Wander TDEV Measurements for Inexpensive Oscillator

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Outline

- Introduction
- Measurement setup
- Measurement results
- Conclusions

Introduction - 1

- Annex B.1.3.1 of IEEE P802.1AS, D6.2 specifies a wander generation requirement for the free-running LocalClock entity in a time-aware system
- The wander generation is specified in terms of a Time Deviation (TDEV) mask
- TDEV is the square root of Time Variance (TVAR), which is defined as

$$\mathrm{TVAR}(\tau) = \sigma_x^2(\tau) = \frac{1}{6} E\left[\left(\Delta^2 \bar{x}\right)^2\right]$$

$$= \frac{1}{6n^2} E\left[\left(\sum_{i=1}^{n} \left(x_{i+2n} - 2x_{i+n} + x_i\right)\right)^2\right]$$

where

$\tau = n\tau_0$ = observation interval

τ_0 = sampling interval

x_i = measured phase (time) error at the i^{th} sampling time (the units of x_i and $\sigma_x(\tau)$ are the same

Introduction - 2

- TDEV is estimated from a set of measurements as

$$\mathrm{TDEV}(\tau) = \sqrt{\frac{1}{6n^2(N-3n+1)} \sum_{j=1}^{N-3n+1} \left[\left(\sum_{i=j}^{j+n-1} \left(x_{i+2n} - 2x_{i+n} + x_i \right) \right)^2 \right]},$$

$$n = 1, 2, \ldots, \left\lfloor \frac{N}{3} \right\rfloor$$

where

$\lfloor y \rfloor$ denotes the floor function, i.e., the greatest integer less than or equal to y

Introduction - 3

- B.1.3.1 of IEEE P802.1AS/D6.2 states that the wander generation TDEV for the LocalClock entity shall not exceed the mask of Table B-1 and Figure B-1, reproduced below

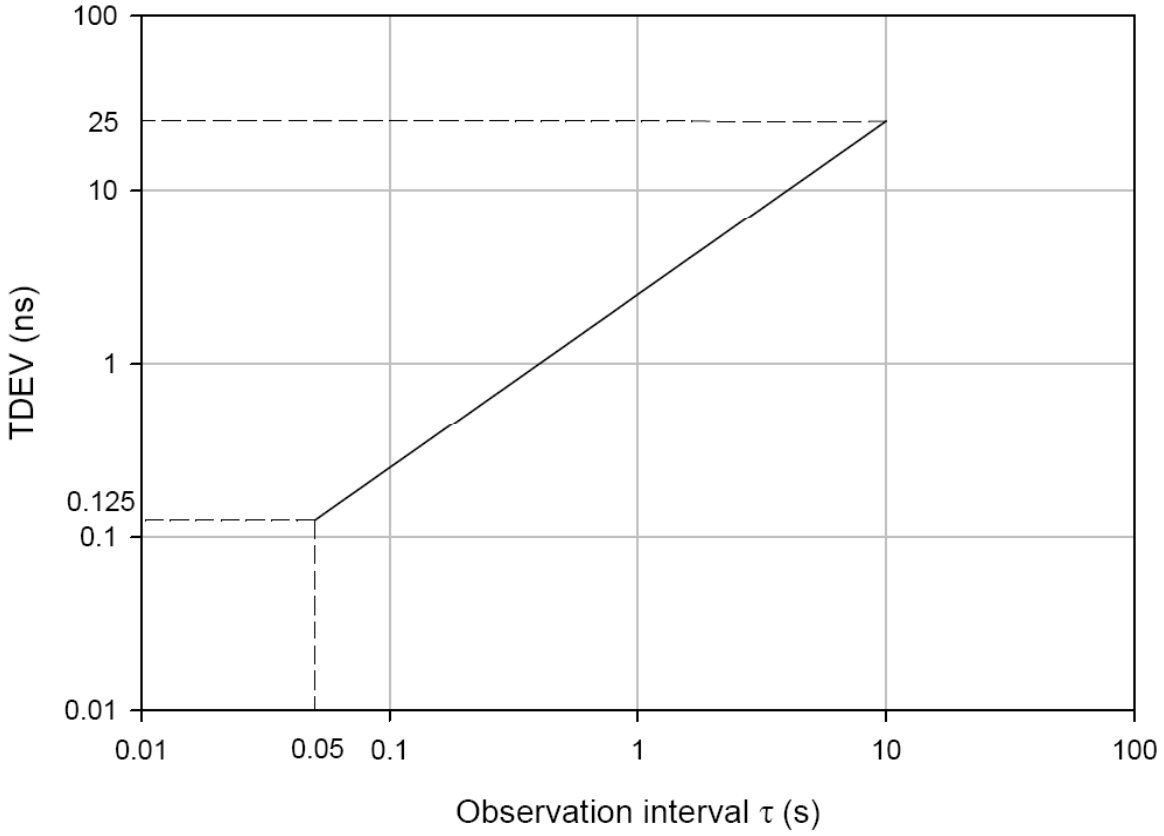


Figure B-1—Wander generation (TDEV) requirement for LocalClock entity

Introduction - 4

Table B-1 — Wander generation TDEV requirement for LocalClock entity

TDEV limit	Observation interval τ
no requirement	$\tau < 0.5$ s
2.5τ ns	$0.5 \leq \tau \leq 10$ s
no requirement	$\tau > 10$ s

- The measurement interval shall be at least 120 s (i.e., at least 12 times the longest observation interval). The measurement shall be made using a low-pass filter with 3 dB bandwidth of 10 Hz, first-order characteristic, and 20 dB/decade roll-off. The sampling interval τ_0 shall not exceed 1/30 s.

Introduction - 5

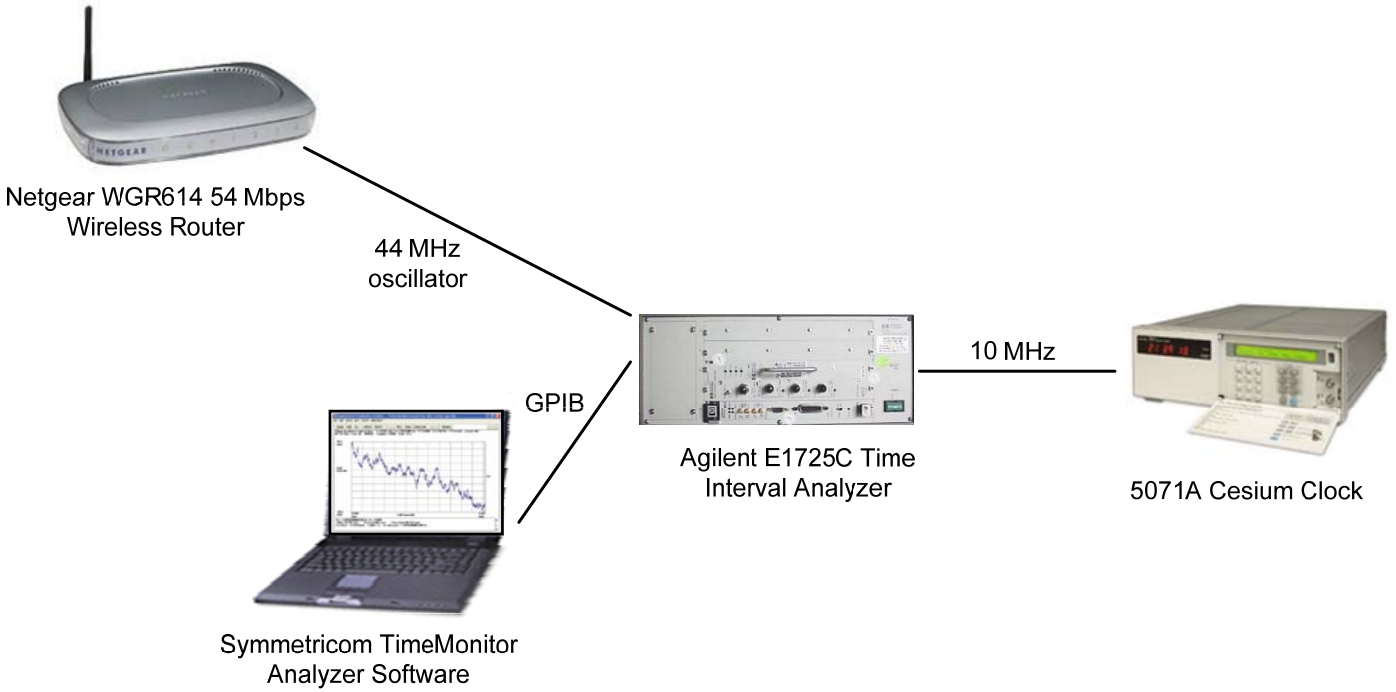
- It is desirable to check whether the above specification can be met by inexpensive oscillators currently used in consumer router or bridge products (wireless or wired)
- This presentation gives measurement results for one such oscillator

Measurement Setup – 1

- The measurement was made using an Agilent E1725C Time Interval Analyzer
  - Measurement data collected and analyzed using Symmetricom TimeMonitor Analyzer software
  - E1725C has a single shot timing resolution of 50 ps, more than adequate for this test
- A 10 MHz reference was supplied to the time interval analyzer from a 5071A Cesium clock
- The measured oscillator was contained in a consumer-grade wireless router product – the Netgear WGR614 54 Mbps Wireless Router
  - 802.11g wireless
  - 4 10/100 Mbit/s Ethernet LAN ports
  - 1 10/100 Mbit/s Ethernet WAN port
  - The measurements were made on one sample device (i.e., one unit)
- The oscillator was accessed by removing the top of the wireless router and using an oscilloscope probe

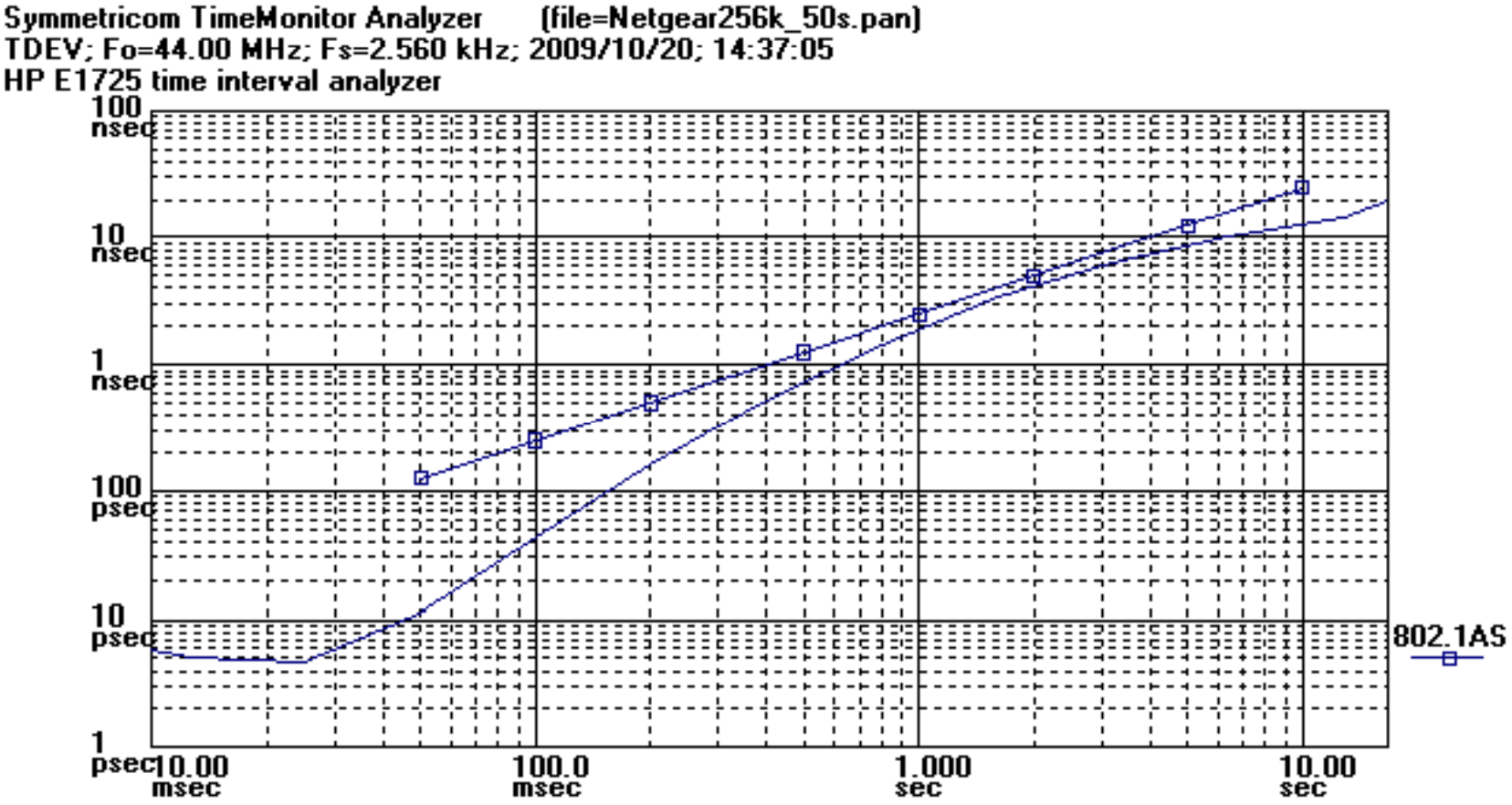
Measurement Setup – 2

- Initially, samples were collected over 50 s at a rate of 2.5 kHz
  - Later test used 1000 s measurement interval
- Timestamps were converted to phase deviation, for the TDEV calculation
- The measured oscillator frequency was approximately 44 MHz



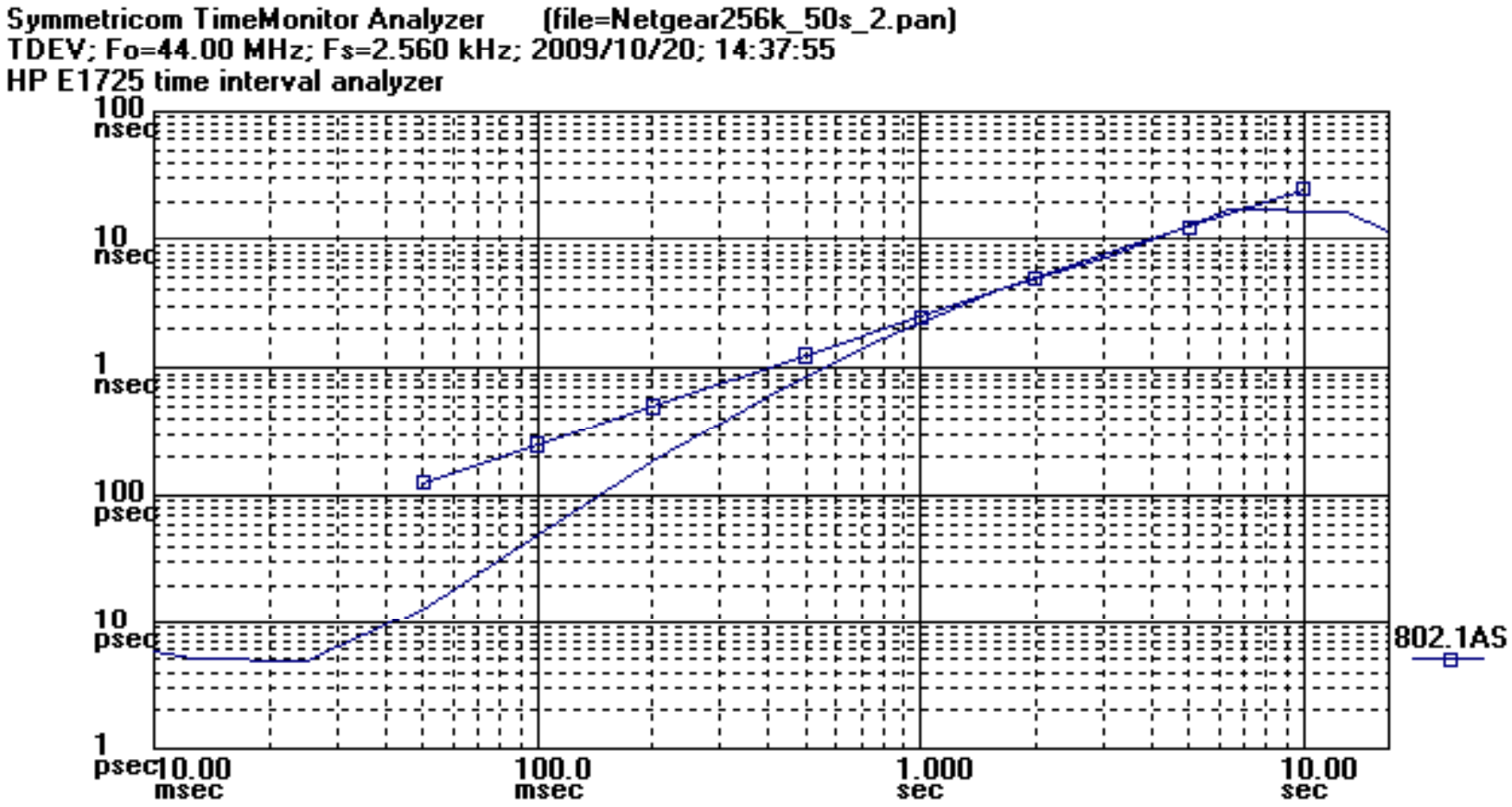
Measurement Results - 1

- TDEV result – first 50 s measurement
  - Passes, though not with a large margin



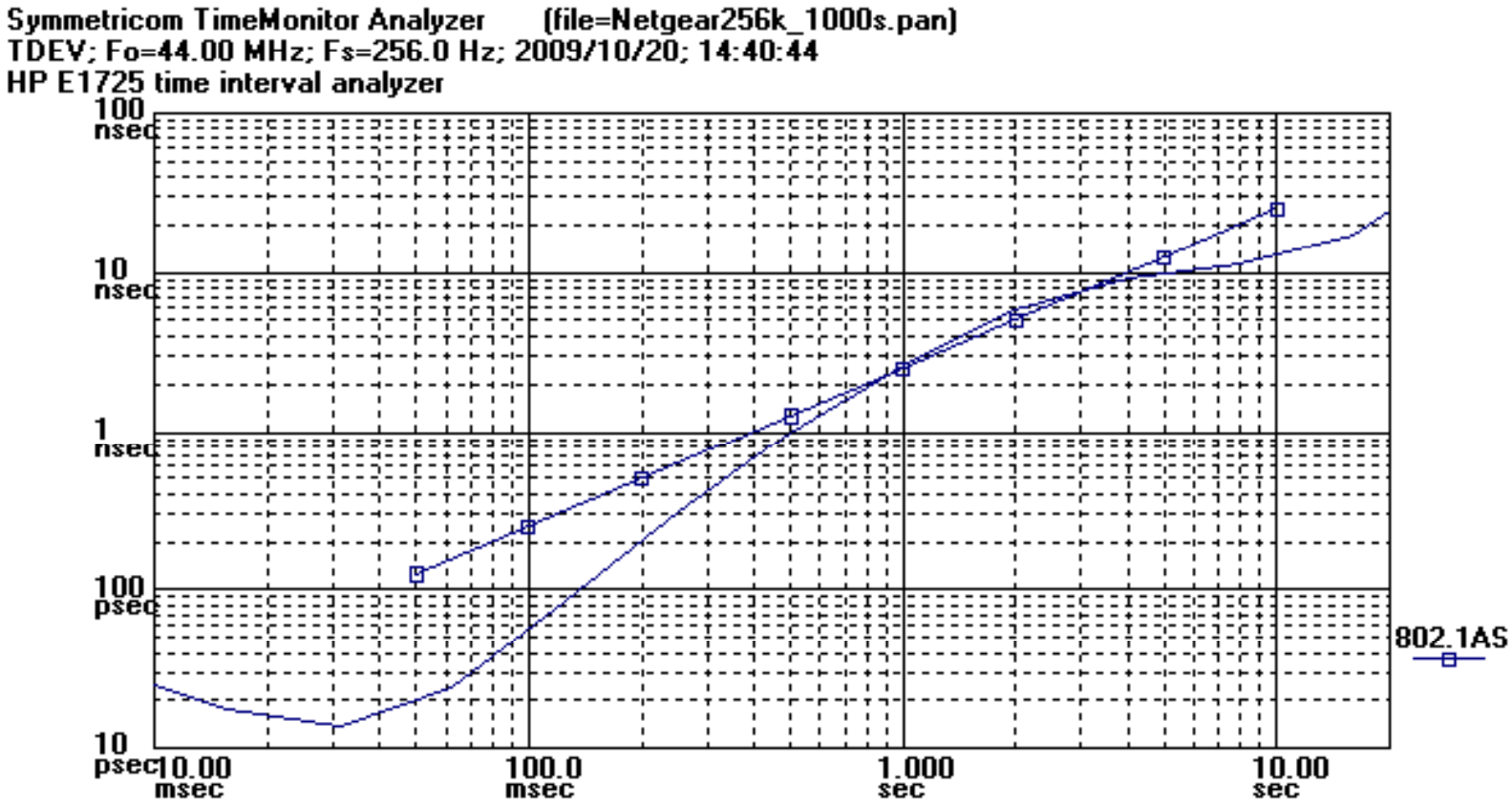
Measurement Results - 2

- TDEV result – second 50 s measurement
  - Marginally fails



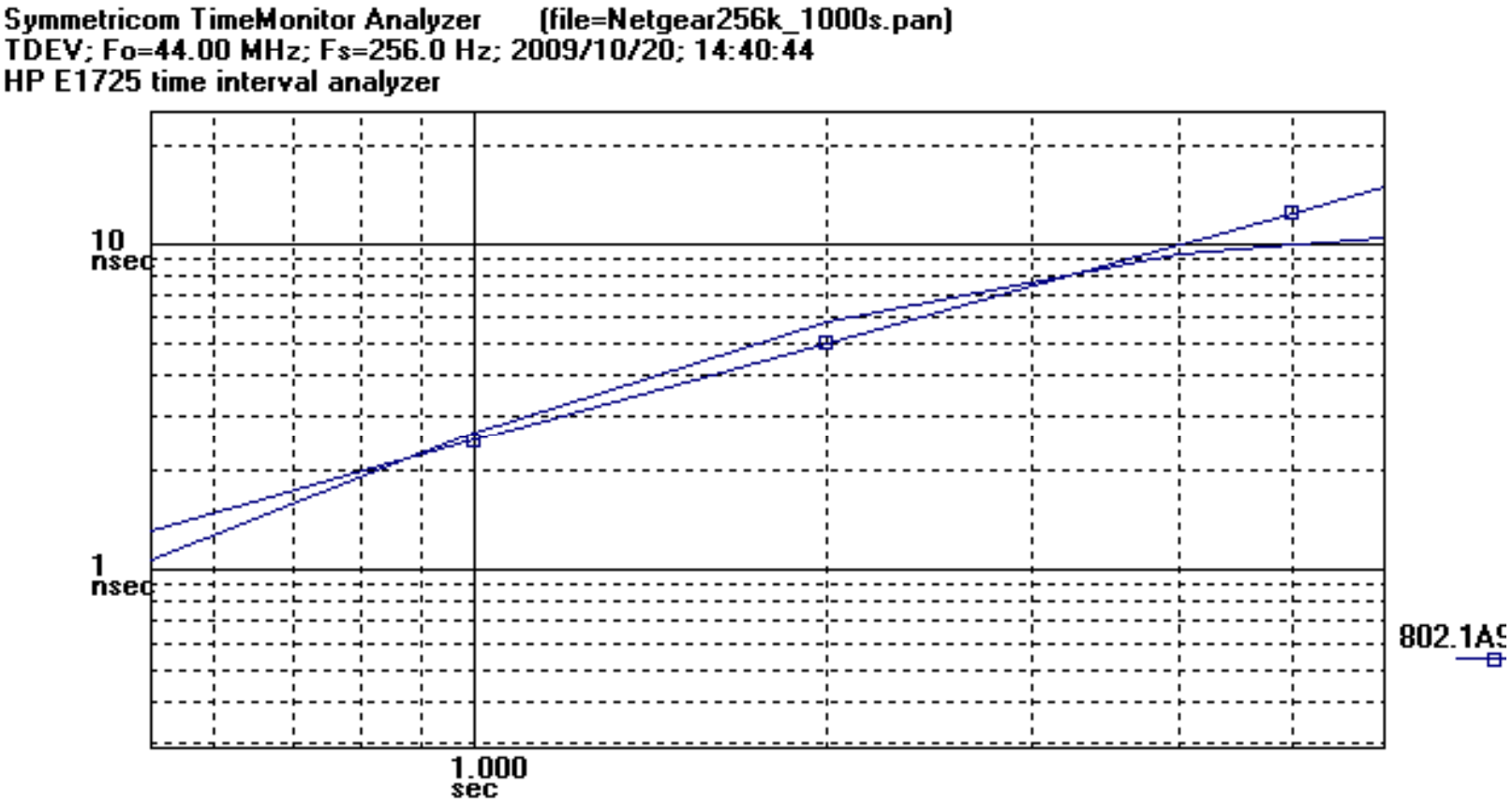
Measurement Results - 3

- TDEV result – 1000 s measurement
  - Marginally fails



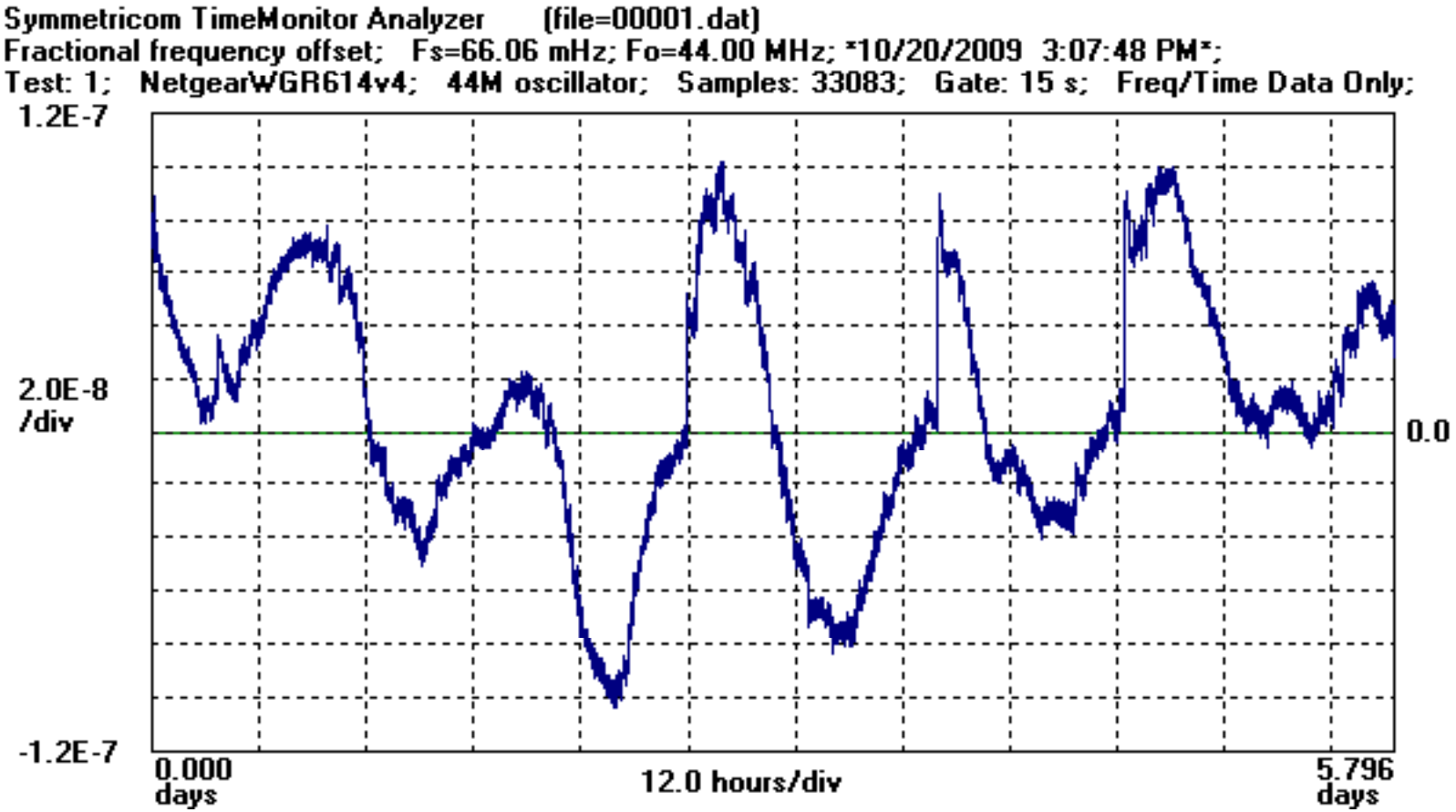
Measurement Results - 4

- TDEV result – 1000 s measurement, region of marginal failure
  - Mask is exceeded by approximately 16%, at 2 s observation interval



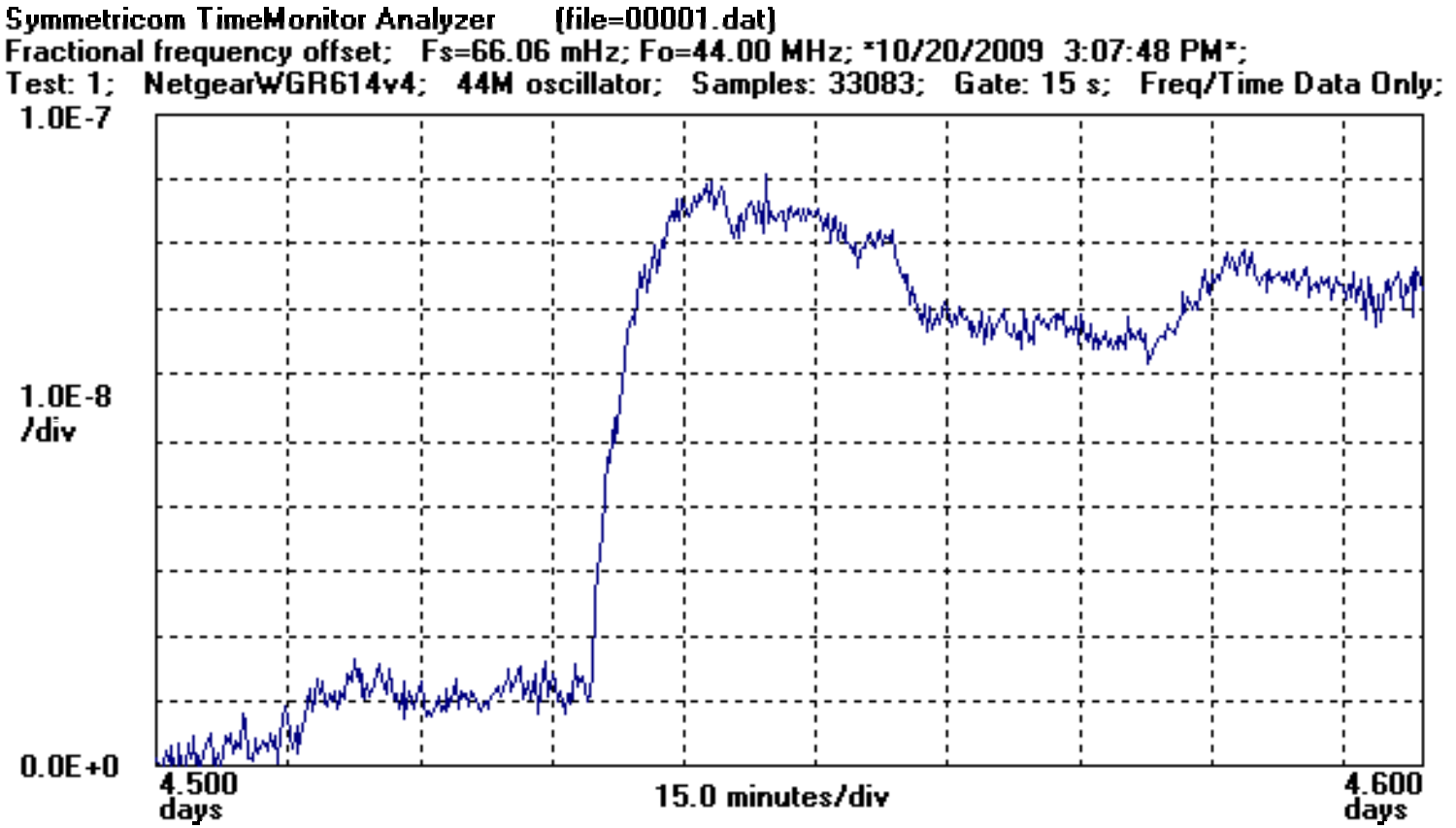
Measurement Results - 5

- Frequency measurement over 6 days (note diurnal cycle)



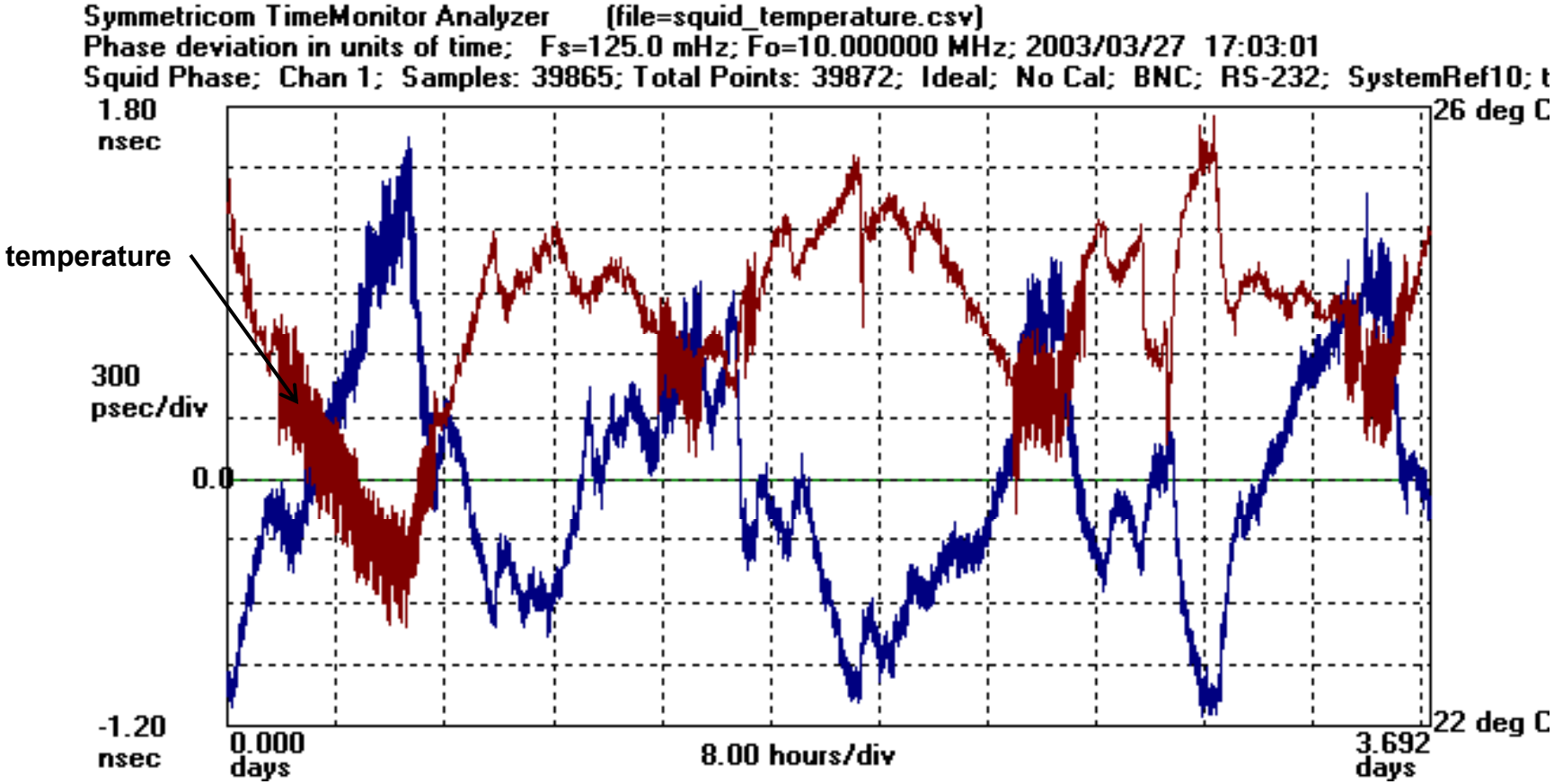
Measurement Results - 6

- Frequency measurement over 6 days, detail of final steep increase
  - Maximum rate of frequency change is on the order of 1.2×10^{-8} /1 min = 2×10^{-10} /s = 0.0002 ppm/s



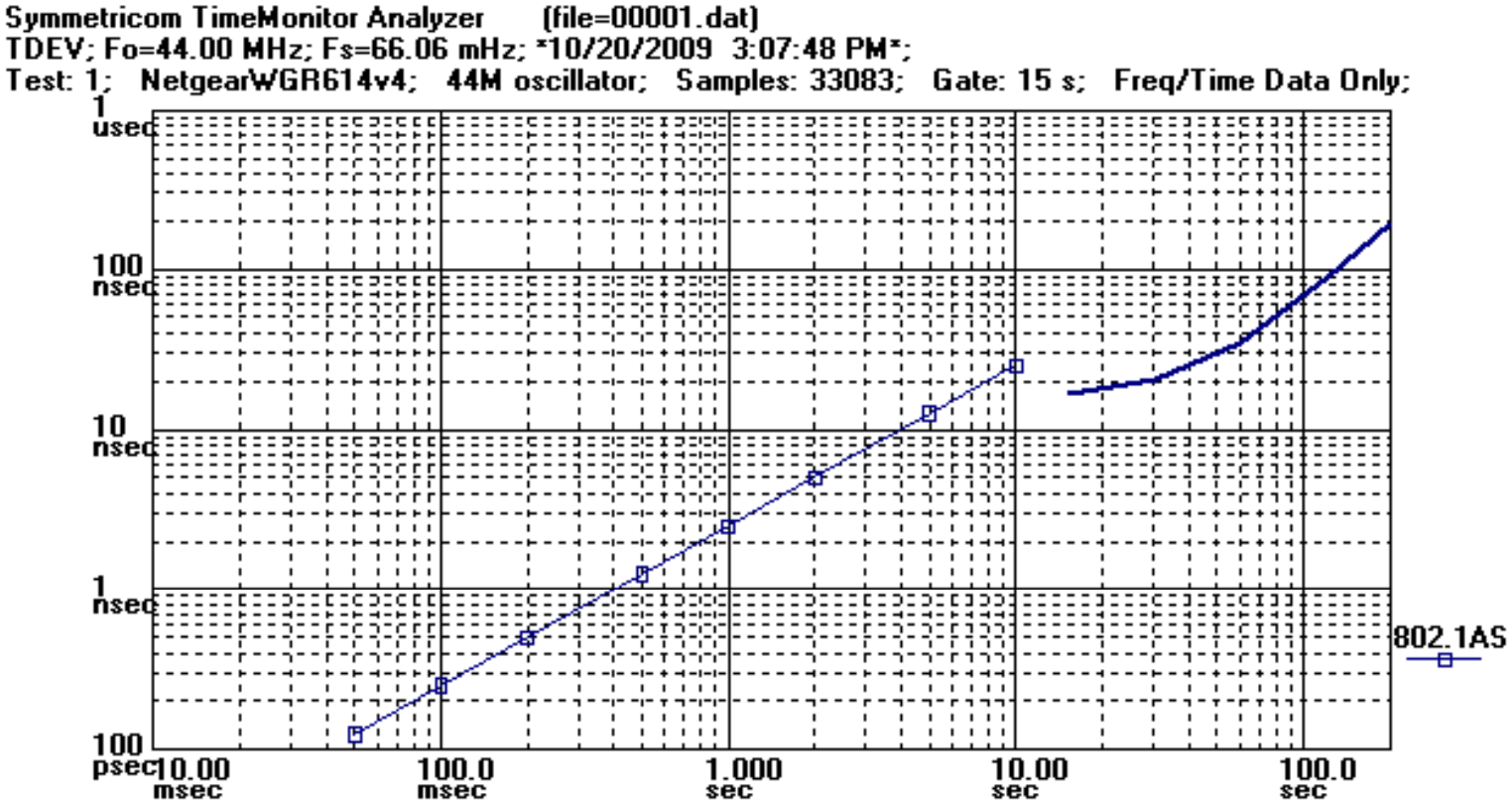
Measurement Results - 7

- Sample temperature (ambient room temperature) and phase error history (red plot is temperature, blue plot is phase error)
  - Temperature variation is representative of conditions in lab for previous measurements (temperature does not change by more than 3 – 4 deg C)



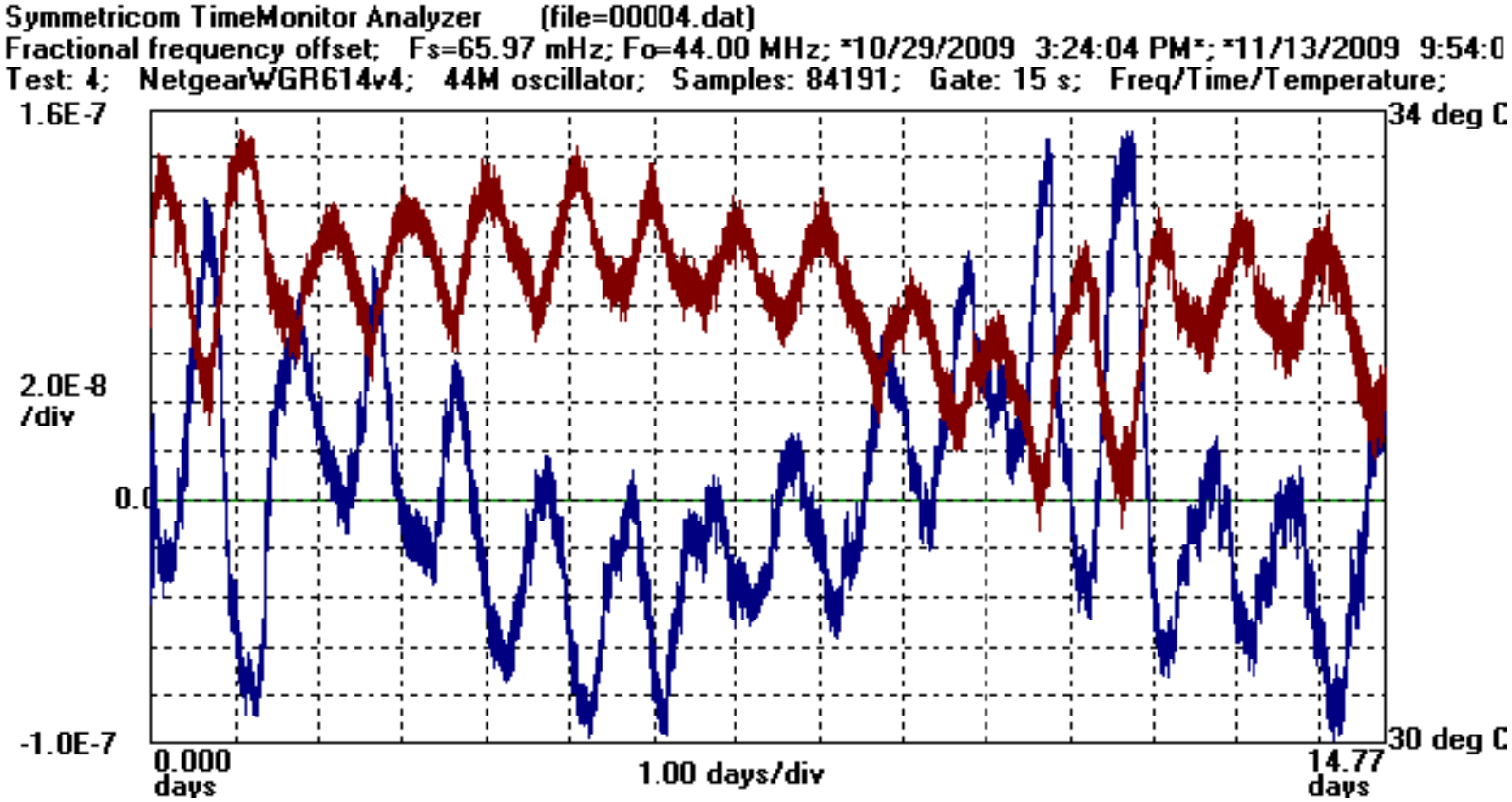
Measurement Results - 8

- TDEV result – 6 day measurement interval (observation interval ranged from approximately 15 s to 200 s)
  - TDEV is within an extrapolation of the requirement



Measurement Results - 9

- Frequency and temperature measurement over 14 days (red plot is temperature, blue plot is frequency)
  - Temperature measurement is at oscillator (it is higher than slide 16 temperature because that is ambient room temperature)
  - Results are qualitatively similar to 6-day results; note diurnal cycle



Conclusions

- Measured TDEV is either very close to the mask or marginally fails for observation intervals in the range of approximately 1 – 3 s
- For observation intervals less than 0.5 s, measured TDEV is well within the mask
- For temperature conditions in the lab (slide 16), maximum rate of frequency change is on the order of 0.0002 ppm/s
  - This indicates that the current 802.1AS assumption of 4 ppm/s or 1 ppm/s (assumption 9 of Annex Z) is extremely conservative
- Frequency variation over 14 days is qualitatively similar to variation over 6 days
- The results are very promising, but indicate that the present TDEV requirement should be increased to allow for margin for observation intervals in the range 1 – 3 s
  - It appears an increase in the mask by a factor of 2 would suffice, providing the performance for timing transport is acceptable (this must be checked via simulation)