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GNSS DIRECTION FINDING

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Abstract. GNSS receivers provide position information in a convenient way. However, additional orientation information cannot be fulfilled directly by a single antenna receiver up to now. This paper describes an approach for determining the orientation by a single GNSS receiver based only on its own static observations. As estimable base quantity, satellite positions are used as a reference in the moment of measuring. For that purpose the direction of each satellite's signal has to be known in relation to the antenna. In order to obtain this information, the signal strength of each satellite is measured. A systematical modulation of the signal, realized by rotating shading, is able to provide the required direction information approximately.

Keywords: antenna orientation, GPS-compass, azimuth, GPS direction finding.

1. Introduction

Satellite positioning is a widespread and common method for determination of coordinate positions. In case only position is required, GNSS provides an ideal tool. However, orientation information, i.e. azimuth, cannot be observed by static GNSS. Two well established methods allow calculating the orientation of GNSS receivers. However, they require that either the receiver is moving, or two antennas or more are used. First, these methods are shortly described followed by the main part, where our approach is introduced and discussed.

2. Direction finding while moving

While a GNSS receiver is moving, its heading can be calculated by the direction of movement. The actual orientation is determined by previous positions. Using methods like Kalman filtering, which make use of several previous positions, can lead to good results (Fig. 1). While the GNSS receiver is mounted on a vehicle like a car, train or an aircraft, the pre-known dynamics of the movement can be used to improve the actual orientation information. The better the dynamic of the movement, the better the orientation can be determined. A basic requirement to the dynamic is that rotation on its own axis can be excluded. In this specific case an orientation cannot be calculated by the previous positions.

3. Direction finding by using two or more antennas

In this example two antennas are required. This method is often used by static measurements, when the receiver is not moving, or, as mentioned before, when the receiver is often turning on its own axis. Such as case is found, for example, in machine guiding, where an excavator is to be guided by GNSS. Therefore, mostly two antenna systems are implemented nowadays. Two antennas are mounted on a known baseline (Fig. 2). Using both antenna positions, orientation of the baseline can be determined.

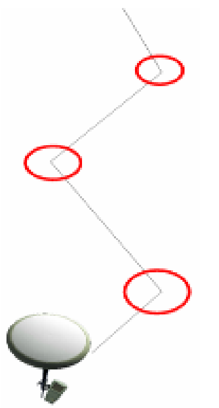

Fig. 1. Moving antenna

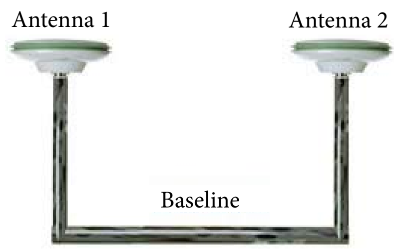

Fig. 2. Antennas on baseline

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Another application is azimuth determination over longer baselines. Here one receiver is placed at the instrument location and the other at the target. The length of the baseline is variable. This method is supposed to replace traditional astronomical azimuth measurements with a high accuracy (Chang, Tsai 2006).

4. Our approach of direction finding

The traditional approach to determine orientation by stars provides the idea for our approach. In astronomy, the angle between the target and a known star is measured from the instrument loction. Knowing the exact time of the measurement allows the calculation of the star's azimuth in the local horizontal coordinate system. The astronomical azimuth of the target is given by the following equation:

$$Az_T = Hz_{\overline{TS}} + Az_S,$$

where Az_T represents the azimuth of the target, $Hz_{\overline{TS}}$ the horizontal angle target to the star and Az_S the star's azimuth.

5. Consideration

Since GNSS is operative, stars are not the only objects in space with known coordinates. Satellites are also defined through their ephemeris. So it should be possible to use satellites instead of stars.

To use satellites instead of stars, we need to be able to measure a reference angle and the angles between different satellite signals and to refer them to the antenna.

6. Signal strength

Since the basic idea, using satellites for both, position and orientation determination seems reasonable, a practicable method for direction detection of the signals is to be found. An estimable base quantity is the received signal strength of all satellites. The signal strength is derived from the measurable signal to noise ratio. The signal to noise ratio of each received satellite depends on several factors. However, assuming a short-time static measurement, the single values can remain stable.

The signal strength can be modulated as follows. By holding absorbing material between satellite and antenna, a reduction of the received signal intensity can be achieved (Fig. 3). Such shading is to show the specific characteristics to reduce the intensity of an electromagnetic wave in the range of 1.5 GHz.

By rotating the shading around the antenna the intensity is reduced depending on their angle of incidence (Fig. 4).

When the signal strength is minimal, we assume the shading exactly on the line between satellite and antenna. Hence, the shading shows the direction of the satellite. Since the satellites azimuth is known, the azimuth of the shading is estimable too.

7. Measurement setup

For measuring purposes a test setup has been assembled at ETH, shown in Fig. 5. Its principal part consists of a small GPS patch antenna. The used antenna receives the L1 signal (Zogg 2003). An attached GPS receiver calculates, based on the raw data, the navigation sentence. These

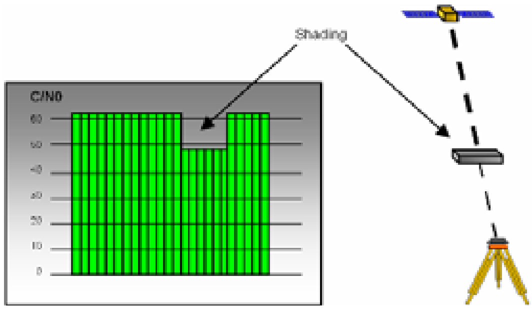

Fig. 3. Shading an reduction in dB

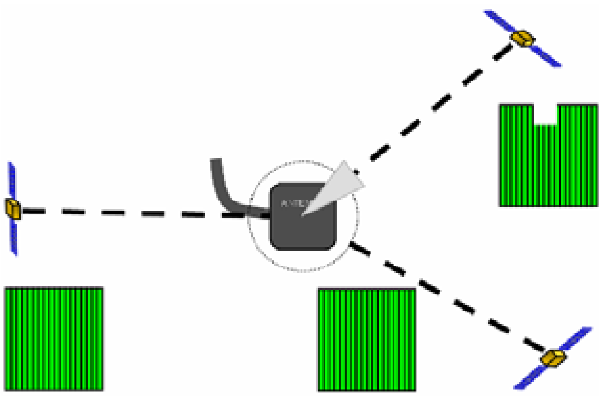

Fig. 4. Rotating shading

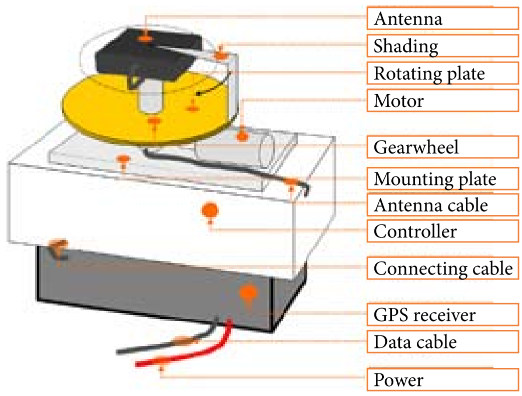

Fig. 5. Measurement setup

sentences are transmitted over RS232 using the NMEA standard. A NMEA parser extracts the signal to noise ratio and shows the signal strength for each satellite in dependence of time. Additionally, the position of the shading bracket is read out.

For the shading bracket, several metals have been tested. Aluminium appeared to have a good capacity to reduce the signal strength. However, after performing several tests, aluminium turned out not to be the best solution. It has, like all metals, a highly conductive surface, that allows a good part of the energy to get reflected. On the one hand, this effect reduces the signal strength at the antenna, but, on the other hand, the reflective characteristic does not absorb the energy, what can lead to reflecting problems. Thus, signals can be reflected back into the antenna. It is a better way to truly absorb the energy. This happens, when the energy encounters an absorbing material, which transforms a part of the energy into heat. Such materials are common to control electromagnetic influences and radiofrequency energy, e.g. in mobile phones

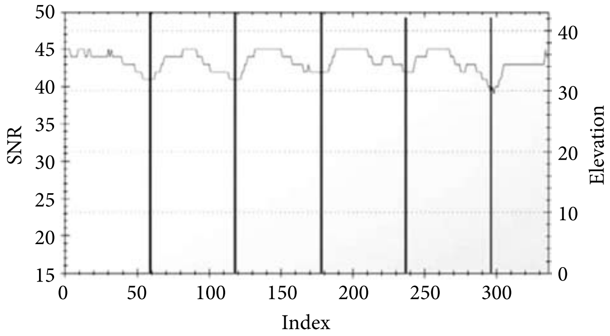

Fig. 6. Recorded signal to noise ratio

(Welch 2006). Tests with such materials have shown a similar reduction of the signal strength, measured in the antenna, such as aluminium.

8. Results

What seems to be clear in theory is not always as simple in practice. The initial results show a good preview of what is possible. Fig. 6 shows the recorded signal to noise ratio of one satellite. The curve describes the measured signal to noise ratio on the y-axis in dB, plotted by the time on the x-axis. The gaps between the blue bars mark the time of a whole revolution of the shading material. The level of these bars represents the scale of the 2nd y-axis, which is the actual elevation of the satellite.

The signal characteristic shows a clear correlation with the revolutions of the shading material. The quality of the received data differs and is not always as reasonable, as shown here. Why it is not always possible to achieve a good quality and reasonable results will be a part of further research.

9. Conclusion

This paper discussed the basic idea and some first results of our approach, which allows to determine orientation information by one single GNSS receiver. The main advantage of the described approach is that it does not require a lot of equipment. The results shown here are preliminary but are encouraging and demonstrate more potential. The results also show that some improvements need to be made. However, it is worth to invest further research in order to be capable to substitute multi-antenna systems by just one antenna in the near future.

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Research interests: GPS measurement; development and investigation of GPS-based orientation; engineering geodesy.