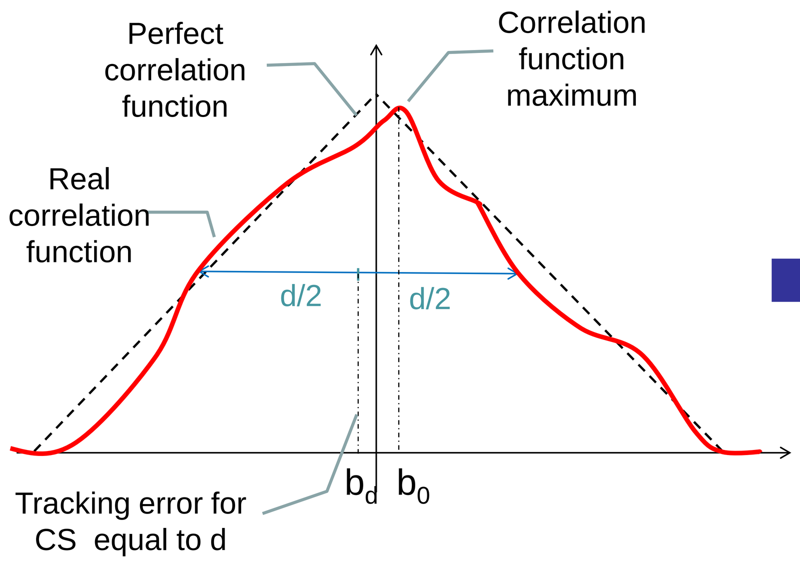
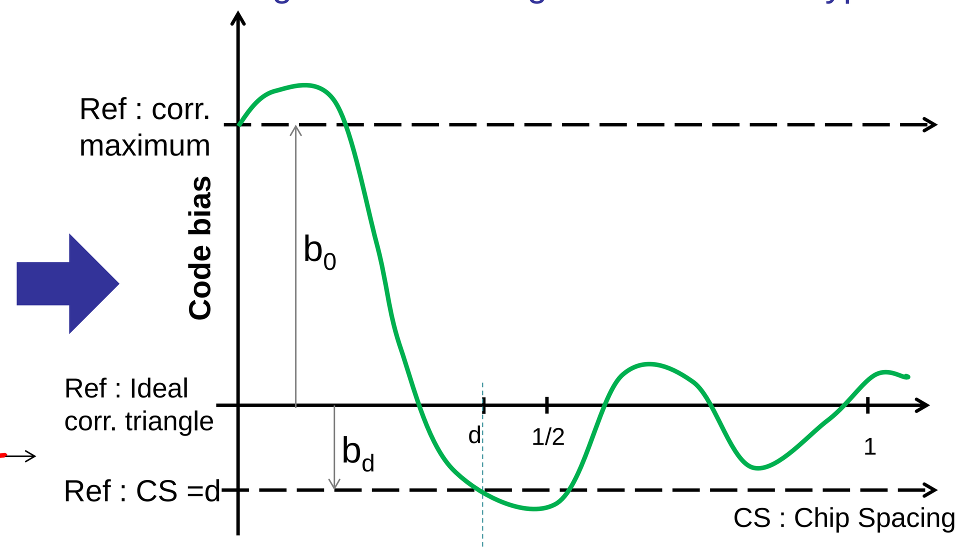
P1-C1 DCB determination using a high gain antenna coupled to the LCI method. Receiver type impact

L. Lestarquit, Y. Grégoire, F. Mercier
CNES, Toulouse, France (Laurent.lestarquit@cnes.fr)

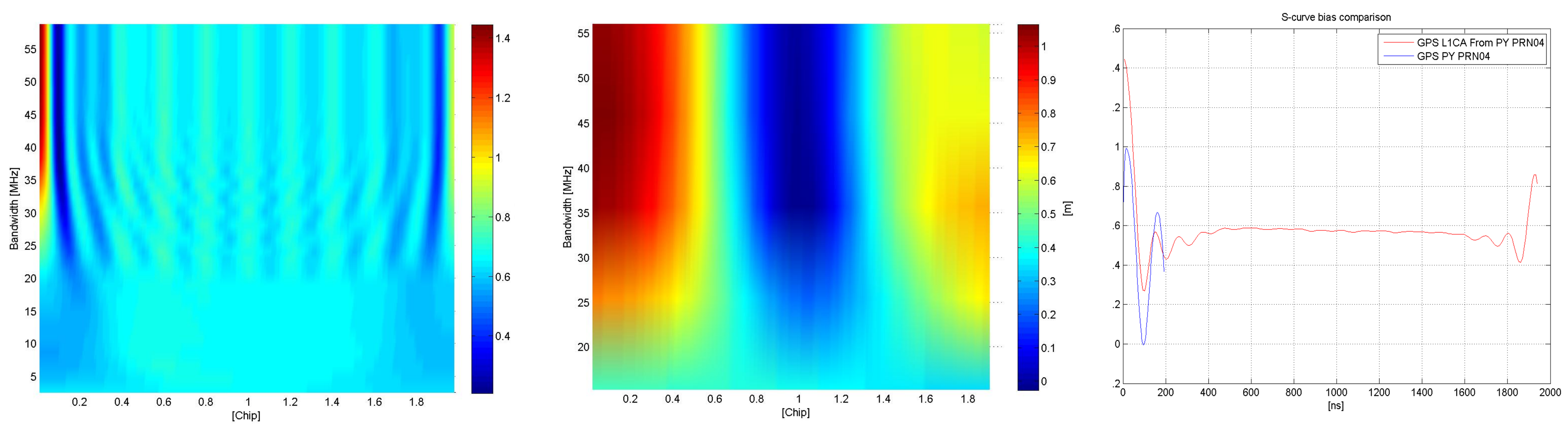
P1-C1 DCB determination using an High Gain Antenna (HGA)

Methodology : The correlation function distortions are determined with an accuracy enabling to determine tracking errors at the centimeter level. This is done using a reasonably sized (several meters) High Gain Antenna and the Long Coherent Integration (LCI) method in which the signal is coherently integrated over several tens of seconds. Discussion about this method can be found in [1]. Then the tracking error is computed taking into account the receiver bandwidth and discriminator type. Using a directional antenna allows not to be bothered by the multipath error.





P1-C1 bias determination : The LCI are done on C/A and P code conjointly, using synchronized code replica. The absolute P1-C1 bias is simply obtained by differentiating. It is the **absolute P1-C1 DCB** provided the antenna and RF recording chain are calibrated, and the calibration curve is accounted for. In the example below, the reference replicas was obtained by tracking P-code with 1 chip spacing and a receiving BW greater than the satellite transmit BW (Our signal recorder had a 62.5 MHz BW).



The above graphs show, for PRN04 the C1 bias (left) and P1 bias (middle) as a function of receiver BW and discriminator chip spacing (CS), and on the right the P1-C1 bias for full signal BW for PRN04. For both C/A and P code, the bias variation is up to 1 meter according to the receiver characteristics (and even higher for double delta type discriminators). The difficulty is that these characteristics are generally not available from the GNSS receiver manufacturers, and only speculations can be made. As P(Y)-code is a fast code (10.23 Mchip/s) and given the 24-MHz GPS declared bandwidth, it is likely that most P-code receivers have the same characteristics, that is a 1 chip discriminator spacing and a 20 MHz RF bandwidth, even though smaller chip spacing could be possible. But for C/A code tracking, there are plenty of discriminator types, chip spacing and RF bandwidth possible

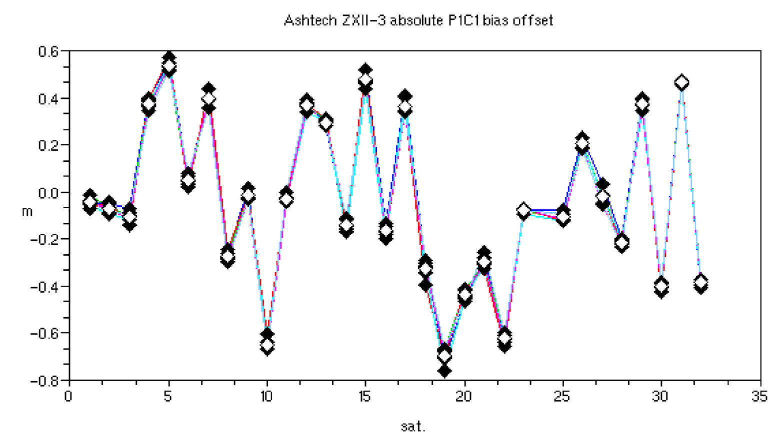
P1-C1 DCB determination using GNSS receivers

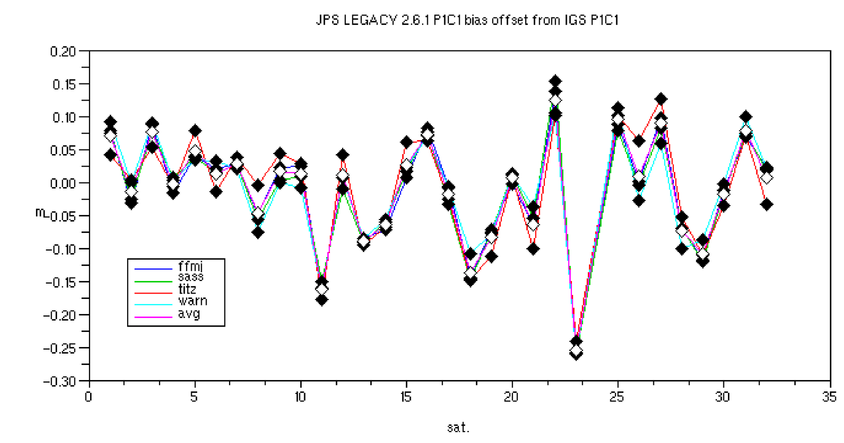
The link between P1-C1 biases that affect real-world GNSS receivers and the P1-C1 DCB computed using the LCI and HGA measurement need to be made. We have a data set of signal measurement collected at the Leeheim Spectrum Monitoring station (Germany) on march 14, 2012.

Methodology :

- Direct determination for receivers producing both C1 and P1 observable : Ashtech Z12, JPS LEGACY, Septentrio PolarX 2&3
- Indirect determination using Melbourne-Wubbena combination, GRG WSB parameters and wide-lane ambiguity resolution for receivers producing C1 observable only (Trimble NETR5 & NETR9)
- use of 30s rinex data from IGS station located if possible in Europe (co-visibility with Leeheim antenna)
- 25° elevation mask to discard multipath. Stations with too many outliers are removed.
- Averaging (median) over 3 days : 13, 14 & 15 march 2012
- constellation zero-mean condition applied

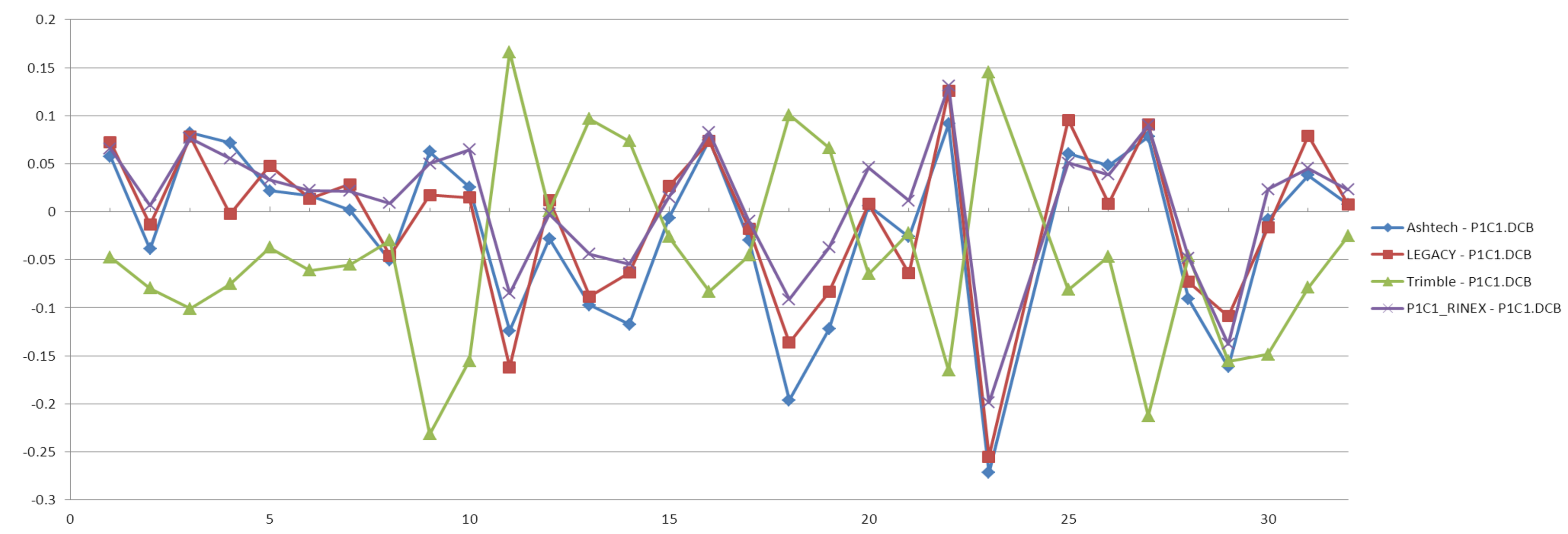
Results :





The above mentioned receivers producing C1 & P1 observable had a very close behavior and their P1-C1 DCB is within a few centimeters of the CODE P1C1yymm_RINEX.DCB file. The Trimble receivers have a different behavior with offset reaching as high as 30 cm, the worse PRN being PRN 9, 1, 23 and 27. The values contained in the CODE file P1C1yymm.DCB is close to be an average for the 2 types of receivers.

P1-C1 difference with CODE P1-C1yymm.DCB file (in meters) for several receiver types:

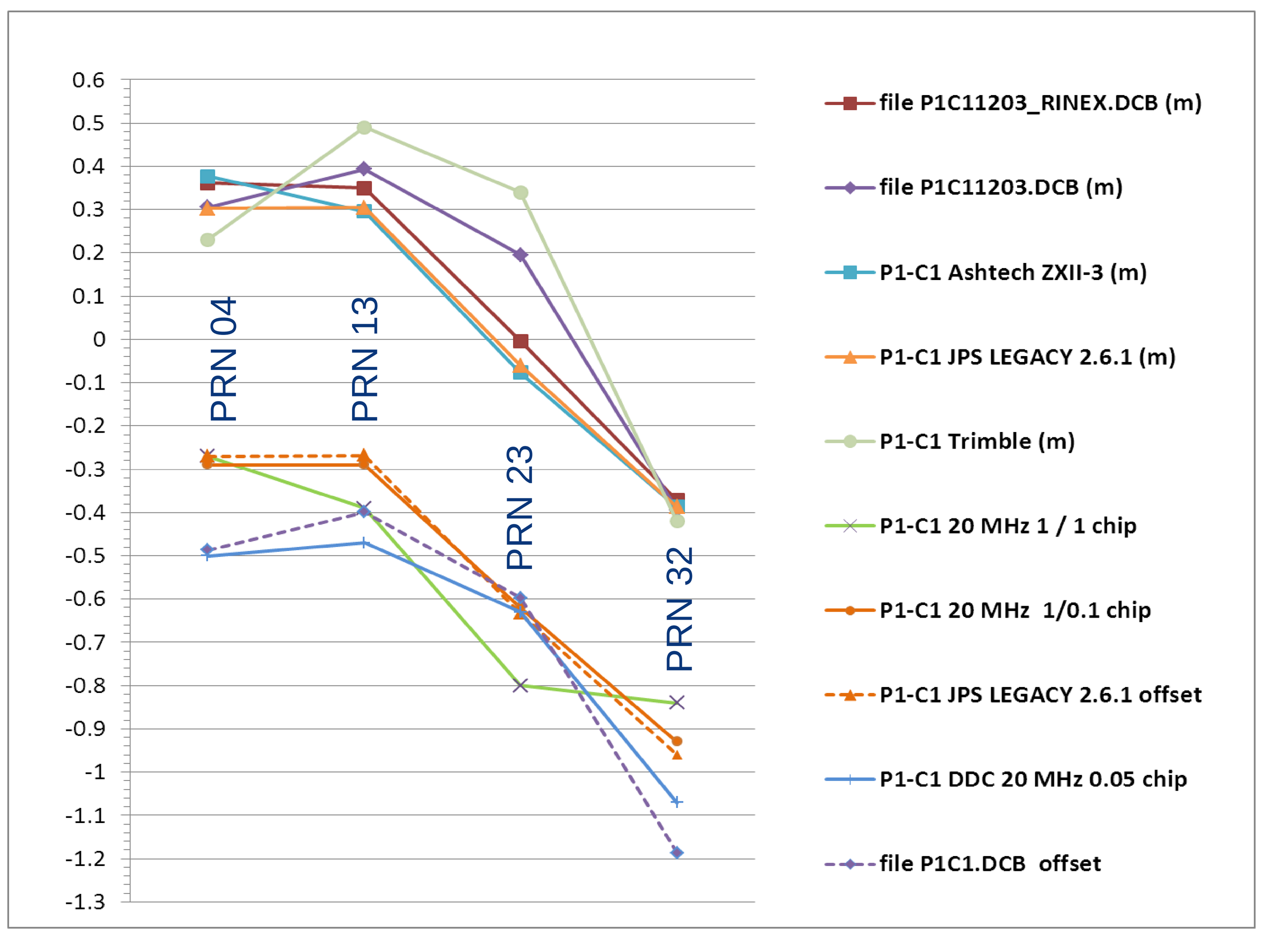


Comparisons of computations derived from HGA+LCI method with GNSS receiver measurements

In the collected signal dataset, only 8 GPS satellites were recorded. For the moment, the P1-C1 DCB could only be computed for 4 GPS satellites from block IIA and IIR : PRN 04, 13, 23 & 32. For block IIF & IR-M, we are currently working on issues due to the presence of M-Code.

For P code, we assumed 1 chip spacing discriminators for all receiver, and 20 MHz BW as it is the bandwidth that is likely to be used by geodetic receivers.
It also provide a **reference** against which the P1-C1 bias is computed for receiver that don't produce P1 observables.
For C/A code, 1 chip, 0.1 chip & 0.05 chip narrow discriminators as well as 0.05 chip DDC discriminators have proved to show distinct behavior.

We would need to make measurement of all the 32 GPS satellite to have a better picture. Short term stability of the P1-C1 biases could also be studied using a calibrated HGA with the ICL method.



As a constellation "zero mean" constraint is applied to the DCB computed using un-calibrated GNSS receivers or published by CODE, an offset is applied to match to the DCB computed using the HGA+ICL method (dotted curve on the graph).

We have found that the JPS LEGACY receiver closely match the P1-C1 computed for a 20 MHz RF BW, a 1 chip spacing for P code, and a 0.1 chip spacing for the C/A code discriminator with a 2 cm accuracy. (orange curves)

The DCB published by CODE are close to those computed for a 0.05 chip spacing double delta type discriminator. But further analysis would be required with all 32 satellites recorded with the HGA. Further analysis is needed for the Trimble receivers as well.

It is interesting to notice that the PRN 23 satellite has a very stable bias when computed from the HGA data whereas it has one of the largest variation when computed from GNSS network and applying the constellation zero mean constraint.

It would be highly desirable that receiver characteristics that have an impact on P1-C1 DCB bias are disclosed by the manufacturers, at least for geodetic receivers used in the IGS network. This would allow classifying receivers in families according to their characteristics. This is a first step necessary to investigate to which extent the dependency of P1-C1 DCB on receiver characteristics affects the accuracy of IGS products.

This study focused on the GPS P1-C1 biases, but other DCB combination with low chipping rate codes are expected to face similar issues : GLONASS P1-C1, GPS & GLONASS P2-C2, and also DCB combinations with future Galileo C1 signals.

References:

[1] Lestarquit, L., Gregoire, Y., Thevenon, P., "Characterizing the GNSS Correlation Function using a High Gain Antenna and Long Coherent Integration - Application to Signal Quality Monitoring," *Proceedings of IEEE/ION PLANS 2012*, Myrtle Beach, South Carolina , April 2012, pp. 877-885.
[2] Wong, G., Phelts, R.E., Walter, T., Enge, P., "Alternative Characterization of Analog Signal Deformation for GNSS-GPS Satellites," *Proceedings of the 2011 International Technical Meeting of The Institute of Navigation*, San Diego, CA, January 2011, pp. 497-507.

Conclusion

We have demonstrated, despite having a reduced set of data available, that signal distortion measurements made using an High Gain Antenna coupled to the Long Coherent Integration (LCI) method can explain the observed P1-C1 DCB discrepancies according to the receiver make and manufacturer.
It would be highly desirable that the receiver characteristics that have an impact on P1-C1 DCB bias are disclosed by the manufacturers, at least for geodetic receivers used in the IGS network.