RASANT
Radio **A**ided **Sa**tellite **N**avigation **T**echnique

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The Radio Aided Satellite Navigation Technique – RASANT – provides a DGPS service in real-time, using RDS as the additional data channel.

Here, the authors describe how a Global Positioning System basically works and how the geographical resolution of such a system can be reduced to around 1 – 3 metres, by the use of RASANT.

A RASANT service is due to commence nationwide in Germany later this year.

1. Introduction

In May 1995, the Working Committee of the Surveying and Mapping Authorities of the Federal Republic of Germany (AdV) decided to introduce a real-time Differential Global Positioning System (DGPS) service throughout the country.

DGPS uses an additional data channel to improve greatly the accuracy of the basic Global Positioning System (GPS) network of satellites; in non-military applications, the accuracy of the GPS network is only about 100 m.

As shown in *Table 1*, the German DGPS service will comprise four separate options; each one will offer a different degree of accuracy. The first option – EPS [Echtzeit Positionierungs Service (real-time positioning service)] – will be launched nationwide in Germany later this year, offering a real-time positioning accuracy of 1 – 3 m. EPS relies on the use of RASANT (**R**adio **A**ided **Sa**tellite **N**avigation **T**echnique), which has been developed by the Westdeutscher Rundfunk (WDR) and the Landesvermessungsamt Nordrhein-Westfalen (the Surveying and Mapping Agency of Northrhine Westfalia). RASANT uses the FM Radio Data System (RDS) as the additional data channel.

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Table 1
The four DGPS service options planned for Germany.

Service option	Result	Data medium	User's port	Accuracy
EPS (real-time positioning service)	Real time	AM and FM radio	RTCM 2.0	< 3 m
HEPS (high-precision real-time positioning service)	Real time	2 m band	RTCM 2.1	< 1 dm
GPPS (geodetic precision positioning service)	Nearly on-line	Telecommunication channel	RINEX	= 1 cm
GHPS (geodetic high-precision positioning service)	Post-processing	Telecommunication channel	RINEX	< 1 cm

2. *Why do we need DGPS services?*

GPS is a worldwide navigation system which uses a network of satellites in non-geostationary orbits (see *Fig. 1*). It was originally developed by the U.S. Department of Defense for military use but, for several years, it has also been available for civilian applications.

GPS satellites transmit coded information about time and their ephemeris[1]. A GPS receiver measures the propagation delays of the signals, determines the distance to each satellite – the *Pseudo Range*, which is modified by deliberate error sources – and calculates its own latitude, longitude, altitude, course and speed.

The greatest of the existing errors is caused by a technique named *Selective Availability* (SA) – an intentional degradation for non-military applications. Mainly because of SA, the overall positioning accuracy of GPS – for civilian use – is about 100 m for 95 % time. This level of accuracy is totally inadequate for many civilian applications and, hence, solutions based on DGPS have been developed.

1. Parameters which describe the orbits of the satellites.

If there are two GPS receivers at different locations, each one registering identical signals, then the accuracy of the system can be augmented. For example, the baseline between the two receiving points can be computed with an accuracy of up to several millimetres when the data are combined for post processing. This technique is typically employed in surveying and is of no further interest in this article.

For use in real-time applications, a one-way data link is necessary. Critical points are the data transmission rate and the distance between the two receivers. At low data rates (e.g. 100 bit/s), an accuracy of 1 – 3 m is possible up to a distance of 1000 km between the receivers. At higher data rates (e.g. 2400 bit/s), an accuracy of several centimetres is possible up to a distance of 10 – 20 km between the receivers.

The low data rates offered by FM/RDS are suitable only for low-accuracy DGPS applications. High-accuracy applications, on the other hand, can only be achieved by making carrier phase measurements. This demands high data-rates and therefore must make use of telecommunication media other than RDS, e.g. telephone networks, cellular radio or Digital Audio Broadcasting (DAB).

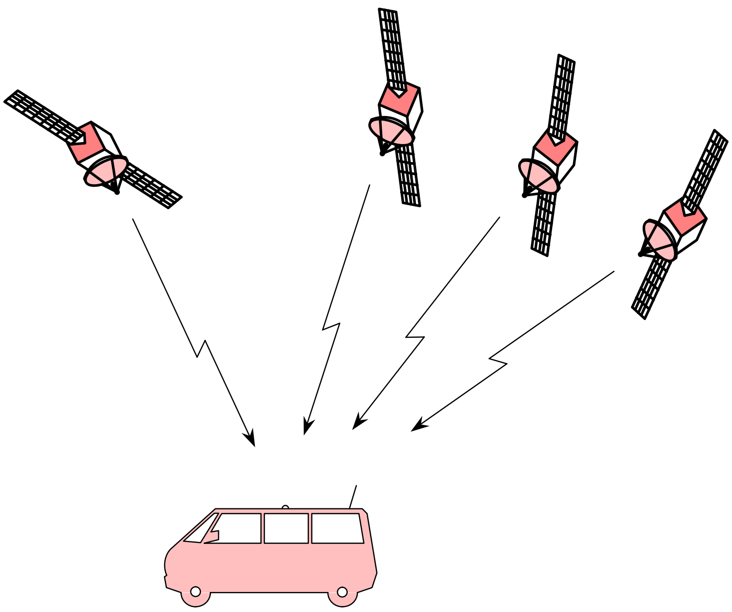

Figure 1
The basic GPS technique.

3. *DGPS correction format – RTCM*

In 1983, The U.S. Institute of Navigation asked the Radio Technical Commission for Maritime Services (RTCM) to develop recommendations for transmitting differential corrections to users of GPS. A Special Committee, No 104, was established and it published Version 2.0 of the RTCM

Correction Format in 1990. A further-developed version – Version 2.1 – was published in 1994; it contains additional formats which support applications for the real-time measurement of movement.

RTCM Version 2.1 provides 63 different message types, of which 26 are currently defined. Some are tentative or reserved, while eight of the message types are fixed (see *Table 2*). Each type starts with a header and the technical information is allocated to a variable number of 30-bit words.

Message type	Function
Type 1	Differential GPS corrections
Type 2	Delta differential GPS corrections
Type 3	Reference Station parameters
Type 5	Constellation health
Type 6	Null frame
Type 7	Beacon almanacs
Type 9	Partial satellite set differential corrections
Type 16	Special message

Table 2
The eight fixed message types of RTCM Version 2.1.

4. How does RASANT work?

The real-time GPS applications described above are based on a GPS reference station (see *Fig. 2*). A GPS receiver, placed at a known position, is able to compute the distances to the various satellites and to compare them with the measured pseudo ranges. The calculated differences are called Pseudo Range Corrections (PRCs) and they are applicable over extensive areas. These differences, and other additional information, are determined continuously and are stored within the RTCM messages.

The RASANT technique can process and transmit the complete variety of RTCM messages via RDS. However, due to the low data-rate of the present RDS service, RTCM message types 1, 2, 3, 5, 9 and 16 are modified and conveyed in an appropriate DGPS format called *DGPS variants*.

Nearly all types of GPS receivers with DGPS capability can add these PRCs to their own pseudo ranges and improve the positional accuracy from 100 m down to between 1 and 3 m (see *Figs. 3* and

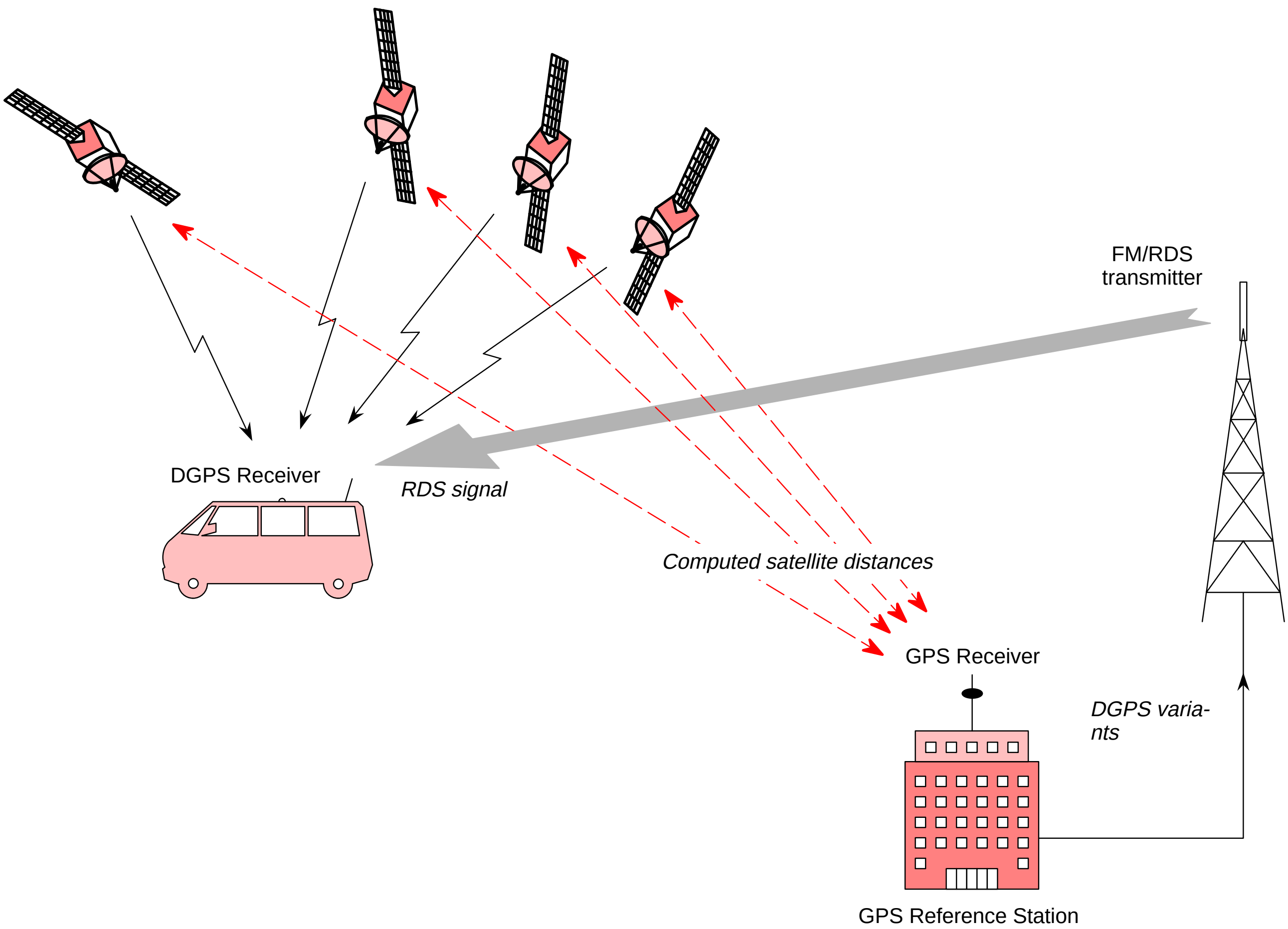

Figure 2
The RASANT method of DGPS.

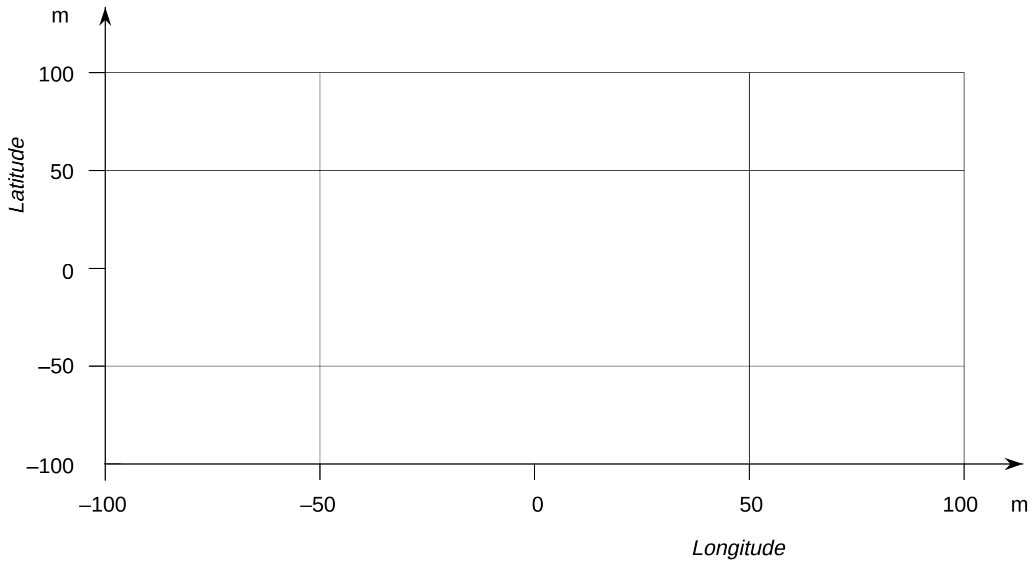

Figure 3
Plot of measurements showing the positional accuracy of the GPS system (non-military applications).

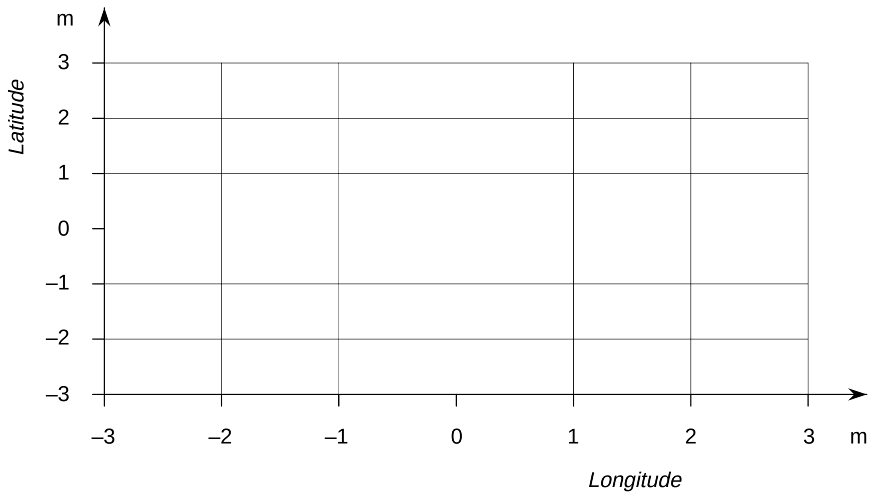

Figure 4
Plot of measurements showing the positional accuracy of the RASANT system.

4). Tests have shown that this accuracy decreases by up to 1 m for every 250 km of separation between the GPS reference station and the DGPS receiver.

5. Features of RASANT

5.1. Software

The RASANT software is composed of two components:

RASREF for management at the reference station;

RASMOBIL for use in static or mobile applications.

At the GPS reference station, RASREF condenses the standardized RTCM messages and stores this information as DGPS variants. These variants are transmitted cyclically by RDS. At the DGPS receiver, RASMOBIL selects the DGPS variants from the whole RDS data stream. The original RTCM Correction Format is then reconstituted and offered to the interface of the DGPS receiver.

5.2. Procedures for data reduction and format management

The RASANT software provides high accuracy for the user and security for the data transmission, by means of features such as the following:

5.2.1. PRCs in 37 bits

For an average number of satellites, the Type 1 RTCM message (the most important and most frequently transmitted message) is 500 to 700 bits long and is split into independent parts. Within RASANT, this data is rearranged so that the data concerning each individual satellite requires only 37 bits and can therefore be conveyed in only one RDS group. Additional overhead information, which is necessary to reconstruct the exact RTCM message, is required only a few times per minute.

This rearrangement of the satellite data guarantees a stabilized evaluation of the data. As already noted, to transmit the original RTCM format takes a long time. Furthermore, if jamming, disturbances or interference were to occur, the whole contents of the message from all the satellites would be destroyed. By creating self-sufficient or autonomous groups, only the information relating to one satellite can be affected by a jamming event; the rest of the data remains undisturbed.

5.2.2. Integer Timing Management

PRCs are not transmitted with their actual value, but are related to the last integer minute of Coordinated Universal Time (UTC) by means of the Range Rate Conversion (RRC). The mobile station has to reconstruct the current value of the PRC by using its own clock. The frequent transmission of the *z*-count[2] can so be avoided and the PRCs become nearly independent of any overhead information. The data for nine satellites need $9 \times 37 = 333$ bits, instead of the 680 bits needed by the original RTCM Correction Format.

5.2.3. Accelerated processing

As mentioned in *Section 4*, the PRCs are determined continuously. The PRC of each satellite is guaranteed to be a maximum of one second old when it is transmitted. The average age of the

2. In RTCM, the modified *z*-count is used as the reference time for the message parameters.

Mr. Stefan Sandmann *studied surveying engineering at the University of Bonn. Specializing in statistics, he received his degree, Dipl.-Ing., in 1989.*

In April 1992, Mr. Sandmann joined the Landesvermessungsamt Nordrhein-Westfalen (i.e. the Surveying and Mapping Agency of Northrhine Westfalia) as a scientific engineer in the department of geodetic processing. Here, he is responsible for the development of fundamental control software, particularly for use when making GPS measurements.

Since 1994, Mr Sandmann has been involved in the development of a real-time application to improve the accuracy of the current GPS service, using RDS. He took part in the CENELEC meetings where the EN 50067 Standard was upgraded to include OPEN DGPS.

Mr. Paul Raven *received his diploma in surveying at the University of Bochum, Germany, in 1978, and joined the Surveying and Mapping Agency of Northrhine Westfalia. Currently, he is a project engineer in the horizontal control net section of the Agency, specializing in GPS real-time positioning and navigation.*

Mr. Raven has been involved in all phases of the development of a nationwide system in Germany to transmit GPS correction data using RDS. His special contributions have been concerned with the format specifications and the coding structure of RASANT.

Mr. Günter Schoemackers *studied mathematics and physics at Cologne University. Since 1986, he has worked in the transmitter engineering department of the German broadcaster, Westdeutscher Rundfunk (WDR).*

Mr. Schoemackers' area of responsibility is software development for the broadcasting network, and the administration of the scientific computer network. He has taken part in the development of RASANT from the beginning.

PRCs used by the mobile receiver can be reduced by about 80 %.

5.2.4. Satellite Priority Control

A priority judgement process investigates the course of the satellite's PRC values over a time interval and favours those satellites which lead to the best results for the position of the mobile receiver.

5.3. System tests

RASANT, in the present version described above, provides respectable accuracy and high integrity – despite using only a low proportion of the overall RDS capacity. For the proven accuracy level of 1 – 3 m, an RDS capacity of 1 group/second is sufficient. In this case, the main Open DGPS variants are supported. More capacity is required if additional variants are used, e.g. the Alternative Frequencies of the transmitters which carry RASANT.

6. Technical realization

6.1. FM transmitter

A RASANT GPS reference station consists of a GPS receiver with RTCM differential capability, a small PC and a power supply unit. These components are built into a 19-inch module that can be installed in one of the racks of the FM transmitter. Connections to a GPS antenna, to the RDS encoder and to a 230 V power supply are sufficient to make the module work.

6.2. User equipment

At present, three different solutions are available for mobile RASANT applications, with prices starting at about 1,000 DM (not including the GPS equipment).

The first solution is an FM receiver on a PCMCIA card, with the decoding software running under MS Windows 3.1. With this unit, and a PCMCIA DGPS receiver, only one notebook PC is necessary to run RASANT and, if desired, the positions can additionally be presented on a digital map. The second solution is an FM receiver/decoder which is integrated in a black box. This unit needs no human operation; FM transmitters which carry RASANT are found automatically and the RTCM data is given out. The third solution – which is offered by another supplier – has similar features to this version.

7. Conclusions

Differential GPS, as realized by the RASANT technique, is becoming a powerful new tool for a wide variety of industries and for a large number of users. It has to be remembered that, with the accuracies that can be achieved with RASANT, GPS is no longer just a navigation technique: it is now an accurate method to measure position and movement of any kind.

The clients of such a service can be found in the areas of administration, economics, business, research etc. Typical applications are fleet management, data capture for Geographic Information Systems (GIS), agricultural applications, farming etc.

Many applications of DGPS extend beyond regional boundaries; they reach nationwide or even Europe-wide proportions. So, it seems inevitably necessary for companies of different regions to cooperate and to provide a unique system with common standards throughout Europe.

The tests made on RASANT have been very successful and it will be introduced all over Germany in 1996.

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