## European Position Determination System

# Technical Standards

**Revised 2nd Edition**

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**Contents:**

# 1 General

## 1.1 Global Navigation Satellite Systems (GNSS)

*EUPOS* uses the following GNSS as described:

- European Galileo as basic standard when available;
- U.S. Global Positioning System (GPS) as basic standard until complete availability of Galileo, and as additional standard after complete availability of Galileo;
- Russian Global Navigation Satellite System (GLONASS) as optional standard, recommended to be used;
- Chinese COMPASS/BeiDou as optional standard when available.

N.B.: A high number of available GNSS satellites is especially required in high-density urban areas. Therefore development of *EUPOS* for all available GNSS is recommended.

## 1.2 Geodetic reference system and frame

The official geodetic terrestrial reference system for *EUPOS* is the European Terrestrial Reference System 1989 (ETRS 89) and its actual frame.

N.B.: It is recommended to use the official regional transformation parameters and regional quasigeoid parameters for unified precise transformations of coordinates between ETRS 89 and the available conventional geodetic reference systems.

## 1.3 *EUPOS* availability

*EUPOS* aims for annual system availability of at least 99%, guaranteed by *EUPOS* appropriate technical and organisational measures.

# 2 *EUPOS* sub-services

The multifunctional permanent Differential GNSS (DGNSS) service *EUPOS* contains the following sub-services:

- *EUPOS* DGNSS for real-time DGNSS applications by code and code-phase measurements with metre up to sub-metre accuracy;
- *EUPOS* Network RTK for real time DGNSS applications by carrier phase measurements with centimetre accuracy;
- *EUPOS* Geodetic for post processing applications by code and phase measurements in static or kinematic mode with decimetre up to sub-centimetre accuracy.

## 2.1 *EUPOS* DGNSS

For real time navigation and real time position determination with an accuracy of 2 m up to 0.5 m for dynamic applications and up to 20 cm for static applications, depending on the applied rover equipment, *EUPOS* provides DGNSS corrections in standard data format defined by the Radio Technical Commission for Maritime Services, Special Committee 104 (RTCM SC-104). *EUPOS* DGNSS data are provided via

- mobile Internet as basic standard, provided via media such as GPRS (General Packet Radio Service), UMTS (Universal Mobile Telecommunications System), HSDPA (High-Speed Downlink Packet Access), Wireless Local Area Network (WLAN), etc.;
- broadcast as optional standard, via media such as VHF 2 m or 4 m radio, radio broadcast, TV broadcast, and when available Internet User Datagram Protocol (UDP) multicast, etc.

The user interface is DGNSS correction data in the international standard data format RTCM SC-104 version 2.x (RTCM SC-104 version 2.x) with a reduced number of message types similar to RTCM SC 104 version 2.0 and RTCM message type 59 FKP if provided via mobile Internet, and the same data as used for *EUPOS* Network RTK if provided via broadcast media. Using radio broadcast the user's technical equipment has to select the required RTCM message types by itself.

N.B. 1: The FKPs have a range of about 500 km up to 700 km for *EUPOS* DGNSS.

Using mobile Internet, the user's rover receiver has to send its position in a GGA string (NMEA 0183 version 3.01 formatted) to the provider's Internet NTRIP caster to select the favourable *EUPOS* reference station automatically. But also the user's direct selection of the *EUPOS* reference station is supported. If broadcast is used, the selection of the favourable *EUPOS* reference station has to be carried out by selection of the corresponding station.

N.B. 2: Mobile Internet is already now or near-term available in all *EUPOS* member countries. This is good value media particularly for real time applications. The data provision via mobile Internet requires ensuring the authenticity of official *EUPOS* DGNSS correction data as well as offering protection against unauthorised use (cf. 2.4).

The optional standard "broadcast" is particularly of interest for applications of institutions and organisations that are responsible for security tasks, such as police, fire services and rescue services, but also for hazardous materials transportation, shipping, public transport, etc. It is more reasonably priced than mobile Internet for the user, and it is an essential advantage for providers that an unlimited number of users can utilise the broadcasted *EUPOS* data simultaneously.

## 2.2 *EUPOS* Network RTK

For precise real-time position determination with an accuracy ≤ 2 cm (1σ, horizontally) *EUPOS* strives to provide DGNSS correction data that support all existing network RTK solutions (FKP, non-physical reference station, and MAC). It is expected that the next RTCM 3.x format would fulfil this functionality.

Until then the standard data formats defined by RTCM are *EUPOS* standard for this procedure. To give the flexibility to the users all networking solutions are supported (FKP, non-physical reference station, MAC).

*EUPOS* Network RTK data are provided via

- mobile Internet as basis standard in formats RTCM SC 104 versions 2.x and 3.x;
- broadcast as optional standard in format RTCM 2.3;

N.B.: Using RTCM 3.1 MAC fixed cells can also be transmitted via broadcast media.

The user interfaces are DGNSS correction data in the international standard data format Radio Technical Commission for Maritime Services, Special Committee 104,

- version 2.3 with the message types 1, 2, 3, 14, 16, 20, 21, 23, 24, 31; 59 FKP or non-physical reference station;
- version 2.3 with the messages 3, 16, 18, 19, 22, 23, 24, 36, 59 FKP or non-physical reference station;
- version 3.0 with the messages 1003 or 1004,1011 or 1012, 1005 or 1006, 1007 or 1008;
- version 3.1 amendment 2 with the messages 1003 or 1004, 1011 or 1012, 1005 or 1006, 1007 or 1008, 1032, and 1030, 1031 non-physical reference station or (GPS only) 1014,1017 MAC or 1014, 1015, 1016 MAC.

N.B. 1: The FKPs have a range of about 100 km up to 200 km for *EUPOS* Network RTK.

Using mobile Internet the user's rover receiver has to send its position in a GGA NMEA string (NMEA 0183 version 3.01 formatted) to the provider's Internet NTRIP caster to select the favourable *EUPOS* reference station automatically in case of FKP use, or for a non-physical reference station to be generated according to the rover's location, or for a master station and several auxiliary stations to be selected automatically according to the rover's location. But also the user's direct selection of the favourable *EUPOS* reference station is supported. If broadcast is used, the selection of the favourable *EUPOS* reference station has to be carried out by selection of the corresponding station.

For the generation of a non-physical reference station the rover receiver has to send its position in a GGA string (NMEA 0183 version 3.01 formatted) to the respective *EUPOS* networking centre at minimum 10-second rate. This helps the network operators to investigate user problems.

N.B. 2: Cf. 2.1.

### 2.3 *EUPOS* Geodetic

For post processing applications *EUPOS* provides observation data of the reference stations via

- Internet.

The user interfaces are GNSS observation data in the international standard data format Receiver Independent Exchange Format version RINEX 3.0, also for the third GPS frequency L5 and Galileo. It is recommended for a limited period to provide both formats RINEX 2.11 and 3.0.

*EUPOS* Geodetic supports post-processing applications that require accuracy in the range of decimetres up to sub-centimetre depending on the user's equipment and the duration of the measurement.

N.B. 1: The web sites at the *EUPOS* web-servers, installed in the member countries to provide RINEX and virtual RINEX data, will be linked to the *EUPOS*.org web site, if the respective *EUPOS* provider agrees with the procedure. The order of RINEX data can be arranged only via the national web site.

### 2.4 Encryption of *EUPOS* real time data

To ensure authenticity of the official *EUPOS* DGNSS and *EUPOS* Network RTK data, to prevent modification or manipulation of *EUPOS* real time data, to disable unauthorised use of *EUPOS* services or re-broadcasting of the data, it is recommended to encrypt the data by the use of the international standard "Private Services" of the Radio Technical Commission for Maritime Services, Special Committee 104. It is expected that a corresponding standard will be agreed within 2008 by the RTCM SC-104.

## 3 *EUPOS* payment

| *EUPOS* sub-service | data format | time installment | use unit | charge | remarks |
|---|---|---|---|---|---|
| DGNSS | RTCM 2.3, | 1 second | defined by start and end calendar date | flat sum[2)] | for one complete area unit in one country |
| | | | 1 minute | 1 unit | ever begun use unit |
| Network RTK | RTCM 2.3, 3.0, 3.1 | 1 second | 1 minute | flat sum[2)] | for one complete area unit in one country |
| | | | | 1 unit | ever begun use unit |
| Geodetic | RINEX 2.11, 3.0 | ≤ 1 Hz | 1 minute | 1 unit | for 1 reference station, ever begun use unit |
| | | > 1 Hz[1)] | 1 minute | 1 unit | |

[1)] If available by the respective *EUPOS* provider.
[2)] Always for broadcast and/or if RTCM SC -104 encrypted data are provided, but also for special user agreements.

The charges are individually collected by the service provider in every *EUPOS* member country.

The charges for *EUPOS* Geodetic use are determined automatically by the providing software in the *EUPOS* networking centres and can be levied directly or by invoice.

# 4 Technical and organisational standards for the operated *EUPOS* reference station systems

## 4.1 National *EUPOS* reference station system

A national *EUPOS* reference station system consists of

- *EUPOS* reference stations at a distance of about 50-70 km or more depending on the topography and networking software's performance, higher density can be useful in conurbations;
- Communication lines between reference stations and *EUPOS* control centres;
- Control centre per *EUPOS* member country, advisable is to have two control centres, one as a backup in case of failures;
- Internet RTCM NTRIP casters to provide *EUPOS* DGNSS and *EUPOS* Network RTK, advisable is to have two casters on two different IP addresses. It is recommended to install Internet NTRIP casters on Internet servers of a telecommunication company in order to fulfil the aimed *EUPOS* availability of 99% at least;
- Optional broadcast transmitters to provide *EUPOS* DGNSS and *EUPOS* Network RTK;
- Internet server to provide *EUPOS* Geodetic, advisable is to have two, one as a backup in case of disturbances or failures;
- At least two *EUPOS* monitoring stations per *EUPOS* member country;
- *EUPOS* quality management measures.

The common use of reference stations at the borders of neighboring countries is recommended (*see guideline for cross-border data exchange*).

### 4.1.1 *EUPOS* reference station

Necessary hardware and software components of *EUPOS* reference stations are:

- Geodetic dual/multi frequency GNSS receiver;
- Receiver, capable of remote control via IP – if not able, necessary software and hardware equipment for control and supervision of the basic functions including data communication and teleservice.
- Interfaces for data communication with the *EUPOS* NSC;
- Absolute Phase Center Variation individual calibrated GNSS antenna. Choke Ring antenna are to be used;
- It is recommended to apply lightning protection;
- Uninterruptable power supply (UPS) and if possible emergency generator, too;
- Call cash electrical outlet (telephone switch box) or IP-based power control unit for cold starts in disturbance cases by teleservice (optional).

Sites are selected so the horizon would be free of obstructions and reflective surfaces as far as possible and so far-field and near-field multipath effects on satellite signals would be avoided. By using appropriately calibrated choke ring antennas possible multipath effects are further counteracted. Reference station sites have to be chosen so that the long-term stability of the GNSS antennas would be ensured (*see guidelines for single site design*).

The coordinates of the stations will be determined with high precision, both in ETRS 89 and in conventional geodetic reference systems (*see guidelines for reference frame fixing*).

N.B.: The loss of GNSS data can be avoided for post processing even if the data transmission is cancelled temporary to the *EUPOS* networking station by equipping the reference stations with memory capacity of at least 100 MB.

#### 4.1.1.1 Receiver basic settings

*EUPOS* reference station GNSS receiver is to adjust for following parameters:

- Elevation mask: Between 0° and 5°, depending on the local obstructions;
- Measurement interval: 1 Hz (higher time instalment upon special request for *EUPOS* Geodetic, if available by the respective *EUPOS* provider).

#### 4.1.1.2 Antenna calibration

In the *EUPOS* reference station network only antenna types with available absolute PCV calibration results can be used.

GNSS antennas and radomes (if used) at *EUPOS* reference stations are to be individually absolute calibrated with regard to offset and phase centre variations (PCV) for all signal frequencies of all used GNSS in 5°-steps for elevation and azimuth (elevation: 0° up to 90°, azimuth: 0° up to 360°).

### 4.1.2 *EUPOS* National service centres (NSCs)

*EUPOS* NSCs are the centres of the national *EUPOS* reference station systems. They are connected with all own national *EUPOS* reference stations and with the neighbouring reference stations of other countries across the border via their *EUPOS* NSCs. Like *EUPOS* reference stations also NSCs needs uninterruptable power supply (UPS) and if possible emergency generator, too, an air condition – if required – as well as call cash electrical outlet (telephone switch box) for cold starts in disturbance cases by teleservice. For guaranteeing the striven minimum availability of 99% the *EUPOS* NSCs are advisable to be duplicated.

Main functions of the *EUPOS* NSCs are:

- Active remote control of all own connected *EUPOS* reference stations;
- Data collection of all connected *EUPOS* reference stations and quality control of the *EUPOS* DGNSS data in addition to *EUPOS* monitoring stations;
- Computing the real-time *EUPOS* sub-services DGNSS and Network RTK and transmitting the *EUPOS* data to the Internet NTRIP casters, and to broadcast transmitters if offered. A pre-extrapolation of the FKPs should be used for time response in agreement with the function if necessary;

  The procedure of networking reference stations serves among other things to improve profitability, precision and homogeneity of the *EUPOS* solutions by modelling distance dependent effects of GNSS error components, particularly ionospheric, tropospheric and orbit effects. Profit of using network RTK corrections (FKP, non-physical reference station corrections or MAC) are shorter initialisation times, higher reliability and improved accuracy for real time position fixing;
- Transmitting RINEX data for *EUPOS* Geodetic sub-service to the Internet servers and long-time storage of these data (two years at least, the best is the unlimited long term storage), to guarantee later use and particularly to make possible the certification of correct *EUPOS* Geodetic RINEX data in cases of recourse against the *EUPOS* provider. For long term storage it is sufficient to store RINEX files with 30 s data rate at least, 1 s data rate best;
- Cross-border real time data exchange;

- Fulfilling of quality management measures in cases of *EUPOS* reference station system malfunctions by an automatic alarm plan and if demanded by manual intervention and manual remote maintenance.

### 4.1.3 *EUPOS* DGNSS and *EUPOS* Network RTK mobile Internet providing

Providing DGNSS and Network RTK correction data via the Internet is the standard procedure of *EUPOS* for real time applications. It enables near-term establishing of these sub-services with moderate costs and based on available communication infrastructures. *EUPOS* DGNSS and Network RTK mobile Internet provision uses the Networked Transport of RTCM via Internet Protocol (NTRIP, topical version is 1.0, cf. www.rtcm.org) with following additional specifications:

- Use of the User Datagram Protocol (UDP). It is aimed to use UDP unicast in future NTRIP 2.0.
- Connection set-up by
  - server receiving an NMEA 183 version 3.1.0 $GPGGA string or an NMEA-AdV $PGPPADV.110 string from the user equipment for the selection of the nearest available *EUPOS* reference station or generation of a non-physical reference station or selection of a predefined MAC cell or a master and a number of auxiliary stations, in each case automatically;
  - direct selection of the *EUPOS* reference station by the user, too. The last functionality would be important for several users, e.g. governmental authorities which are interested in secrecy of there application also against the provider.

It is recommended to install the Internet NTRIP Caster duplicated directly by a commercial telecommunication company to guarantee the striven *EUPOS* quality.

### 4.1.4 Broadcasted *EUPOS* DGNSS and *EUPOS* Network RTK

Broadcast via media, such as VHF 2 m or 4 m radio, radio broadcast, TV broadcast, and when available Internet User Datagram Protocol (UDP) multicast, etc., is the optional standard to provide *EUPOS* DGNSS and *EUPOS* Network RTK. If an *EUPOS* member country decides to use broadcast media for the whole area or on special sites it is necessary to guarantee the full quality as for *EUPOS* at all. Therefore the duplication of radio transmitters and data communication paths is needed. It is especially recommended to install broadcast transmitters on high buildings, e.g. at TV/ radio service towers, for a suitable transmission range whenever possible.

### 4.1.5 *EUPOS* Internet servers for providing *EUPOS* Geodetic and *EUPOS* Virtual RINEX

The *EUPOS* RINEX data are to transmit for the sub-service *EUPOS* Geodetic and *EUPOS* Virtual RINEX by the *EUPOS* networking station to an Internet server in short time for near real time post processing and post processing user applications. It is recommended to transmit current data every four minutes particularly for near real time post processing user applications. A confirmation of data transmission and automated check of data completeness by means of software allow to add missed data.

Derivative time of topical 1 s data rate RINEX data: four weeks at least, depending on the available capacity of the Internet server.

It is advisable that the Internet server is duplicated to ensure the striven *EUPOS* availability of 99% at least.

### 4.1.6 *EUPOS* monitoring stations

Monitoring stations are a fundamental part of the *EUPOS* quality management, needed to control availability and quality of *EUPOS* DGNSS and RTK correction data, etc. It is possible to install the monitoring stations at the site of *EUPOS* reference stations directly. This would be a reasonably priced solution, because the reference station equipment could be used in parallel for the monitoring station. But for a full control of the networking correction data it is advisable to place some monitoring stations at least independently of the reference station sites or to use them as mobile stations. At least two monitoring stations are necessary because no alarm plan would automatically be activated by a *EUPOS* system malfunction if the only existing monitoring station would be disturbed. Handling the monitoring stations it is required to take into account the ranges of networking corrections.

### 4.1.7 *EUPOS* quality management measures – basic principles

A quality management strives for guaranteeing a minimum 99%-level of annual *EUPOS* system availability and integrity in the operation phase. Technically standard measures are:

- Duplication of *EUPOS* NSCs, monitoring stations, RTCM NTRIP casters for sub-services *EUPOS* DGNSS and *EUPOS* Network RTK, internet servers for sub-service *EUPOS* Geodetic, and broadcast transmitters for sub-services *EUPOS* DGNSS and *EUPOS* Network RTK, too, if the optional service is offered. According to the requirements duplication of data communication paths;
- Protection of all *EUPOS* reference station system components from power fluctuations and failures by independent (uninterruptible) power supplies (UPS) and if possible by connection to emergency generators;
- Continuous reception and check of provided *EUPOS* DGNSS and Network RTK by monitoring stations in real time and also continuously monitoring and checking of *EUPOS* Geodetic RINEX data;
- Malfunctions automatically activate an alarm plan which sets off appropriate corrective measures. Depending on the requirement, data links, computers or transmitters etc. are switched over and different reference stations will temporarily be used as principal reference station for the appropriation of correction data;
- The system will be designed so that the technical equipment generally manages itself and the *EUPOS* operation will be maintained automatically. All malfunctions etc. will be recorded automatically and evaluated within the framework of the quality control management. Malfunctions, faults and losses of quality are therefore identified in real time automatically;
- Positions of reference station antennas will be checked adequate regularly (automatically) for any displacement;
- The establishment of an emergency callout service is recommended. It would be informed in cases of failures, disturbances and quality deterioration by the *EUPOS* system automatically.

# 5. Required *EUPOS* user equipment

## 5.1 *EUPOS* DGNSS

The following user equipment is required for using *EUPOS* sub-service DGNSS

- via mobile Internet:

  a suitable GNSS receiver, a mobile Internet device, NTRIP client software and an RTCM decoding module or a suitable GNSS rover system, including all functions.

- via broadcast (optional *EUPOS* Standard):

  a suitable GNSS receiver, a suitable broadcast receiver according to the used broadcast service's transmission medium and an RTCM decoding module or a suitable GNSS rover system, including all functions.

## 5.2 *EUPOS* Network RTK

The following user equipment is required for using *EUPOS* sub-service Network RTK

- via internet:

  a geodetic dual/multi frequency GNSS receiver, a mobile Internet device, NTRIP client software and an RTCM decoding module or a suitable GNSS rover system, including all functions.

- via broadcast (optional *EUPOS* Standard):

  a geodetic dual/multi frequency GNSS receiver, a suitable broadcast receiver according to the used broadcast service's transmission medium and an RTCM decoding module or a suitable GNSS rover system, including all functions.

## 5.3 *EUPOS* Geodetic

For the use of *EUPOS* sub-service Geodetic (RINEX and Virtual Rinex) a suitable GNSS receiver, Internet connection and a computer with software for post-processing position determination are required. If the user intends to determine positions following the measuring in the field directly a mobile Internet connection at the computer makes this possible.

# Appendix

## A.1 *EUPOS* Steering Committee resolutions regarding the *EUPOS* Technical Standards

**Resolution 3.8 of the 3rd Conference of the *EUPOS* Steering Committee, Riga, Latvia, 10 – 11 June 2003, agenda item 6.1: *EUPOS* Standard Summary**

(The decided mainly changes between the *EUPOS* Standard Summary's draft version and the decided version, topicality June 11th, 2003 are left out.)

The *EUPOS* Steering Committee decides that the *EUPOS* Standard Summary, topicality June 11, 2003, is to be used by all members and partners of *EUPOS* as obligatory *EUPOS* standards.

These standards are to be used exclusive for a time period of five years at minimum.

In cases of further development of the technical standards a downward compatibility has to be guaranteed.

Changes of the standards need an *EUPOS* Steering Committee resolution.

Thus there is given a good basis for establishing a unified multifunctional ground based DGNSS infrastructure in Central and Eastern Europe as well as the needed security for investment to the industry.

**Resolution 12.2 of the 12th Conference of the *EUPOS* Steering Committee, Vilnius, Lithuania, 20 – 21 September 2007, agenda item 5: *EUPOS* Standard Summary**

The *EUPOS* Steering Committee requested its Office (ISCO) to revise the *EUPOS* Standard Summary 1st Edition of 11 June 2003 and to separate the *EUPOS* Technical Standard definitions from general information and Terms of Reference at the 9th ISC Conference. The ISCO presented the revised draft Terms of Reference, including general information, at the 12th ISC Conference. The ISC approved the draft.

*EUPOS* Terms of Reference define the organisational section of the *EUPOS* Standards and are to be used by all members and partners of *EUPOS* as obligatory *EUPOS* standards.

The ISCO is responsible for updating the Appendix of the Terms of Reference. Other alterations to the *EUPOS* Terms of Reference require an *EUPOS* Steering Committee resolution.

**Resolution 13.2 of the 13th Conference of the *EUPOS* Steering Committee, Bucharest, Romania, 23 – 24 April 2007; agenda item 5: *EUPOS* Technical Standards**

The *EUPOS* Steering Committee decides that the *EUPOS* Technical Standards, topicality April 24th, 2008, are to be used by all members and partners of *EUPOS* as obligatory *EUPOS* standards. Changes of the standard definitions need an *EUPOS* Steering Committee resolution.

## A.2 List of acronyms and abbreviations

| | |
|---|---|
| cf. | confer (= compare) |
| DGNSS | Differential Global Navigation Satellite System |
| ETRS 89 | European Terrestrial Reference System 1989 |
| EUPOS | European Position Determination System |
| EUPOS ISC | EUPOS International Steering Committee |
| EUPOS ISCO | EUPOS International Steering Committee Office |
| EUPOS NSC | EUPOS National Service Centre |
| FKP | Flächenkorrekturparameter (*areal correction parameters*) |
| HDSPA | High-Speed Downlink Packet Access |
| ISC | cf. EUPOS ISC |
| ISCO | cf. EUPOS ISCO |
| GNSS | Global Navigation Satellite Systems |
| GLONASS | Global Navigation Satellite System (RF) |
| GPRS | General Packet Radio Service |
| GPS | Global Positioning System (USA) |
| IP | Internet Protocol |
| MAC | Master and Auxiliary Concept |
| N.B. | Nota bene |
| NMEA | National Marine Electronics Association |
| NSC | cf. EUPOS NSC |
| NTRIP | Networked Transport of RTCM via Internet Protocol |
| PCV | Phase Centre Variations |
| RINEX | Receiver Independend Exchange Format |
| RF | Russian Federation |
| RTCM (SC) | Radio Technical Commission for Maritime Services (Special Committee) |
| RTK | Real Time Kinematic |
| UMTS | Universal Mobile Telecommunications Systems |
| UDP | User Datagram Protocol |
| UPS | Uninterruptible Power Supply |
| VHF | Very High Frequency |
| WLAN | Wireless Local Area Network |

## A.3 List of Updates

none