TM290
GNSS Receiver Operations at an UTC Lab
A Guide to Delays Measurements

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Revision History

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Contents

1 Introduction

The purpose of this technical note is to help laboratory staff during the operation of a GNSS station. Specifically to help them measuring the quantities that are relevant for the configuration of an UTC link. It must be understood that even if the receiver calibration is fully performed by a third party (Manufacturer, G1 or G2 laboratory), some quantities must be measured by the laboratory staff by using his own equipment and procedure, and the same measurements should be repeated periodically and any time the staff detects some unexpected anomaly of the GNSS station. The results of those measurements, performed at the initial setup should be reported to the calibration responsible accompanied by its uncertainty. In case of an onsite calibration process the measurement of the quantities related to the travelling equipment can be performed by the staff of the G1 laboratory or by the local staff under the supervision of the G1 laboratory that assumes the responsibility of the uncertainty. This document focus therefore on the measurement of the receivers that are owned directly by the lab. It is important to stress out that the laboratory is to describe clearly the definition of the time marker of the UTC(k). Many laboratories define the time marker of a PPS signal as the instant when the rising edge of the pulsed electrical signal crosses a voltage threshold level of 1 V, at a well defined reference plane, and when properly terminated. Nevertheless each laboratory is free to chose a different definition being aware of the fact that this can impact the uncertainty budget. We will now start by defining some general concepts related to the receiver operation at a lab.

1.1 Definition of Interfaces and Relevant Quantities

Looking at Figure 1 we can define the following entities:

- A = antenna phase center.
- B = Antenna output connector. See Fig 2.
- C = Receiver GNSS signals input connector. See Fig 3.
- D = Receiver PPS IN connector. See Fig 3.
- E = Receiver PPS OUT connector. See Fig 3.
- F = Otherwise defined reference point as for the Ashtech Z12 T, or TTS-5 receiver.
- R = Reference point chosen for a given receiver.
- K = External clock input of the receiver, typically at 10 MHz.
- P = PPS output of the UTC(k) distribution amplifier. See Fig 4.

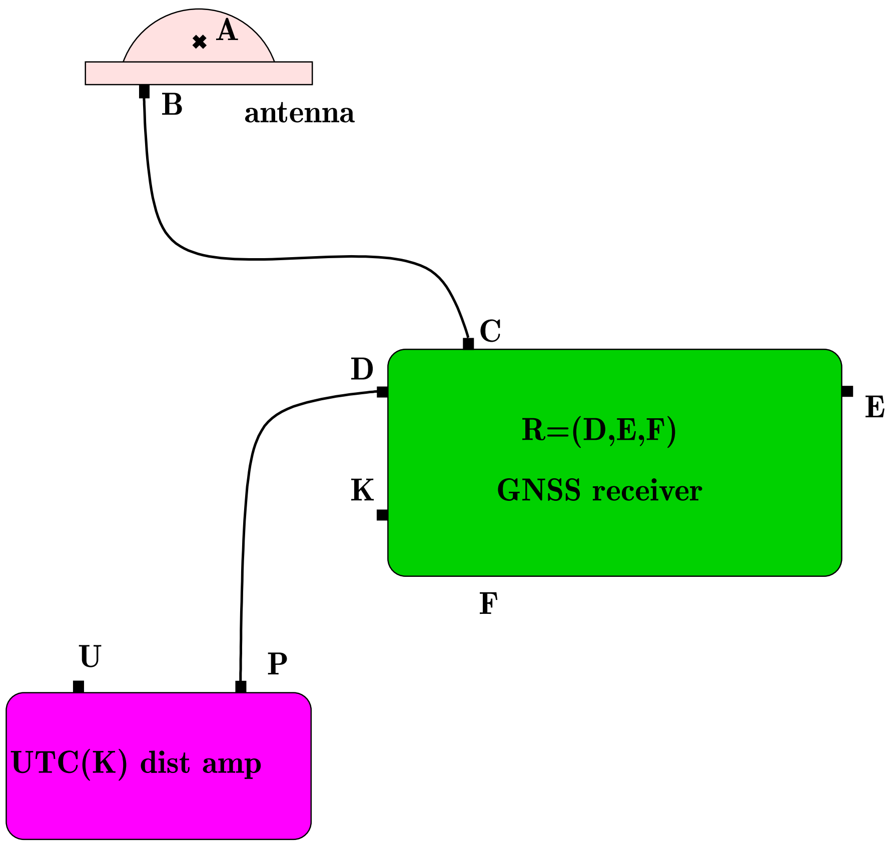

Figure 1: Setup of a generic GNSS receiver in a UTC(k) laboratory.

- R = Receiver reference point. A conventional point that has a non varying delay with respect to the internal time base. The receiver reference point will be either D,E or F.
- U = UTC(K) reference point. See Fig 4.

Starting from them we can then define the following quantities:

- Antenna delay = B-A. Time delay between the antenna phase center and the reference plane of the antenna connector, this can be different for different carriers mainly because they travels through different RF filters.
- Receiver delay = R-C. Time delay between the receiver signal input connector and the receiver reference point, this can be different for each ranging code type.
- INTernal DeLaY (INTDLY) = (B-A) + (R-C). Sum of the antenna and

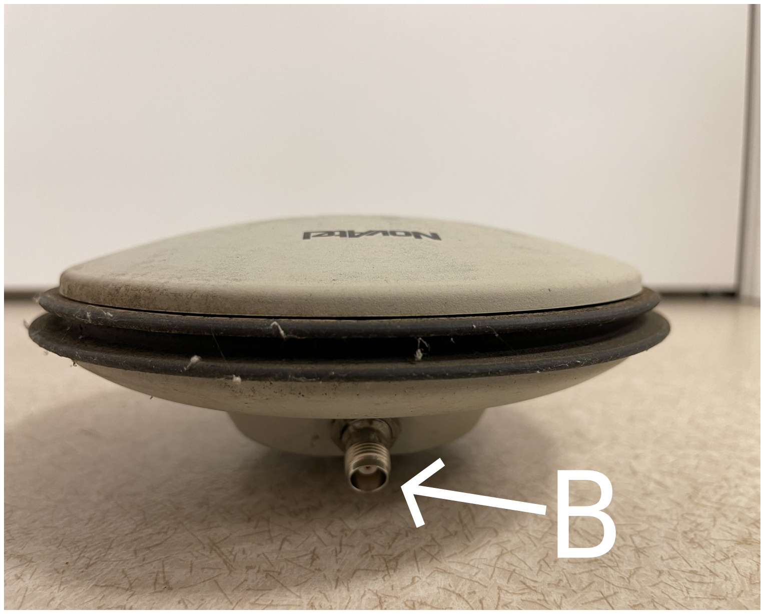

Figure 2: Example of a geodetic antenna.

receiver delay. Since this delay cannot be disentangled in a relative calibration they grouped together.

- Antenna CABle DeLaY (CABDLY) = C - B. Time delay of the entire cable path from the antenna to the receiver. This might include multiple cable and signal splitters.
- REFDLY = R - U. Time delay between the UTC(k) reference point and the receiver reference point.

2 REFDLY

The following sections well be dedicated to the REFDLY measurement. The REFDLY is the delay experienced by the UTC signal from the UTC(k) point to a reference point of the receiver. It is a fundamental quantity because allows to link the UTC(k) timescale to the GNSS time transfer equipment. Without its measurement, any change in the distribution of the signals from the UTC(K) to to the receiver would require a new calibration of the GNSS equipment. The ability of a laboratory to repetitively measure without loosing uncertainty allows the lab to change the UTC(k) generation and distribution keeping the link uncertainty unchanged. To quantify it, one or more measurement using a Time Internal Counter (TIC) are required. Additional measurement using an oscilloscope might be needed. In the next section the operations needed to take

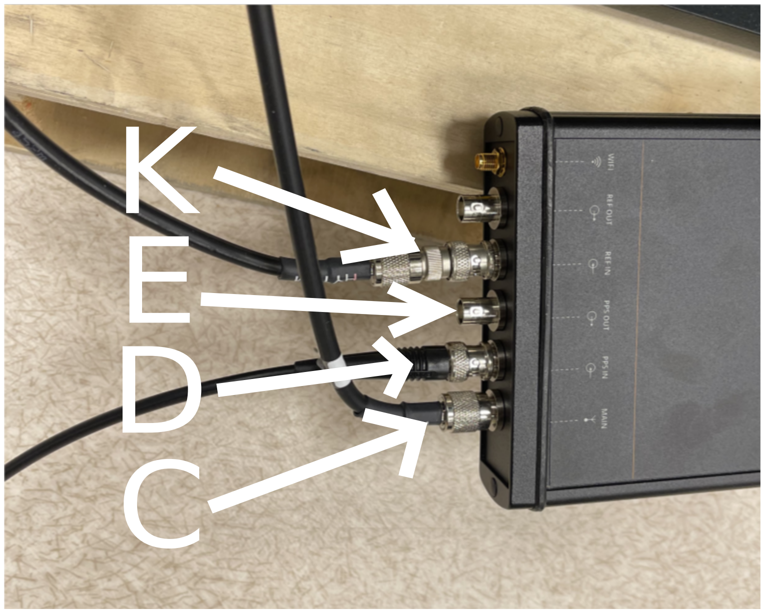

Figure 3: Example of a timing reciver.

such measurements will be described. If you want to measure the REFDLY of a specific receiver please refer to section 4.

3 Measurement Operations Using Time Interval Counter

In the following subsections we will describe how to perform the set of measurement that are needed to obtain the previously defined REFDLY. In such description we will assume that the UTC(k) signal is defined at 1 V on 50 Ω, in case it is not this has to be taken into account. We will start by describing the measurement that can be done with a Time Interval Counter (TIC). They will be performed using the so called "pivot method" that will be duly introduced using Fig 5 as visual aid. For an evaluation of its uncertainties see [1]. The method requires two different measurements. It is important to highlight that all signals used should be coherent (not drifting one to each other), otherwise no meaningful measurement can be obtain. During both measurement a pivot signal should be connected to the start of TIC, see aforementioned Fig 5 and Fig 6 which report the example of a Keysight 53230A TIC during operation. Before staring the measurement (ΔT_1 and ΔT_2) it is important to set the TIC trigger level to 1 V and the input impedance to 50 Ω. The two measurements can be then perfomed using a cable once connected to the first PPS source (J in Fig 5) and once connected to the second PPS source (K in Fig 5). The delay

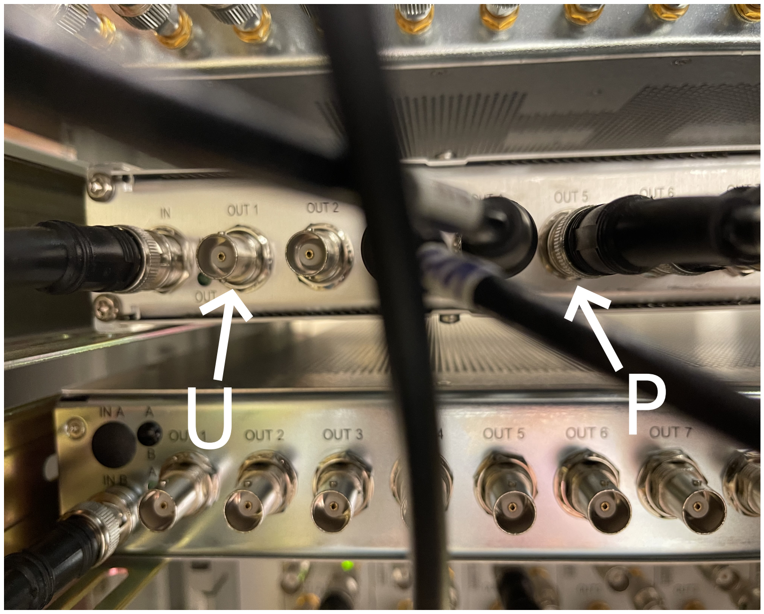

Figure 4: Example of a distribution of reference PPS signals.

between the two PPS source (J and K in Fig 5) can then simply been obtained by subtraction:

$$J - K = \Delta T_1 - \Delta T_2 \tag{1}$$

with ΔT_1 being the first measurement and ΔT_2 being the second one. This method can be used to measure the PPS IN - UTC(k) delay (D - U) or the PPS OUT - UTC(k) delay (E - U).

3.1 Measurement of PPS IN - UTC(k) Delay

To measure the UTC(K) - PPS IN delay (D - U) proceed in the following way:

1. Set the TIC trigger level to 1 V and the input impedance to 50 Ω.
2. Connect the pivot signal to the Start of the TIC.
3. Take a measurement cable that can reach both the UTC(k) and the output of the cable connected to PPSIN.
4. Disconnect the cable entering the PPS IN of the receiver (Point D).Using a BNC adapter (female - female) connect such cable to the measurement cable.
5. Take the first measurement ΔT_1 averaging at least 100 measurements.

6. Now disconnect the measurement cable from the BNC adapter and connect it the UTC(k) point to the stop of the TIC. The other side of the cable should remain connected to the Stop of the TIC.
7. Take the second measurement ΔT_2 averaging at least 100 measurements.
8. Compute the PPS IN - UTC(k) delay (D - U) as $\Delta T_1 - \Delta T_2$.

The BNC adapter introduce a delay of about 100 ps, that should be taken into account if aiming at such accuracy.

3.2 Measurement of PPS OUT - UTC(k) Delay

To measure the UTC(K) - PPS OUT delay (E - U) proceed in the following way:

1. Set the TIC trigger level to 1 V and the input impedance to 50 Ω.
2. Connect the pivot signal to the Start of the TIC.
3. Take a measurement cable that can reach both the UTC(k) and the PPS OUT of the receiver.
4. Connect the measurement cable on one side to the PPS OUT of the receiver and on the other side on the stop of the TIC.
5. Take the first measurement ΔT_1 averaging at least 100 measurements.
6. Now disconnect the measurement cable from the PPS OUT of the receiver and connect it the UTC(k) point to the stop of the TIC. The other side of the cable should remain connected to the Stop of the TIC.
7. Take the second measurement ΔT_2 averaging at least 100 measurements.
8. Compute the PPS OUT - UTC(k) delay (E - U) as $\Delta T_1 - \Delta T_2$.

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4 Receiver Specific Operations

In this section for each different receiver model the reference point is indicated and the type of measurement needed for the REFDLY computation are listed.

4.1 Septentrio Polarx3 Receiver

For this receiver the reference point (R) is the PPS OUT (E). To compute the REFDLY please follow the procedure described in Subsection 3.2. The REFDLY is then simply the PPS OUT - UTC(k) (E - U) delay.

4.2 Septentrio Polarx4 Receiver

For this receiver (as for the Polarx3) the reference point (R) is the PPS OUT (E). To compute the REFDLY please follow the procedure described in Subsection 3.2. The REFDLY is then simply the PPS OUT - UTC(k) (E - U) delay.

4.3 Polarx5TR Receivers

For the Polarx5TR it is important to distinguish two cases, deepening on the activation or not of the auto-compensation mode.

4.3.1 Auto compensation not activated

In this case as for the Polarx3 and Polarx4 receivers the reference point (R) is the PPS OUT (E). To compute the REFDLY please follow the procedure described in Subsection 3.2. The REFDLY is then simply the PPS OUT - UTC(k) (E - U) delay.

4.3.2 Auto compensation activated

In this case the reference point (R) is the PPS IN (D). To compute the REFDLY please follow the procedure described in Subsection 3.1. The REFDLY is then simply the PPS IN - UTC(k) (D - U) delay.

4.4 Mesit GTR55 Receiver

In this case the reference point (R) is the PPS IN (D). To compute the REFDLY please follow the procedure described in Subsection 3.1. The REFDLY is then simply the PPS IN - UTC(k) (D - U) delay.

References

[1] G D Rovera et al. "Time delay measurements: estimation of the error budget". In: *Metrologia* 56.3 (May 2019), p. 035004. DOI: 10.1088/1681-7575/ab14bb. URL: https://dx.doi.org/10.1088/1681-7575/ab14bb.

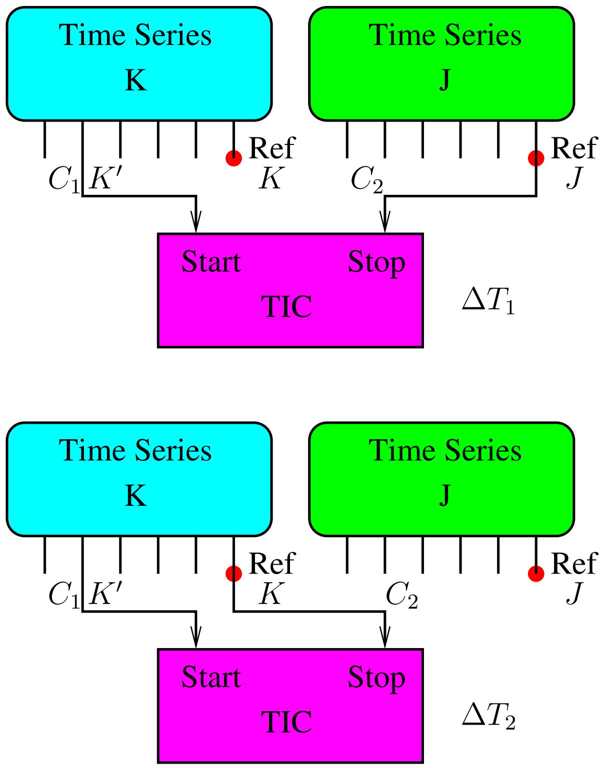

Figure 5: Illustration of the differential measurement technique called "pivot method". Cable C1 is connected to the pivot, while cable C2 is successively connected to the reference point of time series J and K. The difference between the measurements ΔT_1 and ΔT_2 provides the time difference between the two time series. Some uncertainties introduced by the are mitigated, because they are common to both measurements, and no prior knowledge of the cables delays is needed.(From [1]).

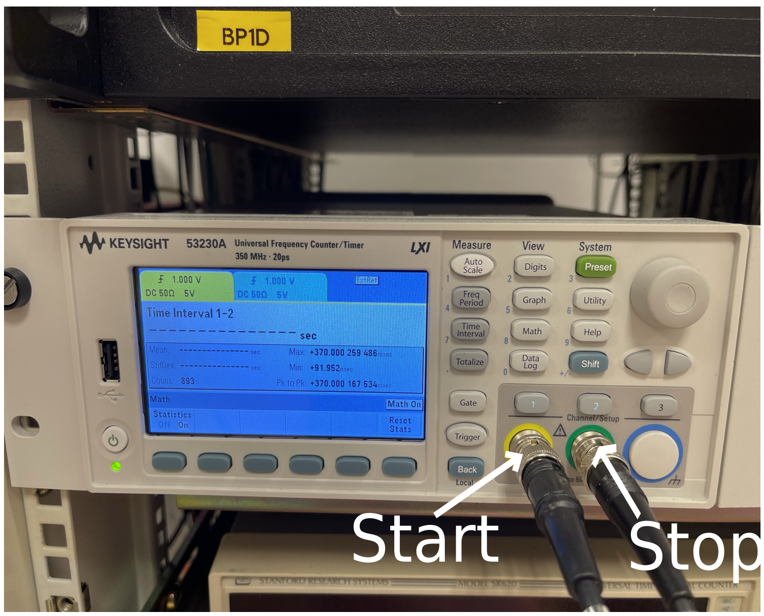

Figure 6: Keysight 53230A TIC during operation.