GNSS CALIBRATION REPORT

KZ03 TRANSFER

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REFERENCES

REFERENCES	
RD01	**BIPM report 2021 1001-2020_GPSP3C1-GALE3_Group1-trip_V1-2**
RD02	**BIPM guidelines for GNSS calibration, V4.0, 05/08/2021**
RD03	**J. Kouba, P. Heroux, 2002, *"Precise Point Positioning Using IGS Orbit and Clock Products,"* GPS Solutions, Vol 5, No. 2, 12-28**
RD04	**BIPM report 2021 1201-2021_GPSP3C1-KZ_V1-0**
RD05	**BIPM Procedure for computing raw difference of GNSS code measurements for geodetic receivers, dclrinex software version 3.1, April 2021**

ACRONYMS

ACRONYMS	
BIPM	**Bureau International de Poids et Mesures, Sèvres, France**
CGGTTS	**CCTF Generic GNSS Time Transfer Standard**
DCLRINEX	**Differential calibration software using the pseudoranges directly read from the RINEX files, software was provided by the BIPM**
EURAMET	**The European Association of National Metrology Institutes**
GNSS	**Global Navigation Satellite System**
IGS	**International GNSS Service**
KZ	**Kazakhstan Institute of Standardization and Metrology**
PPP	**Precise Point Positioning**
PTB	**Physikalisch-Technische Bundesanstalt, Braunschweig, Germany**
RINEX	**Receiver Independent Exchange Format**
R2CGGTTS	**RINEX-to CGGTTS conversion software, provided by ORB / BIPM**
TDEV	**Time deviation**
TIC	**Time interval counter**
VNIIFTRI	**Allrussisches Forschungsinstitut für physikalisch-technische und radiotechnische Messungen**

SUMMARY

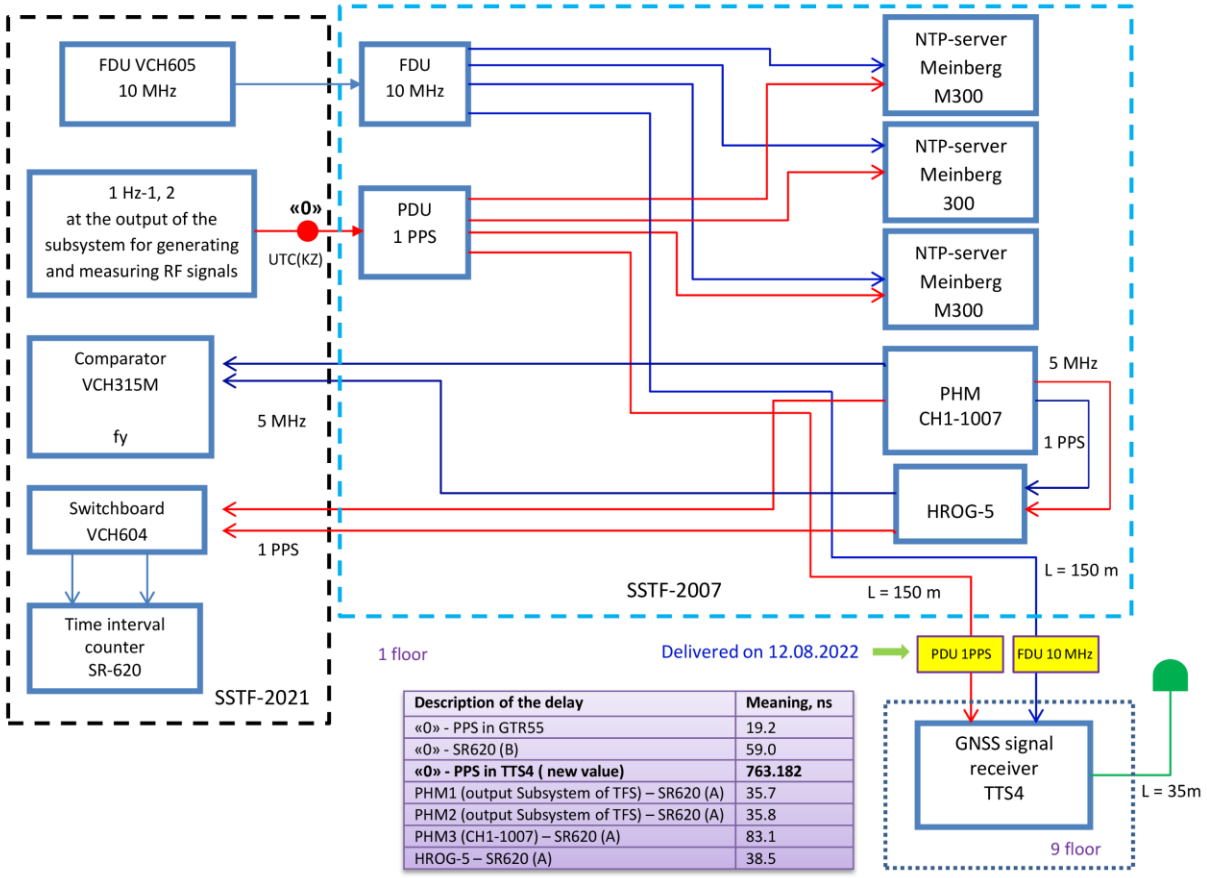
As part of the support of the BIPM Time and Frequency Group by EURAMET G1 laboratories, PTB conducted a relative calibration of the GNSS receiver KZ03 from KZ with respect to their receiver KZ04. The latter was last calibrated in 2021 by VNIIFTRI [RD04]. This report describes the transfer of internal delays from KZ04 to KZ03. Results provided are the new receiver's internal delays for GPS P-code signals on the two frequencies L1 and L2 (INT DLY (P1), and INT DLY(P2)), on GPS C/A-code signals (INT DLY (L1C)), and Galileo E1 and E5a. The delays were determined using the DCLRINEX software, which was provided by the BIPM [RD05]. The results will be reported using Cal_Id 1202-2021 addendum.

The final delay values are reported in Table 2-1, the respective uncertainties are reported in lines 9a and 9b of Table 3-1. Note, that the uncertainty of the delay values of the reference receiver KZ04 is not included in the current uncertainty estimate. After an initial exercise using data from 59792 to 59795, the configuration of the receiver KZ03 was slightly changed, and the final results are based on a comparison during days MJD 59818 – 59821.

As a reminder: All uncertainty values reported in this document are 1-σ values. In the Annex the BIPM information table is added.

1. RECEIVER SET-UP AT KZ

The set-up of the receiver KZ03 in KZ is depicted in Figure 1-1 for 1 PPS signals and 5 MHz signals. Figure 1-2 depicts the set-up of the receiver KZ04. Details regarding the receivers can be found in the calibration information sheet in the annex.



Description of the delay	Meaning, ns
«0» - PPS in GTR55	19.2
«0» - SR620 (B)	59.0
«0» - PPS in TTS4 (new value)	**763.182**
PHM1 (output Subsystem of TFS) – SR620 (A)	35.7
PHM2 (output Subsystem of TFS) – SR620 (A)	35.8
PHM3 (CH1-1007) – SR620 (A)	83.1
HROG-5 – SR620 (A)	38.5

Figure 1-1: 1 PPS and 5 MHz signal distribution to KZ GNSS receivers

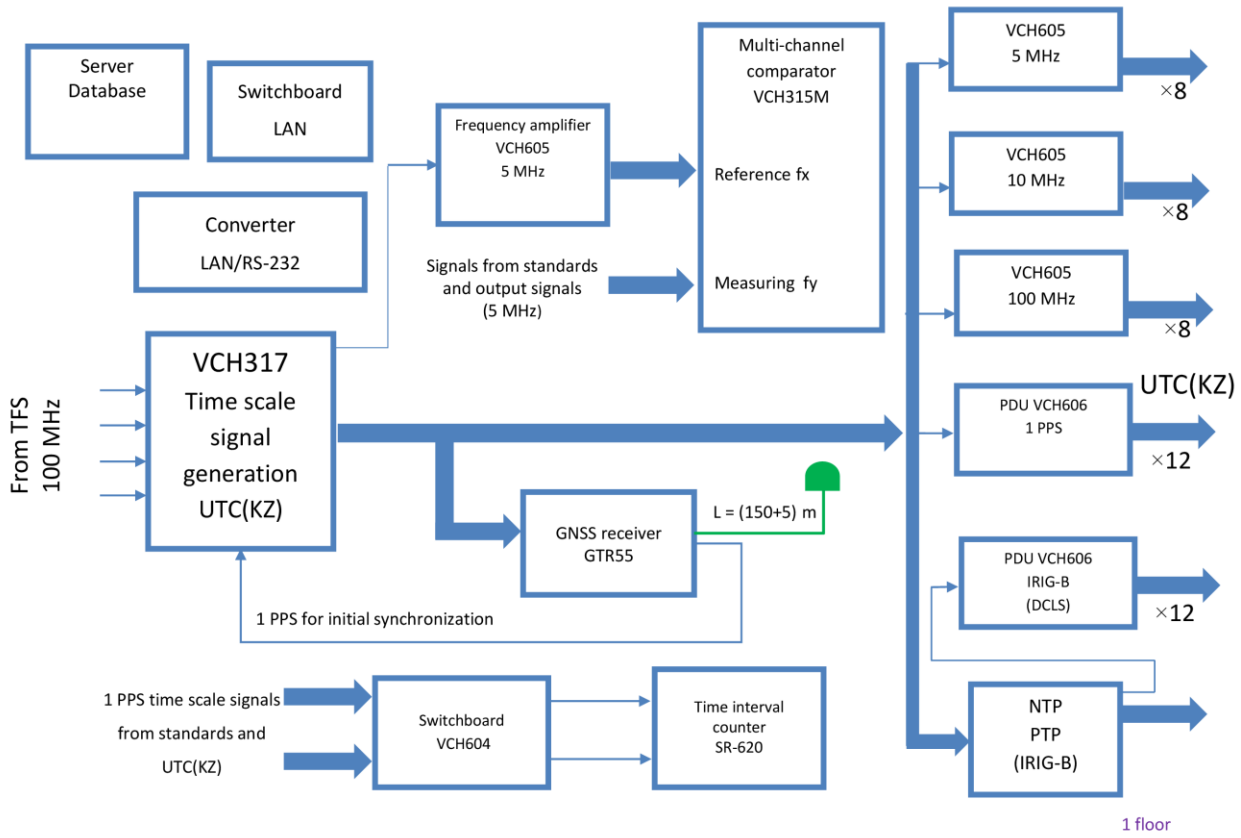


Figure 1-2: Measurement and output-signal generation scheme at KZ

2. DETERMINATION OF KZ03 INT DELAYS AUGUST 2022

The period 59818 to 59821 (4 days) was chosen to determine the KZ03 INT DLY values. KZ04 served as reference. The raw code differences (RAW DIF) between KZ03 and KZ04 were determined using the DCLRINEX software [RD05]. Figure 2-1 shows the raw code differences and TDEV analysis for GPS signals and Figure 2-2 for Galileo signals. The medians of the raw code differences are -1173.6 ns (P1), -1177.6 ns (P2), -1172.8 ns (C1), -1172.1 ns (E1) and -1177.8 ns (E5a).

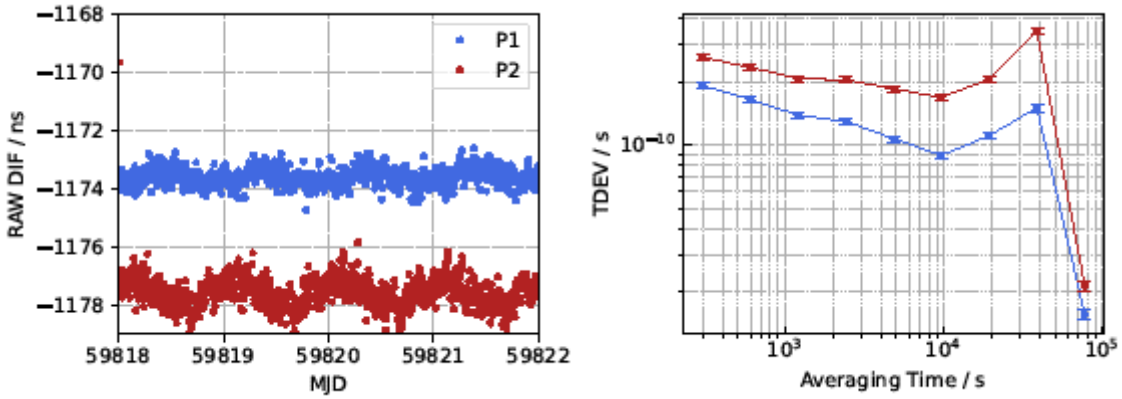


Figure 2-1 RAW DIF values obtained for KZ03 against KZ04 and TDEV analysis for GPS signals

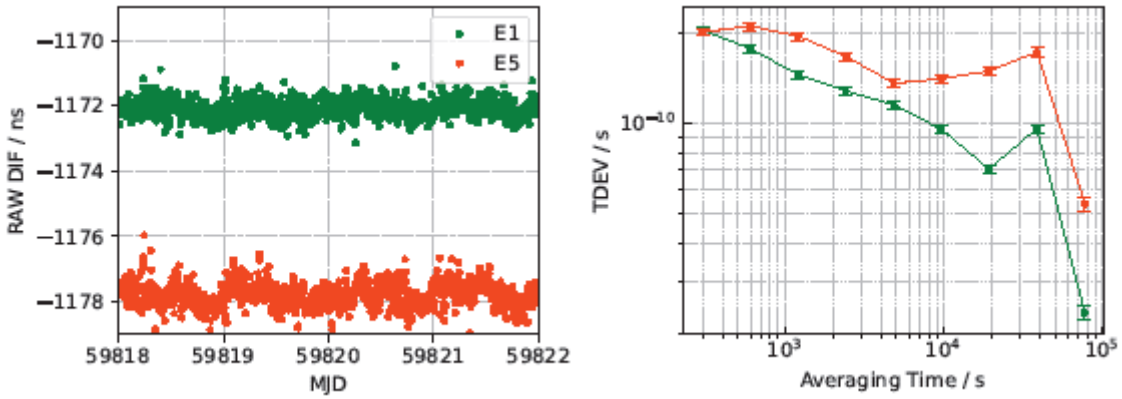


Figure 2-2 RAW DIF values obtained for KZ03 against KZ04 and TDEV analysis for Galileo signals

The INT DLY values of a new receiver can be determined from the raw code differences to a reference receiver as

$$\begin{aligned}\mathrm{INT\ DLY_{new}}(f) = {} & \mathrm{INT\ DLY_{ref}}(f) + \mathrm{RAW\ DIF_{new-ref}}(f) + \mathrm{REF\ DLY_{new}} - \mathrm{REF\ DLY_{ref}} \\ & + \mathrm{CAB\ DLY_{ref}} - \mathrm{CAB\ DLY_{new}},\end{aligned} \quad (1)$$

with the reference delay values (REF DLY) and antenna cable delay values (CAB DLY) known for both receivers. These values are listed in the calibration information sheet in the Annex.

The results are given in Table 2-1.

Table 2-1 INT DLY values in ns determined for receiver KZ03 in September 2022

Signal	Mean	Median	SigmaE	Nepoch
GPS P1	-36.0	-36.0	0.29	1152
GPS P2	-41.7	-41.7	0.54	1152
GPS L1C	-34.3	-34.3	0.33	1152
Galileo E1	-34.3	-34.4	0.29	1152
Galileo E5a	-40.1	-40.1	0.37	1152

3. INT DLY UNCERTAINTY EVALUATION

The overall uncertainty of the INT DLY values obtained as a result of the calibration is given by

$$u_{CAL} = \sqrt{u_a^2 + u_b^2}\,, \tag{6}$$

with the statistical uncertainty u_a and the systematic uncertainty u_b. The statistical uncertainty is derived from the TDEV at 50000 s. The systematic uncertainty is given by

$$u_b = \sqrt{\sum_n u_{b,n}}\,. \tag{7}$$

Values in column f3 are calculated according to u(f3) = $\sqrt{\{u(f1)^2 + (1.54 \times u(f1\text{-}f2))^2\}}$ for GPS and for the Galileo delays according to $\sqrt{\{u(f1)^2 + (1.26 \times u(f1\text{-}f2))^2\}}$.

Table 3-1: Uncertainty contributions for the GPS calibration of receiver delays

	Uncertainty	Value f1 (ns)	Value f2 (ns)	Value f1-f2 (ns)	Value f3 (ns)	Description
1a	u_a (KZ, GPS)	0.25	0.25	0.35	0.60	CC measurement uncertainty at KZ for GPS, TDEV max
1b	u_a (KZ, Galileo)	0.14	0.14	0.20	0.29	CC measurement uncertainty at KZ for Galileo, TDEV max
2	$u_{b,11}$	0.2	0.2	0.28		Multipath at KZ
3	$u_{b,12}$	0.5	0.5	0		Uncertainty estimate for the KZ03 CAB DLY
4	$u_{b,13}$	0.5	0.5	0		Uncertainty estimate for the KZ04 CAB DLY
5	$u_{b,21}$	0.5	0.5	0		Connection of KZ03 to UTC(KZ) (REF DLY)
6	$u_{b,22}$	0.5	0.5	0		Connection of KZ04 to UTC(KZ) (REF DLY)
7	$u_{b,23}$	0.1	0.1	0		TIC nonlinearities at KZ
8a	$u_{b,INT}$ (GPS)	1.0	1.0	0.3	1.1	
8b	$u_{b,INT}$ (Galileo)	1.0	1.0	0.3	1.1	
9a	$u_{CAL,0}$ (GPS)				1.3	
9b	$u_{CAL,0}$ (Galileo)				1.1	

ANNEX: BIPM CALIBRATION INFORMATION SHEET

Laboratory:	**KZ**
Date and hour of the beginning of measurements:	2022-08-27 0:00 UTC (MJD 59818)
Date and hour of the end of measurements:	2022-08-30 24:00 UTC (MJD 59822)

Information on the system		
	Reference:	**Local:**
4-character BIPM code	**KZ04**	**KZ03**
Receiver maker and type: Receiver serial number:	MESIT GTR55 S/N 2107240	PIKTIME TTS-4 S/N 0139
1 PPS trigger level /V:	1	1
Antenna cable maker and type: Phase stabilised cable (Y/N):	Andrew Heliax LDF4-50A Y	Andrew FSJ1-50A Y
Length outside the building /m:	4	4
Antenna maker and type: Antenna serial number:	NovAtel, NOV-850 NMLK20420025F	JAVAD, RingAnt-G3T 00636
Temperature (if stabilised) /°C	N/A	N/A

Measured delays /ns		
	Reference:	**Local:**
Delay from local UTC to receiver 1 PPS-in (X_P) / ns	19.2	674.921
dDelay from 1 PPS-in to internal Reference (if different): (X_O) / ns		
Antenna cable delay: (X_C) / ns	611.5	147.50
Splitter delay (if any):		

Data used for the generation of CGGTTS files		
	Reference:	**Local**
☐ INT DLY (or X_R+X_S) (GPS) /ns:	17.9 (P1), 16.2 (P2), 18.8 (C1) (*)	−36.27 (P1), -42.13 (P2), -34.65 (C1)
☐ INT DLY (or X_R+X_S) (GALILEO) /ns:	18.0 (E1), 18.0 (E5a) (**)	−37.64 (E1), -40.5 (E5a) (***)
☐ INT DLY (or X_R+X_S) (GLONASS) /ns:	19.0	−46.65
☐ CAB DLY (or X_C) /ns:	611.5	147.50
☐ REF DLY (or X_P+X_O) /ns:	19.2	674.921
☐ Coordinates reference frame:	ITRF	ITRF
X /m:	1277097.41	1277096.77
Y /m:	3802828.26	3802827.04
Z /m	4942471.08	4942472.20

General information

☐ Rise time of the local UTC pulse:	2.5 ns
☐ Is the laboratory air conditioned:	Yes
Set temperature value and uncertainty:	22 °C ±1 °C, 40 % ±7 %

(*) values based on [RD04]

(**) values read from EZKZ4MJ.DDD files, likely determined by the manufacturer or by UFE (CZ)

(***) initially, no Galileo signal delays for KZ03 were known. In an early phase of the cooperation, we provided the Galileo delays reported here, based on comparison KZ03-KZ04 during MJD 59792 to 59795.

All coordinate values were checked using PPP NRCan and found correct within low single-digit cm.

END of DOCUMENT