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Safety critical objekts and buildings have to be permanently monitored in respect to deformations, movements or other critical events. In many applications the results are needed near or in realtime with an accuracy in the mm-range and if the thresholds are exceeded warnings or alarms have to be automatically generated. Since more than ten years a specific and unique measurement system using the NavStar-GPS-Satellites has been developped and applied to permanently monitor slow movements or deformations (< 10 cm /minute) with high accuracy (1 mm) in realtime over long periods (several years): The so-called

SMMS - Slow Motion Measurement System

- Permanent PDGPS-measurements and calculations in real time -

The measurements and calculations are based on simultaneously observed GPS-Satellites of an own reference station and one or more rover stations. The high accuracy is achieved with low cost single frequency GPS-receivers using their code and phase observations (**P**recise **D**ifferential **G**lobal **P**ositioning **S**ystem) in conjunction with a sophisticated ambiguity solving and filter technique. The movements or deformations are calculated in real time in respect to the fixed antenna of the reference station. The result is a threedimensional baseline vector with its north-, east-, and height components which can be optionally transformed to other global or local coordinate systems. It is possible to simultaneously determine the baseline vectors of several rovers in a separate calculation for each rover. The actual and former results of all rovers are analyzed and graphically displayed in a plot program in which other parameters (e.g. sea level) can be additionally shown. If necessary an alarm program automatically generates alarm and warning messages if predefined thresholds are violated. The messages are sent via SMS or the network to the reponsable persons. All calculations are performed on a standard PC which can be remotely controlled from anywehre using a modem or the network and the well-known ***PCAnywhere*** software from Symantec.

Fig. 1: 8-channel GPS-receiver with RS422/232-converter and lightning fuse

Abb. 2: GPS-antenna with mounting

On the reference station and each rover station a GPS-receiver with its antenna is needed. To reduce the risk of vandalism and theft well-proven low cost GPS receivers are used (see Fig. 1 and 2). The receivers are mounted in water and dust protected housings close to the GPS antenna. In regions with a high risk of snow a radom is used (see Fig. 3) for protection. The receivers are powered by a 12-15 V line and the communication between the PC and the receiver is performed either by a standard RS232-data line (in case of lines less than 200 m) or by a RS422-data line for which on both line ends a RS232/RS422-converter is needed. All lines are protected against high voltages or lightning strokes by appropriate fuses. Optionally instead of the RS232/RS422-data lines lightwave lines can be used. In this case no fuses are needed for the data lines.

Fig. 3 (above): GPS-antenna with radom

Fig. 4 (right): GPS-point for monitoring the slope close to a road

To achieve the high accuracy GPS receivers delivering the code and the phase measurements of the L1-signal are required. In case of four or more simultaneously tracked satellites on the reference and on the rover station every ten seconds a new baseline vector is calculated using the phase measurements in a specific semi-kinematic algorithm based on a Kalamfilter in which the ambiguities and the coordinates are defining the state vector. Thus it is possible to calculate the coordinates in case of only four satellites available. After a signal interruption or after a period with less than four satellites the algorithm is able to resolve the ambiguities within some epochs if the movements are < 1 cm/min. All calculations are performed in the WGS84 or ETRS89 coordinate system. Using global and local transformation parameters the coordinates can be transformed to any local coordinate system, e.g. the object coordinate system of the building (see Fig. 5).

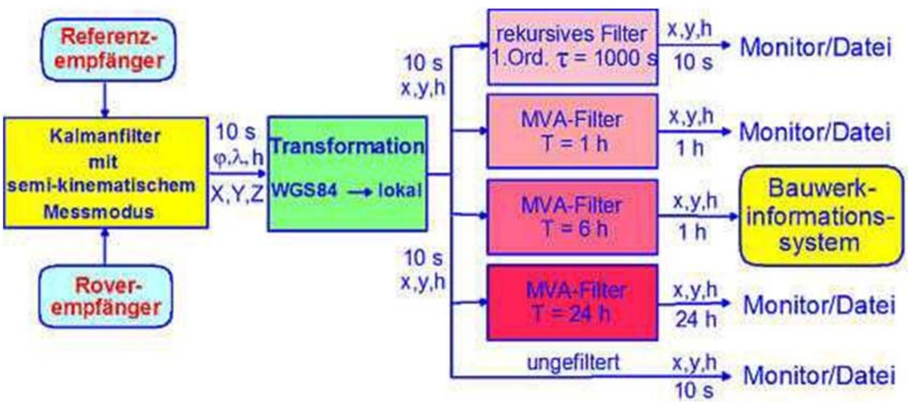

Fig. 5: Overview of the algorithms of the SMMS

After solving the ambiguities the accuracies of the coordinates of the phase calculations are varying in the range of 5 mm to 30 mm depending on the satellite configuration (DOP-values). To improve the accuracy several digital filters are already applied to the calculations. The accuracy achieveable depends on the characteristic and the length of the filters applied. In case of using the output of the 24h-moving average filter standard deviations (95%) of 1 mm for the horizontal components and of 2 mm for the vertical components (height) are achieveable. Fig. 6 is showing the typical standard deviations of the components in dependency of the filter length.

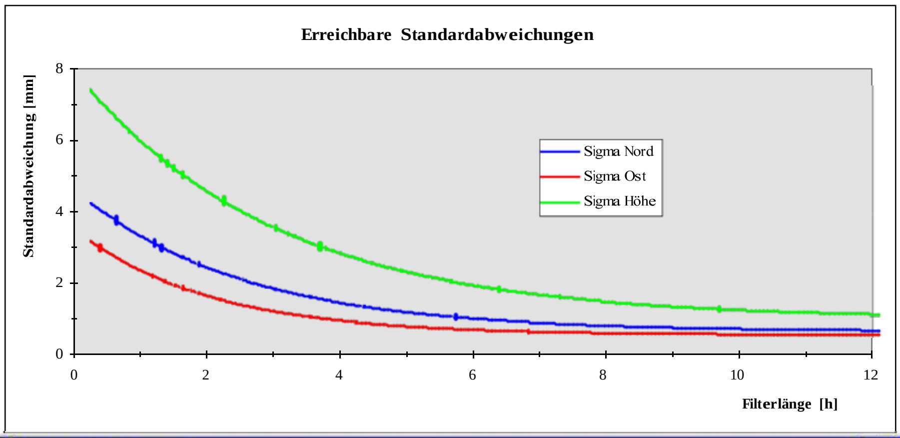

Fig. 6: Typical standard deviations (north, east, height) (95%) in dependency of the filter length

Each baseline vector is independly calculated. To get a quick overview of all calculations the actual and former results of all rovers are commonly displayed by a further program acquiring the results of all calculations. A traffic light (**green**, **yellow**, **red**) informs about the actual state of each object point for which the coordinate changes of a period of 200 days are plotted in a scrollable graphic (see. Fig. 7). Further and older informations can also be displayed in numerical form with some mouse clicks.

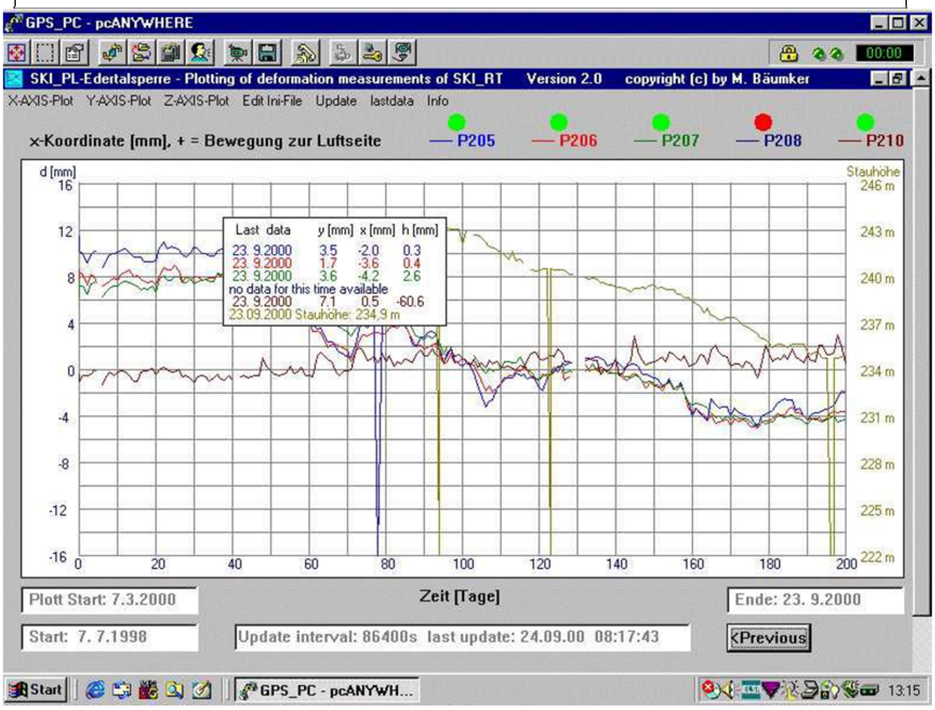

Fig. 7: Plot program (screenshot of a remote control session with PCAnywhere)

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