GUIDELINES FOR EPN STATIONS & OPERATIONAL CENTRES

EPN Central Bureau
C. Bruyninx, epncb@oma.be

Updates:

Oct. 4, 2021
- Updated link to NTRIP software

Oct. 4, 2019
- RINEX 2 submission optional if RINEX 3 is submitted
- ETRS89 coordinates in real-time streams
- Creation of RINEX files from receiver raw data
- Update of several links
- Submission of RTCM 3 preferred above RTCM 2
- Inclusion of description of MSM message types
- Updated link to ECGN Guidelines
- Remove submission of .SUM file to data centres

April 11, 2017: Regional data centre OLG is replaced by new data centre BEV in data flow figures.

Oct. 26, 2015
- Section 2.4.1: updated method for measuring connection between station marker and levelling network
- Section 3.2 : Stations tracking more than two frequencies or satellite systems in addition to GPS and GLONASS must submit data files in both the RINEX 2 (dual frequency GPS and GLONASS) and RINEX 3 format (GPS, GLONASS plus other GNSS, SBAS, etc.). Removal of the '.flg' convention for data transmission.

May 28, 2013: Major revision and restructuring reflecting current state-of-the art.

June 13, 2012: Modified links due to the EPN CB web site restructuring

Feb. 1, 2012: Correction of description of stream

March 8, 2010:
- Section 2.1: updated 2.1.2, 2.1.14 & 2.2.0, added 2.1.19, 2.1.20, 2.1.22 & 2.1.25, updated 2.1.27, added 2.1.29, related to absolute antenna calibrations and multi-GNSS antenna
- Section 2.2: updated 2.2.2
- Section 2.3: updated 2.3.1 for on-line station log submission tool
- Section 2.4: updated 2.4.1
- Section 3.2: added 3.2.1: submission of hourly data is mandatory, updated 3.2.5 on data latency
- Section 3.3: updated 3.3.1
- Section 3.6: updated 3.6.1, updated 3.6.6 for RINEX header
- Section 3.7: updated 3.7.4, added 3.7.6

May 15, 2007: Section 3.7.4: update of mandatory messages

March 1, 2007: Section 3.7: update of mandatory messages

Dec. 5, 2006:
- Added guidelines for stations streaming real-time data
- Promote usage of multi-GNSS equipment
- Recommendation for new antennae/radomes or antenna/radome replacements to be absolutely calibrated

Very strict rules are inconsistent with the voluntary nature of the EUREF Permanent Network (EPN). However, stations participating to the EPN must agree to adhere to certain standards and conventions which ensure the quality of the EPN. This document lists the ***requirements*** *that all* ***EPN Tracking Stations*** *(TS) and* ***Operational Centres*** *(OC) must follow, as well as some additional desirable characteristics, which are not mandatory, but enhance a station's or OC's value to the EPN.*

For historical reasons, existing EPN stations may not adhere to all guidelines described in this document. However, it is expected from station managers and operating agencies that when upgrading equipment at an existing EPN station, this new equipment will be conform with the guidelines.

For proposed EPN stations please follow the stepwise "Procedure for Becoming an EPN station": http://epncb.oma.be/_organisation/guidelines/procedure_becoming_station.pdf (which includes a reference to this document).

For IGS tracking stations, please refer to "IGS Site Guidelines" http://kb.igs.org/hc/en-us/articles/202011433-Current-IGS-Site-Guidelines available from the IGS Central Bureau.

In the following text we distinguish site and station as follows:

- *A site is a local geographical area where one or more geodetic markers are available. Each of the geodetic markers can be characterised by an IERS DOMES number (required for an EPN station). The first five numbers of the DOMES number of markers located on the same site are identical.*
- *A station observes at a unique geodetic marker (and DOMES number) at a site with a specific receiver and antenna. Multiple stations can exist at one site, and even on one geodetic marker (e.g. two receivers connected to the same antenna).*
- *Using RINEX 2 conventions, a station is characterized by a unique 4-character identification (ID) and is occupied with a specific GNSS receiver and antenna. In cases where multiple GNSS receivers are split off from the same antenna, each GNSS receiver is considered a separate station and a different 4-character ID needs to be defined. The first four characters of the RINEX data files correspond to the station 4-character ID. Each station is documented using a unique station log. The 'Surveyed Local ties' section in the station log describes how different geodetic markers at the station's site are related to each other.*

CONTENTS

1 ORGANIZATION OF THE EPN DATA FLOW

1.1 Network Components

En route to Analysis Centres and other users, the tracking data collected by permanent GNSS receivers flow through the following components of the EPN network:

- **Tracking Station (TS)**: Permanent GNSS tracking receivers and antennae on suitable geodetic markers.
- **Operational Centre (OC)** or Operating Agency: performs data validation, conversion of raw data to the Receiver Independent Exchange Format (RINEX), data compression, generation of real-time streams, and data upload to the Data Centres and the Broadcasters through the Internet. For some stations, the OC is identical with the institution responsible for the respective station (i.e., the OC is identical with the TS).
- **Local Data Centre (LDC)**: Collects the hourly and daily RINEX data of all stations in a local network and distributes them to the users (local and EPN). For many of the local networks, the LDC will be identical with the Operational Centre. The LDC will forward the data (or a selection) of the local stations to the Regional Data Centres. If there is no LDC available for a particular station, then its data will flow directly from the OC to the Regional Data Centres.
- **Regional Data Centre (RDC)**: It collects the hourly and daily RINEX data from all EPN stations. The RDC makes the data available to the local, regional and IGS users.
- **Local Broadcaster (LB):** It receives the real-time data streams from the stations in a local network and disseminates them, without changing them, on request to clients. Clients may be users, monitoring tools, Regional Broadcasters, Data Centres, or Analysis Centres.
- **Regional Broadcaster (RB):** It receives all the EPN real-time data streams and disseminates them, without changing them, on request to clients. Clients may be users, monitoring tools, other broadcasters, Data Centres, or Analysis Centres.
- **High Rate Data Centre (HDC)**: It collects the real-time data from all EPN stations, archives them in 15-min high rate RINEX format and makes them available to the users.

To guarantee the availability of the EPN data at the regional level, two RDCs are in operation. Each RDC makes available the data of all EPN stations.

In the following, we will use the wording “Data Centre” (DC) for both the RDC and LDC, and “Broadcaster” for both the LB and RB.

2 Requirements for Permanent Stations

EPN tracking stations should fulfil the guidelines below.

2.1 Equipment

Receiver

The GNSS receiver must be set to

2.1.1 Track satellites down to a cut off of 0°.

2.1.2 Track as many satellites, healthy and unhealthy (all-in-view tracking), from as many constellations as possible (within receiver limitations), always including all GPS satellites as a minimum.

2.1.3 Record phase and code measurements (at least one of each) from at least two frequencies (three frequencies expected for new receivers). For 2 frequency GPS and GLONASS this includes: P1(and/or C1), L1, L2, P2, (and C2, if available from the receiver).

2.1.4 Disable pseudorange and/or phase smoothing. If activated by mistake, any changes in the receiver setting shall be reported in the station log.

2.1.5 Synchronize the actual instant of observation with true GPS time within ± 1 millisecond of the full second epoch.

Additionally desired characteristics are:

2.1.6 The receiver must be capable of providing GLONASS and Galileo measurements (or easily upgradeable via firmware) in addition to GPS.

2.1.7 The receiver must be capable of providing third frequency measurements in the RINEX data files for all constellations.

2.1.8 The receiver must be set to provide signal-to-noise values for all tracked signals: S1, S2, etc in the RINEX files at the highest precision possible.

2.1.9 The logging of Doppler observations is recommended.

2.1.10 The receiver and ideally other station equipment, such as computers, should be protected against power failures by providing surge protection and backup power wherever feasible.

2.1.11 The receivers shall be upgraded with firmware upgrades from the manufacturer within 6 months of the firmware publication. Firmware updates shall be noted in the station log, and announced via an EUREF mail.

Antenna and Radome

2.1.12 Avoid using radomes unless required operationally, for instance due to weather conditions, antenna security, wildlife concerns, etc.

2.1.13 The antenna (+radome, if any) must be known to the IGS and EPN; a standard name must be designated for the antenna and radome in ftp://epncb.oma.be/pub/station/general/rcvr_ant.tab.

2.1.14 The antenna (+radome, if any) must be included in the EPN phase centre variation file (see http://www.epncb.oma.be/_documentation/equipment_calibration/) with zenith and azimuth-dependent absolute calibration values down to the horizon.

2.1.15 The antenna must be levelled and oriented to True North using the defined antenna reference marker (see vendor instructions, contact the Central Bureau with questions).

2.1.16 The antenna must be rigidly and securely attached to the top of the station monument.

2.1.17 The eccentricities (easting, northing, height) from the marker to the antenna reference point (ARP, defined for each antenna in ftp://epncb.oma.be/pub/station/general/antenna.gra) must be surveyed and reported in the station log and RINEX headers to ≤ 1 mm accuracy.

2.1.18 The antenna height eccentricity with respect to the marker must be less than 10 m, the horizontal eccentricities must be below 5 m (see also 2.1.21).

2.1.19 The antenna radome, if used, should be spherical, mounted concentrically over the average phase centre height of the antenna and properly aligned following the manufacturer instructions.

Additionally desired characteristics are:

2.1.20 The antenna must be capable of tracking new GPS, GLONASS, and Galileo signals (even if the receiver is not (yet) capable to do so).

2.1.21 Horizontal eccentricities (northing and easting) of 0 are preferred. The results of repeated local ties, connecting the antenna reference point to the marker must be carefully documented.

2.1.22 It is recommended to clean the antenna (without changing its position or removing it!) at least once a year. During winter time, remove snow coverage as frequently as possible. Report the cleaning in the station log.

2.1.23 If a radome must be used, radomes uniformly manufactured are preferred.

2.1.24 Absolute individual antenna calibrations of an antenna are preferred. New individual absolute antenna calibrations for an antenna+radome pair have to be sent to EPN CB prior to installing the antenna+radome pair.

2.1.25 If an uncalibrated antenna/radome (see ftp://epncb.oma.be/epncb/station/general/calibration.txt) is removed, please make it available to a calibration facility for individual calibration and send the calibration to the EPN CB.

Operation

2.1.26 Stations must be planned and installed for continuous and permanent and operation.

2.1.27 Site location must be secured over the long-term so that changes of antenna location at the site are highly unlikely in the foreseeable future (no planned construction, demolition, etc in the site vicinity).

2.1.28 Minimally, the station must provide 24hr daily files at 30 sec sampling, delivered as soon as possible after 23:59:30 for the previous day

Additionally desired characteristics are:

2.1.29 In case a major equipment upgrade is foreseen at a well-performing station, e.g. upgrading from GPS-only to multi-GNSS tracking capability, then install the new equipment on a new monument and propose the station to the EPN. Keep the old station simultaneously in the EPN as long as possible.

- Ample, reliable power and communications (preferably Internet) to enable reliable data transfer
- Physical site security, appropriate to local necessity.

2.2 Marker and Monument

2.2.1 The station permanent marker shall be appropriate to allow the assignment of an M-type IERS DOMES number, to indicate the antenna is referenced to a physical point on a monument or pillar (see: http://itrf.ensg.ign.fr/domes_desc.php).

2.2.2 The marker should fulfil standard requirements for a first order geodetic monument with respect to stability, durability, long-term maintenance, documentation and access. The marker description should be fully documented in the EPN station log file.

2.2.3 Obstruction should be minimal above 5 degrees elevation, but satellite visibility at lower elevations is encouraged whenever possible (see 2.1.1).

2.2.4 Signal reception quality has to be verified, especially with respect to interference of external signal sources like radars, and with respect to multipath.

2.2.5 The antenna must be setup to minimize code and phase reflections (multipath), by mounting it away from close reflecting surfaces or by applying some passive protection directly below the antenna (microwave absorbing material, etc).

2.2.6 Local ties to other markers on the sites should be determined in the ITRF coordinate system to guarantee 1-mm precision in all three dimensions. Offsets are given in delta-X, delta-Y, delta-Z, where X, Y, Z are the geocentric Cartesian coordinates (ITRF).

2.2.7 The station should not be moved to a different monument unless absolutely necessary. Moving to a new monument would require that a new station be established with a separate station ID and log.

2.2.8 If upgrading a station from a bad monument design to a better antenna mount, involving moving the original marker, then the upgrade is essentially the commissioning of a new station, so all guidelines are fully applicable (see '2.5 New Stations').

2.2.9 When moving a station to a different monument at the site is unavoidable, parallel operations are required for as long as possible (3 months or more if possible) between the old and new station positions.

2.3 Collocated Instruments, Markers and Local Ties

2.3.1 Additional monuments (preferably at least three) are desirable for surveys, testing and operating equipment in parallel during upgrades, but it is preferable to maintain one station as the principle station for the EPN.

2.3.2 Co-location with other geodetic techniques such as SLR, VLBI, DORIS or gravimeters is highly desired.

2.3.3 Precise meteorological instrumentation is encouraged:

- Data are to be prepared in RINEX "m" files. See the RINEX specifications, http://www.epncb.oma.be/_documentation/formats/rinex.php.
- RINEX 'm' data is to be transmitted on the same schedule as the RINEX observation files (hourly for hourly stations; otherwise daily).
- Data sampling interval must be less than 60 minutes and is recommended to be 10 min.
- Pressure sensor accuracy must be within 0.5 hPa.
- Temperature sensor accuracy must be at least 1 Kelvin.
- Drift and bias must be minimized.
- Temperature effects on the pressure measurements should be minimized, e.g. with solar shielding or by placing the sensor in a nearby building if necessary.
- Measurement of the instrument height in relation to the GNSS antenna mark must have an accuracy of 1 m or better.

- Meteorological instruments are to be calibrated periodically according to the manufacturer's recommendations to assure the above accuracy specifications are met. The calibration dates should be included in the station log.

2.3.4 Other scientific systems which rely on accurate positioning, such as timing labs, are also recommended where appropriate.

2.3.5 The 3-dimensional local ties between the GNSS marker, co-located instrumentation (e.g. DORIS, SLR, VLBI, gravity, tide gauge, levelling) and other monuments should be re-surveyed as frequently as practical (ideally each 2 years) to an accuracy of 1-mm and reported in ITRF:

- The marker → antenna reference point eccentricities should be re-verified during such a survey.
- Repeat the survey after known motion incidents such as earthquakes.
- All survey data, but especially ties to other IERS/IGS/EPN markers, should be rigorously reduced in a geocentric frame related to ITRF (preferably ITRF itself) and the results be made available in SINEX format (defined at https://www.iers.org/IERS/EN/Organization/AnalysisCoordinator/SinexFormat/sinex.html), including full variance-covariance information.
- Survey notes and intermediate results of the 3D ties shall be preserved and made available publicly.
- For the local ties, the guidelines derived by the European Combined Geodetic Network (ECGN) "ECGN Standards for Local Ties" (http://www.epncb.oma.be/_documentation/guidelines/ECGN_local_ties_standards.pdf) should be followed.

2.4 Link with the UELN and ETRS89

It is recommended to

2.4.1 Connect the GNSS marker to the UELN and the national precision levelling network either using precise levelling or a local GNSS campaign. For the levelling connection, the ECGN guidelines "ECGN Standards for the Levelling Connection of the ECGN Station" (http://www.epncb.oma.be/_documentation/guidelines/ECGN_levelling_standards.pdf) should be followed.

2.4.2 Integrate the station marker in the national official densification of the ETRS89. For performing national densifications of the ETRS89, the "Guidelines for EUREF densifications" (http://www.epncb.oma.be/_documentation/guidelines/Guidelines_for_EUREF_Densifications.pdf) should be followed.

2.5 New Stations

In addition to 2.1 - 2.4, new stations should respect the requirements below. The EUREF Governing Board (GB) will evaluate the benefits of a proposed EPN station.

2.5.1 New stations must provide an added-value to the EPN, according to the objectives of EUREF.

2.5.2 New stations can only be integrated in the EPN after following the 'Procedure for Becoming an EPN Station', see http://epncb.oma.be/_documentation/guidelines/procedure_becoming_station.pdf

2.5.3 New stations must have equipment capable of

- tracking all GPS, GLONASS and Galileo signals (or easily upgradeable via firmware)
- providing third frequency measurements in the RINEX data files (L5) for all constellations

- providing real-time data using the Ntrip technology, preferably in RTCM 3.x or, in future, RTCM HP-MSM (see section 3.3 for explanation).

2.5.4 Set to provide signal-to-noise values for all tracked signals: S1, S2, etc in the RINEX files at the highest precision possible.

2.5.5 Agencies are encouraged to select potential new stations whose station monument

- is conform with current best practices observed by principal geodetic agencies. A drilled-braced tripod structure or tapered pillar type monument are typically constructed. Roof or structure mounted antennas should be avoided.
- foundation shall extend to bedrock or be deeply embedded into the stable subsurface and isolated from surface effects where bedrock is not accessible.
- is on a stable regional crustal block, away from active faults or other sources of deformation, subsidence, etc.
- is on firm, stable material, preferably basement outcrop.
- is not located on soil that might slump, slide, heave, and does not vary in elevation (e.g. because of subsurface liquid variations).

2.5.6 The station location should not

- suffer from significant changes to the surroundings (changes to buildings or trees; new construction, etc…) foreseen or likely
- have excessive radio frequency interference
- have excessive RF reflective surfaces (fences, walls, etc.) and other sources of signal multipath
- have excessive natural or man-made surface vibrations from ocean waves or heavy vehicular traffic.

2.5.7 Co-location with other geodetic techniques such as SLR, VLBI, DORIS, absolute or superconducting gravimeters, Earth tide gravimeters, seismometers, strain meters, and ocean tide gauges are also desirable and will enhance the value of the station for multi-disciplinary studies.

2.6 Switch between operational and inactive status

2.6.1 When a station has been excluded from the EPN combined solution for more than 3 months, the EPN CB labels this station as inactive. Stations can be classified as inactive for several reasons, e.g.:

- bad data quality or metadata inconsistencies
- the station has temporarily stopped submitting RINEX data

2.6.2 Inactive stations can recover the operational status when they fulfil the requirements for EPN stations again.

3 Requirements for Operational Centres

The Operational Centres (or the station Operating Agency) control the station(s) of a particular (local) network from the operational point of view. They form the link between the stations, the EPN Data Centres and Broadcasters (if applicable).

3.1 Responsibilities

Data Archiving, Quality and Distribution

The agency accepting responsibility for proper station operation must

3.1.1 Ensure that the GNSS equipment, and its surroundings, is not disturbed or changed unless a clear benefit outweighs the potential for discontinuities in the time series. Examples include: equipment failure, planned upgrade of obsolete equipment or vendor-recommended firmware updates

3.1.2 Archive the station's data (preferably in its native format) in case needed for data recovery or engineering purposes

3.1.3 Download raw data from the receivers of the local network and reformat them into the agreed-upon exchange format (according to the guidelines in 3.2 and 3.3)

3.1.4 Check on regular basis the results of GNSS data quality checks (e.g. performed by the EPN CB) to detect potential performance degradations of your station.

3.1.5 Take appropriate action if the station performance degrades, e.g. the alert/engagement of on-site staff

3.1.6 Ensure full responsibility for reliable data handling and transmission to the relevant Data Centres and real-time Broadcasters, if any (according to the guidelines in 3.2 and 3.3)

3.1.7 Correct the meta-data in the RINEX header (see 3.2.7), real-time streams (see 3.3.8) or station log (see 3.1.10) as soon as possible, if an inconsistency advisory is received from the CB

3.1.8 Must maintain full capability to repair, upgrade and maintain the station and its software systems, even if the original engineers are no longer available.

Station logs

The agency accepting responsibility for proper station operation must

3.1.9 Document changes at the station (or its environment) by submitting an UPDATE station site log, within one business day, to the Central Bureau, using the "Metadata Management and distribution system for Multiple GNSS Networks (M³G)" available from https://gnss-metadata.eu/.

3.1.10 Correct the station log as soon as possible, if an advisory of station log inconsistencies is received from the CB.

Station Pictures

The agency accepting responsibility for proper station operation must

3.1.11 Provide pictures of the antenna installation in the 4 cardinal directions (as a minimum), the monument and its vicinity; update them after configuration changes: http://epncb.oma.be/_networkdata/sitepicturesubmission/

Individual Antenna Calibrations

If available, the agency accepting responsibility for proper station operation must

3.1.12 Submit individual antenna calibration files to the EPN CB at least three working days prior to the installation of the antenna at the station.

Operational Centre Form

The agency accepting responsibility for proper station operation must

3.1.13 Maintain the Operational Centre (OC) form (available from ftp://epncb.oma.be/pub/center/oper/) using the "Metadata Management and distribution system for Multiple GNSS Networks (M^3G)" available from https://gnss-metadata.eu/.

EUREF mail

The EUREF mail exploder notifies the EUREF community through E-mail about events related to the EUREF Permanent Network, for example: station configuration changes, abnormal stations conditions, analysis results, etc.
Archives and subscription information is available from
http://epncb.oma.be/_newseventslinks/EUREFmail/

The agency accepting responsibility for proper station operation must

3.1.14 Subscribe to EUREF mail

3.1.15 Follow EUREF mail on a regular basis to remain informed on EPN developments.

3.1.16 Send (in advance if possible, otherwise within one business day) an advisory EUREF mail in the following cases:

- Station status messages which can affect position solutions or which requires a station log update:

  Changes in antenna, radome, receiver, cabling, frequency standard, receiver settings (such as elevation cut off angle), or environment (such as tree removal or building construction).
- If a RINEX file must be resubmitted to a DC due to corruption, incorrect metadata, etc.
- If a station is expected to be unavailable for more than one week.
- When a station is decommissioned permanently.
- When a problem or error in the station or its station log is discovered and corrected. Briefly describe in the message what was changed.

Place the 9-character station ID (as used in RINEX 3) in the Subject line.

3.2 Format and Distribution of Hourly and Daily Data

EPN stations make their hourly and daily RINEX data routinely available at two DCs. The names of these DCs are indicated in the station log as the "Primary Data Centre" and "Secondary Data Centre". Based on this principle, each station/OC can distribute its data following one of the three standard data flow schemes given in Figure 1.

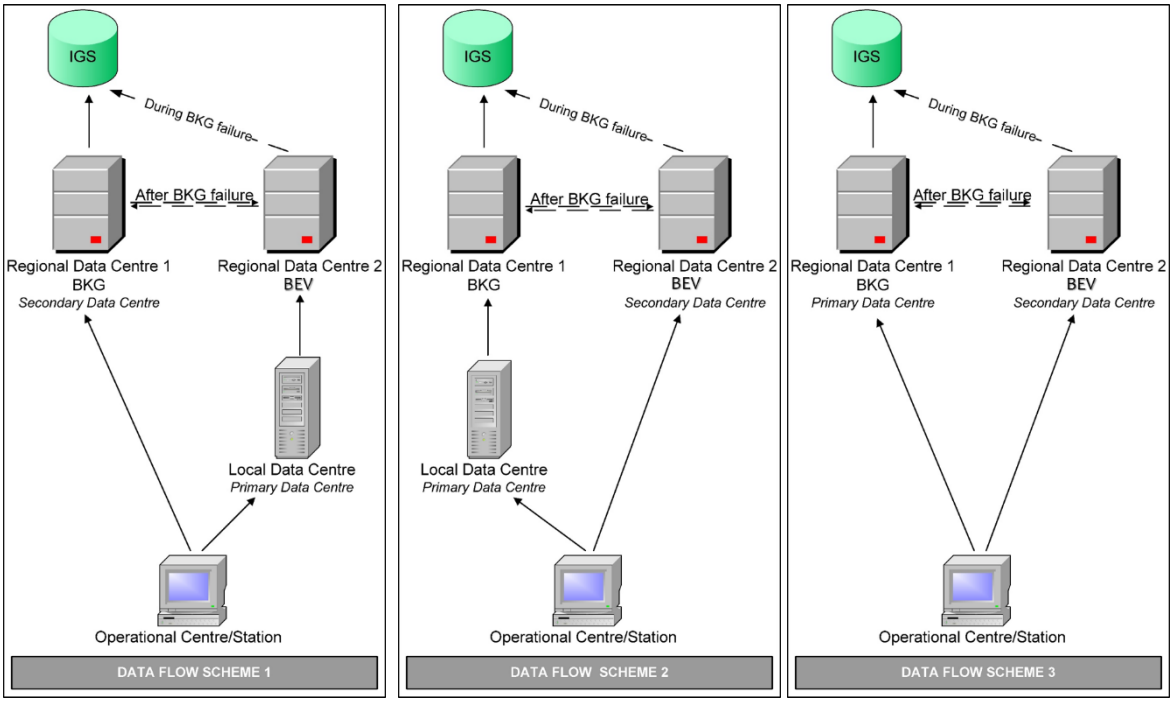

Figure 1: Standard data flow schemes for hourly and daily data within the EPN.

Exceptionally, if none of the schemes in Figure 1 can be applied, the scheme given in Figure 2 can be used. In this scheme, the station/OC submits its data only to one Data Centre, noted as the 'Primary Data Centre' in the station log. In case of a failure of this LDC, the data flow will be interrupted. For this reason, this last scheme is not considered as optimal.

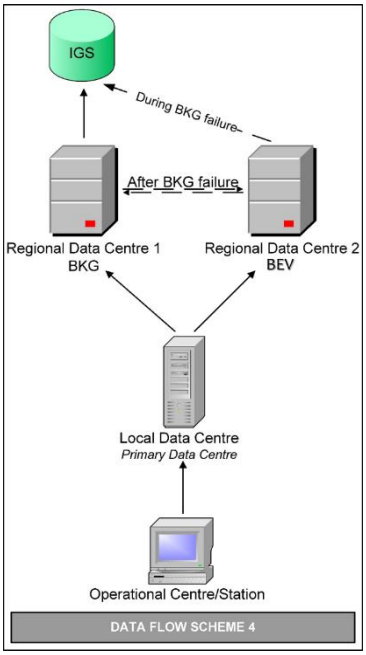

Figure 2: EPN data flow scheme for hourly and daily data, used only in case the standard data flow schemes cannot be implemented.

3.2.1 The station must provide hourly and daily observation files to the relevant Primary and Secondary Data Centres (as indicated in the station log) in the RINEX format. Check the currently used standard RINEX format from http://epncb.oma.be/_documentation/formats/rinex.php.

3.2.2 RINEX data files must be directly generated from the receiver's native data files (not from real-time data streams), and tagged in GPS time.

3.2.3 Stations tracking more than two frequencies or tracking satellite systems in addition to GPS and GLONASS (GPS, GLONASS plus other GNSS, SBAS, etc.) must submit data files in the RINEX 3 format. Optionally, data can also be provided in the RINEX 2 format.
Stations tracking only dual frequency GPS and GLONASS can submit data files in the RINEX 2 or/and RINEX 3 format. Repeated switching between RINEX 2-only or RINEX 3-only submissions is not allowed.

- RINEX Observation files will normally be exchanged in the Hatanaka Compact form.
- All observation files are then compressed (UNIX compressing .Z – for RINEX 2 format) or gnuzipped (.gz – for RINEX 3 format) for transmission to the DCs.
- The RINEX navigation and meteo files are prepared in a compressed (or gnuzipped) form.
- File naming conventions set forth in the RINEX 2 and 3 format descriptions, Section 4 "The Exchange of RINEX files" will be followed.

3.2.4 Even if the station receiver is capable of providing high rate or low latency data, daily and hourly observation data must be distributed at 30 second intervals aligned to :00 and :30.

3.2.5 The daily observation files contain the observations collected between GPS time 00:00:00 and 23:59:59.

3.2.6 The hourly observation files data contain the observations collected between GPS time 00:00 and 59:59 of each hour.

3.2.7 RINEX observation header information, especially the 4-character station ID, receiver and antenna information, DOMES number, and antenna eccentricities, must be up-to-date and must match the information in the station log. The following conventions are used:

- The 4-character station ID must be found in the "MARKER NAME" field
- The DOMES number must appear in the "MARKER NUMBER" field.
- The receiver serial number, type and firmware must be found in the "REC # / TYPE / VERS" fields
- The antenna serial number, antenna type and radome type (if no radome is used, use "NONE") must be found in the "ANT # / TYPE" fields
- The RINEX headers must begin showing an equipment change as near as possible to the actual time of the change.

3.2.8 The daily RINEX navigation message file contains all messages with TOC/TOE (time of clock, time of ephemeris) between 00:00 and 23:59 GPS time of the respective day.

3.2.9 The station's data handling and transmission to the relevant Primary and Secondary Data Centres by the station operator must occur reliably as scheduled (within 10 minutes after the last recorded epoch for daily files and 5 minutes for hourly files) using automated procedures and verified to be uncorrupted and complete in order to avoid resubmissions.

3.2.10 After a communication outage between the station and the OC, or between the OC and the DCs, all recovered data files must be submitted to the DCs as quickly as possible. At least a retry should be done within the hour. The usage of automated procedures is strongly recommended. Missed hourly data files should be transmitted only for files less than 3 days old. An EUREF mail shall be sent explaining the outage and the data availability over the period.

3.2.11 In case of reliable hourly data upload, it is possible to discontinue the submission of the daily files. The following procedure must be adopted:

1) Send an e-mail to the DC some days before you intend to cancel the transfer of daily files announcing that intention and ask the DC to concatenating the hourly files to daily ones
2) Wait for the confirmation of the DC
3) If the DC agrees, stop the transfer of daily files

Additionally desired characteristics are:

3.2.12 The submission of mixed navigation files (MN extension for RINEX 3) is recommended instead of submitting a separate navigation file for each constellation.

3.2.13 The signal-to-noise observables (S1, S2, etc…) should be included in RINEX files (see 2.1.10).

3.2.14 Stations equipped with high-precision weather sensors are encouraged to submit the daily RINEX meteo files (see 2.3.3).

3.3 Format and Distribution of Real-time Data

In addition to the standard (hourly and daily) data flow, stations are encouraged to make their data available in real-time using the Ntrip-technology. Similar to the RINEX hourly and daily files, these real-time streams are generated from the receiver's native data.
Stations streaming real-time data make their data available at the Regional Broadcasters who make available all EPN real-time data streams. If the station is part of a local network, it can also make available its real-time data at a Local Broadcaster. This data flow scheme, therefore, corresponds to the scheme given in Figure 2.

3.3.1 Real-time data should be sent in real-time using the Ntrip-server software (http://igs.bkg.bund.de/ntrip/about) or, if available, the manufacturer's software, to (at least) two independent Regional Broadcasters listed in http://epncb.oma.be/_networkdata/data_access/real_time/broadcasters.php, one of them being the Regional Broadcaster at BKG.

3.3.2 Alternatively, station operators can make the data available so that it can be pulled by the Regional Broadcasters, either from a Local Broadcaster or from the receiver itself.

3.3.3 Real-time station operators must strive to meet the following objectives:

- The station Internet service should be sufficient to meet the minimum performance standards required to send 1-Hertz data to two or more real-time broadcasters. Generally speaking a latency of two seconds or less from station to data centre is acceptable.
- Stream data should not affect completeness of the file based data sets. Hourly and daily files from streaming stations should contain all the data from each epoch and all epochs within the file period.

3.3.4 The format of the data stream should be RTCM 3.x. It is recommended to use RTCM-Multiple Signal Messages (RTCM-MSM). The advantage of the RTCM High Precision MSM (HP-MSM) message types will be the full compatibility with RINEX 3. MSM information for streaming station operators will be found at http://rts.igs.org or at http://www.rtcm.org (with charge)). Stations still transferring data in the RTCM 2.x format are encouraged to update the transfer to RTCM 3.x.

3.3.5 The minimal requirement for data submission is 1 Hz containing full code and carrier phase observations.

3.3.6 After a communication outage or reception of a NABU message, the data flow should be restored as quickly as possible, preferable using an automated procedure.

3.3.7 RTCM code and phase observations shall not be corrected to refer to the antenna reference point. If the correction is applied, the antenna type in the stream is typically set to NULLANTENNA (message types 1007/1008 for RTCM 3.x).

3.3.8 Meta-data reported in the stream (e.g. antenna/radome and receiver type, antenna eccentricity) should be in agreement with the information provided in the station log.

3.3.9 The station coordinates reported in the stream in message type 1006 (1005) should be the coordinates of the Antenna Reference Point (and not the Marker) and consistent with the ETRS89 coordinates maintained by the EPN Reference Frame Coordinator. For that purpose, the operator needs to enter the antenna height as well as the ETRS89 station coordinates in the receiver. Depending on receiver type, the ETRS89 coordinates entered in the receiver are the coordinates of the marker (available from ftp://epncb.oma.be/pub/station/coord/EPN/RTCM.CRD) or the coordinates of the Antenna Reference Point (available from ftp://epncb.oma.be/pub/station/coord/EPN/RTCM-ARP.CRD).

3.3.10 Stations streaming RTCM MSM (RTCM 3.x (x=2,3)) should stream additional information on top of GPS and GLONASS and / or two frequencies to exhaust the potential given by this format. The use of MSM 7 is recommended while MSM4 or MSM5 are allowed. Table 2 lists exemplarily the MSM messages types for GPS. For GLONASS (1081-1087), Galileo (1091-1097), SBAS (1101-1107), QZSS (1111-1117) and BeiDou (1121-1127) the content is analogous.

Message type	Content
1071	Compact GPS Pseudoranges
1072	Compact GPS PhaseRanges
1073	Compact GPS Pseudoranges and PhaseRanges
1074	Full GPS Pseudoranges and PhaseRanges plus CNR
1075	Full GPS Pseudoranges, PhaseRanges, PhaseRangeRate and CNR
1076	Full GPS Pseudoranges and PhaseRanges plus CNR (high resolution)
1077	Full GPS Pseudoranges, PhaseRanges, PhaseRangeRate and CNR (high resolution)

Table 2: RTCM 3.x (x=2,3) MSM message types for GPS

3.3.11 Stations streaming RTCM3.x (x=0,1,2) must at least stream message types 1004, 1006 (use 1005 only if 1006 is not available) and 1008 (use 1007 only if 1008 is not available) (see Table 3). GPS/GLONASS stations streaming RTCM 3.x should stream in addition message type 1012.

Message type	Content
1003	GPS code and carrier phase observations
1004	GPS code and carrier phase observations + CNR (carrier to noise ratio) + code ambiguity
1005	(X,Y,Z) coordinates of the antenna reference point
1006	(X,Y,Z) coordinates of the antenna reference point + height of antenna reference point above marker
1007	Antenna and radome type description (using IGS naming conventions)
1008	Antenna and radome type description (using IGS naming conventions) + antenna serial number
1012	GLONASS code and carrier phase observations + CNR (carrier to noise ratio) + code ambiguity
1019	GPS satellite broadcast ephemeris
1020	GLONASS satellites broadcast ephemeris

Table 3: RTCM 3.x (x=0,1,2) message types

3.3.12 Stations still streaming RTCM2.x (x=1, 2, 3) must at least stream message types 3, 18 and 19; they are encouraged to stream messages types 22, 23 and 24 in addition (see Table 4).

Message type	Content
3	(X,Y,Z) coordinates of antenna phase center, cm-precision
18	Carrier phase data
19	Code data

22	(dX, dY, dZ) corrections to message 3 coordinates to achieve mm-precision for L1 and L2 antenna phase center + height of antenna phase center above marker
23	Antenna and radome type definition
24	(X,Y,Z) coordinates of the antenna reference point

Table 4: RTCM 2.x (x=1, 2, 3) message types

Acknowledgments

This document was assembled from many preceding documents, including the previous version of "Standards for EPN Stations and Operational Centres", "Procedures for Becoming an EPN Station" and the latest version of "IGS Site Guidelines". Thanks are due to EUREF colleagues that have provided suggestions on this version.
This document is maintained by the EPN Network Coordinator at the EPN Central Bureau. Please direct comments, questions, and suggestions to epncb@oma.be.