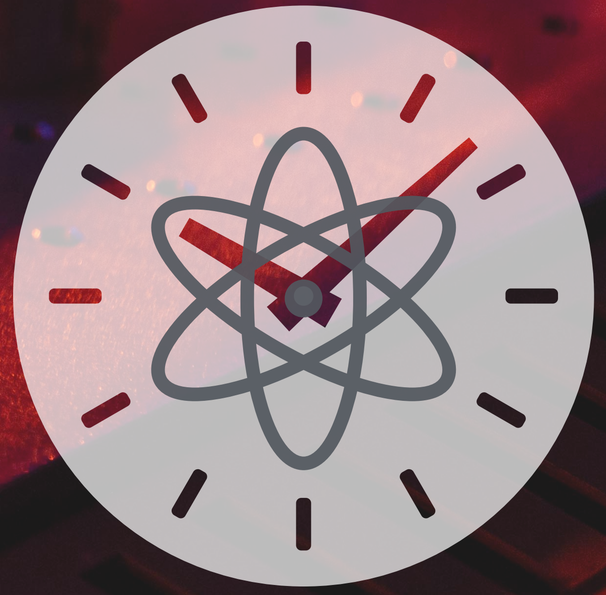
Procedure for computing raw differences of GNSS code measurements for geodetic receivers

BIPM-SIM UTC Summer School 2025
El Marqués, Querétaro, May 7-9



Carlos Andrés Ortiz Cardona / Time and Frequency / May 8th, 2025

BIPM 1875 – 2025 CELEBRATING 150

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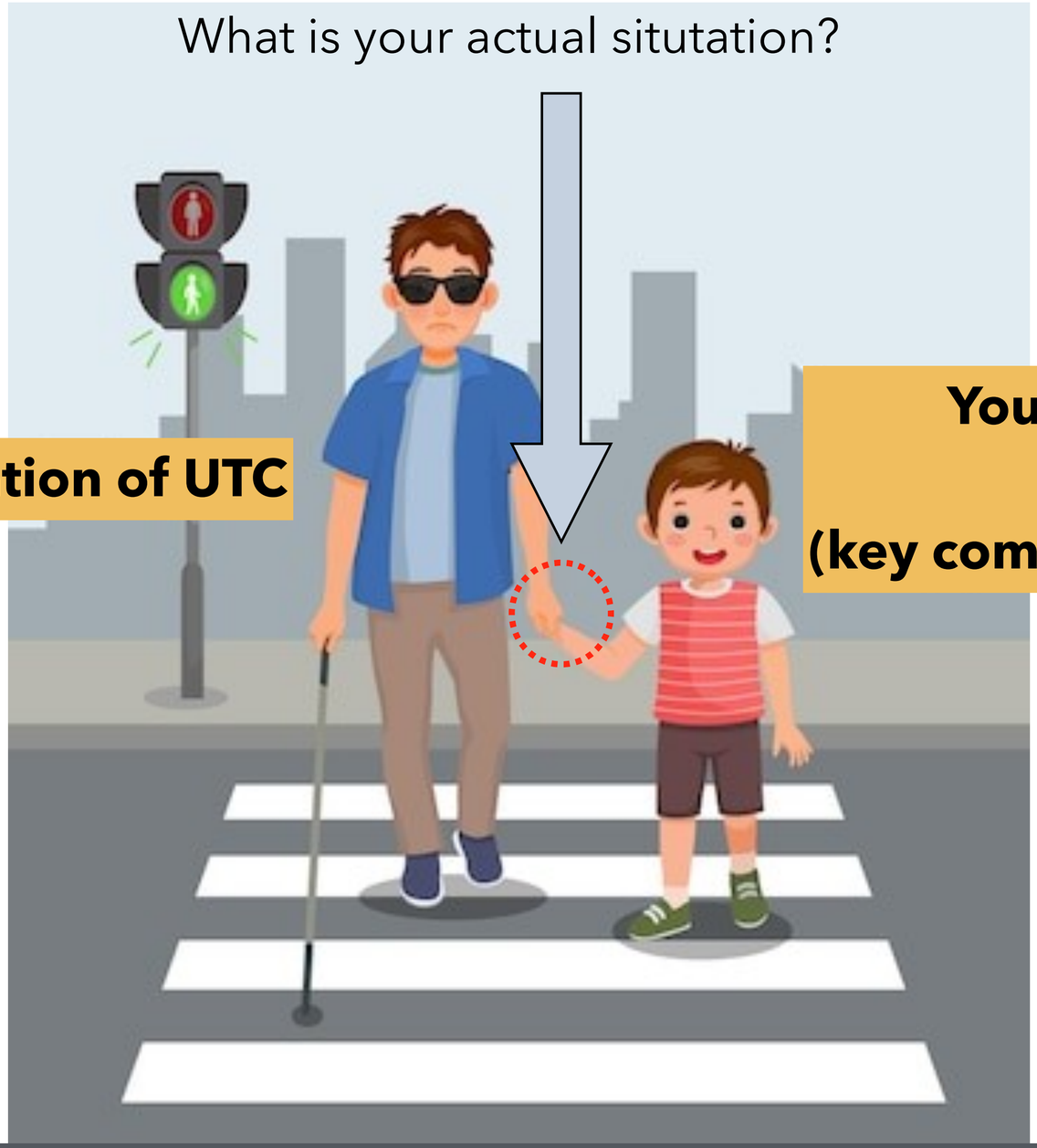
What is your actual situtation?



Your local realization of UTC

Your well (?) calibrated GNSS receiver (key comparison CCTF-K001.UTC)

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A single program (*dclrinex.f*) generates raw differences from the Rinex files.

A script (*dclrinexplot.sh*) run the program and generate plots of raw differences and their time stability.

Information based on Annex 3 / V 3.2 / August 2021

GNSS Receiver **A** (Reference)
Known:

- CAB_d
- REF_d
- INT_d (depends on frequency)

Problem-solving Strategy

$$TOTAL_{delay} = CAB_{delay} + INT_{delay} - REF_{delay}$$

GNSS Receiver **B** (DUT)
Known (carefully measured before):

- CAB_d
- REF_d
- Antenna position (PPP service)

Unknown:

- INT_d

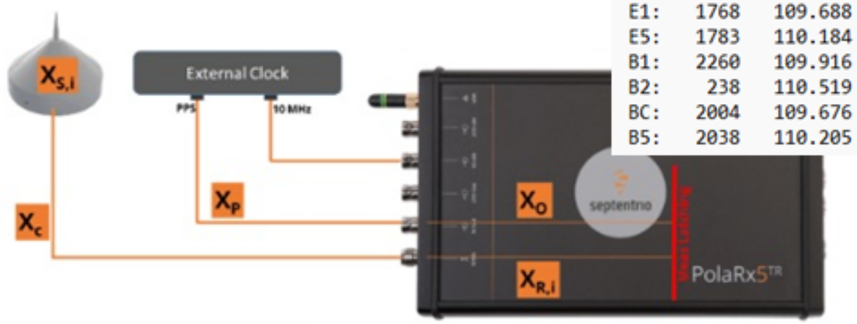
Obtained with dclrinex (raw differences of GNSS code measurements)

```
Number of  300s epochs in out file =   288
Code #pts, median/ns, ave/ns, rms/ns
C1:   2670   109.759   109.755     1.155
C2:   2050   109.055   109.105     1.052
P1:   2557   109.433   109.453     0.955
P2:   2556   108.893   108.911     1.277
D1:   1967   112.070   111.990     1.849
D2:   1599   110.473   110.420     1.473
R1:      0     0.000       NaN       NaN
R2:      0     0.000       NaN       NaN
E1:   1768   109.688   109.713     1.054
E5:   1783   110.184   110.263     0.832
B1:   2260   109.916   109.942     1.563
B2:    238   110.519   110.277     1.238
BC:   2004   109.676   109.644     1.071
B5:   2038   110.205   110.245     0.900
```

$$\Delta TOTAL_d = \Delta CAB_d + \Delta INT_d - \Delta REF_d$$

$$\Delta INT_d = \Delta TOTAL_d - \Delta CAB_d + \Delta REF_d$$

$$INT_dB = INT_dA - \Delta INT_d$$



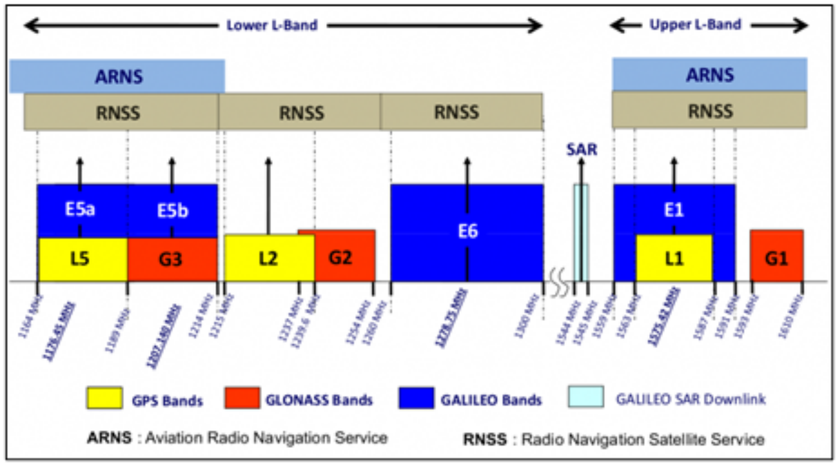
$X_{s,i}$: delay in antenna for signal i
$X_{R,i}$: delay in RF section of receiver for signal i
X_c: delay in RF cable (including amplifier and splitter)
X_p: delay in PPS cable
X_o: delay between PPS IN connector and internal receiver time reference (X_o = 0 on PolaRx5TR when auto-calibration is enabled)

Internal Delays

	GPSL1	GPSL2	GLOL1	GLOL2	GALE1	GALE5a	BDSB1I	BDSB2I
INTDLY (X_S+X_R)	71.700 ns	76.400 ns	0.000 ns	0.000 ns	0.000 ns	0.000 ns	0.000 ns	0.000 ns

Cable Delay
CABDLY (X_C) 116.800 ns

Reference Delay
REFDLY (X_P+X_O) 46.771 ns



Steps:

1. Download program and script from BIPM's website.
dclrinex.f - last modified on August 27th, 2021.
dclrinexplot.sh - Last modified on August 30th, 2021.

Note: if you are using a Unix-like environment and command-line interface (CLI) for Microsoft Windows, like Cygwin, you have to create an executable (.exe) file. For Cygwin the command is
$ gfortran dclrinex.f -o dclrinex.exe

https://webtai.bipm.org/ftp/pub/tai/publication/gnss-calibration/doc-soft/

2. Retrieve Rinex observation files from both GNSS receivers (1 per day with an interval of 30 s). The maximum of days (advised) is 9.

You can use Rinex 2 (AGGO2330.24O) or Rinex 3 (AGGO00ARG_R_20242330000_01D_MN.rnx)

Note: Rinex 3 can use the same format as Rinex 2 (you have to program it on your GNSS receiver).

RINEX file naming conventions

RINEX 2 format files

nnnnDDDS.YYt[*.cmp*]

where:

nnnn	=	4 character station ID
DDD	=	3 digit day of year (inc. leading zeros) of first epoch of data in the file
S	=	Hourly session ID letter corresponding to first epoch of data in the file. "a" = 00:00:00 - 00:59:59 (GPS time); "b" = 01:00:00 - 01:59:59; …. ; "x" = 23:00:00 - 23:59:59
YY	=	2 digit year (inc. leading zero) of first epoch of data in the file
t	=	File contents indicator. "o" = observations; "d" = Hatanaka compacted observations; "n" = GPS orbits; "g" = GLONASS orbits
cmp	=	[Optional] Compression method. E.g. "*zip*", "gz"

RINEX 3 format files

nnnnMRCCC_S_YYYYDDDHHMM_PPU_FFU_CT.fmt[*.cmp*]

where:

nnnn	=	4 character station ID
M	=	Monument number. Currently only zero (0) is used
R	=	Receiver number. Currently only zero (0) is used
CCC	=	ISO country code (GBR)
S	=	Data source. "R" = receiver; "S" = stream; "U" = unknown
YYYY	=	4 digit year of first epoch of data in the file
DDD	=	3 digit day of year (inc. leading zeros) of first epoch of data in the file
HH	=	2 digit hour (inc. leading zero) of first epoch of data in the file (GPS Time)
MM	=	2 digit minute (inc. leading zero) of first epoch of data in the file (GPS Time)
PP	=	2 digit file period (inc. leading zero)
U	=	Units of period *PP*. "M" = min; "H" = hour, "D" = day; "Y" = years; "U" = unspecified
FF	=	2 digit frequency of the observations (inc. leading zero)
U	=	Units of frequency *FF*. "C" = 100Hz; "Z" = Hz; "S" = sec; "M" = min; "H" = hour; "D" = day; "U" = unspecified NB - *_FFU* is omitted for files containing navigation data
C	=	Constellation indicator. "M" = mixed; "G" = GPS; "E" = Galileo; "R" = GLONASS; "C" = Beidou; "J" = QZSS; "I" = IRNSS; "S" = SBAS
T	=	Data type indicator. "O" = observations; "N" = navigation; "M" = meteo (no associated constellation so *MM*)

3. Download Rinex (2 or 3) navigation files (also known as GNSS Broadcast Ephemeris Files)

(brdc0390.25n or BRDC00IGS_R_20242330000_01D_MN.rnx)

The daily GNSS broadcast ephemeris file is a merging of the individual mixed navigation files. This file is updated several times throughout the day as more input files become available.

https://cddis.nasa.gov/Data_and_Derived_Products/GNSS/broadcast_ephemeris_data.html

IGS: International GNSS service

NOTE: All useful files should be in the same directory.

What is the progam (dclrinex.f) doing?

From the GPS observations, for example, it forms the L1, L2 and L5 phase differences, checks for gross phase outliers and cycle slips by comparing the time evolution of the phases, and solves for the baseline between the phase centers of the two antennas. If not enough L5 phase data is found, the L5 baseline is taken as the mean of L1 and L2. Similarly, the baseline at any other frequency is taken as the mean of L1 and L2.

Then the program forms the pseudorange differences for a list of codes, accounting for the geometric effect of the computed baseline.

Number of 300s epochs in out file = 288

	Code	#pts	median/ns	ave/ns	rms/ns
GPS	C1:	2670	109.759	109.755	1.155
	C2:	2050	109.055	109.105	1.052
	P1:	2557	109.433	109.453	0.955
	P2:	2556	108.893	108.911	1.277
Glonass	D1:	1967	112.070	111.990	1.849
	D2:	1599	110.473	110.420	1.473
	R1:	0	0.000	NaN	NaN
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Galileo	E1:	1768	109.688	109.713	1.054
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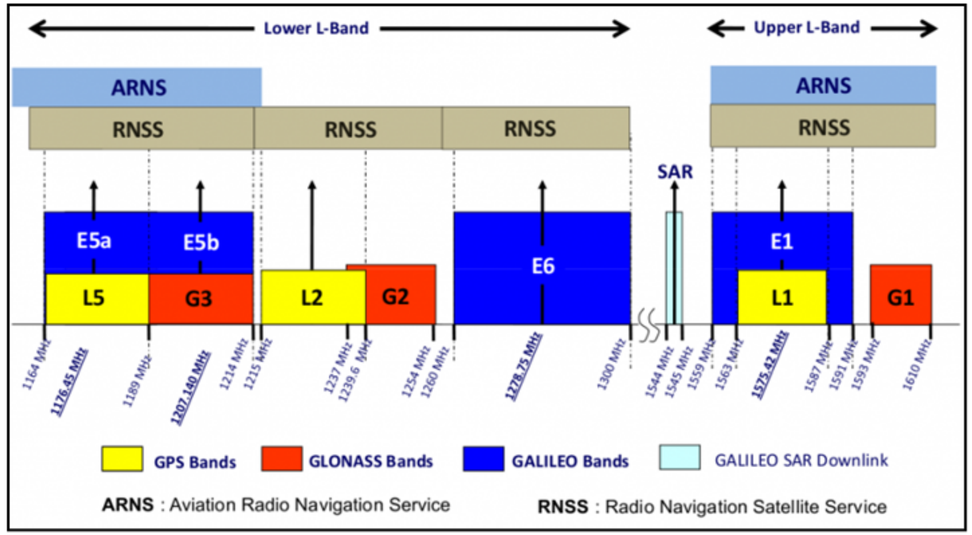

Using the progam (dclrinex.f) :

dclrinex sss1 sss2 yydoy .xxxx dur OPTION

e.g. dclrinex AGGO SIMr 24233 7 GPSSOL

where:

sss1 = The four or nine-character code of station 1 (traveling system), used to name its Rinex files

sss2 = The four or nine-character code of station 2 (local system), used to name its Rinex files

yydoy = first day of Rinex files (last two digits of year + day of year number)

.xxxx = option to specify precise start time as a fraction of the first day

dur = number of consecutive days to process (maximum advised is 9)

OPTION = P1ISC1: Use C1 measurements instead of P1, for a station with no P1 data

LZYYYY: Use files LZYYYYmj.day to report station 2 to the same reference as station 1.

GPSSOL to process only GPS (default = all four GNSS)

BDSGEO to process BeiDou geostationary satellites (def=no)

NOBDS2 to remove BeiDou 2 satellites (def=process)

NOBDS3 to remove BeiDou 3 satellites (def=process)

NOBDS to remove BeiDou satellites (def=process)

NOGAL to remove Galileo satellites (def=process)

NOGLO to remove GLONASS satellites (def=process)

ALLCOD to process all codes including non CGGTTS V2E (def=only CGGTTS codes)

BIGDIF to write all raw code differences in the output file .dif (def=smaller file)

ELMIxx to remove elev<xx deg (def=05)

If several options are used, they should be entered between " ".

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Example Using the progam (dclrinex.f) :

Compute the raw differences of the calibrate system PolarRx5TR (AGGO) with the uncalibrated system PolarRx5TR (SIMr) for 7 days of operation starting August 20, 2024 with the line command:

dclrinex AGGO SIMr 24233 7

Output files (dclrinex.f):

Three ASCII output files are created: and named sss1sss2yydoy_dur.EXT where:

- sss1sss2yydoy_dur.sum Summary with essential information.
- sss1sss2yydoy_dur.lis Long listing including all warning messages (For debugging purposes only).
- sss1sss2yydoy_dur.dif List of code differences at the requested interval

Warning: Previous files with the same filename should be removed before running the script!

Output files with names ss1sss2yydoy_dur_Xij.pdf contain plots of two codes differences and Time deviations for the recognized dual-frequency combinations.

In addition, temporary ascii files named ZZ.tmp, medZZ.tmp, tdevZZ.tmp containing the plotted values are created and overwritten at each run. Here 'ZZ' indicates the code and corresponds to the Rinex 2 code, with the exception of GLONASS for which D1/D2 is used for C1/C2 and R1/R2 is used for P1/P2.

Prepare a calibration report for BIPM:

1. Introduction
2. Results
3. Uncertainty
4. Conclusion

https://webtai.bipm.org/ftp/pub/tai/publication/gnss-calibration/guidelines/

Annex 4

¡Gracias!

30 AÑOS 1994 - 2024 CENAM
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