UVLBI MEMO #010

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To: UVLBI Group
From: Shep Doeleman
Subject: CSO/SMA Clocks for April 2006 VLBI

This memo lays out the elements that go into determining the best CSO/SMA station clock for fringe searches of the April 2006 230GHz VLBI. The two sites were SMTO on Mt. Graham, AZ., and the CSO on Mauna Kea. On Mauna Kea, the Local Oscillator signal for the CSO receiver was generated at the SMA (where the Hydrogen maser resides) and sent via optical fiber to the CSO. The IF from the CSO is sent back along a separate fiber to the SMA vault room where it is then patched up via fiber to the SMA correlator room. All the VLBI recording hardware (DBE + MarkB) was located in the correlator room.

A VLBI site with a significant cable delay between the receiving antenna and the recording system will appear to have a clock that is advanced with respect to a UTC reference. The delays in the CSO/SMA system are shown in the figure below:

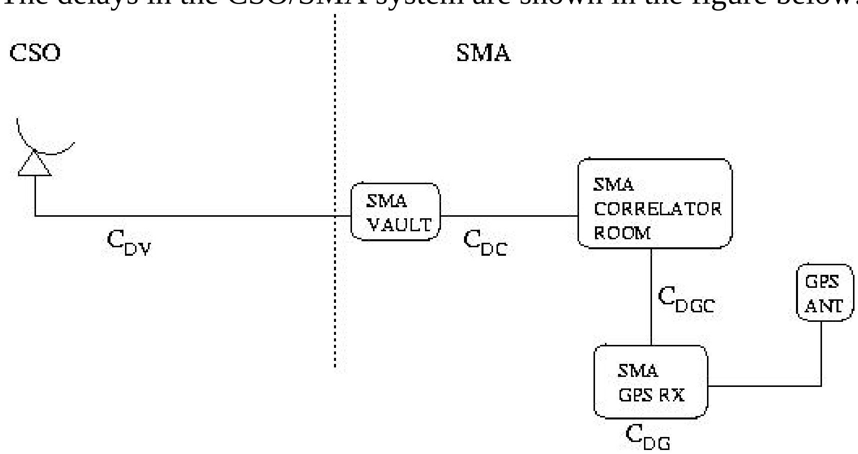

Figure 1: Delays in the CSO/SMA VLBI setup

And the appropriate clock for use during correlation on the Mark4 correlator will be:

$$CSO/SMA\,Clock = C_{UT0} + C_R(t - t_0) + C_{DV} + C_{DC} - C_{DGC} + C_{DG}$$

where

C_{UT0} is the (Mark5b 1pps – station GPS 1pps) difference at time t_0 with the Mark5b leading the GPS being defined as positive.

$C_R(t - t_0)$ is the maser rate times the time offset between t_0 and the current epoch. If the Mark5b 1pps is advancing relative to GPS, then C_R is positive.

C_{DV} is the fiber delay between the CSO and SMA Vault room.

C_{DC} is the fiber delay between the SMA Vault room and the Correlator room.
C_{DGC} is the total cable delay in the GPS antenna/rx system.
C_{DG} is the internal cable compensation delay set in the GPS rx.

At epoch 2006 096 13:56 UT, C_{UT0} was measured to be -1.065μs with a digital scope, and over the course of the experiment C_R was determined to be +1.9ps/s (see figure 2). In an email dated 26 July 2006, Jonathan Weintroub gives a value for C_{DV} of 2.18μs and a value for C_{DC} of 0.21μs. In addition, Jonathan says that there is no internal cable compensation delay set in the SMA GPS receiver. At this time the value of C_{DGC} is not known, but it is probably smaller C_{DC}.

Given this information, the appropriate clock offset used for correlation at Haystack should be:

$$CSO / SMA\,Clock(\mu s) = 1.325 + 1.9 \times 10^{-6}(t - t_0)$$

with t_0 set at 2006 096 13:56 UT. Since 30 May 2006, the 230GHz VLBI processing has been using the following VEX section for the CSO/SMA clock:

```
$CLOCK;
def Cs; clock_early=2006y091d05h20m :  1.24 usec : 2006y096d13h56m0s  : 1.9e-12 ; enddef;
```

This clock setting differs by only 0.085μs from the latest value estimated in this memo and would not shift fringes outside the nominal +/- 1μs delay search window.

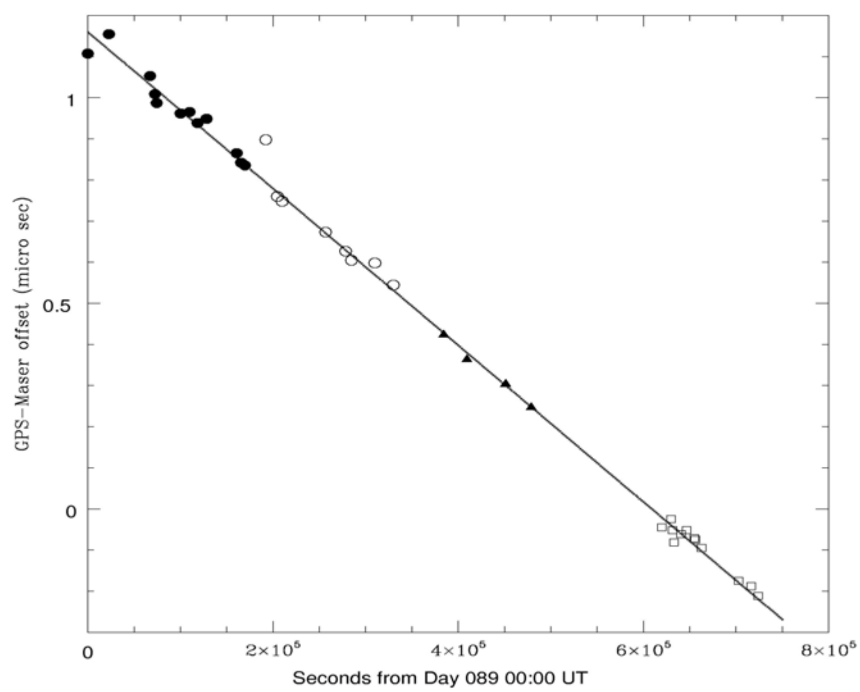

Figure 2: P2 Maser rate during April 2006 230GHz VLBI. Best fit rate is +1.9ps/s.