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GPS PROTOCOLS

Michal Sustek, Miroslav Marcanik, Milan Oplustil, Zdenek Urednicek
Faculty of Applied Informatics, Tomas Bata University in Zlin,
Zlin, Czech Republic.

Abstract
The contribution describes the basic principles of measurement and the use of global positioning systems, focusing on the most widely used system NAVSTAR, including used protocols. It deals NMEA protocols-which today ranks among the most widespread GPS system, RINEX-which is an interpretation of "raw" data, these systems, and RTCM-which is an alternative for NMEA with the difference that is much used in the GLONASS system.

Keywords: GPS;protocols; NMEA; RINEX;RC-104.

INTRODUCTION

The need to know its place and purpose of humanity was already known at the time of nomadic tribes, even though it was not the exact coordinates, but rather about the features and layout of the new territory to be able to survive. With the increasing development and demarcation of borders of individual states are at the forefront seceded and precise geographic coordinates, and it's no surprise that over time, methods of identifying and mapping increasingly refined. Nowadays, because there is a large geographic area Navigation Satellite Systems (GNSS), in which it is possible to include the most common navigation system NAVSTAR GPS, but also GLONASS (Russia) and GALILEO (European Union).

In positioning systems are distinguished two methods for aiming points, these are the absolute and relative, both of which can be used in static and kinematic mode. In the static application, the receiver is during the measurement due to the earth's surface at rest. On the other hand, in the kinematic applications is the antenna relative to the surface of the earth in motion. The accuracy of static methods and speed of kinematic measurements contributed to the development of technologies whose combination leads to rapid positioning. It is a method of Rapid Static and Stop & Go. Another development from the perspective of hardware receivers led to the creation of options "real-time" measurement techniques.

Due to the mass spread of GPS technology, it is not surprising that they constitute a resource of information that must be processed. The problem may be a transmission with a device to the software that was created by another manufacturer. It leads to the need for at least some of the protocols to standardize. Among the most used include NMEA, RTCM SC-104, and RINEX.

GPS HISTORY

The GPS system has its roots in the 60s of the 20th century. The primary purpose for which the system was designed in the effort to obtain a universal, highly accurate and easily accessible positioning and navigation system, which at that time replaced the myriad specific devices. The main problem with these devices is their cost and limited use. Based on these facts, the US Navy and Air Force began independently to study the possibility of using a radio signal that would be sent from the satellites and the possibility of its use for navigation. Navy sponsored two research programs. These were Transit and Timation. On the other hand, the Air Force participated in a similar program 621B System. In 1973, there was a compromise that united researcher programs under a single program known as GPS. The first phase of the GPS had a set budget to $ 100 million. [3]

Between 1978 and 1985 there was a total of 11 satellites launched, but one of them was destroyed in a failed launch. The initial service of life which has been determined by these satellites was only three years, but the most of them worked over 10 years. In the 80 years was sent into orbit by an additional 23 satellites. Currently, this system consists of 24 satellites. Like a number of other technologies, it was the first major test for the deployment of GPS in military operations in the Persian Gulf. The system enabled the orientation in rough desert terrain with great precision. It is said that one of two things that stood for victory in this war conflict was just a GPS (the other was night vision). It is, therefore, understandable that in addition to the Gulf War, the system was deployed in countless other military operations.

GPS METHODOLOGY

The GPS has two basic measurement methodology, these are absolute (autonomy) and relative (differential) positioning. Both of these methods can be used for static and kinematic positioning application. Under static positioning, the receiver during the measurement due to the earth's surface at rest, on the other hand in kinematic applications, the antenna relative to the surface of the earth in motion. The accuracy of static methods and speed of kinematic measurements contributed to the development of technologies whose combination leads to rapid positioning. It is a method of Rapid Static and Stop & Go. Another development from the perspective of hardware receivers led to the creation of options "real-time" measurement techniques (RTK).

Statistic Method

The relative measurement method allows determining the differences between GPS coordinates of the satellite system and the reference point. The various distances to the satellites must be determined simultaneously from the examined and the reference point. Under static measurements are determined vectors connectors points of interest (in figure 1). The static method allows you to use for the production of geodetic networks for a large area. When repeated measurements over a sufficiently large time interval, it is possible to track the movements of tectonic points. Creating such a geodetic network is much less time consuming than building a conventional geodetic. Interestingly, when measuring longer distances with higher precision than with the traditional measurements. The minimum number of stations that can perform measurements are 2. The time measurement is known as observation cycle which is dependent on the length of the vector. [2]

Table 1: Relation of vector length to observation cycle

Vector length (km)	Observation cycle (min)
0, 1-1	10-30
1-5	30-60
5-10	60-90
10-30	90-120

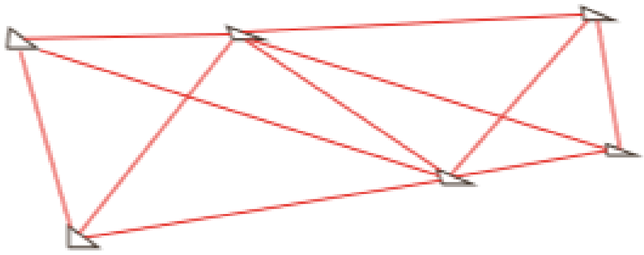

Figure 1: Statistic Method [2]

Fast Statistic Method

This method is similar to the normal static method. However, the main difference is at the time of measurement, which is significantly shorter. This reduction was made possible by technologies and rapid measurement of ambiguity when it advantageous to use two frequency receivers with P-code and configuration is required advantageous satellites. The optimal configuration appears 5-6 satellites above the elevation of 15 degrees above the horizon. [2]

Two ways of using this method:

a) The receiver determines from the P-code a pseudo-range, the accuracy is better than 10 cm, and the combination of the phase measurement ambiguities determined in minutes.

b) The second principle uses statistical procedures which utilize redundant observations from multiple satellites. Even with this approach are ambiguities identified in minutes. The success of this approach is dependent on the number and configuration of satellites.

This methodone can see in figure 2. It is implemented with the help of two receivers and is to be used up to a distance of 15 km around the reference point whose coordinates are known. One receiver is the reference point, and other is mobile which gradually moves to determined points. It is necessary that the receiver, which is located at the reference point, during the measurement receives satellite signals. On the other hand, the mobile receiver performs only short measurements at points of contact, and during its motion is turned off. The accuracy of coordinate measuring is between 5 and 10 mm. This method is used for thickening networks in local triangulation, measurements at the border, and in the detailed measurements. [2]

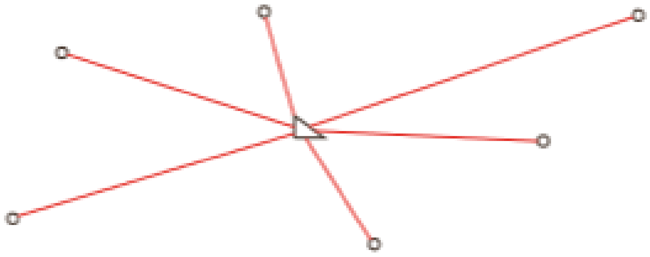

Figure 2: Fast Statistic Method [2]

Stop&Go Method

Stop and Go method (figure 3.) is one of the fastest ways of determining the coordinates of points of interest with a precision of 1-2 cm with very short observational cycles. This method, which is halfway between the static and kinetic variant, therefore, referred to as semi-kinetic. To determine ambiguity before the start of measurement in kinematic mode endpoints known starting base on which are known coordinate differences with a mean error of at least 5 cm or by using the exchange of antennas between two nearby receivers (5-10 m). [2]

If signal is not interrupted and it takes the receiver signal from at least 4 satellites for 4-10 measurements, it is possible to replace the antenna receivers. After adjustment the same number of measurements, the antenna will move to their own devices and can start the actual measurement. At the starting point remains the reference instrument, taking on both devices start measuring the kinematic mode. The second unit will gradually move to the detailed points, which receives a twice or more receives signals from satellites. There is a need to switch modes SURVEY (for measuring) and ROVING (for moving). During the actual move between points, the receiver must continuously monitor signals selected satellites (at least 4). This measurement method is fast and efficient and it is particularly suitable for measuring in civil engineering. [2]

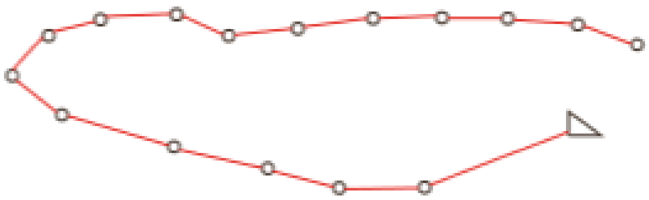

Figure 3: Stop&Go Method [2]

Kinematic Method

Kinematic measurement methods can be used for determining the path of the moving object on which is placed a mobile

receiver. In these cases, we speak of the continuous kinematic method (so-called. "True kinematic"). [2]
The speed with which the receiver moves can be used to assess the accuracy. The second (so-called reference) receiver is located at the point with known coordinates. Both receivers must simultaneously receive satellite signals. A distinction is made in principle two modes kinematic measurements. [2]

- Kinematic measuring with static initialization
- Kinematic measuring with initialization on the move

In the case of measuring with static initialization at the beginning of the measurement procedure exactly as method Stop & Go. In the latter case uses the technology of ambiguity resolution in motion (i. e. On the fly-OTF). [2]
After selecting the time interval which will determine the position of the mobile receiver (from 0, 5s-without stopping over point) can start the actual measurement. The accuracy of this method will be within 1-2 cm. These methods are primarily used in the navigation of moving objects (vehicles, boats, aircraft), determining their trajectories like. It one can see in figure 4. [2]

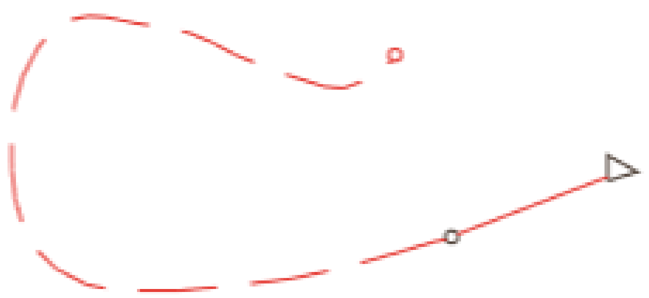

Figure 4: Kinematic Method [2]

GPS Properties

Electromagnetic signal L1 is relatively resistant to weather influences, so due to rain, fog and other phenomena occurs only to a slight weakening of the signal. The signal, however, is not able to pass through obstacles such as walls of buildings, underground, lush vegetation, the trees and the like. It follows that a necessary condition for receiving the signal line of sight of the sky.

Accuracy

GPS accuracy is affected by numerous factors, but the most significant influence, which is, fortunately, past was the introduction of restrictions SA (Selective Availability-The availability of only some). The reason for introducing this limitation was the initial focus on the GPS for military sector and was therefore initially coded so that it can fully utilize precision only the US military. Although the civilian sector could use GPS services, with an accuracy in the size of several hundred meters. The turning point occurred in 2000 when B. Clinton ordered the deactivation of SA. [3]
GPS deviation is therefore nowadays determined by some factors, which more or less influence the precision. These factors are: [3]:

- The signal delay in the ionosphere-10 meters
- The signal delay in the troposphere-1 meter
- Deflection satellites of the indicated position-1 meter
- The inaccuracy of the clocks of the satellite-1 meter
- Receiving a false echo-0. 5 meter
- Custom receiver noise-2 meters
- Noise on the other satellites-1 meter
- Gross human error (error in the conversion of coordinates, incorrectly chosen ellipsoid etc.).

The indicated deviation in meters only serves as an indicative, but a real contribution to the overall uncertainty is primarily dependent on the deployed satellites (PDOP parameter – Dilution of Precision). Although the receiver selects a combination of satellites that has the best PDOP parameter, it cannot completely eliminate the deviation. In calculating the coordinates based on coordinate each other deviation. Generally, determining height is less accurate than the geographical coordinates.

GPS Protocols

GPS receivers nowadays their massive deployment represents a considerable source of information that must be processed. A problem may constitute a transmission from a GPS device to a program that was created by another manufacturer. The reality is that receivers often used a large amount of protocols that were used and often were not adequately documented. This led to the formation of protocols for communication satellites with the actual receiver. These protocols include, for example. NMEA, RTCMSC-104, and RINEX.

NMEA

NMEA Association states on its website [3] that this communication standard is subject to copyright and can only be purchased from the association. Prices range in the hundreds of dollars, while other resources that exist on the Internet are not authorized and may constitute copyright infringement and may contain information that is outdated.
The baud rate ofNMEAis 4800, the number of data bits is 8, while the seventh bit (MSB – Most Significant Bit) is always zero. All data is sent as sentences that are allowed only printable ASCII characters and line breaks control characters <CR><LF>.

NMEA sentences:

- talker sentences
- proprietary sentences
- query sentences

The general format of talker sentences

The first two letters, which follow the *$* are identified like *tt* and represent the talker's identifier, three more letters are *SSS* represents sentences identifier. These are followed by data items separated by commas, which is bound by an optional checksum. The sentence is completed with <CR><LF>. The importance of individual data items is clearly defined for a specific sentence. In cases where an item of data is not available for data field it remains empty, but the comma that separates data fields remain. Checksum begins with * at which the two hexadecimal digits that interpret the logical

XOR operation of all the characters between $ and *. Each message has a limit of 80 characters, without starting and terminator symbol. [3]

$\$ttsss, d1, d2 \ldots < CR >< LF >$

The general format of proprietary sentences

Proprietary sentences are very similar to talker's sentences, but their aim is to provide an opportunity for device manufacturers to define their own reports. In his description, it differs in its early characters. This sentence begins the sequence with *$Psss*. The rest of the sequence is identical with talker's sentence. [3]

$\$Psss, d1, d2 \ldots * hh < CR >< LF >$

The general format of query sentences

NMEA's query sentences have a specific format, which only partly resembles other data formats this protocol. Compared with proprietary and talkers sentences it is significantly shorter, however, it still clearly illustrates the listeners needs. Thus, constitute a simple way can the listener from the speaker's request to send a specific sentence. The sequence of *tt* indicates the ID of the device making the request. On the other hand, symbols *ll*refer to a device that accepts the request. Sign Q is a required character that serves as an identifier that is the query sentence. [3]

$\$ttllQ, sss * hh < CR >< LF >$

Detailed description of sentences

Among the most commonly used sentences include the talker's sentences, namely RMC (Recommended Minimum Navigation Information), GGA (Global Positioning System Fix Data), GSA (GPS Dilution of Precision and Active Satellites).

RMC – example

*$GPRMC, 170138. 615, A, 4912. 2525, N, 01635. 0378, E, 0. 04, 16. 43, 280705,,*32*

GGA-example

*$GPGGA, 170139. 615, 4912. 2526, N, 01635. 0378, E, 1, 07, 1. 0, 357. 5, M, 43. 5, M, 0. 0, 0000*7D*

GSA-example

*$GPGSA, A, 3, 29, 26, 22, 09, 07, 05, 04,,,,,,1. 7, 1. 0, 1. 4*30*
RTCM SC-104

This communication protocol was based on the request for development of recommendations for the transmission of differential corrections for GPS users navigate the Institute for the USA, presented by Radio Technical Commission for Marine Services. Its creation was dealt specifically commission no. 104, called "Differential NAVSTAR GPS service. " This recommendation contains steps to facilitate the implementation of transmission correction data definition that will be transmitted, the minimum time between transmissions, and the size of the data segment protocol data units, ranges, and resolutions. Among other recommendations, the committee was in charge of the preparatory steps for the eventual implementation of a data communication channel.

Recommendations made by the Commission also contained a proposal pseudo-satellite arrangement, which was perceived as a special service involving the transmission of DGPS differential corrections on frequency L1. From the user's perspective, it would appear as pseudo-satellite other standard satellites whose signals would be processed directly by the GPS receiver. This would eliminate the need for a special data channel for transmitting corrections. Besides to the other benefits ofDGPS this structure led to increasingreliability so that it would provide a further possibility of measuring the apparent distance.

The actual standard RTCM SC-104 defines the transmission data of a digital format, the basic building block is the message extension frame, which consists of a plurality of different 30-bit words. Each of these words has one or more parameters that can cross the boundary between words. The data transfer uses the first 24 bits and the remaining 6 are used for security, which allows it to detect and correct data errors occurring during transmission.

The first version of the standard was published in November 1985, on the basis of practical experience it in January 1990 had a minor adjustment. Over the years, this recommendation was identified as robust and have been collectively accepted by both manufacturers and users in both North America and Europe. In January 1994 there was a further adjustment, which included an extension in the issue kinematic measurements in real time. Over time, the standard RTCM got up to version 3. 2, which was published in 2013.

Type 1 message contains data for all the satellites from the perspective of a single reference station. These data are composed of the following information:

2) *Correction of the pseudo-range from reference station s for each satellite to reach i in time t_0, which is calculated according to the equation $V_{PR}^{i}(t0) = \rho_s^i(t0) - PR_s^i(T0)$. $PR_s^i(T0)$ represents the pseudo preset from the base station, which is regulated via the receiver clock offset, group delay, offset-hour satellite and its relativistic effect.*
3) *The rate range correction V_{PR}^{i} for user measurement time t with respect to time t_0 reference station.*
4) *An estimate of 1-sigma uncertainty of correction that is due to signal-to-noise ratio and the multipath system.*

Type 2 message includes the difference between corrections pseudo-range and distance from a reference station to all satellites in the rangeof two consecutive navigation messages. The message is often combined with the first type in cases where the user is not able to decode ephemerides newly captured the satellite.

Type 3 message contains the coordinates of the reference station located closest to the frame of reference WGS84 if that is not defined a message type 4 refers to the date of the reference station.

Type messages 18 and 19 contain the raw information about the phase of the carrier (18) and the pseudo-range observations (19) of the reference station. How to define standards for the measurement is not repaired ephemerides information from messages broadcast satellites. On the other hand, there is of course used for error estimation internal clock satellites. The main advantage of using this type of

message is that there is no need to use sophisticated computational models of the reference stations, but simply their observations across the coordinates and information about the transmission antenna to the user.
In opposition to messages 18 and 19, the messages 20 and 21 that already contain the correct values of carrier phase and pseudo-range measurements. Correction carrier phase V_{CP}^{i} is calculated on a selected range of supporting carrier φ^{i} at time $t0$ calculate from the geometric series ρ^{i} . Thus equation$V_{CP}^{i}(t0) = \rho_{cycles}^{i}(t0) - \varphi^{i}(t0)$.
Using message type 22 is allowed to use sub-millimeter resolution for the coordinates of the reference station during kinematic applications. Also provides information on the height above sea level of the reference station antenna. Very often it is used in combination with the message type 3, which allows the reconstruction coordinate L1 APC.
Message type 23 defines the type of antenna used meets the standard IGS, which is used for naming. Type 24 contains the coordinates in the WGS84 system or PE90 ARP in the sub-millimeter range.
Type 31 is similar to the message type 1, a fact that provides the ability to use corrections for GLONASS system. Message type 59 is proprietary and is currently used by different manufacturers, but in most cases, the model contains information from a network of reference stations.

RINEX

This standard was created by the Institute of Astronomy at the University of Bern. It served as the format for the data transmission between institutions which participate in the project of creating a precision geodetic reference network. It was implemented in May 1989, but already a year later some changes were made and it was accepted its second version (RINEX v2). Recently passed this format several modifications related to the use of the GLONASS system and files mainly include mixed GPS / GLONASS, the definition of the GLONASS system time, sets of navigation dataare currently valid standard RINEX v3. 0. [4]
This is the agreed ASCII format measured data, which enables data transfer between different types of GPS devices and different evaluation system. Most such programs have an opportunity for input and output RINEX format and also include modules for mutual conversion data in araw internal binary format and RINEX format.
Within version 3. 0 are defined three types of files:

- File of measured data
- File of broadcast satellite navigation data
- File of meteorological data

Table 2: Rinex [4]

File Type	ASCII File	Compressed File		
		UNIX	VMS	DOS
Measurement	Ssssdddf. yyO	Ssssdddf. yyO. Z	Ssssdddf. yyO_Z	Ssssdddf. yyY.
Navigation	Ssssdddf. yyN	Ssssdddf. yyN. Z	Ssssdddf. yyN_Z	Ssssdddf. yyX
Meteo	Ssssdddf. yyM	Ssssdddf. yyM. Z	Ssssdddf. yyM_Z	Ssssdddf. yyW

Where:

ssss	four-digit code word station
ddd	the serial number of the first record in
f	the serial number on a given day session
yy	the last two digits of the year

Set of measurements consists of blocks containing phase measurements on one or both frequencies (L1, L2), the code pseudo-range measurements (C / A code on frequency C1) P-code to the first or both frequencies (P1, P2), which belong to the individual epochs measurement. Each of these blocks is preceded by the date, time, a number of satellites received PRN and optional data on repair time clock receiver. Pseudo-ranges expressed in length units (meters), the phase values are continually measured in cycles of a carrier wave. Data that are recorded using squaring receiver must be labeled with factor wavelengths 2. Some special receivers also record the measurement of Doppler frequency in Hz for both frequencies (D1, D2) which are further processed by the evaluation software. [4] All of these variables have a fixed format. They conceived and order, however, may vary based on the equipment used. RINEX format allows a seamless record of rapid stations and kinematic data acquired by the mobile receiver.
Navigation data file contains orbital data from all satellites, like satellites hours, information on the state apparatus on satellites and pseudo-expected measurement accuracy. It also contains navigation messages received by the GPS receiver at the time of measurement. This means in practice, covering the time interval observational session.
The meteorological data file includes a time value associated with a calibrated surface barometric pressure in mB, the dry air temperature in degrees Celsius and relative humidity in %. All of this set covers data from one station at a certain time interval.

CONCLUSION

In the Global Navigation Systems, we have two basic methodologies of positioning, they are the absolute and relative method. Both methodologies can be used in static and kinematic mode. Under static positioning, the receiver during the measurement due to the earth's surface at rest, no other side in kinematic applications, the antenna relative to the surface of the earth in motion. The accuracy of static methods and speed of kinematic measurements contributed to the development of technologies whose combination leads to rapid positioning. It is a method of Rapid Static and Stop & Go. Another development from the perspective of hardware receivers led to the creation of options "real-time" measurement techniques.
There are a wide number of standards that are at issue positioning systems exists, but currently, there are three basic standards to which it is able to operate most receivers. This is a standard NMEA, RTCM SC-104, and RINEX. NMEA a transfer rate of 4800 baud rate, the number of data bits is eight and every seventh bit is zero. All data are sent to sentences that are allowed only printable ASCII characters and line breaks control characters <CR><LF>. We can have three types of sentences-the talker, proprietary, and query

sentences. Standard RTCM SC-104 defines the data transfer binary format. The basic building block of a message or a framework consists of plenty of 30-bit words. Each word contains one or more parameters and can go beyond individual words. To the data transfer is used the first 24 bits and the remaining 6 bits are used for security. It allows to detect and correct data errors occurring during transmission. RINEX standard is ASCII format of measurement data, which is applicable to transfer between different types of GPS and evaluation system. They make up "raw" GPS data. As part of the latest version of this standard are distinguished three types of files. Measured data, navigation data and meteorological data which are transmitted by the satellite.

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REFERENCES

[1] J. Sebesta. *Global Navigation Systems*. Edition. 1. Brno: Brno University of Technology, Faculty of Electrical Engineering and Communication, Department of Radio Electronics, 2012, 132 s. ISBN 978-80-214-4500-0.

[2] O. Svabensky, J. Weigel and R. Machotka. *Methodology of GPS measurement and evaluation* [online]. Brno, 2005. Available from: http://fast. darmy. net/opory%20-%20IV%20nMgr/HE09_M01-Semin%C3%A1%C5%99%20GPS. pdf. Study Materials. Brno University of Technology. 8. 6. 2016

[3] J. Martinek. GPS and communication protocolNMEA. *ABC Linux* [online]. 2010. Available from: http://www. abclinuxu. cz/serialy/gps-a-komunikacni-protokol-nmea 8. 6. 2016

[4] *RINEX Utility-USER Guide* [online]. 2014. ISBN 96-310021-2101. Available from: http://www. navcomtech. com/navcom_en_US/docs/download_center/user_manuals/current/96_310021_2101RevD_Rinex_Utility. pdf?locale=navcom_en_US 10. 6. 2016

[5] RTCM SC-104. *TekmonGeomatics* [online]. 2010. Available from: http://www. tekmon. eu/2-5-1-rtcm-sc-104-transmission-protocols/ 10. 6. 2016

[6] J. B. Neumann, K. J. Vandierendonck, A. Manz and T. J. Ford. Real-Time Carrier Phase Positioning Using the RTCM Standard Message Types 20/21 and 18/19. *Novatel* [online]. 2010, (5). Available from: http://www. novatel. com/assets/Documents/Papers/File47. pdf 10. 6. 2016