D-GNSS ACCURACY TESTS AT BUCU EPN STATION

Tiberiu Rus, Johan Neuner

Technical University of Civil Engineering Bucharest – Faculty of Geodesy
Lacul Tei Blv.124, sect.2, Bucharest, Romania
e-mail: rus@mail.utcb.ro;neuner@geodezie.utcb.ro

Abstract

Since June 1999, EUREF-EPN station in Bucharest ("Bucu")joined EUREF-IP project in cooperation with BKG, Frankfurt a.M. (Germany). Ntrip technology was tested as usefull tool in order to achieve and to disseminate D-GNSS data. Based on Ntrip technolgy and handheld receivers, D-GNSS tests were performed at Bucu station to establish the accuracy of differential positioning. Three different positioning techniques were compared: GPS alone, D-GPS based on EPN and D-GPS based on EGNOS. The results are presented together with some comments.

1. Introduction

D-GNSS[1] positioning helps today in many applications. A D-GNSS user benefits today of an increased accuracy in comparison with absolute point positioning without differential corrections. Around EUREF GPS station in Bucharest ("BUCU"), D-GPS tests were performed in order to estimate positioning accuracy. Starting from June 2003, "Bucu" station was included in EUREF-IP network disseminating D-GPS corrections (RTCM 2.0) by internet (broadcaster BKG Frankfurt a.M.)..

2. GNSS Augmentation Systems

GNSS (Global Navigation Satellite System) includes mainly the two well known systems: NAVSTAR-GPS (Navigation System with Time And Ranging) and GLONASS (Global Navigation Satellite System).
Augmentation systems to navigation systems were developed as follows:
a. Regional augmentation systems (fig.1)including mainly WAAS - (Wide Area Augmentation System) - USA-2 satellites; EGNOS (European Geostationary Navigation Overlay Service) - Europe - 3 satellites - operating April 2004); MSAS (MTSAT-Satellite-Based Augmentation System) - Japan.
b. National / Local D-GNSS networks (Germany, Austria, France et. al.);

[1] D-GNSS – Differential Global Navigation Satellite System

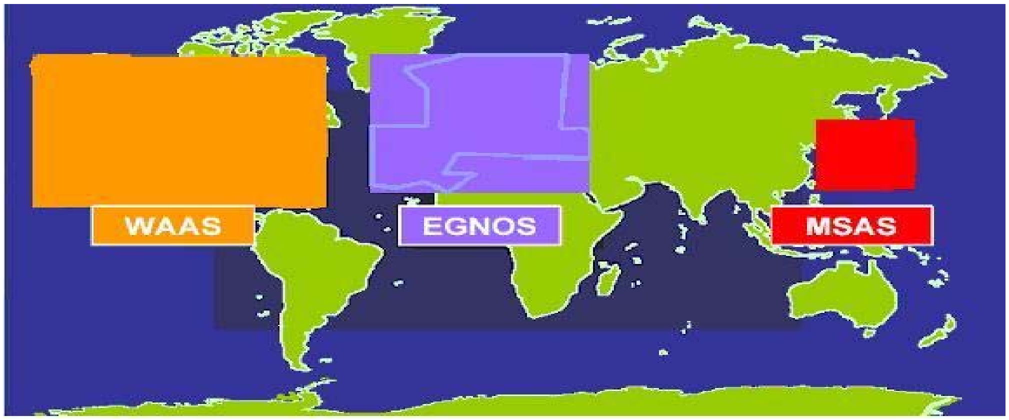


Figure 1: GNSS Augmentation Systems Coverage [ESA, 2003]

3. EGNOS and SISNET. EUREF and EUREF-IP.

In EUROPE, D-GNSS signals are send today not only via INMARSAT satellites, but via internet, too. The concept is similar to D-GNSS corrections transmitted by a part of EUREF-EPN stations in "EUREF-IP" project . The idea it is to disseminate diferential corrections generated at permanent stations by the use of *internet* network and tools.
SISNET (Signal In Space through Internet) network was promoted by ESA (European Space Agency) to realize D-GNSS data transfer from EGNOS ground stations by internet.
EGNOS (fig.3)data are transmitted to the users from a data server (TCP/IP protocol). Users access internet and get data, process data and obtain differentially corrected positions.

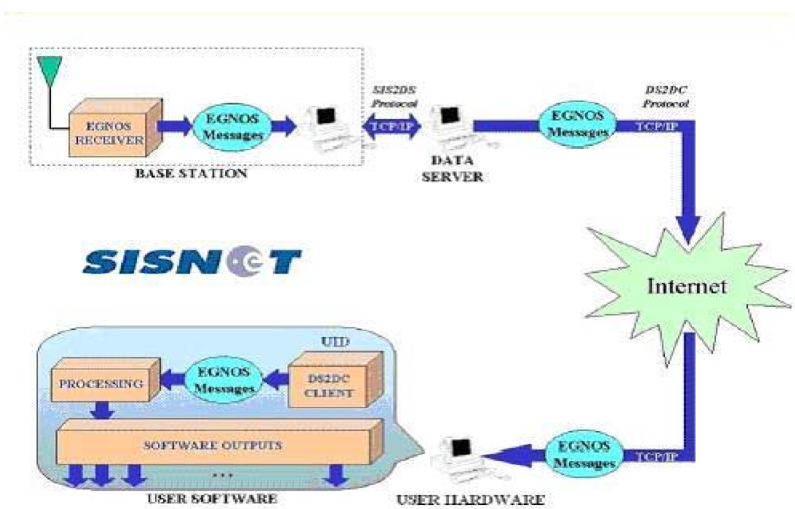


Figure 2: Sisnet Architecture [ESA, 2003]

Figure 3: EGNOS - RSIM (Reference Stations and Integrity Monitors)

- **EUREF - IP network (fig.4) was promoted by EUREF to disseminate D-GNSS corrections generated by EUREF-EPN.**

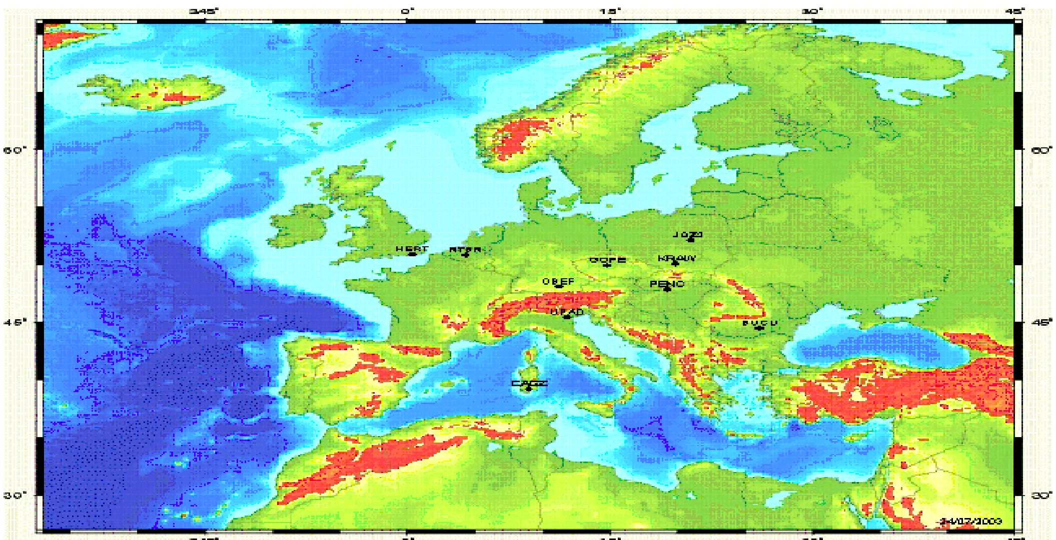


Figure 4: Euref -Ip Network [Euref, 2000]

Table 1 – D-GNSS Stations from EUREF-EPN

#	Network	Mountpoint	Id GNSS	System	Type	Format
1	EUREF	BUCU0	Bucharest	GPS	No	RTCM 2.0
2	EUREF	CAGZ0	Cagliari	GPS+GLO	L1&L2	RTCM 2.1
3	EUREF	GOPE0	Praha-Ondrejov	GPS+GLO	L1&L2	RTCM 2.2
4	EUREF	HERT0	Hailsham	GPS+GLO	L1&L2	RTCM 2.2
5	EUREF	JOZ20	Jozefoslaw-Warsaw	GPS+GLO	L1&L2	RTCM 2.2
6	EUREF	KRAW0	Krakow	GPS	L1&L2	RTCM 2.2
7	EUREF	MAR60	Maartsbo	GPS+GLO	No	RTCM 2.3
8	EUREF	PENC0	Penc-RT	GPS	No	RTCM 2.0

NTRIP (Network Transfer via Internet Protocol) software package was realized in EUREF-IP project for D-GNSS data transfer [Weber, 2002].

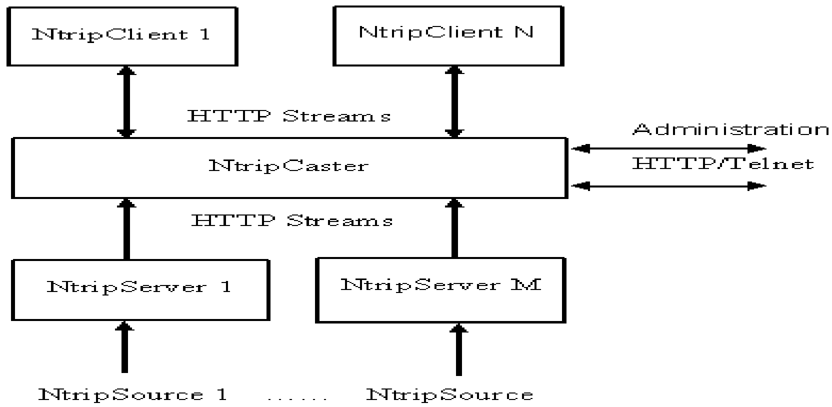


Figure 5: NTRIP modules [Euref, BKG]

Euref-Ip and Sisnet have some important benefits for the user's community as follows:
1. Better "view" of EGNOS signals in difficult places (urban canyons, forests et al.);
2. No necessary GNSS receivers with EGNOS (WAAS) capability (RTCM input only necessary);
3. Rate of data transfer from internet to the GNSS receivers (users) good enough for mobile applications ;
4. Easy to be implemented on palmtops (iPAQ PDA) together with GSM(GPRS) terminals follc ˙ ıg UID(User Interface Document - UID);
5. Data form.. .n EUREF-IP and SISNET compatible with other D-GNSS systems (national or local).

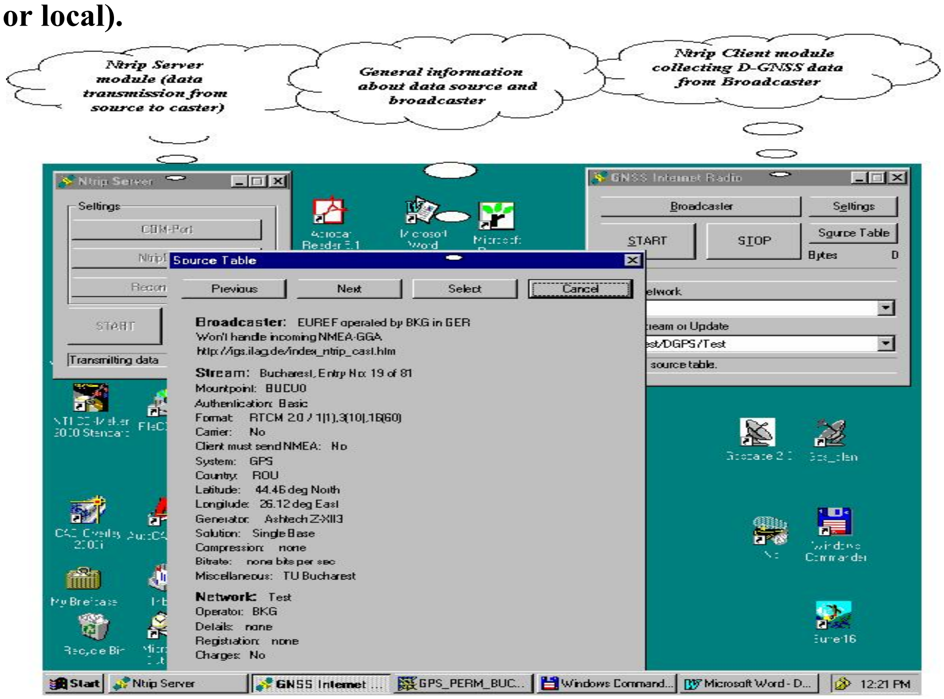


Figure 6: Ntrip - Server and Ntrip Client running at "Bucu" perm. station

4. Experiments

Based on GPS equipments available at Bucu permanent station and software modules the following tests were realized:
- D-GPS corrections genereation in RTCM 2.0 (Radio Technical Committee for Maritime Services) format - frames: 1(1), 3(60), 16(60);
- D-GPS corrections transmission by internet to EUREF-IP broadcaster in Frankfurt a.M. and other user's destination;
- D-GPS corrections collecting by internet (from EUREF-IP broadcaster in Frankfurt a.M.);
- D-GPS service monitoring at Bucu station;
- comparison of GPS positioning in 3 cases:
1. without D-GPS;
2. with D-GPS corrections from EGNOS;
3. with D-GPS corrections directly from ground stations (EUREF-IP, EGNOS et al.);
- possibility to implement D-GNSS services for monitoring / navigation (car monitoring and navigation, river ship navigation).

Available Equipments

a) Hardware and software equipments available from "Bucu" permanent station

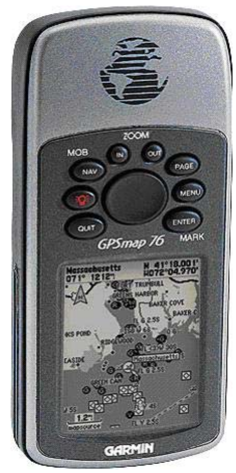
- GPS receiver - 2 frequencies - Ashtech Z12;
- internet / GSM communication;
- PC – Pentium II; Notebook – Pentium IV;
- perm. station software GPS Base – Terrasat, Germany;
- D-GPS generation module (format RTCM 2.0 – 1(1), 3(60), 16(60));
- Ntrip-Server for D-GPS corrections transfer;
- NtripClient-Internet Radio - D-GPS and EGNOS data collecting from ground stations;
- other “freeware” software for data acquisition (format NMEA - National Marine Electronics Association and proprietary Garmin), decoding – “rtcmw” (author M.Baeumker, Bochum, Germany) and navigation: VisualGPS vs.3.33, GPSTrackMaker vs.11.8.187 (autor Odilon Ferreira Junior, Belo Horizonte – MG - Brazilia).

b) Mobile GPS Equipments
- Handheld GPS receivers from GARMIN with WAAS (EGNOS) capability:
- 12 channels, 1 frequency (L1);
- D-GPS capability in RTCM and Garmin proprietary format;
- 1 second interval data;
- two way communication interface RS-232 compatible; import / export NMEA 0183 and RTCM format;
- Manufacturer accuracy for D-GPS: about 3-5m 95% in position, and +/- 0.05 m/s for velocity.

Garmin LVS 35 receiver

Garmin eTrex VISTA receiver

Garmin eTrex VENTURE receiver



Garmin *GPSmap 76S* receiver

Figure 7: Handheld GPS Receivers

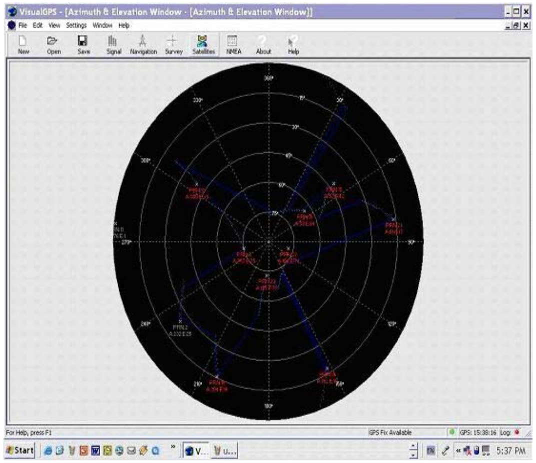
D-GPS data used in experiments was available from:

- **own source - "Bucu" GPS permanent station;**
- **by internet from EUREF-IP broadcaster (BKG Frankfurt a.M., Germany);**
- **from EGNOS augmentation system.**

♦ ***Experiment - CASE 1***

Without D-GPS corrections - Horizontal positioning accuracy was about +/- 5-10 m in "good conditions" (>5 satellites, PDOP < 5) or about 3 m (static) with more than 6 satellites.

- **Static - GPS positions were determined *simultaneously* with two receivers: 1 Garmin handheld GPSMAP 76S receiver and 1 *Trimble 4600LS* receiver;**
- **Kinematic - GPS positions were determined simultaneously with two receivers: 1 Garmin handheld GPSMAP 76S receiver and 1 Garmin LVS 35 receiver (external antenna);**



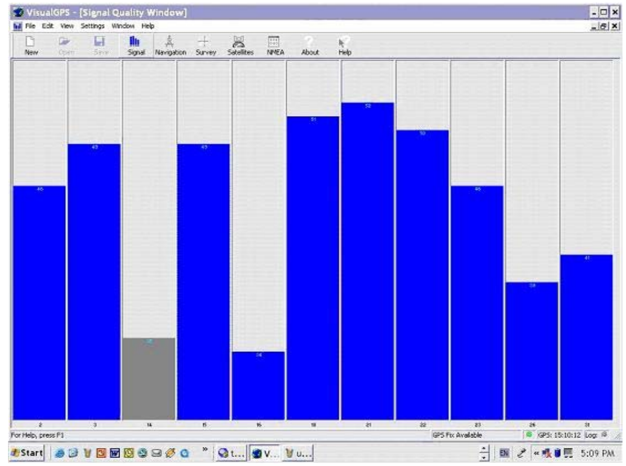


Fig.8 a) Satellite sky - view in "good conditions" Fig.8b) SNR plot in "good conditions"

Figure 9: Kinematic tests with GPSMAP 76S and Garmin 35 LVS receivers

♦ *Experiment - CASE 2*

With D-GPS corrections from EGNOS - horizontal positioning accuracy obtained was about 2-4 m static and 3-6 m kinematic;

Navigation (kinematic) tests were performed with RTCM input from EGNOS and NMEA output from handheld GPS receiver. The practical aspects derived from this experiment conclude that:

- **not all satellites in view received EGNOS corrections;**
- **EGNOS signals most difficult to acquire in urban canyons (as Bucharest) or forests;**
- **EGNOS signals most difficult to acquire in Romania due to EGNOS coverage (Romania situated at Eastern EGNOS border);**
- **EGNOS satellites contacted in Romania at low elevation - ID 44 - contacted all the time at less than 40 degrees elevation.**

♦ *Experiment - CASE 3*

In this case D-GPS corrections were collected directly from ground stations (EUREF-IP, EGNOS) horizontal positioning accuracy obtained was about 0.5-2 m static;

D-GPS data collected by internet from ground stations:BUCU – Bucharest - EUREF: [a) direct from the station; b) via Frankfurt a.M.], SOFI – Sofia (Bulgaria) - EGNOS SZEK – Szekesfehervar (Hungary) – EUREF, PENC - Penc (Hungary) – EUREF, FFMJ – Frankfurt (Germany) – EUREF, HERT - Hailsham (UK) – EUREF.

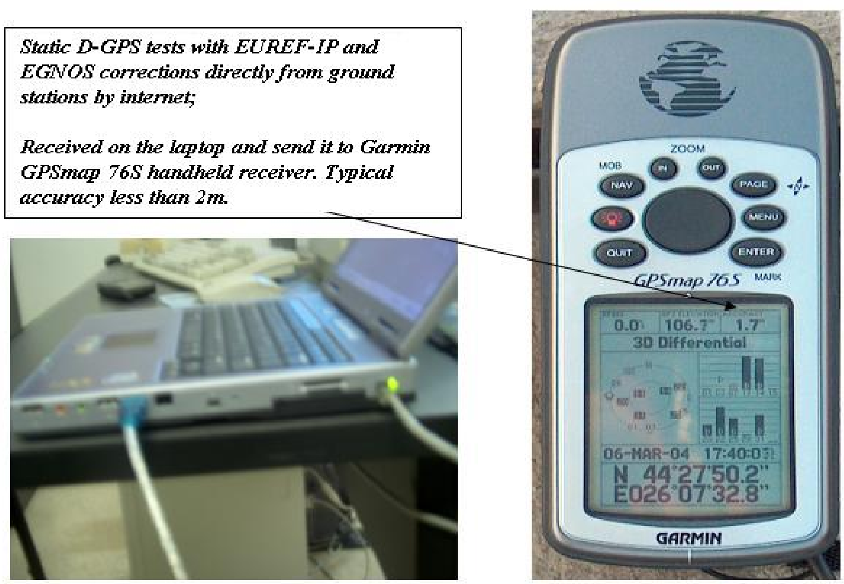


Fig.10 D-GPS Tests with RTCM corrections directly from ground stations

An important factor studied was the "age" of D-GNSS data. On this topic two situations were considered: test with D-GPS corrections from "Bucu" to USER and test with D-GPS corrections from "Bucu">Frankfurt>"Bucu" to USER;

From these experiments was observed an influence in horizontal positioning accuracy less than 0.2m. In the same time it is possible that satellite constellation can differ from Broadcaster to USER if long distance between.

5. Conclusions.

Today D-GNSS technology can be introduced for monitor/navigation positioning with accuracy of about 1-5m, static or kinematic.
It is necessary to manage all possible error sources as: data transfer delay, D-GNSS equipments, D-GNSS data sources, EGNOS coverage et al.
It is necessary to establish in Romania a D-GNSS service based on GNSS permanent stations already installed.

Acknowledgements: ***I express my thanks to RQA IMPEX COMPANY SRL – Bucharest, Garmin representance in Romania who kindky let at our disposal Garmin (eTrex and GPSMAP 76S) receivers during tests.***

References

G. Weber, H. Gebhard, D. Dettmering, Networked Transport of RTCM via Internet Protocol (Ntrip), Presentation, IAG, Saporro, Japan, 2003-7-02, RTCM Paper 167-203/SC104-314;
G. Weber, D. Dettmering, H. Gebhard, Real Time GNSS via Internet Protocol Status & Standardization, Federal Agency for Cartography and Geodesy, BKG, Frankfurt, CGSIC 43rd Arlington, Virginia, March 10-11, 2004;
T.Rus, GNSS Differential Positioning Technologies (in Romanian), Conference – Group G2-Digital Maps, January 16, 2004, Giurgiu, Romania;
T.Rus, J. Neuner, GNSS Applications in Technological and Natural Hazard Areas, Regional Workshop on the Use of Space Technology for Disaster Management for Europe, 19-23 May 2003, Braşov, Romania;
***** SISNeT Technical Note, SISNeT brochure, June 2002**
***** SISNeT Technical Note, SISNeT User Interface Document Issue 2.1, June 2002.**

EUREF-IP Real-Time Project
http://www.epncb.oma.be/projects/euref_IP/euref_IP.html
Avalability in Europe
http://igs.ifag.de/root_ftp/misc/ntrip//maps
Networked Transport of RTCM via Internet Protocol (Ntrip) Documentation
http://igs.ifag.de/root_ftp/software/NtripDocumentation.zip
Ntrip Software Downloads
http://igs.ifag.de/index_ntrip_cast.htm
EUREF-IP Real-Time Project at Bucu EPN station
http://193.231.4.70:8888/EUREF_IP.html
D-GNSS Tests at Bucu EPN station
http://193.231.4.70:8888/Galileo/corectii_D_GNSS_5.html
http://193.231.4.70:8888/Galileo/corectii_D_GNSS_6.html
ESA-Navigation-Egnos web page
http://esamultimedia.esa.int/docs/egnos/estb/egnos_pro.htm
ESA-SISNeT web page
http://esamultimedia.esa.int/docs/egnos/estb/sisnet/about_sisnet.htm