



## **APN-041: Network RTK**

# Overview

This application note includes background information on Network RTK and general guidance on how to use it. The majority of the content in this application note is from a distribution report done for NovAtel Inc. titled *Network RTK Status Western Europe* by Hans-Jürgen Euler from *inPosition gmbh*<sup>1</sup>.

## 1.1 About Network RTK

Network RTK development started over ten years ago with the introduction of real-time GPS baseline solutions. Around the world, there were activities surrounding Network RTK but in Germany, the idea to install permanent base stations for high-precision RTK applications was fostered. Network RTK uses permanent base station installations, allowing kinematic GNSS users to achieve centimeter accuracies without the need for setting up a GNSS base station on a known site.

Using permanent base stations is advantageous in areas with considerable GNSS surveying activity because many users can share the infrastructure and the associated costs. Some of the installations are operated by companies that provide service to the surveying community. Installations can be a single base station, a number of single base stations, or networked base stations. A single base station within 20-30 km from the rover is typically required if a user is operating in a standard base to rover mode. Otherwise the performance, accuracy, and the reliability of user's RTK may be degraded.

For the base operator, networking reduces the number of base stations that are needed to provide a given level of accuracy to the rover so integrating several base stations into a network improves the accuracy and increases the overall user system performance. Networking also reduces the number of base stations required to cover a large area. These permanent base station networks require real-time communication to a networking computation center and real-time estimation of biases between bases.

An understanding of applied corrections or the processing procedure is also very important because the installations rely on proprietary computation algorithms and formats that could restrict the field equipment. It is in the interest of service providers to supply the service for more than a single type of RTK field equipment.

Many Network RTK methods exist, but currently, VRS (Virtual Reference Station), iMAX, FKP (Flächen Korrektur Parameter - the German phrase for spatial correction parameter) and MAC (Master-Auxiliary Concept) are the most common.

The calculations required to produce the observation information follow these principal sequences for data handling:

1. Base station observation information transfer to a central location.
2. Integer ambiguity resolution for observations between base stations.
3. Fit model parameters to deviations.
4. Determination of corrections for rover position and correction of observations.
5. Calculation of the rover's position based on its observation information and network information.

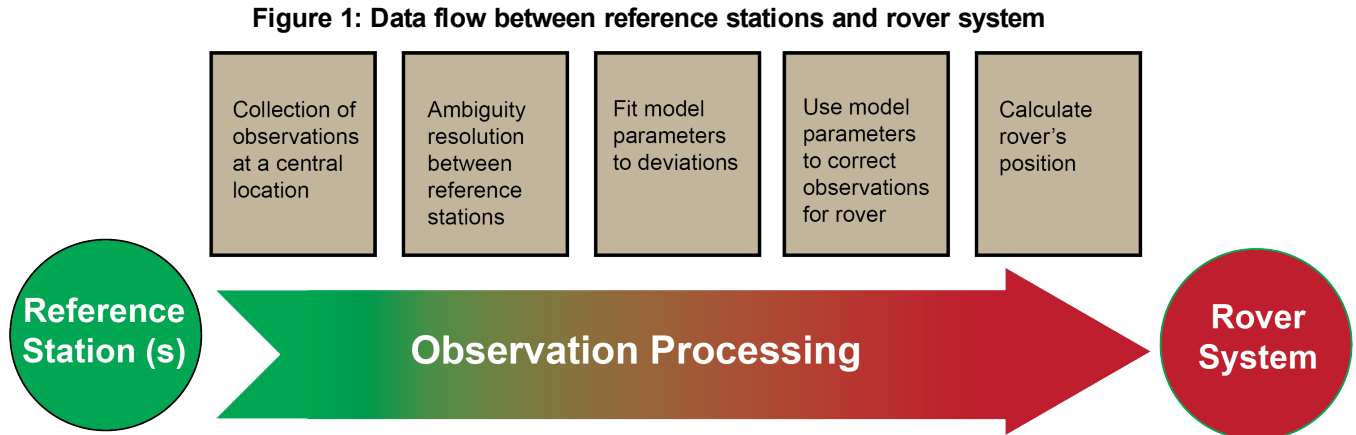
These principal steps are used by different Network RTK software and remote firmware. Some of these calculation steps might be combined into one step, but this does not change the overall principle. See *Figure 1: Data flow between reference stations and rover system* on the next page.

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<sup>1</sup>Hans-Jürgen Euler (December 2005), Reference Station Network Information Distribution. International Association of Geodesy Commission 4: Positioning & Applications. Retrieved October, 2007 from, **IAG WG 4.5.1: Network RTK**.

## 1.2 Independent RTCM Format

Traditionally, the communication interface between different manufacturers' GNSS equipment is the manufacturer independent RTCM format. Networking services based on either FKP or VRS approaches provide the observations via the RTCM standard, but are currently operating in a mode not defined in the standard document and/or disseminating additional information in a proprietary message. RTCM delivers a container (message type 59) for proprietary information, but the content is not specified in the standard.



The previous figure shows the sequence of operations and calculations required until a rover's position is calculated. Current network approaches are to distribute the principle calculations between the software of the network and the rover. As long as calculation steps are performed within the same software, these steps can be combined into one step. For more information on these steps, refer to [Reference Station Network Information Distribution](#) by Hans-Jürgen Euler.

## 1.3 Network RTK Methods Supported by NovAtel Receivers

### 1.3.1 VRS

The virtual reference station (VRS), or virtual base station (VBS), method, introduced by Trimble, calculates a set of corrections from a virtual base station in the vicinity of a rover receiver. All baseline-length-dependent errors, such as abnormal troposphere variation, ionospheric disturbances and orbital errors are removed from the VRS because the virtual base is so close to the rover. The rover sends the position to the network in a standard NMEA (National Marine Electronics Association) GGA message and the network software calculates the position of the VRS. The VRS corrections are sent back to the rover and the rover calculates its position. Most rovers receive VRS data for a calculated base station that is only a few meters away.

VRS data is supplied as RTCM messages RTCM1819 or RTCM2021 and RTCM V3 messages RTCM1003 and RTCM1004 .

The VRS approach requires bi-directional communication for supplying the rover's position to the networking software.

### 1.3.2 iMAX

The iMAX method, introduced by Leica Geosystems, calculates a set of corrections based on the rover position, similar to VRS. However, instead of calculating the base station observations for a location close to the provided rover position, original observation information is corrected at the base station position and sent to the rover in a compact form. In VRS, use of a virtual base station, close to the rover, may disguise the residual ionospheric errors in the base observations. However, iMAX provides actual base station position information therefore, the

real distance to the base can be computed from the base station coordinates, and the rover may be able to open its settings to estimate the remaining residual ionospheric delay. The iMAX method may trigger the rover to open its settings further than required since the networking software removes at least part of the ionospheric disturbances. However, compared to VRS above, this approach is safer since it notifies the rover when there might be baseline-length-dependent errors in the observation information.

iMAX uses RTCM 3.0 Network RTK messages and requires bi-directional communication to the networking software for supplying the base station observation information.

### **1.3.3 FKP Reference Station Information**

The FKP method is another approach that delivers the information from a base station network to the rover. No precise knowledge of the rover's position is required for providing the correct information. The corrections are deployed as gradients to be used for interpolating to the rover's actual position. RTCM Version 3 transmits the GPS gradients through message 1034 and GLONASS gradients through message 1035. Refer to RTCM Standard 10403.1 for details regarding the layout of each message.

In contrast to VRS, FKP can be used for broadcast installations. Bi-directional communication between the rover and the network is not mandatory, but for large networks different access numbers or points are required. When bi-directional communication is available, FKP installations require NMEA coordinates. These positions are used to determine the most suitable base station FKP constellation for the user. The advantage of this is that only one access point is required to cover the whole network. This is important for users covering large regions with different base stations close to the working area.

### **1.3.4 Mac (Master-Auxiliary Concept)**

The basic principle of the master-auxiliary concept is to provide, in compact form, as much of the information from the network and the errors it is observing to the rover as possible. With more information on the state and distribution of the dispersive and non-dispersive errors across the network, the rover is able to use more intelligent algorithms in the determination of its position solution. Each supplier of reference station software will have their own proprietary algorithms for modeling or estimating these error sources. The rover system can decide to use or to neglect the network RTK information depending on its own firmware algorithm performance.

MAC uses defined RTCM messages so, in theory, each installation should be identical and have no proprietary messages. The formats of these messages are still under discussion by the RTCM standards committee but once they are defined and the initial algorithm implementation is complete, it will be easier for manufacturers of rover equipment to support MAC.

## **1.4 Commands**

The **RTKNETWORK** command sets the RTK network mode for a specific network. For information about this command, refer to the **RTKNETWORK** command in the [OEM7 Commands and Logs Reference Manual](#).