In-orbit timing calibration of Suzaku satellite, and the design of the timing system on Astro-H

Yuki. Terada (Saitama Univ), on behalf of the Suzaku (and Astro-H) team
Timing System onboard Suzaku

No on-board GPS system

Satellite bus

Sub systems (payload)

Onboard Main computer

Master clock

Onboard computer

Electronics DAQ

Non-Intelligent Node

Time counter

Intelligent Node

TI (20+12 bit)

512 kHz clock

128 kHz clock

20+12 bit

5+14 bit

Compare

Every observation
(typically 2 days)

Compare

(5 contacts per day)

Long coverage

Fine resolution

Ground

Downlink Station

UTC (yyyymmmdd hh:mm:ss.uuuuuu)

resolution ~ 10,100 us

Orbit error 10km ~ 30 us

5+14 bit

7.8 msec (Psum mode)

61 μ sec (32 μ s in condition)

HXD

8 sec (normal mode)

XIS

2 or 1 sec (normal mode with 1/4 or 1/8 window option)
Relative Timing Calibration between instruments, the XIS and HXD

by Matsuta and the XIS team

The HXD has higher timing resolution.  
→ Check cross correlation function between light curves of the XIS (1/8 option) and HXD PIN

The XIS time is consistent with the HXD time.  
→ Concentrate on the HXD timing.
Relative Timing Calibration with periodic signals

<table>
<thead>
<tr>
<th></th>
<th>Crab</th>
<th>PSR B1509-58</th>
<th>Her X-1</th>
<th>AE Aqr</th>
<th>A0535-262</th>
<th>AM Her</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (ms)</td>
<td>33 ms</td>
<td>151 ms</td>
<td>1.24 s</td>
<td>33 sec</td>
<td>103.4 s</td>
<td>11139s</td>
</tr>
</tbody>
</table>

- **Crab**: 33 ms
- **PSR B1509-58**: 151 ms
- **Her X-1**: 1.24 s
- **AE Aqr**: 33 sec
- **A0535-262**: 103.4 s
- **AM Her**: 11139 s

Terada et al. 2008a
Terada et al. 2008a
Enoto et al. 2008
Terada et al. 2008b
Terada et al. 2006
In studying now

OK in 33ms – 11 ksec range
New data

Periodic signals:

Comparison with other observations

Confirmed, 1 nsec stability per day (1.9x10^{-9})
Cross Timing Calibration with Crab

March 17-20, 2007, simultaneous observation of Crab (Y. Terada et al. 2008a)

One of the successful results of IACHEC activities!

- Arrival time in X-ray exceeds 330 μsec from that in Radio band. (same result as Rots et al. 04)
- Arrival times with X-ray satellites are consistent within ~100 μsec
Absolute Timing Calibration with Crab

Compared with Pulse arrival times of Jodrell Bank Radio Observatory

- Known BUG in processing after 2009/1/1 (1.000000 sec) / FIXED

deviation ~ 230 μsec
Timing System in the future mission, Astro-H

- **Satellite bus**
  - On-board GPS system
  - Master clock
    - 1 M, 1 Hz clock
    - Synchronized
  - Onboard Main computer
  - SpaceWire link
    - Fixed delay + jitter
  - Onboard computer
  - Intensive Node
    - TI (26+6 bit)
    - 26+6 bit
  - Time counter
    - TBD bit
    - Free RUN
  - Non-Intelligent Node
    - Time counter
    - Time counter
    - Long coverage
    - Compare (every sec)

- **Sub systems (payload)**
  - Electronics
    - DAQ
  - Sensor

- **Ground**
  - Downlink Station
    - UTC (yyyyymmdd hh:mm:ss.uuuuuu)
  - Compare (5 contacts per day)

- **Now in design phase**
  - Use GPS system, master clock is synchronized to this
  - Use SpaceWire link
    - no exclusive line from master clock
    - deliver sub-sec information via TIME_CODE
    - and over-sec information via RMAPwrite
    - having fixed delay and jitter
      - (depends on network configuration)
Summary

- Suzaku carries the HXD with 61 usec timing resolution and the XIS with normally 8 sec timing resolution.
- The times between the XIS and the HXD are consistent with each other within 20msec.
- The stability was confirmed as $1.9 \times 10^{-9}$ from the comparison between arrival time of the main pulse of Crab in Radio and Suzaku.
- Simultaneous observation of Crab with Suzaku, INTEGRAL, Swift, and RXTE was performed in 2007 as a timing calibration. The absolute timing of these satellites are confirmed in 100 usec order.
- The timing accuracy of Suzaku was tested by many Crab observations, and confirmed as $<230$ usec.
- We are now developing the timing system on Astro-H, which uses Spacewire network.

Timing working group was inactive in the last IACHEC workshop. ➔ Restart the activity in this 4th workshop?