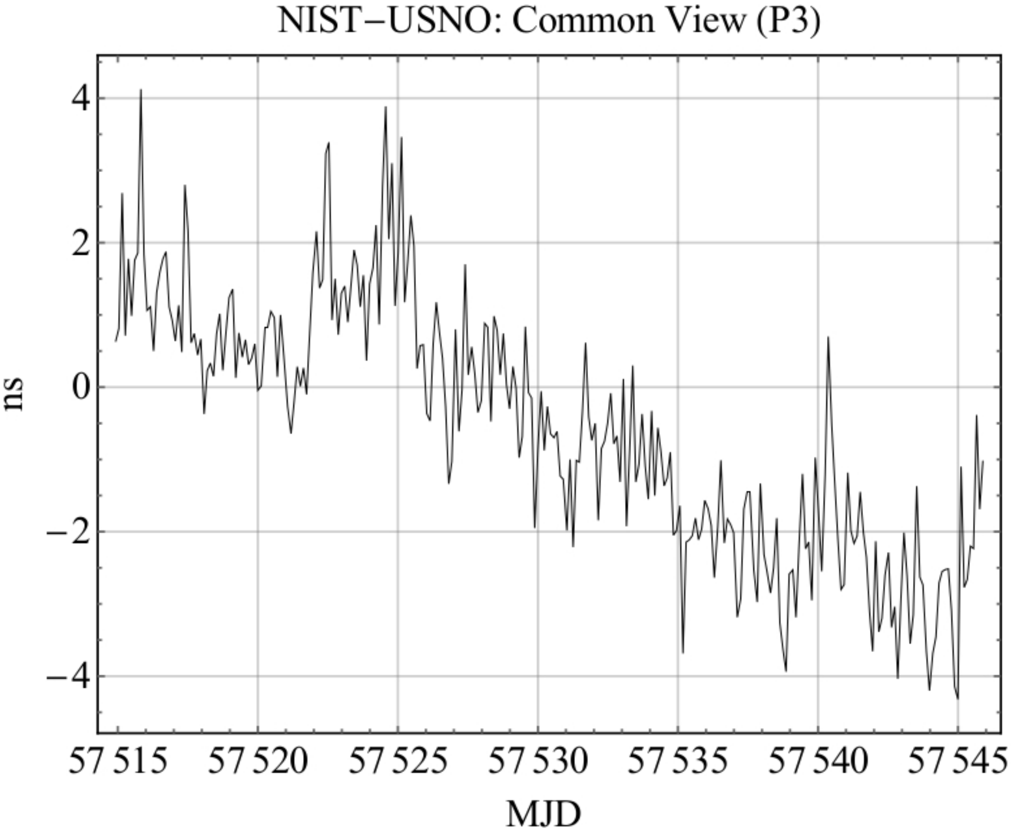

Figure 7: GPS Common view time difference between NIST and USNO for computed every 160 min starting MJD 57514.11528 and ending at MJD 57545.89583. MJD 57514 is May 6, 2016. The average time difference over ∼30-day test period for 16 min interval data was $\langle \Delta t \rangle = -0.5$ ns, with a standard deviation of 1.7 ns.

References

[1] NIST Quality Manual, NIST-QM-I

[2] NIST Quality Manual, NIST-QM-II

[3] *NIST Calibration Services User Guide,* NIST Special Publ. 250, current version and fee schedule is available at: http://www.nist.gov/calibrations

[4] http://www.guidetech.com/computer-based-instruments.html

[5] http://www.microsemi.com/products/timing-synchronization-systems/test-measurement/test-sets/5120a# overview

[6] W. J. Riley, *Handbook of Frequency Stability Analysis,* NIST Special Publ. 1065, 136 p., July 2008. Available at http://tf.nist.gov/general/pdf/2220.pdf

[7] http://www.nrcan.gc.ca/earth-sciences/geomatics/geodetic-reference-systems/tools-applications/10925