High Rate Performance Assessment of GNSS Raw Data Based on the DLR Experimentation and Verification Network

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BIOGRAPHIES

Thoralf Noack holds a Dipl. Ing. in Electrical and Electronic Engineering from Technical University of Dresden. He worked as an application engineer and consultant in acoustical measurement engineering. Since 1998 he is working as a Research Associate at the IKN, department of navigation., primarily leading the development of GNSS reference and monitoring systems.

Evelin Engler received a PhD in communication engineering from the Technical University of Dresden in 1987 and has long experiences in communication and navigation theory. Since 1992 she works as a Research Associate in the navigation group of the IKN primary in research areas like design and development of simulation facilities as well as development of GNSS navigation algorithms and correction techniques.

Dietmar Klähn is the leader of the multisensor navigation group of the Department of Navigation of the IKN. He holds his PhD degree in physics from the University of Rostock. His experiences are in the fields of theoretical physics, numerical mathematics, communication theory, microwave network theory and design, GPS algorithms, quality control, and design of GNSS reference and monitoring stations. In 1999 the ESTB Iono Processing Module was designed and implemented into the ESTB CPF by an IKN team under his leadership.

ABSTRACT

In co-operation between DLR IKN and the German aerospace company Jena-Optronik GmbH, the ‘Experimentation and Verification Network’ (EVNet) was developed over the past years. The EVNet was designed to provide a basic infrastructure realizing the networked reception, transmission, archiving, and distribution of any kind of GNSS data as well as derived products via Internet in nearly real time. For this purpose a set of sensor stations - each equipped with GNSS-receivers and optional meteorological sensors, a processing host, and additional components to fulfill the requirements of a complete remote control system - are currently installed on selected world wide locations to support the research and development activities of the IKN in the field of GNSS/Galileo verification, validation, and application.

The added value of the EVNet is determined by the processing components to implement the GNSS data assessment and the provision of derived data products in the context of the GNSS/Galileo verification, validation of services, and of a Local Element development. A case in point of such processing modules is the high-rate phase processor developed by IKN using the particular feature of the EVNet to operate with 50 Hz GNSS high rate data to full capacity. Its objectives and features cover the self-contained detection of cycle slips, the estimation of momentary phase noise, the identification of non-regular phase fluctuations, providing a quantification and validation of the performance of GNSS/Galileo phase measurements in real time. The capabilities of the phase processor have been verified on the basis of data originating from different locations under various propagation conditions. The benefits of the high-rate processing technique will be demonstrated by comparison with conventional 1 Hz results, focusing on the phase behavior during periods of perturbed ionospheric conditions and on the achievable continuity of phase data. Furthermore, by-products of the phase processor like ionospheric propagation errors rates will be analyzed in correspondence with the signal strength behavior provided by an amplitude processor of the EVNet.

INTRODUCTION

The development of future navigation systems like the European GALILEO, the modernized GPS or advanced augmentation systems announces the establishment of new applications with a higher potential in positioning accuracy and reliability. To achieve performance levels as required for special applications, e.g. precision approaches in aviation, additional infrastructure components also referred to as Regional Components or

Local Elements will be necessary. The main task of such components consists in the support of the users with additional *regional* information concerning the current state of the receiving conditions for each satellite link in nearly real time. For the establishment of a suitable environment to test first prototypes of such local elements including the required processing facilities the IKN has developed a new infrastructure called as “Experimentation and Verification Network - EVNet” to acquire, monitor, process, and distribute GNSS raw data as well as higher order data (e.g. status information) as a whole. Besides, this network offers the ability to test and tune new processing algorithms and methods under consideration of specific user and application oriented requirements (e.g. error bounds, integrity level, detection of ionospheric anomalies etc.)

Based on the research and development activities in the context of GNSS verification and validation and the development of Local Elements as well as trough the continuous improvement of the receiver performance related to the increased update rate of raw data measurements, IKN has realized two prototypes of EVNet processors which enable a raw data assessment based on GNSS high rate data. The first processor realizes the assessment of the signal strength behavior and the detection of increased signal strength fluctuation induced e.g. by the ionosphere or by jamming. The second processor covers the independent detection of cycle slips and data gaps per carrier, the estimation of the momentary phase noise, the identification of non-regular phase fluctuations, and the quantification of the performance of GNSS/Galileo phase measurements in real time.

EXPERIMENTATION AND VERIFICATION NETWORK (EVNet)

The EVNet which was the basis for all performance assessments inside this paper was designed as a near real-time network for the acquisition and distribution of GNSS data. It consists of a set of modular hardware and software components. Currently the network is tuned to be operated primary for the reception, processing, and distribution of spatial distributed GPS signals as well as assisting meteorological data via Internet communication links. In detail, the EVNet consists of the four main elements

- Sensor Stations,
- Central Processing and Control Facility (CPCF),
- External Processing Facilities,
- and User Components.

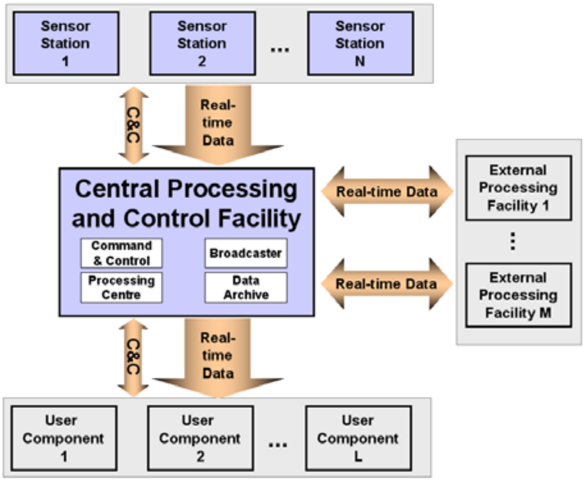


Figure 1: General block diagram of EVNet

As shown in Figure 1 all data streams coming from the sensor stations at first pass the Central Processing and Control Facility (CPCF). A broadcaster is responsible to receive these data streams and to distribute them to clients described as user components (customers) or external processing facilities. In the processing centre of the CPCF, these streams may be processed to higher level products which can also be disseminated to the clients using the same common distribution mechanism. Furthermore the CPCF contains a command and control module to administrate the EVNet services and to control the access to real-time data streams on a per-sensor level. To automatically store all real-time data streams or specific subsets a data archive is implemented. This archive provides a WWW front-end which allows to download archived data via a conventional browser. All communication between the distributed components of the EVNet is performed via the Internet. No dedicated communication lines are required. Although the EVNet is not intended to be a high-security network, various features like encrypted communication protocols and authentication procedures are implemented to ensure integrity of the transmitted data and to reduce the risk of abuse. A detailed description of the architecture and technical realization of the EVNet system can be found in [1].

One main objective of the EVNet consists in its utilization as a ground infrastructure platform for Local Elements within the scope of augmented systems for high precision and safety related navigation applications. Therefore currently the primary focus is laid on the development and implementation of basic processing routines required to analyze the performance of GNSS systems based on the primary raw data. Raw data within this context comprises signal strength, code, and carrier phase measurements. An important requirement for Local Elements under consideration of their applicability for applications related to safety, have to be seen in the development of real time processing algorithm which are able to detect failures and interferences. Therefore, within the scope of safety related applications a loss of lock of a signal is less critical than the corruption of signals under influence of natural and technical impacts. To determine such events and to find indicators to distinguish between different sources of influence the availability of high rate receivers has led to the installation of a network of 5 receivers on different EVNet sensor stations located in European and Equatorial regions (see Figure 2).

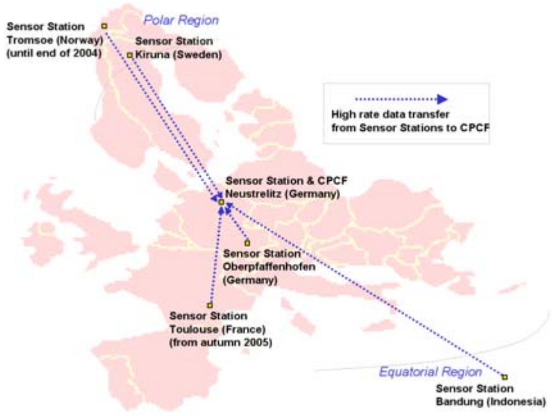
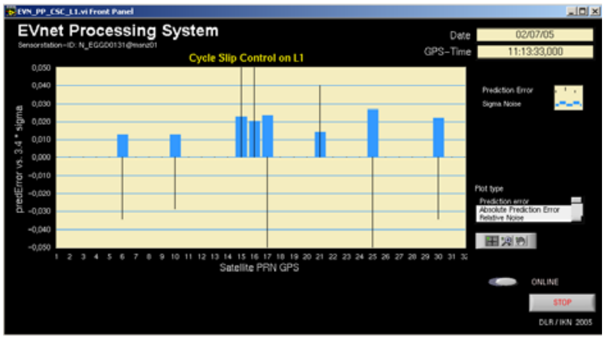


Figure 2: Network of EVNet high rate receivers in European and Equatorial regions

Each sensor station operates in continuous mode and can be configured and commanded via EVNet remote control utilities from the CPCF located in Neustrelitz (Germany). The processing of the data streams takes place at the processing centre of the CPCF. Therefore, measurements of the signal amplitude of both carriers, of the carrier to noise ratio and of the L1 and L2 phases are used, to estimate different indicators for the occurrence of any irregular behaviour of signal strength, S4 scintillation index, variances of the phase noise, or Slant TEC values.



Sensorstation-ID: N_EGGD0131@monz01

Date 02/07/05

GPS-Time 11:13:33,000

Figure 3: Momentary prediction error (black) and variance (blue) of L1 phase values for acquired GPS satellites

An example of a Graphical User Interface of the EVNet to display specific indices like the prediction error of the phase noise (difference between the measured and the predicted phase) and statistical values like the current phase variance is shown in Figure 3.

HIGH-RATE DATA PROCESSING TECHNIQUES

At the sensor stations of the EVNet specific Javad high-rate navigation receivers (Javad LEXON-GGD) have been employed. This receiver type provides raw data with an update rate of 50 Hz. On the one hand, this enables to apply data processing techniques with an increased data base per time slot, and on the other hand to detect narrowband effects at the GNSS signals like ionospheric scintillations. Additionally, the receiver delivers data describing the signal amplitude and the signal to noise ratio (SNR) with 50 Hz update rate, which are needful to assess the signal performance in relation to the states of the incoming GNSS signals.

Signal strength assessment

As a result of a modified firmware, our Javad Legacy high-rate receivers provides signal amplitudes for all coded in-phase and quadrature components at both carriers in addition to the conventional SNR. According to the limitations of the receivers SNR binary format, a 0.1dB quantization effect is induced. Additionally, some reduced temporal variation of the SNRs can be observed due to some decreased update rate during receiver internal SNR data generation. In comparison to the SNRs as the quotient of signal power and noise, the amplitude measurements can be considered as a direct indicator of the signal strength. Evidently, they change unsmoothed with an update of 50 Hz. Obviously, the amplitudes corresponding to the L1 and L1 P-code measurement are strongly correlated, which can be explained by the cross correlation technique used by civil receivers. Namely, expected power differences in the order of 3 dB between the L1 in-phase and quadrature signal power and between L1 and L2 signals cannot be confirmed [2]. Therefore the provided amplitudes must be considered as receiver specific amplitude values.

Preparing the real-time assessment of the signal strength of incoming GNSS signals based on the provided amplitude requires the clarification of the occurrence of special effects influencing the data availability and continuity. So it has been found, that sometimes the recorded amplitude data includes short-term disturbances by the receiver itself at time periods of increased receiver stress (e.g. if more then 12 satellites are tracked with 50 Hz simultaneously). They result from a miss-assignment (permutation) of some satellite(s) to the tracking channel and affect the recorded amplitudes at all channels, synchronously. Therefore a pre-processing procedure is needed to identify such permutations and to remove the corresponding data from the signal strength assessment.

Such as observed at the data of others receivers, provided data includes sometimes zero values, if the receiver internal estimation processes don’t be finished. Such data samples must be additional removed by the pre-processing technique.

For the realization of the signal strength assessment it is necessary to clarify the temporal and spatial dependencies of the relative amplitudes to enable a differentiation between regular and disturbed behavior. An important fact in this context is that the signal power transmitted by a GPS satellite decreases up to 6 dB during its life span [3]. Therefore, the spatial and temporal dependencies respectively magnitude and variance must be analyzed per satellite, individually. The preliminary analysis of amplitudes gathered at the sites Tromsoe (Norway) and Neustrelitz (Germany) demonstrated that the signal strength variances depend mainly on the signal strength magnitude [5], at most days.

Approximating the variance as a function of the magnitude of the signal strength by a polynomial of second order based on all data samples per day results in very similar dependencies at both sites (see Figure 4).

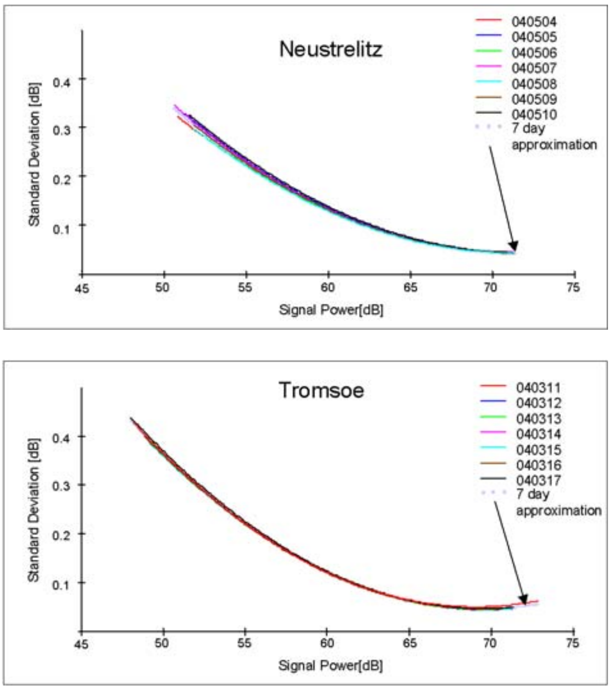


Figure 4: Standard deviation as a function of signal power at successive days (yymmdd) for the sites Neustrelitz (Germany) & Tromsoe (Norway)

Only at ionospheric disturbed days like the 31st October 2003 increased signal strength fluctuations can be observed sometimes at several satellites ([4], Figure 5). Otherwise by the repetition of satellites passes after a solar day [3] nearly the same geometric and environmental conditions during signal transmission and therefore nearly identical magnitudes can be assumed.

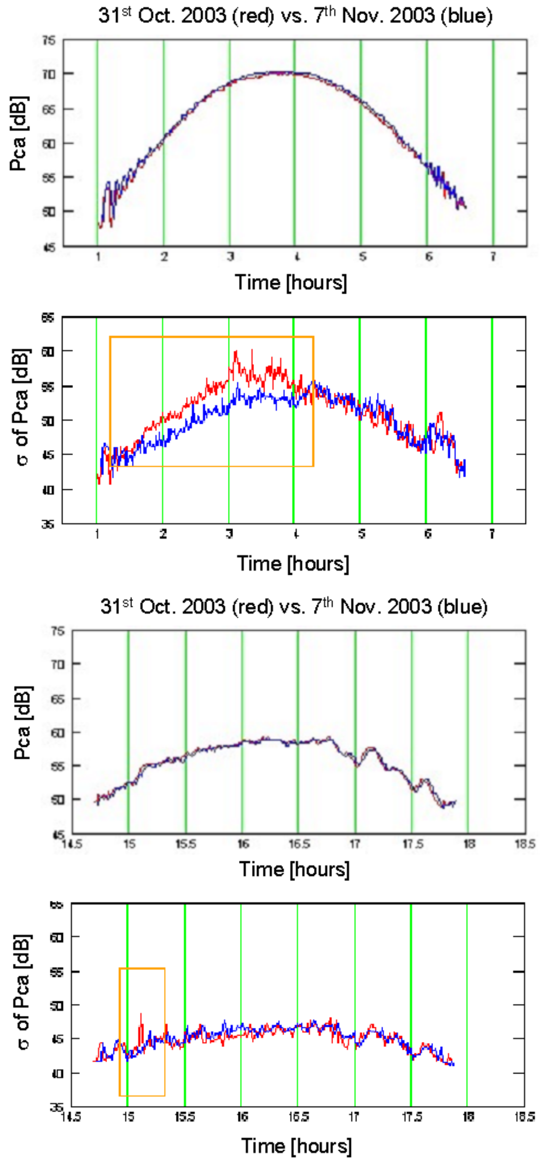


Figure 5: Signal power (P_{CA}) and its standard deviation (σ of P_{CA}) of GPS satellite 1 observed at 2 different days illustrated in dB (depending of the visibility shift of the GPS satellites for fixed positions of ~4 minutes per day the time scale of the 31st October has been lateral adjusted by ~0.45 hours for a better comparison)

The processor implemented in the EVNet is used for the signal strength assessment and for the detection of ionospheric induced amplitude scintillations. It consists of a pre-processing unit, which is responsible for the data management, for the estimation of the momentary signal power characteristics and for the detection of (unintended) permutations and/or zero values at the incoming amplitude values. Based on some sequence of previous data the temporal signal power behavior (dB) is modeled by a polynomial of second or third order. The standard deviation of the approximation error is interpreted as the momentary standard deviation of the signal power itself. Using the polynomial, the signal power at the next time step can be predicted. Comparing the measured signal power with the predicted value enables the detection of occurred permutation. It has been shown [5] that the behavior of the prediction error follows an exponential distribution, whereby the factor λ is about 5.5. Therefore, if the prediction error exceeds the decision level

$$\text{level} = \frac{-\ln(1-\text{Prob})}{\lambda} \quad ,$$

a permutation is detected. The value Prob as a configuration parameter specifies the assumed probability of permutation occurrence. Zero values are removed directly.

Based on the available “relative” amplitude values the main processor unit evaluates the momentary signal power. In the first step the signal power is verified respectively the allowed value range composed by the geometric and environmental reference value (station and link specific) and by the power dependent standard deviation (common or station dependent). In a second step the prediction errors calculated in the pre-processing unit are used to assess the momentary power variations respectively the occurrence of ionospheric induced scintillation. For this purposes the prediction errors are normalized on the reference standard deviation. During some time segment, e.g. 1 minute, the number of increased prediction errors is counted and the corresponding amplification factor of the variance is determined. Both values are used to differ between regular and disturbed signal power behavior and to indicate the occurrence of ionospheric scintillation or maybe other disturbances.

At this point it must be mentioned, that the processor operates with pre-specified configuration parameter sets. To achieve an improved relevance of the configuration parameter, an additional analysis function is implemented in the EVNet to calculate daily statistics and distribution functions describing the link and station dependent behavior of the signal power magnitude and standard deviation.

Phase assessment

To enable the use of phase measurements for positioning in the navigation sector the phase processing is focused on cycle slip detection and ambiguity determination. In case of sensor stations, geodetic positioning, or local augmentation the receiver normally operates at locations with reduced multipath impact in static mode. In these application areas preferred methods for the cycle slip detection are techniques based on a linear combination of code and phase measurements at both carriers developed by Blewitt [6]. The difference of these wide-lane carrier phase combination and of the narrow-lane code phase combination results in a term, which is free of influences from geometric range, clock errors and ionospheric/tropospheric propagation impacts:

$$\varphi_{\text{BLW}} = (N_1 - N_2) - \frac{1}{c}\left(f_1 n_1 - f_2 n_2\right) + \frac{m_1 \cdot f_1 + m_2 \cdot f_2}{c} \frac{f_1 - f_2}{f_1 + f_2}$$

A full or half wave length cycle slip Δ(N1) or Δ(N2) can be identified by jumps of 0.5 or 1.0 cycles. Assuming, that the phase noise at both carrier (n1 and n2) can be neglected in comparison to the multipath magnitude (m1 and m2) at the range measurements, a multipath free cycle slip detection can be assumed, if the multipath impact does not exceed the 20 centimeter level. Operating with an adaptive decision level derived from the momentary standard deviation of φ_{BLW} on the one hand reduces the detection potential of small scale cycles, and on the other hand implicates a misdetection of cycle slips during periods of increased multipath errors. Furthermore, by the temporal correlation of the multipath behavior a data base of several minutes is needed to get a representative estimation of the mean value and the standard deviation of the value φ_{BLW}.

The other group of cycle slip detection techniques operates with combinations of the dual phase measurements suppressing either the ionospheric propagation error (LC) or the sum term of geometric range, clock, and tropospheric errors (LG). Assuming an ideal approximation of the temporal behavior of the included terms (either ionospheric delay or sum term), the allowed phase noise level of such combinations LC or LC can be up to 4.6 or 4.7 centimeters without influence on the cycle slip detection process. The critical point using these techniques results mainly from the approximation error during the modeling of the temporal behavior of the ionospheric delay or the sum delay induced by the geometric change, the troposphere and the clock errors. Operating with first or second derivation of such phase combinations to simplify the temporal modeling reduces the allowed noise level by 3 dB per deviation.

The high-rate phase pre-processor developed by IKN and implemented in the EVNet operates with the temporal deviation of single phase measurements and the algorithm is a technique combining temporal modeling of the phase rate and adaptive tracing respectively the cycle slip decision level. The expected modeling errors of the phase rate induced by the change of the geometric range and the estimated error based on processed phase measurements for all available satellites at the site Tromsoe are shown in Figure 6. Though a significant difference between the results based on simulation or measurement can be observed, the standard deviation of the prediction error based on real data is around 0.028 cycles (corresponding to a range of ±0.1 cycles assuming a normal distribution of the phase noise and the approximation error) and ensures normally sufficient decision reserve respectively the detection of cycle slip induced jumps (at minimum 0.25 cycle for half wave length cycles).

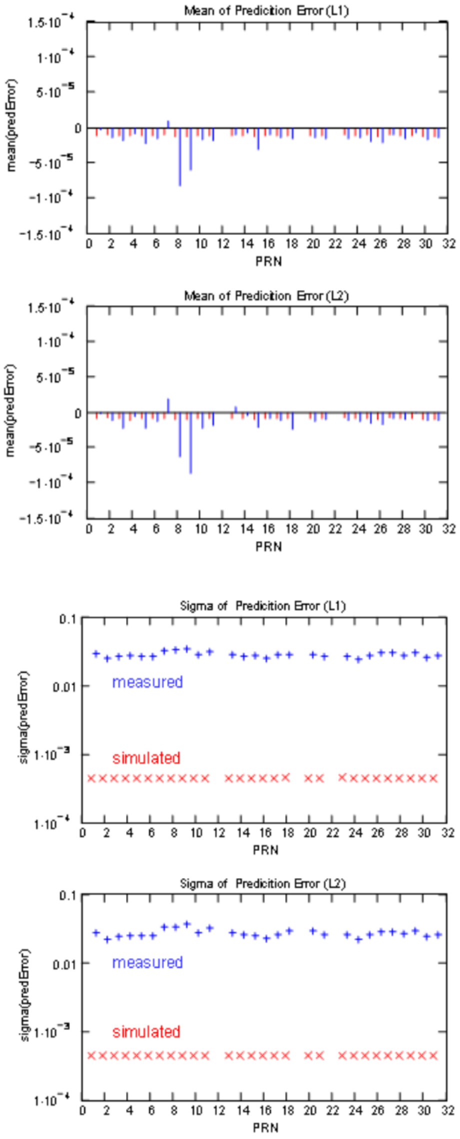


Figure 6 : Mean value and standard deviation of the prediction error in cycles for L1 and L2 per satellite respectively the simulated behavior (red –modeling error of geometric range) and the behavior derived from real measurement (blue) at the 7th Nov. 2003 (Tromsoe – Norway) using a data rate of 50 Hz

In this context, an unsolved question concerns the natural maximum of ionospheric induced prediction errors and the corresponding risk of misdetection of cycle slips. Using a standard deviation controlled decision level enables the phase pre-processor to adapt its reaction on the momentary phase characteristics.

To consider the impact of rapid changes of the ionospheric propagation delay on the processing, phase measurements collected at the site Tromsoe with different receivers (Javad LEXON GGD – DLR (50 Hz / 1Hz), Millenium – ESTB station (1 Hz)) during a strongly ionospheric disturbed time period have been processed (Fig. 7). Though PRN 11 has been tracked at elevation angles higher than 50°, TEC rates (TEC – Total Electron Content as a quantity describing the ionospheric induced delay) up to 2 TECU per second can be observed.

In the case of 1 Hz phase processing the estimated phase noise (see Javad and Millenium results at 1 Hz) is strongly corrupted by the estimate of the ionospheric induced prediction error. During the considered hour at 76 epochs the Millenium provides none or zero L2 phases. Furthermore, at 13 epochs a cycle slip at the L2 phase measurements is detected. Depends on this the data have to be divided in 7 segments, for which a recalculation of the ambiguities was needed. In comparison to the Millenium results the estimated phase noise of the Javad for 1 Hz data is similar. But during the whole time (1 hour) no cycle slips and data gaps have been detected by our algorithm. Therefore the Javad phase data consist of one segment, for which the ambiguities have to be determined. Consequently, the curve of the relative slant TEC describes the true variation of the ionospheric delay. The Javad 1 Hz result is confirmed by the results gathered with an 50 Hz update rate, though in the estimated phase noise no dependencies respectively increased TEC rates can be found.

At this point it shall be mentioned, that at 1 Hz processing the data history of the previous 50 seconds and at 50 Hz of the previous second is needed to enable the cycle slip detection per carrier. That means, an increased data rate implicates a faster decision respectively the occurrence of cycle slips.

Operating with the Blewitt technique, the number of detected cycle slips depends on the used factorization of the standard deviation dependent decision level and on the length of the data history used to determine the momentary standard deviation and mean value (see Tab 1).

Respectively the considered data examples it can be found, that in the case of the Javad data a longer data history and a decision level of 5σ is needed to achieve comparable results based on improved statistical values. Otherwise in the case of the Millenium data non-detected cycle slips must be assumed using a 5 minute data base and a decision level of 5σ. Under consideration of the EVNet objectives, to operate in real time assessing the phase measurements respectively propagation impacts, the DLR high-rate pre-processor , primarily will be used.

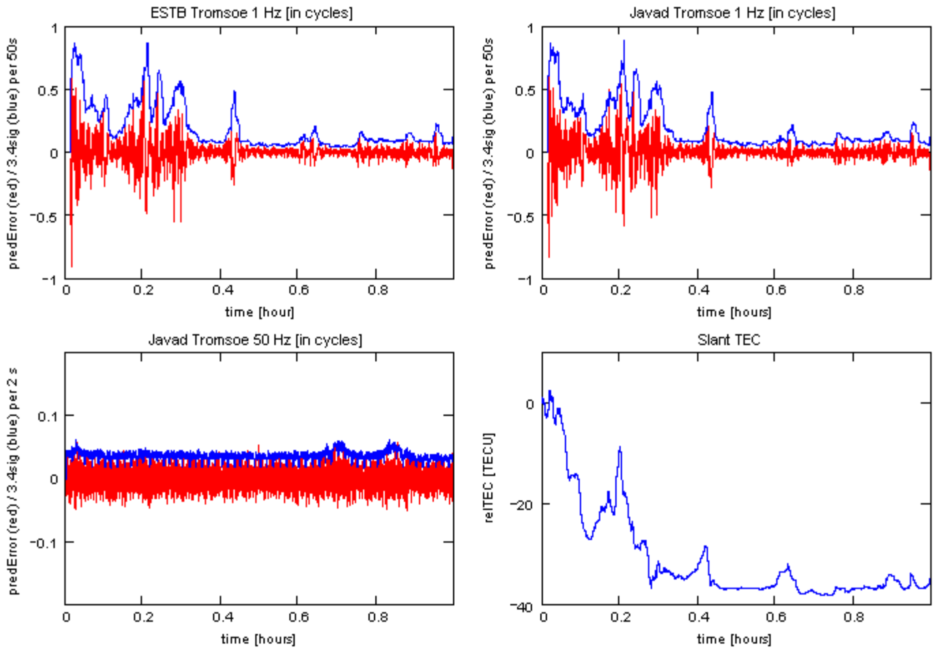


Figure 7: Estimated L1 phase noise (red) for measurements collected at site Tromsoe on 31st Oct. 2003 for GPS PRN 11 for different receivers and data rates, the behavior of the adaptive decision level (blue), and the corresponding relative Slant TEC

Tab. 1: Number of detected cycle slips for different configurations using φ_{BLW}

data history	decision level	Javad Legacy (50 Hz)	Javad Legacy (1 Hz)	Millenium (1Hz)
1 s	3.4	619	-	-
	4.0	151	-	-
	5.0	3	-	-
50 s	3.4	48	14	28
	4.0	6	6	21
	5.0	0	0	19
300 s	3.4	-	9	11
	4.0	-	4	11
	5.0	-	0	9

Measured Cycle Slips: Javad = 0, Millenium = 13

PRELIMINARY UTILISATION AND ASSESSMENT RESULTS

Both described EVNet processors (Amplitude and Phase Processor) are suitable besides others to be used as basic processors in the context of GNSS signal assessment in real time. For these processors an overview of the on-going implementation of services utilising the processor results is shown in the following figure (Fig 8).

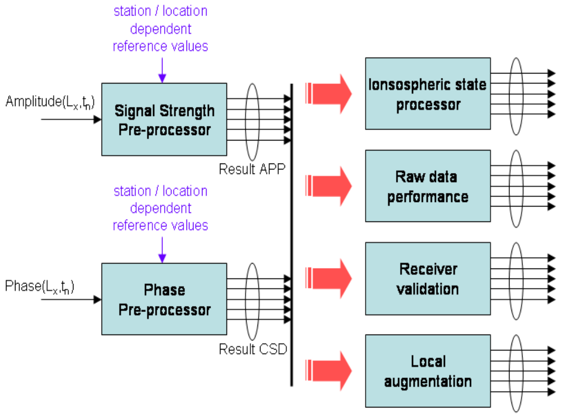


Figure 8: EVNet based services in the context of signal strength and phase assessment

Service 1 - Ionospheric state assessment

The ionospheric state is often described by TEC maps describing the occurred absolute ionospheric delay in its spatial and temporal context. They are inappropriate to provide information with high temporal and spatial resolution needed to assess the ionospheric impact on the tracking capability of GNSS receivers. Based on the provided information (momentary assessed amplitude and phase variances, slant TEC rates, occurred cycle slips and data gaps) the determination of the momentary magnitude of ionospheric disturbances respectively raw data availability can be realised.

Service 2 - Raw data assessment

For GNSS based positioning and navigation services the raw data performance concerning e.g. accuracy, continuity etc. plays an important role. The analysis of signal strength dependent raw data performance under consideration of different error sources in the future enables an improved modelling of UERE performance in the context of atmospheric and environmental reception conditions.

Service 3 - Receiver validation

In a lot of cases the internal signal and processing technique of receivers are sparsely published. However it's well-known, that detected cycle slips, data gaps or the observed phase noise are terms describing the specific receiver behaviour and its reaction on external influences. Hence for the utilisation of data and the correct interpretation of constructive data products an assessment of the used reception equipment is considered quite essential.

Service 4 - Local Augmentation

Local augmentation covers the assessment of the GNSS positioning and navigation performance under realistic conditions and leads to the provision of additional signals und data products to achieve a local improvement (accuracy, safety) of GNSS based positioning. For this purposes different error sources must be separated under consideration of natural and technical dependencies to ensure system and environmental relevant correction and information.

First assessment results

The following examples have to be considered as case studies dealing with the before mentioned applications of the EVNet and the implemented processors. One objective of the operation of the EVNet is focussed on the experimental verification of the implemented processors to provide evidence for their eligibility.

Considering the detected cycle slips at 2 days and comparing the results for independently assimilated data at the same location (Fig. 9) results in the following conclusions:

- The number of cycle slips is slightly increased, if rapid changes of ionospheric delays occur. Larger differences are induced by the type of raw data of the used receivers. Therefore the number of cycle slips is a bad indicator to estimate the magnitude of ionospheric disturbances. One requirement to archive comparable results would be that at minimum for ionospheric assessment purposes the same receiver types have to be used.
- High-rate processing improves the separation potential between occurred cycles slips and occurred phase fluctuations and increases therefore the provision of continuously phase segments. Therefore a firmware internal high-rate assessment of phase measurements could increase the continuity of phase

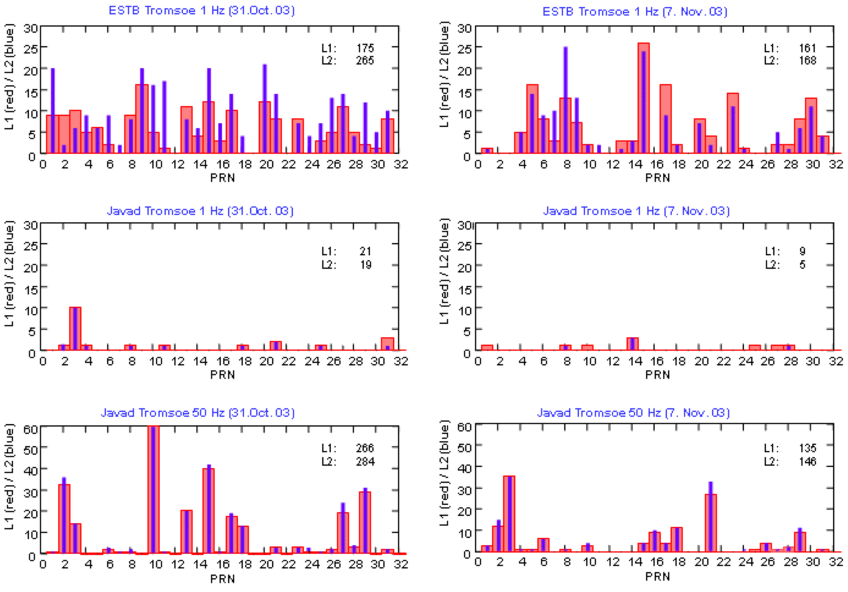


Figure 9: Number of detected cycle slips (red – at L1, blue – at L2) at days with different ionospheric conditions (Tromsoe, 31st Oct. 2003 - strongly disturbed, 7th Nov. 2003 – slightly disturbed)

measurements (same ambiguity) and could deliver flags signing the change of ambiguities.

- A side-effect of adaptive cycle slip detection covers the provision of a phase noise estimate, which reproduces the ionospheric impact in the case of 1 Hz processing, and which at 50 Hz enables the development and implementation of on-going error separation techniques based e.g. on spectral and correlation analysis techniques respectively their specific signatures.

In Fig. 10 periods of increased signal strength variances (see blue and green plots) are pictured for amplitude data collected at both days in Tromsoe.

Additionally, the derived slant TEC rates from phase measurements are shown in Fig. 11. A combined analysis of both graphics enables first conclusions respectively the correlation between signal strength variances and rapid changes of ionospheric delays. It can be seen,

- that an accumulation of increased signal strength variances and rapid changes of ionospheric delays correspond with the strongly ionospheric disturbed day (31st Oct. 2003) and occur around mid night, between 5 and 6 o'clock, and during evening hours,
- that an occurrence of rapid slant TEC changes is not absolutely correlated with increased signal strength variances, but can be correlated,
- that an accumulation of increased signal strength variances can be observed during satellite rise and fall and shows therefore the increased indefiniteness of the signal strength during this time. At this point it must be additionally mentioned, that the used configuration of the Javad receiver acquired the raw data according to the elevation as masked by environment.

The spikes observed in the slant TEC rate in Figure 11 might lead to the impression, to result from undetected cycle slips. To disprove, the detailed slant TEC rate behaviour of selected examples as given in Figure 12 with a higher temporal resolution must be considered. Here it can be seen, that a continuous increase of the slant TEC rate takes place. Furthermore, in consequence of the rapid change of the slant TEC rate the receiver lost its capability to provide phase measurements any longer.

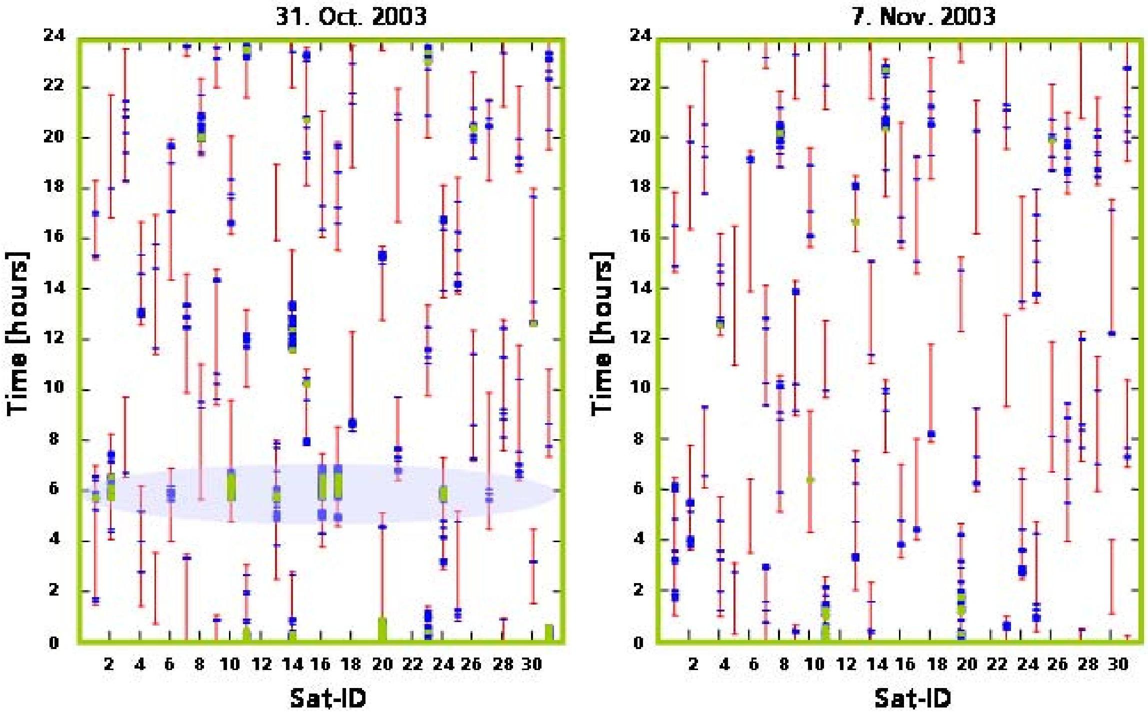


Figure 10: Periods of increased signal strength variances (blue - level greater 0.7 and probability greater than 20 %; green – level grater than 1.0 and probability greater than 50 %) at considered days in Tromsoe (red – periods of delivered and processed amplitude data)

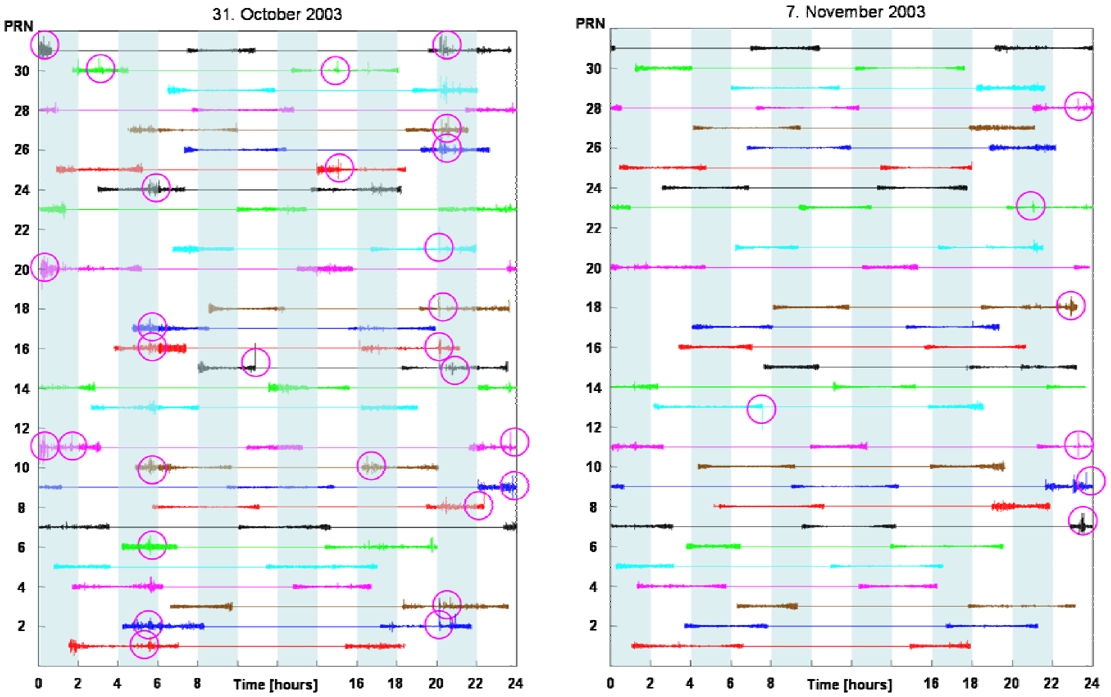


Figure 11: Derived slant TEC rates using pre-processed phase measurements (TEC rate per satellite is shifted to the PRN number, whereby a difference between neighboured PRN number corresponds with a TEC rate of 1 TEC/s)

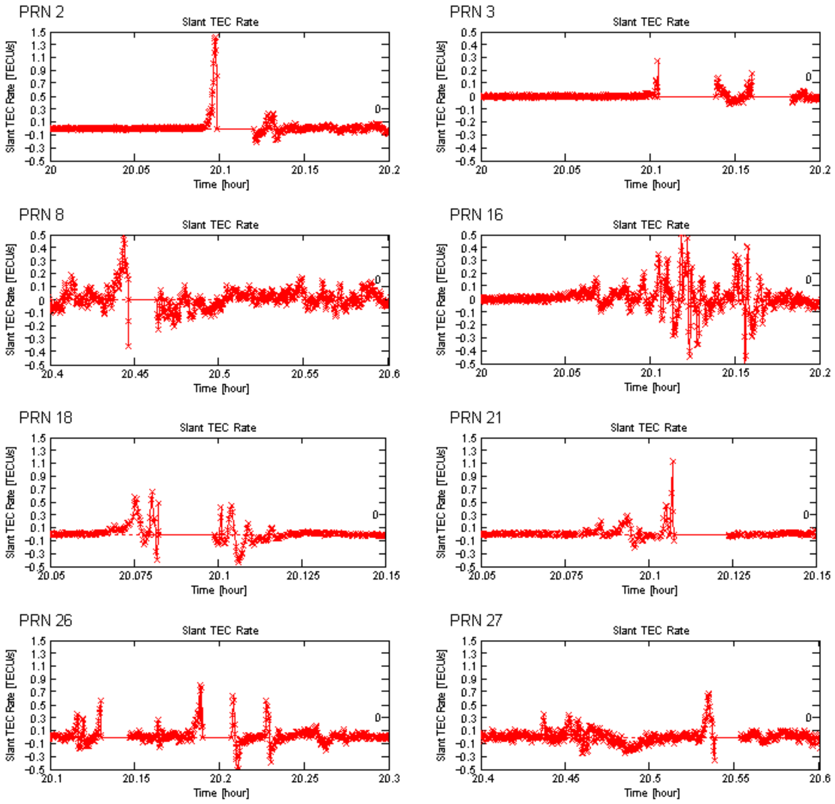


Figure 12: Slant TEC rate for selected examples at the 31st October 2003

SUMMARY

It was illustrated that the implementation of the Experimentation and Verification Network provides the possibility to acquire, process and distribute high rate GNSS raw data. This enables new approaches concerning the rapid performance assessment of GNSS raw data. The development of specific processing algorithm as part of the EVNet itself or as part of routines integrated into external processing facilities and their easy on the fly integration offers the possibility to use the EVNet within the scope of validation purposes and the development of Local Elements for existing and future GNSS.

In this paper, two prototypes of EVNet raw data processors have been prototyped to investigate the behavior of amplitude and phase measurements based on modified Javad high rate receivers (50 Hz). It has been shown that both processors are suitable to be used as basic processors in the context of GNSS signal assessment in real time. In this context the assessment primary comprises ionospheric state assessment, raw data assessment, receiver validation and local augmentation.

A general conclusion consists in the requirement to apply comparable measurement equipment (receivers) to avoid misinterpretations of processing results. As a new feature the phase processor comes with the quality to implement the cycle slip detection and correction without any need for range measurements. Furthermore, it could be shown that high-rate processing improves the separation potential between occurred cycles slips and occurred phase fluctuations and increases therefore the provision of continuous phase segments.

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