The Differential Global Positioning Service RASANT (Radio Aided Satellite Navigation Technique)

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Abstract:
The service field 'Real Time Positioning Service (in German: Echtzeit-Positionierungs-Service EPS)' within the 'Satellite Positioning Service of the German National Survey (SAPOS)' is realized through the technical solution 'RASANT'[1]. RASANT delivers DGPS correction data in the format RTCM[2] Version 2.0 via the Radio Data System (RDS) of FM broadcasting stations. RASANT decoders are available in the market. The DGPS data are received and fed into a DGPS-receiver. Static and kinematic positions with an accuracy of 1...5 m are delivered. Currently all 11 German public broadcasting corporations transmit RASANT data parallel to one of their word or music programs. About 10 firms are manufacturing RASANT receivers for prices between 1,000.- and 2,500.- DM. The user fees are included in the selling price.
Actual examples for applications in the fields of navigation, agriculture, GIS, fleet management and transportation are given.

1 Introduction

The satellite positioning service SAPOS of the German Länder's Surveying and Mapping Administrations provides correction data for navigation and positioning using the Differential Global Positioning System (DGPS). SAPOS delivers coordinate positions in the range of meter or centimeters in real time dependent on the users precision needs and the quality of his satellite receiver. SAPOS delivers a direct realization of the spatial reference system ETRS89 (for the navigation problem ETRS89 is identical to WGS 84). The coordinate transformation from WGS 84 into Potsdam Datum, the coordinate system of existing maps and datapools in Germany, is immediately possible.
For a special service field of SAPOS, the 'Real Time Positioning Service (in German: Echtzeit-Positionierungs-Service EPS)' the technical solution RASANT[1] is used. With RASANT, positioning and navigation in the range of 1 m to 5 m is possible. The transmission of SAPOS-RASANT correction data using the Radio Data System (RDS) of existing FM stations has been realized by all the 11 public broadcasting corporations of Germany.
In this paper the development of the system and some practical applications of several meter accuracy are presented.

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[1] Radio Aided Satellite Navigation Technique

[2] Radio Technical Commission for Maritime Services

2 Improvement of position accuracy using differential GPS (DGPS)

Users of Geographic Information Systems (GIS) have to relate technical data and measured values of different kind (e.g. earth surface structure, environmental data, power networks and lines, pipes and mains) to a geographical reference. They do so by assigning a coordinate. The position accuracy of "100 m which is available from civil GPS receivers is not sufficient for many professional applications. GPS reference stations deliver DGPS correction data which enhance position accuracy to 1 - 5 m.
For the transmission of data from the reference receiver to the user receiver the data format RTCM[2] Version 2.0 is used. RTCM goes for a standard and is widely respected by the receiver manufacturing industry. About 71% of the GPS receivers on the market have the capability to process RTCM V. 2.0 data. Computed correction data is made available to any other user by radio, broadcast or telephone.

3 RASANT - Transmission of DGPS correction data

As a prior condition for the success of DGPS in real time an appropriate method of data transfer is required. Since 1989 the Westdeutscher Rundfunk in Cologne (WDR) and the Landesvermessungsamt Nordrhein-Westfalen in Bonn (LVermA NRW) have been developing a solution of this problem. The technique 'RASANT' is to broadcast DGPS correction data formats RTCM Version 2.0 via the Radio Data System of FM radio stations **(Figure 1)**. Since 1996 the final version of the RASANT format is in use. The 11 publicly funded German radio stations and the 16 surveying and mapping agencies of the Länder are cooperating to provide RASANT data for the whole of Germany.

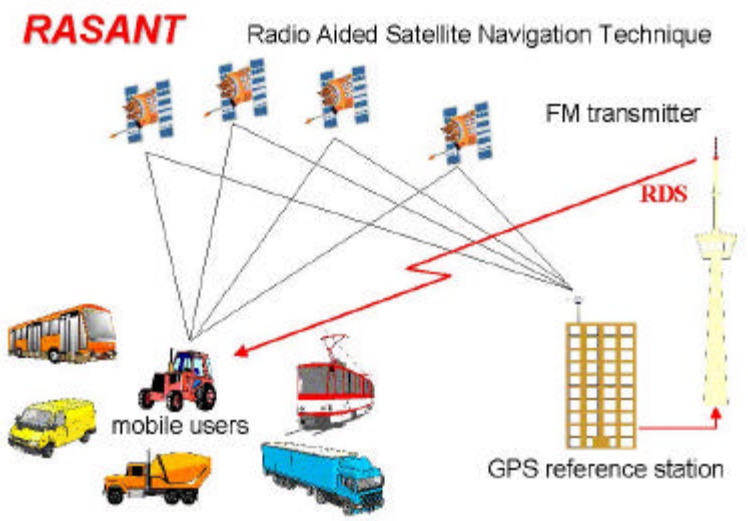

Figure 1

3.1 Data transfer by the Radio Data System

The Radio Data System RDS comes along with the audio broadcasting programs on 87 - 108 MHz and gives information e.g. about radio program codes and types, traffic messages and other additional information. For the transport of DGPS data the German broadcasting agencies have conceded a data rate of 1.5 RDS groups, i.e. 55 bps (bit per second). This is 13% of the maximum load of 420 bps that RDS (as it is installed in Germany) can handle.
The RTCM correction data must reach the users GPS receiver without delay. As the data grow older the user position accuracy is worsening. The RTCM Version 2.0 data for 7 visible satellites contains 530 bits. A simple transmission of these data would take about 10 seconds and the age of the data would grow too old. For a quick and safe transmission some special strategies had to be developed and have been implemented in the RASANT software. A patent relating to the method of data processing is pending.
So the conceded low data rate is sufficient to generate a list of satellite pseudoranges with an average age of 3.5 seconds on the users side. Positions with an accuracy of 1 m to 5 m depending on the quality of the users GPS receiver

are created. Licensed manufacturers have developed user units on the basis of format descriptions and source codes. These RASANT receivers decode RDS and reconstruct the standardized format RTCM which is fed into a DGPS receiver.

3.11 The story of RASANT

The idea to disseminate DGPS correction data via the Radio Data System was born in a conference between LVermA NRW and WDR in November 1989. The staff of the transmitter and high frequency department was searching for a means to georeference their signal strength measurements in the transmitter areas. The choice of GPS had been made impossible by the imminent GPS signal degradation by Selective Availability (SA). For field strength measurements an accuracy of at least "30 m was required. The Standard Positioning Service level of "100 m made GPS useless for this purpose. In this situation it suggested itself to apply Differential GPS, place a reference station at a transmitter and use the Radio Data System to broadcast the correction signals. This was the beginning of the cooperation of LVermA and WDR and the division of labor: LVermA provides the reference station, WDR is responsible for the data transport.

In August 1990 a first field test of the method was carried out: a GPS reference station was installed at the transmitter Bonn-Venusberg and several previously surveyed points 20 km around with known coordinates were measured by DGPS. The correction data came through the air along with a radio program of WDR. The corrected coordinates were displayed by the field DGPS receiver within seconds. They were mostly within a few meters of the pre-surveyed values when the GPS signals were not obstructed and the FM signals were not disturbed. This test showed that the method worked well.

In October 1992 the first permanent reference station with an Ashtech Z12 GPS receiver was installed at the transmitter Nordhelle on a hill of 660 m height in the Sauerland mountains. The GPS antenna was mounted on the 45 m platform of the 160 m concrete tower at the southernmost point of the railings. Thus the tower was in the north of the antenna, coincided with the circle around the celestial pole which is free of GPS satellites and did not cause signal obstructions.

In the following winter lightning strikes in the vicinity of the tower caused trivial damages of the receiver for three times. So the reference station was relocated to Bonn in May 1993 and later to Langenberg in the heart of NRW, all typical FM transmitters. In these locations no lightning damages occurred. The GPS signals were transferred to all other transmitters needed to cover the whole of NRW, and since April 1995 100% of NRW was provided with RASANT.

In the following years all the 11 German public broadcasting corporations adopted RASANT in cooperation with their 16 Länder related Surveying and Mapping Agencies. In the beginning of 1999 the whole area of Germany is provided with RASANT data. Also the Catalonian broadcasters and surveyors in Spain are testing RASANT.

3.12 RASANT - the final version

The RTCM message type #1 which carries the pseudo range corrections (PRC) for all visible satellites contains for e.g. 9 satellites about 680 bit. On the other side, the so called RDS group, the unit that carries all information of RDS, has a maximum load of 37 bit. This means that about 19 RDS groups are required to distribute the whole RTCM message type #1 and convey it to the user. When the radio signals are jammed and only one single RDS group is not received correctly, the whole radio telegram is disturbed and useless. On the users side the latest set of corrections cannot be replaced by the preceding ones, instead these grow older and have to be used until the next set arrives correctly. The position solution generated by antiquated corrections contains a growing error. If the age amounts to 20-25 seconds the error at current level of Selective Availability (SA) amounts to 10-20 meters and makes the procedure worthless.

The early tests made clear that a special treatment was necessary to make the RDS data transmission safer and quicker. A special RASANT format was developed which is adapted to the structure of RDS. The RTCM message was condensed with the effect of acceleration and partitioned with the effect of insensitivity to jamming. On the users side an intelligent decoding and reconstruction of the original RTCM message is necessary and gives the chance to rule the access to the data. Users must buy a RASANT receiver. The purchase price contains a certain amount of revenue for the service providers.

3.13 Features of RASANT

The RASANT software consists of two components:

RASREF for data 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.

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:

PRC 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. By 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 original 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 or disturbances occurs, the whole contents of the message from all the satellites is destroyed. By creating autonomous or self-sufficient groups, only the information relating to one satellite can be affected by a jamming event, the rest of the data remains undisturbed.

Integer Timing Management

PRC 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[3] can so be avoided and the PRC become nearly independent of any overhead information. The data for 9 satellites need 9 x 37 = 333 bits , instead of the 680 bits needed by the original RTCM correction format.

Accelerated processing

As mentioned earlier, the PRC are determined continuously. The PRC of each satellite is guaranteed to have a maximum age of 1 second when it is transmitted. The average age of the PRC used by the mobile receiver can be reduced by about 80%.

Satellite Priority Control

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

[3] In RTCM the modified z-count is used as a reference time for the message parameters

3.2 Installation of the Real Time Positioning Service RASANT in Germany

The AdV[4], which is the congregation of the surveying and mapping administrations of the German Länder, decided in 1995 to establish a satellite based positioning service named SAPOS throughout Germany. In SAPOS different service levels offer positioning in real time or postprocessing, with centimeter accuracy for surveyors or meter accuracy for navigation and GIS applications **(Table 1)**. The data are generated by a growing number of GPS reference stations all over Germany. They are provided to the user by different communication links as RDS, Telephone, GSM, two-way radio (160 MHz).

In 1996, AdV decided that the technical realization of the service level EPS for meter accuracy should be RASANT.Between the AdV und the ARD[5], which is the platform of the radio stations working under public law in Germany, a fundamental agreement for a long-term operation of RASANT exists. The radio stations of Bavaria, Berlin, Northrhine-Westphalia and Saxony and their corresponding surveying and mapping agencies have signed bilateral treaties for an operation period of 10 years. The other Länder are still under negotiation. Nevertheless RASANT is on the air today in all the 11 German transmission areas. Spain has adopted the technique also and RASANT is currently broadcast by the Broadcasting Corporation of Catalonia.

SAPOS - German National Survey Satellite Positioning Service

Service	Time to result	Transmission	Data Format	Accuracy
EPS Real Time Positioning Service	Real time	Radio Data System (RDS) of FM radio stations, 87-108 MHz	RTCM 2.0	1-3 m
HEPS Precise Real Time Positioning Service	Real time	5 separate radio frequencies at ~160 MHz, exclusively used	RTCM 2.1	1- 5 cm
GPPS Geodetic Positioning Service	Postprocessing Within ~15 min.	Telephone, GSM	RINEX	1 cm
GHPS Precise Geodetic Positioning Service	Postprocessing	Mail etc.	RINEX	< 1 cm

RTCM = Radio Technical Commission for Maritime Services
RINEX = Receiver Independent Data Exchange Format

Table 1 SAPOS

3.3 The realization of RASANT receivers and hardware units

When the RDS data is received by a common RDS radio receiver (like those frequently installed in cars today) the software RASMOBIL on a small computer reads the DGPS data, decompresses it and reconstructs the original RTCM 2.0 format.
Firms wanting to develop user units receive the formats and the software RASANT by signing a contract with our

[4] Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland (AdV) , (Working Committee of the Surveying Administrations of the Länder of the Federal Republic of Germany)

[5] Arbeitsgemeinschaft der Rundfunkanstalten der Länder der Bundesrepublik Deutschland (Working Committee of the Public Broadcasting Corporations of the Länder of the Federal Republic of Germany)

agency. We do this as preliminary helper of a future RASANT Coordinating Committee (RCC). About 10 mostly small firms have signed for a development of user units at their own risk. Seven firms have presented finished devices **(Figure 2)**. Four receivers have been tested in static and kinematic mode and have shown results equal to a reference solution. Devices with a double VHF tuner component have especially proved worthwhile.

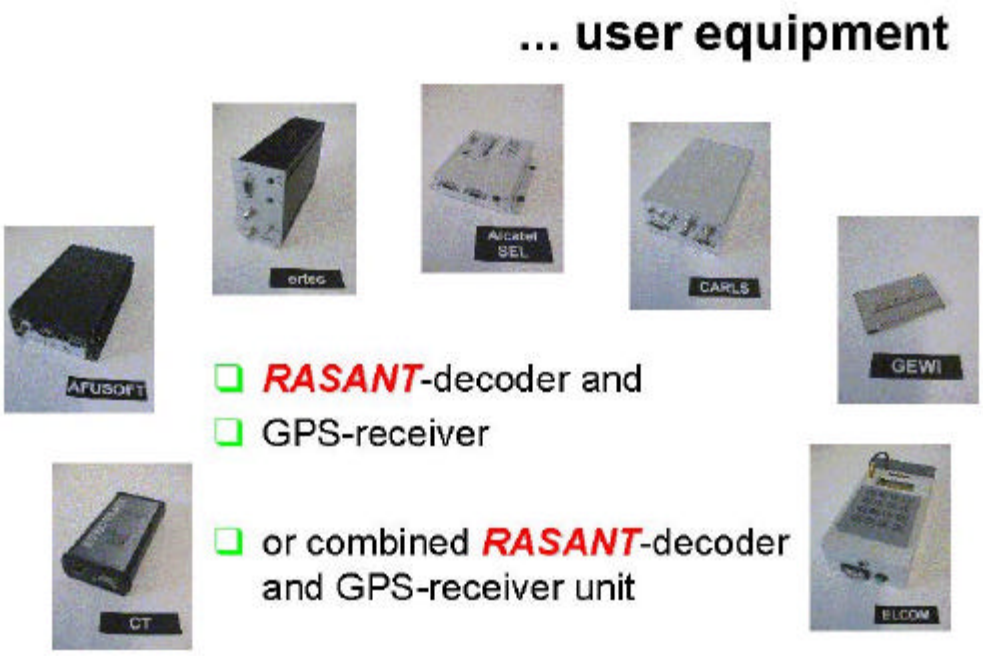

Figure 2

3.4 Accuracy and costs for the user

With a RASANT receiver (from 1,000.- to 2,500.- DM) in combination with a standard DGPS receiver (from 500.- DM) the user's 2D-position errors amount to 3 m...5 m. With geodetic receivers (from 3,000.- DM) the accuracy is increased to 1 m...3 m in static mode. User fees are raised through a lump sum of 15 % of the selling price. Between 300 and 400 RASANT receivers have been sold. Mass production has not started yet but will of course lower the prices.

4 Applications of SAPOS-RASANT, system developments, prototypes

The positioning service SAPOS offers precise positions in the spatial reference system of the German national survey by means of RASANT receiver units. For many fields of application there is a demand for ready-made solutions appropriate to special technical problems. Chiefly the combination of the coordinate position with fitting maps in the background have a broad potential in the market **(Figure 4)**. This is a sector of worthwhile activities for manufacturers and firms.
Some examples and approaches of special technical applications of SAPOS-RASANT are presented here.

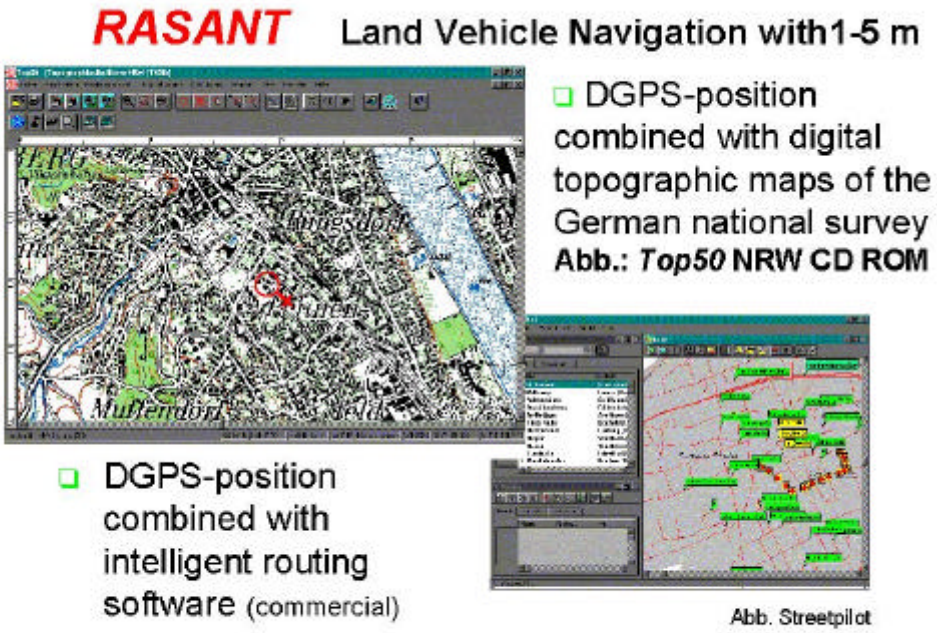

Figure 4

4.1 Collecting technical data with spatial reference

RASANT is used for the update of topographic maps in the scales of 1:5000 to 1:25000, especially for the ATKIS project[6]. ATKIS is the digital topographic map of the AdV. Geocoded objects of the surface of the earth are georeferenced in a digital landscape model with a one-meter accuracy **(Figure 3)**.

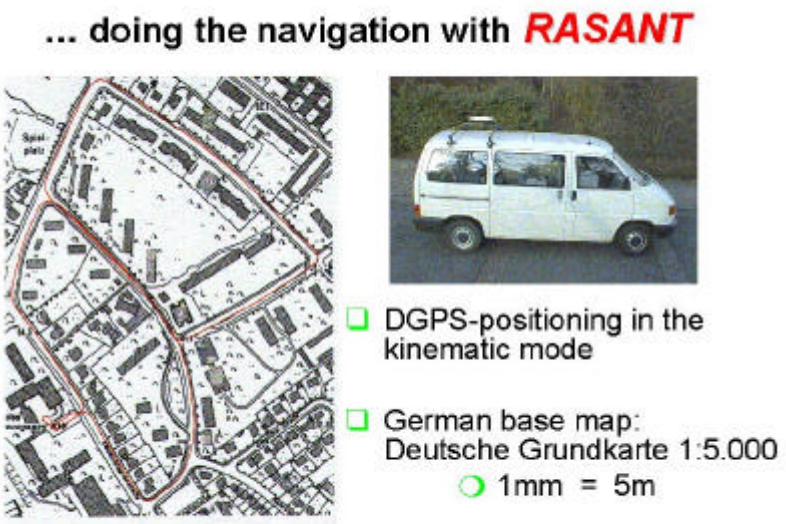

Figure 3

The broadcasting corporation Westdeutscher Rundfunk and the other radio stations also use RASANT in order to plan and maintain their network of transmitters. They check the quality of the broadcasting conditions in their transmission

6 Authoritative topographic cartographic information system

area.
Road conditions can be recorded and linked with their coordinate position with RASANT. A special vehicle equipped with video camera and laserscanning systems detects potholes, uneven and rough surface etc. Systems in use are called "ARGUS" (Automated Road Condition Graduating Unit System) and "SCRIM" (Sideforce Coefficient Routine Investigation Machine). The need for local repairs can thus be easily decided on the basis of computer gathered data.

4.2 Agricultural applications

In farming the use of herbicides can be reduced when the whole field is not sprayed but only the location where the weeds really are. At the University of Bonn a sprayer with a liquid output control steered by RASANT has been developed. The location of the weeds has been mapped before in a conventional manner. The amount of herbicide could be reduced in this example by 30 - 40 % which is of course an environmental success **(Figure 5)**. Other developments are ongoing with the recording of the location and amount of cereal while harvesting by the harvester. Consequently fertilizer can be used according to the yield data to adjust the differences in growth.

Figure 5

4.3 Mobility of blind people supported by RASANT

The European Community funded project MoBIC (Mobility of Blind and Elderly People Interacting with Computers) tries to design a guidance system for blind and elderly people. For the positioning DGPS via RASANT is used. Communication between man and machine is mainly by voice. Digital maps must satisfy the utmost requirements with regard to accuracy, detail and completeness of topographic objects. Here digital cadastral maps only can deliver the geometric base **(Figure 6)**.

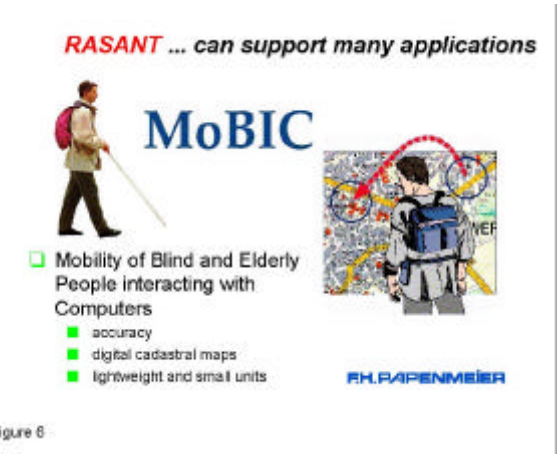

Figure 6

4.4 Logistics at the government building site Berlin-Spreebogen

The logistics of the parliament and government building site 'Spreebogen' in the center of Berlin is coordinated with the help of DGPS via RASANT. In order to guarantee well-balanced traffic on the building site and to minimize waiting periods and road traffic congestion, all vehicles for delivery and supply have to follow a time schedule. For the time between entering and leaving the building site the position of every truck is monitored by RASANT and radioed to the

site office's traffic management system **(Figure 7)**.

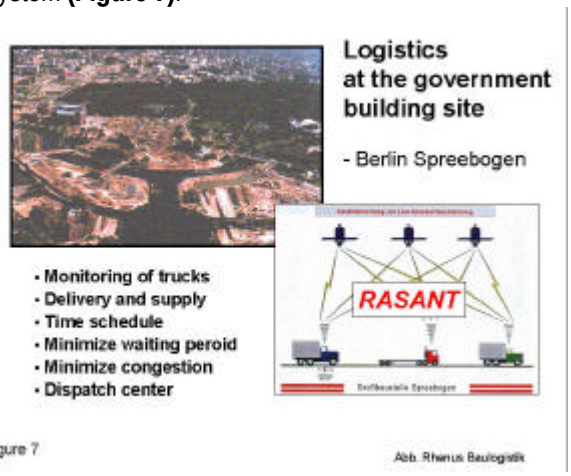

Figure 7

Abb. Rhenus Baulogistik

4.5 Public transportation services

In the field of public transportation services in cities several projects are ongoing to examine the benefits of information systems for passengers. As an example the topical position of the next bus to come is displayed at the stop. A tram triggers the phase of traffic lights and obtains a high priority in the flow of traffic. The precise coordinate of the bus or tram from RASANT makes the permanent installation of signaling systems along the street which report the actual position of a public vehicle obsolete **(Figure 8)**.

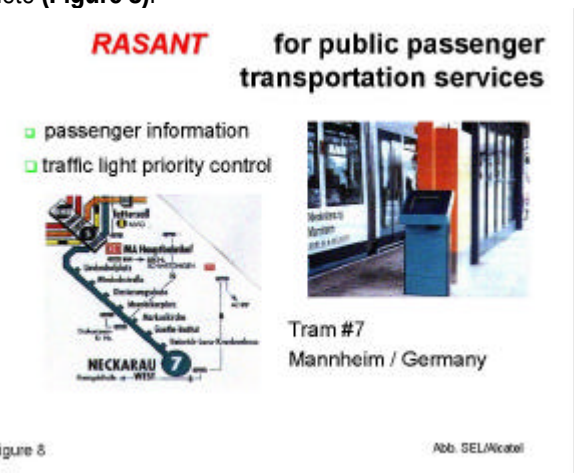

Figure 8

Abb. SEL/Alcatel

5 Summary

With the RASANT data transfer technique, SAPOS offers a standardized and inexpensive real time positioning service. In cooperation of the German broadcasting corporations and the surveying and mapping agencies of the Länder, RASANT is provided in a uniform way for the whole of Germany via the RDS of FM radio stations. RASANT receivers are available on the market and allow, in connection with GPS receivers, navigation with 1-5 m accuracy.
The use of this precise navigation result depends upon the user needs and has to be integrated into special user terminals. There are interesting examples and projects which realize precise navigation and the spatial reference of technical data by RASANT.

6 References

W. Lindstrot, W. Plöger
Möglichkeiten eines Echtzeit-DGPS-Dienstes über Rundfunk
Zeitschrift für Satellitengestützte Positionierung, Navigation und Kommunikation (SPN), Herbert Wichmann Verlag Karlsruhe, Heft 4/92, Seíte 123-126

W. Lindstrot
Metergenaue Echtzeit-Positionierung mit EPS-RASANT
Vermessung und Raumordnung, Ferd. Dümmler's Verlag Bonn, Heft 3+4/96, S. 177-185

P. Raven, S. Sandmann and G. Schoemackers
RASANT: Radio Aided Satellite Navigation Technique, EBU Technical Review No. 267, Spring 1996

C. Elsner
DGPS-Echtzeitpositionierung mit Korrekturdatenübertragung über UKW-Rundfunk - RASANT, Seminar "Raumbezug durch satellitengestützte Verfahren", Vermessungs- und Katasterverwaltung Sachsen-Anhalt, 26.11.1997, 1. Auflage 1997