Low cost GPS-based time and frequency products, an update.

Tom Clark, GSFC/NVI (k3io@verizon.net)

&

Rick Hambly, CNS Systems (rick@cnssys.com)

With special thanks to

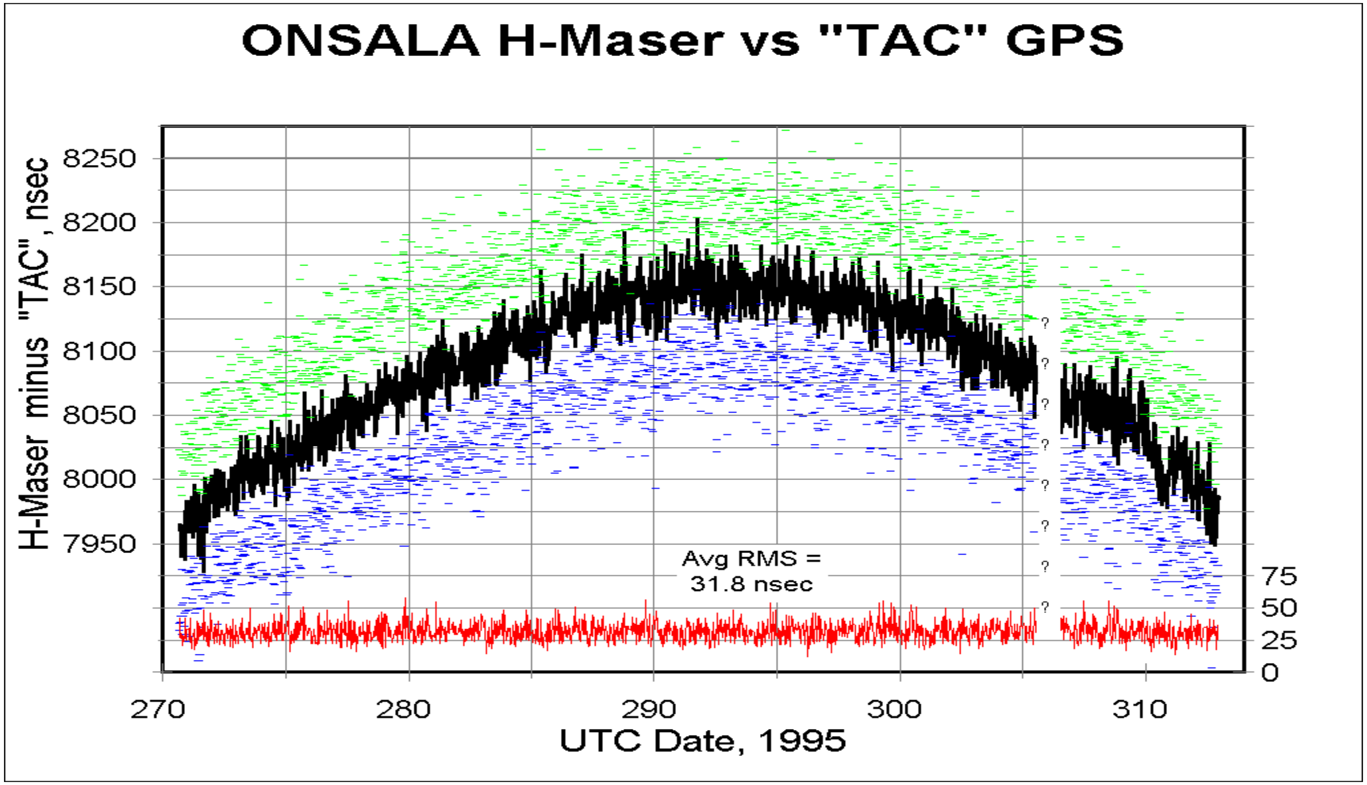
Chopo Ma, NASA/GSFC

Art Sepin, Synergy-GPS

Mike Cizek, CNS Systems

Our Brief History of GPS Timing

- The history of the 1990-2000 period can be found on www.gpstime.com in our 2000 ION paper *"**Low-cost, High Accuracy GPS Timing**"*
- In 1993, TC started developing a low cost GPS Clock using the Motorola PVT-6 single board GPS while on sabbatical at Onsala. Onsala also introduced us to the idea of using the HP53131 Time-Interval Counter as a dedicated timing monitor.
- By 1995 TC & NASA/GSFC group had produced 50 copies of TC's original "Totally Accurate Clock" (a.k.a. "TAC-1"). Motorola discontinued the PVT-6 series of receivers.



Our Brief History of GPS Timing

- Motorola announced the 8-channel ONCORE receivers in 1995 which we used in our second generation timing receiver, a.k.a. the TAC-2 and CNS Clock. Ultimately, more than 1000 of these receivers were produced.
- By 2001, Motorola introduced the new M-12 series.
- By 2002, it became obvious that the absolute (w.r.t. USNO) M-12 receiver timing had diverged by 10s of nsec thru several model changes. Rick took 4 CNS clocks equipped with M-12+ to the USNO for a zero-baseline intercomparison with the Master Clock; see www.gpstime.com for the paper "***Critical Evaluation of the Motorola M12+ GPS Timing Receiver vs. the Master Clock at the United States Naval Observatory, Washington DC".*** The original "prime" receiver from the USNO test is our "Gold Standard" reference.

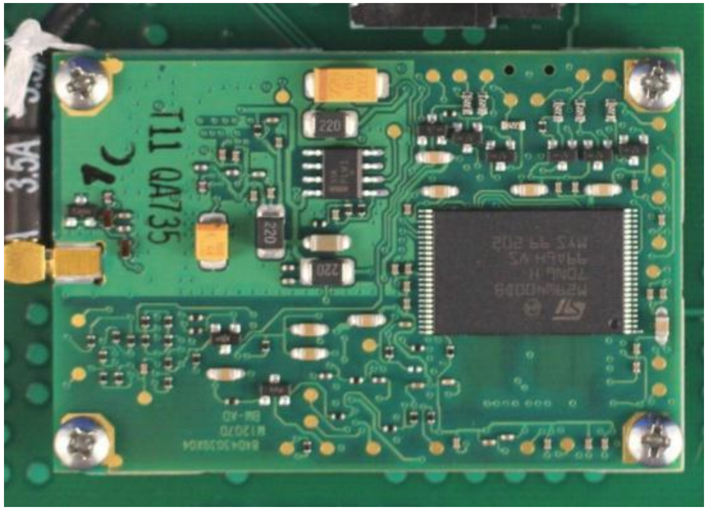
Our Brief History of GPS Timing

- Anticipating the need for a M-12 replacement, Synergy examined the uBlox LEA-6T receiver. Because of the large installed base of Motorola and iLotus receivers, a hybrid M-12 emulator was developed:
- The Synergy SSR-6T is mechanically and electrically compatible with the M-12 and includes a µP to convert the native uBlox binary command set to the Motorola @@ binary format.

All of which brings us to this paper.

Comparing an M12+, M-12M & uBlox LEA-6

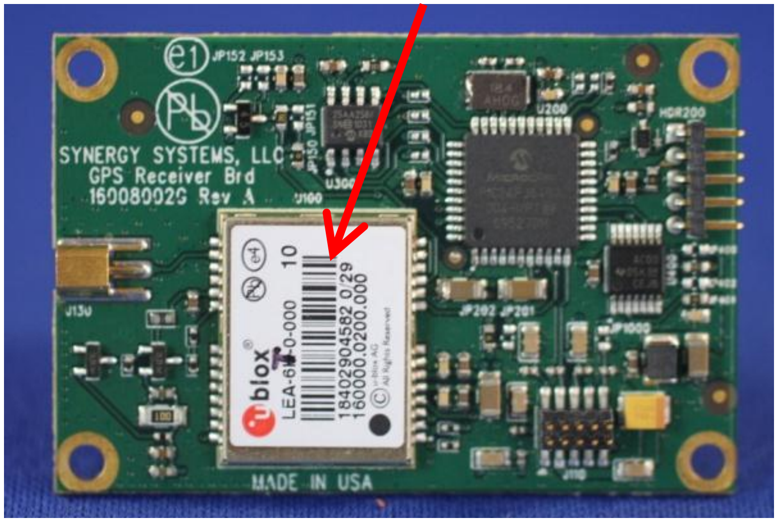
An iLotus M-12M module. The M12+ looks just the same



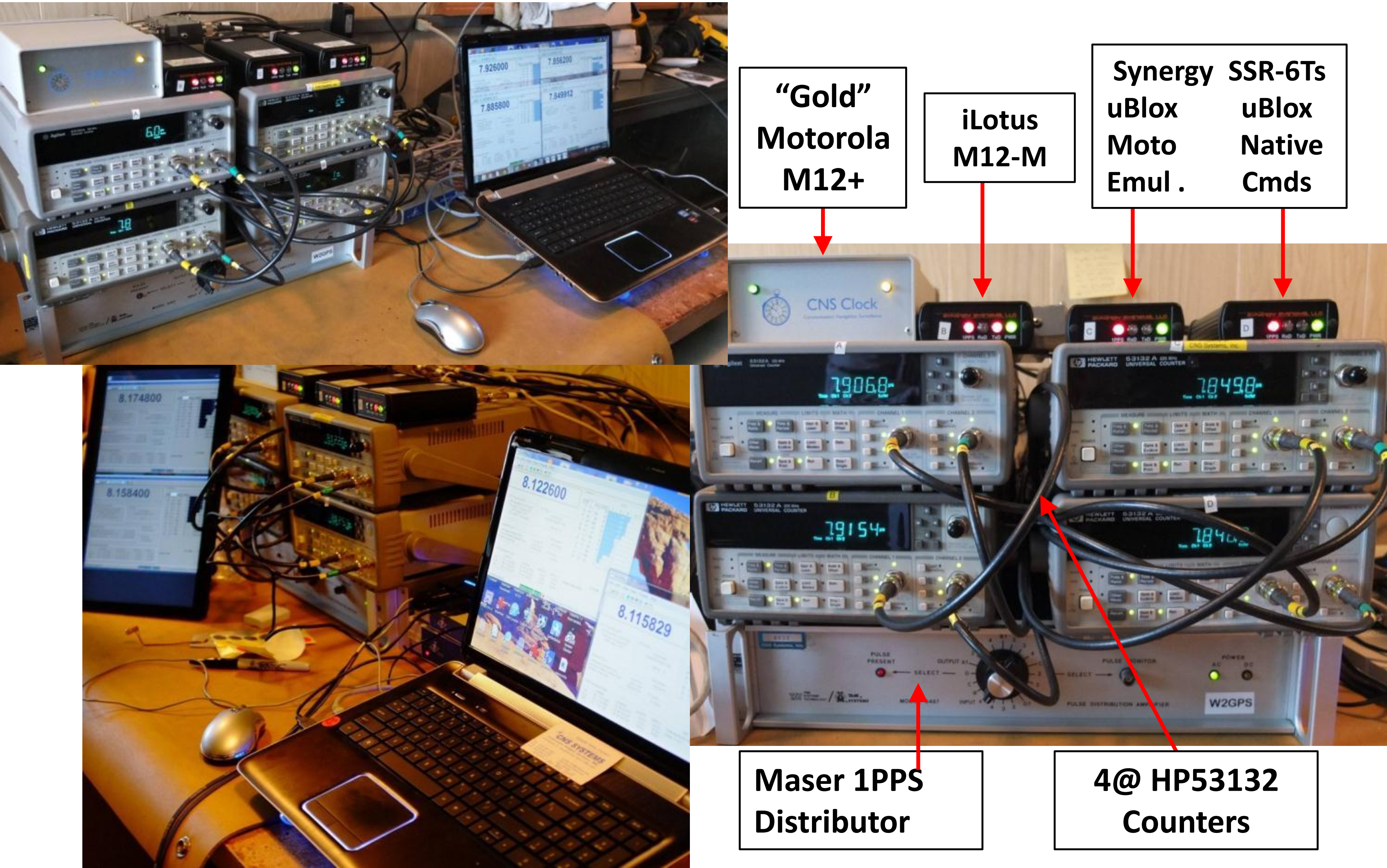
Top side

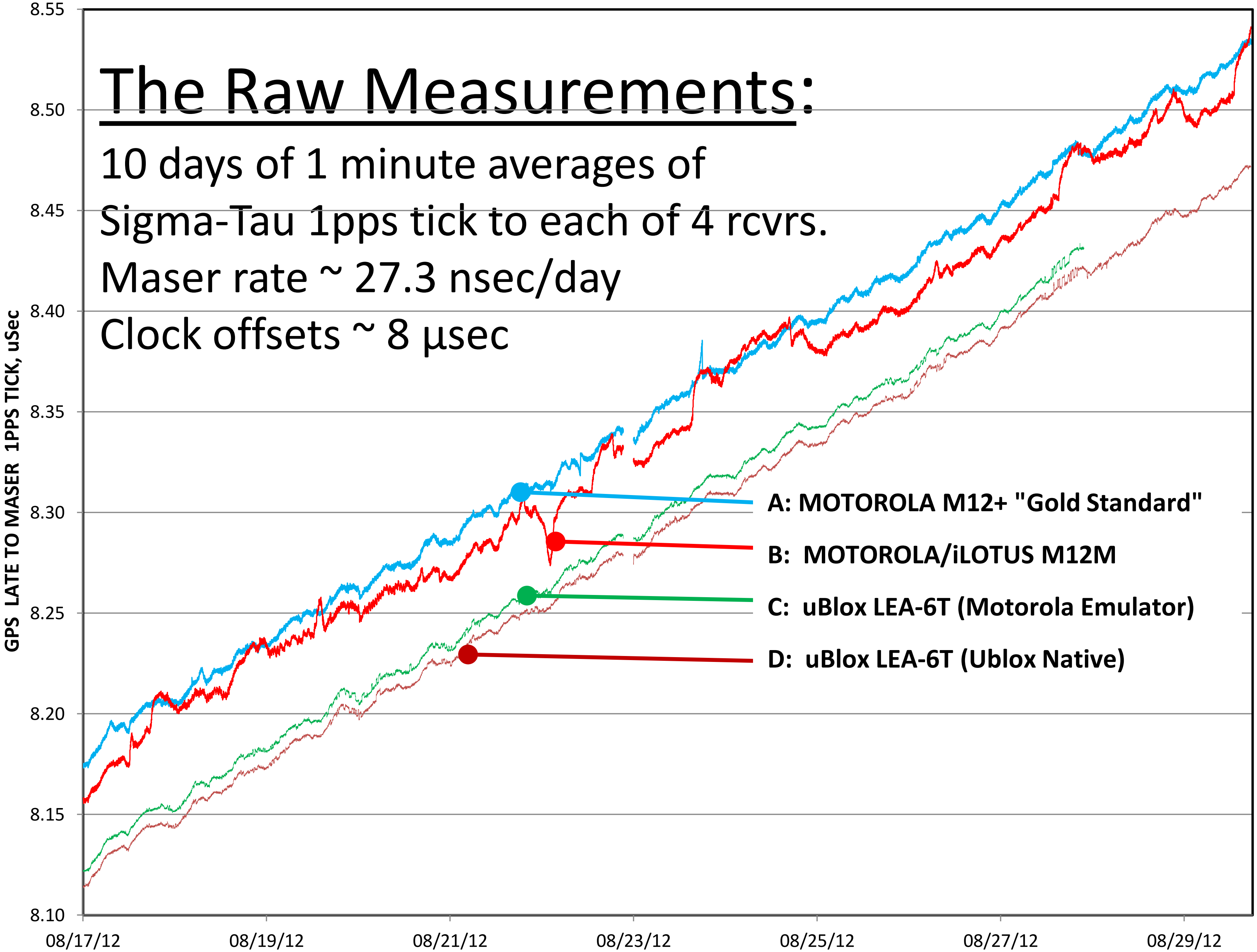
The Synergy uBlox SSR-6T

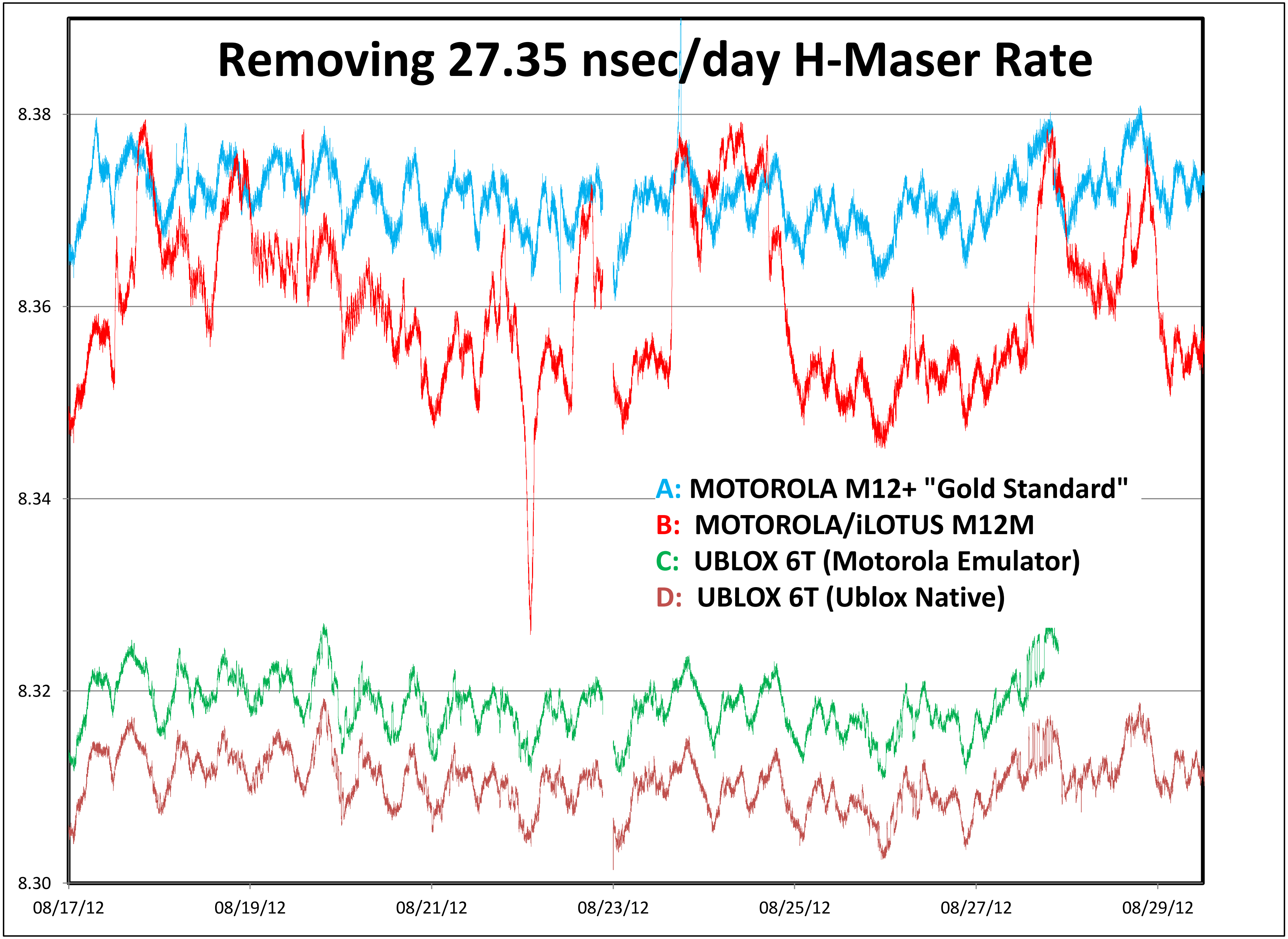
The guts are on the Bottom Side



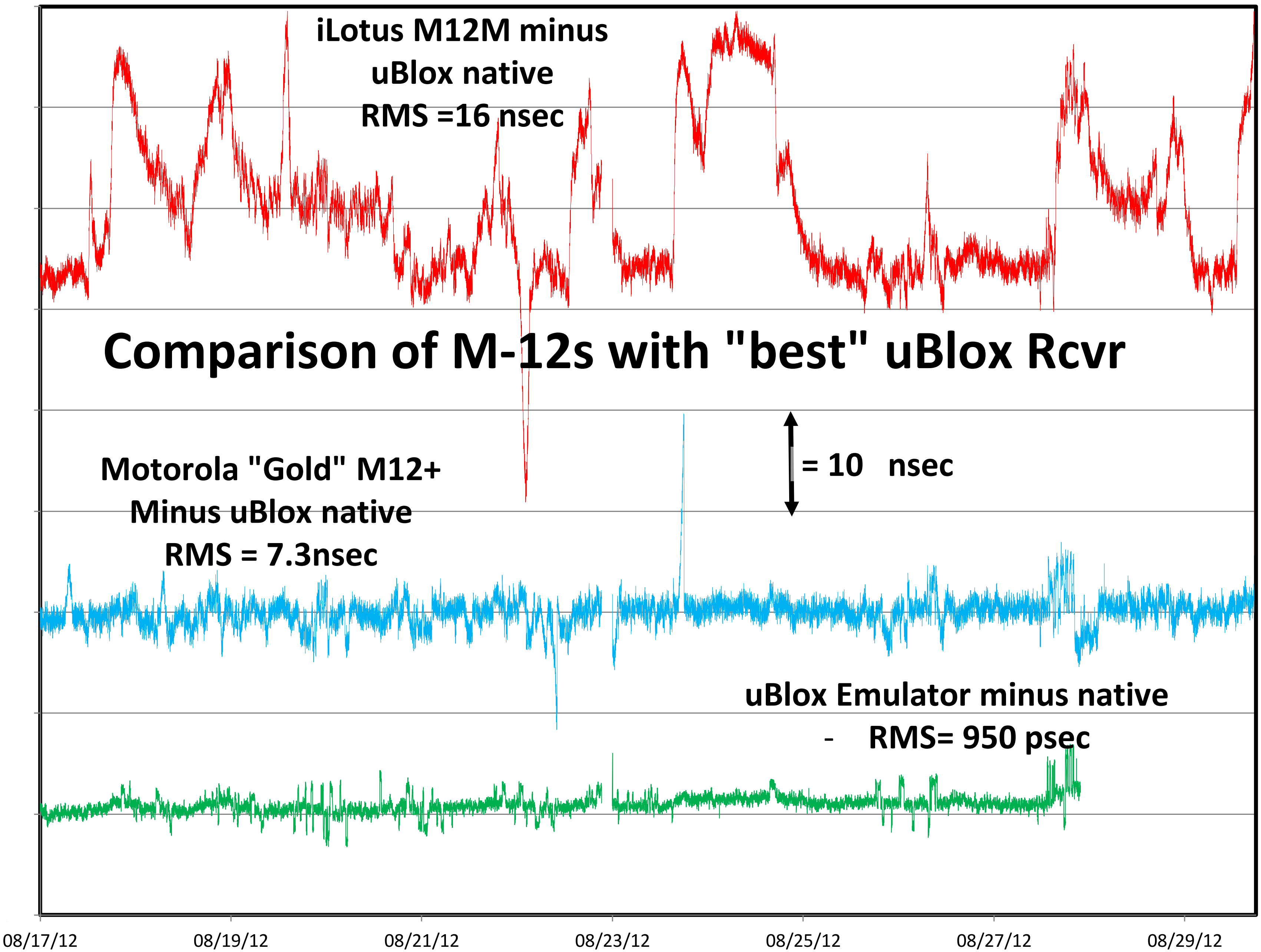
The 4 Receiver test at GGAO:




The Raw Measurements:
10 days of 1 minute averages of
Sigma-Tau 1pps tick to each of 4 rcvrs.
Maser rate ~ 27.3 nsec/day
Clock offsets ~ 8 µsec
A: MOTOROLA M12+ "Gold Standard"
B: MOTOROLA/iLOTUS M12M
C: uBlox LEA-6T (Motorola Emulator)
D: uBlox LEA-6T (Ublox Native)
GPS LATE TO MASER 1PPS TICK, uSec
8.55
8.50
8.45
8.40
8.35
8.30
8.25
8.20
8.15
8.10
08/17/12
08/19/12
08/21/12
08/23/12
08/25/12
08/27/12
08/29/12

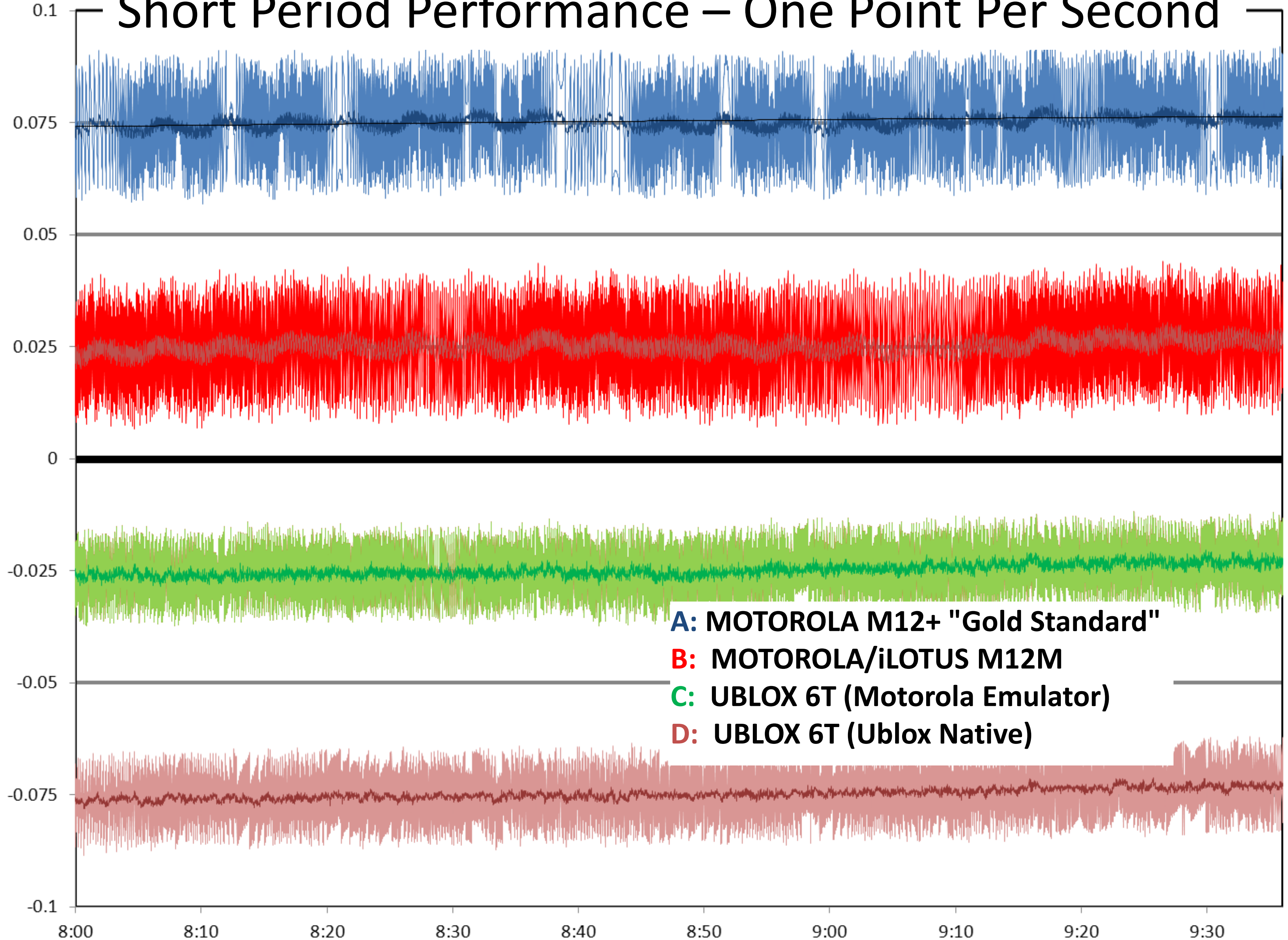


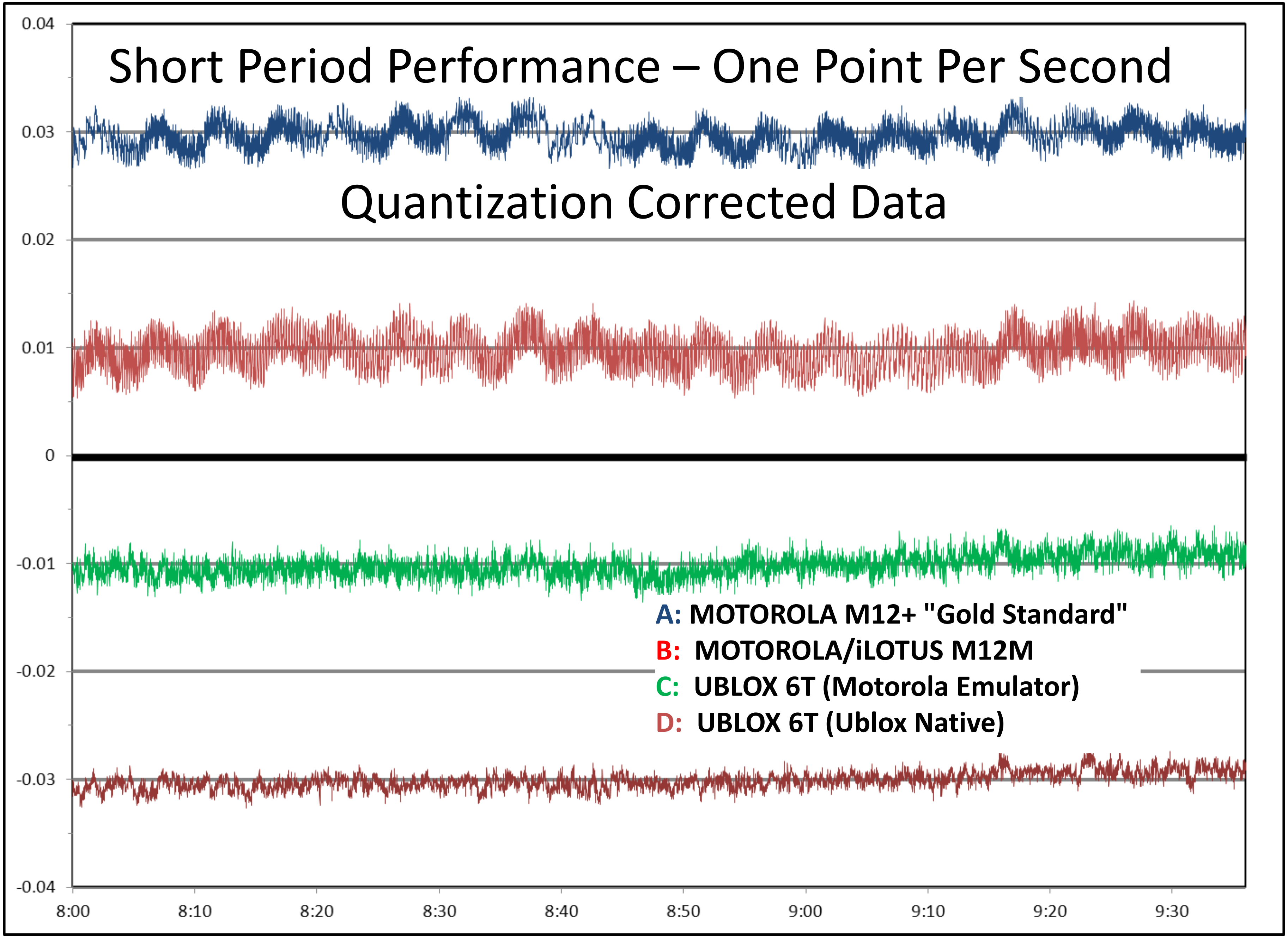
Removing 27.35 nsec/day H-Maser Rate
8.38
8.36
8.34
8.32
8.30
08/17/12
08/19/12
08/21/12
08/23/12
08/25/12
08/27/12
08/29/12
A: MOTOROLA M12+ "Gold Standard"
B: MOTOROLA/iLOTUS M12M
C: UBLOX 6T (Motorola Emulator)
D: UBLOX 6T (Ublox Native)



iLotus M12M minus
uBlox native
RMS =16 nsec
Comparison of M-12s with "best" uBlox Rcvr
= 10 nsec
Motorola "Gold" M12+
Minus uBlox native
RMS = 7.3nsec
uBlox Emulator minus native
- RMS= 950 psec
08/17/12
08/19/12
08/21/12
08/23/12
08/25/12
08/27/12
08/29/12

Short Period Performance – One Point Per Second




Short Period Performance – One Point Per Second
Quantization Corrected Data
A: MOTOROLA M12+ "Gold Standard"
B: MOTOROLA/iLOTUS M12M
C: UBLOX 6T (Motorola Emulator)
D: UBLOX 6T (Ublox Native)
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
8:00
8:10
8:20
8:30
8:40
8:50
9:00
9:10
9:20
9:30

Conclusions

1. Small, low cost GPS receivers can provide remarkably high performance (tens of nsec) timing as is needed for VLBI and other systems.
2. The current production iLotus M12M we tested showed jumps at the 10 nsec level. Some more M12M's need to be tested to see if this just a problem of this particular unit.
3. The uBlox based Synergy SSR-6T series of receivers can replace the M12+ and M12M while delivering superior performance.
4. **In fact, the two uBlox based Synergy SSR-6Ts that we tested were a factor ~5 BETTER than the old M12s in all aspects except for a "DC" epoch bias ~30 nsec.**

Questions?