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INVESTIGATION OF GPS POSITIONING ACCURACY NEAR A DECIDUOUS FOREST AREA

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Abstract: *This article evaluates the accuracy and performance of GPS positioning near a forest area. In such cases, positions are calculated from weak signals that tend to be less accurate. Moreover, the results show that there were significant differences depending on season (May vs. October) regarding the accuracy and precision of the measured coordinates; also, accuracies were different depending on the seasonal forest characteristics. Therefore, practical recommendations for each case were established in order to help foresters select the most suitable situation. The results indicated that the season was a significant factor for the GPS surveys.*

Key words: *Navigation, Precision, Signal Attenuation, Signal Multipath, Forest Area.*

1. Introduction

Barriers such as bushes or trees are a common source of diffraction of the GPS signals. Under these conditions, the GPS signal can be 'bent', as the satellites' signals are visible, but they are geometrically blocked. In all situations when GPS signal diffraction, additional phase delays occur also. This is known as a range error, which affects the obtained accuracy of the GPS results. The main effect of the forest is signal diffraction, as the signals are either completely blocked or weakened by leaves. This means that there are fewer satellites available for the receiver. Signal attenuation (that is, signals which are weakened by passing through the foliage) can cause a degradation of accuracy as well. Signal reflection (known as multipath) can cause significant errors, especially for static point features [4], [6, 7].

The parameters affecting attenuation under foliage are listed below [5, 6], [8], [10]:

- Thickness of trunks and branches;
- Thickness of leaves;
- Density and humidity of leaves;
- Type of foliage (e.g., type of tree);

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- Thickness of foliage;
- Season, in the case of deciduous trees;
- Number of tracking channels;
- Receiver mechanization and SNR;
- Receiver code accuracy;
- Receiver re-acquisition time (due to the relative motion between leaves and receivers);
- Multipath;
- Antenna Sensitivity (Elevation).

The reflected signals are known as multipath signals. As foliage and tree density increase in summer, GPS surveys near the forest become increasingly difficult. The noise term of GPS data can be calculated from the measured carrier-to-noise power density ratio (C/N0). A different approach to the SIGMA models also uses signal quality indicators such as signal-to-noise ratio (SNR) to reduce errors due to multipath [1], [3], [6, 7], [9, 10].

Geodetic GPS antennas are designed to operate with a few dB gains at the zenith and a negative gain at very low elevations; i.e., the C/N0 will vary with the elevation of the arriving signal. The distinction is between a ‘clear’ signal and a signal which is affected by diffraction effects. Such signals generally have lower C/N0 values than ‘clear’ signals at the same azimuth and elevation. The envelope of the highest C/N0 values represents the best signal quality to be achieved at a certain GPS site. If such diffraction effects are not recognized, the GPS results can be significantly distorted and may even lead to wrong estimates. However, it is indicated that diffraction effects (compare the C/N0 values in reference vs. rover points) reduce the power of GPS signals. Similar to the SIGMA-ε model, the SIGMA-Δ model weighs phase observations with C/N0, the difference between the measured C/N0 and the expected C/N0 (C/N0 matrix), Δ value. The SIGMA-Δ model is an excellent model to reduce signal diffraction effects [1], [3], [7].

GRAZIA is a kinematic GPS software based on Kalman filters with various data modeling functions for high accuracy. Meanwhile, a number of models have been implemented for data clearing and systematic error reduction. The performance of the filter can be adjusted depending on the specific application. In principle, SIGMA uses the measured carrier-to-noise intensity ratio (C/NO) to model the variances of the GPS signals’ phase. Signal diffraction (attenuation) leads to unusually low C/NO values and is considered to be a systematic error in the variance matrix of phase data. The effectiveness of the SIGMA model reduces the signal diffraction effects on static and kinematic GPS results [1], [3], [7].

The purpose of this study is to show how deciduous trees affect the position accuracy of GPS in May and October.

2. Materials and Methods

The study was carried out in the Alpine region of Navistal, Austria (Figure 1). A geodetic network consisting of 6 (six) stations was determined using static GPS measurement methods. GPS data was collected with six GPS receivers (P1, P2, P3, P4 and P6 Ashtech Z12 receivers, P2, P5 Ashtech G12 receivers and Ashtech choke ring Antennas (DM)). The minimum elevation cut-off angle and the sampling rate were 5 degrees and 5 seconds (15–16 October 2002) and 10 seconds (13–14 May 2002), respectively [2], [7]. Two measurement sessions were carried out and the leaves and density of the deciduous trees were increased in May session but not in October session. The sky over two points was tipically obscured in May by the natural, mixed forest coniferous and deciduous tree canopies that dominated the study area; in October, the trees were defoliated.

Firstly, the GPS data was processed using the GRAZIA GPS processing software. In this section, the baseline (P1–P5) is very close to the forest area. The purpose of these experiments was to identify the signal diffraction effects at a GPS location near the forest area. The antenna of base station (P1) was located near the forest and the antenna of rover station (P5) was installed near the forest (Figures 1 and 2).

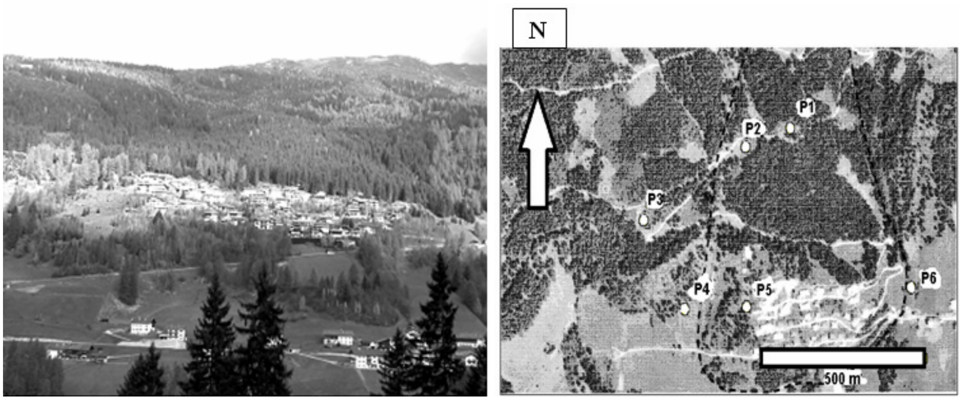

Fig. 1. *Project area (left) and GPS network in the project area (right)* [2], **[**7*]*

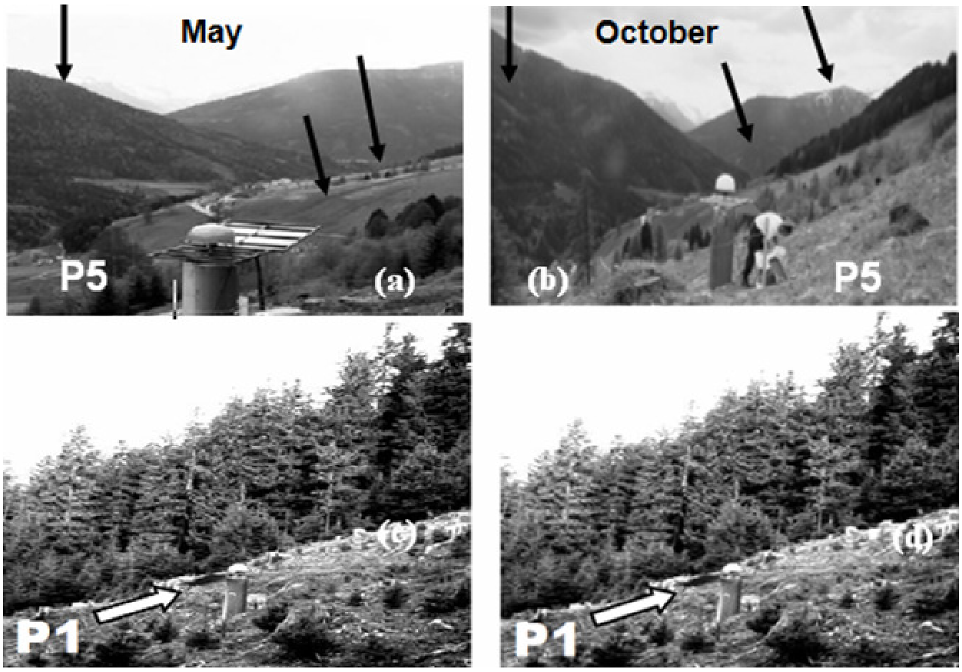

Fig. 2. *Point 5 (a, b) and Point 1 (c, d)* **([2])**

The trees were serious obstacles as they occluded almost 20% of the sky (Figure 3). Two satellites (PRN 1, 13) were shaded by the trees (Figure 3 [2], [7]).

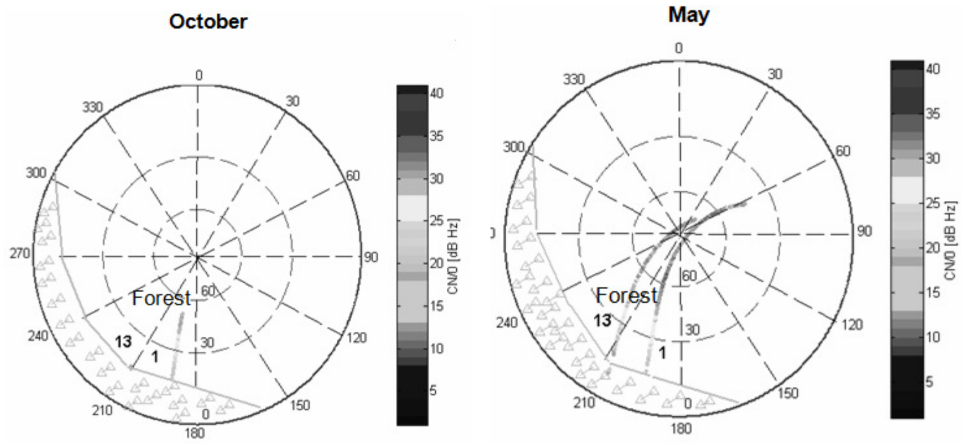

Fig. 3. *Skyplot, C/N0, Elevation graphics of the rover point, P5 in October and in May*

3. Results

As an obstacle, the forest mainly caused shading of the satellites and signal diffraction effects, as seen in Figure 3 (PRN 1, PRN 13). When the satellites disappeared behind the trees between 13:00 and 15:00 hours, the pair showed a residual degradation. As soon as the satellites were obstructed by the trees, the double difference residuals showed strong fluctuations. These were due to the irregular signal distortion effects caused by the leaves and branches of the trees. The maximum differences were several cm. This pattern can be found for all the tree-shaded satellites, for example Double Difference Residues of PRN 13 (Figure 4). Diffraction is shown with a below-expected refraction (diffraction loss) of C/NO values and an increase in signal path length. For large objects, C/NO falls almost below the detection threshold when the line of sight directly to the blocked satellite is away from the edges of the object. Satellites can no longer be observed.

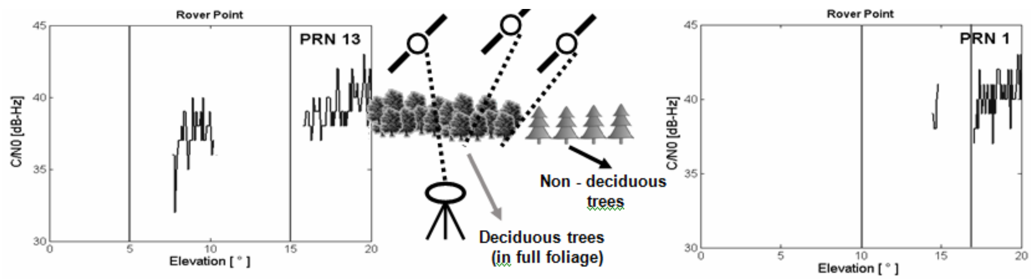

Fig. 4. *C/N0 and elevation graphics of the baseline P1–P5 in May (rover point, P5)*

C/NO values of PRN 1, 13 are shown in Figure 5. C/N0 values fluctuated when satellites (PRN 1, PRN 13) were hidden behind the trees. These results were caused by irregular signal degradation effects by the leaves and branches of trees. PRN 13 and PRN 1 satellites were initially observed at a low altitude in the blocked area of the sky in October (Figure 3). The satellites began to disappear behind the trees between 2:00 and 4:00 hours. DDR values showed an increasing bias as soon as the satellites were obstructed by the trees. This was due to the irregular signal distortion effects caused by the leaves and branches of the trees. The maximum differences were of few cm (Figures 5 and 6).

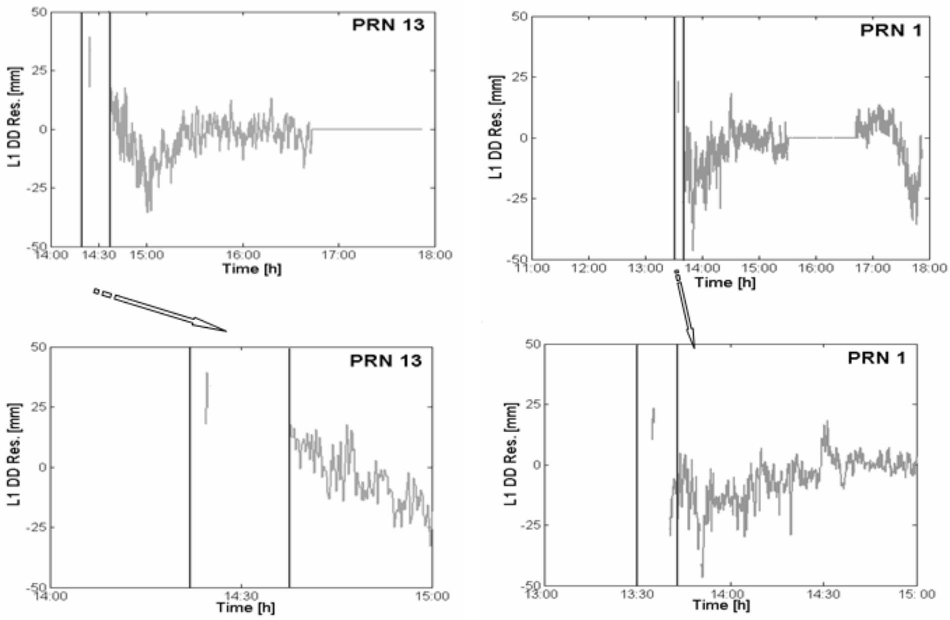

Fig. 5. *DDR L1 (Double difference residuals L1) in May graphics of the baseline P1–P5 (rover point, P5)*

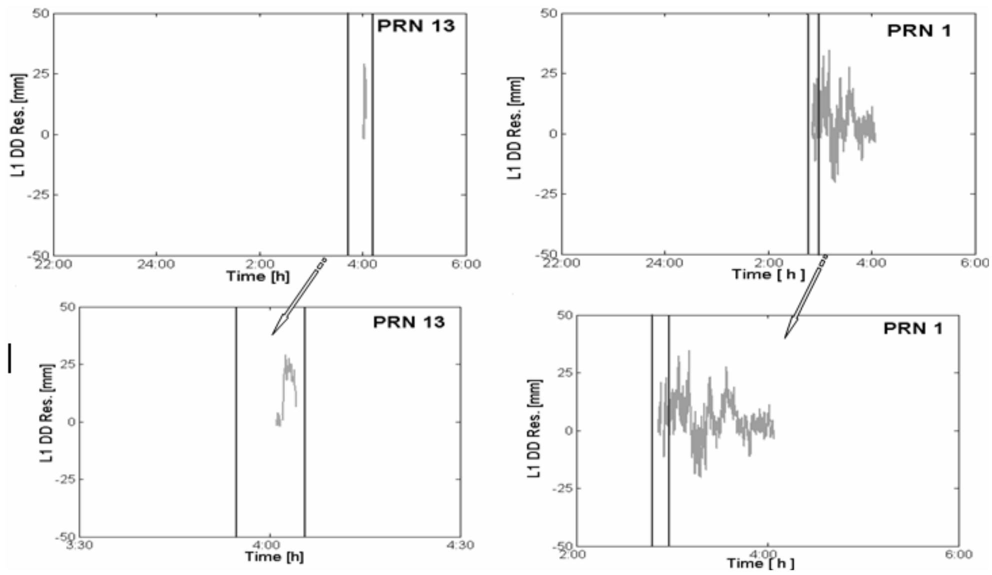

Fig. 6. *DDR L1 (Double difference residuals L1) in October graphics of the baseline P1–P5 (rover point, P5)*

The C/N0 values of PRN 1, 13 can be seen in Figure 7. Once the satellites (PRN 1, PRN 13) were deeply hidden behind the trees, their C/N0 values showed fluctuations. These situations occurred because of the irregular signal distortion effects caused by the foliage and the tree branches.

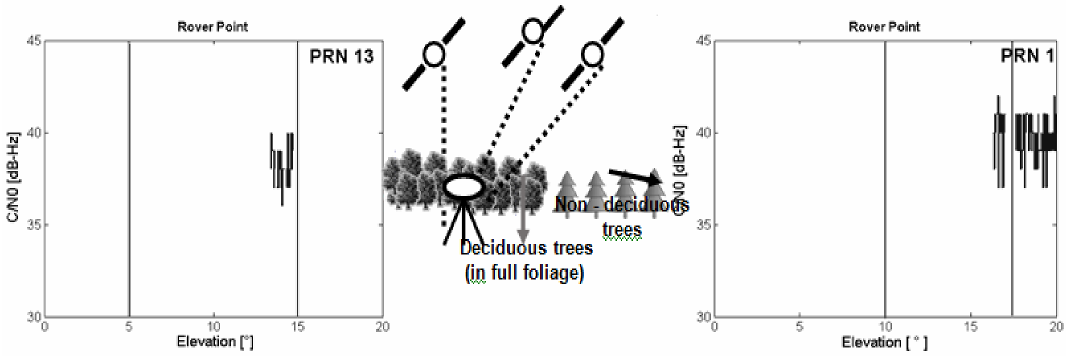

Fig. 7. *C/N0 and Elevation graphics of the baseline P1–P5 in October (rover point, P5)*

In spring (May), the tree cover can be much thicker than in autumn (October). In spring, the density of leaves is much higher than in autumn. As a result, positions are calculated from weak signals and tend to be less accurate. The effects of the forest crowns (deciduous trees) and season (survey time) can significantly affect the accuracy of the GPS positions (Figure 8).

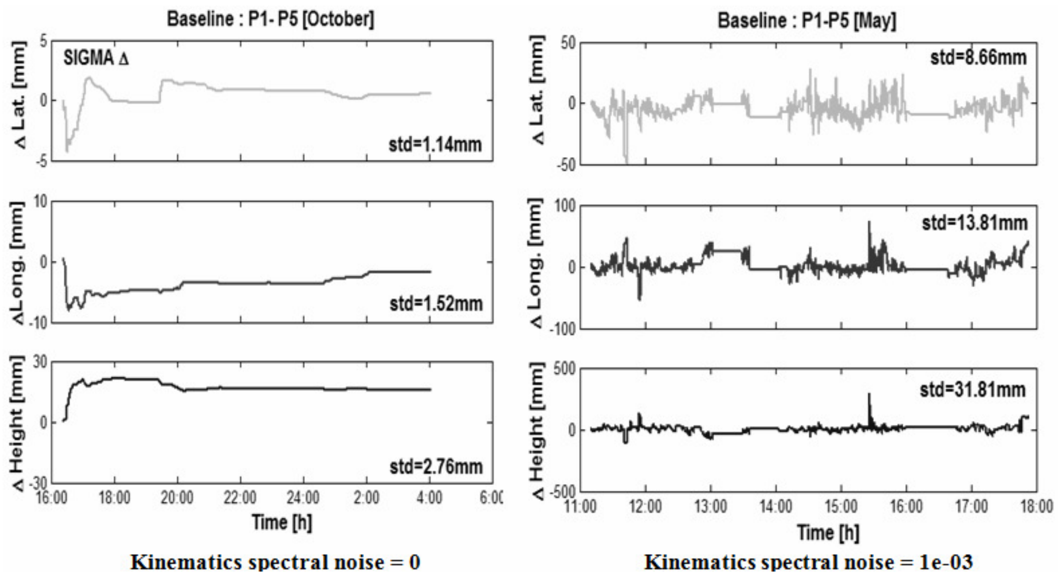

Fig. 8.*The standard deviation graphics of coordinate differences in May and October surveys (using GRAZIA software and SIGMA Δ model)*

GRAZIA software was used for processing the measurements of the baseline (P1–P5) in May and in October. The standard deviation of the measurements in May is high, but not in October (Figure 8). These results show, therefore, that season (in the case of deciduous trees) and the density of foliage are very important parameters for GPS accuracy and productivity.

4. Conclusions

The effects of forest vegetation (deciduous trees) reduce the accuracy of GPS positions. The effects of a forest on a GPS signal include diffraction, attenuation, and reflection. For data collected in May, the leaves and density of deciduous trees were increased and it became more difficult to take GPS measurements near the forest. Signals were affected by the canopy and of course this influenced the quality of computed positions. Deciduous trees (density of leaves) have been shown to cause a much stronger signal attenuation in May. In this case, DDR values showed an increased bias due to weak signals. The standard deviation of the measurements taken in May is 1-3 mm, but 9-32 mm in October. Seasonal variation effects on the accuracy of baselines components were analyzed. The obtained results showed that seasonal variation is a significant factor for determining the accuracy of GPS surveys.

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