Extremely accurate timing with a new interface for the Motorola GPS modules

R. Ambrosini, G. Maccaferri, M. Roma,
A. Maccaferri, A. Scalambra

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Abstract

Any VLBI station requires knowing the synchronization error of the local time with respect to the UTC scale. The benefit is twofold: first, the process of data correlation can avoid loosing time for the initial search of the maximum fringe amplitude ("blind correlation"); secondly, it is possible to monitor the real good health of the station atomic standard, at least over long averaging time.
Recent work of Tom Clark [1] has shown how the Motorola Oncore receivers for the Global Positioning System can be used for such an application. We have built a new simpler interface for the UT+ units of the same family and tested it, against our H-Maser frequency standard.

The ultimate resolution for a timing application relates to the length of the modulation C/A code (1MHz), the internal algorithm, used by the receiver to track the GPS time, and the intentional degradations applied to the signal by the Department of Defense (like the "selective availability" and possibly others).

Simple data averaging can reduce the measurement noise from 300ns to typically 30ns. This allows a significant comparison between UTC and the local atomic clock, based on the H-Maser, over a few days.

1. The new interface

Motorola has produced different models of GPS receivers: the Oncore family had been optimized in different configurations for both navigation and timing applications. Now the UT+ module has superseded the old ones and, at lower cost, is declared to be dedicated only for timing. The new unit is pin-compatible with the Oncore VP module, but it differs in the way it is handled the case of a wrong timing. RAIM is called the special software code that can kill the usual 1PPS (one peak per second) output when this happens.

An american organization can deliver trough the Internet (www.tapr.org) an interface board, full of many options and suitable for almost all the Motorola, Garmin types of GPS receiver modules. Our application is so special that we decided to redesign the interface with the least number of components really needed to operate only the VP and UT+ modules.

In fig. 1 we report the pin assignment of the unit. Apart from the power supply, you can see the three terminals for the serial connection with the controlling PC (Tx, Rx and Ground) and the two terminals for the 1PPS signal.

We have bought the model R5222U1111, equipped with a rechargeable a Ni-Cd battery on board. It keeps running time, even with no power applied, speeding up the next acquisition when power will come back.

All the new units deliver and accept the serial bi-directional signals as inverted TTL levels. Then a single IC, like the Maxim232, can make them compatible with the RS232 standard of a PC, by transferring the voltage levels and re-inverting the signals.

Finally we have buffered the 1PPS output, in such a way that it is possible to distribute the signal over four ports, each driving almost any length of coax cable, terminated in its characteristic impedance (50 Ω). The satisfactory behavior of the 74F04 IC in this application is shown in Fig. 2. The upper plot shows the rising edge of the 1PPS signal at the module output, as seen by the high impedance load of the oscilloscope. The bottom plot shows the well acceptable degradation after 30m of coax terminated into a 50 Ω load, from 10ns to 13ns.

A complete wiring of the simple interface we have built, is reported in Fig. 3. On the left, it appears the pin assignment of the GPS module and on the right the connection with the serial port of the PC. The schematic shows that also the 1PPS signal has been inverted, before the conversion with the Maxim232. This is required by the compatibility with the old software code [1] and the new one [2], which exploit all the capabilities of the Motorola module.

A simple led flashes on the front panel at the 1PPS rate, to show the alive condition of the unit. For the sake of completeness, we remind here that the unit requires a very special RF connector for the antenna lead. In the MaCom catalog it has the part number 5807-7985-09.

2. Measurements

Giuseppe Maccaferri wrote the LabView routine which reads the HP universal counter sampling the time interval between the 1PPS delivered by the GPS module and the station 1PPS (derived by division from the 5 MHz output of the H-Maser).

Fig.4 shows a typical data acquisition over one day, one measurement per second (for graphic reasons the X-axis is limited to 32000 points). The new UT+ module does not seem to offer any improvement in time stability as declared by the manufacturer. As far as we have seen until now, we did not see any case where the RAIM alarm has been activated.

3. References

[1] Tom Clark, see for example, "Totally accurate Clock" at the site www.tapr.org

[2] TAC32 by CNS systems. See www.cnssystem.com

4. Acknowledgment

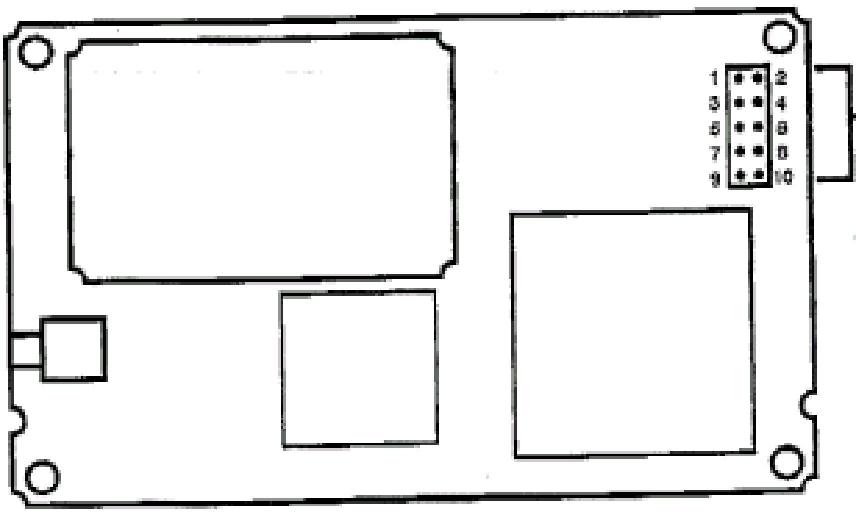
We thank Dr. G. Tomassetti for revising the paper and G. Minarelli for drawing Fig.3.

B. Pin Out Designations

DESCRIPTION	SIGNAL	PIN #
Externally Applied Back-Up Power	Battery	1
+5 Vdc Regulated	5V PWR	2
Ground (5 Vdc return)	Ground	3
Not used by customer	Vpp	4
NOT USED (leave open)	*NOT USED (leave open)*	5
1 Pulse Per Second Output	ONEPPS	6
1 Pulse Per Second Return	ONEPPS RTN	7
Transmit 5 V Logic	TTL_TXD	8
Receive 5 V Logic	TTL_RXD	9
Transmit/Receive Return	TTL_RTN	10

2.5 ÷ 5.25 V
15 μA – (60 μA Max)
4.75 – 5.25 V
[178 mA]

GPS NP Oncore Circuit Board



DA: VILLA C.
A: DR. AMBROSINI

Cordiali Saluti

BFI IBEKSA S.p.A.
Via Massena, 18
20145 - MILANO
Telefono 336.23.208
Fax 336.11.603

Fig .1

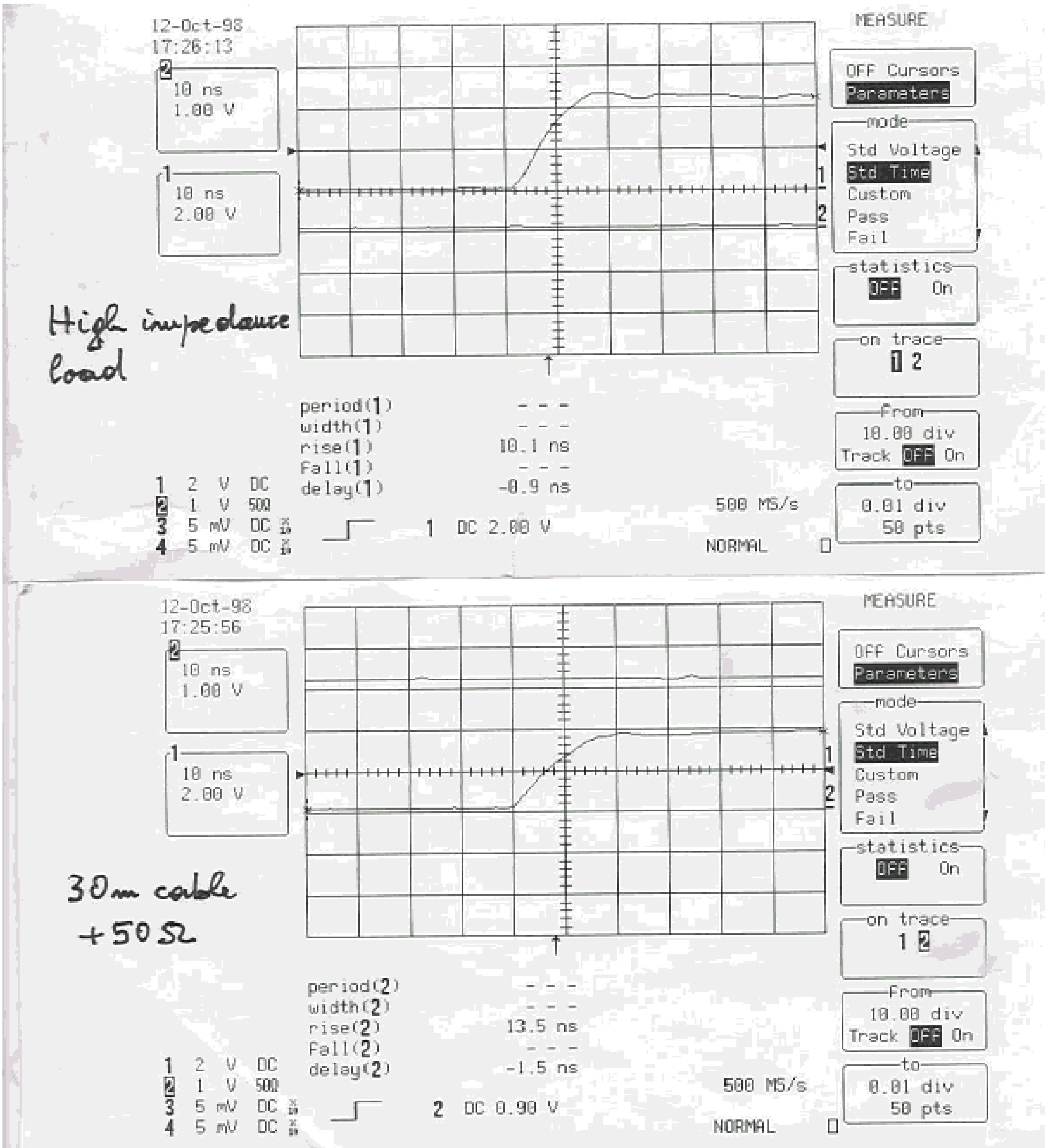

12-Oct-98
17:26:13
10 ns
1.00 V
10 ns
2.00 V
High impedance load
MEASURE
OFF Cursors
Parameters
mode
Std Voltage
Std Time
Custom
Pass
Fail
statistics
OFF On
on trace
1 2
from
10.00 div
Track OFF On
to
0.01 div
50 pts
period(1) - - -
width(1) - - -
rise(1) 10.1 ns
fall(1) - - -
delay(1) -0.9 ns
500 MS/s
NORMAL
1 2 V DC
2 1 V 50Ω
3 5 mV DC
4 5 mV DC
1 DC 2.00 V
12-Oct-98
17:25:56
10 ns
1.00 V
10 ns
2.00 V
30m cable
+50Ω
MEASURE
OFF Cursors
Parameters
mode
Std Voltage
Std Time
Custom
Pass
Fail
statistics
OFF On
on trace
1 2
from
10.00 div
Track OFF On
to
0.01 div
50 pts
period(2) - - -
width(2) - - -
rise(2) 13.5 ns
fall(2) - - -
delay(2) -1.5 ns
500 MS/s
NORMAL
1 2 V DC
2 1 V 50Ω
3 5 mV DC
4 5 mV DC
2 DC 0.90 V

Fig .2

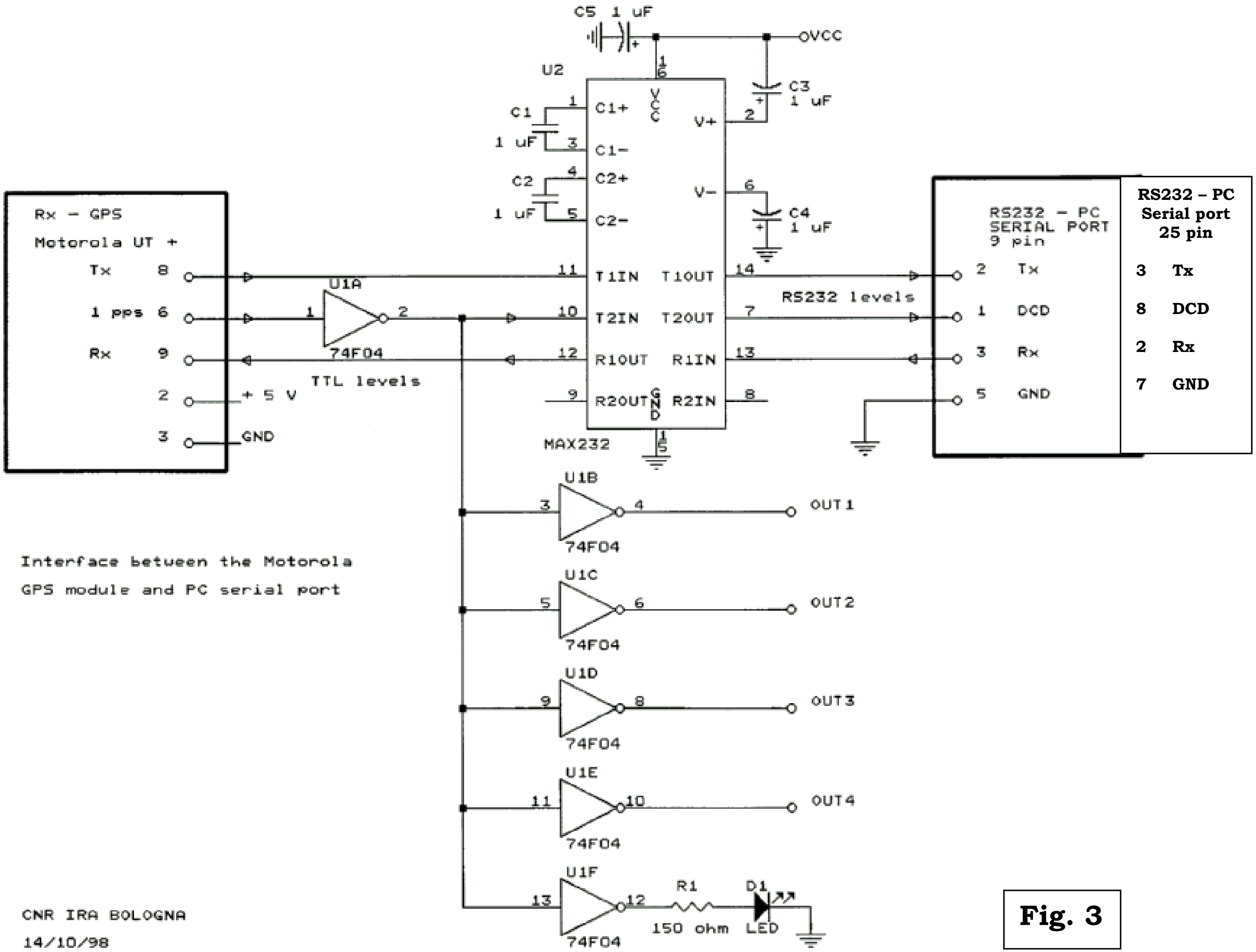

C5 1 uF
OVCC
U2
C1
1 uF
C2
1 uF
C1+
C1-
C2+
C2-
VCC
V+
V-
C3
1 uF
C4
1 uF
T1IN
T2IN
R1OUT
R2OUT
T1OUT
T2OUT
R1IN
R2IN
GND
MAX232
Rx - GPS
Motorola UT +
Tx 8
1 pps 6
Rx 9
2
3
+ 5 V
GND
U1A
74F04
TTL levels
RS232 levels
RS232 - PC
SERIAL PORT
9 pin
2 Tx
1 DCD
3 Rx
5 GND
RS232 – PC
Serial port
25 pin
3 Tx
8 DCD
2 Rx
7 GND
U1B
74F04
OUT1
U1C
74F04
OUT2
U1D
74F04
OUT3
U1E
74F04
OUT4
U1F
74F04
R1
150 ohm
D1
LED
Interface between the Motorola
GPS module and PC serial port
CNR IRA BOLOGNA
14/10/98

Fig. 3

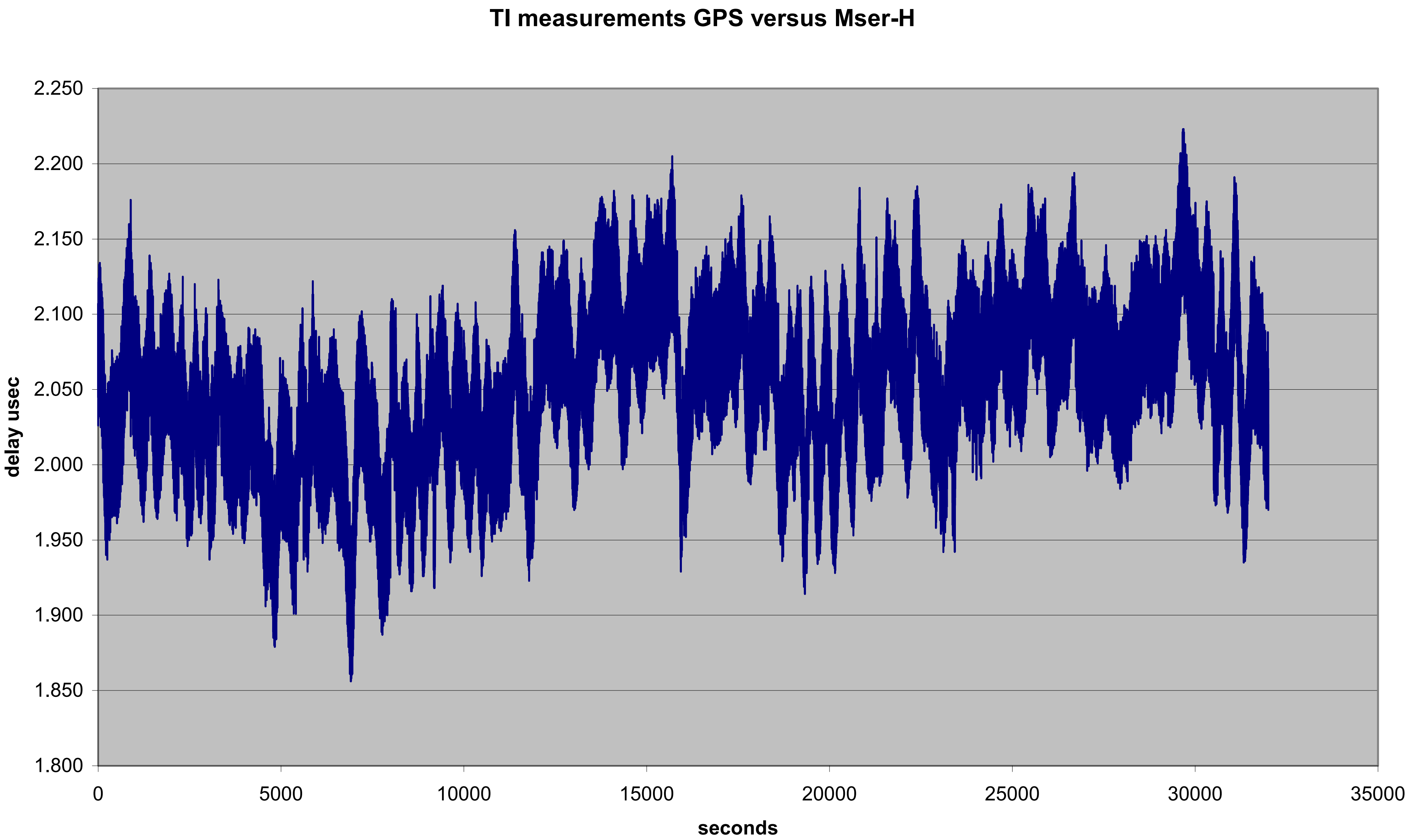

TI measurements GPS versus Mser-H
delay usec
2.250
2.200
2.150
2.100
2.050
2.000
1.950
1.900
1.850
1.800
0
5000
10000
15000
20000
25000
30000
35000
seconds

Fig. 4