Establishment & Testing of Dubai Virtual Reference System (DVRS) National GPS-RTK Network

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Dubai Emirate GPS TimeLine

- 1990 → Dubai Municipality started using GPS for control points Establishment.
- 1995 → Connection to ITRF93 Reference Frame.
- 1997 → Implementation of Classical RTK for Different survey work.
- 1998 → Determination of Dubai Emirate Precise Geoid Model.
- 1999 → Adoption of Geocentric Datum and Realization of ITRF93.
- 2001 → Establishment of Dubai Virtual Reference System (DVRS).
- 2001 → Real Time GPS Positioning by single Rover.
- 2002 → Replacement of Conventional Levelling By GPS Heighting

Establishment of GPS-RTK Network

Introduction:

- GPS technology is a fast and accurate method of determining the location of any point of interest anywhere on earth at any time during the day or night

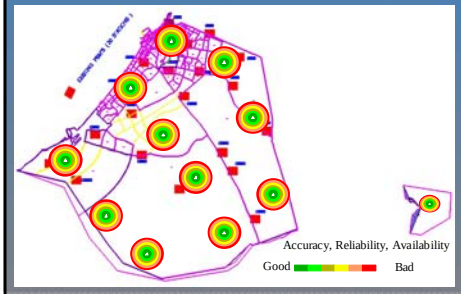
- Real-Time Kinematics (RTK) GPS is now widely used for surveying and other precise positioning applications in Dubai Emirate

Establishment of GPS-RTK Network

Limitations of Classical RTK Surveying:

- Systematic errors
- Range of available radio telemetry solutions
- Base station must be established close to the work area (5km) to ensure accuracy.
- It need a good coverage of Control Network.
- Productivity of the surveyor is Decreased each time the base station has be set up at different reference station.
- Each surveyor need two sets of GPS-receivers

GPS Survey With Classical RTK



Establishment of GPS-RTK Network

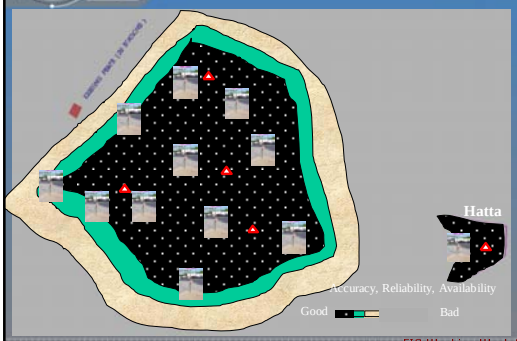
Objective of DVRS Establishment :

- Reduce Dependency on Ground Control Points.
- Increase Productivity, Decrease Cost and minimize Labour.
- Real Time Kinematics (RTK) applications
- To Insure an accuracy of 1-2 cm in Planimetery and 2-5 cm in altimetery
- Realisation and continuous improvement of the International Terrestrial Reference Frame (ITRF)

Objective of DVRS Establishment :

- Absolute sea level determination
- Monitoring of the deformation of the earth
- Facilitate the studies on the ionospheric model and the determination of the atmospheric water vapour content
- Application for the geodynamic and scientific studies
- Combination of the GPS derived ellipsoidal heights with a precise geoid model to replace conventional leveling.

DVRS Network

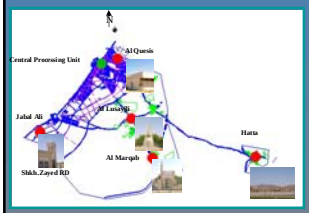


Network Design

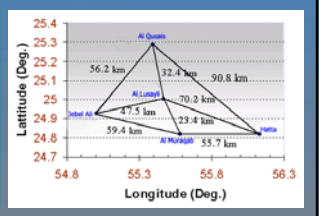
The conditions considered in designing the DVRS Network:

- Network coverage of RTK services of whole Dubai Emirates.
- Stable site (minimal local horizontal and vertical movement).
- Stable antenna mount.
- Minimum electromagnetic interference.
- Adequate security for equipment.
- Receiver and communications hub located inside a building
- Providing protection from weather and elements.
- Antenna located in a minimal Multipath environment.
- Continuous long-term operation.
- Availability of power supplies and telecommunication connection.

Network Design



DVRS Stations Location Map



DVRS Stations Distances

DVRS System Configuration

•Hardware Configuration at Reference Station

- GPS Antenna (Leica AT 504 choke-ring)
- GPS Receiver (Leica MC 500)
- ALCATELE MODEMS

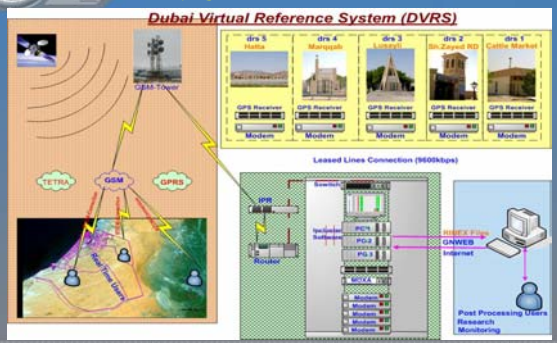
GPS Receiver Leica MC 500

•Hardware Configuration at Central Processing Unit

- 3 Personnal computers connected in network.
- MOXA to convert serial port R232 into TCP-IP
- 5 Modems for receiving raw data from 5 RS.
- Router to receive 30 calls simultaneously through IPR (There is a plan to increase the capacity to accomedate 60 calls at time).

(IP-cluster software function is to make the raw GPS data coming from reference stations avialbel for two PC in Real Time through virtual IP adress)

DVRS Lay-Out



•DVRS Software

The software used in the DVRS is the GEO ++ Software known as Global Navigation Satellite System - State Monitoring And Representation Technique (GNSS-MART) Software

The advantages of GNSS-MART could be listed as:

- Capability of Networking with spacing more than 50km to enable position fixing
- Centimeter accuracy in Real Time and Post Processing
- Elimination of Antenna Phase Center variations by antenna calibrations
- GNNET processes correction signals of several PDGPS reference stations in the RTCM 2.1 format such as they are created by GNREF

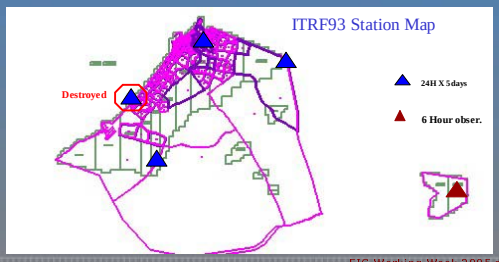
The advantages of GNSS-MART could be listed as:

- Communication between the reference stations via modem connection, via transparent network connections (e.g. via Ethernet TCP/IP, ISDN-Routing) or via the normal RTCM-correction data signal (e.g. 2m radio)
- Simultaneous processing of Five reference stations
- Generation of correction parameters for an extended RTCM,virtual reference stations (VRS), Pseudo Rereference Station (PRS) or Area Correction Parameters (FKP)

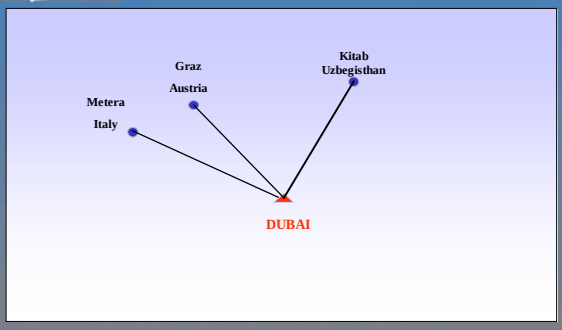
ITRF93 Connection

-Five days 24 Hours continuous observations for 4 Stations & 6 Hour for one station.

- GPS Receivers Used Trimble SSI.

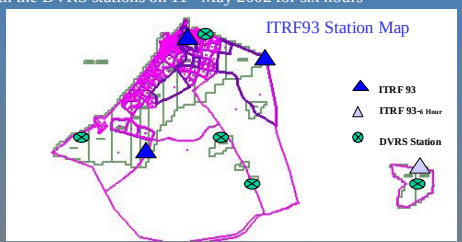


International ITRF Stations Used



DVRS Station Connection to ITRF 93 Stations

-Four (4) stations from the DUREF-95 have been re-observed simultaneously with the DVRS stations on 11th May 2002 for six hours



-Helmert transformation parameters can be derived in order to established the relationship between ITRF93 and ITRF2000 coordinates

Assessment of DVRS

The DVRS system is fully tested with regard to The following :

- Altimetric & Planimetric Accuracies
- Speed of Operation
- Implementation in Various Survey Activities, Demarcation, Alignments, Providing Survey Controls, GPS Levelling & DTM Generation.
- Network Coverage
- GSM Coverage
- Telephone Connection Time
- Corrections Receiving Time
- Rover Initialization Time

Investigating Positioning Accuracy Using the DVRS Network :

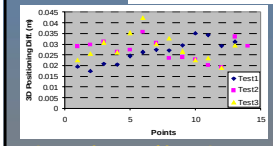
- The DVRS availability and general positioning accuracy at three independent locations :

1- located a few kilometers away from the (Al Qusies) station

2- Close to the (Al Lusali) station near to the centre of the network

3- Southern border of the network coverage area

The 2D Accuracy less than 2 cm & for height 3 cm



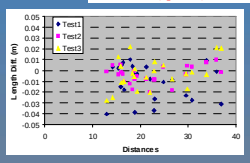
3D external accuracy of the DVRS

	σ_E	σ_N	σ_h
Al Qusies Test 1	0.019	0.016	0.024
Al Lusali Test 2	0.012	0.007	0.032
Border Test 3	0.009	0.012	0.026

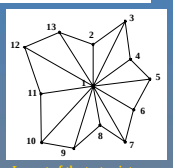
Average coordinate standard deviations at different locations within the network (m)

Investigating Positioning Accuracy Using the DVRS Network :

The 3D (spatial) difference ranged between 081 cm and 3.61 cm



Differences in length computation



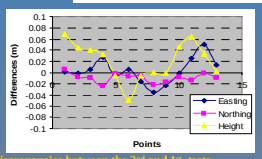
Layout of the test points

	Test1	Test2	Test3
Average	- 0.010	- 0.004	- 0.003
Max.	0.010	0.010	0.022
σ	0.019	0.009	0.014

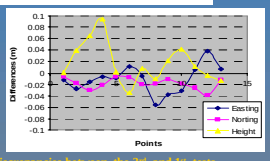
Table 4.2 Statistics of distance discrepancies (m)

Testing of Precision and Compatibility of DVRS Results

The Planimetric (E&N) discrepancies < 5cm & Altimetric < 6 cm



Discrepancies between the 2nd and 1st tests



Discrepancies between the 3rd and 1st tests

Discrepancies		E	N	h
Test2- Test1	Average	0.004	-0.009	0.021
	Max.	0.050	0.006	0.069
	σ	0.023	0.013	0.040
Test3-Test1	Average	-0.011	-0.018	0.027
	Max.	0.038	-0.007	0.102
	σ	0.027	0.021	0.039

Statistics of coordinate discrepancies between the three independent DVRS tests (m)

Investigating System Reliability and Robustness

- In order to test the DVRS output reliability and robustness, particularly in case of failure of one of the reference stations, a set of ten points were surveyed 2 km away from the 'Al Lusayli' reference station using the DVRS RTK data under two scenarios

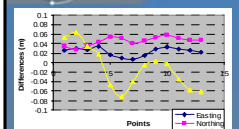
1. In the first, the data of all five reference stations were incorporated in the computation of the phase measurements corrections
2. The measurements of the " Al Lusayli" reference station were eliminated in the process of computing the DVRS data, resembling a case of failure of this station

	All DVRS stations low PDOP			LSLY is disabled low PDOP			LSLY is disabled High PDOP		
	σ_E	σ_N	σ_h	σ_E	σ_N	σ_h	σ_E	σ_N	σ_h
Average	0.008	0.009	0.019	0.016	0.017	0.038	0.040	0.015	0.080
Max.	0.007	0.011	0.023	0.024	0.022	0.050	0.047	0.020	0.090

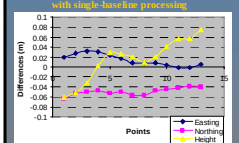
Accuracy < 6cm

Average Coordinate Standard Deviation for Different Scenarios (m)

Comparison with Results of A Single Reference Station for Short Ranges



Coordinate discrepancies for test1 with single-baseline processing



Coordinate discrepancies for test3 with single-baseline processing

	Single Reference Station			DVRS		
	σ_E	σ_N	Σ_h	σ_E	σ_N	σ_h
Test1	0.013	0.011	0.034	0.015	0.008	0.031
Test3	0.022	0.016	0.049	0.012	0.010	0.027

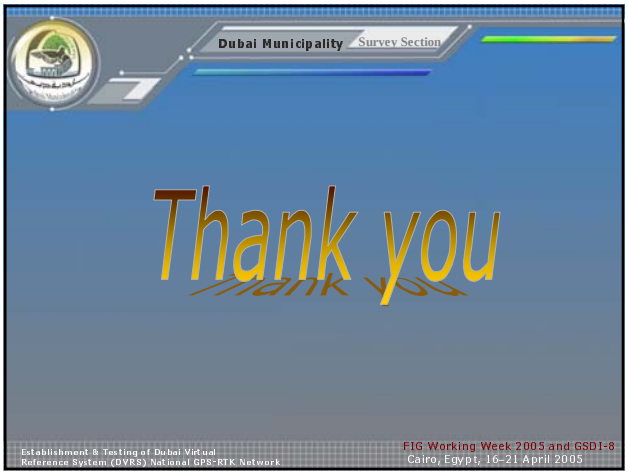
Accuracy Comparison between using a single reference station and the DVRS (m)

		E	N	h
Test1	Average	0.024	0.045	- 0.012
	Max.	0.035	0.058	0.064
	σ	0.026	0.048	0.046
Test3	Average	0.014	- 0.049	0.015
	Max.	0.032	- 0.039	0.074
	σ	0.021	0.055	0.051

Statistics of coordinate discrepancies between the DVRS and the single-reference (m)

Conclusions

- The performance of the Dubai Virtual Reference System (DVRS) has been investigated as an example of the RTK networks
- The system absolute accuracy was first tested by comparing the DVRS estimated coordinates for a set of 13 points with their accurate coordinates, which have been previously determined by a precise surveying using a total station.
- The 3D (spatial) positioning differences between the two techniques, reflecting the DVRS external accuracy, ranged between 0.81cm and 3.61 cm
- The accuracy of relative positioning was tested by studying differences between distances derived from the DVRS estimated point coordinates against their precise values The differences were within 1 cm on the average for the three tests, with a maximum value of 2.2 cm
- The system proves to be reliable and robust particularly in case of failure of one of the reference stations


Dubai Municipality
Survey Section
Thank you
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