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To: IVS VGOS Technology and Operations Groups
From: A. E. Niell and M. Titus
Subject: Processing the clock break at KOKEE12M in vt7142 (2017/05/22)

Introduction

The first occurrence of a clock break with a broadband system occurred at KOKEE12M (hereafter Kokee) during vt7142 (17MAY22) at the time of a maser 'glitch' (143-1044). The glitch caused the RDBEs to lose the 5-MHz signal from the maser. When the RDBEs re-sync'd, they apparently triggered on different cycles of the 5 MHz reference frequency from the maser, resulting in 'dot' times that differed from each other by several hundred nanoseconds (ns) and differed from the maser tick by more than a microsecond (μsec), compared to the differences of approximately -19 ns at the beginning of the session.

This had several effects.

- For correlation, a different value of the clock offset for Kokee was required after the time of the clock jump.
- For post-correlation *fourfit*, the values of the *apriori* sampler_delays had to be adjusted.
- For the geodetic estimation, a clock break had to be introduced at the time of the maser glitch.

These are explained more fully below.

The purpose of this memo is to document what occurred and how it was dealt with at the correlator and in the post-correlation processing.

What happened at the station

Chris Coughlin (email Date: Tue, 23 May 2017 17:56:25 +0000) reported an apparent maser time jump of ~0.7 μsec for the Sigma Tau maser compared to GPS. He also reported that the DOT2GPS values on the RDBEs changed to four different amounts. From the Kokee Start and Stop messages it can be seen that the DOT2PPS values changed from the usual value of approximately -19.5 nanoseconds at the beginning of the session to values ranging from -2.3 μsec to -1.2 μsec for the four RDBEs.

The DOT2PPS values of the four RDBEs changed by different amounts: Bands C and D differed by multiples of 200 ns (within 1 ns) with respect to Band A, and these three differed from Band B by 100 ns plus the multiple of 200 ns.

Effect of the clock jump on the recorded data: correlation and *fourfit*

In *fourfit* a sampler_delay value is given for each band; however this is only an *a priori* value to determine which 200-ns ambiguity the multi-tone phase cal delay is on. The value for a band should be approximately the average of the ‘PC X (or Y) delay’ values given on the *fourfit* plot for that band plus-or-minus n*200. The value of ‘n’ is chosen to give the same single band delay (SBD) to within 50 ns in all bands.

Scan 143-1555 Band A was e-transferred first for a fringe search. After much effort (with the emphasis on ‘much’) we found fringes at a clock value of 6.450 µsec using GGAO at its expected clock value. For the other three bands fringes were found with the same clock but at SBDs offset by multiples of close to 200 ns. They were brought to near the same SBD as Band A by adjusting the sampler_delay parameters to the values given in Table 1. When a scan prior to the clock break was correlated, a different clock value was found for Kokee that differed from the after-clock-break value by -0.39 µsec, not 0.7 µsec as given in the message from Kokee. The discrepancy is not understood. (A message of inquiry was sent to Kokee 17/01/02.) The sampler_delay values for Kokee from a preceding session were found to work before the clock break.

The sampler_delay values used before and after the clock jump are given in Table 1, along with the values obtained for the first of the CONT17 sessions. For the CONT17 session the clock offset from GPS, as reported in the Start message, and the sampler_delay values were made consistent by subtracting 800 ns from the sampler_delay values used before the clock break in vt7142.

Table 1. Sampler delay values before and after the clock break for vt7142, and for b17337. The values used for the Kokee clock offset at the correlator are given in the right-most column.

	Band A (ns)	Band B (ns)	Band C (ns)	Band D (ns)	Kokee clock offset (usec)
before break	1000	1280	1280	1280	6.060
after break	1000	400	1080	1400	6.450
b17337	200	476	476	476	4.445

The pc_phases after the clock break were re-determined from scan 143-1152 (3C418). This may have been a poor choice since, for a later session, vt7254, 3C418 is one of the sources with large post-fit delay residuals in nuSolve, possibly due to source structure. (As of 18/01/06 this has not been investigated.)

Processing the clock break in nuSolve

In nuSolve the clock break can be inserted by either 1) estimating the magnitude or 2) inserting a fixed value, each at a specified epoch. Since the changes in DOT times seemed to be due to an interruption of the 5 MHz reference frequency, a reasonable cause could be ascribed to the loss of sync of the RDBEs at the time of the maser glitch and then to a re-sync’ing at a subsequent zero-crossing of the 5 MHz signal; this would result in a change of an unknown multiple of exactly 200 ns (1/5e6). In processing the data with nuSolve we first estimated the clock jump, which gave an estimate of 401 ns. Since this is close to an expected 2*200 ns, we inserted a fixed jump of 400 ns without estimation. (See Appendix for details.) Processing with the fixed clock jump did not appear to introduce any unexpected post-fit delay residual characteristic, and the baseline length to Westford is consistent with other sessions within the length uncertainties.

Summary and recommendation

The maser glitch at Kokee caused both the DOT2PPS and the DOT2GPS values to change in the RDBEs. After considerable fringe searching at the correlator, a new value was found for the Kokee clock after the time of the glitch, and new values of the sampler_delay parameters were derived. However, there was no way to verify that the RDBEs were in fact working after the maser glitch occurred. Fortunately, aside from the quantized jumps in the RDBE time stamps, they appeared to function properly.

The DOT2PPS value on setup typically takes a value of -1.9e-08. Acceptable values are also -1.5e-08 and -2.3e-08. These represent 5, 4, and 6 sample delays through the RDBE, respectively, and so far have not been found to affect the geodetic results, even when a change of one sample has occurred during a session.

If either the DOT2PPS or the DOT2GPS values jump during a session, a clock break will be needed in the geodetic solution. Therefore , *since the state of the RDBEs cannot be easily verified after such an occurrence, we recommend that the personalities of all RDBEs be re-loaded in either case*.

Appendix: how to process a clock break in nuSolve (Bolotin et al 2017)

In nuSolve on the stations tab:

i. double-click on the Clk.Brks column of the station with the (expected) clock break,

ii. Click ‘Add’

iii. Specify the Epoch of the clock break (e.g. 2017/09/12/10:45)

iv. If estimating the magnitude, click on the box ‘Estimate clock break parameters …’

    If specifying a fixed value, do not check the box, but specify the value as ‘Value(ns)’.

v. Click OK; click OK.

vi. Continue usual processing with nuSolve.

References

Bolotin, S., K. Baver, J. Gipson, D. Gordon, and D. MacMillan, 2017, νSolve-0.5.0: User Guide, ftp://gemini.gsfc.nasa.gov/pub/misc/slb/nuSolveUserGuide-0.5.0.pdf.