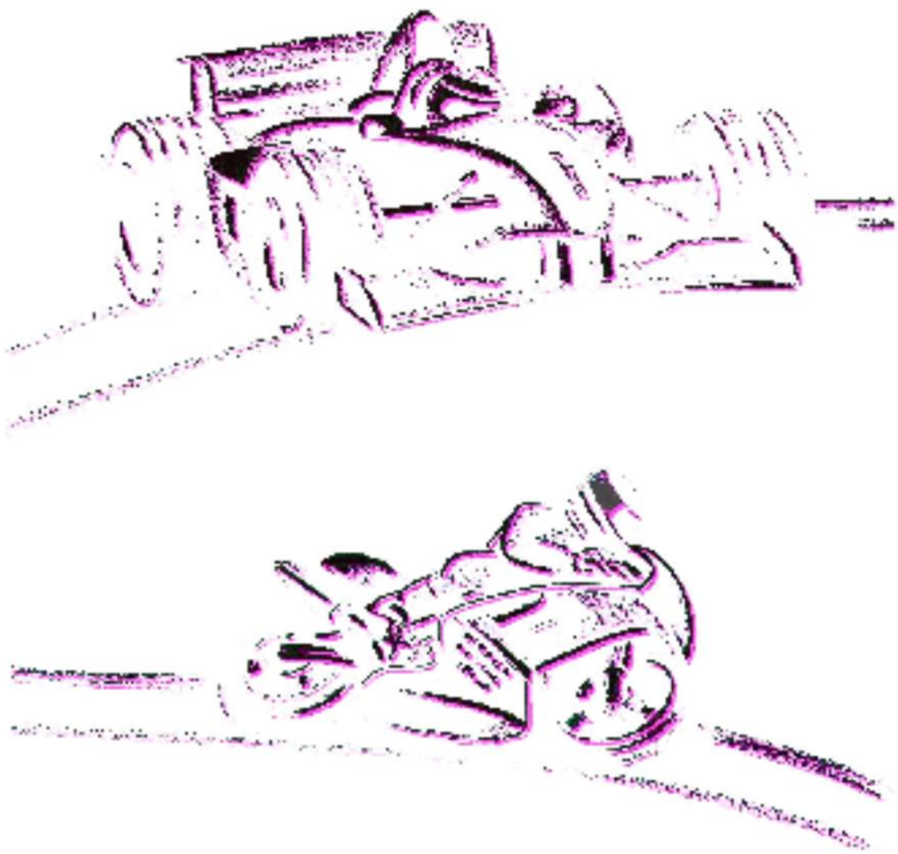
- English -



GPS/GNSS

Real Time Kinematic (RTK)

1 Revision History

Revision	Description	Release Date	Author
0	Initial Release	2023-03-20	FS

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3 Introduction

Global Navigation Satellite Systems (GNSS) are used to determine a position on earth and to receive a globally valid time signal.

The general term for satellite navigation is GNSS but the term GPS (Global Positioning System) has become a synonym for this technology, but GPS is only one of the four GNSS.

Besides GPS, there are the satellites systems called GLONASS (Russian Federation), Galileo (Europe) and BeiDou (China).

The more satellites are used to determine the position, the more accurate and stable the determination of the position and thus the determination of the speed.

Documentation reference
For more information on the theory and exact functionality of GNSS positioning, we recommend the u-blox GPS-Compendium_Book

In order to improve the accuracy of GNSS reception, additional systems (SBAS – Satellite Based Augmentation Systems) have been set up, which are mainly intended to eliminate ionospheric errors in GNSS reception.

For this purpose, several geostationary satellites permanently transmit the correction values for the ionospheric error measured by reference stations.

The following errors can be compensated for with SBAS systems:

- Errors of the satellite clocks
- Satellite orbit errors
- Ionospheric errors
- Errors due to operational disturbances of individual satellites

However, for normal GNSS receivers the positional accuracy is not precise enough for some applications!

Further Information
A detailed overview over the existing modules can be found on the products area on our website or the overview can be downloaded by clicking here!

Important information
Precision is not only the most important point when using GNSS, especially in racing and other sports it is also important for also having good dynamical capabilities of GNSS signal!
For more information about the importance **GPS/GNSS dynamics** please see manual **Revision of GNSS modules** on our website:
http://2d-datarecording.com/downloads/manuals/

3.1 Real Time Kinematic (RTK)

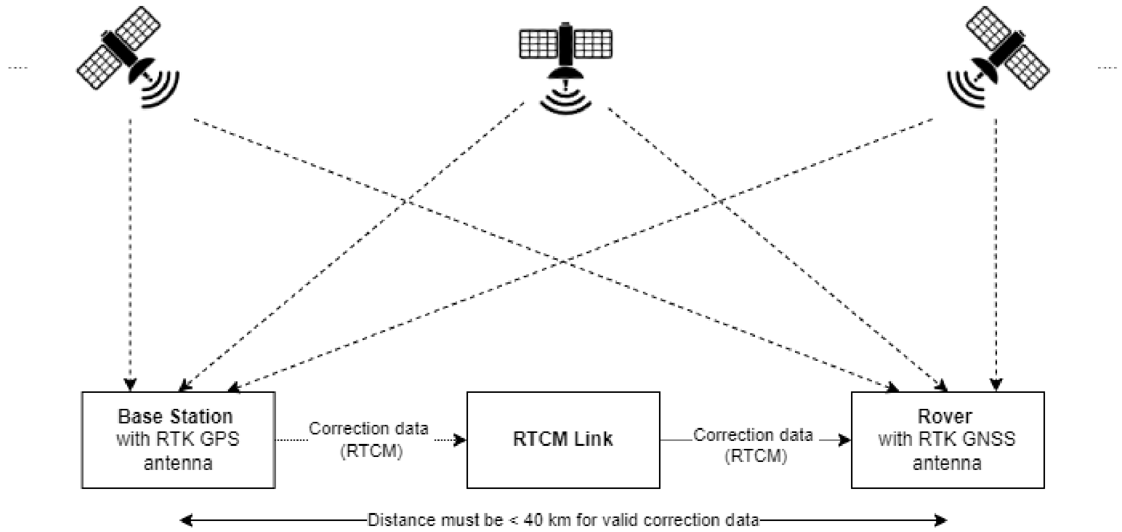
Real Time Kinematic (RTK) is a technique used to enhance the precision of position data derived from Global Navigation Satellite Systems (GNSS), such as GPS, GLONASS, BeiDou or Galileo.

In order to achieve a positional accuracy of **±1cm** so-called correction data is used which is generated by a (usually locally fixed) Base Station. The correction data fundamentally is the difference between an exactly known and currently detected GPS/GNSS position of Base Station and is caused by ionospheric errors and thus are responsible for the GPS/GNSS position deviations between actual position and detected position of GPS/GNSS receivers. The errors affect all GPS/GNSS signals in a given area equally (~ radius 20 km around Base Station).

Via the RTCM Link the RTCM (Radio Technical Commission for Maritime services) correction data is transferred from Base Station to the moving GPS/GNSS receivers called Rovers. By internally applying it in Rovers to the received GPS/GNSS positions, the Rovers positional accuracy is reduced to **±1cm.**

A GPS/GNSS RTK system consists of the following components:

Glossary	
Base Station	A GPS/GNSS receiver for acquiring correction data
RTCM Link	A medium to transport the correction data stream from the **Base Station** to the **Rover**
Rover	Moving GPS/GNSS receiver which uses correction data to increase the accuracy of position data up to (**±1cm**)!



Similar to the normal reception of GNSS satellite signals, the transmission time and thus the distance between satellite and GNSS antenna is also determined, but with RTK the sinusoidal signal transmitted by the satellite is evaluated for the current carrier phase of this signal. Therefore, the accuracy of transmission time is highly increased, what results in high accurate distance between satellite and module! If the now more precise distance between satellite and GNSS antenna is received by several satellites, the position of the GNSS antenna can be determined via triangulation, as with the usual GPS/GNSS, with RTK to a positional accuracy of **±1cm**.

When using RTK, the external conditions (shielding of the satellite signal by houses, trees, ...) as well as the weather conditions (sunny, cloudy, ...) play an even greater role than with normal GNSS antennas, since these external influences degrade the received sinusoidal signal and thus make carrier phase detection more difficult.

4 RTK applications

As soon as **highest positioning accuracy in dynamic situations** is necessary, it is recommended to use the 10 Hz RTK module with correction data to achieve a positioning accuracy of up to one centimetre. However, precision is not only the most important point when using GNSS, especially at brake/acceleration tests, racing and other sports it is also important for also having good dynamical capabilities of GNSS.

The 2D RTK Rovers are suitable for applications **with normal dynamic requirements** and **laptiming via GNSS**, like the normal 10 Hz modules.
For RTK use a good antenna mounting is necessary as RTK operation require higher signal quality.

Due to their very small and robust design and the antennas connected via cables, the 2D RTK modules (2D mobile RTK Base Station & 2D RTK Rover) can also be used very well in applications with very limited installation space. The use of up to two antennas on one rover or the use of several individual rovers in conjunction with the 2D analysis software allows a wide range of applications to be realized!

Automotive

- Tests and validation of Advanced Driver Assistance Systems (ADAS)

  With two individual 2D-RTK-Rovers (**two antennas** on **two vehicles**) the directional vector between them can be calculated with 1 cm accuracy up to 250 km/h, due to 2D's proprietary GPS/GNSS position correction algorithm, e.g., for active cruise control validation.

- Slide slip angle

  With Rover with two 2D-RTK-antennas (**two antennas** on **one vehicle**) the directional vector between them can be calculated with 1 cm accuracy up to 250 km/h, due to 2D's proprietary GPS/GNSS position correction algorithm, e.g., for slide slip angle calculations

- Vehicles inclination/tilting while driving

  With Rover with two 2D-RTK-antennas (**two antennas** on **one vehicle**)

- Full three-dimensional trace of driving line

Racing

- High accuracy driving line analysis
- Distance to Apex calculation
- Track limit calculations
- Jump height detection (Motocross)

Industrial

- Bending of crane booms under load
- Load positioning (ships, forklifts, cranes, …)
- Ship loadings
- Autonomous vehicles/objects

5 RTK components

5.1 Base Station

Base stations generally consist of a RTK GPS/GNSS receiver that detects the current GPS/GNSS position and compares it to the actually known position of the base station to create what is called correction data. Simply, the correction data is the difference between the known position and the detected position, which is caused by various types of errors in the GPS/GNSS signals and affects all GPS/GNSS signals in a given area, and thus also the signals received by Rovers. The errors are responsible for the GPS/GNSS position deviations.

Through an interface, this correction data is transmitted in a standardized data transfer format called *RTCM* (Radio Technical Commission for Maritime services) to the Rover(s) to improve their positional accuracy.

2D offers its own mobile base stations (Datasheet), which are very easy to set up, can be easily transported and be used as stationary as well as moving Base Station!

Normally 2D mobile (transportable) Base Stations are used at serval testing grounds and thus are not mounted fix on one point. Therefore, it can work in Survey Mode to use the connected GPS/GNSS antenna to detect its own position from this GPS/GNSS data and use it as “known position” for creating correction data.

Glossary	
Correction data	Created by Base Stations to correct errors applied to GPS/GNSS signals due to ionospheric errors. Correction data is only valid around 40 km around respective Base Station and transferred via RTK Link to Rover(s) in a standardized data transfer format called *RTCM* (Radio Technical Commission for Maritime services).
Public Base Station	Public institutions such as universities or other research facilities often provide correction data from their own surveyed base stations for a fee.
2D mobile Base Station	2D offers its own mobile base station with its own power supply due to its robust, waterproof and compact design. Can be used as stationary but easily transportable Base Station when RTK should also be available far away from other (public) Base Stations. By Survey Mode own position is detected as “known position”.
Survey Mode	Detecting static GPS/GNSS position of Base Station over longer time period (e.g., 5 minutes) to use the position as “known position”.

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5.2 RTCM Link

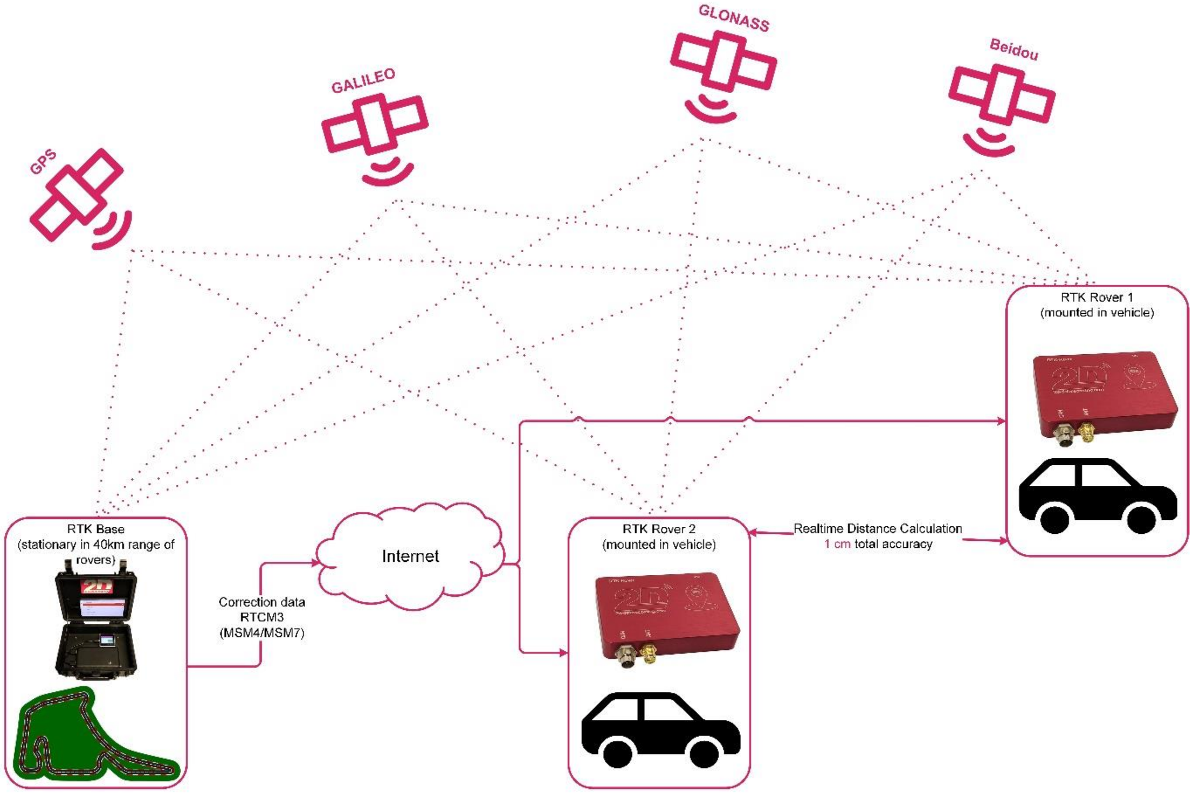
RTCM link is a medium to transport the correction data stream from the **Base Station** to the **Rover(s)**.

At 2D Base Stations basically three options are available to transfer correction data:

- Transfer via **Internet**
- Transfer via **Radio Frequency (RF)** (1-20 km, depends on local restrictions)
- Transfer via **direct Wi-Fi link** (< 250 m)

5.2.1 Via Internet

Both the 2D Base Station and 2D RTK Rover modules have built-in Wi-Fi that can be set via a user interface to connect each module to a local Wi-Fi or mobile hotspot (multiple Wi-Fi connections configurable) to upload (Base Station) or download (2D RTK Rover) correction data to a 2D-hosted Internet server to establish the RTCM link via internet between Base Station and Rover(s).



5.2.2 Via Radio Frequency (RF)

Also, 2D Base Station and 2D RTK Rover both have the option to use 433/866/2400 MHz radio frequency transmission for transferring correction data from Base Station to Rover(s) for local operation up to 20 km operation radius, without requiring any internet connection at all. Use of RF depends on local restrictions.

5.2.3 Via direct Wi-Fi link

Instead of transferring correction data via RF in local operation without any internet connection, also the Wi-Fi interfaces of the 2D modules can be used in combination with external antennas to set up the RTCM Link via Wi-Fi point-to-point connection (< 250 m) via 2D Base Station and 2D RTK Rover(s).

5.3 Rover

GPS/GNSS receiver which uses the received correction data to increase the accuracy of their position data up to **±1cm**! The 2D-RTK-Rover(s) must be connected to RTK Link to receive correction data which is applied online in module to the received GPS/GNSS signals to achieve the high accuracy.

Also, **without** suppling correction data the RTK GPS/GNSS module they can be used as normal GPS/GNSS receivers with general positional GPS/GNSS accuracy.

The outstanding small and very robust design of the 2D-RTK-Rover (Datasheet) also makes it suitable for projects with very limited installation space like motorcycles or mountain bikes. The actual RTK GPS/GNSS antenna can also be mounted very well outside the vehicle or at exposed locations of the test vehicle via the cable connection to the actual rover module (up to 5 m cable possible).

2D Rovers also accept correction data provided by publicly operated base stations (e.g., RTK2GO) can also be used.

5.3.1 2D-RTK-Rover-Types

2D-RTK-Rover via CAN (Datasheet)	
RTCM Link	To receive correction data the module can be connected to internet via the built-in Wi-Fi to receive the correction data from server hosted by 2D or using a RF antenna.
Processing	The correction data is applied online in Rover to the received GPS/GNSS signals to achieve the high accuracy.
Output	2D-RTK-Rover outputs the already corrected GPS/GNSS data as normal as CAN messages on CAN-bus to log them in any 2D Logger. 2D-RTK-Rover with CAN-output can be connected to any point of CAN-bus system.
GNSS-Rate	10 Hz (GPS, Glonass, Galileo, Beidou)
Comment	2D-RTK-Rover offers the possibility to connect 2 antennas, so with **two antennas** on **one vehicle** the directional vector can be calculated, e.g., for slide slip angle measurement.

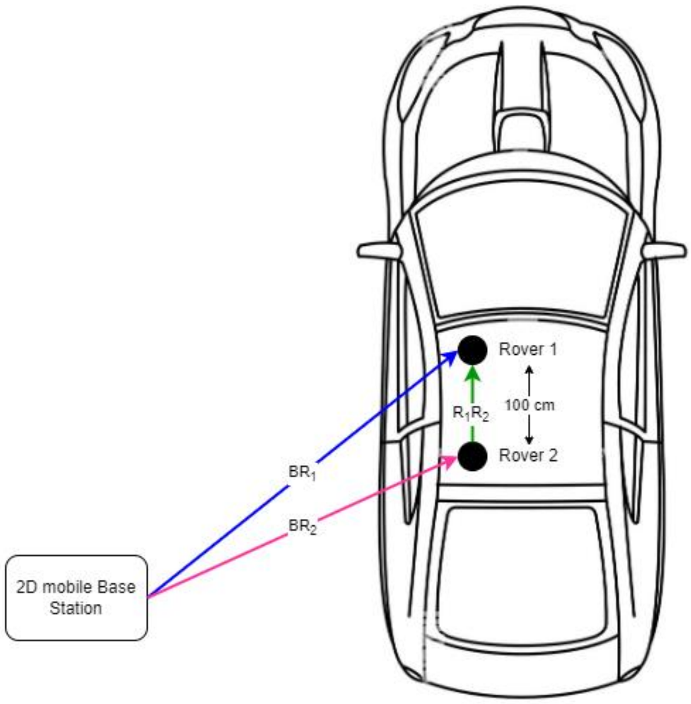
2D-RTK-Rover via serial Port (e.g. Sticklogger V4w RTK)	
RTCM Link	As interface to RTCM Link a Sticklogger with internal Wi-Fi interface (e.g., SLV4w RTK) can be used which hotspot is connected to internet to receive correction data and directly apply it to on serial port incoming GPS/GNSS data.
Processing	The correction data is applied online in Sticklogger to the received GPS/GNSS signals to achieve the high accuracy.
Output	Sticklogger V4w RTK directly stored corrected GPS/GNSS data.
GNSS-Rate	10 Hz (GPS, Glonass, Galileo, Beidou)
Comment	All in one logging and RTK module with all known Sticklogger functionalities

Further Information
Please contact 2D via email mail@2d-datarecording.com for customized advice on the 2D RTK Rover module that is right for your application!

5.3.2 Base line vector between two Rovers (Proof of Concept)

In 2D-Rover-Systems various channels are available as well as distance channels which are providing the current distance (as vector **BR_1** & **BR_2**) between Rover and Base Station. By having all distances of Rovers to Base Station (no matter if moving or stationary) also the vector **R_1R_2** between the Rovers and thus the distance can be calculated with a +/- 1 cm accuracy.

For testing two individual 2D RTK Rover systems were placed on a car´s roof with a distance of 100 cm (base line) between the Rover antennas:



Under real urban driving conditions without houses, trees and bridges 2D RTK system is able to determine the distance between two GNSS modules (rovers) with an accuracy of base line of almost +/- 1 cm up to a speed of 300 km/h.

5.3.3 ADAS setup

This proof of concept is transferrable to the application when the two Rovers are **not** placed on same vehicle like in ADAS tests.

By knowing the position of Rovers on vehicle all distances between different points of cars chassis can be calculated: