The Malaysia Real-Time Kinematic GNSS Network (MyRTKnet) in 2010 and Beyond

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Key words: GNSS, Real-Time Kinematic, Positioning

SUMMARY

The Department of Survey and Mapping Malaysia (JUPEM) is the competent authority in maintaining the National Spatial Reference System. This is carried out through the setting up of a surveying infrastructure that includes horizontal and vertical survey controls throughout the country for the eventual purpose of national development, security and defence. In line with the government's efforts to enhance its public delivery system, one of the many initiatives undertaken by JUPEM is through the use of real-time GNSS survey technology for the dissemination of various geodetic products and services.

Since 1997, JUPEM has been developing the capability for real-time data streaming from a network of continuously operating reference stations. Currently there are 78 stations, with spacing of between 30 to 120 km, providing real-time corrections with a latency of under one second using Virtual Reference Station (VRS) technique. Each station of the network is equipped with a high precision dual frequency GPS receiver that is operational 24 hours daily. The acquired GPS data is transferred on a daily basis to the Central Processing Centre at JUPEM's Headquarters in Kuala Lumpur via the internet. This network is known as the Malaysia Real-Time Kinematic GNSS Network or MyRTKnet. In addition to enhancing and maintaining the nation's geodetic reference system, applications of MyRTKnet include a critical role in supporting e-Cadastre initiative via Coordinated Cadastral System (CCS) as well as collecting of mapping features through Computer Assisted Topographic Mapping System (CATMAPS); location-based activities; fleet tracking and management; and the ability to characterize the free electron content of the ionosphere.

This paper introduces a new GPS positioning by way of RTK-GPS (VRS) using MyRTKnet services as provided by JUPEM. It also outlines the chronicle development of the new network. Finally it discusses on the various potential applications of MyRTKnet.

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1. BACKGROUND

1.1 Introduction

The Department of Survey and Mapping Malaysia (JUPEM) is the competent authority in providing both horizontal and vertical survey control to the surveying community in Malaysia for the purpose of national development, security and defense by setting up surveying infrastructure throughout the country. In line with the government's endeavour to improve its delivery mechanism, there have been many initiatives made by JUPEM. One of them is the effort made to use real-time survey technology for the improvement of its many services and dissemination of various geodetic products rendered by JUPEM.

In 2003 JUPEM has implemented a real-time kinematic network project that is known as Malaysia Real-Time Kinematic GNSS Network (MyRTKnet). The system then has twenty seven (27) RTK stations forming the network that covering the whole Peninsular Malaysia and two (2) Major cities in Sabah and Sarawak.

In an effort to give better services to the user, the MyRTKnet system was expanded and upgraded by JUPEM from 2006 to 2008. Under this project, fifty one (51) MyRTKnet GNSS reference stations have been established and to date there are seventy eight (78) GNSS reference stations throughout the country

1.2 Existing Scenarios

Real-Time Kinematic (RTK) is now widely used for surveying and other precise positioning applications. The classical RTK technique requires that GNSS data can be transmitted from a single base receiver to one or more roving units.

RTK can provide centimeter position accuracy, but the accuracy and reliability of the standard RTK solution decreases with increasing distance from the Base Station. This limitation on the distance between the roving GPS receiver and the RTK Base Station is due to the systematic effects of ephemeris, tropospheric and ionospheric errors. These systematic errors result in reduced accuracy and increasing initialization time as the distance between base and rover increases.

Besides the aforementioned constraint, the limitation is also due to the range of available radio telemetry solutions. In practice, this means that a temporary RTK Base Station must be established close to the work area, often at a location that does not provide any physical security or continuous power supply. Each time such a temporary reference station is established, there is a likelihood of introducing an error in the reference station coordinates that will be transferred into the position calculated by the rover RTK receiver. Such an error can easily go undetected when using a single base station.

1.3 Objectives

In order to take full advantage of the real-time capabilities of the RTK network, MyRTKnet has been designed with the following objectives:

i. To establish a network of permanently running GNSS base stations, at a spacing of 30 to 150 km, feeding GNSS data to a processing centre via frame-relay IPVPN communication network.

ii. To establish a central facility that will model the spatial errors which limit GNSS accuracy through a network solution and generate corrections for roving receivers positioned anywhere inside the network with an accuracy better than a few centimeters (dense network) to a few decimeters (sparse network) in real time.

iii. To establish a web site that will make available near real time (3 – 4 hours) reference station data to the users for post-processing differential GNSS throughout the coverage area.

2. NETWORK DESIGN

2.1 Objectives

The primary goals in designing the system were for efficient and easy operations, facilitate user understanding of the network and for expandability. Some empirical numerical limits have been suggested for IP addressing and efficient operation of the system. The networking protocol used is the Internet Protocol (IP). Though contained in a single private network, the system was split into 2 subnets which is not representative of classical IP subnet class. As such this network is considered as 'classless'. Each subnet consists of all reference stations and the Control Center.

2.2 Malaysia Real Time Kinematic GNSS Network (MyRTKnet)

The RTK Network Solution concept is based on having a network of seventy eight (78) GNSS reference stations continuously connected via IPVPN to a Control Centre (**Figure 1**). The computer processor at the Control Centre continuously gathers the information from all GPS receivers, and creates a living database of Regional Area Corrections.

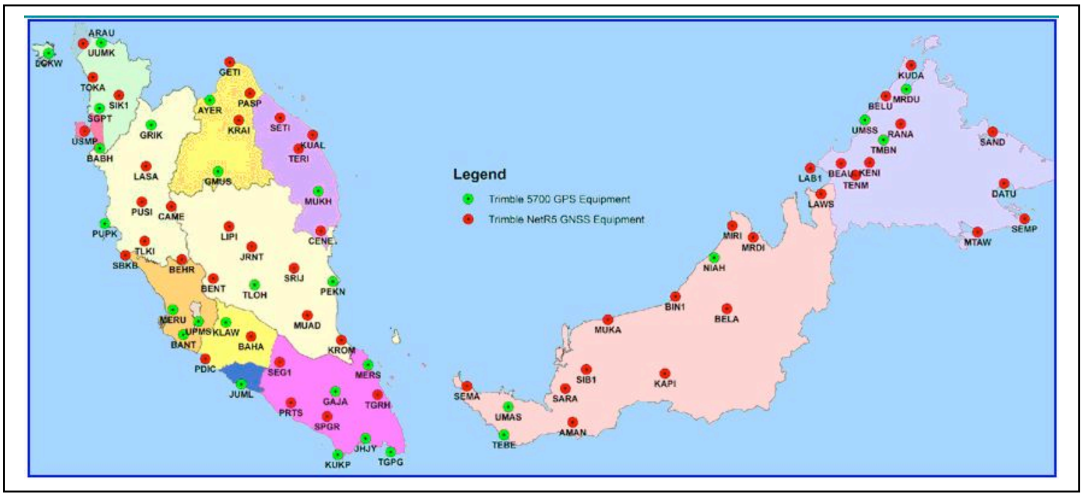

Figure 1: MyRTKnet

2.3 Physical Telecommunications

The physical telecommunications infrastructure is provided by the IPVPN over COINS frame relay system. This system works by connecting any respective site into the Telekoms Malaysia frame relay network. The service is available throughout Malaysia except for some isolated locations. The advantage of using IPVPN verses point to point leased lines is that IPVPN will require only a single high speed connection and modem at the Central Control rather than a connection comprising of a modem and separate leased line for each station. A schematic representation of the system communications is shown in **Figure 2**.

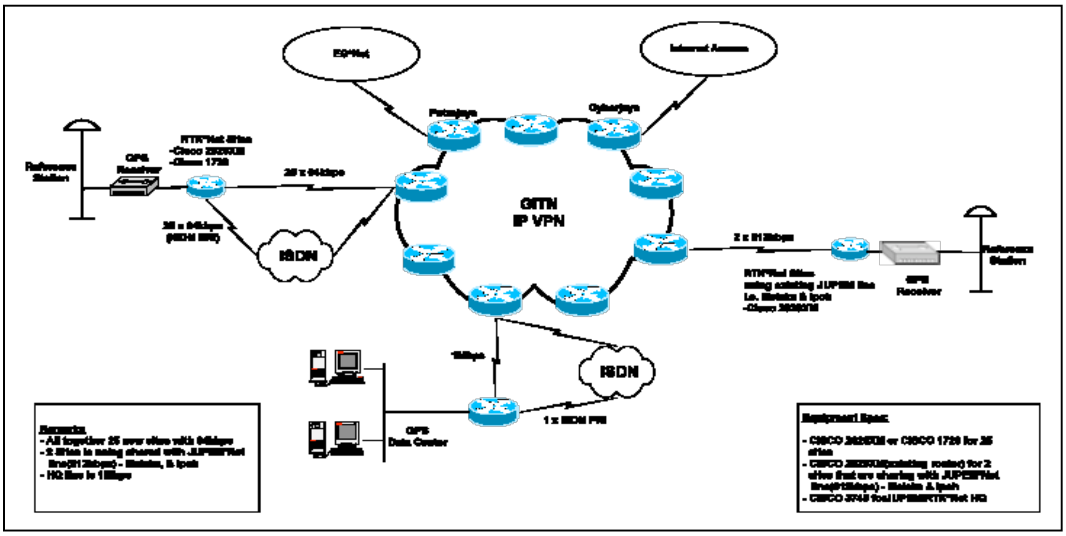

Figure 2: IPVPN Networking

3. REFERENCE STATIONS

3.1 Physical Enclosure

The physical enclosure for the equipment at each site is a small structure or allocated room of approximately 3m x 4m. This room is being cooled by 2 air conditioners that alternate during the day such that the total time that any one unit is on over the entire day is 12 hours.

3.2 System Schematic

The system schematic for the reference stations are shown in **Figure 3**.

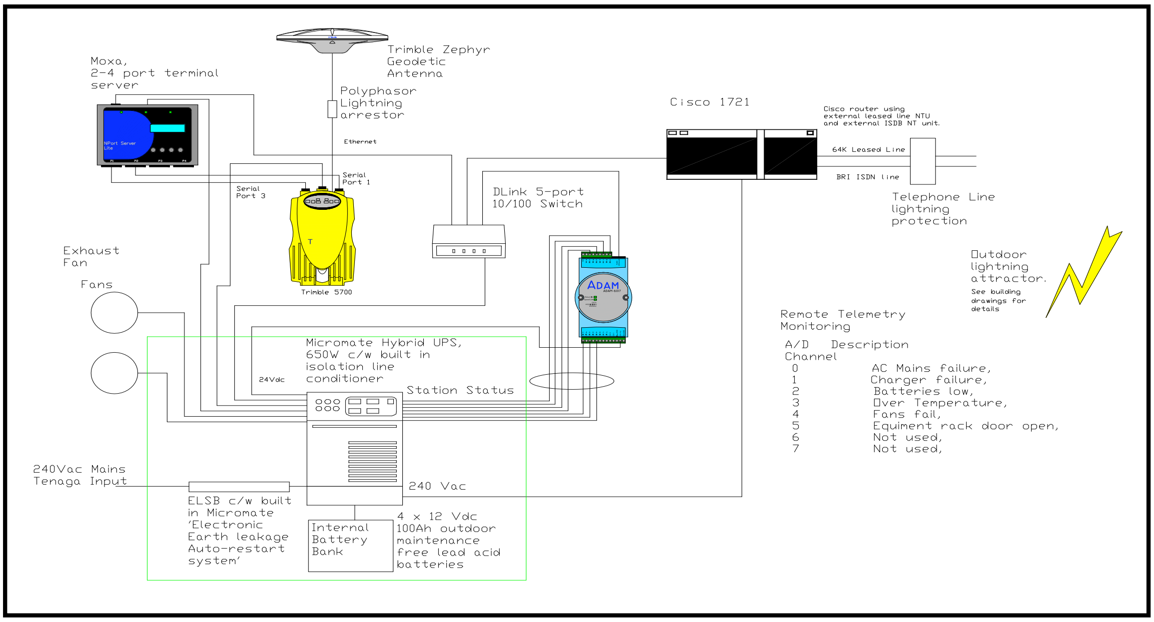

Figure 3: Reference Station Schematic

The Reference Station consists of the following:

- ATI 750 router (27 stations)
- Cisco 1800 router (51 stations)
- Dlink 5port Switch 10/100Mbps
- Trimble 5700 with Zephyr antenna (27 stations)
- Trimble NetR5 with Zephyr antenna (51 stations)
- Advantech Adam 6017 A/D module
- Micromate Hybrid UPS System for 48 hours back up power
- Micromate RS2888 Auto Restart System
- Lightning protection
- Moxa 5410 terminal server (27 stations)

The system is designed for autonomous operation and is able to run for 48 hours without power.

4. CENTRAL CONTROL KL

4.1 Hardware

The hardware for the CC KL configuration is shown in **Figure 4**.

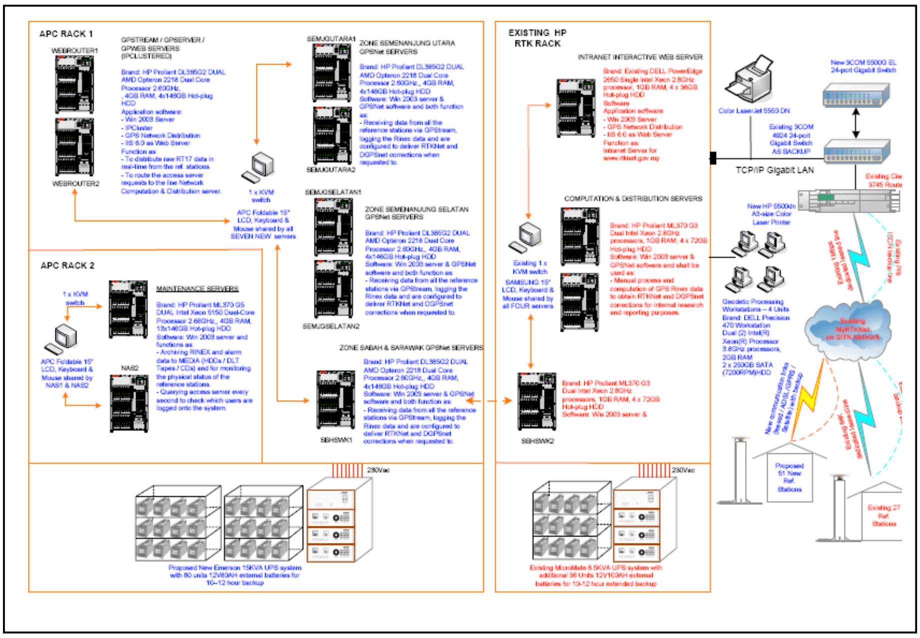

Figure 4: Hardware for CC KL

The Control Centre consists of the following:

- Six (6) GPSnet Server with hot swap redundancy
- Two (2) Maintenance server for system monitoring and data archiving
- 3745 Cisco router for access to the Internet and IPVPN
- UPS to hold the system for 2 days backup
- Two (2) Webrouter servers for web server and data distribution
- Monitor for Maintenance Server
- 3COM 10/100/1000 switch to interconnect all components

4.2 Computer Systems

The system comprises 3 HP Proliant servers and a single rack mount router computer, GPStream server. Each of these computers and their respective function are discussed below.

4.2.1 GPSNet Servers

The VRS computers are server grade HP Proliant computers configured in a pure 'hot standby' mode and are designated as GPSNet primary and GPSNet secondary. Each of the servers is on line with the VRS application running. Both servers receive data from all the reference stations, logging these RINEX data and deliver RTKnet corrections when connected. However, it is the function of the Webrouter server to distribute the reference station receiver data to the GPSNet servers and controls which server get user requests for RTKnet or DGPSnet corrections.

Since both servers are online, should primary server fail to operate, any online field user receiving RTKnet or DGPSnet corrections will lose their connection and the line will hang up. As soon as the field user calls back in, the GPStream application in Webrouter server will detect the failure of the primary server and will pass the request from the user to secondary server. Since both servers would be continuously logging data, none of the logged RINEX data would be affected.

4.2.2 Webrouter Server

The Webrouter server has two functions:

- To distribute the raw RT17 data in real-time from the reference stations to the six (6) GPSNet servers.
- To route the requests from the users to the online VRS server.

User requests for RTKnet or DGPSnet corrections are sent to the Webrouter server. The Webrouter server is in continual communication with both GPSNet servers and as aforementioned, can detect the failure of one in seconds. If the primary GPSNet Server does not respond to the Webrouter server's requests, it will forward the corrections' request to the next server in its list, in this case the secondary GPSNet Server. Since the secondary GPSNet Server is already online and the ionospheric model computed, corrections will be delivered to the field user almost immediately.

4.2.3 Maintenance Server

The maintenance and archiving server is used for archiving RINEX and alarm data to CD and for monitoring the physical status of the reference stations. An application running on the archiving machine will check the reference station status every 5 minutes. Also on this machine is an application that make at every second to check which users are logged onto the system. This data is logged so that phone billing records may be cross checked.

All computers are located in a 42U 19" rack with the GPSNet servers and the Webrouter server sharing a monitor, keyboard and mouse via a KVM switch and the archiving/maintenance server having its own monitor, keyboard and mouse. All monitors, mice and keyboards are located at work table near the rack. Telnet access to the routers and remote sites are done from here.

4.3 Virtual Reference Station

4.3.1 Reference Station Connections

The Stream server is configured to connect to the reference stations in socket client mode. This connection will initialize the receiver and start the RT17 data stream. It will then setup socket servers that can be connected to by the GPSNet servers to receive the streamed RT17 data. In this way both GPSNet servers will receive the data rather than only one. This connection will initialize the receiver and start the RT17 data stream.

4.3.2 Remote User RTK or DGPS Call In

GPSNet is configured in socket server mode for the RTKNet and DGPSNet modules. The remote user will use the registered Telco Mobile Phone Internet Connection through GSM or GPRS to access the Control Centre KL. When a call comes in, the router will authenticate the user before connecting to the system, by using the username and password. If it is in the authorization database, the connection is allowed to proceed, else the line is dropped. When the connection proceeds the router brings the line up and immediately connects to the appropriate socket on the Webrouter server. The Webrouter server then queries both of the available servers. If they both answer, the request is sent to primary server. If only the secondary answers the request is then sent there. The Webrouter server will continue to forward requests to and from the GPSNet servers. The field user is now connected and following the reception of a GGA NMEA string by the GPSNet server, GPSNet will begin sending RTK or DGPS corrections from a 'virtual base' whose coordinates are based from the field user submitted GGA string.

4.4 Archiving/Monitoring

User accounting will be done from the archiving and maintenance server. An application will make query every second to check when users connect and disconnect to the server. The time the connection was initiated and the time the connection was terminated will be logged to a file.

4.5 Hot Swap

The system proposed runs the GPSNet servers in a 'hot standby mode' in which the secondary GPSNet server is up, connected to the reference stations and running VRS. The secondary GPSNet server is also logging RINEX data along with the primary GPSNet server. The only thing that will happen when the primary GPSNet server fail is that the GPStream application in Webrouter server will forward RTKnet and DGPSnet corrections' requests to the secondary GPSNet server. Thus, switching to the standby system will be done in seconds after the fault is confirmed rather than the 20-30 minutes with the clustering solution.

5. MyRTKnet SERVICES

5.1 VRS Correction

a) Within the limits of our MyRTKnet Dense Network, MyRTKnet provides VRS GNSS corrections with an accuracy of 1 to 3 cm horizontally and 3 to 6 cm vertically.
b) Distance dependent errors are considerably minimized with utilization of the MyRTknet network, thereby achieving increased accuracy and reliability.
c) RTK Surveying works at its optimum with a base station network to achieve the pinnacle of RTK Technology production potential.

5.2 Static Correction Data

a) Within the larger limits of the Single Base Station Coverage, MyRTKnet Solutions provides data for post-processing of static survey sessions, enabling positioning in the order of 1 cm or even millimeter recovery limit. The data is provided in the standardized RINEX format and is available via our password protected internet website.
b) Information with a data rate of 1-15 seconds is stored indefinitely.
c) Post-processing provides the highest accuracy and is suitable where increased precision is required.

5.3 DGPS Correction

a) This application is a sub-meter Mapping and Navigation Technology.
b) The service provided by MyRTKnet Solutions includes data for post-processed positioning and Real Time Correction. Any receiver that is capable of Real Time Corrections and cell phone data service can be used to receive MyRTKnet Solutions' Real Time RTCM corrections.
c) Distance dependant errors are eliminated for users' observations due to MyRTKnet Solutions' array of base station locations.
   - Mapping and Navigation
   - Other Sub-Meter Uses

5.4 Hardware Requirement

MyRTKnet Solutions correction can be applied to any mobile receiver capable of connecting to a data cell phone. Cell phone reception, therefore, is a requirement of the VRS correction service. Presently, there are mobile receivers which have both the capabilities of wireless connection to the cell phone and data collector. Any single or dual frequency GNSS receiver can be used to collect data and for static correction data application, post-processing software package is needed to reduce the data to final position that uses standard RINEX files.

5.5 Possible Field Applications

MyRTKnet services can be used for various surveying applications ranging from setting up of control to the detailing of project sites; its usage will benefit not only the surveyors, but also many other GNSS users who rely on these utilities to locate their positions and for navigation. The following are some of the possible field applications of MyRTKnet services:

- Engineering Survey
- Topographic Survey
- Boundary Survey
- Construction Staking
- Utility Extension Survey
- Flood Survey Study and Analysis
- Photogrammetric Control Surveys
- GIS Applications
- Control surveys for monumentation
- Wetland Location Surveys
- Soil Location Survey
- Flagging Clearing Limits
- Tree Surveys
- Mapping and Navigation

6. MyRTKnet TESTING

6.1 Case Study for High Accuracy VRS Correction Test

a. The objective of the High Accuracy VRS Correction Test is to compare GPS observed coordinates with their corresponding published GPS geodetic values. The test was carried out at the existing GPS geodetic network. An example of the layout of the network test site is shown in **Figure 5**.

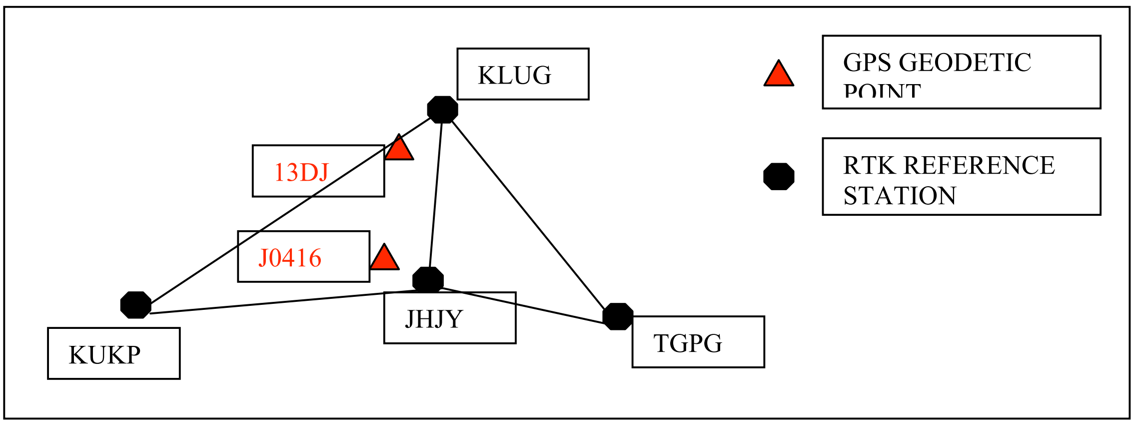

Figure 5: JOHOR BAHRU Area

b. For this case study in Johor Bahru, there are four (4) GPS reference stations namely KUKP, JHJY, TGPG and KLUG. The test was carried out using VRS technique with 5 sessions of observation (consisting of 10 measurements in each session) on 2 GPS receivers.

c. The final observed coordinates values below were the results of the average of the whole set of observations:

Station Name	Observed Coordinates	Known Coordinates	Difference (m)
North Component			
1. J0416	1° 27’ 42.50174 “	1° 27’ 42.50173 “	0.001
2. 13DJ	1° 49’ 39.95325 “	1° 49’ 39.95309 “	0.004
East Component			
1. J0416	103° 46’ 24.09220 “	103° 46’ 24.08998 “	0.005
2. 13DJ	103° 38’ 24.93991 “	103° 38’ 24.93867 “	0.037
Height Component			
1. J0416	11.927	11.866	0.061
2. 13DJ	49.357	49.353	0.004

Table 2: High Accuracy VRS Correction Test Results

d. The results show that the accuracies in the horizontal and height component were less than 1 cm and 9 cm respectively. It also shows that for areas within 30 km from the network, the accuracies obtained were within the said levels.

6.2 Case Study for Network Base DGPS Correction Test

a. The objective of the Network Base DGPS Correction Test is to compare GPS observed coordinates with their corresponding published GPS geodetic values. The test was carried out at the existing GPS geodetic network in Peninsular Network. An example of the layout of the network test site is shown in **Figure 6**.

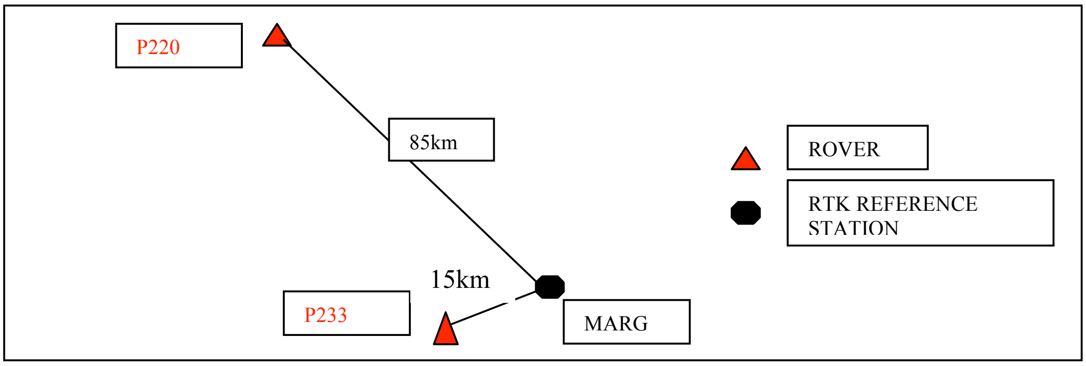

Figure 6: DGPS Network

b. The test was carried out using *Network Base Differential GPS (DGPS)* technique with 5 sessions of observation (consisting of 10 measurements in each session) on 2 GPS receivers.

c. Two dual frequency GPS receivers were used in the test. The observation criteria applied was similar to the test in para 6.1.

d. The final observed coordinates values below were the results of the average of the whole set of observations:

Station Name	Adjusted Coordinates	Known Coordinates	Difference (m)
North Component			
1. P233	1° 27' 10.84805 "	5° 12'10.85003 "	-0.059
2. P220	4° 52' 32.63529 "	4° 52' 32.63501 "	0.008
East Component			
1. P233	103° 4' 38.142713 "	103° 4' 38.14063 "	0.062
2. P220	1° 27' 47.15990 "	101° 57' 47.15827 "	0.049
Height Component			
1. P233	8.304	8.370	-0.065
2. P220	93.320	93.282	0.038

Table 3: Network Base DGPS Test Results

e. The results show that the accuracies in the horizontal and height component were between 1 to 6 cm and 3 to 6 cm respectively. It also shows that for areas within 30 km from the network, the accuracies obtained were within the said levels.

6.3 Case Study for Virtual RINEX Test

a. The objective of the Virtual RINEX Data Test is to compare the GPS coordinates obtained from the processing of the Virtual RINEX data with their corresponding published GPS geodetic values. The test was carried out at the existing GPS geodetic network in Peninsular Network. An example of the layout of the network test site is shown in **Figure 7**.

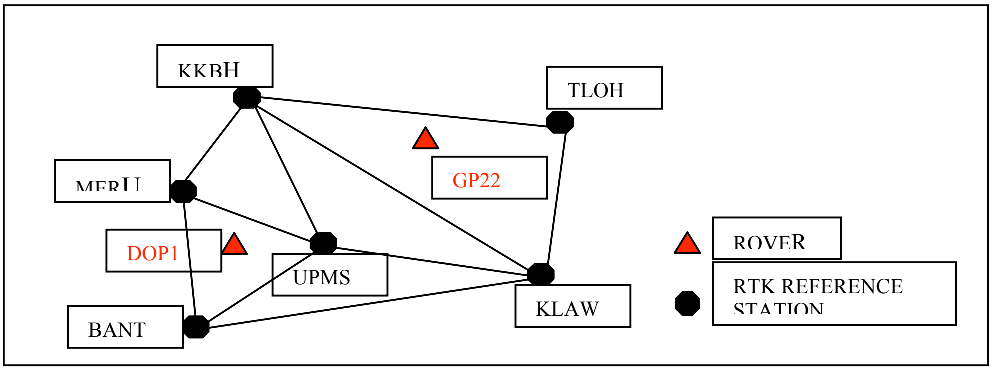

Figure 7: Virtual RINEX GPS network test site

b. The Network site comprises of six (6) GPS reference stations (known stations) namely KKBH, MERU, UPMS, BANT, KLAW and TLOH. The test was carried out using GPS *Static* technique with 2 sessions of 10 minutes on 2 GPS receivers.

c. Two dual frequency GPS receivers were used in the test. The observation criteria applied was similar to the test in para 6.1.

d. The comparison of the final adjusted coordinates and the published coordinates are as follows:

Station Name	Adjusted Coordinates	Known Coordinates	Difference (m)
North Component			
1. DOP 1	3˚ 01’ 29.09642 ”	3˚ 01’ 29.09652 “	-0.002
2. GP22	3˚ 29’ 47.69166 “	1˚ 27’ 47.69176 “	-0.002
East Component			
1. DOP 1	101˚ 26’ 44.87642 “	101˚ 26’ 44.87652 “	-0.002
2. GP22	102˚ 23’ 56.20633 “	102˚ 23’ 56.20651 “	-0.005
Height Component			
1. DOP 1	61.188	61.123	0.065
2. GP22	49.301	49.261	0.050

Table 4: Virtual RINEX Test Results

e. The results show that the accuracies in the horizontal and height component were 1 cm and between 5 - 7 cm respectively. It also shows that for areas within 30 km from the network, the accuracies obtained were within the said levels.

7. CONCLUSION

This paper introduced a new GNSS positioning by way of RTK-GPS (VRS) using MyRTKnet services provided by JUPEM. MyRTKnet has been successfully accomplished and implemented through the establishment of a Network of 78 reference stations equipped with GNSS receiver, antenna, communication server/router, software, power supply, UPS, lightning arrestor and other accessories and equipments necessary for the full working of the station. The Control Centre has also been established equipped with computation server, software, power supply, UPS, communication router/server, Web server and other accessories and equipment necessary for the operations of the facility.

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