



**Concept
for the
implementation of dGPS-beacons for augmentation
signals
in line with the IALA-Standard
for navigation systems
on the
Danube waterway**

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1 Basics on GPS (Global Positioning System)



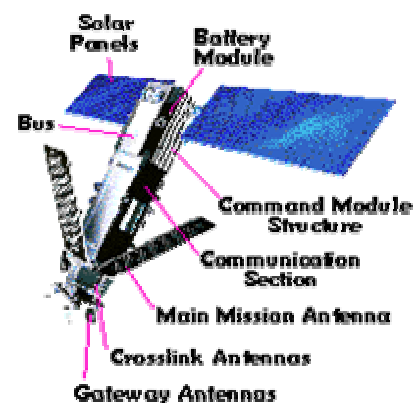
under the assistance of the US military a worldwide available network for satellite navigation has been built up. **GPS (Global Positioning System)**. The system consists of 27 satellites (9 Block II, 16 Block IIA, 2 Block IIR)

- Official configuration consist of 24 satellites (II/IIA)
- 21 operating satellites plus 3 stand by satellites
- 3 new Block IIR satellites since end of 1998

in approximately 20.000 m height, transfers data of the L- and S-band down to earth. These data is encoded by the military P-code and the C/A-code for civil usage. The US department for defence is able to adulterate the C/A data in a special region during a crisis. Then only an inaccurate positioning is possible because the accuracy varies about +/- 100m. This

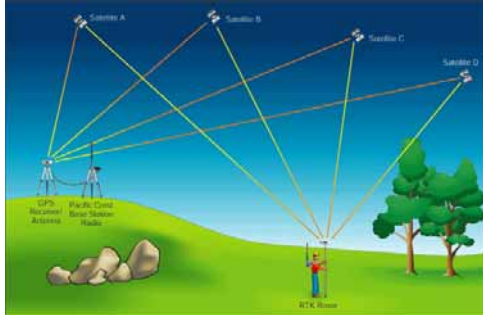
program is called **Selective Availability (SA)**. If the SA is activated the accuracy is about +/- 100m. Since May 2nd 2000 the SA is turned off. Therefore, the accuracy is about +/- 13m (95%).

The satellites are sending their own orbit data as well as the data on circulation of the other satellites and accurate time signals. Based on this data the position of the satellites can be calculated. Modern GPS-receivers work with 12 parallel channels. Three are used for the position fixing (Triangulation). A fourth is used to calculate the altitude. The other eight channels also receive satellite signals and the GPS-device processes this data together with the first mentioned four channels to a reliable and uninterrupted measurement.



2 Basics on DGPS

The accuracy of 100 m is not adequate for many civil users. In order to provide an accuracy of better than 3 m, even if the SA is activated, a small trick is necessary. A second GPS-receiver is placed at a location where the coordinates are known. This receiver serves as a reference station. The received satellite signals and the known coordinates of the position are compared. The difference is sent to the mobile GPS-receiver via radio communication. All neighbouring GPS-receivers can adjust their position with the aid of the received differential data. This procedure is called **dGPS (differential GPS)**.



Through the destination of the carrier phase of the individual satellite signals the accuracy can be improved to 1 cm at maximum. This is called **pdGPS (precision dGPS)**. With the aid of measurement of carrier phase and adoption of dead reckoning it can even be used for automatic guidance of vehicles.

Beneath the improvement of the accuracy another crucial advantage can be achieved by the installation of a dGPS reference station. The functionality and accuracy of the GPS-satellites as well as the dGPS beacons is checked 24 hours a day. In the area, which is covered by dGPS signals information about the quality of digital navigation can be received continuously. The monitoring of the dGPS-stations can be occurred by a separate central control centre via WAN. In cases of errors or degradations of the positioning accuracy the user can be informed immediately.

Further details according to dGPS basics are included in annex 1.

3 Status in Germany

For reasons of compatibility to the maritime traffic Germany decided to use dGPS according to the IALA-standard. This step had to be taken because near the coast sea-going vessels cruise on inland waterways. As a consequence double equipment aboard the vessels is not necessary.

The IALA developed a concept for maritime areas which uses GPS linked to an additional terrestrial differential component. According to the IALA-specifications 120 dGPS-reference stations have been constructed whereof two of them are in German territory: Groß Mohrdorf, originally Wustrow serves the western Baltic sea, Helgoland the German bays as well as the bordering maritime waterways.



The two dGPS-reference stations have been approved in the third quarter of the year 1996 for general shipping.

The reference stations have been adjusted by the water- and shipping directorate and they have a range of about 285 km. The data sheet of the used reference station is included in annex 2. The two reference stations cover the whole german coast area with dGPS-radio navigation service. Another station will be implemented 2002 near Zeven (53N17, 09E15). Worldwide approxi-



mately 200 reference stations will be constructed.

The wide geographical coverage with only a few reference stations leads to a high economic efficiency referring to the construction and the maintenance of the dGPS-service. The achievable accuracy of 1 – 5 m is an important precondition for the multi functionality. Many groups of users shall benefit from the dGPS-service, whereas the basic aim is in the range of maritime navigation and maritime measurements. The dGPS-service serves the security of navigation and will therefore be sent unencoded.

The IALA has defined system requirements for maritime dGPS-services, a concept for reference stations and a concept of frequencies. As a result there are guidelines for the transmission of dGPS- augmentation signals according to the IALA-standard. A component of the standard is the way of formatting data recommended by the RTCM. The „Special Committee No. 104“ defined under the identification RTCM 134-89 / SC 104-68 a way of formatting DGPS- augmentation signals. The ITU additionally has worked out a radio transmission protocol for the IALA-standard and recommends its usage. The reference stations Groß Mohrdorf and Helgoland follow the guidelines of the IALA and ITU, and the following frequencies have been chosen within the range of maritime radio beacons: 308 kHz (Groß Mohrdorf) and 298,5 kHz (Helgoland). A bit rate of 200 Bit/s has been chosen. In the course of the turnoff of the SA at May, 02nd 2002 the bit rate has been lowered to 100 Bit/s.

The stations contain a GPS-receiver, RTCM-formatting tool, modulator, mid wave transmitter and mid wave antenna including adjusting unit. The dGPS-augmentation signals are sent by the mid wave antenna. For security reasons significant system components like GPS-receiver and MW-transmitter are redundant. For supervision reasons on location another GPS-receiver including MW-receiver and processor for error detection and integrity analysis is in operation. For „Post Processing“ reasons the raw data is recorded (GPS-frequency L1 and L2). The connection to the network makes a remote diagnostic and remote control available. A availability of 99,9 % shall be guaranteed.

In order to check the functionality and the accuracy of the dGPS-service various surveys have been carried out whereat different GPS-receivers have been used. It was proved that high class GPS-receivers achieved an accuracy of approximately 1m, while low class GPS-receivers, without phase smoothing, achieve an accuracy of 5m.

The usage of this dGPS-service is for free.

In Germany the coverage of dGPS according to the IALA-standard is planned to be in operation by the end of 2003. The location of the beacons and further technical details are included in annex 3.

4 Status in Europe

The following map shows the coverage of the dGPS-service according to the IALA-standard in Europe.



Further stations mainly in the Mediterranean sea are planned or under construction. By installing dGPS-beacons according to the IALA-standard in Germany and later on along the Danube to the Black Sea the coverage will be improved.

5 Suggestion for the Danube waterway

For the coverage of the Danube the following assembly is suggested



Attention should be paid on the fact that these suggestion is based an a range of 200 km and ideal conditions of propagation. Only a correct calculation of the propagation aligned to the selected frequency show the real propagation of each beacon. The three southern beacons could also be located southern the Danube, which means the location can be adopted to local conditions.

Possible locations are:

- Austria: between Krems and Vienna
- Hungary: vicinity of Kalocsa (approximately 100 km southwards of Budapest)
- Serbia-Montenegro: vicinity of Veliko Gradište (~ 70 km westwards of Belgrad) or
- Rumania: westwards vicinity of Moldova Nouă
- Rumania: vicinity of Caracal (~ 180 km SWW of Bukarest)
- Rumania: vicinity of Hârșova (~ 190 km eastward of Bukarest)

Technical details as well as constructional arrangements can also be found in annex 3. A concept for handling operational concept has to be generated for each beacon according to the arrangement of the nationally responsible body.