The utilization of mobile base station in cadastre surveying

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Abstract. A baseline is one of the problems in the Continously Operating Referrence Stations (CORS) utilization using the Real Time Kinematic-Networked Transport RTCM via InternetProtocol (RTK-NTRIP) method. A long baseline becomes a constraint to solving ambiguity resolution. It causes correction loss and the receivers need a long time to receive a fixed solution. Therefore, a base station can be installed closer to the measurement site, so it is movable and not permanent. It is called a mobile base station, which makes the baseline shorter. The purpose of this paper is to evaluate the level of efficiency and precision from the utilization of mobile base station. The same samples were measured twice from the two different stations: the base station and the mobile base station. The results show that the average observation duration using the mobile base station is 1.27 minutes, while directly from the base station is 10.73 minutes. The mobile base station can improve the measurement efficiency by 11.84%. The lateral difference is 0.026-0.168 metres for agricultural area and 0.025-0.153 metres for residential area. The difference of land parcels area stay within the allowable tolerance of ± 0.5√L.
Keywords: Cadastre, CORS, Baseline, Mobile Base Station.

1. Introduction

Land parcels measurement methods using Global Navigation Satellite System (GNSS) technology are growing fast. One of the examples is Real Time Kinematic Network (GNSS-RTK Network) or Continously Operating Referrence Stations (CORS). GNSS-RTK Network or Continuously Operating Reference Stations (CORS) are comprised of permanent ground based GNSS receivers at known locations, where the observation data are sent via high-speed communication links to a network data center for archiving, distribution or processing[1].

CORS is used by The Ministry of Agraria dan Tata Ruang/Badan Pertanahan Nasional (Kementerian ATR/BPN) for cadasatre surveying to produce data that can ensure legal certainty over the position, boundary, and area of parcels. In Indonesia, CORS are called as Jaringan Referensi Satelit Pertanahan (JRSP).

JRSP is able to provide wider access in real time using communication system which is called Networked Transport RTCM via Internet Protocol (NTRIP) for streaming GNSS data. The NTRIP consists of three components: server, caster and client. The server will stream data from the caster through NTRIP Server via Internet Protocol (IP). These data can later be retrieved from the caster through the NTRIP client[2]. Each base station, as a NTRIP caster, connects to the NTRIP server over the internet. The NTRIP server stands by to wait for requests from the rover. The rover, as NTRIP client, requests to the NTRIP server over the internet to get position corrections. The NTRIP server sends corrections to the rover from the closest base station (as the NTRIP caster). The NTRIP server selects the closest base station to the rover to get the shortest baseline. It provides a high position accuracy.

The closest base station plays a role as a master station. There is no requirement for the master station to be the closest reference station to the rover as it is simply used for data transmissions and does not play a special role in correction computations. This enables compatibility for one-way and two-way communications receivers. In broadcast mode (one-way), the master station is predetermined by the network while in automatic mode (two-way), the master station is chosen as the reference station closest to the rover[3]. In addition to its real time, CORS can also be used for post processing using Receiver Independent Exchange Format (RINEX) format data which is recorded and stored on each base station.

The speed and stability of internet connection is very important to support NTRIP communication system. A weak and slow internet connection can delay the process of transmitting data corrections from the base station to the rover. The problem on the internet connection can decrease the efficiency of observation time. In fact, on the blank spot area of the internet connection, the real time kinematic NTRIP (RTK NTRIP) using JRSP is unable to perform.

In East Java, the base stations are installed on the land office's rooftop. However, there are still several land offices which are not equipped with the base station yet, so it is a problem in the cadastre surveying using CORS, especially the land offices with large administrative areas. The problem is related to the location of the land parcels. The measurement of the land parcels using CORS which are located far away from the base station makes a long baseline. Differential positioning system is greatly affected by the length of the baseline: the shortest baseline results in better accuracy[4]. A long baseline makes the rover receive corrections from the base station slowly. The long distance is a problem in solving ambiguity resolution and it causes data lost when it is sent from the base station to the rover[5]. In consequence, the rover takes a long time to get fixed solution and land cadastre surveying becomes inefficient.

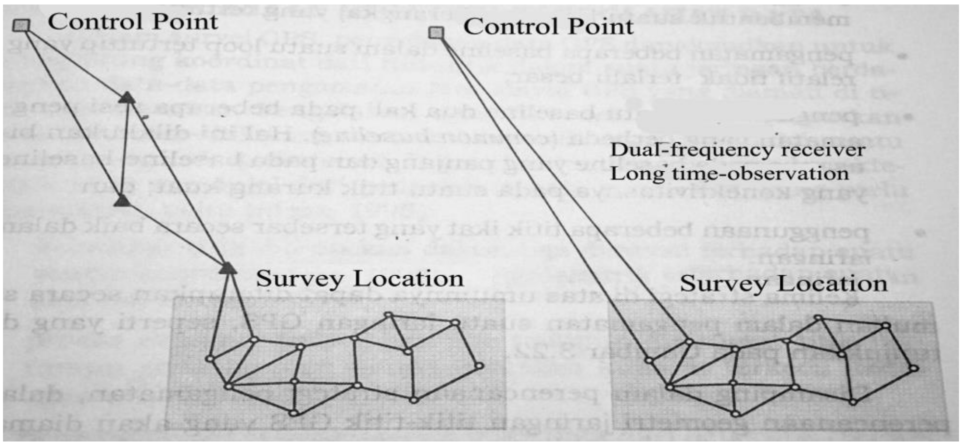

Figure 1. Closer Control Point Mechanism. The right sketch use a long baseline for measurement. It makes a long time observation and has to use dual-frequency receiver. On the left sketch, a baseline is shortened by installing/building the control point near the survey location. The control point in this paper is the base station while the installed control point is the mobile base station.

The problem can be solved by shortening the baseline as shown in Figure 1. The baseline is shortened by installing the base station closer to the measuring site. This base station is called the mobile base station because it can be installed anywhere (but still in the internet connection coverage area) and be built easily closer to the measuring site. In the other words, it is not installed permanently on somewhere or building rooftop. The mobile base station is set up using a geodetic GPS receiver. The fixed coordinate is measured through static positioning and calculated by post-processing method. The GPS receiver is connected to server by the modem. The modem has functions as a network data communications system and sends the corrections using Networked Transport of RTCM rover via the Internet Protocol (NTRIP) to the rover, so that the mobile base station can produce more accurate data efficiently. This paper is focussed on the level of efficiency and precision from the utilization of mobile base station.

2. Method

In this method is divided into two parts, i.e. materials and procedure.

2.1. Materials

To install the mobile base station, below are some of the equipments or instruments needed:
1. Geodetic GPS receiver as mobile base station (Trimble NetR9 Geospatial).
2. Rover (JAVAD TRIUMPH-VS and Leica Viva NetRover GS08).
3. Blitar City Land Office's Base Station.
4. Information Geospatial Agency's (Badan Informasi Geospasial) base station site Malang City.
5. Handphone for tethering.
6. GSM card (Telkomsel).
7. Laptop.
8. Accu.
9. Modem.

The Trimble NetR9 was chosen because of the RJ45 jack. It was the reason why the mobile base station used in this research can connect to the server and the other base stations in the network. The RJ45 connects to the modem as data communication system over the internet.

There are two brands of rover: JAVAD and Leica. The JAVAD is used to observe the samples whereas the Leica is used for log data static-positioning. The reason why Leica is used is because when post-processing using LGO, the data does not need to be converted.

Some sets of software are also needed to process and calculate the data, i.e :
1. Leica Geo Office for post-processing.
2. Justin Link to download data from the rover (JAVAD TRIUMPH-VS) to laptop.
3. AutoCAD Map 3D 2012 to plot the coordinates and calculate the area parcels.
4. Leica Spider.
5. Microsoft Office Excel 2007 for statistical calculation.

2.2. *Procedure*

There were three stages in this research: Pre-survey, Survey, and Data Processing.
1. Pre-Survey
    a. Pre-survey consisted of some preparations, i.e. the instruments, creating a pre-survey work map (Figure 2), observing and writing down the observation duration. The duration counted from the rover connect to NTRIPserver untill get fixed solution using RTK-NTRIP method.
    b. The instruments were JAVAD TRIUMH-VS, handphone/modem, work map, and observation form. The handphone/modem was used for tethering as system comunication data and correction for RTK-NTRIP. JAVAD TRIUMH-VS has wi-fi feature.
    c. The points were spread into four quadrant. Each quadrant was divided to several ranges i.e. 5 km, 15 km, and 20 km from Blitar City Land Office's Base Station.

The RTK-NTRIP method was used to measure every point and to obtain the slowest time to get fixed solution. Then, the mobile base station was utilized in the selected point or range which had the longest duration to receive the fixed solution. The mobile base station construction is shown in Figure 3.

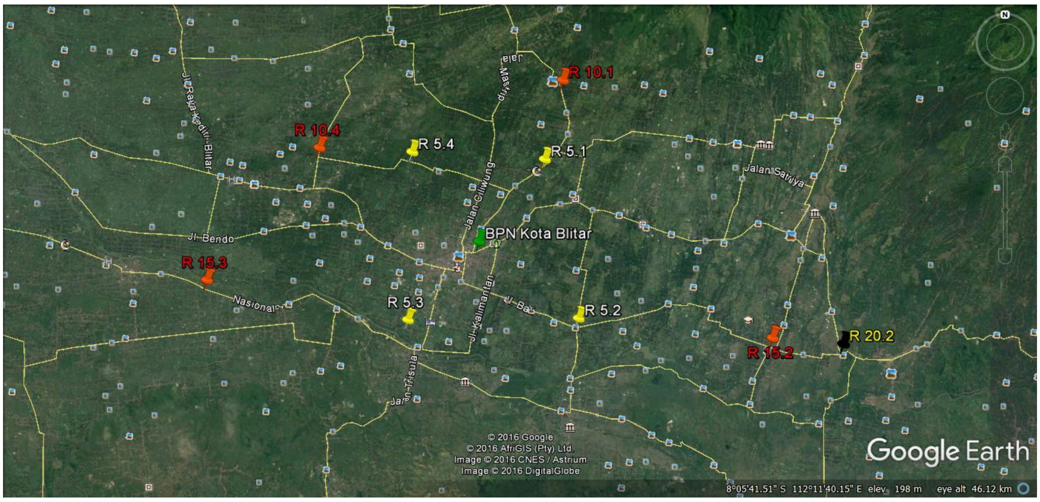

Figure 2. The Pre-Survey Work Map. The points spread into several radius in four quadrants and as the origin is "BPN Kota Blitar". R 5.3 represents the point of 5 km radius in quadrant III. Meanwhile, R 10.1 represents the point of 10 km radius in quadrant I. Etc.

Figure 3. The Mobile Base Station. Intalled on point open-view-sky location. Used Trimble NetR9 Geospatial. Connected to laptop for configured, modem for streamed data, and accu for power supply.

2. Survey

In this stage, each sample was measured twice: using the mobile base station and without the mobile base station. The first survey using the mobile base station needed some equipment:

a. Trimble NetR9 Geospatial as mobile base station, Leica Viva NetRover GS08 as mobile base station's cordinate data logger, LGO software for post-processing, modem, laptop, accu
b. JAVAD TRIUMPH-VS as rover.
c. The mobile base station was installed in the quadrant and radius which had the longest duration to fixed solution according to the pre-survey results. The distribution of samples were plotted in survey work map as shown in Figure 4.
d. The coordinate of mobile base station was measured on 8th April 2017 through static positioning using Leica NetRover. The measurement time was approximately one hour.
e. The coordinate of mobile base station was differential-GNSS-measurement to the BIG's base station site Malang City, so raw data from the Leica NetRover and BIG's base station site Malang City were downloaded to the laptop and calculated by post-processing method.
f. Then, the antena was replaced with the Trimble's antenna. The mobile base station was set from antenna, NetR9, laptop, modem, and accu as power supply.

g. The function of modem was to connect the mobile base station to the NTRIP server and stream corrections via NTRIP to the rover.
h. The laptop was used to configure the Trimble receiver through web interface, input the coordinate (X,Y,Z) of mobile base station, and also to configure it to the Leica GNSS Spider as shown in Figure 5. According to the Leica GNSS Spider, the site has to receive at least five satellites before it can stream corrections.
i. Afterwards, the mobile base station was ready to stream data corrections. Then, the rover could start to observe the samples. The samples were 22 points spread out into four quadrant as shown in Figure 4.
j. The first observation which took place on 8th April 2017, the samples were observed by using the mobile base station as NTRIP caster.

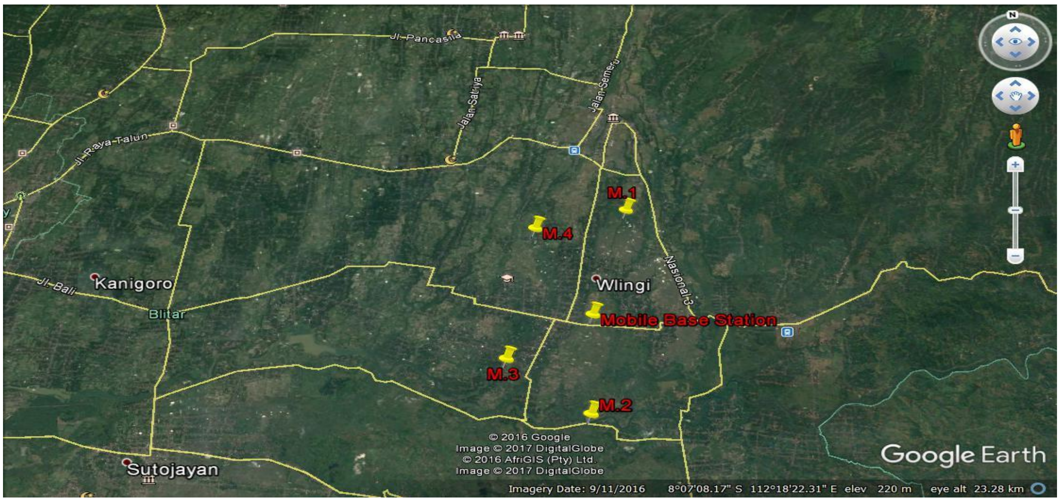

Figure 4. The Survey Work Map: Distribution of Samples. The points were conditioned in radius < 3 km from mobile base station. Spread into the four quadrants. Located in the ideal obstruction for GNSS survey.

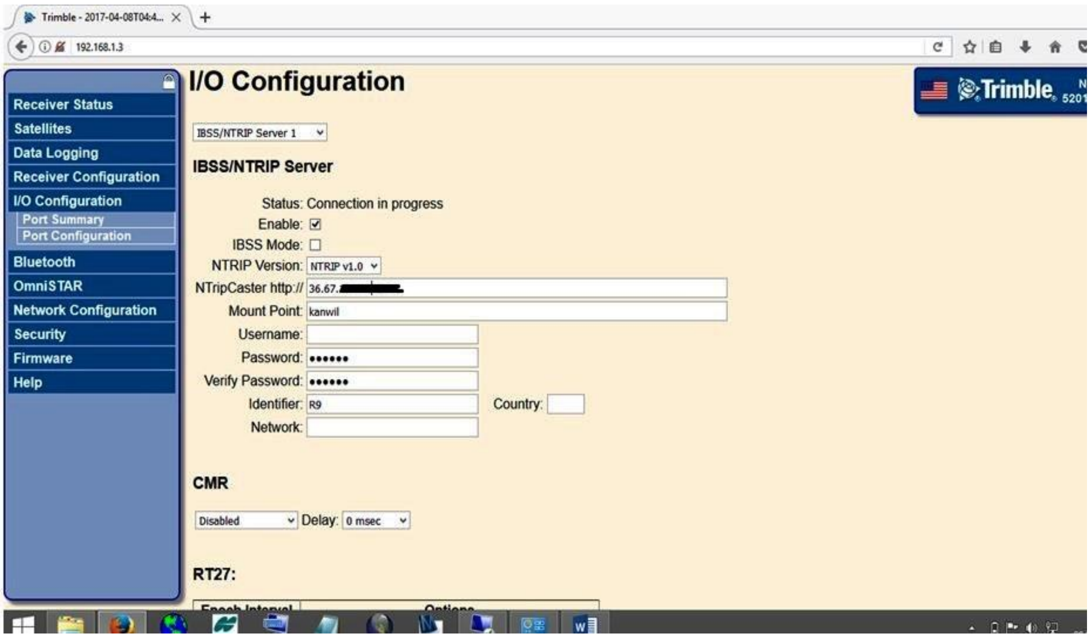

Figure 5. Configuring Through A Web Browser. 192.168.1.3 is NetR9's IP. "NTRIPCaster http://" was filled with NTRIPServer IP. Insert the password. Then, mobile base station is integrated.

Meanwhile, on the second survey, the mobile base station was switched off (without the mobile base station), the needed equipment ranged as following:

a. Blitar City Land Office's Base Station.
b. JAVAD TRIUMPH-VS as rover.
c. During the observation which took place on 11th April 2017, the samples were observed again without the mobile base station. The Blitar City Land Office's Base Station played role as NTRIP caster. In this section, the mobile base station was switched off (deactivated).
d. The same samples of 22 points were measured again.

3. Data Processing

The data were procesed with some software, there were Microsoft Excel 2007, AutoCAD Map 3D 2012, and Justin Link.

a. The coordinates from 22 sample points were downloaded to laptop by using Justin Link. There were two kinds of coordinates: coordinates using the mobile base station and coordinates without the mobile base station.
b. The coordinates were plotted to AutoCAD Map 3D 2012.
c. The coordinates difference data were input to Microsoft Excel and calculated with $\sqrt{(\Delta X^2+\Delta Y^2)}$ formula. These differences were between coodinates using the mobile base station (MBS) and without the mobile base station (BS).
d. The duration data were input and calculated ~~by~~ using Microsoft Excel.
e. The statistic test used Data Analysis Tools menu in Microsoft Excel.

The research method applied was comparative experiment with quantitative approach. Comparative experiment means that the experiment includes data comparison from the same samples over the different treatments. The reason why quantitative approach was chosen was because the data would be processed statistically. In addition, the sampling technique is called purposive sampling, which is a sampling technique in which the researcher relies on his or her own judgment when choosing members of population to participate in the study.

Each sample was measured twice: first, measured using mobile base station; second, measured without mobile base station (used Blitar City Land Office's Base Satation), and then compared to each other. The framework is presented in Figure 6.

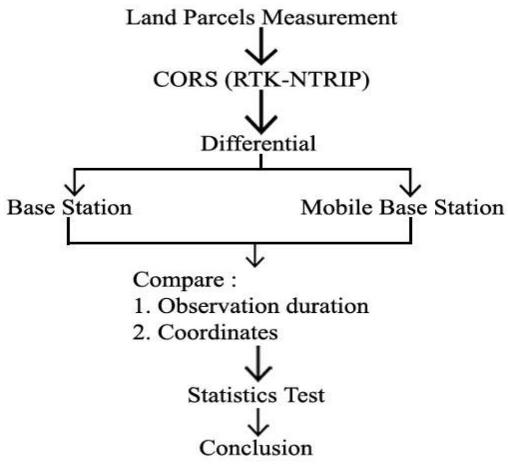

Figure 6. The Framework. The samples were measured by using base station and mobile base station. The methods was RTK-NTRIP. The results were duration and coordinates. Both of them were compared and tested by statistic test.

3. Result and Discussion

3.1. The Difference of Observation Duration

The samples location were chosen in radius approximately 17 km (18.790 km to be more precise) from Blitar City Land Office's Base Station. Based on Table 1 below, this distance had the longest time observation, i.e. 630 seconds. It was caused by the long baseline. The long baseline had an effect on the ambiguity resolution, because satellites' signal had to pass the thick atmosphere before it was received by the rover. It also affected the corrections-delay. Therefore, the baseline was shortened by installing the mobile base station in this location.

Table 1. The Observation Duration.

Point	Baseline (km)	Quadrant	Duration (second)
R5.1	5.399	I	60
R10.1	8.987	I	60
R5.4	5.756	IV	240
R10.4	9.596	IV	60
R10.3	7.058	III	240
R5.3	5.149	III	120
1	4.816	III	60
R5.2	6.914	II	60
R15.2	15.633	II	60
R20.2	18.790	II	630

The mobile base station was installed on 8th April 2017 at 09:00-13:00 WIB (Waktu Indonesia Bagian Barat/ Western Indonesian Time. It is time zone division that exist in Indonesia which is 7 hours ahead of Coordinated Universal Time). Through static positioning method, the coordinate was measured by using Leica NetRover GS08 and processed by using Leica Geo Office 7.0.0.0. The coordinate is $8^0$08'32,39534" S; $112^0$19'08,91440" E; 225,4412 metres above ellipsoid.

Each sample was measured twice, i.e. using the mobile base station (MBS) and without the mobile base station (BS). The observation of samples using mobile base station was done on 8th April 2017 at 14:15 – 17:01 WIB and in this section, the mobile base station plays a role as a master station. Then, the observation without mobile base station was done on 11th April 2017 at 14:30 – 16:45 WIB. This time window was chosen to obtain the same ionosphere condition as in the previous observation when using mobile base station.

The duration of observation using the mobile base station (Table 2) and without the mobile base station (Table 3) was compared. The aim was to obtain the difference observation duration at the same point of each quadrant. The obervation duration using mobile base station was faster than that without the mobile base station as shown in Figure 7.

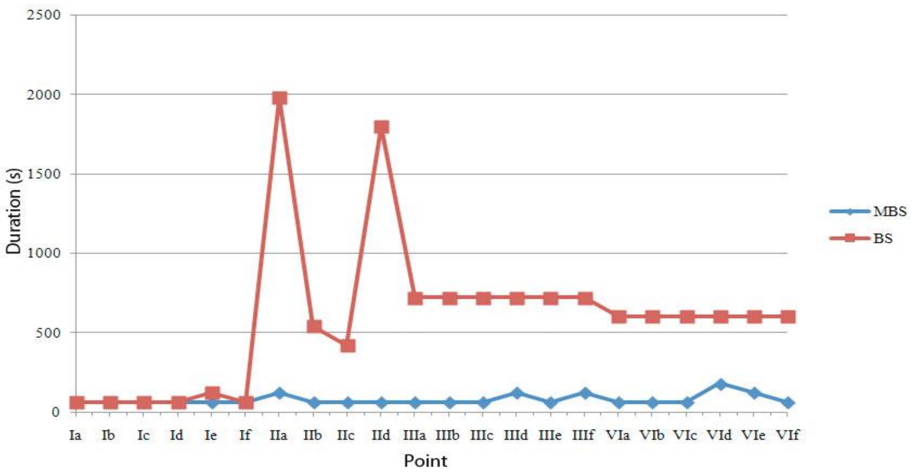

Figure 7. Diagram of Duration Difference. MBS was measured by mobile base station, while BS was not. MBS needed short time to get fixed solution rather than BS needed. The biggest difference was in quadrant III.

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Table 2. The Observation Duration Using Mobile Base Station.

Quadrant	Point	Baseline (km)	Duration (second)
I	1C	3.909	60
I	1C1	3.909	60
I	1C2	3.909	60
I	1C3	3.909	60
I	1C4	3.909	60
I	1C5	3.909	60
II	1A	3.358	120
II	1A1	3.358	60
II	1A2	3.358	60
II	1A3	3.358	60
III	b	2.525	60
III	C1	2.525	60
III	D	2.525	60
III	E	2.525	120
III	F	2.525	60
III	F1	2.525	120
IV	1B	3.118	60
IV	1B1	3.118	60
IV	1B2	3.118	60
IV	1B3	3.118	180
IV	1B4	3.118	120
IV	1B5	3.118	60

Table 3. The Observation Duration Without Mobile Base Station.

Quadrant	Point	Baseline (km)	Duration (second)
I	Sawah b1	17.157	60
I	Sawah b2	17.157	60
I	Sawah b3	17.157	60
I	Sawah b4	17.157	60
I	Sawah b5	17.157	120
I	Sawah b6	17.157	60
I	Sawah b7	17.157	60
I	Sawah b8	17.157	60
I	Sawah b9	17.157	60
II	Bola 1	16.227	1980
II	Bola 2	16.227	540
II	Bola 3	16.227	420
II	Bola 4	16.227	1800
III	Voli 7	15.481	720
III	Voli 2	15.481	720
III	Voli 3	15.481	720
III	Voli 4	15.481	720
III	Voli 5	15.481	720
III	Voli 6	15.481	720
IV	Sawah a1	15.794	600
IV	Sawah a2	15.794	600
IV	Sawah a3	15.794	600
IV	Sawah a4	15.794	600
IV	Sawah a5	15.794	600
IV	Sawah a6	15.794	600

A large duration difference took place in quadrant II, which was caused by the long baseline and the day time environment. Meanwhile, a small duration difference took place in quadrant I, which was caused by the ionospheric effects.

The ionosphere affect the observation duration. At 14.30 WIB, the ionosphere condition is not stable yet as the effect from the sun wave to the ionosphere. Meanwhile, at 16.00 WIB the ionosphere condition is stable because the distance between the sun and the ionosphere is far, so the effect of sun wave decreases.

The ionosphere condition can look at The Network Online Visualisation of Accuracy (NOVA) Maps. The NOVA Maps are some features of Leica Spider QC which can visualize in real time the ionosphere and troposphere conditions and the problems in a network. The NOVA can provide quality control to the user with this color gradations. It enables users to visualize the spatial and temporal quality of single base and network RTK positioning over their network. Real time maps show the distribution of residual ionosphere and troposphere/orbit error enabling users to monitor the network status and identify problem areas in the network. Network users can view the maps over the web to get assurance on the quality of the corrections provided by the network and to decide between using nearest site and network RTK corrections for the specific location of their survey. The visualization of NOVA Maps on 11th April 2017 at 14:40 WIB is shown in Figure 8.

Table 4. t-Test for The Difference of Observation Duration.

	Duration of MBS	Duration of BS
Mean	1.272727273	9.909090909
Variance	0.303030303	68.18181818
Observations	22	22
Pearson Correlation	0.288571429	
Hypothesized Mean	0	
df	21	
t Stat	-4.991447925	
P(T<=t) one-tail	3.05802E-05	
t Critical one-tail	1.720742871	
P(T<=t) two-tail	6.11605E-05	
t Critical two-tail	2.079613837	

Table 4 shows that the observation duration between using the mobile base station and without mobile base station is significantly different. The observation duration using mobile base station is faster than that directly from base station.

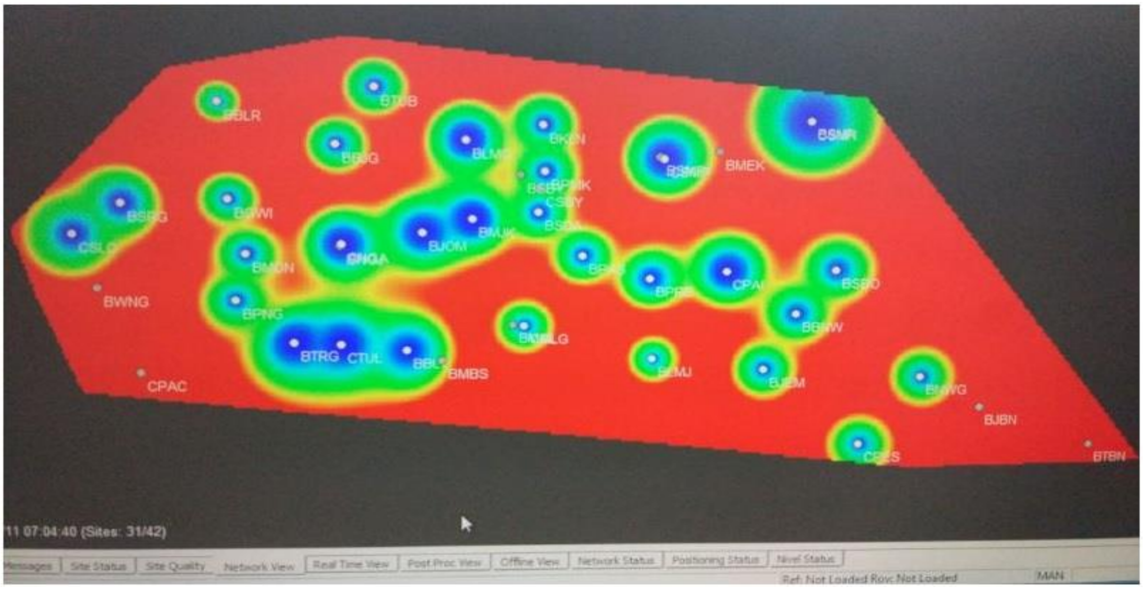

Figure 8. The Ionosphere Condition on 11 April 2017 at 14:40 WIB. The blue area is ideal radius for measurement. The green area is still secure too. The yellow area indicates the ionosphere effect has begun to appear. The red area is not ideal for measurement, because the effect of the ionosphere

is great. As a result, the measurement on red areas will be difficult to get fixed solutions. So, avoid measurements at 11:00 am to 02:00 pm (local time).

3.2. The Coordinates Difference

Each sample was measured twice: using the mobile base station and without mobile base station (directly from base station). The measurement used the same rover (JAVAD Triumph-VS). The measurement using mobile base station is a short baseline, while the measurement directly from the base station is a long baseline. The mobile base station functions to shorten the baseline. A GPS baseline is formed by two GPS receivers, which is installed in each point (each end point) of the measured line. They collect data from the same GPS satellites at the same time. The duration of observations varies based on the the baseline length and the accuracy needed. It is measured typically an hour or more. When the data from both points is later combined, the difference in position (Latitude, Longitude and Height) between the two points is calculated with special software. Many of the uncertainties of GPS positioning are minimized in these calculations because the distortions in the observations are similar at each end of the baseline and cancel out. The accuracy obtained from this method depends on the duration of the observations, but is typically about 1 part per million (1 millimetre per kilometre), so a difference in position can be measured over 30 kilometres with an uncertainty of about 30 mm, or about 100 mm over 100 kilometres[6].

Table 5. The List of Coordinates.

Point	MBS Coordinate		BS Coordinate	
	X	Y	X	Y
1C/a	181147.062	603450.441	181147.063	603450.470
1C1/a6	181121.986	603453.390	181121.960	603453.392
1C2/a7	181095.176	603455.966	181095.206	603456.030
1C3/a8	181094.259	603432.638	181094.204	603432.651
1C4/a9	181117.360	603432.119	181117.309	603432.035
1C5/a10	181141.808	603429.104	181141.804	603429.078
1A/2a3	178174.113	596920.462	178174.017	596920.523
1A1/2a2	178165.305	596918.011	178165.351	596918.002
1A2/2a1	178162.603	596934.045	178162.619	596934.109
1A3/2a	178171.983	596936.551	178172.010	596936.560
F1/3.a	178012.835	598240.430	178012.895	598240.391
b/3.a1	178001.668	598245.385	178001.644	598245.449
C1/3.a2	177989.596	598249.953	177989.593	598249.800
D/3.a3	177982.623	598233.554	177982.612	598233.577
E/3.a4	177995.453	598227.866	177995.479	598227.807
F/3.a5	178007.257	598225.003	178007.291	598224.867
1B/a	179698.514	602788.595	179698.650	602788.424
1B1/a5	179675.266	602795.565	179675.227	602795.681
1B2/a4	179678.360	602808.662	179678.424	602808.763
1B3/a3	179680.360	602831.768	179680.442	602831.632
1B4/a2	179707.070	602826.157	179707.174	602826.134
1B5/a1	179701.907	602803.191	179702.014	602803.320

Based on the coordinates list above, the value of lateral difference can be calculated by using formula $\sqrt{(\Delta X^2 + \Delta Y^2)}$.

Table 6. The Coordinates Difference.

Point	ΔX (m)	ΔY (m)	Lateral (m)	Tolerance (m)	Accept/Reject
1C	-0.001	-0.029	0.029	0.250	Accept
1C1	0.026	-0.002	0.026	0.250	Accept
1C2	-0.030	-0.064	0.071	0.250	Accept
1C3	0.055	-0.013	0.057	0.250	Accept
1C4	0.051	0.084	0.098	0.250	Accept
1C5	0.004	0.026	0.026	0.250	Accept
1A	0.096	-0.061	0.114	0.100	Reject
1A1	-0.046	0.009	0.047	0.100	Accept
1A2	-0.016	-0.064	0.066	0.100	Accept
1A3	-0.027	-0.009	0.028	0.100	Accept
F1	-0.060	0.039	0.072	0.100	Accept
b	0.024	-0.064	0.068	0.100	Accept
C1	0.003	0.153	0.153	0.100	Reject
D	0.011	-0.023	0.025	0.100	Accept
E	-0.026	0.059	0.064	0.100	Accept
F	-0.034	0.136	0.140	0.100	Reject
1B	-0.136	0.171	0.218	0.250	Accept
1B1	0.039	-0.116	0.122	0.250	Accept
1B2	-0.064	-0.101	0.120	0.250	Accept
1B3	-0.082	0.136	0.159	0.250	Accept
1B4	-0.104	0.023	0.107	0.250	Accept
1B5	-0.107	-0.129	0.168	0.250	Accept

There are two classifications for tolerance: tolerance by 0.250 m for agricultural area and tolerance by 0.100 m for residential area. This rule is regulated by The Technical Instruction of PMNA/KBPN No. 3/1997 (*Petunuk Teknis PMNA/KBPN 3/1997*). There are three rejected-points, i.e. 1A, C1, and F. It was caused by an unstable surveyor when holding the pole between the first measurement and the second measurement on the same point.

To test the precision level, the statistic test for each classification was conducted.

Table 7. t Test for Agricultural Area.

Difference of X		Difference of Y	
Average of ΔX	-0.029	Average of ΔY	-0.001
α	0.05	α	0.05
Df	11	df	11
SD	0.06754	SD	0.09601
μ_0	0	μ_0	0
t table	2.20099	t table	2.20099
t test	-1.49178	t test	-0.04209

Table 8. t Test for Residential Area.

Difference of X		Difference of Y	
Average of ΔX	-0.007	Average of ΔY	0.018
α	0.05	α	0.05
Df	9	df	9
SD	0.04459	SD	0.0792
$\mu 0$	0	$\mu 0$	0
t table	2.26216	t table	2.26216
t test	-0.5319	t test	-0.69877

The α represents the significance level and it is the probability of rejecting the null hypothesis in a statistical test when it is true. The null hypothesis means it is not significant difference between coordinates using mobile base station and without mobile base station. So, not significant means precise. The null hypothesis is true if t test < t table. The $\mu 0$ is the expected value of difference.

Table 7 and Table 8 show that every t test value is smaller than t table. Statistically, the coordinates from utilizing of mobile base station were precise.

3.3. The Land Parcels Area Difference

This research used 7 (seven) land parcels which were formed by 22 points of samples. The land parcels were spread into four quadrants (with the origin in the mobile base station point). The distance between the 22 points of samples and the mobile base station ranged between 2.5 km to 4 km. Meanwhile, the distance between those sample points and Blitar City Land Office's Base Station ranged between 15.7 km to 17.1 km.

Table 9. The Land Parcels Area.

Point	Area (m^2)		ΔL	Tolerance
	MBS	BS		
Parcel 1	542	545	- 3	± 11.656
Parcel 2	560	562	- 2	± 11.842
Parcel 3	152	150	+ 2	± 6.144
Parcel 4	212	214	- 2	± 7.297
Parcel 5	244	244	0	± 7.810
Parcel 6	344	349	- 5	± 9.307
Parcel 7	598	594	+ 4	± 12.206

The ΔL is the area differences between measurement using mobile base station (MBS) and without mobile base station (BS). The tolerance is regulated in The Technical Instruction of PMNA/KBPN No. 3/1997 by $\pm 0.5\sqrt{L}$. Table 9 shows that the area differences (ΔL) stay within the allowable tolerance of $\pm 0.5\sqrt{L}$.

4. Conclusions

The research results presented in this paper clearly show that the average observation duration without mobile base station is 10.73 minutes and can be accelerated to 1.27 minutes when using mobile base station. So, the utilization of mobile base station accelerates the duration by 11.84% and still allows a precise coordinates or insignificant difference with the coordinates measured directly from the base station (without mobile base station). The measured land parcels area also stay within the tolerance by The Technical Instruction of PMNA/KBPN No. 3/1997.

Avoiding the observation at 11:00-14:00 local time can also accelerate the duration because in the GNSS, an ideal ionosphere condition is required, as shown in Figure 9.

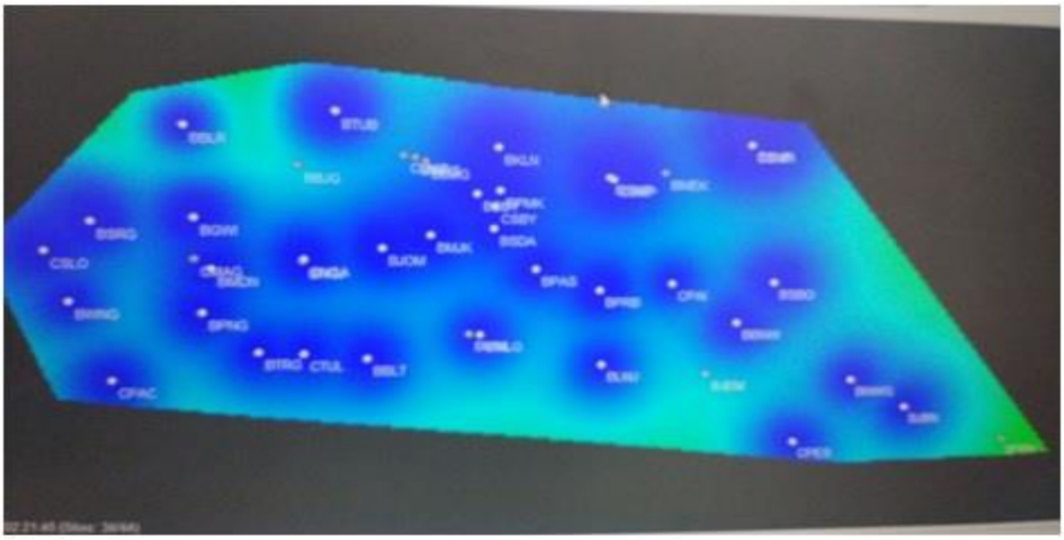

Figure 9. The Ideal Ionosphere Condition. The Network Online Visualisation of Accuracy (NOVA). The NOVA is a feature of Leica Spider QC which can visualize in real time the ionosphere and troposphere conditions and the problems in a network. NOVA can provide quality control to user. The color gradations on the NOVA make it easy for the user to decide to use the nearest site with the measurement location to get the best correction at specific times and locations. The quality of the correction can be either network corrections or single reference station corrections (nearest site).

The utilization of mobile base station has some limitations. There are the receiver antenna spesifications, power supply, and internet connection. First, the receiver antenna spesifications for mobile base station is not the same as the chokering spesifications on the land office's base station. The effect is the mobile base station need more time to ambiguity fixing before it can stream the corrections. Second, the power supply is needed for switch on the laptop and modem. Last, the mobile base station can only work in the area with internet connection. The reason is RTK-NTRIP can only work in area with internet connection.

5. Acknowledgments

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6. Appendices

Appendix A. The Observation Time of Pre-Survey

Point	Baseline (km)	Quadrant	Clock Observation			
			Start/ Connect	Stand alone	Float	Fixed
R5.1a	5.399	I	07:50	07:50	07:50	07:50
R5.1b		I	-	-	-	07:54
R5.1c		I	08:04	08:04	08:05	08:05
R5.1d		I	-	-	-	08:13
R5.1e		I	-	-	-	08:16
R10.1a	8.987	I	8:54	8:54	8:55	8:55
R10.1b		I	-	-	-	8:59
R10.1c		I	-	-	-	9:02
R10.1d		I	-	-	-	9:06
R10.1e		I	-	-	-	9:09
R10.1f		I	-	-	-	09:12
R5.4a	5.756	IV	09:53	09:54	09:54	-
				09:56	09:57	09:57
R5.4b		IV	-	-	-	10:02
R5.4c		IV	-	-	-	10:06
R5.4d		IV	-	-	-	10:09
R10.4a	9.596	IV	10:45	10:45	10:45	10:45
			-	-	10:46	10:55
			-	-	10:56	
R10.4b		IV	-	-	11:00	
			-	-	11:15	
R10.4b1		IV	-	11:17	11:18	
			-	11:24		
R10.3	7.058	III	15:39	15:40	15:40	15:43
		III	15:44	15:44	15:44	15:45
R5.3a	5.149	III	16:10	16:10	16:11	16:12
R5.3b		III	-	-	-	16:15
R5.3c		III	-	-	-	16:18
R5.3d		III	-	-	-	16:21
1	4.816	III	16:39	16:39	16:39	16:40
2		III	-	-	-	16:45

3		III	-	-	-	16:48
4		III	-	-	-	16:51
R5.2a	6.914	II	08:23	08:23	08:23	08:23
R5.2b		II	08:27	08:27	08:27	08:27
R15.2a	15.633	II	09:06	09:06	09:06	09:06
R15.2b		II	09:10	09:10	09:10	09:10
R20.2a	18.790	II	09:31	09:31	09:32	09:38
R20.2b		II	09:42	09:42	09:42	09:42
R10.4	9.595	IV	8:08	8:08	-	8:09
R5.4	5.846	IV	8:31	8:31	8:32	8:32
R10.1a	8.935	I	9:25	9:25	-	9:26
R10.1		I	9:27	9:27	-	9:27
R5.1	5.398	I	10:03	10:03	-	10:03

Appendix B. The Observation Time By Using The Mobile Base Station (MBS)

Quadrant	Point	Baseline (km)	Clock Observation				Duration (minute)	Latency (ms)
			Start/Connect	Stand alone	Float	Fixed		
	1C		16:54	16:54	16:54	16:55	1	
	1C1				16:57	16:57	1	
I	1C2	3.909				16:58	1	29
	1C3				16:59	16:59	1	
	1C4					17:00	1	
	1C5					17:01	1	
	1A		15:23	15:23	15:24	15:25	2	
II	1A1	3.358				15:26	1	49
	1A2					15:27	1	
	1A3					15:28	1	
	b		14:15	14:15	14:15	14:15	1	
	C1					14:28	1	
III	D	2.525				14:33	1	49
	E					14:35	2	
	F					14:36	1	
	F1					14:38	2	
	1B		16:13	16:13	16:13	16:14	1	
	1B1				16:15	16:15		
IV		3.118		16:16		16:16	1	36
	1B2			16:19	16:19	16:20	1	
					16:20			

1B3	16:25	16:25	16:25	16:28	3
1B4			16:31		
		16:34	16:34	16:36	2
1B5			16:37	16:38	1

Appendix C. The Observation Time Without The Mobile Base Station (BS)

Quadrant	Point	Baseline (km)	Clock Observation				Duration (minute)	Latency (ms)
			Start/ Connect	Stand alone	Float	Fixed		
I	Sawah b1	17.157	16:30	16:30	16:30	16:30	1	30
	Sawah b2		16:31	16:31	16:32	16:32	1	
	Sawah b3					16:33	1	
	Sawah b4		16:34	16:34	16:34	16:34	1	
	Sawah b5					16:36	2	
	Sawah b6				16:36	16:36	1	
	Sawah b7					16:37	1	
	Sawah b8					16:38	1	
	Sawah b9					16:39	1	
II	Bola 1	16.227	14:38	14:38	14:39	15:12	33	45
	Bola 2				15:04	15:13	9	
	Bola 3				15:07	15:14	7	
	Bola 4				15:09	15:09	30	
III	Voli 7	16.481	15:22	15:22	15:22	15:34	12	59
	Voli 2					15:37	12	
	Voli 3					15:37	12	
	Voli 4					15:38	12	
	Voli 5					15:39	12	
	Voli 6					15:39	12	
IV	Sawah a1	15.794	16:01	16:01	16:02	16:11	10	43
	Sawah a2					16:12	10	
	Sawah a3					16:13	10	
	Sawah a4					16:15	10	
	Sawah a5					16:16	10	
	Sawah a6					16.18	10	

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