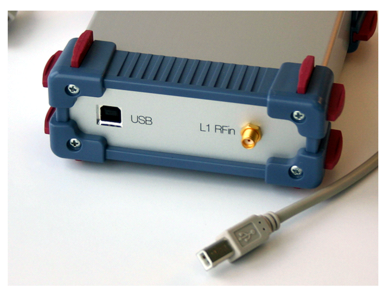
Status of Software Receiver Technology at University FAF Munich and IFEN GmbH

Institute of Geodesy and Navigation
Institut für Erdmessung und Navigation
IfEN GmbH

Input Sources:

Single Frequency L1 Frontend:

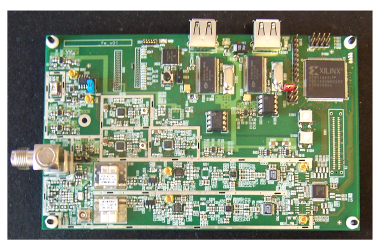
For GPS/INS integration, Galileo algorithms testing, ...



Frequency Bands: L1
Bandwidth: 10 MHz
Sampling Rate: 23 MHz
ADC-Bits: 1.5 bits
Connector: USB 2.0
Internal Buffer: Yes
Frontend Design: IfEN GmbH [2]

Triple Frequency L-Band Frontend:

For reference station operation, RTK measurements, ...

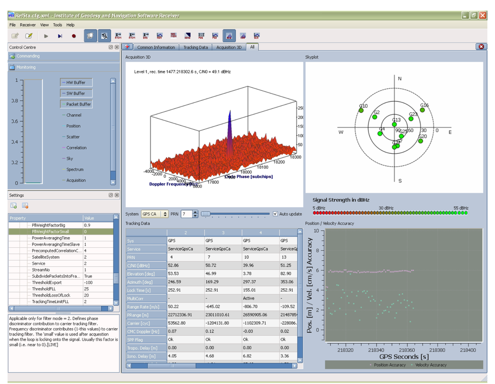


Frequency Bands: L1, L2 and L5
Bandwidth: 13 or 18 MHz
Sampling Rate: 20.48/40.96 MHz
ADC-Bits: 2 or 4 bits (L5 only 4 bits)
Connector: 2 x USB 2.0
Internal Buffer: No
Frontend Design: Fraunhofer IIS with University FAF Munich [1]

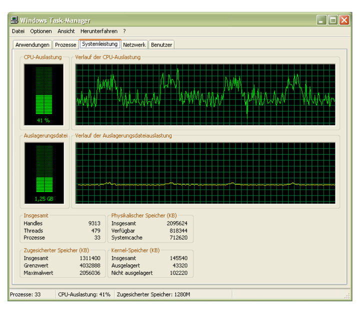
Signal Recorder plus Laboratory Setup:

If none of the USB-frontends fits ...

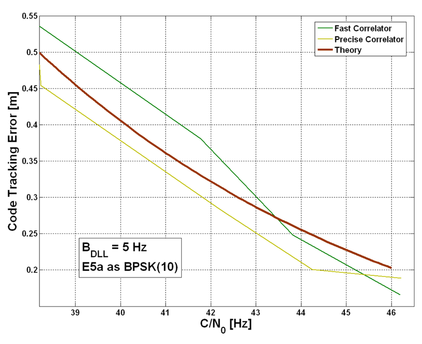
Bandwidth: Defined by laboratory equipment
ADC Board: ICS-572B
Sampling rate: < 100 MHz
ADC-Bits: 16 bit
Number of Simultaneous Frequency Bands: 2
Connector: Data provided via file input (post-processing)
Recorder Provider: EHS Systems



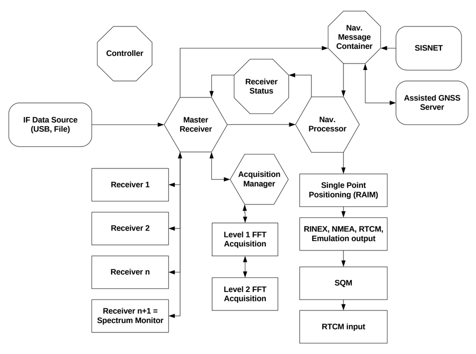
Software receiver screenshot



Processing load during reference station operation



Galileo E5aI code tracking error for two different correlator implementations
!Precise: Hardware like 64 bit NCO
!Fast correlator: Optimized code for SSE

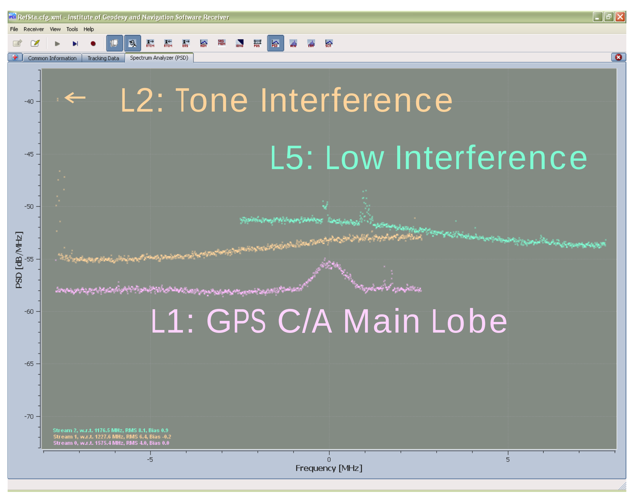


Block diagram of the receiver core software

Station Monitoring:

Spectrum Monitoring:

It may happen, that intentional or unintentional interference signals are received by a reference station receiver, which usually causes a C/N0 degradation of the GNSS signals. Interference is more likely to occur on L2 and L5 than on L1. Most types of interference can be detected by a spectrum analyzer which is integrated in the software receiver.

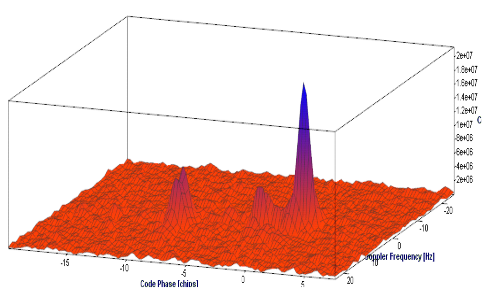


Software receiver spectrum view of the GNSS signal environment at University FAF

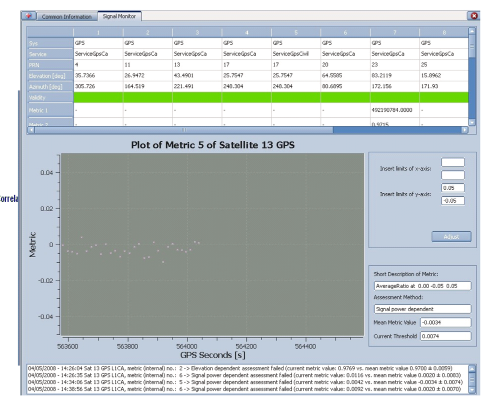
Signal Quality Monitoring:

Signal Quality Monitoring (SQM) is a technique to verify that the broadcast GNSS waveforms comply to their specifications. The waveforms may be corrupted by satellite payload failures, receiver hardware failures or to a certain extend by severe multipath.

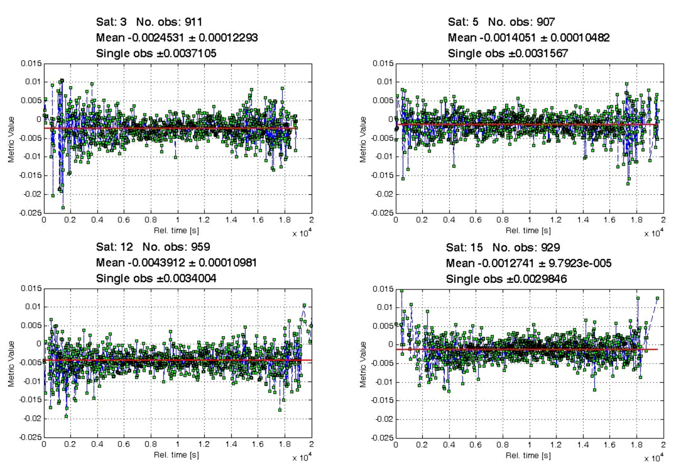
Signal quality monitoring is based on the evaluation of multi-correlator values which are combined to so-called 'metrics'. The metric values are constantly compared to their nominal values and deviations from the nominal values indicate a specific failure in the received signal [4].



Multi-Correlator values for a moving software receiver tracking a Galileo E5a pseudolite signal. Multipath occurs a several code phase and Doppler offsets



Signal monitor screenshot



GPS C/A code metric values for different satellites.
Metric type: $(I_{0.05} - I_{-0.05})/I_{0.0}$

New Observables:

Double Difference Correlator:

A software receiver provides an inherent flexibility to handle new measurements in addition to the conventional observables (code/carrier pseudorange, Doppler, C/N0). This may provide increased positioning performance.

A promising technique which exploits this new possibilities is to form double difference observations at correlator level instead on pseudorange level. This allows to run the carrier phase tracking loop (e.g. the PLL) on double difference data which is free of any satellite or receiver clock effects. Furthermore, double difference correlator values are data bit free. The carrier tracking performance is increased by 6-20 dB [3]. The proposed scheme anticipates that carrier pseudorange values $\varphi(t)$ in [rad] plus complex prompt correlator values $P_{trk}(t)$ are available for post-processing.

Processing Scheme Outline:

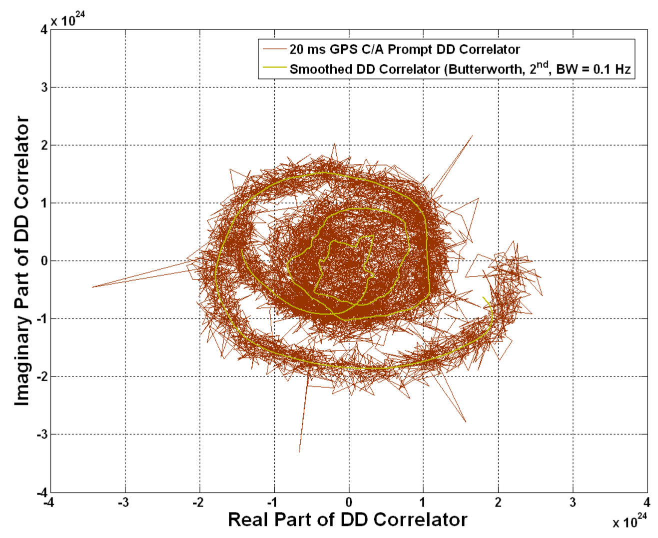
!The output correlator values $P_{trk}(t)$ have to be first converted into raw correlator values $P(t)$ which are independent of the receiver tracking scheme.

$$P(t) = \exp\{+i\hat{\varphi}(t - T_{coh})\} P_{trk}(t)$$

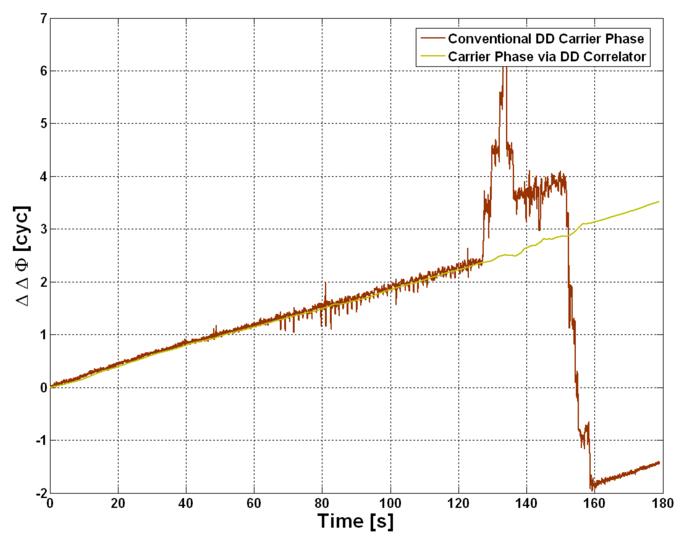
!Raw double difference correlator values are formed between two receivers *n, m* and two satellites *k, l*

$$\nabla\Delta P(t) = P_n^k(t)\bar{P}_n^l(t)\bar{P}_m^k(t)P_m^l(t)$$

!Raw double difference correlator values behave smoothly and can be well filtered. After filtering carrier phase "tracking" is more stable.



Example of double difference correlator values (unfiltered and filtered). GPS C/A, baseline length approx. 50 m, static antennas, PRN 13 and 23. Signal artificially attenuated by "waving" hands above the antenna



Double difference carried phase pseudorange obtained conventionally and via double difference correlators

References:

[1] Anghileri et al.: "Performance Evaluation of a Multi-frequency GPS/Galileo/SBAS Software Receiver", Proc. ION-GNSS 2007, Fort Worth, Sept. 25-28, 2007.
[2] Restle et al.: "NavX®-NSR – A Novel Galileo/GPS Navigation Software Receiver", Proc. ION-GNSS 2007, Fort Worth, Sept. 25-28, 2007.
[3] Pany, T.: "Nutzen des Post-Processings von aufgezeichneten GPS-Zwischenfrequenzsignalen zur Positionierung bei Abschattungen und im Indoor-Bereich", Österreichische Zeitschrift für Vermessung und Geoinformation, Heft 4/2006.
[4] Stöber et al.: "Implementing Real-time Signal Monitoring within a GNSS Software Receiver", Proc. ENC-GNSS 2008, Toulouse, April 22-25, 2008.

Performance Evaluation:

Measurement Date: Feb. 2nd 2008, DOY 35
DLL Carrier Aiding: Yes, by FLL assisted PLL
DLL/FLL/PLL-Bandwidth: 0.01 Hz / 2 Hz / 18 Hz
Multipath Mitigation: Optimized code reference waveform
Dynamic Sample Rate Reduction: Yes
Antenna: Novatel GPS-704x
LNA: Custom build, F = 0.5 dB
Frontend: Triple Frequency L-Band, with 13 MHz
Number of Channels: All in view
Elevation Cutoff: - 2°
Measurement Rate: 1 Hz
Computer: 2 x Xeon each 2 cores, Windows XP
Computer Purchase Date: 2006
Tracked Services: GPS C/A, GPS L2CM (as pilot - currently no data bit transmitted), SBAS, GIOVE A E1(B+C), GIOVE A E5a (I+Q)

Performance Parameters:

Code Error: Code minus carrier pseudorange in [m], ionosphere removed via polynomial fit
Receiver Detected Cycle Slips: marked as 'Red Stars'
Signal Power: Estimated C/N0 via differential detector