Report of Absolute Calibration of AKAL golden receiver chain

Antenna: Leica AR20
Serial number: 20146022
Receiver: PolaRx5 GTR (Septentrio)
Serial number: 4701210
Owner: ESA (AKAL)
Firmware version: 5.1.2
Cable: HUBER+SUHNER SucoFeed ½', length: 50m
Calibration Date: January/2018
Receiver calibration temperature: 23°C
Location: ESTEC, The Netherlands
Method: AKAL Absolute Calibration
Performed by: GMV (Esteban Garbin and Piotr Krystek)

The absolute calibration of the receiver chain for AKAL project was performed at ESTEC. The calibration was performed following the procedures created during the AKAL project (EGEP-103), developed by GMV with ESA support.

1.1. ANTENNA CALIBRATION VALUES

The Antenna Calibration was performed in the CATR facilities at ESA/ESTEC, considering the calibration campaign of January 2018 and a bandwidth tailored for the modulation of each signal is used.

Table 1. ***Final Group delay values for the different GNSS signals. Modulated BW averaging.***

GNSS signal	*Mean Group Delay [ns]*		*Uncertainty [ns]*	*Frequency [MHz]*
	*@ARP**	*@APC**		
'L1C'	23.42	23.68		*1575*
'L1P'	23.51	23.77		*1575*
'L2P'	19.90	20.17		*1227*
'L5Q'	23.84	24.11		*1176*
'E1C'	23.38	23.64		*1575*
'E5Q'	23.84	24.11		*1176*
'E7Q'	20.48	20.75	*0.49*	*1207*
'E8Q'	21.56	21.83		*1191*
'E6C'	21.22	21.49		*1278*
'G1C'	26.89	27.14		*1602*
'G1P'	26.89	27.15		*1602*
'G2C'	18.18	18.45		*1246*
'G2P'	18.20	18.48		*1246*

**@ARP – group delay referenced to Antenna Reference Point (defined by manufacturer)*
**@APC L1/L2 – group delay referenced to Antenna Phase Center. Signals L1/E1 and G1 were corrected with L1 APC defined by IGS service, while other signals were corrected with L2 APC.*

1.2. CABLE CALIBRATION VALUES

The cable was calibrated following AKAL procedures, by mean of transmission technique. The TNC-to-N adapter was not connected to cable, thus delay introduced by it need to be added. Cable delay is:

195.62 ns +/- 0.12 ns

1.3. RECEIVER CALIBRATION VALUES

For the receiver the Spirent GSS 9000 simulator located in room CJ105 was used, and the calibration uses at least 60 minutes of collected data from RINEX files, and it considers 14 different satellites with different PRNs for GPS and Galileo constellation, and all the frequency slots of GLONASS satellites. The calibrated satellites are located in a geostationary orbit. For the simulator calibration, a 20 MHz Bandwidth filter was used for all the signals.

Table 2 *PolaRx5 Calibration Values, averaging 14 different PRNs*

GNSS Signal	*Avg. Delay [ns]*	*Uncertainty* [ns]*	*X – L1P [ns]*
'L1C'	***10.65***	*0.497*	*0.34*
'L1P'	***10.32***	*0.225*	*0.00*
'L2P'	***9.21***	*0.324*	*-1.11*
'L5Q'	***9.63***	*0.191*	*-0.68*
'E1C'	***10.84***	*0.223*	*0.52*
'E5Q'	***9.68***	*0.228*	*-0.63*
'E7Q'	***7.17***	*0.258*	*-3.15*
'E8Q'	***8.08***	*0.203*	*-2.23*
'E6C'	***12.32***	*0.238*	*2.01*
'G1C'	***9.02***	*0.711*	*-1.30*
'G1P'	***9.30***	*0.526*	*-1.01*
'G2C'	***9.77***	*1.045*	*-0.54*
'G2P'	***9.92***	*0.352*	*-0.40*

**Uncertainty of the mean value over all frequency channels*

Table 3 GLONASS Calibration values

FN->	*-7*	*-6*	*-5*	*-4*	*-3*	*-2*	*-1*	*0*	*1*	*2*	*3*	*4*	*5*	*6*
'G1C'	*7.71*	*9.30*	*8.77*	*7.53*	*9.43*	*9.79*	*9.55*	*9.25*	*8.79*	*8.90*	*8.97*	*9.01*	*9.54*	*9.75*
'G1P'	*8.07*	*8.96*	*8.87*	*9.13*	*9.30*	*9.02*	*9.35*	*9.41*	*9.45*	*9.52*	*9.60*	*9.56*	*9.77*	*10.22*
'G2C'	*10.02*	*8.81*	*9.46*	*9.14*	*10.94*	*8.15*	*9.01*	*9.65*	*9.48*	*10.10*	*8.62*	*10.92*	*10.79*	*11.71*
'G2P'	*9.45*	*9.82*	*10.04*	*10.28*	*9.39*	*9.85*	*9.76*	*9.70*	*9.90*	*10.08*	*10.19*	*9.76*	*10.48*	*10.18*

1.4. COMBINED CALIBRATION VALUES

Table below presents the delay of the receiver chain (receiver, antenna and cable). The data are referenced to the APC of the antenna, for easier implementation into CGGTTS file.

Table 4 Combined calibrated delays with uncertainty

GNSS Signal	Group Delay* [ns]	Uncertainty [ns]
'L1C'	229.95	0.72
'L1P'	229.70	0.56
'L2P'	224.99	0.61
'L5Q'	229.36	0.55
'E1C'	230.09	0.56
'E5Q'	229.41	0.56
'E7Q'	223.54	0.58
'E8Q'	225.54	0.55
'E6C'	229.43	0.57
'G1C'	231.78	0.88
'G1P'	232.07	0.74
'G2C'	223.84	1.17
'G2P'	224.01	0.62

*Values referenced to the APC of the antenna

1.5. POLARX5 CONFIGURATION DURING CALIBRATION

```
setSBFOutput, Stream1, LOG2
setSBFOutput, Stream1, ,
MeasEpoch+GEORawL1+GPSNav+GPSIon+GPSUtc+GLONav+GALNav+GALUtc+GALGstGps+GEONav+P
VTGeodetic+ReceiverSetup+Comment+CMPNav+QZSNav
setSBFOutput, Stream1, , , sec30
setPVTMode, Static
setPVTMode, , , Cartesian1
setStaticPosCartesian, Cartesian1, 3904166.8180
setStaticPosCartesian, Cartesian1, , 301750.5350
setStaticPosCartesian, Cartesian1, , , 5017780.8910
setMultipathMitigation, off
setMultipathMitigation, , off
setElevationMask, PVT, 10
setIonosphereModel, off
setTroposphereModel, off
setReceiverDynamics, Low
setReceiverDynamics, , Static
setRAIMLevels, off
setNWALevels, off
setClockSyncThreshold, , on
setPPSParameters, , , , RxClock
setPPSINParameters, auto
setMarkerParameters, 'GOLD'
setChannelAllocation, Ch01, G01
setChannelAllocation, Ch02, G01
setChannelAllocation, Ch03, G01
setChannelAllocation, Ch04, G01
setChannelAllocation, Ch05, G01
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setChannelAllocation, Ch17, F01
setChannelAllocation, Ch18, F01
setChannelAllocation, Ch19, F01
setChannelAllocation, Ch20, F01
setChannelAllocation, Ch21, F01
setChannelAllocation, Ch33, E01
setChannelAllocation, Ch34, E01
setChannelAllocation, Ch35, E01
setChannelAllocation, Ch36, E01
setChannelAllocation, Ch37, E01
setSatelliteTracking,
G01+G02+G03+G04+G05+G06+G07+G08+G09+G10+G11+G12+G13+G14+G15+G16+G17+G18+G19+G20
+G21+G22+G23+G24+G25+G26+G27+G28+G29+G30+G31+G32+R01+R02+R03+R04+R05+R06+R07+R08
+R09+R10+R11+R12+R13+R14+R15+R16+R17+R18+R19+R20+R21+R22+R23+R24+R25+R26+R27+R28+
R29+R30+E01+E02+E03+E04+E05+E06+E07+E08+E09+E10+E11+E12+E13+E14+E15+E16+E17+E18+E1
9+E20+E21+E22+E23+E24+E25+E26+E27+E28+E29+E30+E31+E32
setSignalTracking,
GPSL1CA+GPSL1PY+GPSL2PY+GPSL2C+GPSL5+GLOL1CA+GLOL1P+GLOL2P+GLOL2CA+GLOL3+GAL
L1BC+GALE6BC+GALE5a+GALE5b+GALE5
setNotchFiltering, Notch1, off
setNotchFiltering, Notch2, off
setNotchFiltering, Notch3, off
setREFOUTMode, , on
setSatelliteUsage,
G01+G02+G03+G04+G05+G06+G07+G08+G09+G10+G11+G12+G13+G14+G15+G16+G17+G18+G19+G20
+G21+G22+G23+G24+G25+G26+G27+G28+G29+G30+G31+G32
setSignalUsage, GPSL1CA+GPSL1PY+GPSL2PY
setLogSession, LOG1, Disabled
setLogSession, LOG2, Disabled
setLogSession, LOG3, Disabled
setLogSession, LOG4, Enabled
setLogSession, LOG1, , , 'rinex301'
setLogSession, LOG2, , , 'SBF_val'
setLogSession, LOG3, , , 'rinex211'
setLogSession, LOG4, , , 'Cal_Rinex'
setFileNaming, LOG2, , 'ORB_val'
setRINEXLogging, LOG1, hour24
setRINEXLogging, LOG4, hour24
setRINEXLogging, LOG1, , sec30
setRINEXLogging, LOG3, , sec30
setRINEXLogging, LOG1, , ,
GPSL1CA+GPSL1PY+GPSL2PY+GPSL2C+GPSL5+GLOL1CA+GLOL1P+GLOL2P+GLOL2CA+GLOL3+GAL
L1BC+GALE6BC+GALE5a+GALE5b+GALE5
setRINEXLogging, LOG3, , , GPSL1CA+GPSL1PY+GPSL2PY+GPSL2C+GPSL5
setRINEXLogging, LOG4, , ,
GPSL1CA+GPSL1PY+GPSL2PY+GPSL2C+GPSL5+GLOL1CA+GLOL1P+GLOL2P+GLOL2CA+GLOL3+GAL
L1BC+GALE6BC+GALE5a+GALE5b+GALE5
setRINEXLogging, LOG1, , , , Channel
setRINEXLogging, LOG4, , , , Channel
setRINEXLogging, LOG1, , , , , v3x
setRINEXLogging, LOG4, , , , , v3x
setRINEXLogging, LOG4, , , , , , Obs