

# **WORKING GROUP C: CALIBRATION ISSUES SUMMARY OF THE DISCUSSION**

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## **ISSUES DISCUSSED**

The attendees were first presented with an initial set of issues and several specific questions that related to these issues. The first issue was systems of interest. The primary interests were in GPS and Two-Way Satellite Time and Frequency Transfer (TWSTFT). Two methods of calibration, absolute and relative, were identified, and examples of each were discussed. The limiting factors that affect calibrations included the instrumentation, cables, environment, and stability. The importance of the verification of a calibration through a time transfer closure to a truth source or agreement with an additional independent measurement was discussed. Last, some consideration was given to what future improvements would affect calibration capabilities.

## **CALIBRATION METHODS**

Two calibration methods were discussed, absolute and relative. In an absolute calibration, the delays in the time transfer instrumentation are discretely measured with the accuracy intrinsic to the calibration equipment or measurement. In a relative calibration, a reference time transfer system is used side-by-side with the subject system to perform measurement comparisons between the two systems. Considerations when performing either type of calibration include maintaining conditions identical to the normal operating conditions of the equipment to be calibrated. Frequency, signal level, and environment are some of the factors. In the absolute calibration method, a test signal generator is used to inject a reference signal into the equipment to be calibrated. The generation of this reference signal must be as accurate as the desired result of the calibration. Also, the reference signal must be consistent to provide repeatability in the measurements. In the relative calibration method, the reference time transfer system must be stable at the desired accuracy level during the period of the calibration.

## **GPS RECEIVER CALIBRATION**

The factors that affect a GPS receiver calibration were discussed. The precise position of the receiver antenna represented in the GPS reference frame is important. All cable delays from the antenna to the receiver input must be measured and taken into account. The receiver should be tested to determine if

delays change with signal power level variation. The GPS signal normally varies a few dB over each satellite's visibility. Also, it may be difficult to create exact conditions of the satellite signal with a reference test signal used in an absolute calibration. Some multi-channel receivers are susceptible to inter-channel biases. Any calibration should be able to test for this by comparing the delay of a reference signal through the path of each channel. It was discussed that past calibration campaigns were performed only at primary timing standards laboratories and that other users should be included. Examples of absolute and relative GPS receiver calibrations were discussed as provided in Figures 1 and 2, and references were given.

## **TWSTFT CALIBRATION**

The two methods of calibration as applied to TWSTFT were discussed. The absolute method uses a satellite simulator to generate a calibration reference signal. The relative method uses a portable earth station to compare measurements side-by-side with the TWSTFT system to be calibrated. The factors that affect calibration that were discussed include cable impedance mismatching, transmit power dependency, chip-rate dependency, and weather and temperature dependency. The frequency of calibrations was suggested to be at least yearly, and in some precise applications there have been systems that are calibrated continuously. The stability and accuracy of the instrumentation, cables, and connectors are also factors that affect the calibration. Examples of absolute and relative calibrations of TWSTFT systems were discussed as shown in Figures 3 and 4, and references were provided that apply to TWSTFT calibration issues.

## **ADDITIONAL TOPICS**

Several additional topics were discussed concerning the future of calibrations and other issues that should be considered. It was suggested that the replacement of coax cables with fiber optics would enable improvements in calibration accuracy in the future. There are time transfer users of GLONASS who remain active and require calibrations. It is of interest that calibrations of this system be made available to this community. It was suggested that the use of WAAS / EGNOS should be considered for intercontinental common-view time transfer applications. Also, it was suggested that a proposal be made to use calibration campaigns as supplementary comparisons between laboratories at the Working Group meeting, which will be held before the Consultative Committee on Time and Frequency meeting in April 2004.

## **GPS RECEIVER CALIBRATION REFERENCES**

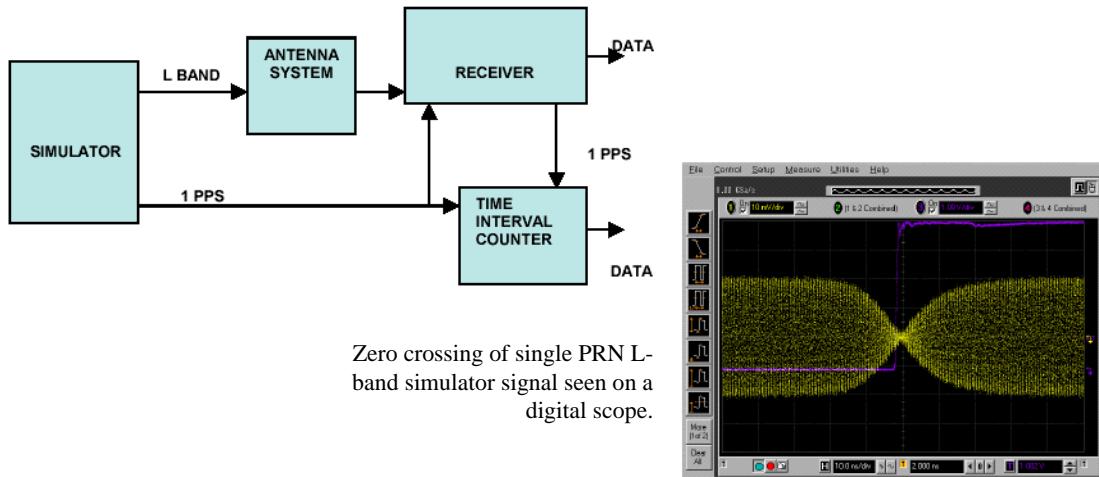
- [1] E. Powers, 2000, "*Calibration of GPS Carrier-Phase Time Transfer Equipment*," in Proceedings of the 31st Annual Precise Time and Time Interval (PTTI) Systems and Applications Meeting, 7-9 December 1999, Dana Point, California, USA (U.S. Naval Observatory, Washington, D.C.), pp. 441-448.
- [2] J. F. Plumb, J. White, E. Powers, K. Larson, and R. Beard, 2002, "*Simultaneous Absolute Calibration of Three Geodetic-Quality Timing Receivers*," in Proceedings of the 33rd Annual Precise Time and Time Interval (PTTI) Systems and Applications Meeting, 27-29 November 2001, Long Beach, California, USA (U.S. Naval Observatory, Washington, D.C.), pp. 349-357.
- [3] P. G. Landis and J. White, 2003, "*Limitation of GPS Receiver Calibrations*," in Proceedings of the 34th Annual Precise Time and Time Interval (PTTI) Systems and Applications Meeting, 3-5 December 2002, Reston, Virginia, USA (U.S. Naval Observatory), pp. 325-332.

- [4] J. Plumb, K. Larson, J. White, E. Powers, and R. Beard, 2003, “*Stability and Error Analysis for Absolutely Calibrated Geodetic GPS Receivers*,” in Proceedings of the 34th Annual Precise Time and Time Interval (PTTI) Systems and Applications Meeting, 3-5 December 2002, Reston, Virginia, USA (U.S. Naval Observatory, Washington, D.C.), pp. 309-324.

## **TWSTFT CALIBRATION REFERENCES**

- [1] G. de Jong and R. van Bemmelen, 2003, “*Evaluation and Improvements of the Calibration of a TWSTFT Station Using SATCOM*,” in Proceedings of the 34th Annual Precise Time and Time Interval (PTTI) Systems and Applications Meeting, 3-5 December 2002, Reston, Virginia, USA (U.S. Naval Observatory, Washington, D.C.), pp. 391-404.
- [2] T. E. Parker, V. S. Zhang, A. McKinley, L. Nelson, J. Rohde, and D. Matsakis, 2003, “*Investigation of Instabilities in Two-Way Time Transfer*,” in Proceedings of the 34th Annual Precise Time and Time Interval (PTTI) Systems and Applications Meeting, 3-5 December 2002, Reston, Virginia, USA (U.S. Naval Observatory, Washington, D.C.), pp. 381-390.
- [3] W. Klepczynski, 2003, “*Systematic Effects in GPS and WAAS Time Transfers*,” in Proceedings of the 34th Annual Precise Time and Time Interval (PTTI) Planning Meeting, 3-5 December 2002, Reston, Virginia, USA (U.S. Naval Observatory, Washington, D.C.), pp. 405-412.

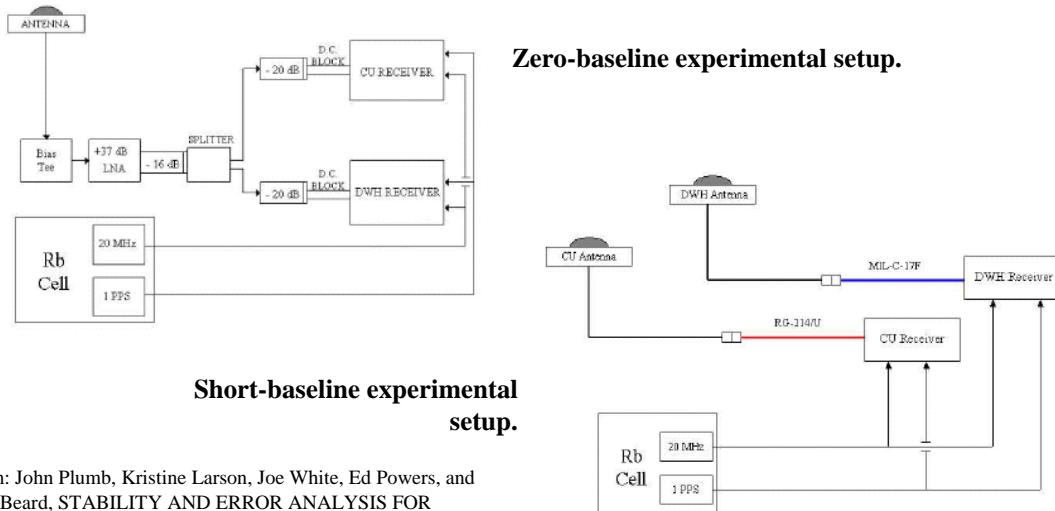
## Example of absolute calibration (GPS Rx)



From: G. Paul Landis, Joe White - LIMITATION OF GPS RECEIVER CALIBRATIONS

Figure 1.

## Example of relative calibration (GPS Rx)



From: John Plumb, Kristine Larson, Joe White, Ed Powers, and Ron Beard, STABILITY AND ERROR ANALYSIS FOR ABSOLUTELY CALIBRATED GEODETIC GPS RECEIVERS

Figure 2.

## Example of absolute calibration (TWSTFT)

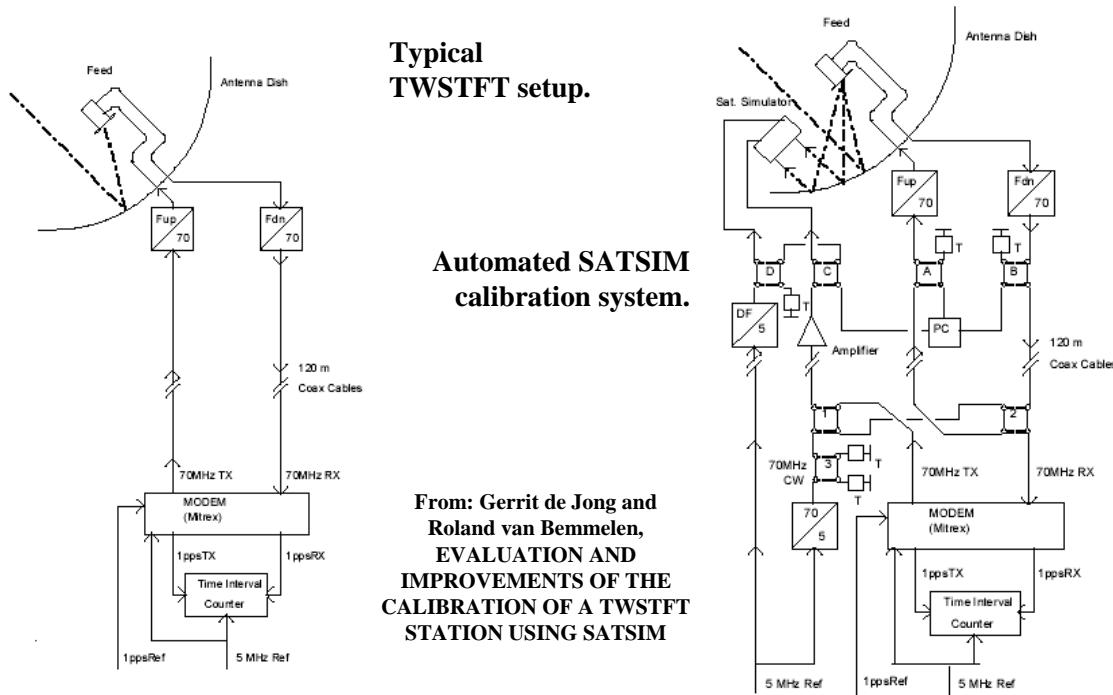


Figure 3.

### Example of TWSTFT Calibration (GSTB V1) between IEN (E-PTS) and PTB

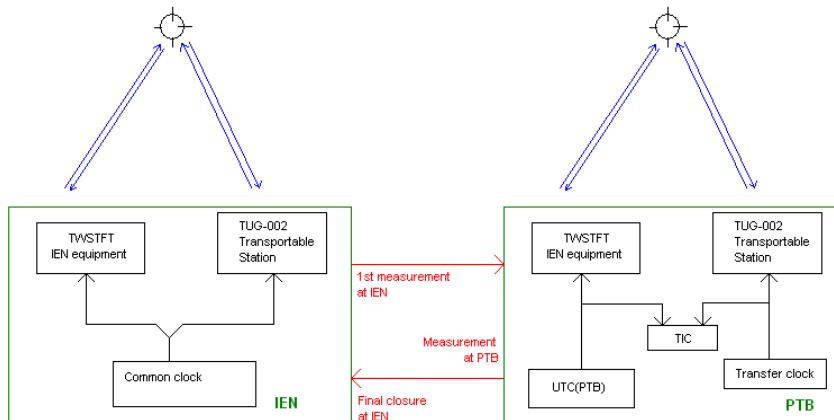


Figure 4.

*35<sup>th</sup> Annual Precise Time and Time Interval (PTTI) Meeting*