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A Study on the Applicability of the Kinematic and the Static GPS Methods for Coastal Ocean Structure Survey

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The position fixing usually is determined by triangulation, traverse surveying and astronomy surveying. However, when the station is moving, it is impossible to determine its position continuously by the former method. By a satellite positioning method(GPS), this problem can be solved. In our study, we used two methods to determine the length and coordinate of a point position. One is a kinematic GPS method and the other is a static one. Each is based on carrier phase measurement and employs a relative position technique. We implemented observation experiments such as Geodimeter and DGPS(Differential GPS) successfully. To estimate the accuracy between the kinematic and static methods, we compared the results of Geodimeter, the kinematic, and the static. The results showed that the static is relatively a little more accurate than the kinematic. However, in the kinematic mode, when we received the GPS data for a long time, we found that the kinematic also had a high accuracy value for the length survey. Finally, we applied the GPS to Jeju Harbor Breakwater to examine the applicability of GPS for coastal ocean structure based on the kinematics and the statics, respectively.

Key words : triangulation, traverse surveying, satellite positioning system, GPS, Geodimeter, DGPS, Jeju Harbor breakwater, coastal ocean structure

1. Introduction

The Global Positioning System(GPS) is originally being developed and operated to support military navigation and timing under development by the Department of Defense(DoD) for over 20 years, consists of 21 satellites, plus three back-up satellites in predictable orbits around the earth(Fig. 1). The characteristics of the system is to provide the geocentric position for individual receivers or the relative positions between co-observing receivers regardless of weather condition during 24-hour[1]. However, the achievable accuracy depends on many factors such as atmospheric conditions, GPS satellite distributions on the satellite orbits, GPS clock and observation places of the land etc[4]. All GPS receivers need direct and unobstructed line of sight access to each satellite and always more than 4 GPS satellites.

GPS consists of the Space Segment(the satellites) and the Control Segment(the network of tracking stations which monitor and control the GPS satellites in orbit)[2,3]. The Control Segments also transmits corrections for the satellite's ephemeris constants and clock offsets back to the satellites themselves[3].

GPS has wide applicability for the terrestrial observation not only a civil construction but also a transportation system. For examples, with a cellular phone or transceiver, it is possible to track vehicles or people on the land[4]. It can also provide an all-electronic chart based on a digitized map base. Nowadays, GPS used for the high precision airplane position, that can reduce the need for

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traditional and expensive ground control in photogrammetry[1].

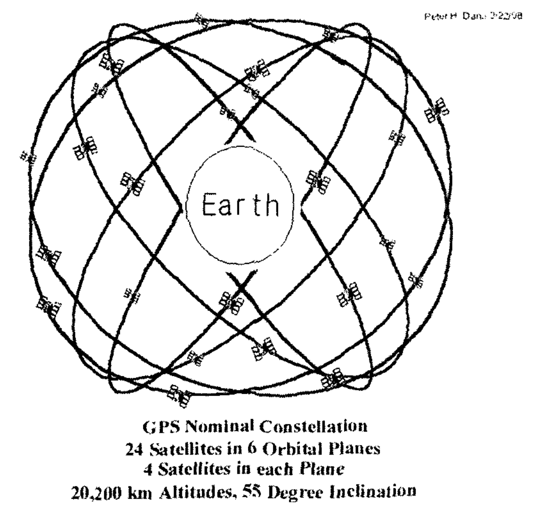


Fig. 1. GPS distributions and orbit on earth.

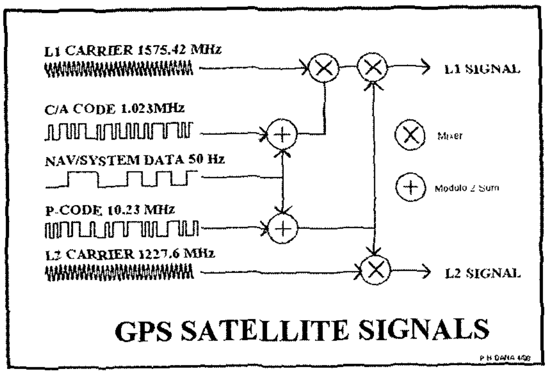


Fig. 2. The characteristics of C/A and P code signals, and L1 and L2 carrier phase signals.

In GPS, there are four types of signal information, that are C/A and P code, and L1 and L2 carrier phase(Fig. 2). The signal frequency of L1 carrier is 1575.42 MHz and carries both the status message and a pseudo-random code for timing. The L2 carrier is 1227.60 MHz and is used for the more precise military pseudo-random code. The C/A(Coarse Acquisition) code and P codes are called pseudo-random code. The C/A code modulates the L1 carrier. It repeats every 1023 bits and modulates at a 1MHz rate. The P code repeats on a seven day cycle and modulates both the L1 and L2 carriers at a 10MHz rate. Since P code is more complicated than C/A it is more difficult for receivers to acquire GPS data[4]. The accuracy of P code is better than C/A code.

The general coordinate system of GPS is based on the WGS 84(World Geodetic System 1984) global grid(Table 1). WGS 84 is an earth fixed global reference frame, including an earth model[6]. The coordinate system was first accepted by the Council of the International Civil Aviation Organization(ICAO) in 1989 as a standard the geodetic reference system[5].

Table 1. Parameters of WGS 84 coordinate system

semimajor axis of ellipsoid	6,378,137 m
flattening of ellipsoid	1/298.25223563
angular frequency	$7,292,115 \times 10^{-11}$ RAD/S
earth's gravitational constant	$3,986,005 \times 10^{8} m^{3}/S^{2}$

GPS system originally was developed from NNSS(Navy Navigation Satellite System) which was created in 1967[6,7]. However, NNSS is unable to provide the accuracy for surveying at the parcel and traverse level since it has a few satellites compared to GPS. Table 2 shows the characteristics of NNSS and GPS.

Table 2. Comparison of characteristics of NNSS and GPS survey

	NNSS	GPS
Orbit	Polar & Circular	Circular
Orbit Height	about 1000 Km	about 2 0000 Kn
Periods	about 100 min.	0.5 days
NO. of Satellite	5-6	24
Frequency	150 MHz, 400 MHz	1227.6 MHz 1575.42 MHz
Measurement method	Doppler	Electromagnetic
Application	Ship and Geodetic Reference Position	Ship, Airplane, Rocket, Survey, and Earth Movement etc.

In this paper, we will apply the GPS techniques to coastal ocean structure to estimate of applicability of GPS. To do this, we firstly test the accuracy of distance from a point to a point. Secondly, the distance is estimated using the Kinematic and the Static GPS positing methods, respectively. The observation results are also compared to those of the Geodimeter. Finally, DGPS will be applied to the coastal ocean structure of Jeju Island.

2. GPS observation method

The GPS observation methods can be divided into 3 parts as the basic, the static and the kinematic methods.

2.1. Basic method(Single GPS method)

From the point of view of surveying or navigation, the GPS system may be viewed simply as a continuous series of radio signals broadcast from orbiting satellites to a radio receiver on the surface of the earth(Fig. 3). These signals contain ephemeris information on the known position of the satellites, as well as, measurement data indicating the distance(range) to each satellite, and information describing the relative velocity of the satellites with respect to the receiver. However, the single of GPS contains a lot of signal errors since the signal can be distorted by some obstacles and atmospheric conditions. For examples, we usually calculate distance to a satellite by multiplying a signal's travel time by the speed of light. But the speed of light is only constant in a vacuum. As a GPS signal passes through the charged particles of the ionosphere and then through the water vapor in the troposphere on the earth, it gets slowed down a bit, and finally, this creates the some kind of error. Also, the transmitted signal from GPS satellites may bounce off various local obstructions before the signal gets to our receiver. From the bouncing effect, the observed distance from a point to points contains some errors. This is called multipath error and is similar to the ghosting like a TV. Therefore, the single GPS observation has a lot of measurement error from 10 to 100 m like Fig. 3. In the civil and environmental engineering aspect, the observation is not so useful.

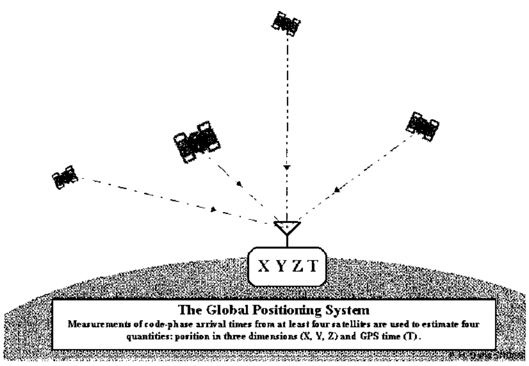


Fig. 3. The method of position survey using single GPS.

2.2. Static Positioning

The typical configuration for Static Positioning is shown below, two units receiving signals from the same constellation of satellites at the same time(Fig. 4). The method is based on DGPS (Differential GPS). The relative position of the two units can be determined to a very high accuracy, in many cases better than a centimeter. If one of these units was located over a point for which we had ground control coordinates it is then theoretically possible to obtain highly accurate coordinates for the other point. Based on the two units, Static Positioning observed several observation points simultaneously for two to three hours. Then the carrier phase observations recorded at individual stations were combined with obser--vations at other stations to form double- and/or triple-difference carrier phase observables. The

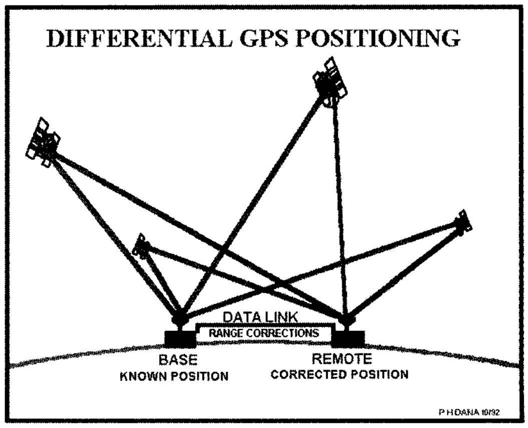


Fig. 4. The method of position survey using DGPS.

static method is then possible to compute the vector between these two units to a much higher degree of accuracy than we can compute absolute latitude and longitude. In this case, we observe some points a little bit long time to receive a lot of data from the GPS since long time observation usually supports much better position data. It is called Static Positioning method.

2.3. Kinematic Positioning

Kinematic Positioning is also a kind of DGPS method. The method was developed in 1985[1]. The method also yields centimeter(and better) relative accuracy in seconds for moving GPS antenna. While one antenna remains stationary at an initial point, the other antenna may continuously move, or move from one station to another. The only constraint on the path of the moving antenna is visibility of the same four satellite at both receivers. Both receivers record the carrier phase observations continuously. Sometimes, antenna-swapping technique fro rapid initialization of the ambiguities. The method is a very useful method for the Kinematic Positioning. In recent, the method is using for high-precision airplane position. To implement the high precision surveys, we have to solve the phase ambiguities. This means that you need to perform a static survey, unless you wish to rely on kinematic ambiguity resolution techniques. While this methods is fairly reliable, we take the minimum time needed to establish GPS ambiguities with some static technique. It means that in any given data set, you can mix any amount of static and kinematic observations when you process GPS network observation.

3. Coordinate Systems

The type of coordinate system used in GPS surveying is an earth-centered cartesian system. Generally coordinates produced by GPS units are geocentric coordinates which appear nothing like geographic coordinates. Geocentric coordinates are based on the centre of the earth and have an X, Y and Z component. The Z axis is from the centre of the earth through the north pole, the XZ plane passes through the Greenwich meridian and the XY plane passes through the equator. Geographic coordinates are in the form latitude and longitude and are located on a spheroid of 'best fit' over the surface of the planet. Transformations between the cartesian coordinates and the spheroidal coordinates can easily be performed in the receivers, as well as transformations between grid mapping systems. There is also a selection of spherical models that can be used as a coordinate datum, some of these can be seen during the set-up options on the navigational GPS units.

In GPS system of Korea, we usually use coordinate transformation system of WGS 84 into Transverse Mercator(Bess1984). The process of coordinate transformation of WGS 84 is as following ;

WGS84 ----> Bassel ----> TM coordinate system

In our case, the origin of TM is that the longitude is 127:00:10.4050 N, the latitude 38:00:00 E. And false easting is 200000 m and false northing is 550000 m,

4. GPS Observation Plan

To receive good data from GPS observation, we need to check GPS satellite position state in sky since GPS are usually controlled by USA and the GPS moved continually. Usually GPS data depend upon the satellite state. It means that as we receive data from GPS satellite as many as possible, we can take high accuracy data so that it is necessary process to check the satellite conditions. To do this, we calculate GDOP(Geometric Dilution of Precision) from Almanac data which is receiving from past the satellite data. Less GDOP value is good for GPS observation. In our study we used Ashetec GPS system during April 10 and

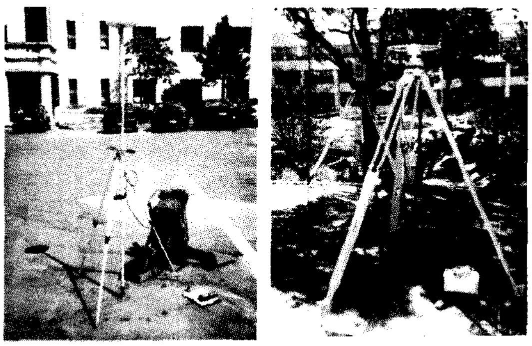


Fig. 5. The GPS and the Geodimeter Instrument for this Research.

17, 1999(Fig. 5).

Fig. 6 and 7 showed GDOP value during this time periods. In Figures, the horizontal lines show hours, the left vertical one is GDOP values and the right is number of GPS satellite. The lower line is GDOP value variation during one day. The upper line is the number of the satellite that is changed from 4 to 9. The figures show that the increase of the number of satellite is strongly related to the GDOP values. As the number of satellite increases, the GDOP decreases. Therefore, in April 10, from 10 to 18 o'clock is the best GPS observation time. However, in April 17, from 20 to 24 o'clock is good to GPS observation. Fig. 8 shows GPS satellite sky plot during April 10 to 17,

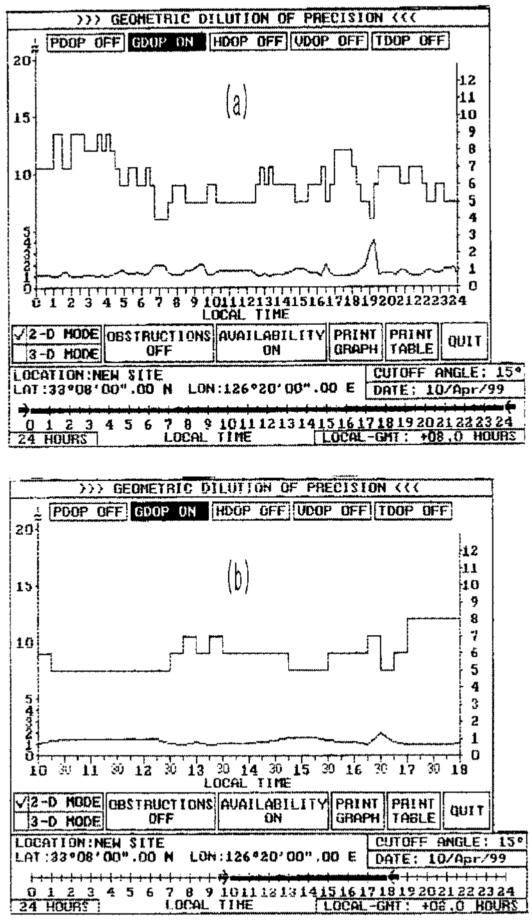


Fig. 6. GDOP and satellites variations during April 10, 1999. (a) shows GDOP variation from 1 to 24 hours April 10. (b) is zoom in of 20:30 to 24 of GDOP in same day.

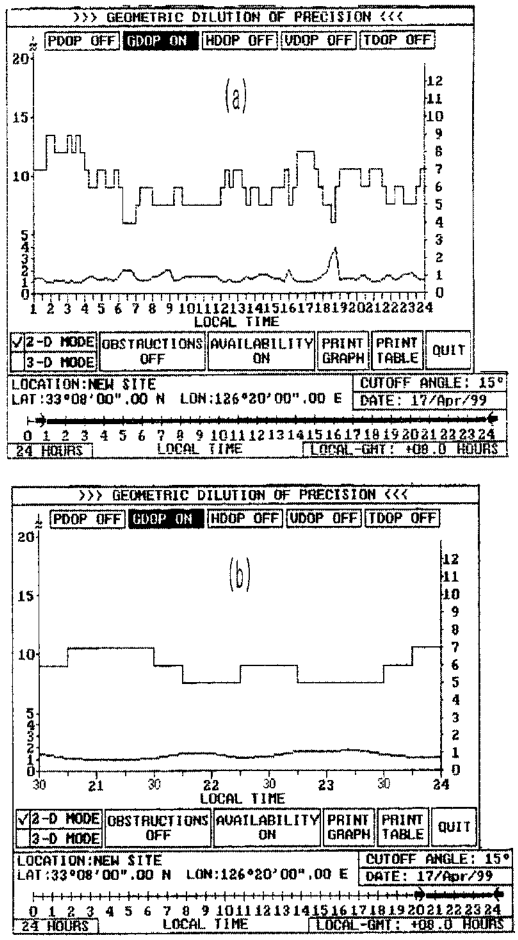
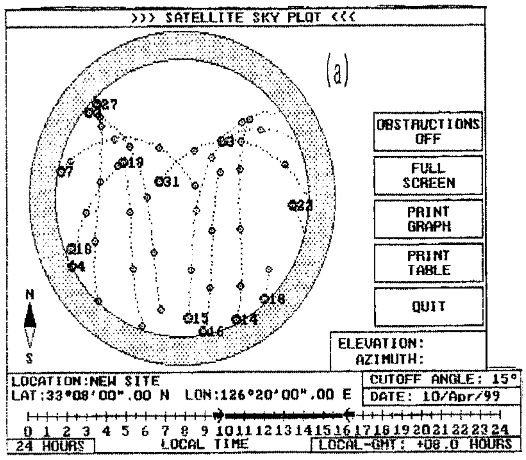


Fig. 7. GDOP and satellites variations during April 17, 1999. (a) shows GDOP variation from 1 to 24 hours April 17. (b) is zoom in of 20:30 to 24 of GDOP in same day.



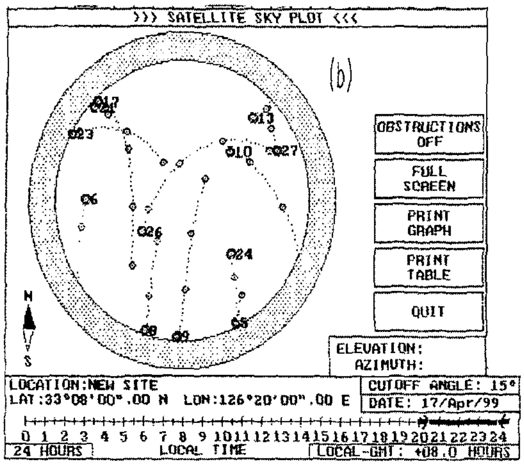


Fig. 8. Satellite sky plots of April 10 and 17, 1999.

respectively. In the figure, we can find that the number of the satellites are more than that of April 17. It means that April 10 is better observation time than April 17. In this study, we used GPS observation data of April 10.

5. Results and Discussions

5.1. Kinematic Method(Real Time Kinematic Method(RTK))

RTK is currently carrier phase observations processed(corrected) in real-time resulting in position coordinates to a 1-2 centimeter accuracy level being available to the surveyor in the field. In other words, what the surveyor sees is what he gets. RTK, consists of two or more GPS receivers, two or three radio-modems, a "fixed-plate initializer", and a handheld survey data collector/computer(TDC1) (Trimble Navigation, 1993).

In our study, one receiver occupies a known reference station and broadcasts a correction message to one roving receivers. The roving receivers process the information to solve the WGS 84 vectors by solving the integers in real-time within the receiver to produce an accurate position relative to the reference station. To estimate the accuracy of the RTK, we compared the results of the RTK with ones of Geodimter that is usually 10 times more accuracy than that of GPS. The real observation was carried out in Cheju National University Campus. The observation results are shown in Table 3. We selected seven stations, the length of the stations are from 686 m to 434 m. In the table, the error of the distance changes from 6.2 cm to 34.1 cm. The fluctuation of the error is strong. To find out the reason, we observed detail variations of length values at a point according to GPS receiving time variations. Table 4 shows error variation at station 6 of Table 3 for the receiving time variation. In the table, as the receiving time of GPS increases, the accuracy also increases. However, longer than 8 minutes shows a constant accuracy in case 1. The case 2 shows that longer than 3 minutes is enough to receive an accurate values. Therefore, usually 3 minutes receiving time, at least, is required for receiving good data from RTK.

Table 3. The different values of Kinematic DGPS survey and Geodimeter for a length

Station	GPS	Geodimeter	Error(cm)
1	686.822	686.884	6.2
2	559.848	559.921	7.3
3	434.109	434.243	13.4
4	266.094	266.187	9.33
5	560.262	559.921	34.1
6	434.105	434.243	13.8

Table 4. The different value variations of Kinematic DGPS survey according to survey time variations at station 6

Time(min.)	case 1	case 2
1	2.000 m	1.500 m
2	0.667 m	0.514 m
3	0.450 m	0.018 m
4	0.350 m	0.023 m
5	0.290 m	0.018 m
6	0.247 m	
7	0.201 m	
8	0.100 m	
9	0.017 m	

Table 5. The different values of Static DGPS Survey and Geodimeter for a length

Station	GPS	Geodimeter	Error(cm)
1	686.658	686.884	12.6
2	559.798	559.921	12.3
3	434.126	434.243	11.7
4	266.077	266.187	11.0

Table 6. Comparison of different values of DGPS survey(Kinematic and Static), Invar Standard Length and Geodimeter

Surveying Measurement	Invar Standard Length	Geodimeter	Static GPS(TM)	Static GPS(WGS-84)	Kinematic GPS
Measurement values	49.820 m	49.823	49.833	49.846	49.852
Different values		Difference of the invar 3 mm	difference of Geodimeter 1 cm	difference of Geodimeter 2.3 cm	difference of Geodimeter 3 cm

5.2. Static method

The static GPS method usually requires longer time than that of RTK. It takes at least 10 minutes observation times. Although the static needs longer time, the accuracy is higher than that of RTK. Therefore, when we need high accuracy GPS data, the static method is more useful. It is sometimes called "post-processing method". This means that after finishing GPS observation, we calculated coordinate of the points. Therefore, it takes longer time to take position data compared to that of RTK.

Table 5 shows the observation results of static method at almost the same position of RTK. The error values are not much changed. The error is from 12.6 to 110 cm. Compared to those of RTK, the variation is very low. It is because the long receiving time gave the relatively constant values.

5.3. Comparison of GPS, Geodimeter and Invar Standard Length

To estimate the accuracy between the kinematics and the statics, we measured the length of 49.820 m as Table 6. In the measurement, Geodimeter error is 3 mm, the statics is 1 cm and 2.3 cm and the kinematics is 3 cm. From the results, The statics has almost three time accuracy compared to the kinematics. Therefore, in our observation, the statics is better than the kinematics for the measurement of length.

5.4. Application of Jeju Harbor

To understand the applicability of the kinematics and the statics methods to coastal ocean structure problem, we applied two methods to Jeju harbor breakwater(Fig. 9). We selected 9 observation points at Jeju Harbor breakwater. The observation results are shown in Table 7. Seven measurements were carried out in the breakwater. In the table, the difference between RTK(kinematics) and the statics is from 2.9 cm to 40 cm. This discrepancy was derived from the observation mistakes and GPS satellite states. In the results, the interesting is that sometimes the difference between the Statics and the Kinematics is almost same in T3-T4. It means that although RTK's accuracy is less than

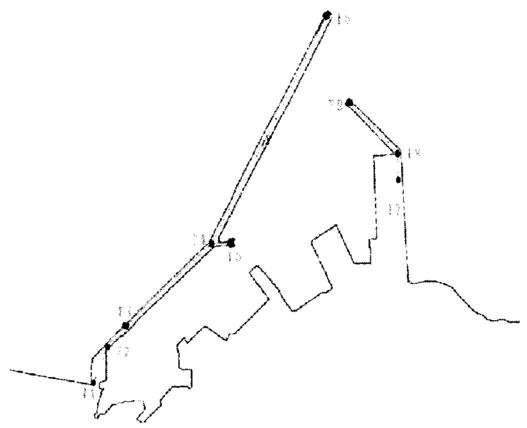


Fig. 9. Jeju Harbor breakwater with observation points(9). In the points, we measure the length and distance between the points.

Table 7. The observation results of Kinematics and Statics of Jeju Harbor

Station(No)	Length (m)		
	RTK	Static	Difference
T1-T2	77.906	78.060	0.154
T2-T3	197.403	197.296	0.107
T3-T4	473.995	473.966	0.029
T4-T5	83.167	82.751	0.416
T4-T6	1055.746	1055.778	0.032
T7-T8	143.764	143.478	0.286
T8-T9	368.385	368.826	0.441

that of the statics, we can receive the excellent results from RTK, although we take a little bit long observation time at RTK. Account for the observation results of Table 7, RTK can be used to estimate the distance economically since it takes less time of observation than that of the statics.

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