ISSN 1407-7345 GEOMATICS ĢEOMĀTIKA 2009-7345

RTCM3.1. MĒRĪJUMU TRANSFORMĀCIJAS ZIŅOJUMA STANDARTS GNSS POZICIONĒŠANAS DIENESTIEM

BASICS OF RTCM 3.1 TRANSFORMATION MESSAGES STANDARD FOR GNSS POSITIONING SERVICES

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Key words: Differential Global Navigation Satellite Systems, mathematical geodesy

1. Introduction

The use of RTK (Real Time Kinematics) in GNSS reference station networks has become the general tool and quickly spreading solution for high precision positioning using Global Navigation Satellite Systems (GNSS). The RTK network approach is the evolution of single base RTK positioning technique, which achieved a RTK cm-solution only in the close range up to 20 km and sub-meter accuracy else by using GNSS positioning. The GNSS measurement for the rover is not the end target for the GNSS user. The reason is that coordinates derived by the RTCM observations corrections provided by the GNSS service in a VRS, ACP or MAX mode of representation are related to the ITRF (International Terrestrial Reference Frame System) based Coordinate Reference System (CRS) of the GNSS-service. This CRS is related to a past ITRF-datum and plate stand, such as e.g. ETRF89 in Europe. In that way it is in a sufficient consistency with the GNSS satellite orbits for the DGNSS-operation mode of a GNSS-service. The GNSS-service users however need to transform that ITRF-based RTK-position (X,Y,Z) - the source CRS in the sense of the RTCM-transformation messages – as the result of the receiver RTK-algorithm using the receivers code and phase measurements together with the service's RTCM corrections to another horizontal and vertical CRS, the so called target CRS. The RTCM transformation messages provide the respective transformation information concerning the transition from the ITRF-based source CRS to the horizontal and vertical target CRS. These user requirements motivated the RTCM (Radio Technical Commission for Maritime Services) SC104 (Special Committee 104 Differential Global Navigation Satellite Systems (DGNSS)) to include in the RTCM correction message, an additional set of transformation messages, enable transform the user of a GNSS service to the plan position and the physical height the target system. The transformation itself is represented by a set of transformation parameters (general trend) associated with a grid of three-dimensional residuals. The essential characteristics of the RTCM transformation messages is, that any existing reference transformation for the 3D (plan and height transition), 2D (horizontal datum transition) and 1D (pure height determination) can be mapped to the grid-based RTCM transformation messages. The "gridding" of any reference transformation is to be done by generating a grid of CRS-points both in the source and in the target CRS and the split of a seven parameter-transformation and a residuals field. This can be done in tow different ways, namely the concept of a global "static grid" and the more flexible concept of a dynamic grid generation [1].

This paper describes the concept of transformation in RTCM 3.1 messages for RTK networks, the basics of mathematical geodesy used in RTCM 3.1 standards, the generation of RTCM 3.1 transformation messages at server side and the implementation of these transformation messages at the client (rover) side.

1.1 Transformation Problems

The earth-fixed ITRF-based position of a point P provided by GNSS is defined with respect to the plan position by two angles related the reference ellipsoid, namely the latitude and longitude(φ, λ), and the ellipsoidal height h. From (φ, λ) the Northern [m] and Eastern [m] are derived according to the projection type. As concerns GNSS-services the GRS80 ellipsoid (same major axis a and two parts of a millimeter the same minor b as the WGS84 ellipsoid) and UTM are presently used as reference ellipsoid and reference projection. The base of the height reference surface (HRS) is either the equipotential surface of the earth gravity field, known as the Geoid, and connected to orthometric heights H-orth, or in modern height systems more and more the quasigeoid QGeoid related to the Molodenski theory, and leading to the normal height type H-normal. The height of the HRS, namely the Geoid or QGeoid, respectively over the ellipsoid is described with N. The HRS fits to the global GRS80 ellipsoid embedded into the ITRF with undulations N of up to about ±100m.

The HRS as well as heights H are nowadays physically defined, namely via the geopotential number C_P of the earth surface point P in the earth's gravity-field together with GRS80 - related normal gravity field U (1a,b) and (2a,b). In case of the HRS type of a geoid and the related orthometric height system a model for the real gravity in the area in regard must be known with respect to the average gravity $\bar{g}_P$ from P along the plumb-line down to the geoid. As $\bar{g}_P$ is not generally available and also gives information about the interior decomposition of the earth, e.g. with respect to natural resources, the Qgeoid and the Normal-height system (1a,b) become more and more popular as the general type of a HRS and a height system, respectively.

Quasi-Geoid N_{QG} and Normal Height H_N	Geoid N_G and Orthometric Height H_{Orth}	
$N_{QG} = \dfrac{W_P - U_Q}{\gamma_Q}$	$N_G = N_{QG} - \dfrac{\bar{g}_P - \bar{\gamma}_P}{\bar{\gamma}_P} \cdot H_P$	(1a,b)
$H_N = \dfrac{W_0 - W_P}{\bar{\gamma}_P} = \dfrac{C_P}{\bar{\gamma}_P}$	$H_{ort} = \dfrac{W_0 - W_P}{\bar{g}_P} = H_N \cdot \dfrac{\bar{\gamma}_P}{\bar{g}_P}$	(2a,b)

Using RTCM observation corrections of the ITRF-based GNSS-service the GNSS receiver computes the coordinates (X,Y,Z)-ITRF/Source of P. The position (X,Y,Z)-target of a regional classical trigonometric network is related to the ITRF source system by a seven parameter datum transition (about 500 classical datum systems exist world-wide). The target reference ellipsoid (about 40 different ones are in use world-wide) is then used for the computation of the horizontal position (φ, λ)-target and the ellipsoidal height h in the target system.

The RTCM-(X,Y,Z)-target was set up with the physical heights H instead of the ellipsoidal height h-target, physical heights H again result form the datum transition together with the residuals (height indicator =1). In the area of GNSS-positioning the physical height H is received from the ellipsoidal height h-source using a geoid-undulation (N-source), which is in modern geoid- and quasi-geoid computation also related to the ITRF.

1.2 Architecture of RTK Network

The concept of permanent GNSS reference stations networks started to expand early in year 1990. The idea is based on establishment of several GNSS reference stations at points with known coordinates connected to a central server managing the whole network. The central server receives at time interval via mean of communications, the GNSS raw readings for each GNSS station and its correction, and then the server can model the error in the area, and produces the required corrections for GNSS rovers within the coverage area [1, 9].

The RTK network of permanent GNSS reference stations is an evolution of the DGPS concept based on using a baseline between a fixed GNSS reference station with known coordinates and a moving rover, where the correction of the GNSS reading at fixed GNSS station is applied at rover position to increase the accuracy of rover positioning. The RTK network establishes several GNSS reference stations that transmit their corrections to a control server that manages the whole system, and then transmits the corrections to users within coverage area.

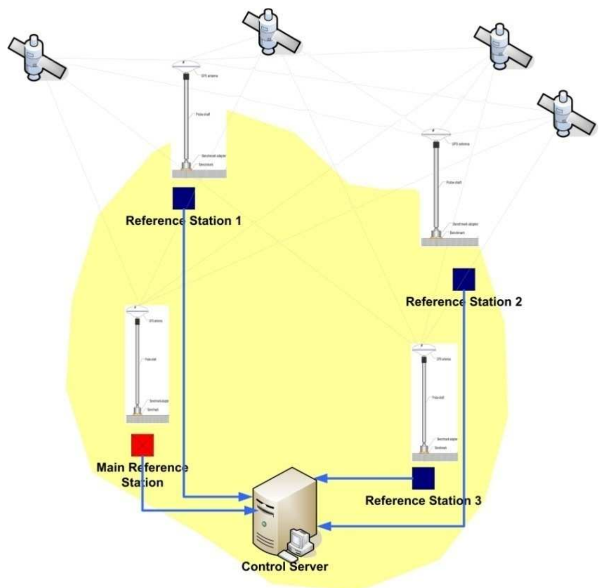

Figure (1) Architecture of RTK Network

1.3 RTCM Correction Data for GNSS-Positioning

The correction data for GNSS-Positioning within RTK networks is a challenging process, and is depending on the architecture of the RTK networks especially the communication tier between rover and control server. Mainly, there are three main methodologies for correcting data in RTK networks for GNSS-Positioning using the RTCM standard, first the Virtual Reference Station (VRS) technique, which requires duplex communication between rover and control server. Secondly, the Area-Correction Parameters (ACP) technique commonly known as FKP can work in simplex mode (broadcasting corrections) or duplex mode. Finally, the Master Auxiliary Concept (MAX) based on simplex mode.

1.4 Transformation of GNSS measurements into user defined CRS

Let us consider the case where the GNSS measurements (B1, L1, h1) are required to be expressed in another geographic and vertical CRS (B2, L2, H). This transformation operation is processed on two successive steps. Step 1 is for the transformation from (B1, L1, h1) to (B2, L2, h2), then Step 2 is for the transformation from (h1 or h2) to (H).

(B1, L1, h1) are the geodetic latitude, geodetic longitude and ellipsoidal height for GNSS measurements, (X1, Y1, Z1) are the geocentric Cartesian coordinates for (B1, L1, h1) in the same datum, (X2, Y2, Z2) are the geocentric Cartesian coordinates for (X1, Y1, Z1) in the target datum, (B2, L2, h2) are the geodetic latitude, geodetic longitude and ellipsoidal height for (X2, Y2, Z2) in the target datum.

Step 1 is implemented by the transformation procedure from geographic CRS1 to geocentric CRS1, then from geocentric CRS1 to geocentric CRS2, and finally from geocentric CRS2 to geographic CRS2, as shown in figure (2).

2. Transformation Sets for 3D Coordinate in RTCM 3.1

The RTCM 3.1 standard supports four sets of coordinate transformation, and they are Helmert transformation formula both the linear expression and strict, and Molodenski abridged formula which calculate directly (B2, L2, h2) from (B1, L1, h1) compacting the three steps of conversion and transformation in single formula, and finally the Molodenski-Badekas transformation which derives the 7 transformation parameters at another point than the coordinates origin, and it requires in addition to the 7 parameters the three coordinates of the point of transformation. Please refer to OGP, "Surveying and Positioning Guidance Note Number 7, part 2"[2] and "Amendment 1 to RTCM standard 10403.1" [6] for full details of the mathematical equations.

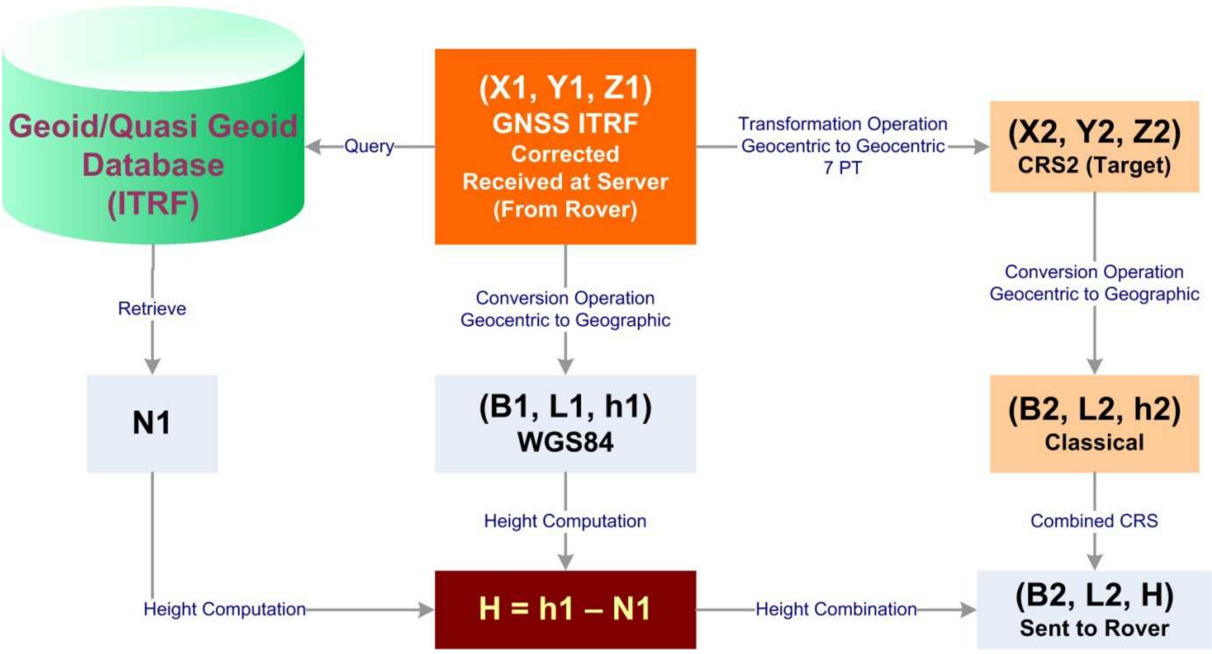

Figure (2) Coordinate transformation from 3D Cartesian CRS1 to Compound User Defined CRS2

2.1 Vertical Datum Transformation

The heights obtained from GPS are typically heights above an ellipsoidal model of the Earth. These GPS ellipsoidal heights are not consistent with spirit leveled heights above mean sea level, or heights above HRS such as geopotential surface often known as orthometric height. The conversion from ellipsoidal to orthometric height requires a geoid height model. The difference between GPS ellipsoidal heights, *h*, and leveled orthometric heights, *H*, is called geoid height, *N* [4, 8].

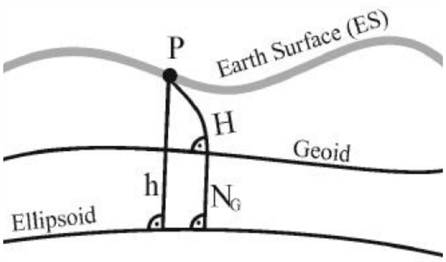

Figure (3) Relation between geoid and ellipsoid

$$H = h - N \qquad (3)$$

The GNSS observations delivers the ellipsoid height at the point of interest, which was considered a revolution in geodesy, where before this value was difficult to quantify. Also, there are several modern methodologies for computing the geoid undulation up to one centimeter accuracy using satellite technology, field gravimeters, and advanced mathematical models.

2.2 Mathematical Formula for the transformation sets in RTCM 3.1

3D Cartesian and Geographic Coordinates

The 3D coordinates transformation between two different datums includes three implicit operations as described in Figure (2). The conversion between Cartesian and geographic coordinates is derived in the following section.

Geographic to Cartesian

The conversion from Geographic to Geocentric in the same datum (same ellipsoid) given as function of geodetic latitude B, longitude L, and ellipsoidal height h, is:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} (N+h)\cos B \cos L \\ (N+h)\cos B \sin L \\ ((1-f)^2 N + h)\sin B \end{bmatrix} \quad (4)$$

Cartesian to Geographic

The conversion from Geocentric to Geographic in the same datum (same ellipsoid) given as function of geodetic coordinates X, Y, Z, is:

$$\begin{bmatrix} \phi \\ \lambda \\ h \end{bmatrix} = \begin{bmatrix} \mathrm{a}\tan(\mathrm{Z} + \mathrm{e}^2 \mathrm{N} \sin\phi)/\sqrt{(\mathrm{X}^2 + \mathrm{Y}^2)} \\ \mathrm{a}\tan \mathrm{Y}/\mathrm{X} \\ \dfrac{\mathrm{X}}{\cos\lambda \cos\phi} - \mathrm{N} \end{bmatrix} \quad (5a)$$

It should be noted that φ and h needs iterations to be computed, where

$$N = \frac{a}{\sqrt{1 - e^2 \sin^2 B}} \quad (5b)$$

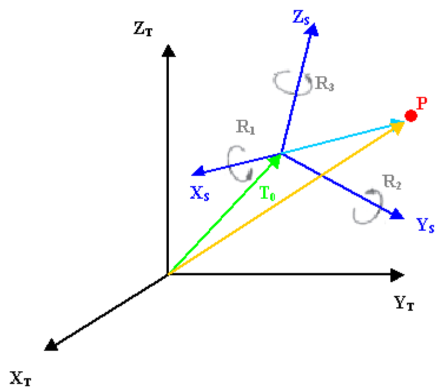

Figure (4) Definition of axis of transformation (Rotations & Translations)

Datum Transition

The 3D coordinates transformation in this case compute the coordinates in the target CRS, given the coordinates in the source CRS and the seven transformation parameters between two datums, which are three translations (dX, dY, dZ), three rotations (Rx, Ry, Rz) and a scale factor M. Subscript T denotes target and S for source CRS.

3. Transformation Messages at Control Server in RTCM 3.1

The RTCM 3.1 standard supports seven types of transformation messages which are message type 1021, 1022, 1023, 1024, 1025, 1026, and 1027 as shown in Table (1) and Figure (5). Please refer to "**Amendment 1 to RTCM standard 10403.1**" [6] for full details of the messages and their data fields' description.

It is clear that only one set of the four available transformation sets will be used, which means only the message types 1021 or 1022 will be used not both. The same concept is applied for message types

1023 and 1024, where the message type 1023 is for geographic coordinates and message type 1024 for Cartesian coordinates.

The remaining three message types 1025, 1026, and 1027 are for map projections parameters. Message type 1025 includes the parameters for all map projections types except for map projection

Lambert Conformal Conical with 2 SP, which is defined in message type 1026, and Oblique Mercator map projection which is defined in message type 1027.

Table (1) List of RTCM 3.1 transformation messages and their description and use

Message Type	Message Name	Description	Use
1021	Helmert/Abridged Molodenski transformation	7 parameters of transformation for Helmert/Abridged Molodenski	Transformation from ITRF to user CRS using Helmert or Abridged Molodenski
1022	Molodenski-Badekas Transformation	10 parameters of Molodenski-Badekas Transformation	Transformation from ITRF to user CRS using Molodenski-Badekas
1023	Ellipsoidal residuals	Residuals in geographic coordinates	Coordinate values are in degrees
1024	Plane Grid residuals	Residuals in Cartesian coordinates	Coordinates values are in meter
1025	Projections (except LCC2SP & OM)	All projection parameters	Conversion to all projections except LCC2SP & OM
1026	LCC2SP Projection	Projection parameters for LCC2SP	Conversion to LCC2SP projection
1027	OM Projection	Projection parameters for OM	Conversion to OM projection

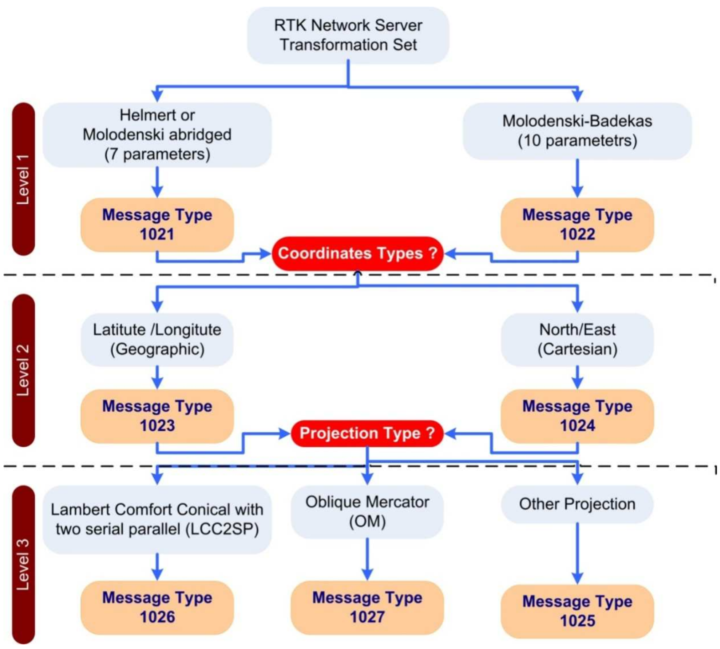

Figure (5) Usage of RTCM 3.1 transformation messages and their levels

Mainly, the decision to transmit message type 1021 or 1022 is based on the type of transformation set used. Secondly, the units of the coordinates determine, if degrees or meters, the use of message type 1023 or 1024. Finally, the type of used projection determines the type of message type 1025 or 1026 or 1027 as shown in Figure (5).

Message Type 1021

The message type 1021 in RTCM 3.1 standard includes the parameters necessary for the transformation of the rover position coordinates from ITRF CRS to another coordinate reference system defined in the same message. The transformation parameters enable the use of Helmert or abridged Molodenski method at the rover side. As described in "**Amendment 1 to RTCM standard 10403.1**", it has 27 data fields, and its size is 412 bits without the size of the characters of the source CRS name and the target CRS name.

The Computation Indicator field (defined as DBF150) describes which transformation to be used.

Computation Indicator field (DBF150)

Value	Description
0	Helmert standard 7 parameters (linear expression)
1	Helmert standard 7 parameters (strict formula)
2	Abridged Molodenski
3	Molodenski-Bakedas

The Height Indicator Field (DBF151)

Value	Description
0	Geometric Height (Ellipsoidal height) (h)
1	Orthometric Height (Physical Height above geoid) (H)
2	Geoid Height (N)

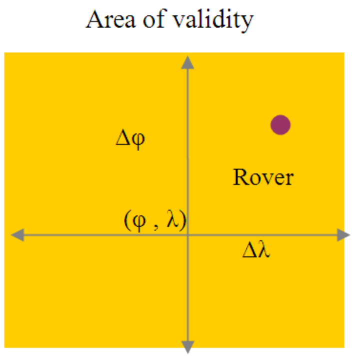

Figure (6) Parameters of Message Type 1021

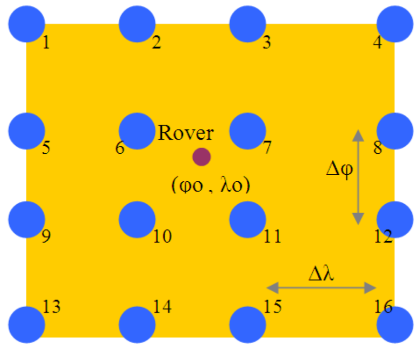

Figure (7) residuals Parameters of Message Type 1023

Message Type 1023

The message type 1023 in RTCM 3.1 standard includes the ellipsoidal residual parameters necessary for the transformation of the rover position coordinates from ITRF CRS to another coordinate reference system defined in the 1021 message. As described in "**Amendment 1 to RTCM standard 10403.1**", it has 35 data fields, and its size is 578 bits.

3.1 Generation of Transformation Messages in RTCM 3.1

The transformation messages in RTCM 3.1 can be divided into 3 levels as shown in Table (2) and Figure (5). The messages generation should follow this order, which means that message for level (1) should be generated first, then message type of level (2), and finally message type of level (3). The essential part in the transformation messages in RTCM 3.1 is the level (1) messages, which describe the main data required for processing the transformation.

The source datum is the ITRF datum, in which the GPS coordinates are delivered. The target datum is depending on the RTK network service provider specifications. A main requirement for the transformation operation is the 7 transformation parameters from source CRS to target CRS, in addition to the height model in the transformation.

Table (2) Level of RTCM 3.1 transformation messages

Message Level	Supported Messages	Description
Level (1)	1021 or 1022	Includes the definition of source and target datums, grid size, 7 transformation parameters, rover position in source CRS, formula used in transformation, height model. This message describes all the data needed to perform the transformation operation.
Level (2)	1023 or 1024	Includes grid size, mean offset, rover position in target CRS, residuals for 16 grid points. This message describes the results of applying the parameters of level(1) message on the rover position.
Level (3)	1025 or 1026 or 1027	Includes the parameters required to convert the geographical coordinates in target CRS into the required projection.

3.2 Static and Dynamic Grids

The generation of seven transformation parameters and the residuals are computed from a grid of 16 points with the rover position at their center. There are two different concepts and respective ways to create the n=16 grid points and the respective RTCM-messages (1021 or 1022 and 1024 or 1024) , namely the so called static and the dynamic grid mode [3].

In case of the static mode, the individual reference transformation(s) of a country or a GNSS service respectively, is (are) applied to generate N virtual fitting points both in the target and the source CRS for the whole country (N >> n; n=16 for the local RTCM grid). Here the grid width has already to be adapted to that of the later RTCM grid. The static seven parameters and the N residual vectors are determined using the N virtual fitting points in a seven parameter transformation for the whole area. The RTCM message is generated as an n=16 point residual extraction round the rover position using the country wide static grid together with the static set seven parameters.

In the concept of the dynamic grid the two sets n= 16 virtual fitting points surrounding the rover (fig. 7) are generated dynamically in real-time on the rover's NMEA-request. So local seven parameters

n = 16 and residual vectors are resulting and are transmitted as message types 1021 (or 1022) and 1023 (or 1024) to the rover [3], [8].

The static grid generates high residuals and leaves larger interpolation errors, which is avoided in the dynamic grid generation due to essentially smaller residuals.

In future the dynamic generation of virtual fitting points and a respective dynamic RTCM transformation message generation will become more and more relevant for several reasons. The first one is, that the concept of a static grid is ineffective or even impossible to be handled for some kind of meaningful parametric reference transformations, e.g. in case of using geopotential models for the height component of the message. A further, and a main reason for following the concept of a dynamic grid and RTCM transformation generation, is due to the necessity of combining subsequent reference transformations with some dynamic components (e.g. plate movements, datum drift), requiring accordingly the generation of dynamically changing virtual fitting points. This holds for the future operation mode of GNSS-services and also for future positioning concepts, like state space representation (SSR), which are both related to a modeling taking place throughout in the dynamic ITRF [3].

3.3 Example from Bavarian Database

The GZTraS (GeoZilla RTCM Transformation Server) is product from GeoZilla (www.geozilla.de). GZTraS is a Windows-based Server for GNSS-Network-Software and provides the functionality of a transformation module to provide RTCM 3.1 transformation messages, and GZTraC is its client software [3]. The beta version of the software includes databases for Bavaria (Bayern) in Germany and Florida in USA. Hereafter a sample of point observed in Bayern area is sent to the server in ITRF CRS, and the server replied with the RTCM 3.1 message for the transformation of the coordinates in addition to the transformation parameters.

The observed point coordinates are (49°.0000, 11°.0000, 580 m) in (B, L, h) format, and received by the server receives in NMEA format. It is transformed to the target CRS using 7 approximate parameters. Following the above concept of dynamic RTCM grid and message generation the server then sets up n=16 virtual grid points in the target CRS. The reference transformation of the DFLBF database for Bavaria [1], [8] is then used at server site to compute the corresponding set of n=16 precise virtual fitting points in the source CRS. The two sets of n=16 points are then used to compute the accurate seven transformation parameters of a similarity transformation (message 1021). The horizontal components of the residuals of the seven parameter transformation are stored as a first part of the RTCM message 1023. The geoid heights N are computed for all n=16 grid-points from the reference transformation of the DFHRS (Digital Finite Element Height Reference System) database of Bavaria ([4], [7]). After a subtraction the mean height offset N_0 (N_0 = 46.920 m) the remaining residuals δN are stored as third component in message 1023, which is based on height indicator 2. So the RTCM transformation message is ready to be sent to the rover on RTCM 3.1 format.

In the example based on real data for Bavaria, the NMEA position of the rover point is reading:

*$GPGGA,082012.12,4900.0000000000,N,01100.0000000000,E,1,6,2.4,580.000,M,,M,2.4,0012*71*

From this we get the following RTCM transformation messages:

Message Type 1021 from Bayern (GeoZilla)

Field Name	Value
Computation Indicator	1
The Height Indicator	2
Latitude of Origin	49.000000
Longitude of Origin	11.000000
Extension in Latitude (N/S)	0.100000
Extension in Longitude (E/W)	0.100000
dX	-551.664000

Message Type 1023 from Bayern (GeoZilla)

Field Name	Value
Latitude of Origin	49.000972
Longitude of Origin	11.001250
Extension in Latitude (N/S)	0.100000
Extension in Longitude (E/W)	0.100000
Mean Latitude Offset	0.000000
Mean Longitude Offset	0.000000
Mean height offset (m)	46.920000

dY	-29.638000
dZ	-444.905000
R1	-0.000247
R2	0.000485
R3	-0.000445
dS	0.999991
as	6378137.000000
bs	6356752.314000
at	6377397.155000
bt	6356078.963000

Residual in Latitude (Point 1)	0.0006000000
Residual in Longitude (Point 1)	0.0003900000
Residual height (Point 1)	0.00000
::	::
Residual in Latitude (Point 16)	xxxxx
Residual in Longited (Point 16)	yyyyy
Residual height (Pont 16)	zzzzzzz

In this example the physical height H = h – N = 580 – 46.920 = 533.800 m

4. Implementation of Transformation Messages at Client Side in RTCM 3.1

The main aim of the transformation messages in RTCM 3.1 standard is to provide the user with the coordinates of the observed GNSS measurements in the required CRS, and the parameters required for projection, and also to provide the physical height of the observed point or its geoid height. All the operations of coordinate's transformation are done on the server side and the client side is blind about these operations.

4.1 Handling the Transformation Results

As shown in Figure (8), the rover receives a set of alternative combinations of RTCM 3.1 messages and each has its own data.

Case (1) 3D Transformation (Plan & Height)

In this case, the rover receives the coordinates in target geographic CRS (B, L)t and the physical height (H) in case of height indicator = 1, or the geoid height (N) over the ITRF datum in case of height indicator = 2. The rover can compute the physical height (H) using: H = h – N, where h is the ellipsoidal height from GNSS measurement. The message type 1023 in RTCM 3.1 includes the transformation parameters in addition to the residuals of 16 grid points around rover position. From this message the rover can recompute the target coordinates based on received 7 parameters, and calculate the standard deviation of errors from the residuals.

Case (2) 2D Transformation (Plan Only)

In this case, the rover receives the coordinates in target geographic CRS (B, L, h)t with the geometrical height (h) in case of height indicator = 0. The rover in this case has to know the geoid height relative to any ellipsoid (the target or

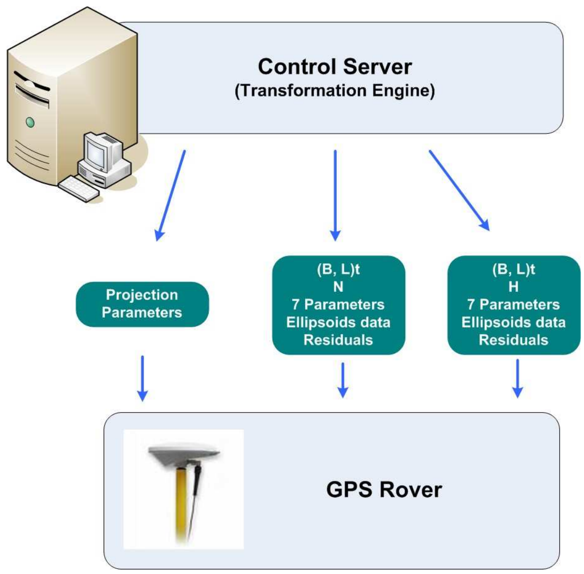

Figure (8) data sent from server to rover source ellipsoids) in order to compute the physical height.

The message type 1023 in RTCM 3.1, includes the transformation parameters, in addition to the residuals of 16 grid points around rover position, including the residual for geometric height (h)t. From this message the rover can recompute the target coordinates based on received 7 parameters, and calculate the standard deviation of errors from the residuals.

Case (3) 1D Transformation (Height Only)

In this case, the rover receives the coordinates in the source geographic CRS (B, L, h)s in the ITRF CRS. The seven transformation parameters in this case are all zero, there will be no coordinates transformation. In case the height indicator = 1, the physical height (H) is transmitted, and the residuals are relative to it. In case the height indicator = 2, the geoid height (N) is transmitted, and the residuals are relative to it, and the physical height can be computed by the equation: H = (h)s – N

4.2 Handling the Projection Parameters

The RTCM 3.1 standard transmits the projection parameters in the message types 1025, 1026, 1027 as described in Table (1). The rover can project the geographic coordinates using the parameters received in the RTCM 3.1 message or any other parameters included at the client side. The essential input to the map projection conversion is the horizontal geographic coordinates (B, L) in the geographical CRS used in map projection. Where:

X = f(B, L) & Y = f(B, L) , and the physical height (H) is the same as in geographic CRS.

5. Conclusion

The RTCM 3.1 is a new standard developed to provide the GNSS user with high accuracy in positioning in addition to the transformation of coordinates in the target CRS with the physical height of the observed point or its geoidal height.

The transformation messages in RTCM 3.1 standard introduces a new concept that utilizes the infrastructure of the RTK network to provide the transformation operation in addition to the physical height which is a main request for all GPS users. The transmission of the coordinates of the observed points in target CRS, and the seven (or ten) transformation parameters, and the physical (or geoid) height of the observed point, in addition to the projection conversion parameters (if any) provides the GNSS user in the coverage area in real time operation valuable data that reduces exponentially the work time and provides a safe mean to reduce errors and increase work efficiency.

This concept is new, and needs to be well established in operation modes, and to be adopted by RTK network service providers and GNSS manufacturers.

It should be mentioned that the transformation messages in RTCM 3.1 standard will not solve classical problems in mathematical geodesy, like the computation of physical height from GPS ellipsoidal height, rather this standard will allow the communication and data transfer between the solutions of these problems and the client side.

Acknowledgment
The author would like to thank Prof. Reiner Jäger for his assistance, support and review of the paper. He always replied to my inquiries in detailed and informative answers. Further I want to thank Mr./Mrs. XXXXX for the final proof-read of the paper.

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Mohamed Eleiche Basics of RTCM 3.1 Transformation Messages Standard for GNSS Positioning Services

As concerns the use of RTCM observation correction data in GNSS positioning services, the coordinates are resulting within the ITRF or in a regional ITRF-realization (e.g. ETRF89 in Europe) as geocentric (x,y,z) or ellipsoidal (φ, λ ,h) coordinates. The users of GNSS services must however normally present their results in the coordinates of regional or local horizontal and vertical datum systems. Therefore, coordinate transformations are necessary. Currently, the pre-calculated transformation parameters and/or geoid-models have to be transferred in advance to GNSS controllers in particular ways.

The aim of the transformation messages of the recent 2007 RTCM 3.1 was to define transformation algorithms and data structures by seven RTCM transformation messages, which allow the GNSS service to transmit respective RTCM transformation messages to the user of the GNSS service. In that way and by the transformation messages' use in the GNSS-controllers, the above ITRF-based coordinates can automatically be transformed to the desired horizontal datum and height reference system, and the above preparation of a data transfer and further manual operations during the GNSS-measurement become obsolete.

The software and communication architecture for the use the RTCM transformations messages in a GNSS service can be realized as a server-client concept. The desired reference transformations are implemented within the so-called transformation modules and as part of the RTCM transformation messages server. In that way, the NMEA-position of the GNSS-rover is used as the basic server request and it is passed through the administrating GNSS networking software to the RTCM transformation messages server. Depending on the configuration of the RTCM transformation messages server, different transformation modules are activated and different message design specifications are holding. Accordingly one or several binary RTCM transformation messages are generated and send via the GNSS network software back to the client of the GNSS-controller.

This paper provides the data structures associated with the transformation messages in RTCM 3.1 standard, and how the client uses the received messages and transforms the ITRF-based position (source system) to the desired horizontal and vertical reference coordinate system (target system) of the user. The seven parameter transformation part, and the conception of residual grids are treated as well as the implementation of the physical height. As concerns the height it is explained, how the RTCM transformation messages represent in two different ways the physical height by using the so-called height indicator.

Mohamed Eleiche RTCM3.1. mērījumu transformācijas ziņojuma standarts GNSS pozicionēšanas dienestiem.

Attiecībā uz novērojumu RTCM korekcijas datu lietošanu GNSS pozicionēšanas dienestiem, tad ģeocentriskās (x,y,z) jeb elipsoidālās (φ,λ,h) koordinātas koriģēšanas rezultātā itransformē vai nu ITRF vai arī reģionālā ITRF sistēmā (piem., ETRF 89 Eiropā). GNSS pakalpojumu izmantotāji rezultātus tomēr parasti lieto reģionālās vai lokālās koordinātu un augstumu sistēmās. Tādejādi nepieciešamas koordinātu transformācijas. Patreiz, apriori aprēķinātos transformācijas parametrus un/vai ģeoīda modeļus īpašā kārtībā pārraida GNSS kontrolieriem vispirms. Patreizējo 2007 RTCM 3.1. transformāciju mērķis ir definēt transformācijas algoritmus un datu struktūras ar septiņiem RTCM ziņojumiem, kas GNSS dienestiem ļauj tos nosūtīt kā attiecīgos RTCM transformācijas ziņojumus GNSS pakalpojumu izmantotājam. Šādā ceļā GNSS kontrolierī lietotie tramsformācijas ziņojumi un augstāk minētās uz ITRF sistēmu bāzētās koordinātas automātiski tiek transformētas uz izvēlētajām horizontālo plaknes koordinātu un vertikālo augstuma koordinātu sistēmu. Sagatavošanās augstāk minētajai datu transformācijai un sekojošām manuālām operācijām GNSS mērījumu laikā kļūst vecmodīga. Programmatūra un sakaru arhitektūra RTCM transformācijas ziņojumu izmantošanai GNSS pakalpojumos var tikt realizēta, lietojot servera-klienta koncepciju. Vēlamo sistēmu transformācijas ieviestas tā saucamo transformācijas moduļu veidā un kā RTCM servera transformācijas ziņojums. Tādā veidā GNSS rovera NMEA ziņojumā pārraidītā pozicija tiek lietota kā pieprasījums bāzes serverim un tas tiek raidīts caur administrējošo GNSS tīkla programmatūru uz RTCM transformācijas ziņojumu serveri. Atkarībā no RTCM transformācijas ziņojumu servera konfigurācijas tiek aktivizēti dažādi transformācijas moduļi un dažādu specifikāciju uzturētas ziņojumu konstrukcijas. Atbilstoši tiek ģenerēti viens vai vairāki RTCM transformācijas ziņojumi binārā kodā un tiek nosūtīti ar GNSS tīkla programmatūru klientam – GNSS kontrolierim. Rakstā analizē datu struktūras, saistītas ar RTCM 3.1 standarta transformācijas ziņojumu, kā arī tas, kā klients lieto saņemtos transformācijas ziņojumus un transformē no ITRF bazes sistēmas (izejas sistēma) uz lietotāja izvēlēto horizontālo un vertikālo atbalsta koordinātu sistēmu (mērķa sistēma).Pārbaudīta septiņu parametru transformācijas daļa un koncepcija par nesaišu tīkla un fiziskā augstuma ieviešanu. Attiecībā par augstumu ir paskaidrots, kā, lietojot t.s.augstuma indikātorus, RTCM transformācijas ziņojumi divos dažādos veidos reprezentē fizisko augstumu.

М.Элейхе. Стандарт сообщения по трансформации измерений RTCM3.1 для служб позицинирования ГНСС.

В отношении к использованию службами позицирования ГНСС корректированных данных наблюдений RTCM, то геоцентрические (x,y,z) или элипсоидальные (φ,λ,h) координаты в результате коррекции трансформируют в систему ITRF или региональную (напр. ETRF89 в Европе систему. Пользователи услугами ГНСС результаты обычно используют региональные или локальные системы координат и высот. Поэтому необходима трансформация координат. В настоящее время вычеслленые авторамы параметры трансформаций и/или сперва в особом порядке передают модели геоида контролерам ГНСС.

Цель современных трансформаций 2007 RTCM3.1 определить алгоритмы трансформации и структуры данных 7 сообщениями RTCM, что позволит службам ГНСС послать как соответствующие сообщения трансформации RTCM пользователю услуг ГНСС. Таким путем сообщения по трансформации которые применяют в контролере ГНСС и вышеупомянутые на системе ITRF основанные координаты автоматически трансформируются на избранные системы координат горизонтальной плоскости и вертикальных высот. Подготовка трансформации данных и последующих мануальных операций во время измерений ГНСС стала старомодной. Программатура и архитектура связей при использовании сообщений RTCM в услугах ГНСС может быть осуществлена в концепции сервер – клиент. Желанные трансформации систем введены в виде т.н. модулей трансформации и как сообщение о трансформации сервера RTCM. Таким образом переданная в сообщении NMEA позиция используется как запрос базовому серверу и запрос передается через администрирующую сеть ГНСС программатуру на

сервер сообщения трансформации RTCM. В зависимости от конфигурации сообщений трансформации RTCM активизируются различные модули трансформации и на различных спецификациях созданные конструкции сообщений. Соответсвенно генерируют один или несколько сообщений трансформации RTCM в бинарный код и посылаются программатурой сети ГНСС клиенту –контролеру ГНСС. В статье анализируются структуры данных связанные с сообщением стандартной трансформации RTCM3.1 а также то как клиент использует полученные сообщения трансформации и переводит с базовой системы ITRT (исходнаясистема) на избранную пользователем систему горизонтальных и вертикальных координат (цеваясистема). Проверены трансформации 7 параметров и концепция о неувязке сети и физической высоты. В отношении высоты поясняется, что используя т.н. индикаторы высоты сообщения трансформации RTCM в двух различных видах представляют физическую высоту.