IEN TWSTFT station report

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TWSTFT at IEN

Major Events

- Apr. 2004. New transceiver for IEN02
- Sep. 2004. IEN02 received the approval from INTELSAT
- Nov. 2004. Comparison campaign between PFS – Intensified schedule (12 measurement/day). Stability evaluation of TWSTFT with respect to GPS CP
- Apr. 2005. IEN02 ready to operate automatically
- May 2005. Satellite switch (IS903 to IS707)
- May 2005. Failure of IEN01 (microwave cable); IEN02 was put in operation
- Aug 2005. IEN01 repaired – cable replaced, calibration lost. IEN01 is kept as backup station
- Nov 2005. TUG01 visited IEN. IEN02 and IEN01 calibration

IEN 01 Setup

Reference type:

IEN Maser #2 (BIPM code 1401102)

Modem Type:

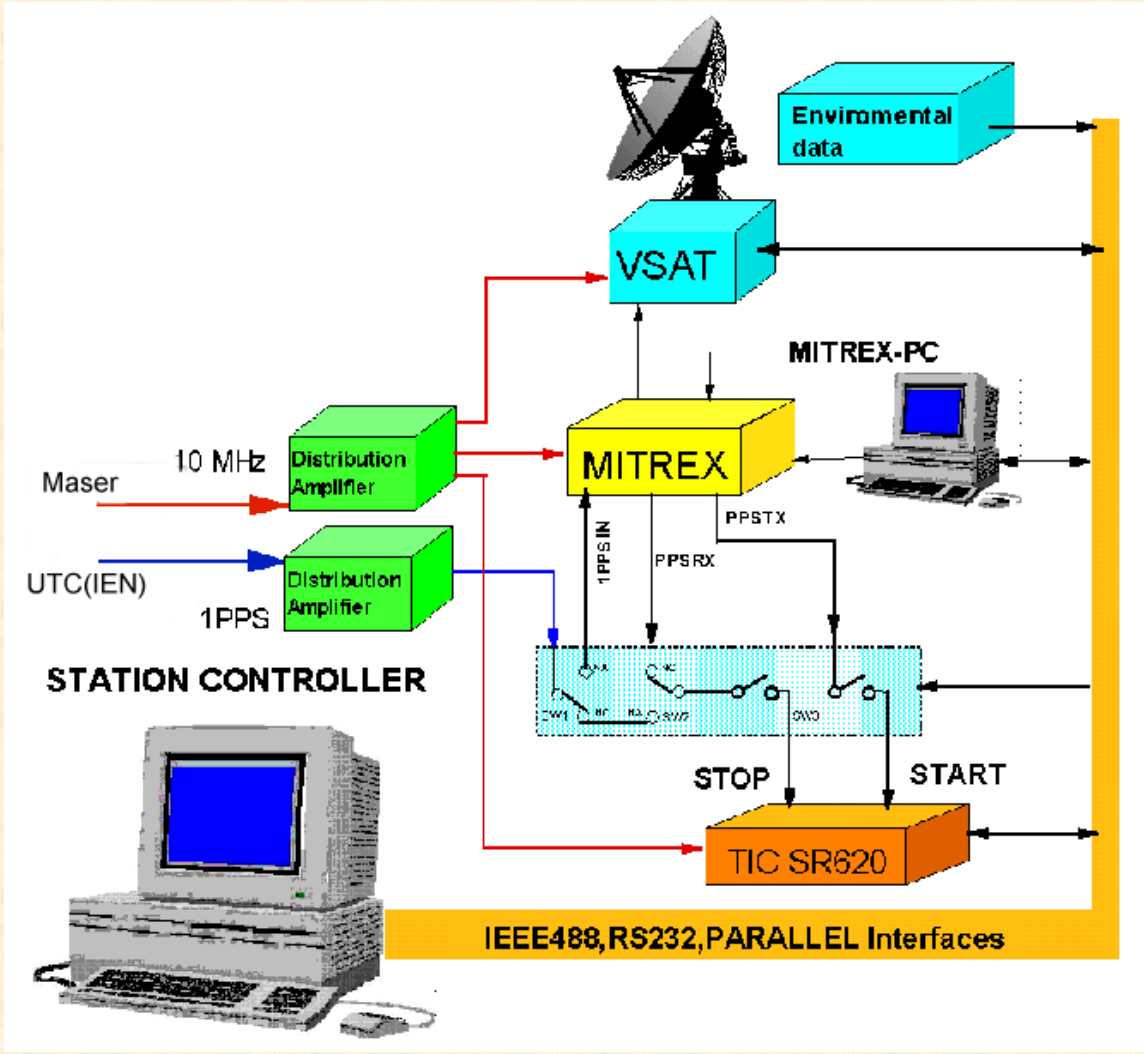
University of Stuttgart/MITREX 2500A (S/N Italy 1). External counter

Link to UTC(IEN):

REFDELAY (UTC(IEN)-1PPSTX) measurement

Min. 04 -> EU labs

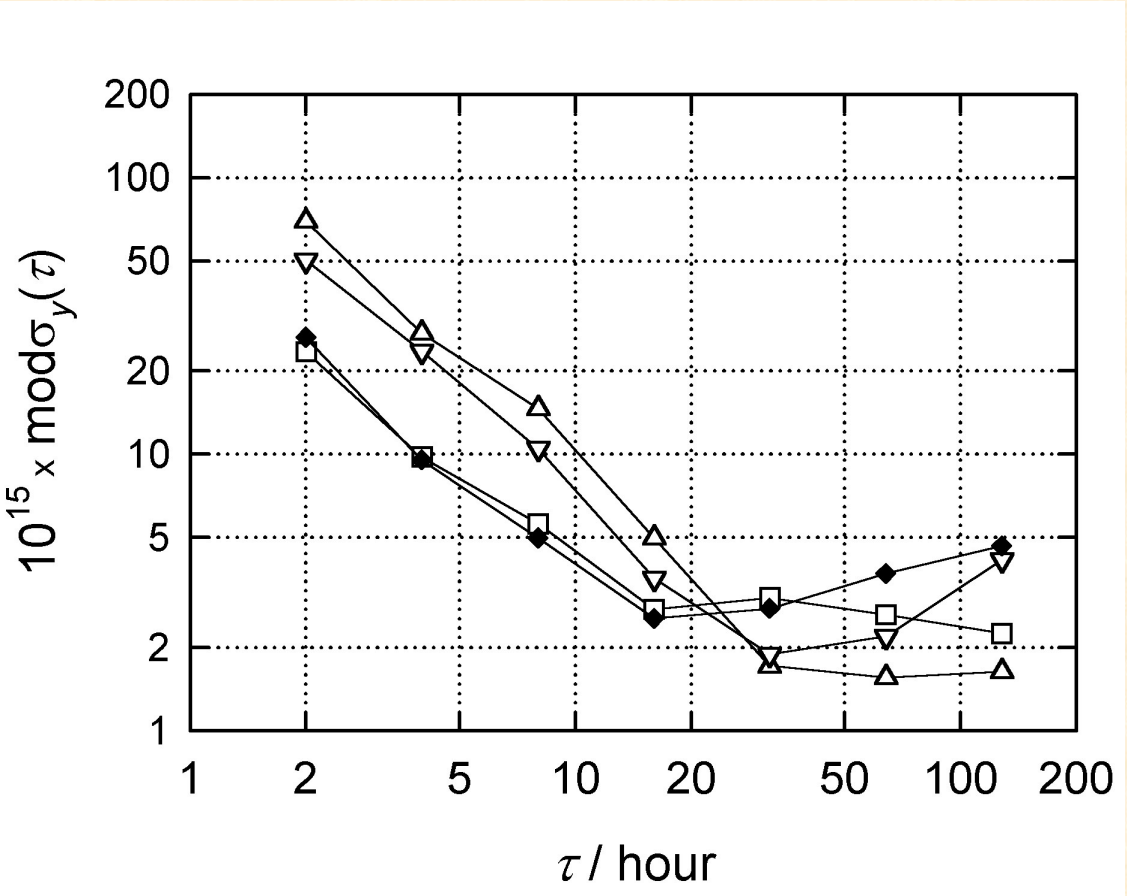
Min. 50 -> USA labs



Comparison campaign between PFS

- **3 PFS (IEN-CsF1, SYRTE-FO2, NPL-CsF1) running at the same time (MJD 53304-53324)**
- **Remote comparison of fountain local oscillators using 3 different methods (TWSTFT, GPS- CP, GPS-P3)**
- **TWSTFT intensified schedule for 30 days**
- **Fountain data analysis "synchronous" with the TWSTFT schedule**
- **Preliminary results presented at EFTF05, extended paper accepted by Metrologia**
  - Frequency transfer stability of TWSTFT EU-EU links $3\text{-}4\cdot10^{-14}$ @ 2h
  - Frequency transfer accuracy better than $6\cdot10^{-16}$ over the period (closure IEN-OP-NPL)

TWSTFT stability



Relative frequency instability, expressed by mod$\sigma_y(\tau)$, in the TWSTFT comparison of masers at OP to the other participating stations. The symbols reflect the remote station for each link: IEN (∇), NIST (Δ), NPL (□), and PTB (♦), respectively.

From A. Bauch et al. Accepted by Metrologia

Installation of a second TWSTFT measurement system at IEN

IEN 02 Station configuration

Modem: Timetech SATRE 079

Transceiver: Anacom Anasat SeKU 4 W (UpLink: 13.75 to 14.5 GHz, Downlink 10.75 to 12.75 GHz)

Antenna: Prodelin model 1184 (1.8 m)

Cables: Modem to Transceiver

(40 m) Andrew FSJ50-A

Intelsat code: `IEN-02K2`

IEN02 Setup

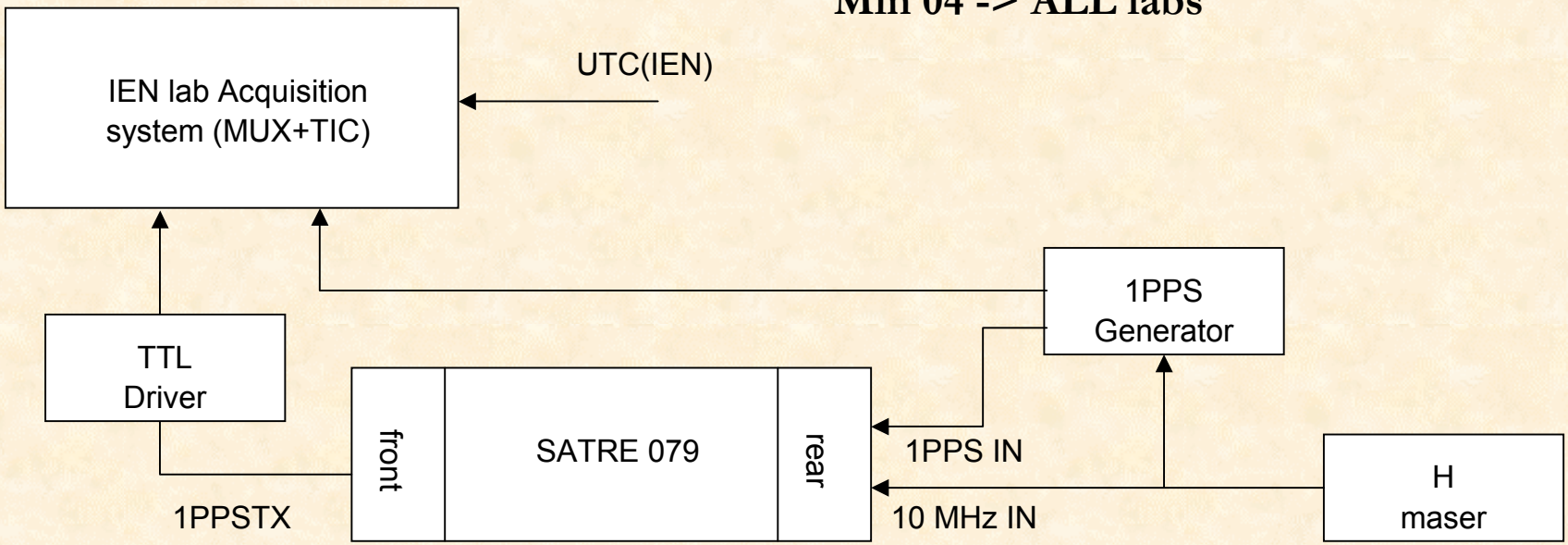
Reference type:

IEN Maser #2 (BIPM code 1401102)

Link to UTC(IEN):

REFDELAY (UTC(IEN)-1PPSTX) measurement

Min 04 -> ALL labs



The TTL driver is required because the 1PPSTX(SATRE) high level is too low to drive the Acquisition System counter, that uses 1 V as trigger level

SATRE Modem

- **Modem SATRE**
  - S/N 079
  - Current software version 4.11.0
- **SATRE Ranging measurements**
  - Internal TIC values (defined in the file SATERM.FLD)
    - Time Tag (Y=-10, -11)
    - Ranging data (Y=50)
- **SATRE Operational parameters measurements**
  - Acquired once per session
    - RX Freq (Y=73), Signal Power (Y=-2), C/No (Y=-16)
- **Scheduler**
  - The internal scheduler is not used
  - Session Parameters defined Internal Configurations (SATERM.0 file used)
  - 1PPS-SYNC not activated regularly (REFDELAY measured with respect to 1PPSTX from the front panel)
- **Modem I/O**
  - Measurements via UDP (port 3020)
  - Commands via TCP (port 2000)
  - Error messages via SYSLOG
  - File exchange (only maintenance) via TFTP

SATRE Time-Tag Bug correction

```
* I5368306.13E
* UTC(IEN) - CLOCK    = +0.000000000000 s
* UTC(IEN) - UTC(TW) = +0.000000076800 s 53669 130000
* UTC(TW)  - 1PPSTX   = +0.000004751438 s 53683 060000
* C1 Rxcode= 4 RxFreq=70199052 RxSig=-51.9 RxC/No= 52.8
* C2 Text= 08.72 Hext= 099.90 Pres= 0999.30
* C3                        IEN01 - PTB01
* DATA = 1PPSTX - 1PPSRX
53683 061300 0.271168866479
53683 061301 0.271168863542
53683 061302 0.271168861057
53683 061303 0.271168855982
53683 061304 0.271168853902
53683 061305 0.271168850228
53683 061306 0.271168847103
53683 061307 0.271168844108
53683 061308 0.271168840963
53683 061309 0.271168837373
53683 061310 0.271168834153
53683 061311 0.271168830833
53683 061312 0.271168827168
53683 061313 0.271168823733
53683 061314 0.271168820303
53683 061315 0.271168816983
53683 061316 0.271168814183
.................
```

1s data fitted with a quadratic model

$$x = At^2 + Bt + C$$

Value x_0 for the ITU file

$$x_0 = At_0^2 + Bt_0 + C$$

```
* EARTH-STAT  LI  MJD  STTIME NTL        TW          DRMS SMP ATL
* LOC    REM          hhmmss  s         s           ns       s
 IEN01  PTB01 05 53683 061300 119 +0.271168670722 0.446 120 119
```

Calculated at

$$t_0 = STTIME + 59.5s$$

How to correct the SATRE Time-Tag in the 1s files

```
.................
53683 061315 0.271168816983
53683 061316 0.271168814183
.................
```

Raw data from SATRE
(Not corrected)

Correction

```
.................
53683 061314.5 0.271168816983
53683 061315.5 0.271168814183
.................
```

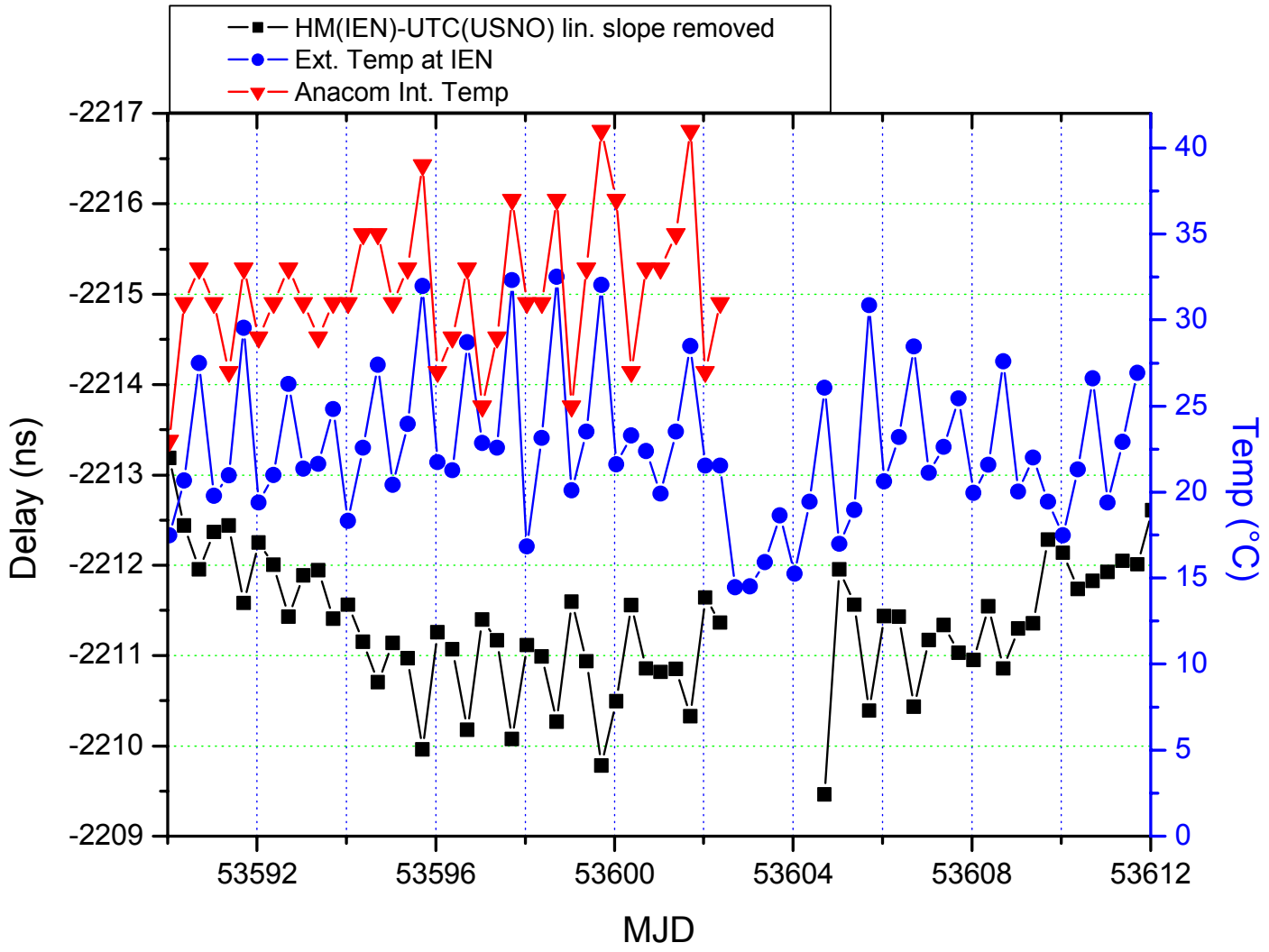
Time-Tag corrected
BUT
The format do not match the ITU definition

```
.................
53683 061315 0.271168815583
53683 061316 0.271168812783
.................
```

14:52:00.0 Raw SATRE datum + [(fit calculated point at 14:52:00.0) - (fit calculated point at 14:51:59.5)]
14:52:01.0 Raw SATRE datum + [(fit calculated point at 14:52:01.0) - (fit calculated point at 14:52:00.5)]

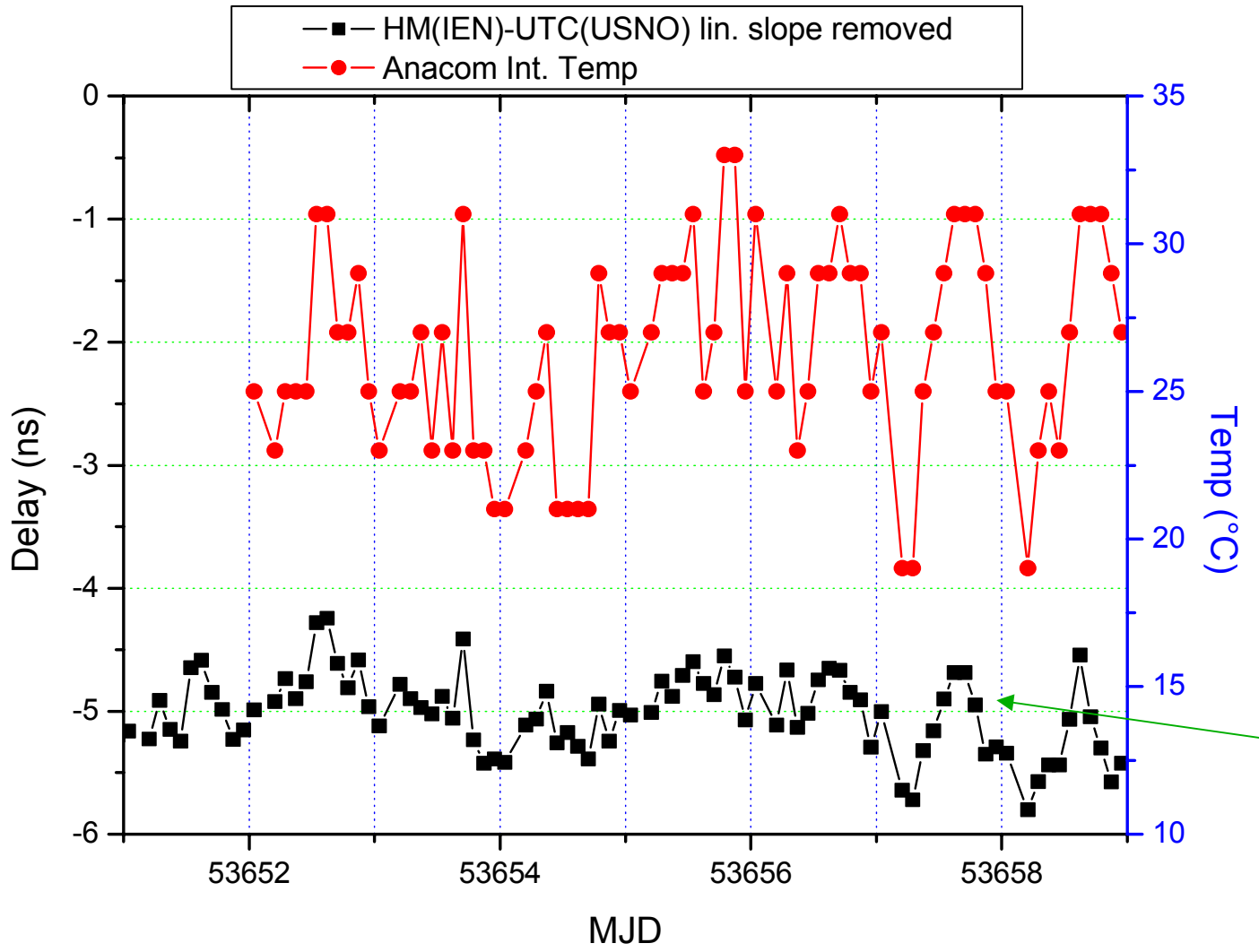
Time-Tag corrected
BUT
The ITU file do not contains raw but processed data

Temperature sensitivity of IEN02



July-August 2005

Temperature sensitivity of IEN02

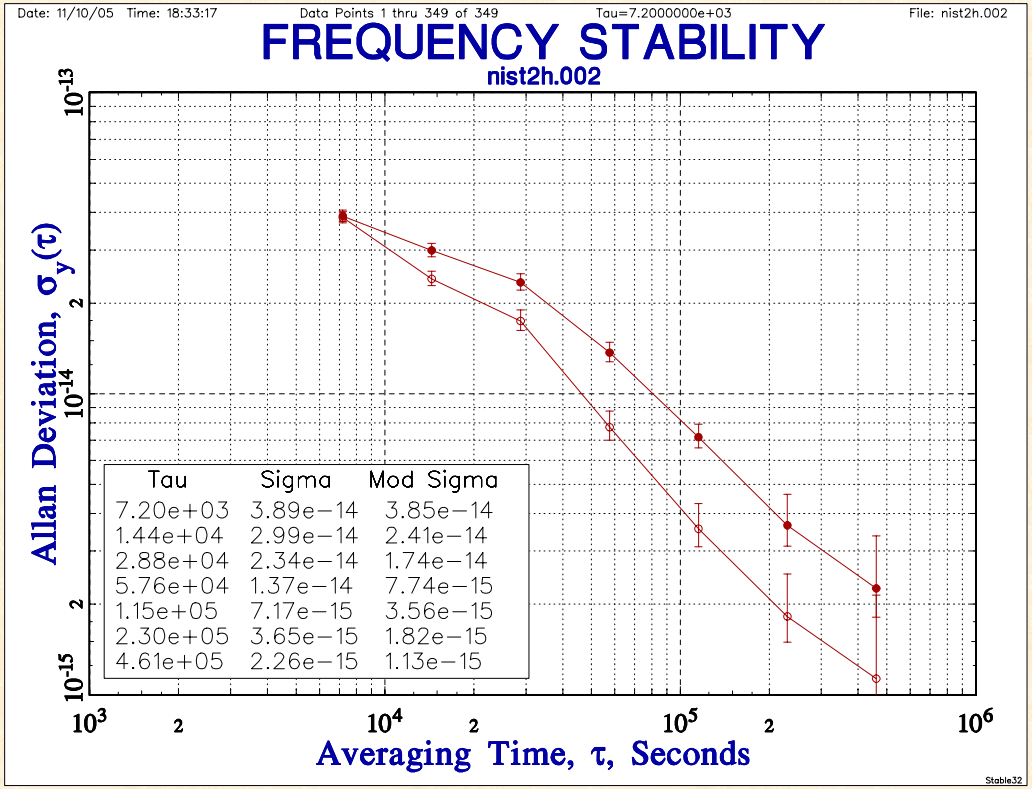


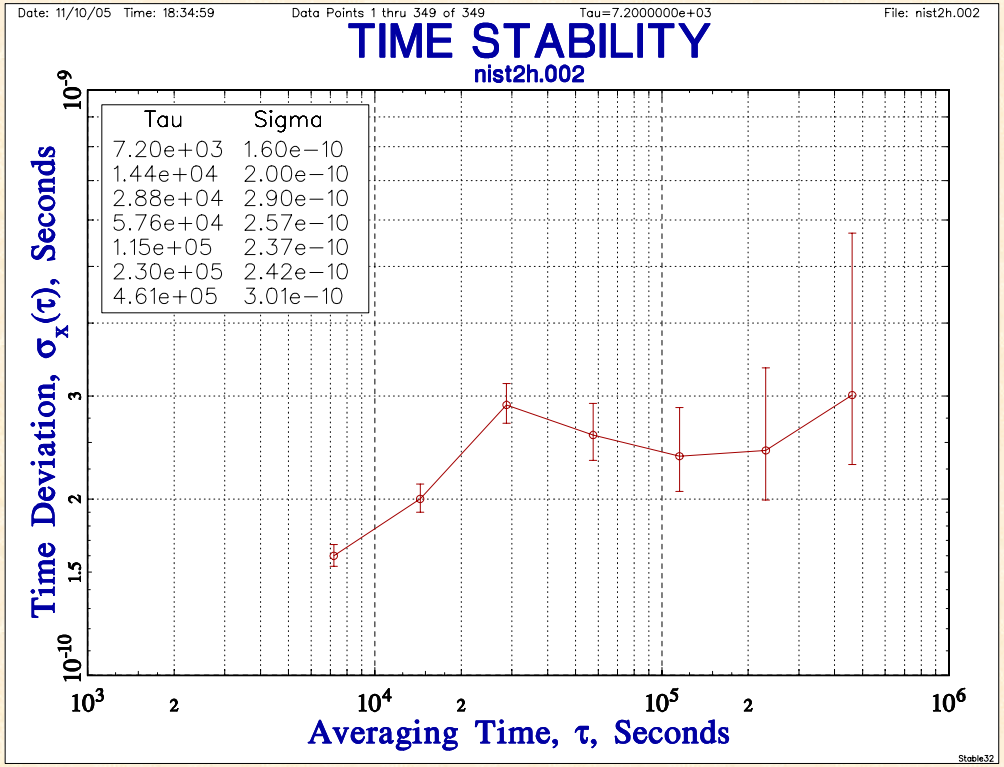
October 2005

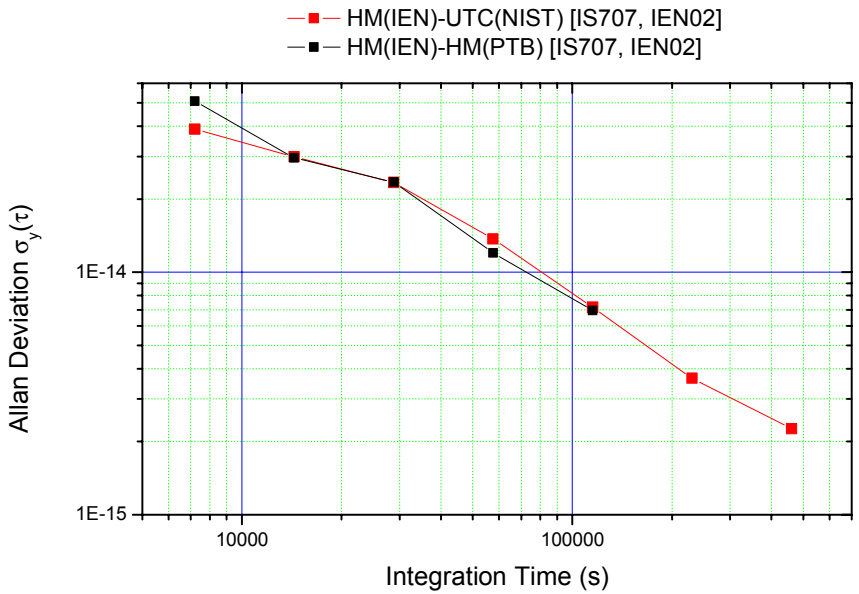
Temperature sensitivity ≈ 100ps/°C

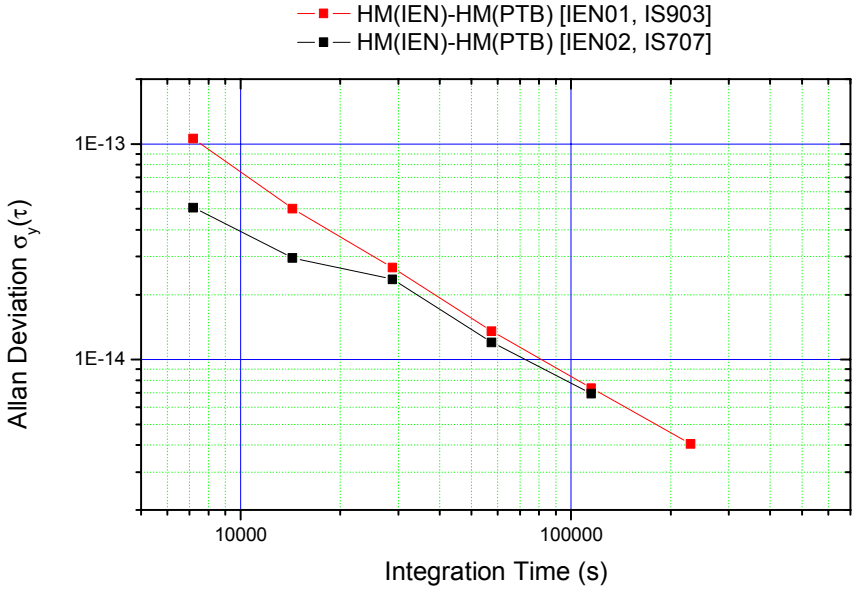
Stability of IEN02

HM(IEN)-UTC(NIST) link
Period MJD 53643-53671



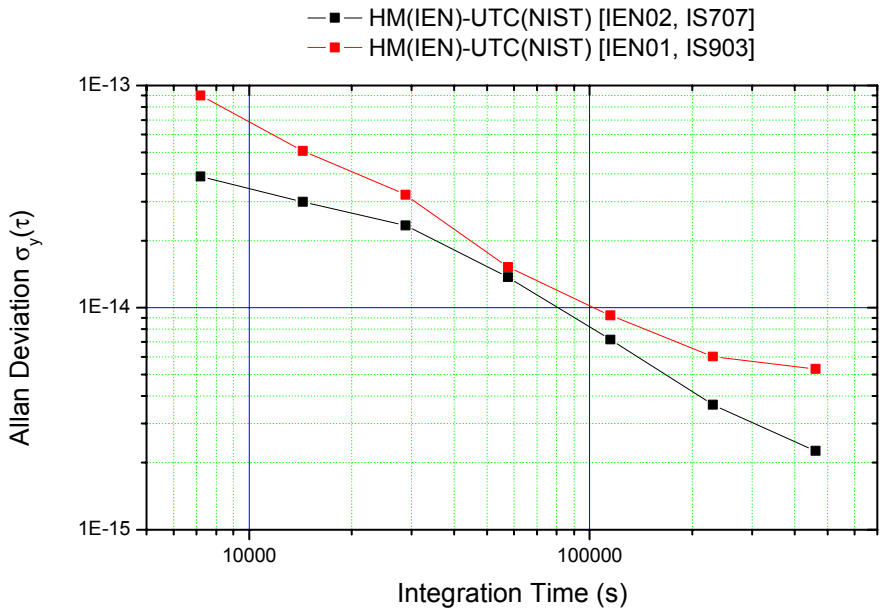






IEN01
Period MJD 53303-53333

IEN02
Period MJD 53643-53671



Satellite Switchover

- **Time jump evaluation technique**
  - PTB01 needed to change a piece of hardware to accomplish the different RX frequency
  - At the switchover date both IEN01 (calibrated) and IEN02 (uncalibrated) were operative
  - INTELSAT provided the use of both IS903 and IS707 for few days around the switchover date
  - At PTB and ROA backup stations were pointed to IS903
  - The IEN01 station did the switchover on MJD 53493 when the IEN02 did extra measurements with IS903 with an extended schedule (odd-hours)
  - Also PTB02 did extra measurements with IS903 with an extended schedule (odd-hours)
  - GPS-CP measurement campaign (AIUB) as reference
  - GPS-P3 data used for reference

Time jump evaluation technique

- **The time jump due to the station and to the Sagnac is accounted in the CALR value**
- **Jump calculated for all the links. Focus on the IEN-PTB lilnk**
  - The ESDVARs values are taken constant
  - For IEN-PTB link 3 data series are available
  - Disregarding the REFDELAY, IEN and PTB measurements are referred to H masers

$$Clk(IEN) - Clk(PTB) = 1/2[(TW(IEN01) - TW(PTB01)) + (ESD(IEN01) - ESD(PTB01))] + CALR(IEN01 - PTB01)[IS903]$$

Before the switch

$$Clk(IEN) - Clk(PTB) = 1/2[(TW(IEN01) - TW(PTB01)) + (ESD(IEN01) - ESD(PTB01))] + CALR(IEN01 - PTB01)[IS707]$$

After the switch

$$Clk(IEN) - Clk(PTB) = 1/2[(TW(IEN02) - TW(PTB02)) + (ESD(IEN02) - ESD(PTB02))] + CALR(IEN02 - PTB02)[IS903]$$

During the switch

Time jump evaluation technique

- **Least square fit on**
  - Linear model (no maser drift accounted) for a short period (MJD 53490 to 53496.9)
  - Quadratic model for a longer period (MJD 53487 to 53501.9)
  - Inclusion of IEN02-PTB02 data

$$\begin{cases} x_k = At_k + b & k = 1 \ldots n \\ x_h = At_h + b' & h = 1 \ldots m \\ x_l = At_l + b'' & l = 1 \ldots m \end{cases}$$

- **Direct bridging**
  - Short period
  - Inclusion of IEN02-PTB02 data

- **Comparison with GPS**
  - GPS-CP (AIUB). Period MJD 53490-53497.9
  - GPS-P3 (BIPM)

Satellite Switchover

	TWSTFT									
	Least Square model								Bridging	
Link	ΔJ (ns) short 1st order	*U*	ΔJ (ns) long 2nd order	*U*	ΔJ (ns) 3-eq.-fit short, 1st	*U*	ΔJ (ns) 3-eq.-fit long, 2nd	*U*	ΔJ (ns) bridging TWSTFT	*U*
PTB – IEN	---	---	+25.897	0.25	+24.207	0.25	+25.694	0.3	+23.925	0.98

	GPS			
Link	ΔJ (ns) bridging TAIP3	*U*	ΔJ (ns) bridging GPS-CP	*U*
PTB – IEN	+26.0	1.0	+25.347	<0.25

- **Official value**
  - +24.207 ns

Station switchover

- **IEN01 failure on MJD 53517 (May 27th 2005)**
  - Failure of the RF cable connecting Transceiver to SSPA
  - Spare cable installed in August

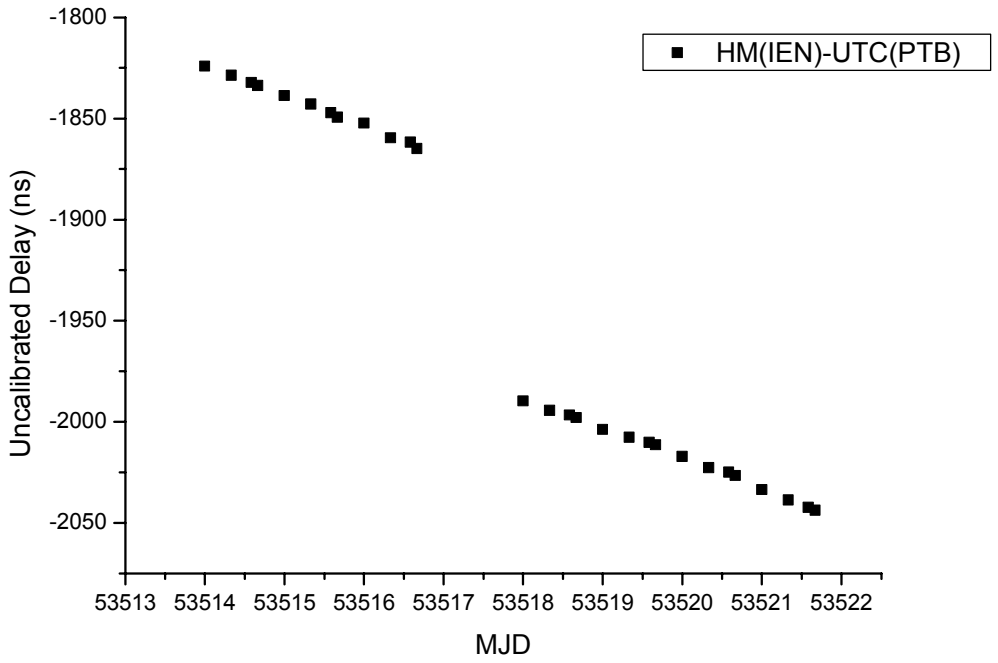
- **IEN02 switch on**
  - IEN02 ready to operate → became the IEN operative station
  - ITU file have continued to report IEN01. IEN02 label can give problems to software in some remote laboratories
  - 1s files no more published because are not corrected for the SATRE time tag bug

- **Porting calibration from IEN01 to IEN02**
  - Time Time Jump IEN01-IEN02 calculated with common methods (linear least square model)
  - Value reported in the ESDVAR

Station switchover

$$Clk(IEN) - Clk(PTB) = 1/2[(TW(IEN01) - TW(PTB01)) + (ESD(IEN01) - ESD(PTB01))] + CALR(IEN01 - PTB01)$$

$$Clk(IEN) - Clk(PTB) = 1/2[(TW(IEN02) - TW(PTB01)) + (ESD(IEN02) - ESD(PTB01))] + CALR(IEN - PTB)$$



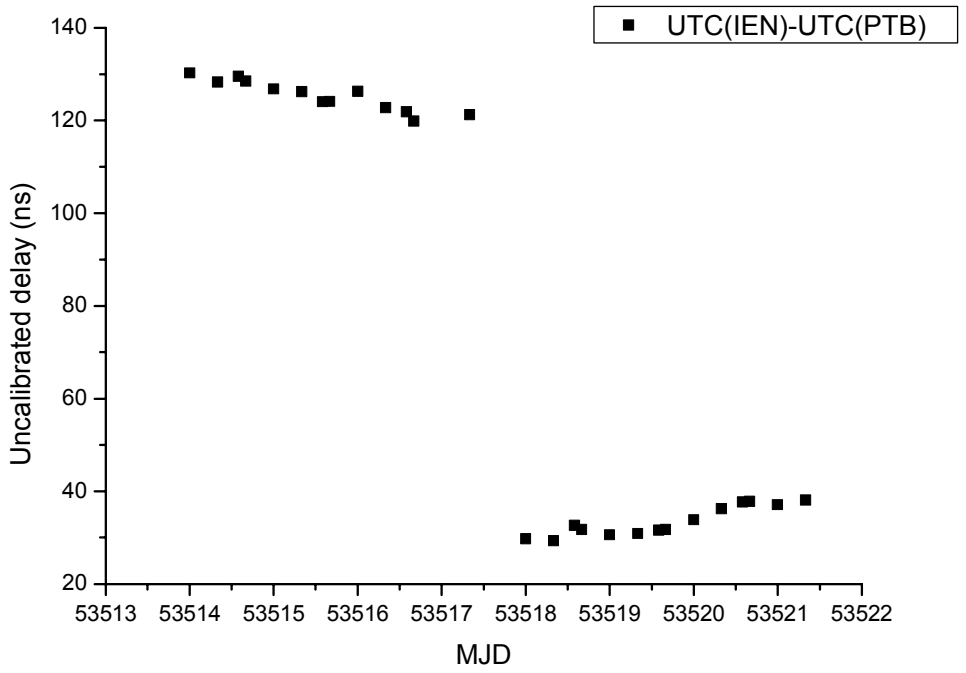
$$\Delta J = 1/2[\Delta ESD(IEN01) - \Delta ESD(IEN02)]$$

$$1/2[\Delta ESD(IEN01) - \Delta ESD(IEN02)] = 106\,\text{ns}$$

Station switchover

$$UTC(IEN01) - UTC(REM) = 1/2[(TW(IEN01) - TW(REM)) + (ESD(IEN01) - ESD(REM))] + [REFDEL(IEN01) - REFDEL(REM)] + CALR(IEN - REM)$$

$$UTC(IEN02) - UTC(REM) = 1/2[(TW(IEN02) - TW(REM)) + (ESD(IEN02) - ESD(REM))] + [REFDEL(IEN02) - REFDEL(REM)] + CALR(IEN - REM)$$



$$\Delta J = 1/2[\Delta ESD(IEN01) - \Delta ESD(IEN02)] + \Delta REFDEI(IEN01 - IEN02)$$

$$\Delta REFDEI(IEN01 - IEN02) = 29.6\,\text{ns}$$

Station switchover

$$\Delta REFDEI(IEN01 - IEN02) = [UTC(IEN) - UTC(TW)]_{IEN02} - [UTC(IEN) - UTC(TW)]_{IEN01}$$

```
* I5368306.13E
* UTC(IEN)  - CLOCK    = +0.000000000000 s
* UTC(IEN)  - UTC(TW)  = +0.000000076800 s 53669 130000
* UTC(TW)   - 1PPSTX   = +0.000004751438 s 53683 060000
```

- **IEN02**

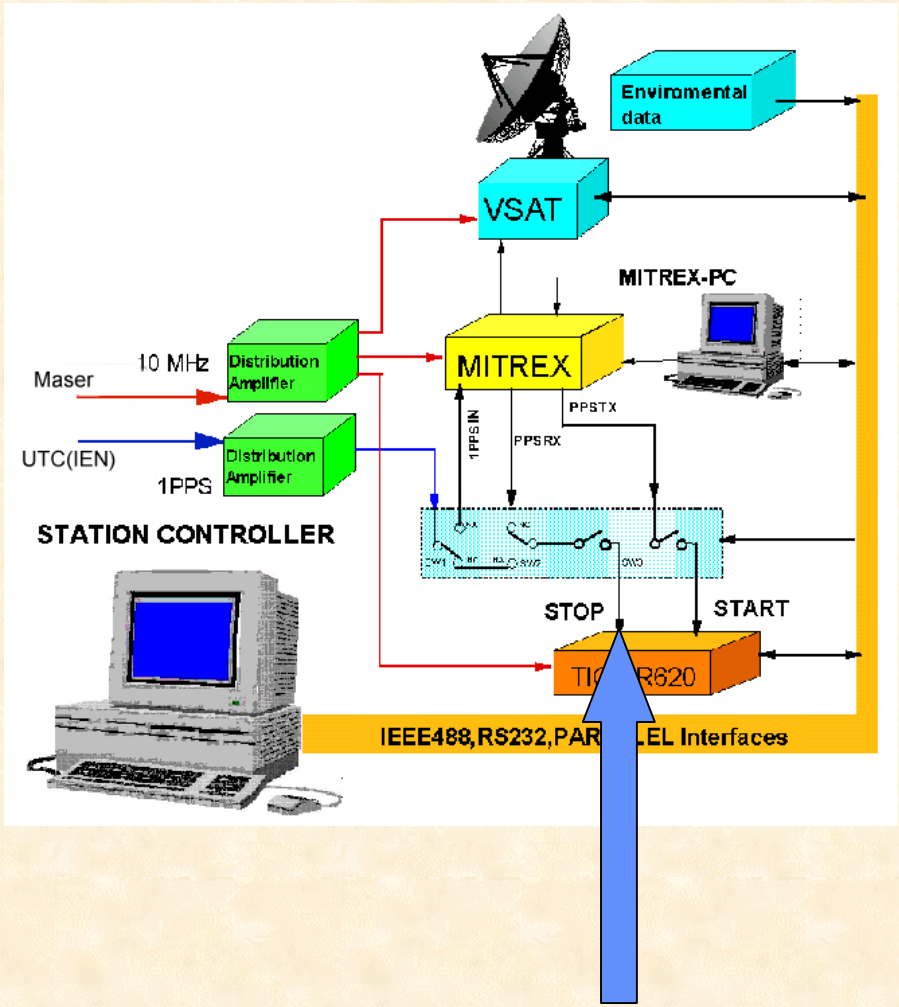
```
* I5320114.04I
* UTC(IEN)  - CLOCK    = +0.000000000000 s
* UTC(IEN)  - UTC(TW)  = +0.000000106260 s 53677 150000
* UTC(TW)   - 1PPSTX   = +0,000004719695 s 53681 145909 Var: 0,027 ns
```

- **IEN01**

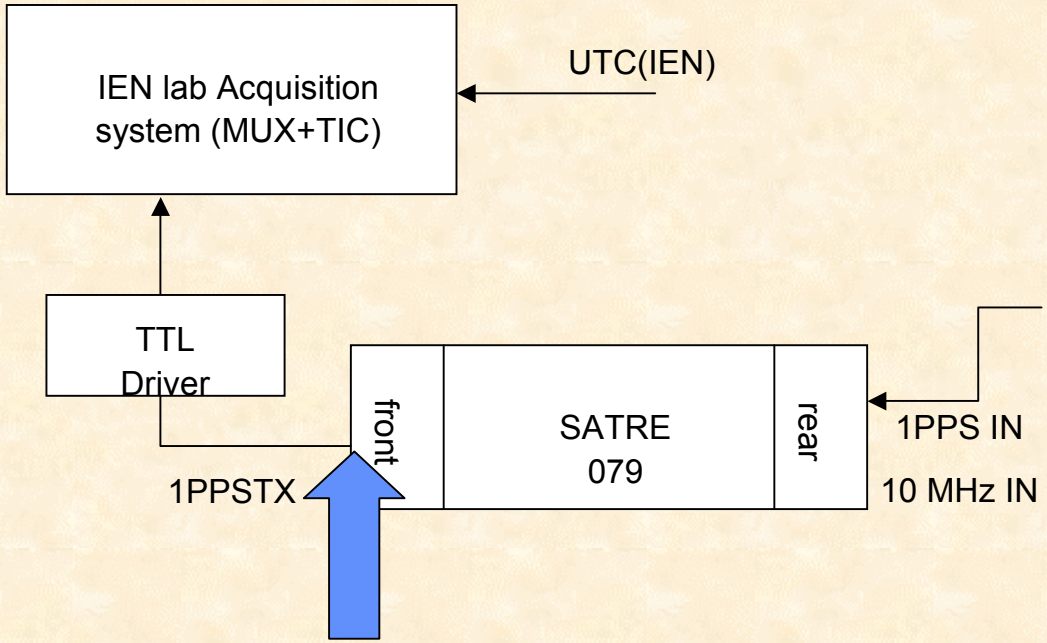
- **For the MITREX convention UTC(TW) is measured at the STOP of the counter that perform the ranging (1PPSRX- 1PPSTX) and REFDELAY (UTC(TW) - 1PPSTX) measurements**

- **Using the SATRE internal counter the START plane is not physically accessible. UTC(TW) must be defined elsewhere**

Station switchover



UTC(TW)[IEN01]



UTC(TW)[IEN02]

$$[UTC(IEN)-UTC(TW)]_{IEN01} = 106.26\,\text{ns}$$

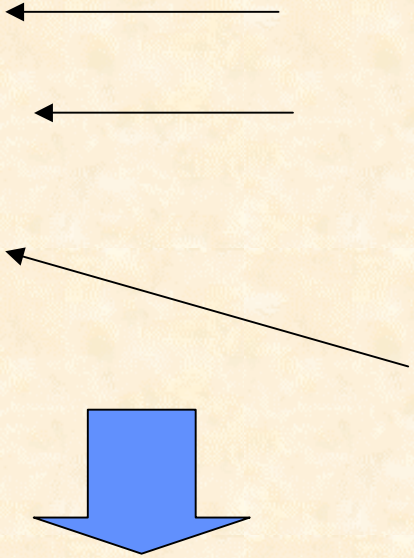
$$[UTC(IEN)-UTC(TW)]_{IEN02} = 110.4\,\text{ns}$$

Station switchover

$$[UTC(IEN) - UTC(TW)]_{IEN02} = 76.8\,\text{ns}$$

$$[UTC(IEN) - UTC(TW)]_{IEN02} = 110.4\,\text{ns}$$

$$[UTC(IEN) - UTC(TW)]_{IEN02} = 100.4\,\text{ns}$$



Estimated with respect to the actual start of the SATRE internal counter

Measured from the 1PPSTX taken from the SMC connector (Front panel)

Measured from the 1PPSTX taken at the output of the TTL driver

- The SATRE 1PPSTX (Front panel) is not synchronous with the start of the internal counter (MITREX convention)
- The internal counter start is delayed by about 35 ns with respect to 1PPSTX
- Is there some calibration constants of the SATRE that alters the internal counter readings?

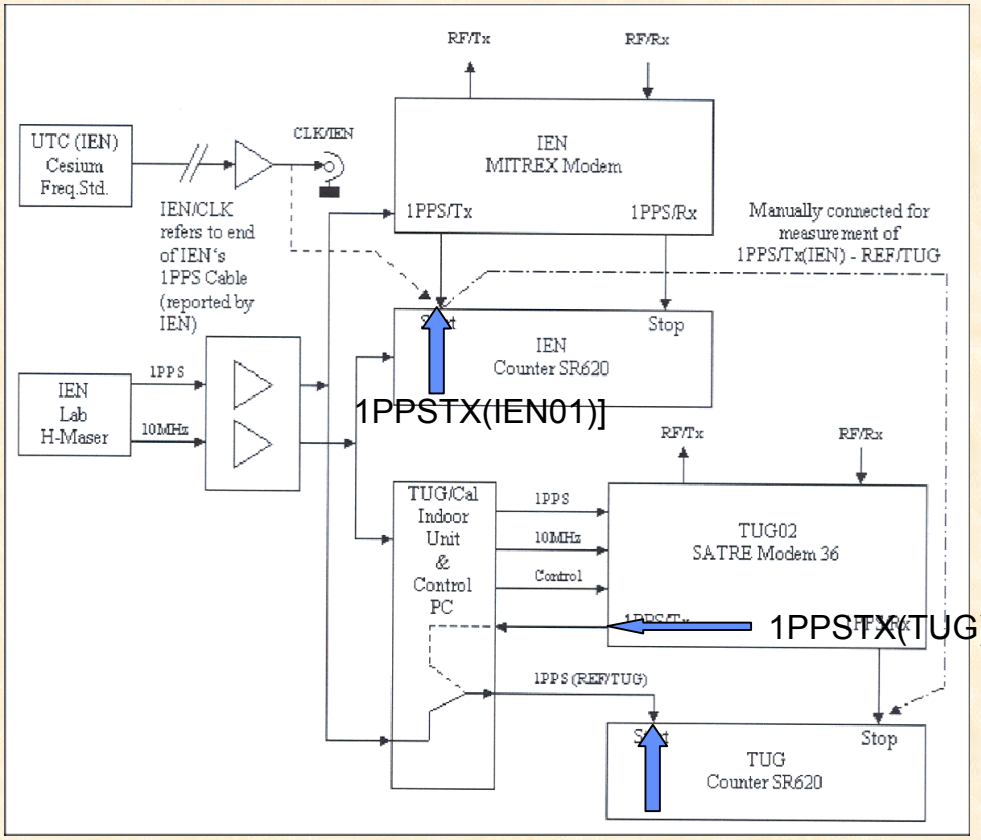
Calibration with TUG01

- **"Northern" calibration trip**
  - Calibration trip including PTB, SP, VSL, NPL, OP, IEN. Closure at PTB
  - Co-location at IEN: 6-7 November 2005
  - Calibration of both IEN02 and IEN01

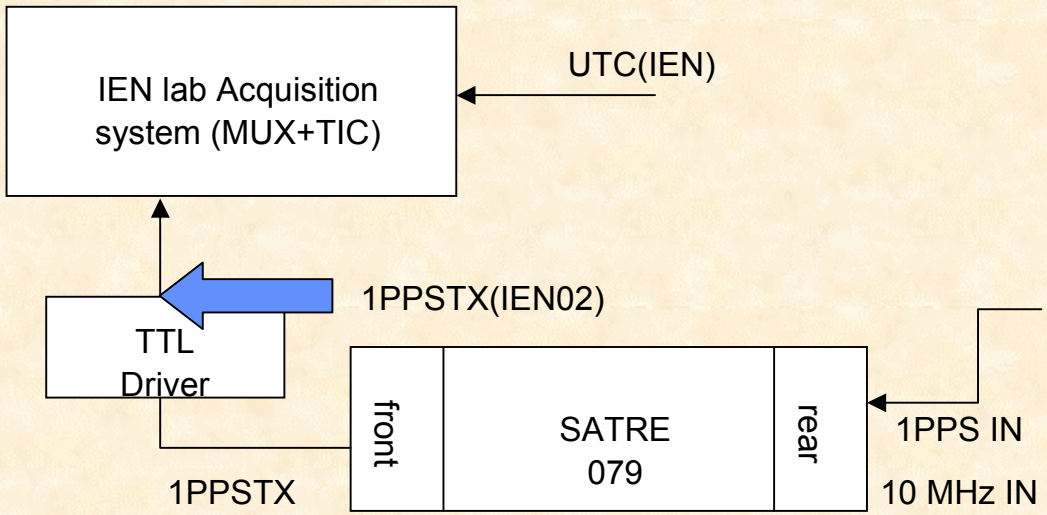
- **IEN 01 calibration**
  - More than 20 data collected during the 7th November afternoon
  - CALR value expected different with respect to the 2003 value. Part of the TX signal path has changed

- **IEN 02 calibration**
  - More than 100 data collected during the 6th (night) and 7th (morning and afternoon) November
  - IEN02 received TUG signal when it was at VSL, OP and PTB. Verification of CALR through "indirect" calibration is possible

RefDelay measurement for calibration



1PPSTX-REF(TUG)



$$REFDEI(IEN) - REFDEI(TUG) = -[1PPSTX(IEN) - 1PPSTX(TUG)]$$

- Both measurements taken with TUG counter
- The 1PPSTX-REF(TUG) is the actual start of the TUG ranging measurements
- TUG has the possibility to refer another point 1PPSTX(TUG)[2003]. It was the reference point for the 2003 CALR value

RefDelay measurement for calibration

- **REFDELAY IEN01**
  - Same configuration as in 2003
  - The 1PPSTX(IEN01) is the actual start of the IEN01 ranging measurements
  - CALR and REFDELAY values uniquely defined

- **REFDELAY IEN02**
  - The 1PPSTX(IEN02) is not the actual start of the IEN02 ranging measurements
  - CALR and REFDELAY values depends on the position of the UTC(TW)[IEN02]. For this calibration it was defined **at the output of the TTL driver**

Future plans

- **During 2006 L. L. will not be at IEN. Other people will take care of the TWSTFT**
  - **Ilaria Sesia** → Technical aspects
  - **Franco Cordara** → Organization aspects (Intelsat etc.)

- **IEN has two operative stations**
  - Common clock experiments
  - Possibility of EU-Asia link

- **Improvements**
  - Temperature control of IEN02 transceiver
  - Software update to acquire ranging data by the two SATRE channels at the same time
  - Possible participation to the EU-Asia link
  - **Long Term**: Substitution of the IEN01 obsolete equipments