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Notations

As presented in [Petit et al., 2001] for the Z12-T, the calibration of a geodetic system is divided in (up to) 6 different parts (Figure 1)

- X_P = Delay of the 1PPS-in with respect to the laboratory reference
- X_O = Delay of the "internal reference" with respect to the 1PPS-in

(X_P + X_o) = REFDLY.

- X_C = antenna cable delay
- [X_D = short cable + splitter delay]

(X_C + X_D) = CABDLY. In practice, X_D is generally not used.

- X_R = receiver internal delay, measured from the "internal reference"
- X_S = antenna delay

(X_R + X_S) = INTDLY.

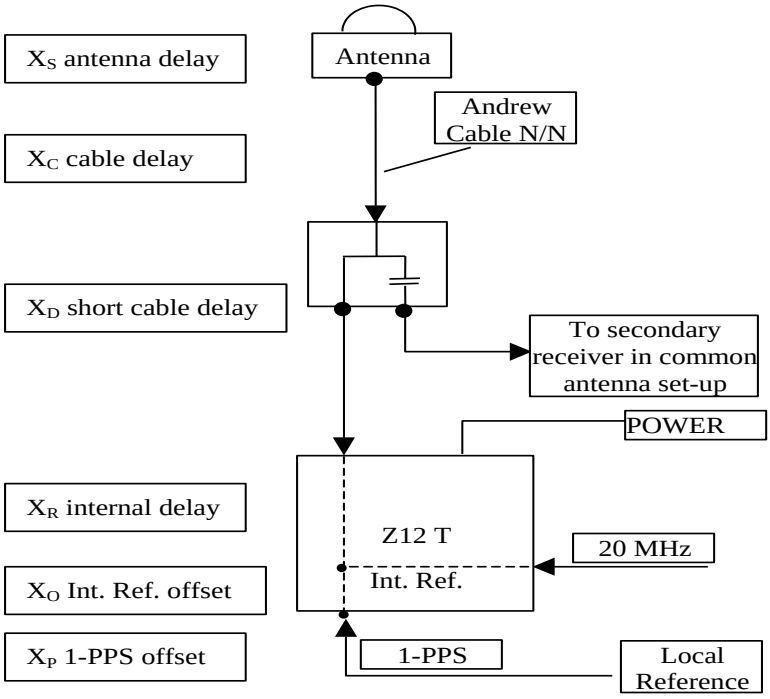


Figure 1: Definition of the different delays used in the most general set-up of a geodetic system (here shown for a Z12-T) from [Petit et al, 2001].

3/ Phase 3

Laboratories: BIPM, SU

3.1/ BIPM (14240)

Period

MJD 56897 to 56902

Delays

All measurements at BIPM carried out by L. Tisserand.
Equipment used to measure internal delay of local receiver is a time interval counter (TIC), model SR620, maker Stanford Research Systems, s/n: 4680, with measurement uncertainty typically less than 0.5 ns (using external reference frequency as timebase).

BP0R:

X_O = 227.9 ns (267.9-48.7+8.7)
X_P = 42.7 ns (BP1R+C139+BP1S+C72)
REFDLY = 270.6 ns
CABDLY = X_C = 133.4 ns (C113)

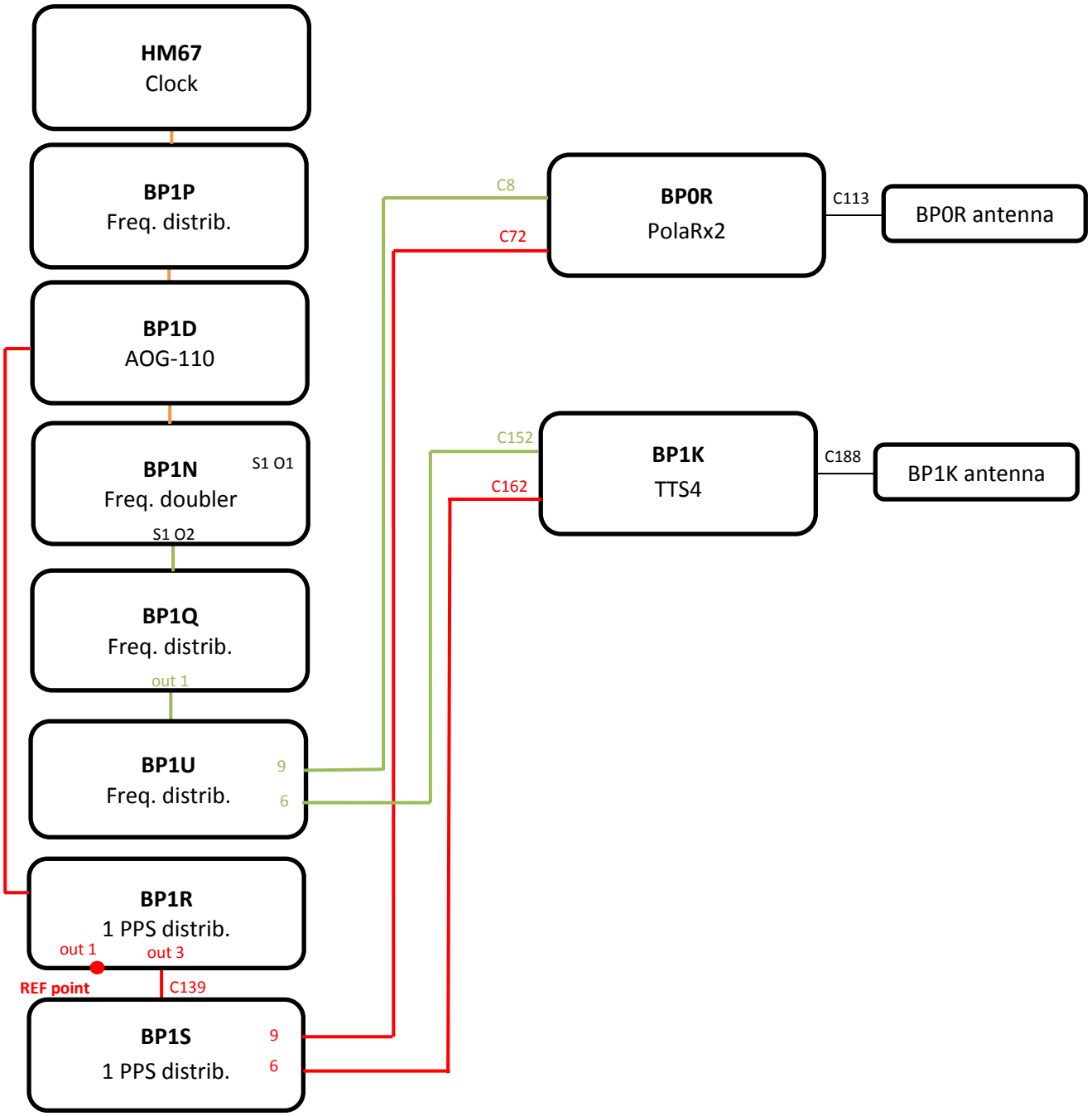
BP1K:

10 MHz factory calibration = 4.45 ns
User frequency to 1 PPS offset (or 1PPS-freq offs)
1PPS-freq offs = 9.95 ns
1PPS-freq corr = -2.55 ns
Total delay = 45.15 ns

X_O = -2.55 ns
X_P = 47.7 ns (BP1R+C139+BP1S+C162)
REFDLY = 45.15 ns
CABDLY = X_C = 142.01 ns (C188)

last update : 23/11/2015

Setup at the BIPM



BP1K-BP0R

COMPUTATION OF BASELINE

Number of codes to fit baseline and biases = 101744
Computed code bias (P1/P2)/m = -8.170 -9.528
Computed baseline (X,Y,Z)/m = -1.481 -0.261 1.347
RMS of residuals /m = 0.688

Number of phase differences to fit baseline = 100243
A priori baseline (X,Y,Z)/m = -1.481 -0.261 1.347
17216 clock jitters computed out of 17216 intervals
AVE jitter /ps = 0.1 RMS jitter /ps = 5.6

Iter 1 Large residuals L1= 0
Iter 1 Large residuals L2= 5
Computed baseline L1 (X,Y,Z)/m = 0.023 0.011 -0.059
RMS of residuals L1 /m = 0.005
Computed baseline L2 (X,Y,Z)/m = 0.034 0.016 -0.032
RMS of residuals L2 /m = 0.005

Iter 2 Large residuals L1= 0
Iter 2 Large residuals L2= 5
Computed baseline L1 (X,Y,Z)/m = 0.023 0.011 -0.059
RMS of residuals L1 /m = 0.005
Computed baseline L2 (X,Y,Z)/m = 0.034 0.016 -0.032
RMS of residuals L2 /m = 0.005

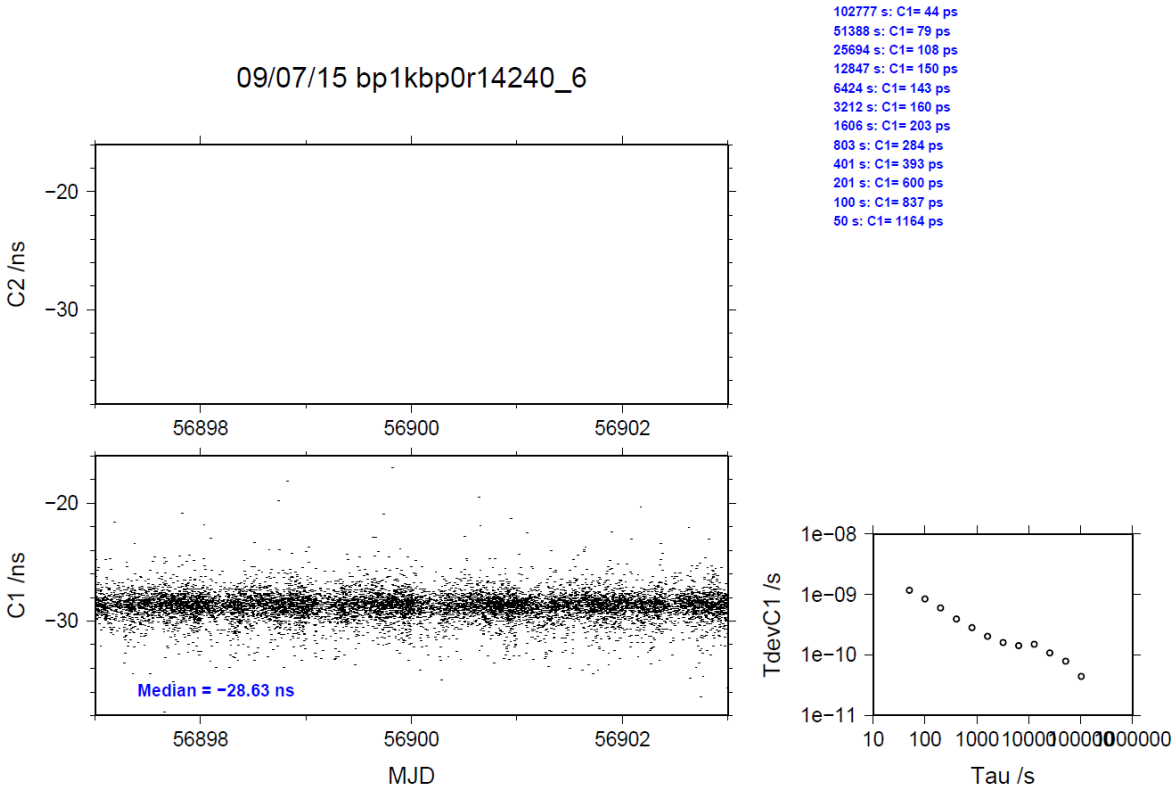
Final baseline L1 (X,Y,Z)/m = -1.458 -0.250 1.288
Final baseline L2 (X,Y,Z)/m = -1.447 -0.245 1.315

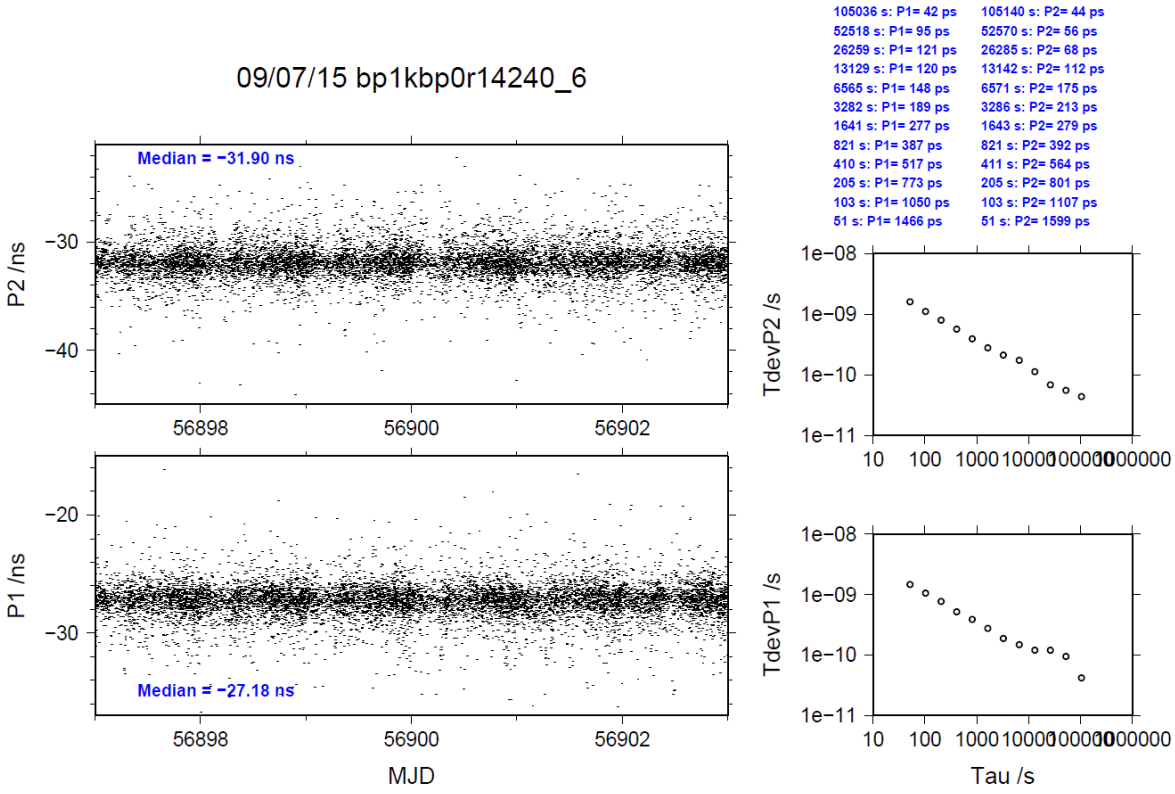
COMPUTATION OF CODE DIFFERENCES

Number of code differences = 103834

Global average of individual differences
Code #pts, ave/ns, rms/ns
C1: 103694 -28.725 2.453
C2: 0-NaN -NaN
P1: 101442 -27.267 3.182
P2: 101370 -31.849 3.271

Number of 300s epochs in out file = 1726
Code #pts, median/ns, ave/ns, rms/ns
C1: 10325 -28.628 -28.695 1.182
C2: 0 0.000-NaN -NaN
P1: 10103 -27.181 -27.260 1.496
P2: 10093 -31.897 -31.847 1.592


09/07/15 bp1kbp0r14240_6
102777 s: C1= 44 ps
51388 s: C1= 79 ps
25694 s: C1= 108 ps
12847 s: C1= 150 ps
6424 s: C1= 143 ps
3212 s: C1= 160 ps
1606 s: C1= 203 ps
803 s: C1= 284 ps
401 s: C1= 393 ps
201 s: C1= 600 ps
100 s: C1= 837 ps
50 s: C1= 1164 ps
C2 /ns
C1 /ns
Median = −28.63 ns
MJD
TdevC1 /s
Tau /s


09/07/15 bp1kbp0r14240_6
105036 s: P1= 42 ps
52518 s: P1= 95 ps
26259 s: P1= 121 ps
13129 s: P1= 120 ps
6565 s: P1= 148 ps
3282 s: P1= 189 ps
1641 s: P1= 277 ps
821 s: P1= 387 ps
410 s: P1= 517 ps
205 s: P1= 773 ps
103 s: P1= 1050 ps
51 s: P1= 1466 ps
105140 s: P2= 44 ps
52570 s: P2= 56 ps
26285 s: P2= 68 ps
13142 s: P2= 112 ps
6571 s: P2= 175 ps
3286 s: P2= 213 ps
1643 s: P2= 279 ps
821 s: P2= 392 ps
411 s: P2= 564 ps
205 s: P2= 801 ps
103 s: P2= 1107 ps
51 s: P2= 1599 ps
Median = −31.90 ns
Median = −27.18 ns
P2 /ns
P1 /ns
MJD
TdevP2 /s
TdevP1 /s
Tau /s

3.2/ SU (15161)

Period

MJD 57183 to 57188

Delays

BP1K:

REFDLY = 201.70 ns
CABDLY = X_C = 142.01 ns

SU19:

REFDLY = 194.45 ns
CABDLY = 48.17 ns

Setup at the SU

BIPM calibration information sheet

Laboratory:	SU
Date and hour of the beginning of measurements:	09 June 2015 (57182 MJD 06 h UTC)
Date and hour of the end of measurements:	15 June 2015 (57188 MJD 04 h UTC)

Receiver setup information

	Local: SU119	**Portable: BP1K**
• Maker:	PikTime Systems	PikTime Systems
• Type:	TTS-4	TTS-4
• Serial number:	119	136
• Receiver internal delay (GPS) :	-21.80 ns	-34.60
• Receiver internal delay (GLO) :	-24.00 ns	-242.17
• Antenna cable identification:	TTS4-119	TTS4-136
Corresponding cable delay :	48.17 ns	142.01 ns
• Delay to local UTC :	194.45 ns	201.70 ns
• Receiver trigger level:	0.5 V	0.5 V
• Coordinates reference frame:	ITRF	ITRF
Latitude or X m	+2845458.99m	+2845460.20 m
Longitude or Y m	+2160956.66m	+2160955.20 m
Height or Z m	+5265991.67m	+5265991.47 m

Antenna information

	Local:	**Portable:**
• Maker:	Leica Geosystem AG	Javad
• Type:	AR25	Ring Ant G3T
• Serial number:	09330030	00526
If the antenna is temperature stabilised		
• Set temperature value :		

Local antenna cable information

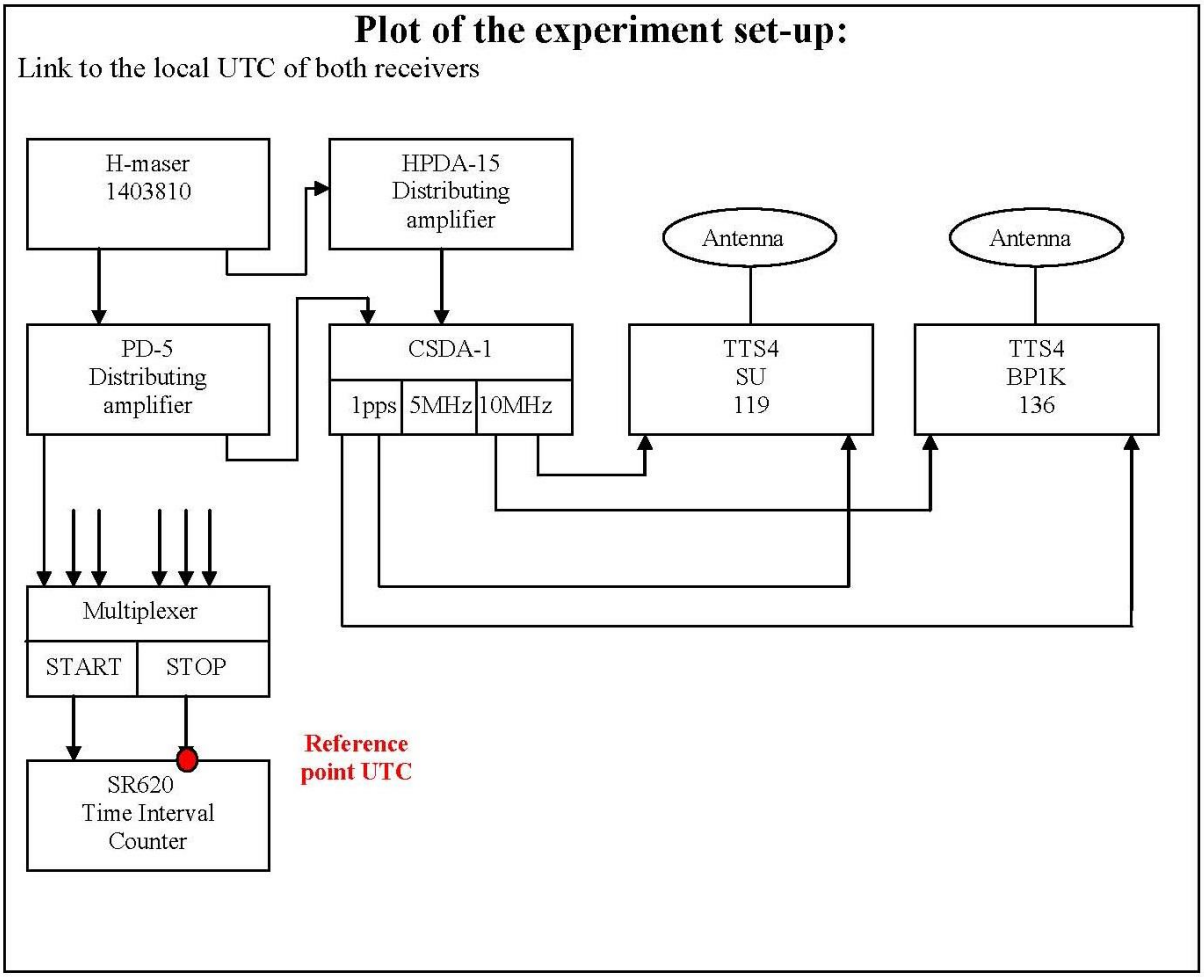
• Maker:	AOS
• Type:	FSJ 1-50A
• Is it a phase stabilised cable:	Yes
• Length of cable outside the building :	5 m

General information

• Rise time of the local UTC pulse:	3.1 ns
• **Is the laboratory air conditioned:**	Yes
• Set temperature value and uncertainty :	19.7 °C ± 0.5 °C
• Set humidity value and uncertainty :	61% ± 8%

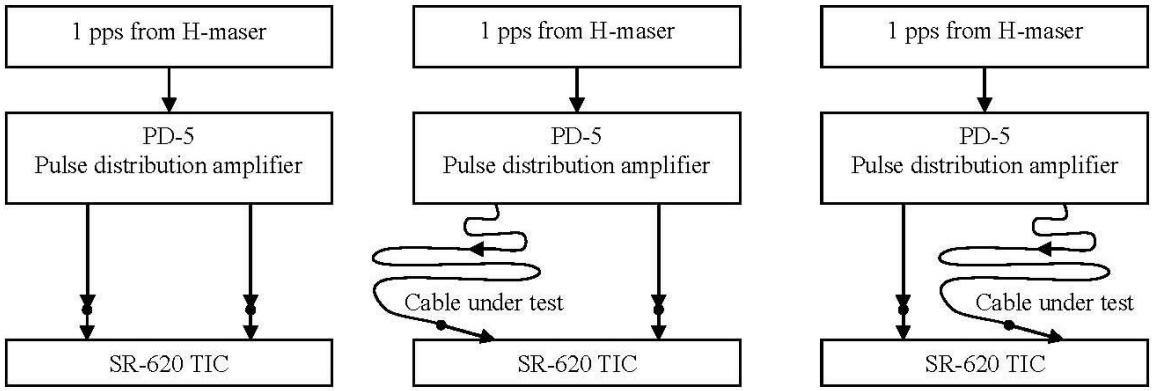
Cable delay control

Cable identification	Delay measured by BIPM	Delay measured by local method
TTS4-136	142.01 ns	141.58±0.02 ns GPS L1C VNA 141.55±0.02 ns GLO L1C VNA


Plot of the experiment set-up:
Link to the local UTC of both receivers
H-maser
1403810
HPDA-15
Distributing
amplifier
Antenna
Antenna
PD-5
Distributing
amplifier
CSDA-1
1pps
5MHz
10MHz
TTS4
SU
119
TTS4
BP1K
136
Multiplexer
START
STOP
Reference
point UTC
SR620
Time Interval
Counter

Description of the local method of cable delay measurement:

1. 1 PPS signal method (1 PPS)

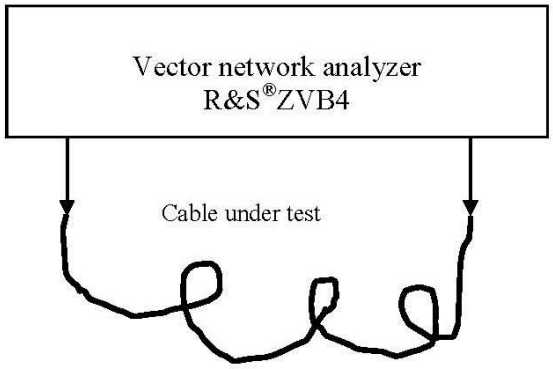


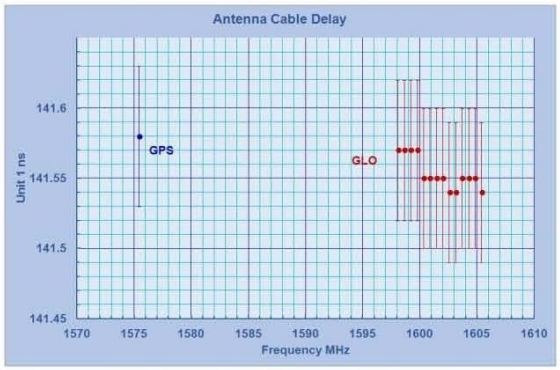
The method used to calibrate the cables is a double weight method in five steps as shown above.
At each step (i) the TIC gives the result (R_i) of 100 measurements.
The test cable delay is then obtained by the following formula:

$$\text{Delay} = \frac{R_2 - \left(\frac{R_1 + R_3}{2}\right) + \left(\frac{R_3 + R_5}{2}\right) - R_4}{2} + \text{corrections}$$

The corrections are estimated delay introduced by adaptors: -0,1 ns / adaptor

2. Vector network analyzer method (VNA)





BP1K-SU19

COMPUTATION OF BASELINE

Number of codes to fit baseline and biases = 128751
Computed code bias (P1/P2)/m = 23.127 21.877
Computed baseline (X,Y,Z)/m = -1.092 1.559 0.178
RMS of residuals /m = 0.690

Number of phase differences to fit baseline = 121772
A priori baseline (X,Y,Z)/m = -1.092 1.559 0.178
14485 clock jitters computed out of 14485 intervals
AVE jitter /ps = 0.0 RMS jitter /ps = 5.3

Iter 1 Large residuals L1= 3
Iter 1 Large residuals L2= 3
Computed baseline L1 (X,Y,Z)/m = -0.099 -0.105 -0.026
RMS of residuals L1 /m = 0.005
Computed baseline L2 (X,Y,Z)/m = -0.096 -0.103 -0.028
RMS of residuals L2 /m = 0.006

Iter 2 Large residuals L1= 3
Iter 2 Large residuals L2= 3
Computed baseline L1 (X,Y,Z)/m = -0.099 -0.105 -0.026
RMS of residuals L1 /m = 0.005
Computed baseline L2 (X,Y,Z)/m = -0.096 -0.103 -0.028
RMS of residuals L2 /m = 0.006

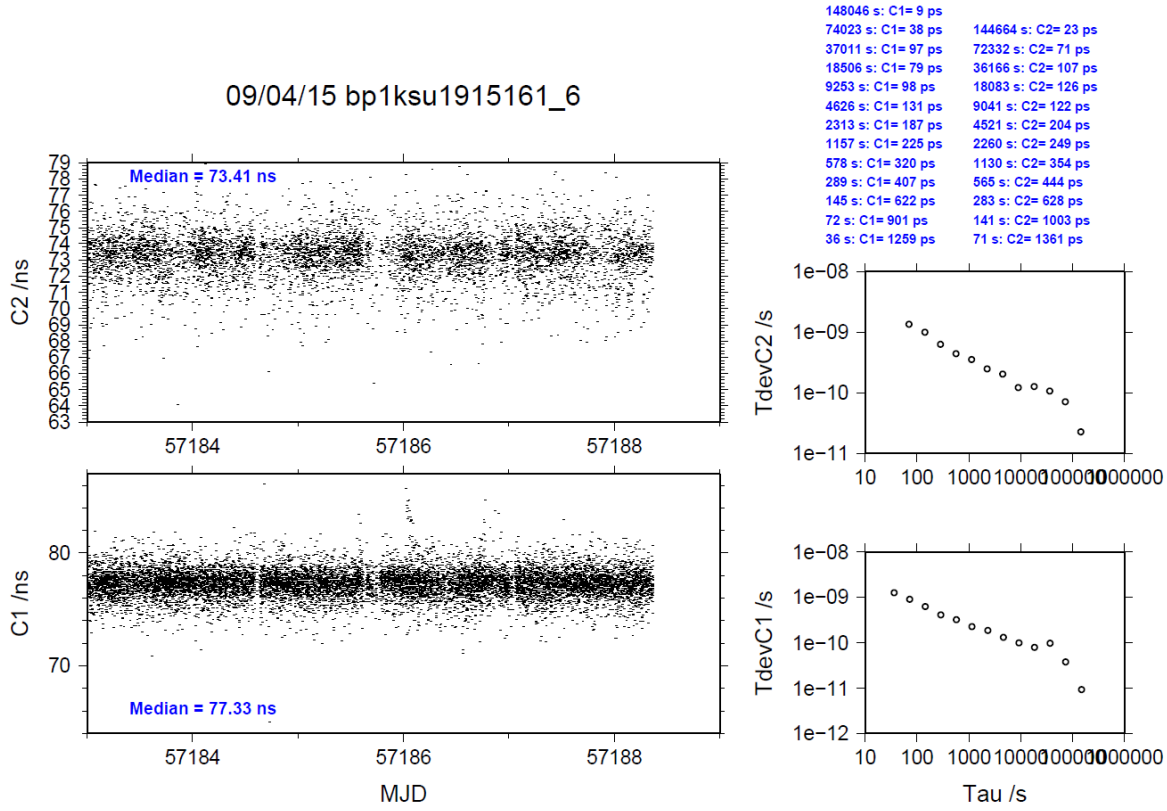
Final baseline L1 (X,Y,Z)/m = -1.191 1.454 0.152
Final baseline L2 (X,Y,Z)/m = -1.188 1.456 0.150

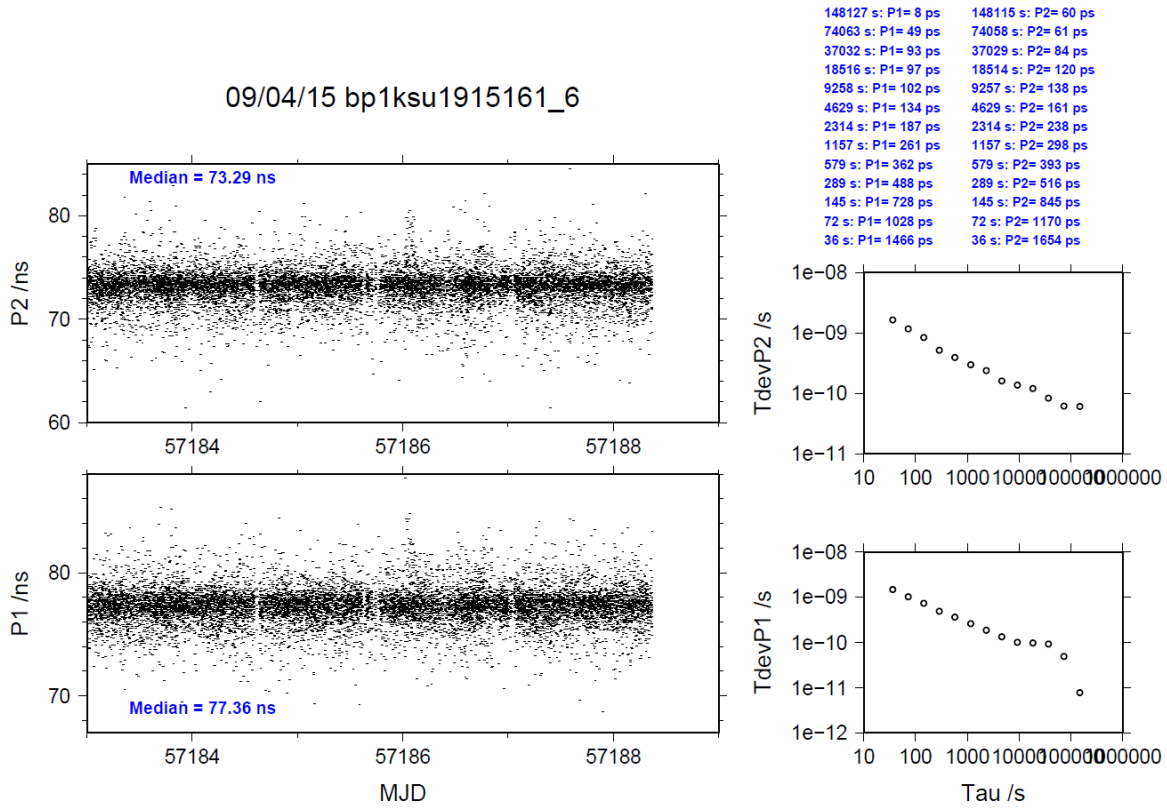
COMPUTATION OF CODE DIFFERENCES

Number of code differences = 129370

Global average of individual differences
Code #pts, ave/ns, rms/ns
C1: 128760 77.295 2.714
C2: 65755 73.304 2.875
P1: 128655 77.308 3.238
P2: 128609 73.138 3.457

Number of 300s epochs in out file = 1522
Code #pts, median/ns, ave/ns, rms/ns
C1: 12833 77.334 77.303 1.261
C2: 6567 73.413 73.318 1.364
P1: 12826 77.356 77.305 1.457
P2: 12827 73.294 73.163 1.650


09/04/15 bp1ksu1915161_6
Median = 73.41 ns
Median = 77.33 ns
C2 /ns
C1 /ns
MJD
148046 s: C1= 9 ps
74023 s: C1= 38 ps
37011 s: C1= 97 ps
18506 s: C1= 79 ps
9253 s: C1= 98 ps
4626 s: C1= 131 ps
2313 s: C1= 187 ps
1157 s: C1= 225 ps
578 s: C1= 320 ps
289 s: C1= 407 ps
145 s: C1= 622 ps
72 s: C1= 901 ps
36 s: C1= 1259 ps
144664 s: C2= 23 ps
72332 s: C2= 71 ps
36166 s: C2= 107 ps
18083 s: C2= 126 ps
9041 s: C2= 122 ps
4521 s: C2= 204 ps
2260 s: C2= 249 ps
1130 s: C2= 354 ps
565 s: C2= 444 ps
283 s: C2= 628 ps
141 s: C2= 1003 ps
71 s: C2= 1361 ps
TdevC2 /s
TdevC1 /s
Tau /s


09/04/15 bp1ksu1915161_6
Median = 73.29 ns
Median = 77.36 ns
P2 /ns
P1 /ns
MJD
148127 s: P1= 8 ps
74063 s: P1= 49 ps
37032 s: P1= 93 ps
18516 s: P1= 97 ps
9258 s: P1= 102 ps
4629 s: P1= 134 ps
2314 s: P1= 187 ps
1157 s: P1= 261 ps
579 s: P1= 362 ps
289 s: P1= 488 ps
145 s: P1= 728 ps
72 s: P1= 1028 ps
36 s: P1= 1466 ps
148115 s: P2= 60 ps
74058 s: P2= 61 ps
37029 s: P2= 84 ps
18514 s: P2= 120 ps
9257 s: P2= 138 ps
4629 s: P2= 161 ps
2314 s: P2= 238 ps
1157 s: P2= 298 ps
579 s: P2= 393 ps
289 s: P2= 516 ps
145 s: P2= 845 ps
72 s: P2= 1170 ps
36 s: P2= 1654 ps
TdevP2 /s
TdevP1 /s
Tau /s

3.3/ SU (15174)

Period

MJD 57196 to 57200

Delays

BP1K:

REFDLY = 201.40 ns
CABDLY = X_C = 141.57 ns

SU19:

REFDLY = 194.45 ns
CABDLY = 48.17 ns

Setup at the SU

BIPM calibration information sheet

Laboratory:	SU
Date and hour of the beginning of measurements:	23 June 2015 (57196 MJD 00 h UTC)
Date and hour of the end of measurements:	28 June 2015 (57201 MJD 00 h UTC)

Receiver setup information

	Local: SU119	**Portable: BP1K**
• Maker:	PikTime Systems	PikTime Systems
• Type:	TTS-4	TTS-4
• Serial number:	119	136
• Receiver internal delay (GPS) :	-21.80 ns	-33.80
• Receiver internal delay (GLO) :	-24.00 ns	-38.58
• Antenna cable identification:	TTS4-119	TTS4-136
Corresponding cable delay :	48.17 ns	141.57 ns
• Delay to local UTC :	194.45 ns	201.70 ns
• Receiver trigger level:	0.5 V	0.5 V
• Coordinates reference frame:	ITRF	ITRF
Latitude or X m	+2845458.99m	+2845460.20 m
Longitude or Y m	+2160956.66m	+2160955.21 m
Height or Z m	+5265991.67m	+5265991.47 m

Antenna information

	Local:	**Portable:**
• Maker:	Leica Geosystem AG	Javad
• Type:	AR25	Ring Ant G3T
• Serial number:	09330030	00526
If the antenna is temperature stabilised		
• Set temperature value :		

Local antenna cable information

• Maker:	AOS
• Type:	FSJ 1-50A
• Is it a phase stabilised cable:	Yes
• Length of cable outside the building :	5 m

General information

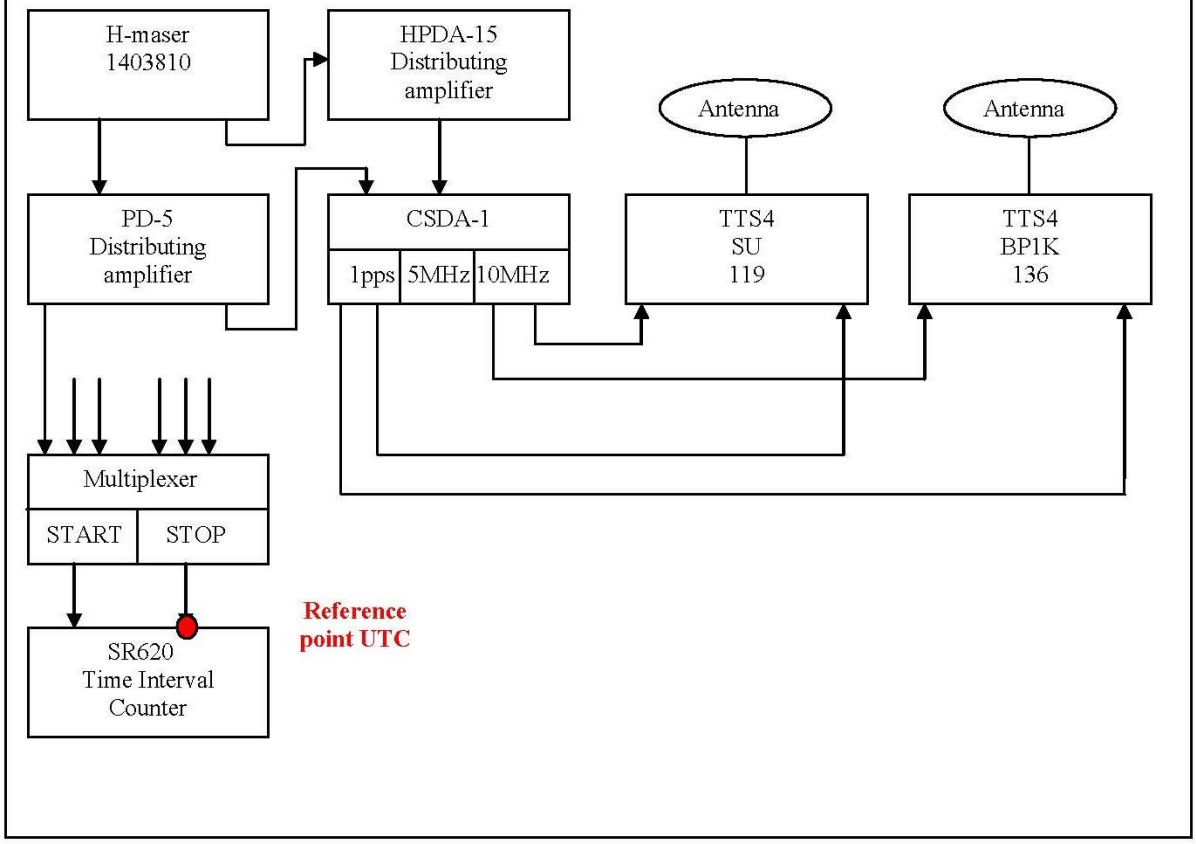
• Rise time of the local UTC pulse:	3.1 ns
• **Is the laboratory air conditioned:**	Yes
• Set temperature value and uncertainty :	19.7 °C ± 0.5 °C
• Set humidity value and uncertainty :	61% ± 8%

Cable delay control

Cable identification	Delay measured by BIPM	Delay measured by local method
TTS4-136	142.01 ns	141.58±0.02 ns GPS L1C VNA 141.55±0.02 ns GLO L1C VNA

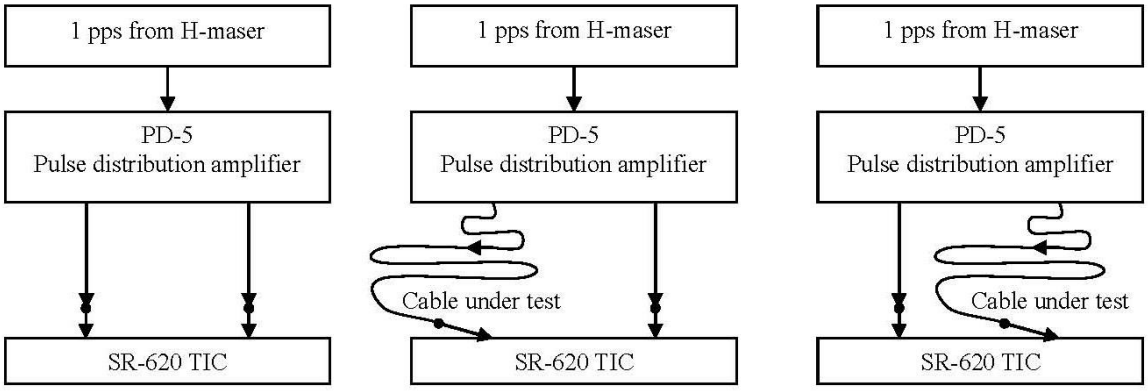
Plot of the experiment set-up:

Link to the local UTC of both receivers



Description of the local method of cable delay measurement:

1. 1 PPS signal method (1 PPS)

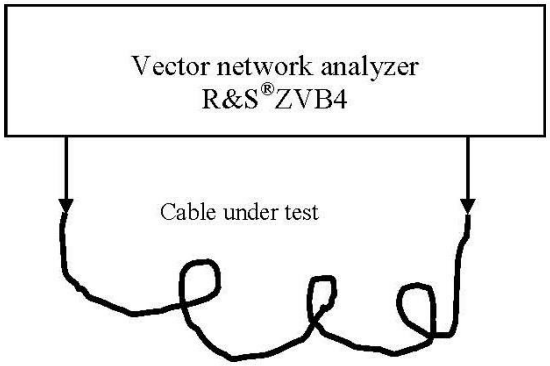


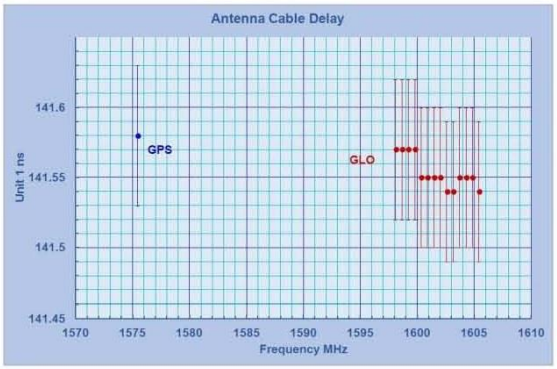
The method used to calibrate the cables is a double weight method in five steps as shown above.
At each step (i) the TIC gives the result (R_i) of 100 measurements.
The test cable delay is then obtained by the following formula:

$$\text{Delay} = \frac{R_2 - \left(\frac{R_1 + R_3}{2}\right) + \left(\frac{R_3 + R_5}{2}\right) - R_4}{2} + \text{corrections}$$

The corrections are estimated delay introduced by adaptors: -0,1 ns / adaptor

2. Vector network analyzer method (VNA)





BP1K-SU19

COMPUTATION OF BASELINE

Number of codes to fit baseline and biases = 101646
Computed code bias (P1/P2)/m = 23.047 21.807
Computed baseline (X,Y,Z)/m = -1.073 1.565 0.230
RMS of residuals /m = 0.695

Number of phase differences to fit baseline = 97325
A priori baseline (X,Y,Z)/m = -1.073 1.565 0.230
12828 clock jitters computed out of 12828 intervals
AVE jitter /ps = 0.0 RMS jitter /ps = 5.7

Iter 1 Large residuals L1= 2
Iter 1 Large residuals L2= 2
Computed baseline L1 (X,Y,Z)/m = -0.141 -0.107 -0.079
RMS of residuals L1 /m = 0.005
Computed baseline L2 (X,Y,Z)/m = -0.132 -0.106 -0.079
RMS of residuals L2 /m = 0.006

Iter 2 Large residuals L1= 2
Iter 2 Large residuals L2= 2
Computed baseline L1 (X,Y,Z)/m = -0.141 -0.107 -0.079
RMS of residuals L1 /m = 0.005
Computed baseline L2 (X,Y,Z)/m = -0.132 -0.106 -0.079
RMS of residuals L2 /m = 0.006

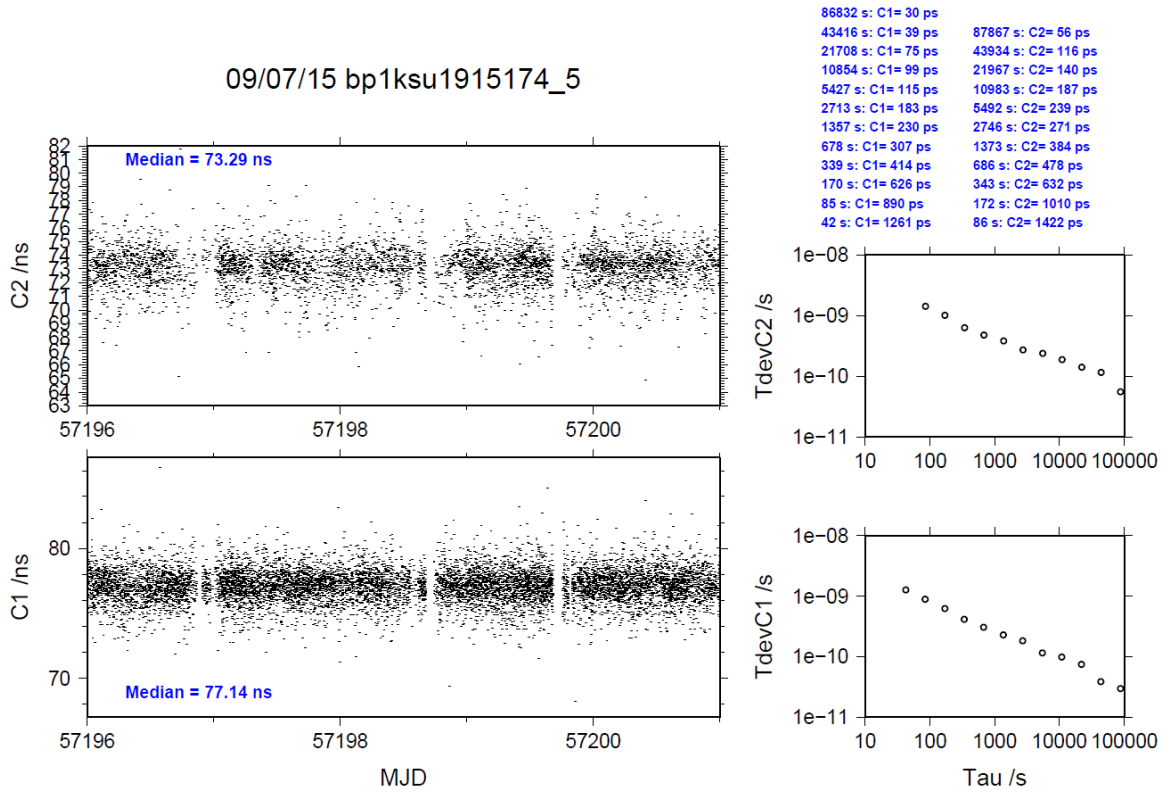
Final baseline L1 (X,Y,Z)/m = -1.214 1.458 0.151
Final baseline L2 (X,Y,Z)/m = -1.205 1.460 0.150

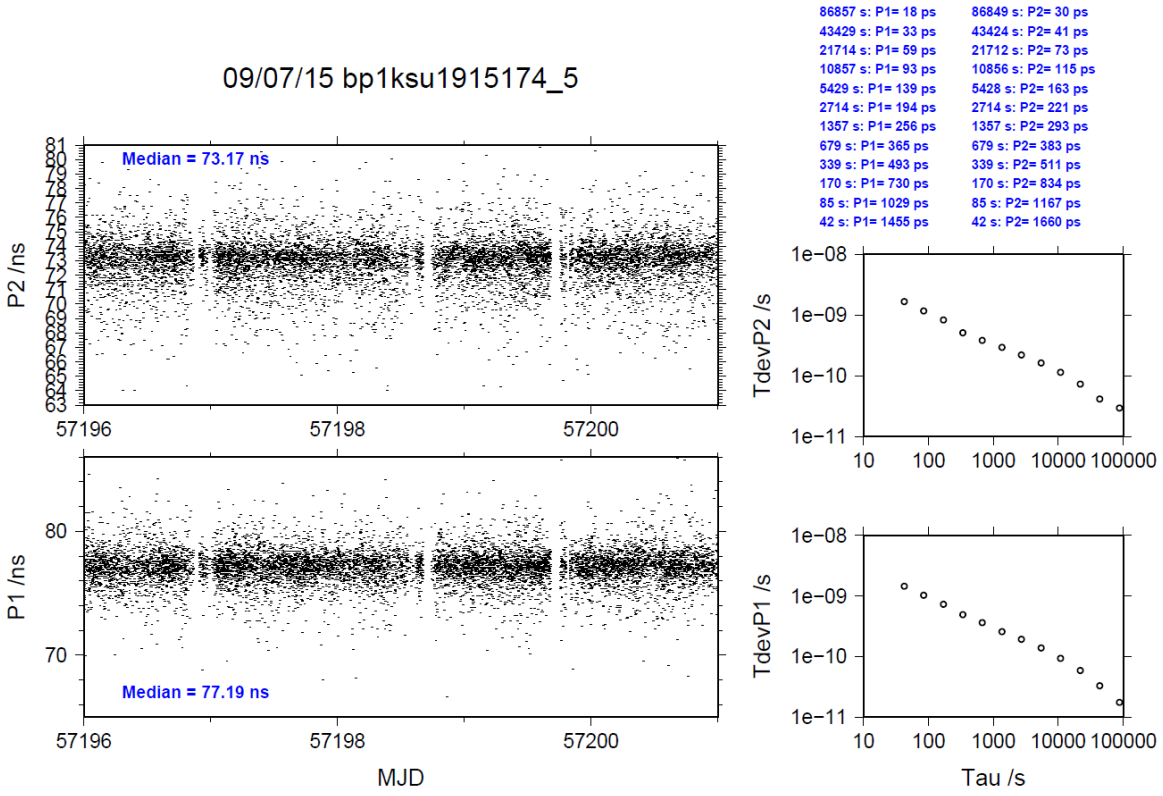
COMPUTATION OF CODE DIFFERENCES

Number of code differences = 101713

Global average of individual differences
Code #pts, ave/ns, rms/ns
C1: 101630 77.131 2.729
C2: 50184 73.198 2.935
P1: 101563 77.142 3.284
P2: 101522 73.000 3.522

Number of 300s epochs in out file = 1371
Code #pts, median/ns, ave/ns, rms/ns
C1: 10183 77.145 77.124 1.257
C2: 5032 73.292 73.195 1.416
P1: 10180 77.195 77.141 1.453
P2: 10181 73.170 73.014 1.639


09/07/15 bp1ksu1915174_5
Median = 73.29 ns
C2 /ns
Median = 77.14 ns
C1 /ns
MJD
86832 s: C1= 30 ps
43416 s: C1= 39 ps
21708 s: C1= 75 ps
10854 s: C1= 99 ps
5427 s: C1= 115 ps
2713 s: C1= 183 ps
1357 s: C1= 230 ps
678 s: C1= 307 ps
339 s: C1= 414 ps
170 s: C1= 626 ps
85 s: C1= 890 ps
42 s: C1= 1261 ps
87867 s: C2= 56 ps
43934 s: C2= 116 ps
21967 s: C2= 140 ps
10983 s: C2= 187 ps
5492 s: C2= 239 ps
2746 s: C2= 271 ps
1373 s: C2= 384 ps
686 s: C2= 478 ps
343 s: C2= 632 ps
172 s: C2= 1010 ps
86 s: C2= 1422 ps
TdevC2 /s
TdevC1 /s
Tau /s


09/07/15 bp1ksu1915174_5
Median = 73.17 ns
P2 /ns
Median = 77.19 ns
P1 /ns
MJD
86857 s: P1= 18 ps
43429 s: P1= 33 ps
21714 s: P1= 59 ps
10857 s: P1= 93 ps
5429 s: P1= 139 ps
2714 s: P1= 194 ps
1357 s: P1= 256 ps
679 s: P1= 365 ps
339 s: P1= 493 ps
170 s: P1= 730 ps
85 s: P1= 1029 ps
42 s: P1= 1455 ps
86849 s: P2= 30 ps
43424 s: P2= 41 ps
21712 s: P2= 73 ps
10856 s: P2= 115 ps
5428 s: P2= 163 ps
2714 s: P2= 221 ps
1357 s: P2= 293 ps
679 s: P2= 383 ps
339 s: P2= 511 ps
170 s: P2= 834 ps
85 s: P2= 1167 ps
42 s: P2= 1660 ps
TdevP2 /s
TdevP1 /s
Tau /s

3.4/ BIPM (15310)

Period

MJD 57332 to 57337

Delays

All measurements at BIPM carried out by L. Tisserand.
Equipment used to measure internal delay of local receiver is a time interval counter (TIC), model SR620, maker Stanford Research Systems, s/n: 4680, with measurement uncertainty typically less than 0.5 ns (using external reference frequency as timebase).

BP0R:

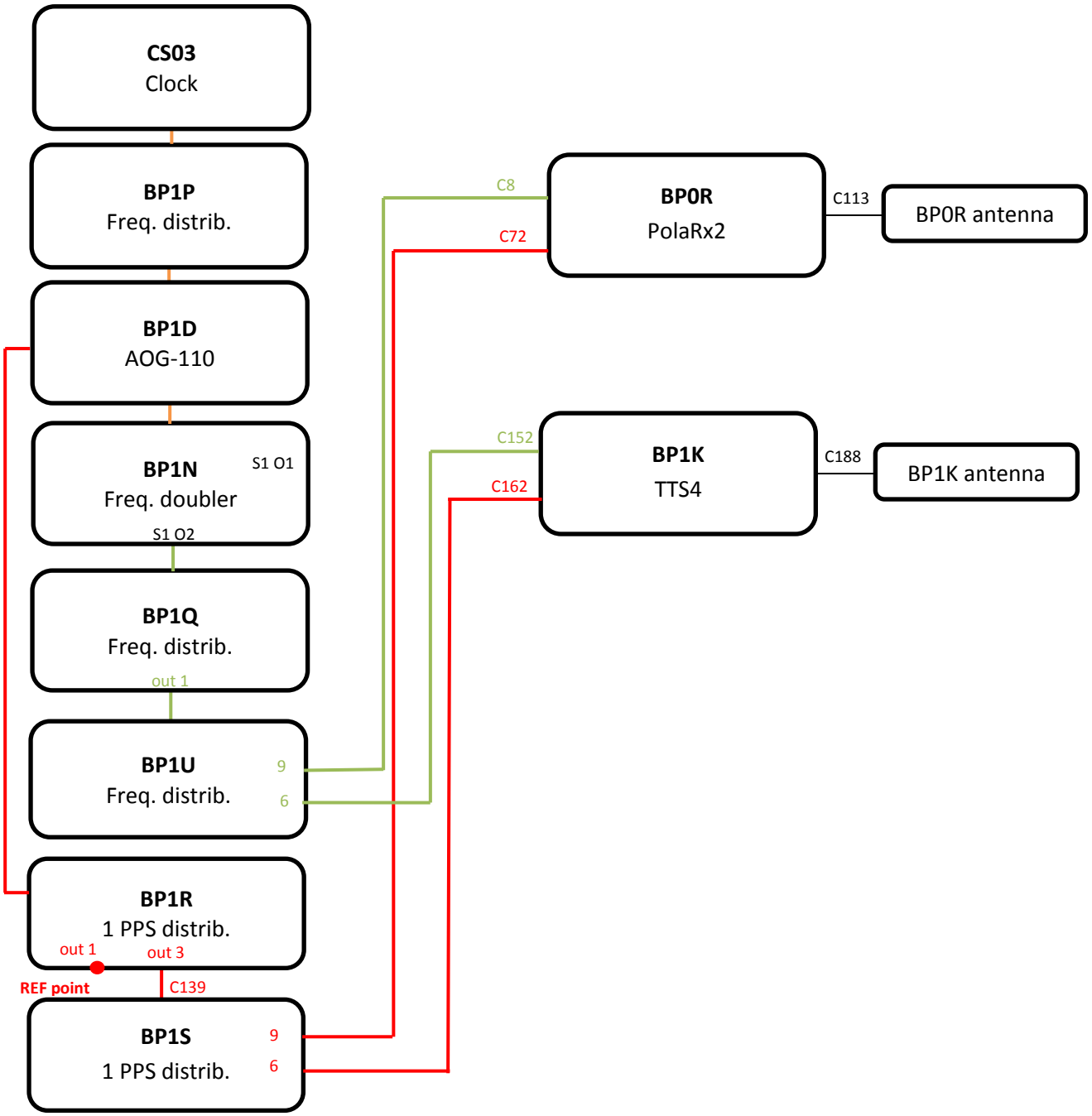
X_O = 246.1 ns (286.1-48.7+8.7)
X_P = 42.7 ns (BP1R+C139+BP1S+C72)
REFDLY = 288.8 ns
CABDLY = X_C = 133.4 ns (C113)

BP1K:

10 MHz factory calibration = 4.45 ns
User frequency to 1 PPS offset (or 1PPS-freq offs)
1PPS-freq offs = 28.73 ns
1PPS-freq corr = 3.73 ns
Total delay = 51.43 ns

X_O = 3.73 ns
X_P = 47.7 ns (BP1R+C139+BP1S+C162)
REFDLY = 51.43 ns
CABDLY = X_C = 142.01 ns (C188)

Setup at the BIPM



BP1K-BP0R

COMPUTATION OF BASELINE

Number of codes to fit baseline and biases = 113387
Computed code bias (P1/P2)/m = -4.476 -5.940
Computed baseline (X,Y,Z)/m = -1.356 -0.313 1.352
RMS of residuals /m = 0.725

Number of phase differences to fit baseline = 110043
A priori baseline (X,Y,Z)/m = -1.356 -0.313 1.352
17120 clock jitters computed out of 17120 intervals
AVE jitter /ps = 0.5 RMS jitter /ps = 6.0

Iter 1 Large residuals L1= 0
Iter 1 Large residuals L2= 1
Computed baseline L1 (X,Y,Z)/m = -0.088 0.030 -0.050
RMS of residuals L1 /m = 0.005
Computed baseline L2 (X,Y,Z)/m = -0.082 0.046 -0.048
RMS of residuals L2 /m = 0.006

Iter 2 Large residuals L1= 0
Iter 2 Large residuals L2= 1
Computed baseline L1 (X,Y,Z)/m = -0.088 0.030 -0.050
RMS of residuals L1 /m = 0.005
Computed baseline L2 (X,Y,Z)/m = -0.082 0.046 -0.048
RMS of residuals L2 /m = 0.006

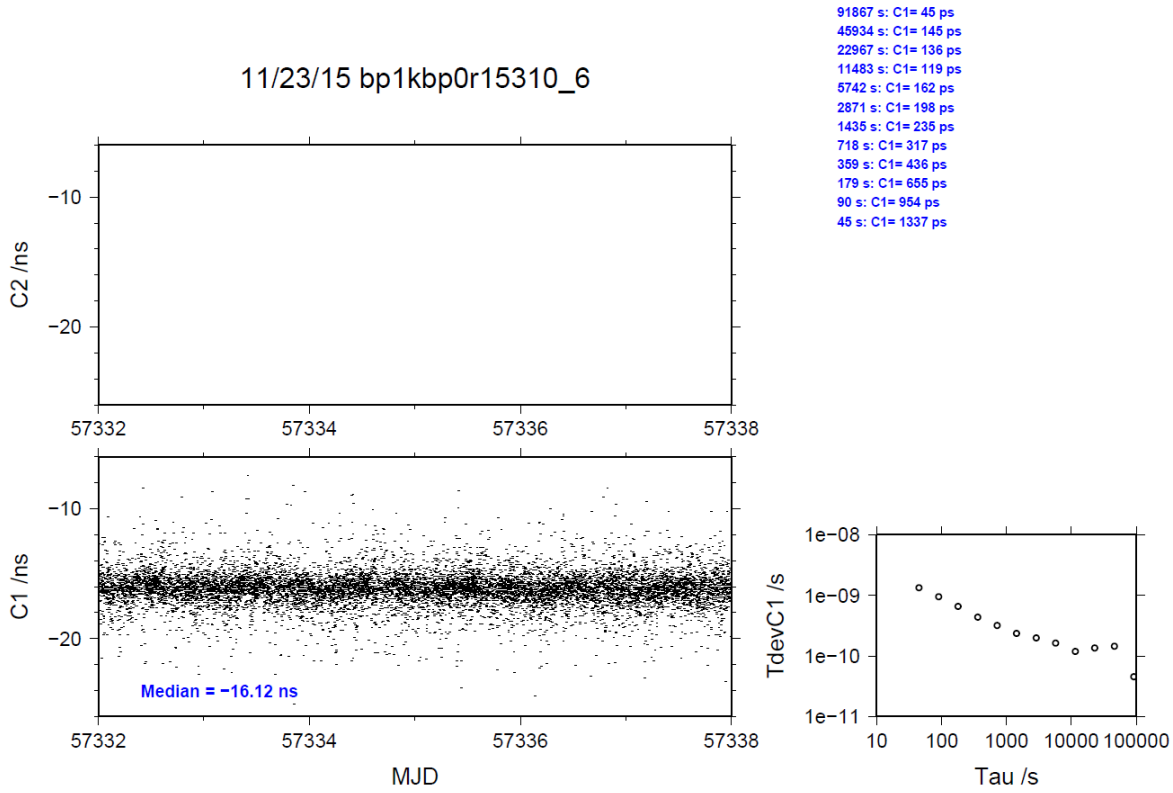
Final baseline L1 (X,Y,Z)/m = -1.444 -0.283 1.302
Final baseline L2 (X,Y,Z)/m = -1.438 -0.267 1.305

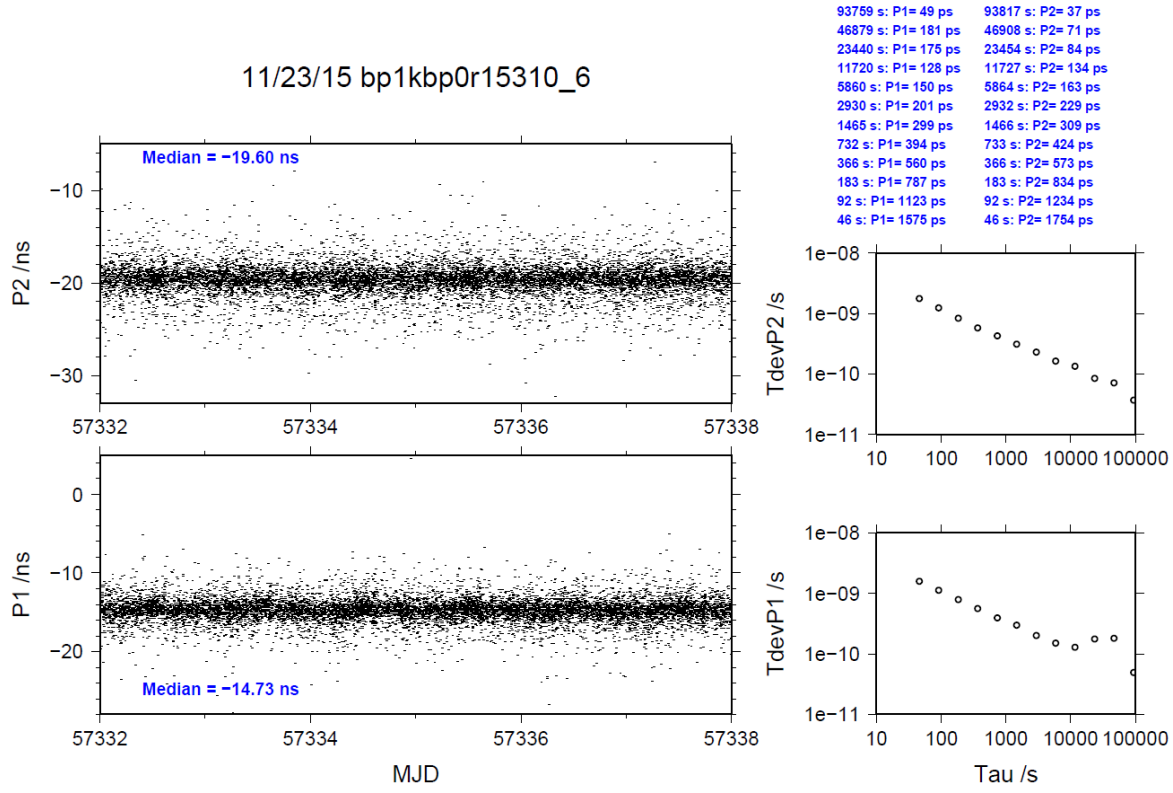
COMPUTATION OF CODE DIFFERENCES

Number of code differences = 116126

Global average of individual differences
Code #pts, ave/ns, rms/ns
C1: 115858 -16.195 2.884
C2: 0-NaN -NaN
P1: 113241 -14.742 3.539
P2: 113124 -19.657 3.608

Number of 300s epochs in out file = 1728
Code #pts, median/ns, ave/ns, rms/ns
C1: 11551 -16.125 -16.142 1.341
C2: 0 0.000-NaN -NaN
P1: 11318 -14.727 -14.751 1.596
P2: 11311 -19.601 -19.658 1.730


11/23/15 bp1kbp0r15310_6
91867 s: C1= 45 ps
45934 s: C1= 145 ps
22967 s: C1= 136 ps
11483 s: C1= 119 ps
5742 s: C1= 162 ps
2871 s: C1= 198 ps
1435 s: C1= 235 ps
718 s: C1= 317 ps
359 s: C1= 436 ps
179 s: C1= 655 ps
90 s: C1= 954 ps
45 s: C1= 1337 ps
C2 /ns
C1 /ns
Median = −16.12 ns
MJD
TdevC1 /s
Tau /s


11/23/15 bp1kbp0r15310_6
93759 s: P1= 49 ps
46879 s: P1= 181 ps
23440 s: P1= 175 ps
11720 s: P1= 128 ps
5860 s: P1= 150 ps
2930 s: P1= 201 ps
1465 s: P1= 299 ps
732 s: P1= 394 ps
366 s: P1= 560 ps
183 s: P1= 787 ps
92 s: P1= 1123 ps
46 s: P1= 1575 ps
93817 s: P2= 37 ps
46908 s: P2= 71 ps
23454 s: P2= 84 ps
11727 s: P2= 134 ps
5864 s: P2= 163 ps
2932 s: P2= 229 ps
1466 s: P2= 309 ps
733 s: P2= 424 ps
366 s: P2= 573 ps
183 s: P2= 834 ps
92 s: P2= 1234 ps
46 s: P2= 1754 ps
Median = −19.60 ns
P2 /ns
P1 /ns
Median = −14.73 ns
MJD
TdevP2 /s
TdevP1 /s
Tau /s