Guidelines for EPN Stations & Operational Centres

EPN Central Bureau <u>epncb@oma.be</u> Draft version 4 (08/11/2004)

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 Stations 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 proposed EPN stations please refer to the document "Procedure for Becoming an EPN station": http://epncb.oma.be/_organisation/guidelines/procedure_becoming_station.html.

For IGS tracking stations, please refer to "IGS Site Guidelines" http://igscb.jpl.nasa.gov/network/guidelines/guidelines.html available from the IGS Central Bureau.

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1 Organization of the EPN Data Flow

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

- **Tracking Stations (TS)**: They set up and operate the permanent GPS tracking receivers and antennae on suitable geodetic markers.
- **Operational Centres (OC)**: They perform data validation, conversion of raw data to the Receiver Independent Exchange Format (RINEX), data compression, and data upload to a data centre through the Internet. For some sites, the OC is identical with the institution responsible for the respective site (i.e., the OC is identical with the TS).
- Local Data Centres (LDC): They collect the data of all stations in a local network and distribute them to the users (local and EUREF). One or more of these stations are part of the EPN. For many of the local networks, the LDC will be identical with their Operational Centre. The LDC will forward the data (of a selection) of the local sites to the Regional Data Centre. If there is no LDC available for particular station, then its data will flow directly from the OC to the European Regional Data Centre.
- Regional Data Centre (RDC): It collects the data from EPN stations which
 - 1. belong to the IGS network
 - 2. have their data not available at a LDC
 - 3. have their data made available at a LDC, but where the RDC is considered as a backup data centre

The RDC makes the data available to the local and regional users (among which the IGS). Within Europe, there is only one Regional Data Centre.

In addition to the RINEX data, the Regional Data Centre collects the weekly SINEX solutions from the EPN Local Analysis Centres and the weekly combined EUREF solution. These SINEX files are made available to interested Agencies.

EPN stations contributing also to the IGS make their data additionally available in one of the IGS Data Centres. In the following, we will use the wording "Data Centre" (DC) for any of the EPN or IGS Data Centres.

2 **Requirements for Permanent Stations**

For a station to be included in the EUREF Permanent Network, the following guidelines will be used to judge the merits of a candidate station. Please consult also the checklist of "Procedures for Becoming an EPN station"

http://epncb.oma.be/_organisation/guidelines/procedure_becoming_station.html

2.1 Equipment and operation

- 2.1.1 The GPS equipment, and its surroundings, must not be disturbed or changed unless a clear benefit outweighs the potential for discontinuities in the time series. Examples include
 - Equipment failure
 - Planned replacement of obsolete equipment
 - Vendor-recommended firmware updates

Receiver

The GPS receiver must

- 2.1.2 Track both codes and phases on L1 and L2 under non-AS (anti spoofing) as well as Anti-Spoofing conditions. Required observables are L1, L2, P2, and at least one of C1 or P1.
- 2.1.3 Be capable of, and set to, record data from at least 8 satellites in view, simultaneously.

- 2.1.4 Track at least with 30 seconds sampling rate. If the sampling rate is faster, the data should be decimated to 30 seconds prior to upload to the Local or Regional Data Centre.
- 2.1.5 Be set to record data down to a cut off of 5 degrees or less.
- 2.1.6 Synchronize the actual instant of observation with true GPS time within ± 1 millisecond of the full second epoch.

Additionally desired characteristics are:

- 2.1.7 Receiver capable of tracking all visible GPS satellites ("all-in-view" tracking) is preferred.
- 2.1.8 The receiver tracking cut off is ideally zero degrees, especially for "all-in-view" receivers.
- 2.1.9 GPS receivers and ideally other station equipment such as computers should be protected against power failures by providing surge protection and backup power wherever feasible.
- 2.1.10 Equipment never used before in the EPN/IGS should be avoided until tested and well understood by IGS or EPN Analysis Centres. Inform the CB of proposed new types of equipment (any receiver or antenna+radome combination not found in ftp://epncb.oma.be/pub/station/general/euref.snx). Test data sets, and analysis of test data, will be helpful. Inform the CB whether these will be available.
- 2.1.11 Receivers should be set to record data from all satellites, including those newly launched or set 'unhealthy'.
- 2.1.12 Receivers and RINEX converters should not be set to smooth data.

Antenna

The GPS antenna must

- 2.1.13 Be represented accurately in the phase centre variation file ftp://epncb.oma.be/pub/station/general/igs_01.pcv. If it is not, contact the CB. A calibration from an independent, recognized laboratory such as NGS (http://www.ngs.noaa.gov/ANTCAL) or Geo++ (http://www.geopp.com) will be required.
- 2.1.14 Be levelled and oriented to True North using the North reference mark and/or antenna RF connector.
- 2.1.15 Be rigidly attached, such that there is not more than 0.1 mm motion with respect to the antenna mounting point.
- 2.1.16 The eccentricities (easting, northing, height) from the primary marker to the antenna reference point (defined in ftp://epncb.oma.be/pub/station/general/antenna.gra) must be surveyed and reported in the site logs and RINEX headers to ≤ 1 mm accuracy.
- 2.1.17 Each eccentricity component must be less than 10 m (see also 2.2.5).

Additionally desired characteristics:

2.1.18 Dorne-Margolin antenna elements and choke ring antennas are preferred.

Radomes

- 2.1.19 Avoid using radomes unless required operationally, for instance due to weather conditions, antenna security, wildlife concerns, etc.
- 2.1.20 Non-hemispherical radomes especially must be avoided when the shape is not required by site characteristics (e.g. for snow rejection)
- 2.1.21 If a radome must be used, an entry for antenna+radome pair must be in the phase centre variation file ftp://epncb.oma.be/pub/station/general/igs_01.pcv.
 - Exceptions (for historical reasons) are listed in

ftp://epncb.oma.be/pub/station/general/uncal_radome.txt

- To use an antenna+radome pair not found in either of these files, contact the CB. A calibration from an independent, recognized laboratory such as NGS (http://www.ngs.noaa.gov/ANTCAL) or Geo++ (http://www.geopp.com) will be required.
- The list of standard receiver and antenna names used within the EPN is available at ftp://epncb.oma.be/pub/station/general/rcvr_ant.tab.

Additionally desired characteristics:

2.1.22 Radomes uniformly manufactured with less than 1 mm variability in thickness are preferred.

Operation

- 2.1.23 Stations must be permanent and continuously operating.
- 2.1.24 The station will have obtained a unique 4-character ID and an IERS DOMES number following the procedures in the "Procedure for becoming an EPN station", http://epncb.oma.be/_organisation/guidelines/procedure_becoming_station.html.
- 2.1.25 The operating agency must always have the capability to repair or improve the station and its software systems, even if the original engineers are no longer available.

Additionally desired characteristics:

- 2.1.26 Precise meteorological instrumentation is encouraged:
 - Data are to be prepared in RINEX files. See the RINEX specification, ftp://epncb.oma.be/pub/data/format/rinex210.txt.
 - Observation interval must be no more than 60 minutes. An observation interval of 10 minutes is optimal.
 - Pressure sensor noise must be no more than 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 GPS antenna mark must have an accuracy of 1 m or better.
 - Data is to be transmitted on the same schedule as the RINEX observation files (hourly for hourly sites; otherwise daily).
 - Meteorological instruments are to be calibrated periodically according to the manufacturer's recommendations. It is recommended to do a periodic calibration against a pressure/temperature sensor operated by a local weather authority and keep a record of the calibration in the site log.
- 2.1.27 Anticipate upgrades to new equipment types, including support to new GNSS signal types, while paying attention to data overlap to avoid discontinuity.
- 2.1.28 Station infrastructure should include:
 - Ample, reliable power and communications (preferably Internet) to enable reliable data transfer
 - Physical site security appropriate to local necessity
- 2.1.29 Other geophysical systems -- such as SLR, VLBI, DORIS, absolute or superconducting gravimeters, Earth tide gravimeters, seismometers, strain meters, ocean tide gauges -- are also desirable and will enhance the value of the station for multi-disciplinary studies.
- 2.1.30 Other scientific systems which rely on accurate positioning, such as timing labs, are also recommended where appropriate.

2.2 Marker

- 2.2.1 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 site log file.
- 2.2.2 Obstruction should be minimal above 15 degrees elevation, but satellite visibility at lower elevations is encouraged whenever possible.
- 2.2.3 Signal reception quality has to be verified, especially with respect to interference of external signal sources like radars, and with respect to multipath.
- 2.2.4 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).

Additionally desired characteristics:

- 2.2.5 The antenna reference point ideally will be mounted directly vertically above the marker (i.e., horizontal eccentricities ideally are zero).
- 2.2.6 Additional monuments are desirable for surveys and testing, but it is preferable to maintain one antenna + receiver pair as the best site for the EPN, rather than to submit more than one "site" to the EPN.
- 2.2.7 3-dimensional local ties between the GPS marker, collocated instrumentation (e.g. DORIS, SLR, VLBI, gravity, tide gauge) and other monuments should be re-surveyed regularly (ideally each 2 years) to an accuracy of 1-mm and reported in ITRF.
 - The marker \rightarrow antenna reference point (ARP) eccentricities should be reverified 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 ftp://epncb.oma.be/pub/data/format/sinex.txt), including full variance-covariance information.
- 2.2.8 When antenna changes are planned, operate both the new and old antennae at the same time first (if an additional monument and receiver are available), and announce to EUREF mail how analysts may get the test data set.
- 2.2.9 Agencies are encouraged to select potential new sites which meet most of the following features, and work toward these characteristics at existing sites. The site location should:
 - be on a stable regional crustal block, away from active faults or other sources of deformation, subsidence, etc. Contact the Reference Frame Coordinator, or the CB for assistance in determining the stability of a particular area, if it is not clear.
 - be on firm, stable material, preferably basement outcrop
 - have a clear horizon with minimal obstructions above 5 degrees elevation
 - The site location should not:
 - be located on soil that might slump, slide, heave, or vary in elevation (e.g. because of subsurface liquid variations)
 - have 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

A physical marker should be provided, to allow the assignment of an M-type IERS DOMES number (see http://lareg.ensg.ign.fr/ITRF/DOMES_DESC.TXT).

2.3 Documentation

Site logs

- 2.3.1 Whenever there is a change to the site information as documented in the station log, the log must be updated:
 - The EPN site description file (site log file) should be updated out and sent to the EPN CB. Refer to ftp://epncb.oma.be/pub/station/general/sitelog_instr.txt for detailed site log preparation instructions. Use the automated site log tester (epcnbslt@oma.be) to verify the format and contents of your site log. Submit the site log using the automated site log submission (epcnbsls@oma.be). Refer to http://epncb.oma.be/_trackingnetwork/sitelog_sub_test.html for detailed instructions. If necessary, site descriptions (photos, maps, etc) should be sent to the Central Bureau.
 - Updates must be sent to the EPN CB within one business day of any change. An announcement of the change must be posted through EUREF mail (http://epncb.oma.be/_newsmails/EUREFmail/)
- 2.3.2 If an advisory of site log inconsistencies is received from the CB, the site log must be corrected as soon as possible.

EUREF mailing list messages

- 2.3.3 When sending a message to the EUREF mailing list about a particular station or stations, place the 4-character site ID(s) in the Subject. Instructions on sending an EUREF mail can be found in http://epncb.oma.be/_newsmails/EUREFmail/mail_rul.html.
- 2.3.4 An advisory EUREF mail message should be sent in the following cases, in advance if possible, otherwise within one business day:
 - Changes in antenna, radome, monument, receiver, cabling, frequency standard, receiver settings such as elevation cut off angle, or environment (such as tree removal or building construction); in general, any change which can affect position solutions. Briefly describe in the message what was changed.
 - 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 site is decommissioned permanently.
 - When a problem or error in the station or its site log is discovered and corrected. Briefly describe in the message what was changed.
- 2.3.5 The agency accepting responsibility for proper station operation must follow the EUREF mail list on a regular basis, either by subscribing or regularly checking the web archive. See the http://epncb.oma.be/_newsmails/EUREFmail/mail_rul.html for subscription information.

2.4 Location

- 2.4.1 The site must occupy a relevant location into the EUREF Permanent Network:
 - For stations installed primarily to contribute to the maintenance of the ETRS89, a minimal distance of 300 km to already existing EPN stations is required, accepting the interest of each nation to have at least one EPN station.
 - Exceptions to this rule are possible for stations submitting hourly data, contributing to EPN Special Projects or collocated with other instruments relevant to the purposes of the EPN (e.g. tide gauges, time laboratories).

2.5 Switch between operational and inactive status

When a station has been excluded from the EUREF combined solution for more than 3 months, the EPN CB labels this station as inactive. As a consequence, the station will be eliminated from the list of operational EPN stations at http://www.epncb.oma.be/_trackingnetwork/siteinfo.html and will be transferred to http://www.epncb.oma.be/_trackingnetwork/inactive.html. Stations can be classified as inactive for several reasons, e.g.:

- the station is excluded from the EPN due e.g. bad data quality or meta data inconsistencies
- the station has been destroyed and is in the process of reconstruction
- the station has temporarily stopped submitting RINEX data
- 2.5.1 Inactive stations can recover the operational status when they fulfil the requirements for EPN stations again.

3 Requirements for Operational Centres

3.1 Responsibilities

The Operational Centres control the sites of a particular (local) network from the operational point of view. They form a link between the sites and the Data Centre. The Data Centre then makes available the data to the Analysis Centres, other Data Centres and individual users.

The Operational Centres are responsible for

- the download of the raw data from the receivers of the local network
- the archiving of the raw data
- the reformatting of the data into the agreed-upon exchange format (RINEX)
- the quality check of the data on a station by station basis (the use of Unavco's QC program is strongly recommended, see 3.4.3)
- the generation of status messages (abnormal conditions), which have to be announced through EUREF mail
- the alert/engagement of on-site staff (abnormal conditions)
- the upload of the data to the Data Centre at agreed-upon times

There are many independent tracking sites that are not part of a local or special network. As such, they are not connected to an actual OC. In this case the organization operating the site also performs the tasks outlined above.

The EPN CB makes available a blank form (ftp://epncb.oma.be/epncb/center/oper/BLNKFORM.OC) for an Operational Centre. This form should be filled out by the Operational Centre or by the agency operating an independent permanent GPS station and sent to the EPN Central Bureau.

3.2 Data flow

- 3.2.1 All data handling, including receiver communication, reformatting, quality check, and transmission to the DC, should be automated by computer(s).
- 3.2.2 The minimal requirement for data submission is daily (24 hour) files with a 30 second sampling interval.
- 3.2.3 For some stations it is mandatory (see 2.4.1) to submit hourly data.
- 3.2.4 After a communication outage between the station and the OC, or between the OC and the DC, all recovered daily data files must be submitted to the DC(s).

- 3.2.5 Transmission of the data to the DC must be verified to be uncorrupted. In addition, the upload should be retried after failure.
- 3.2.6 All data files are to be transmitted simultaneously or at least in quick succession, to at least two data centres (the Primary and Secondary Data Centres). If one of these two centres is temporarily unavailable, it is not necessary to instead send files to a third centre during this period.
- 3.2.7 For standard operations, the daily data delivery to the DC must be done within the same delay as the satellite orbits become available (currently 12 days). Depending on additional requirements (e.g., by contributions to the IGS network, Special Projects) shorter latencies may be necessary.
- 3.2.8 Hourly data files must be uploaded as soon as possible which means within 10 minutes after closing time of hh:59:30 UT.
- 3.2.9 If an upload fails, then a retry should be made as quickly as possible. At least a second retry should be done within the hour.
- 3.2.10 Hourly files, which could not be sent, or have to be updated, must arrive within three days. After that date, updates must be done through the upload of the appropriate daily file.

Additionally desired characteristics:

- 3.2.11 The automated use of a quality check program is recommended to verify data quality (not just metadata correctness), prior to transmission to a DC.
- 3.2.12 It is recommended to make the daily data available as soon as possible after the closing time of the file.
- 3.2.13 Hourly data is preferred, especially in cases where there are few nearby hourly stations in the region.
- 3.2.14 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
 - 2) Wait for the confirmation of the DC
 - 3) If the DC agrees, stop the transfer of daily files

3.3 Data Archiving

3.3.1 The station operating agency must archive the raw (native binary) GPS data, or arrange for this at a suitable agency such as a partner agency, or an Operational Centre. The Local Data centres archive RINEX data for the general benefit of local users and EUREF. The Regional Data Centre archives the RINEX files for the general benefit of EUREF and the IGS.

3.4 Data Validation

- 3.4.1 Data should be checked before being sent to a Data Centre. A minimum verification should consist of a check of
 - the total number of observations
 - the total number of observed satellites
 - the date of the first observation record in the file
 - the station name, receiver/antenna types, antenna height
- 3.4.2 Files, which do not meet the minimum verification, should not be sent to a Data Centre.

Additionally desired characteristics:

3.4.3 The use of a true quality check program is highly recommended, e.g. the QC program, which can be obtained from Unavco (see http://www.unavco.ucar.edu/data_support/software/qc/qc.html).

3.5 Data Format

- 3.5.1 GPS data (observations and broadcast ephemeris) are to be prepared and distributed in the RINEX format, version 2.00 or greater, as specified in ftp://epncb.oma.be/pub/data/format/rinex210.txt or ftp://epncb.oma.bepub/data/format/rinex2.txt
 - Observation files will normally be exchanged in the Hatanaka Compact form. See the RINEX specification ftp://epncb.oma.be/pub/data/format/rinex210.txt and confirm with your DC.
 - All files are ordinarily UNIX compressed (.Z) for transmission to DCs. Confirm with your DC. The RINEX navigation, meteo and summary files are prepared in a compressed form using the standard UNIX compress program.
 - File naming conventions set forth in the RINEX specification ftp://epncb.oma.be/pub/data/format/rinex210.txt, section 4, "The Exchange of RINEX files", will be followed. Some DCs implement lower-case file type codes and/or site IDs. Confirm with your DC. Case must not be used to distinguish between unique files.
- 3.5.2 The daily observation files contain the observations collected between 00:00:00 and 23:59:59 GPS time.
- 3.5.3 The sampling rate (observation interval) of the daily observation file must be the adopted standard, currently 30 sec. Even if the receiver sampling interval is less than 30 seconds, the data submitted to EUREF archives must have a 30 second interval, with observations aligned to :00 and :30 epochs.
- 3.5.4 The daily (24 hour) navigation message file contains all messages with TOC/TOE (time of clock, time of ephemeris) at and between 00:00 and 23:59 GPS time of the respective day. It is recommended to generate a combined daily RINEX navigation file containing non-redundantly all navigation messages collected by all sites of a local network. The filename (part "ssss", see below) should then contain a 4-character code of the Operational Centre.
- 3.5.5 For hourly data uploads,
 - Each file contains the data of one hour, synchronized with GPS time.
 - Files are named as in section 4 of the RINEX specification, but with the file sequence letter "f" replaced with an hour sequence code ('a'=00:00UT to 00:59UT .. 'x' = 23:00UT to 23:59UT).
 - As last file to each group of station files, a flag file with the same name as the observation files but with "flg" (or "FLG") as extension needs to be uploaded. This file contains a list of the uploaded files (excluding the flag file) together with the file sizes (in bytes) so that the receiving data centre can check if the transfer was completely successful (File sizes determined on VMS systems are rounded to the next 512 bytes block).

```
Example: Transmission of: zimm123a.98d.Z, zimm123a.98n.Z,
zimm123a.98m.Z is followed by the transmission of zimm123a.flg (as last file!).
zimm123a.flg contains: zimm123a.98d.Z 234567
zimm123a.98n.Z 12345
zimm123a.98m.Z 9876
```

If the generation of the file list with file size is not possible, an empty flag file properly named can be uploaded instead.

3.5.6 The header information, especially the 4-character site ID, receiver and antenna information, IERS DOMES number, and antenna eccentricities, must be up-to-date and strictly follow the agreed-upon conventions.

- Specifically, they must match the information in the site log and therefore observe the same equipment naming conventions found in ftp://epncb.oma.be/pub/station/general/rcvr ant.tab.
- A radome identifier code from ftp://epncb.oma.be/pub/station/general/rcvr_ant.tab must be found in the ANT TYPE field, in columns 17-20 of this field.
- The RINEX headers must begin showing an equipment change as near as possible to the actual time of the change.
- If an advisory of RINEX header inconsistencies is received from the CB, the headers must be corrected as soon as possible and the corresponding data files must be resubmitted to the DC.
- 3.5.7 Metadata correctness for daily (24 hour) data files must be minimally verified prior to transmission to a DC. Site name, number of observations, epoch, equipment types, interval, and eccentricities must be verified to be correct prior to transmission.

Additionally desired characteristics:

- 3.5.8 Stations equipped with high-precession weather sensors are encouraged to submit the daily RINEX meteo files too.
- 3.5.9 The summary output of the quality check run can be sent to (and made available by) the data centres.
 - File name conventions are similar to the RINEX data files, but using "S" for the file name type, e.g. ZIMM1230.99S.
 - Quality check data is to be transmitted on the same schedule as the RINEX observation files (hourly for hourly sites; otherwise daily).
- 3.5.10 The S1 and S2 observables should be included in daily RINEX files.
- 3.5.11 For data transfer to and from the LDC's, the use of the Hatanaka compression is also recommended.

4 Acknowledgment

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".

Maintenance of this document is managed by the EPN Network Coordinator at the EPN Central Bureau. Please direct comments, questions, and suggestions to epncb@oma.be.