SYNERGY SYSTEMS, LLC

Time proven products and support

Motorola M12+ Precision Timing Receiver

GPS timing receivers have had a long history of being "specialty" products, tending to be larger and more power hungry than standard GPS receivers. They also required special software, hardware, and care in system design in order to perform their function to desired specifications. Drawing on over 10 years of expertise in developing GPS receivers used for precision time transfer, Motorola has just announced the release of the ***M12+ Timing Receiver.*** *In preparation for this release, Motorola (with the assistance of CNS Systems, Inc., and Synergy Systems, LLC) has conducted many weeks of tests and analysis of the performance of the* ***M12+*** *Timing Receiver by comparing its 1PPS output to the United States Naval Observatory MASTER CLOCK (MC) in Washington D.C. This paper will describe both the new* ***M12+*** *timing engine, and the results of these tests.*

INTRODUCTION

Most OEM receiver manufacturers provide support to the timing industry by supplying a 1 Pulse Per Second (1PPS) output of the receiver synchronized to either GPS time or UTC. Motorola introduced the original 6 channel PVT6 GPS core receiver in mid 1992, and followed it up with the 8 channel VP Oncore and UT+ Oncore timing receivers in 1995 and 1997 respectively. These receivers have since found homes in many timing related applications, most notably the telecommunications industry (paging & cellular site synchronization).

Historically, in the development of low cost GPS positioning receivers, the trend has been to focus on cost and performance issues most sensitive to potential high volume purchasers. As such, the foci tend to be (in order of importance).

- Quality and low cost.
- Position and velocity accuracy/stability.
- Stable position data in tough environments (overhanging foliage, blockage by structures: so-called "urban canyons").
- Minimize unstable behavior in sub-optimum conditions.
- Minimize power consumption (especially in portable applications)
- 1PPS performance.

As one might expect, the performance requirements of precision time transfer receivers are quite a bit different, resulting in a listing such as this:

- 1PPS performance.
- Minimize strange behavior in sub-optimum conditions.
- Maximize time accuracy in tough RF environments (co-location with cell sites.)
- Quality and low cost.
- Minimize power consumption.
- Position and velocity accuracy/stability.

This paper will give the reader a brief introduction to the new Motorola M12+ Timing Receiver along with observed performance of the receiver in time transfer applications. The receiver uses a 12 channel parallel architecture with highly integrated carrier aided code-tracking, allowing the receiver to fully exploit the coherency between the broadcast carrier and code through the use of very narrow band (0.005 Hz) code tracking. The pseudo-range data observed by the narrow-band code tracking function is ultimately used to compute satellite time for each satellite observation. After compensating for propagation delay and broadcast satellite clock corrections to produce a local time estimate, the receiver averages local time measurements from up to twelve independent satellite observations to compute a single local time estimate, which then is used to position the 1PPS pulse to coincide to the rising edge of the next UTC or GPS second.

M12+ PHYSICAL AND ELECTRICAL CHARACTERISTICS

Previous Motorola timing receivers such as the VP and UT+ operated on a 5V bus, consumed over 1 watt of power, and had a rather large footprint. Due to dramatic changes in the size and power consumption of micro-electronic components, the M12+ consumes both a fraction of the power, and a fraction of the real-estate of current receivers while offering superior timing performance. A few of the major differences are highlighted in **Table 1** below.

Characteristic	VP/UT+ Receiver	M12+ Timing Receiver
Input Voltage	5VDC	3VDC
Input Current (less antenna)	200 mA	55 mA
Input Power	1W	165mw
Antenna Drive Voltage	5V	3V - 5V
Physical Size	2" x 3.25" x 0.64" (51 x 83 x 16mm)	2.34" x 1.57" x 0.39" (60 x 40 x 10mm)
1PPS Accuracy (raw pk-pk)	104ns	25ns
1PPS Accuracy (rms)	32	8ns
1PPS Accuracy (rms) (sawtooth corrected)	16	4ns

Table 1. Physical, Electrical, and Performance Differences Between M12+ and Earlier Motorola Oncore Timing Receivers

M12+ TIMING RECEIVER ANTENNA DRIVE

One major difference between the older receivers and the M12+ that deserves a little extra attention is the design of the M12+ antenna drive circuitry. While the M12+ is a 3V device, most (if not all) timing antenna low noise amplifiers and supplementary in-line amplifiers require an input voltage of +5V in order to operate to the manufacturer's specifications. In order to support these requirements, the M12+ includes a pin on the 10-pin I/O header which is dedicated to application of antenna drive power. In this way the user may simply apply the required antenna voltage (within a range of +2.5 - +5.5V) to pin 9 of the data header, and the M12+ will loop this voltage through to the RF connector for application to the antenna. Using this architecture the M12+ will drive any currently installed 5V antenna without requiring any modifications to the antenna system. The only action the M12+ takes on this antenna drive is to sense the current being drawn and shutting the drive down if an over-current or shorted condition is sensed, thereby preventing damage to either the receiver or the user's electronics.

As shown in Figure 3 below, the M12+ will supply approximately 90mA to the antenna system before folding back the current. At this point a warning flag is also set in several output messages to alert the user (or the user's software) to the problem.

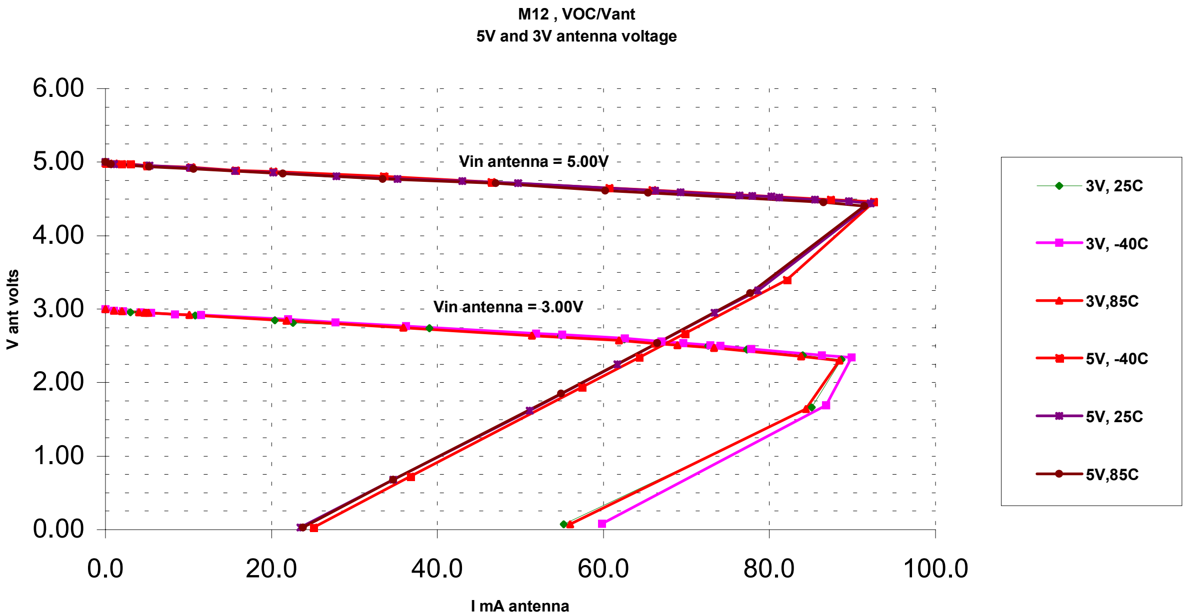

Figure 1. M12+ Timing Receiver Antenna Drive Characteristics

USNO TESTING

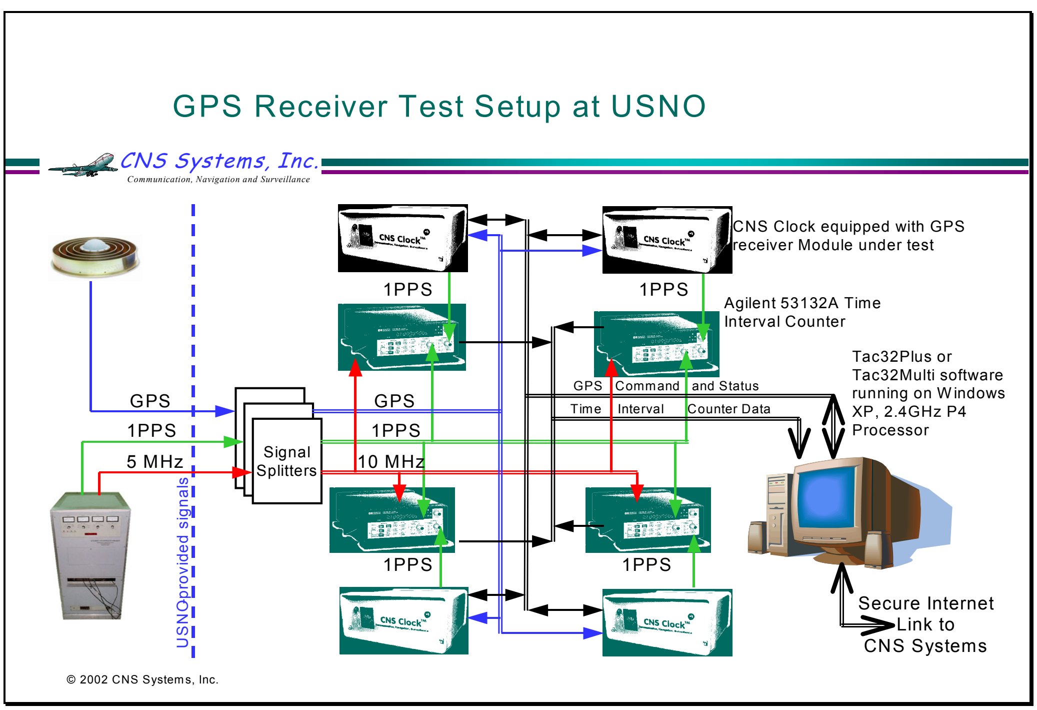

Figure 2. Block Diagram of Test Setup at USNO.

For testing the performance of the M12+ receiver 1PPS output, real time comparisons were made of the 1PPS rising edge as compared to the USNO MASTER CLOCK (MC) in Washington D.C. from July to

September 2002 as final improvements were made to the receiver firmware. The data presented in this paper displays about two weeks (over 300 hours) of continuous data taken using the final production firmware.

The test setup as shown in **Figure 2** was employed for measurement of the absolute time accuracy and frequency stability of the 1PPS signal relative to the MC over a period of time sufficient to observe the effects of satellite constellation changes and receiver firmware implementation. Note that **four** separate M12+ timing receivers were run concurrently so that any variations in accuracy or stability due to component tolerances could be identified. Statistics on the performance of the 1PPS pulse are also available in the raw data collected. The observation time period was selected so that any low frequency outliers that existed in the 1PPS output could be observed in the data. Over a month of data was collected

ABSOLUTE TIME/FREQUENCY PERFORMANCE (USNO OBSERVATIONS)

For all the data observed at the USNO, the receivers were placed in “Position-Hold" mode so that the additional time errors induced by the GPS satellite constellation movement would be eliminated. The absolute coordinates of the antenna were known to an accuracy of better than 1 meter. Delays introduced by all components of the measurement system were carefully measured and calibrated so that the 1PPS pulses produced by the M12+ timing receivers could be accurately referenced to the USNO Master Clock. General calculations of the delay calibrations are shown in **Figure 3**.

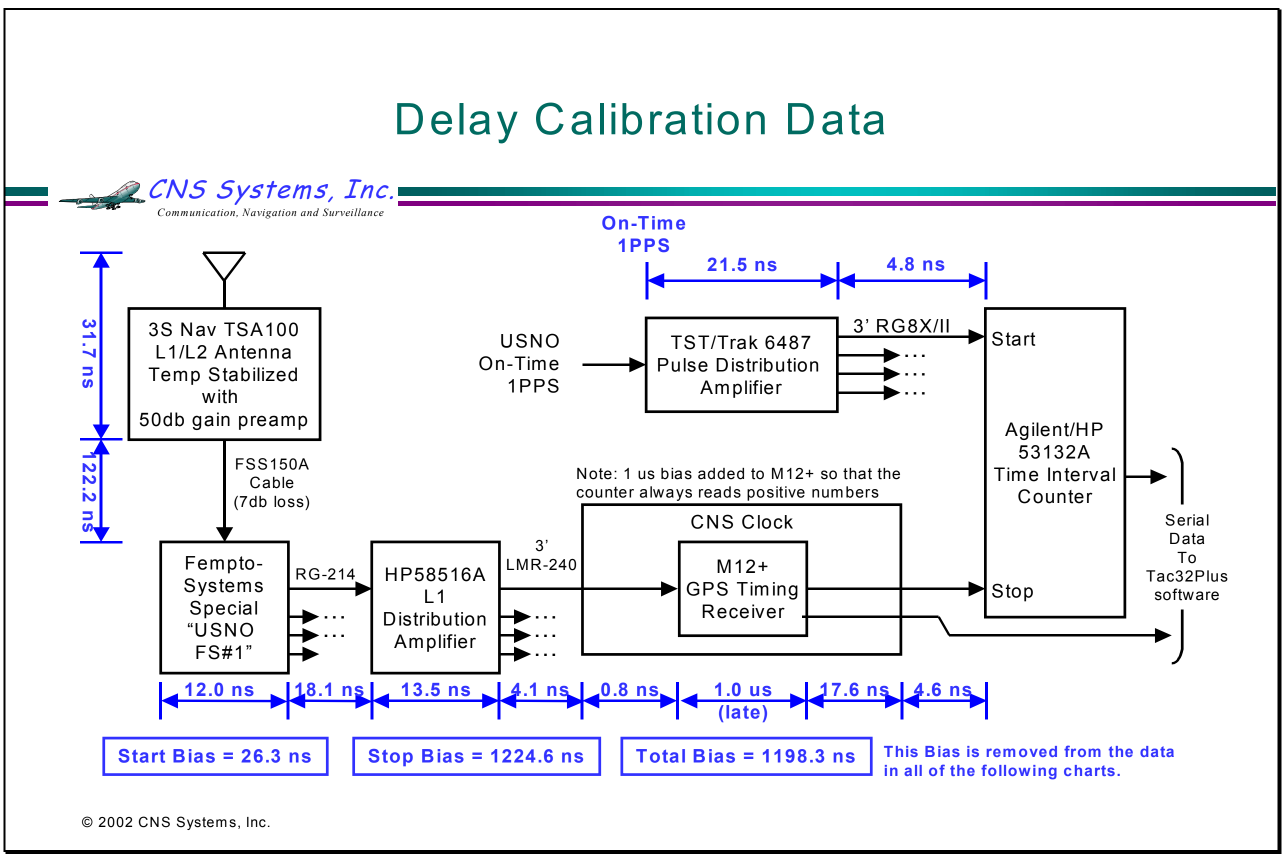

Figure 3. USNO Test System Delay Calibrations

TEST RESULTS

The following graphs demonstrate the 1PPS performance of the M12+ Timing Receivers tested at USNO over a 2 week period in September of 2002.

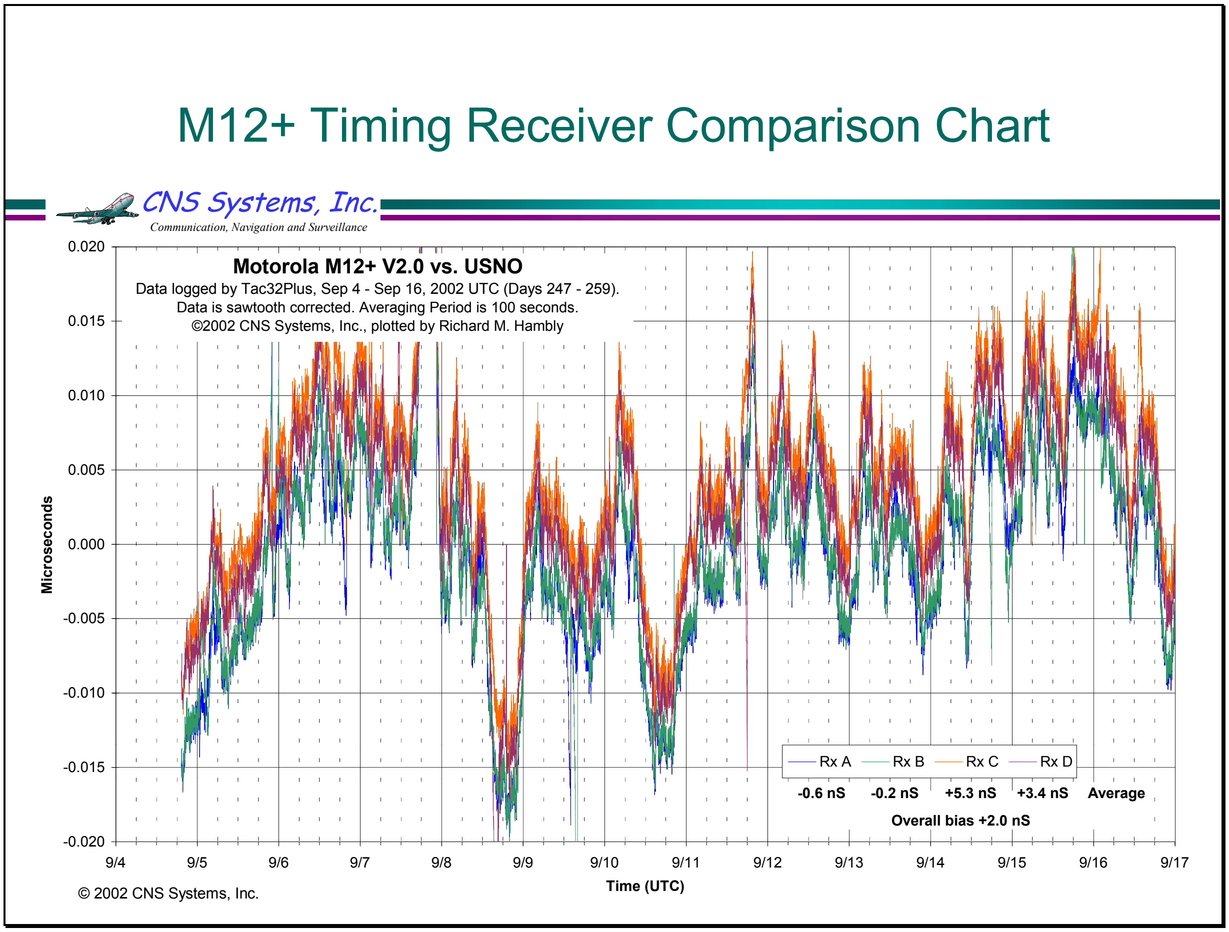

Figure 4. Aggregate Timing Performance of four M12+ Timing Receivers vs. USNO Master Clock

Figure 4 illustrates the stability and extremely tight tracking between the four test units over the 300+ hour test period. The overall bias of the developed 1PPS vs. USNO was approximately 2ns.

Raw Noise Charts – 1 Hour

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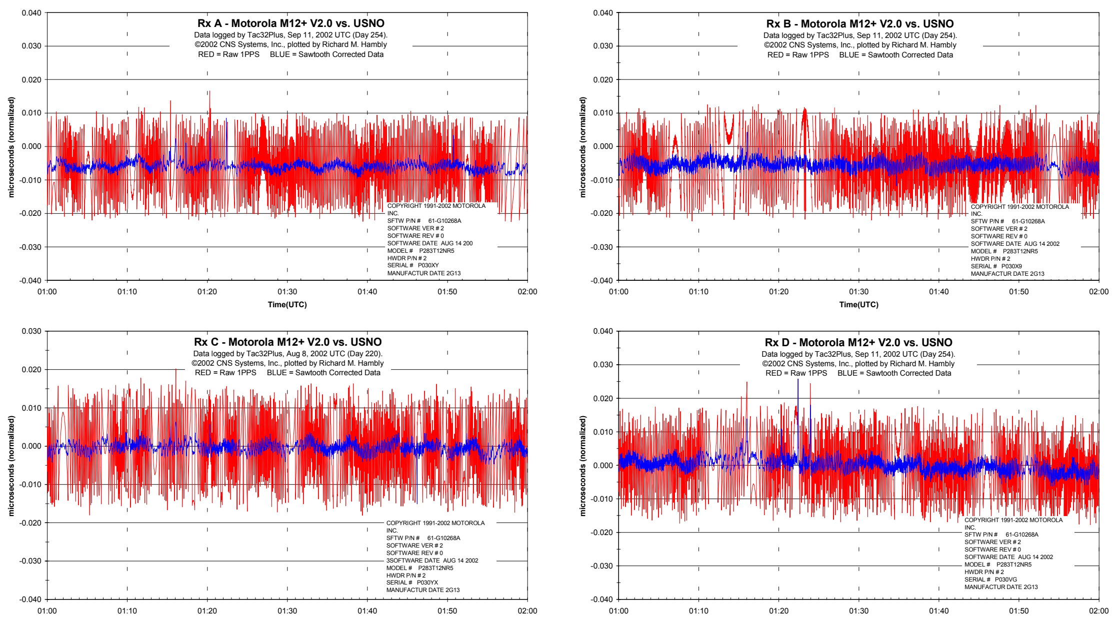

Figure 5. M12+ Timing Receiver Raw 1PPS Noise Over 1 Hour Period

Red = Raw Data **Blue = Sawtooth Corrected Data**

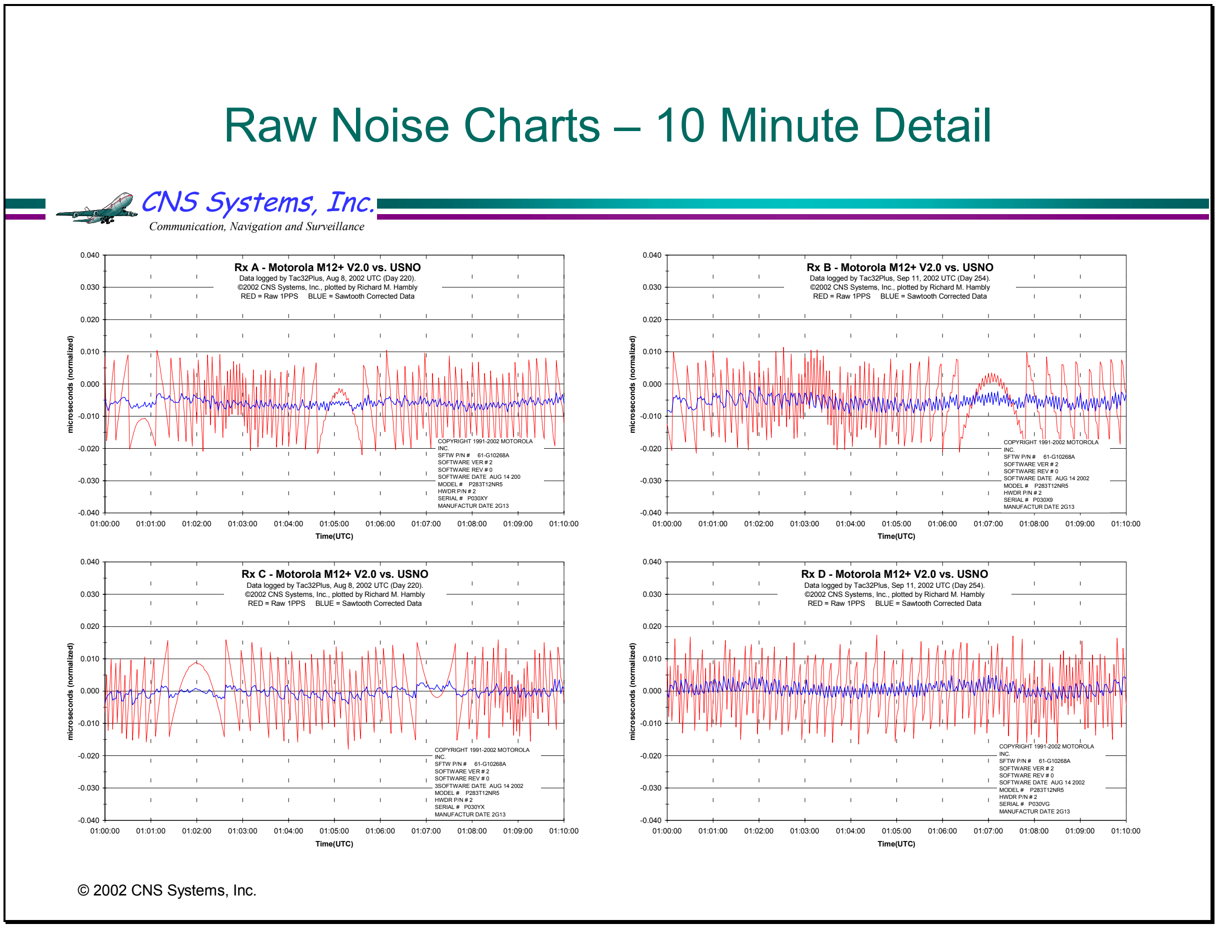

Figure 6. Detail of M12+ Timing Receiver 1PPS Noise

Red = Raw Data **Blue = Sawtooth Corrected Data**

Figures 5 and 6 show detailed 1PPS performance of the four M12+ Timing Receivers vs. the USNO Master Clock. Note that typical pk-pk 1PPS performance is in the range of 20 - 25ns, while sawtooth corrected data is typically 3 - 4ns.

CONCLUSION

The M12+ Timing Receiver from Motorola represents a major step forward in performance, size, and cost reduction for the timing oriented user. As the need for precision time transfer expands worldwide, the advanced features of the M12+ Timing Receiver will allow the system developer to meet these challenges more easily than ever before.

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