KATHMANDU UNIVERSITY

SCHOOL OF ENGINEERING

DEPARTMENT OF GEOMATICS ENGINEERING

A Report on

Post-Processing on DGPS Data

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March 2021

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LIST OF ABBREVIATIONS

DGPS	Differential Global Positioning System
DoP	Dilution of Precision
GNSS	Global Navigation Satellite System
MHz	Megahertz
MUTM	Modified Universal Transverse Mercator
PR	Pseudo-Range
RINEX	Receiver Independent Exchange
RTK	Real Time Kinematics
WGS	World Geodetic System

1. INTRODUCTION

1.1 Background

Differential Global Positioning System, often abbreviated as DGPS, is an enrichment to Global Position System, which provides improved location accuracy and integrity than standard GPS (*Differential GPS Explained*, n.d.). DGPS relies on error correction transmitted from a GPS receiver placed at a known location. The differences between observed and computed co-ordinates ranges (known as differential corrections) at a particular known point are transmitted to users (GPS receivers at other points) to upgrade the accuracy of internally generated position of the user receivers' position. (Parkinson & Enge, 1996)

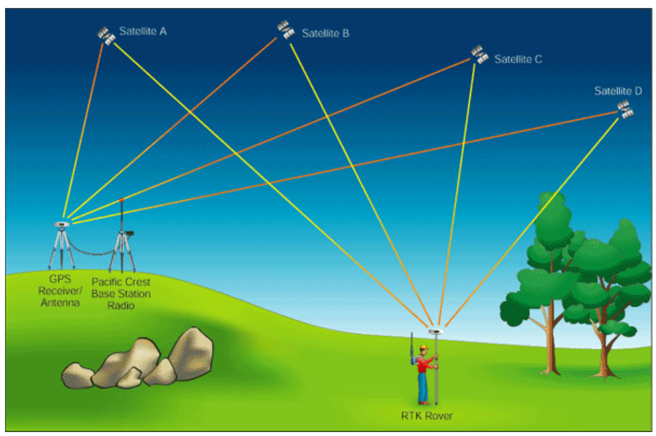

Figure 1. DGPS in Action

(Nasrullah, 2016)

1.2 Why Differential Positioning?

DGPS applies the technique of differential correction in the collected data. Differential correction is a technique that greatly increases the accuracy of the collected DGPS data. It involves using a receiver at a known location - the "base station" - and comparing that data with DGPS positions collected from unknown locations with "roving receivers". DGPS eliminates all the measurement errors in the satellite ranges, thus enabling a highly precise position calculation and is called a differential GPS positioning (Atabudhi, 2019). By using DGPS we can improve our positional accuracy from around

1.5m with standard GPS to around 40cm with DGPS, without the need for post processing (*DGPS Survey Report*, 2016).

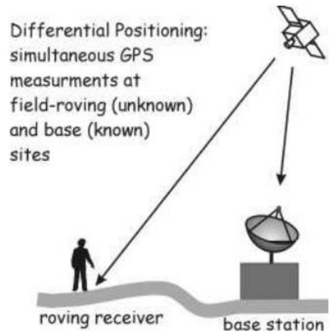

Figure 2. Differential Positioning

1.3 Working Principle of DGPS

GPS acquires coordinate positions through triangulation by determining the distance between an antenna receiver and at least four satellites. Normal code base GPS receivers are typically used for navigation. To improve accuracy, DGPS requires at least two antenna receivers; a base receiver with a known position tracking four or more satellites, and a rover receiver placed on a stable target device for a required length of time. DGPS improves accuracy by reducing systematic errors (e.g. atmospheric delays, precision of orbits) resulting from GPS signal propagation delays or inability to discern the precise details of satellite orbit (Little et al., 2003).

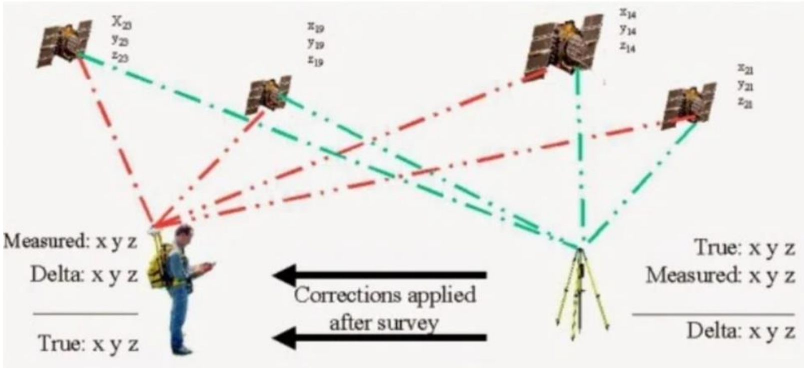

Figure 3. Working Principle of DGPS

(Kaur, 2016)

Fundamentally, the stationery (base station) unit backwards, i.e. instead of using timing to calculate position, it uses its position to calculate timing. This is done because the precise location of stationery receiver is known, and hence, so is the location of the satellite. Subsequently, once the error is known in this unit, it determines a correction factor and sends it to another receiver. And thus, each rover receives the message with correction factor for all satellites (Kaur, 2016).

1.4 Terms Used in DGPS

i) Triangulation: Triangulation is a method for determining a position based on the distance from other points or objects that have known locations.

ii) Time: The time of the measurement is the receiver time of the received signals. It is identical for the phase and range measurements and is identical for all satellites observed at that epoch.

iii) RTK: RTK is an advanced form of DGPS which uses the satellites carrier wave to compare two observations from different receivers within the system, to fine tune the satellite and receiver clock errors, thus improving positional accuracy.

iv) Pseudo-range: PR is the distance from the receiver antenna to the satellite antenna including receiver and satellite clock offsets (and other biases, such as atmospheric delays).

PR = distance + c * (receiver clock offset –satellite clock offset + other biases),

so that the pseudo-range reflects the actual behavior of the receiver and satellite clocks. The pseudo-range is stored in units of meters (*DGPS Survey Report*, 2016).

v) DoP: DoP is an arrangement of satellites in the sky also affects the accuracy of GPS positioning. The ideal arrangement (of the minimum four satellites) is one satellite directly overhead, three others equally spaced nearer the horizon (but above the mask angle).

vi) Code Phase: Code phase is one processing technique that gathers data via a C/A (coarse acquisition) code receiver, which uses the information contained in the satellite signals (aka the pseudo-random code) to calculate positions. After differential correction, this processing technique results in 1-5-meter accuracy.

vii) Carrier Phase: Carrier phase is another processing technique that gathers data via a carrier phase receiver, which uses the radio signal (aka carrier signal) to calculate positions. The carrier signal, which has a much higher frequency than the pseudo-random code, is more accurate than using the pseudo-random code alone. The pseudo-random code narrows the reference then the carrier code narrows the reference even more. After differential correction, this processing technique results in sub-meter accuracy.

viii) L-Band: The group of radio frequencies extending from 390 MHz to 1550 MHz. The GPS carrier frequencies (1227.6 MHz and 1575.42 MHz) are in the L band GPS Signals in detail.

ix) Carriers: The GPS satellites transmit signals on two carrier frequencies. The 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 (*About Positioning Technology From Trimble - GNSS & GPS*, n.d.).

x) Doppler: The Doppler effect or Doppler shift is the change in frequency of a wave in relation to an observer who is moving relative to the wave source.

xi) Multipath: Multipath means that satellite signals do not just arrive in a straight line; they are transmitted in multiple routes while being reflected off mountains, buildings, etc. It takes time for the reflected signals to arrive at their destination. This results in a more distance calculation, and is a factor that negatively impacts accurate satellite positioning.

2. METHODOLOGY

2.1 DGPS Post Processing

In DGPS post processing technique, GPS receivers at reference and remote stations observe coming GPS satellites, record observations in receiver's memory, and then download GPS observations to a computer where software corrects the GPS observations. The positional accuracy of the aftermath of this method is in the range of few mm. to cm (Chao, 1998). To be more precise, the post processing of GNSS signals are more accurate than the RTK because of following reasons:

- Precise orbits and clock information helps to reduce the errors due to satellite position and satellite clock offsets.
- Precise models on troposphere and ionospheric delays can be used for mitigating the corresponding delays.
- Precise antenna calibration models help to reduce the antenna-specific errors.

Workflow:

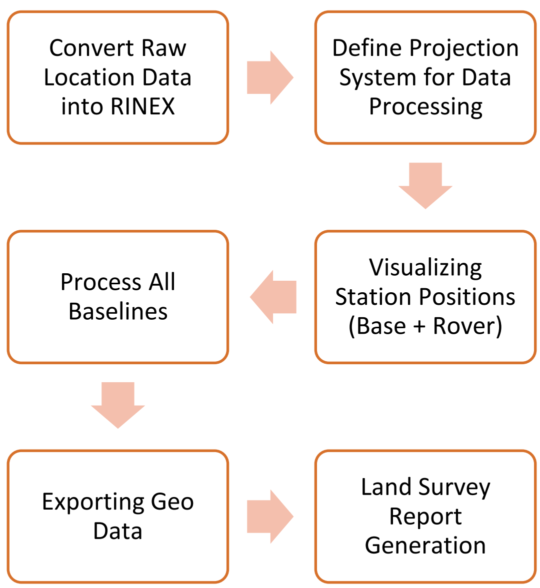

Figure 4. Methodological Flow Diagram

A) Converting Raw Location Data into RINEX

Receiver Independent Exchange Format, an acronym for RINEX is a data interchange format for raw satellite navigation system data. This allows the user to post-process the received data to produce a more accurate result - usually with other data unknown to the original receiver, such as better models of the atmospheric conditions at time of measurement. The raw location data (.dat format) obtained from the observation instrument was logged and converted into RINEX format.

Only GLONASS and GPS were selected in the export system during conversion, which results in three different states for each raw location file viz.

.O → Observation file format

.N → Navigation file

.G → GLONASS file

B) Define Projection System for Data Processing

Prior to the processing of data, a step for defining the projection system was implemented. Since, Nepal uses the Modified Universal Transverse Projection System (MUTM), the associated parameters were manually defined to set up this projection system.

System Name:	MUTM
Vertical Datum:	Ellipsoid
Datum Name:	Everest 1830
Ellipsoid Name:	Everest 1830
Semi-major Axis:	6377276.345 m
Inverse Flattening:	300.8017
DX to WGS84:	282.00 m
DY to WGS84:	726.00 m
DZ to WGS84:	254 m
Projection Class:	Transverse Mercator
Latitude of Origin:	0°00′00″ N
Central Meridian:	87°00′00′ E
Scale Factor:	0.9999
False Easting:	500000 m
False Northing:	0 m

C) Visualization of Stations and Processing all Baselines

After defining the projection system, the observation data (.O) are imported. In this course, the field values for each station are visualized in the tabular form during which the antenna height was adjusted as per the requirement (set to 2 m in my case). The stations as well as baselines joining each station to base station are visualized in the graphic form. Subsequently, all the baselines are processed.

D) Exporting Geo Data to File and Generating Land Survey Report

Finally, the processed data are exported in a .csv file format in tabular form which portrays the easting, northing and elevation values of each station. Also, land survey report is generated which includes all the descriptions regarding the attributes of data, the coordinate system used, logged points, processed vectors and quality report as well.

2.2 Software Used

Following software were used for the processing of data:

- Static to RINEX: To convert raw location data (.dat format) obtained from the observation into RINEX format.
- GNSS Solution: For all the post-processing tasks.

3. RESULTS

The result furnished from the aforementioned post-processing steps is tabulated viz.

Table 1. Final Coordinates of Stations determined by DGPS Survey

Id	Description	X	Y	Z
1000	1000	424223.647	3057324.899	1895.713
1001	1001	424181.5447	3057466.773	1903.5662
1002	1002	424163.4332	3057396.334	1901.8257
1003	1003	424198.9082	3057280.117	1892.2406
1004	1004	424251.3083	3057245.78	1889.345
1005	1005	424241.9383	3057376.675	1895.29
1006	1006	424276.899	3057287.063	1888.3599
1007	1007	424272.3251	3057166.384	1882.8071
1008	1008	424235.4203	3057195.734	1886.8442
1009	1009	424159.6982	3057274.733	1891.9263
1010	1010	424101.4467	3057261.502	1894.9103
1011	1011	424108.9354	3057187.902	1891.1495
1012	1012	424033.8043	3057172.292	1896.1183
1013	1013	423980.806	3057260.395	1909.0021
1014	1014	423959.3206	3057229.999	1911.8412

Land Survey Overview

GNSS Solutions

3/22/2022 4:51:13 PM
www.spectraprecision.com

Project Name : Final
Spatial Reference System : MUTM
Time Zone : (UTC+05:45) Kathmandu
Linear Units : Meters

Coordinate System Summary

Coordinate system

Name :	MUTM
Type :	Projected
Unit name :	Meters
Meters per unit :	1
Vertical datum :	Ellipsoid
Vertical unit :	Meters
Meters per unit :	1

Datum

Name :	Everest1830
Ellipsoid Name :	Everest1830
Semi-major Axis :	6377276.345 m
Inverse Flattening :	300.801700000
DX to WGS84 :	282.0000 m
DY to WGS84 :	726.0000 m
DY to WGS84 :	254.0000 m
RX to WGS84 :	-0.000000 "
RY to WGS84 :	-0.000000 "
RZ to WGS84 :	-0.000000 "
ppm to WGS84 :	0.000000000000

Projection

Projection Class :	Transverse_Mercator
latitude_of_origin	0° 00' 00.00000"N
central_meridian	87° 00' 00.00000"E
scale_factor	0.999900000000
false_easting	500000.000 m
false_northing	0.000 m

Control Points

Name		Components	95% Error	Status
Control Error				
1000	East	424223.647	0.000	FIXED

	North	3057324.899	0.000	FIXED
	Ellips height	1895.713	0.000	FIXED
	Description	*1000*		

Logged Points

Name		Components	95% Error	Status
1001	East	424181.545	0.000	Processed (static)
	North	3057466.773	0.000	Processed (static)
	Ellips height	1903.564	0.000	Processed (static)
	Description	*1001*		
1002	East	424163.433	0.000	Processed (static)
	North	3057396.334	0.000	Processed (static)
	Ellips height	1901.824	0.000	Processed (static)
	Description	*1002*		
1003	East	424198.908	0.000	Processed (static)
	North	3057280.116	0.000	Processed (static)
	Ellips height	1892.239	0.000	Processed (static)
	Description	*1003*		
1004	East	424251.308	0.000	Processed (static)
	North	3057245.780	0.000	Processed (static)
	Ellips height	1889.343	0.000	Processed (static)
	Description	*1004*		
1005	East	424241.938	0.000	Processed (static)
	North	3057376.675	0.000	Processed (static)
	Ellips height	1895.288	0.001	Processed (static)
	Description	*1005*		
1006	East	424276.899	0.000	Processed (static)
	North	3057287.063	0.000	Processed (static)
	Ellips height	1888.358	0.000	Processed (static)
	Description	*1006*		
1007	East	424272.325	0.001	Processed (static)
	North	3057166.384	0.000	Processed (static)
	Ellips height	1882.805	0.001	Processed (static)
	Description	*1007*		
1008	East	424235.420	0.000	Processed (static)
	North	3057195.734	0.000	Processed (static)
	Ellips height	1886.843	0.000	Processed (static)
	Description	*1008*		
1009	East	424159.698	0.000	Processed (static)
	North	3057274.733	0.000	Processed (static)
	Ellips height	1891.925	0.001	Processed (static)
	Description	*1009*		
1010	East	424101.446	0.000	Processed (static)
	North	3057261.501	0.000	Processed (static)
	Ellips height	1894.906	0.001	Processed (static)
	Description	*1010*		
1011	East	424108.935	0.000	Processed (static)
	North	3057187.902	0.000	Processed (static)
	Ellips height	1891.148	0.001	Processed (static)
	Description	*1011*		
1012	East	424033.804	0.001	Processed (static)
	North	3057172.292	0.001	Processed (static)
	Ellips height	1896.116	0.001	Processed (static)
	Description	*1012*		

1013	East	423980.806	0.001	Processed (static)
	North	3057260.395	0.000	Processed (static)
	Ellips height	1909.000	0.001	Processed (static)
	Description	*1013*		
1014	East	423959.321	0.001	Processed (static)
	North	3057229.999	0.000	Processed (static)
	Ellips height	1911.839	0.001	Processed (static)
	Description	*1014*		

Files

Name	Start Time	Sampling	Epochs	Size (Kb)	Type
10001131.22O	22/01/03 09:16:05	5	5637	4923	L1/L2 GPS/GLONASS
1005303A.22O	22/01/03 12:10:20	5	268	188	L1/L2 GPS/GLONASS
1006573B.22O	22/01/03 12:40:45	5	255	206	L1/L2 GPS/GLONASS
1007173C.22O	22/01/03 13:09:30	5	243	215	L1/L2 GPS/GLONASS
1008393D.22O	22/01/03 13:33:35	5	253	207	L1/L2 GPS/GLONASS
1009133F.22O	22/01/03 14:14:45	5	245	201	L1/L2 GPS/GLONASS
1010373G.22O	22/01/03 14:41:15	5	227	196	L1/L2 GPS/GLONASS
1011553H.22O	22/01/03 15:04:45	5	271	204	L1/L2 GPS/GLONASS
1012123I.22O	22/01/03 15:31:10	5	237	202	L1/L2 GPS/GLONASS
1013333J.22O	22/01/03 15:56:35	5	235	209	L1/L2 GPS/GLONASS
1014373K.22O	22/01/03 16:19:50	5	267	223	L1/L2 GPS/GLONASS
10015431.22O	22/01/03 09:56:30	5	365	331	L1/L2 GPS/GLONASS
10021937.22O	22/01/03 10:36:45	5	375	345	L1/L2 GPS/GLONASS
10030338.22O	22/01/03 11:13:30	5	268	241	L1/L2 GPS/GLONASS
10040339.22O	22/01/03 11:39:10	5	235	191	L1/L2 GPS/GLONASS

Occupations

Site	Start Time	Time span	Type	File
1000	January 3 2022 09:16:05.00	07:49:40.00	Static	10001131.22O
1005	January 3 2022 12:10:20.00	00:22:15.00	Static	1005303A.22O
1006	January 3 2022 12:40:45.00	00:21:10.00	Static	1006573B.22O
1007	January 3 2022 13:09:30.00	00:20:10.00	Static	1007173C.22O
1008	January 3 2022 13:33:35.00	00:21:00.00	Static	1008393D.22O

1009	1009133F.22O	January 3 2022 14:14:45.00	00:20:20.00	Static
1010	1010373G.22O	January 3 2022 14:41:15.00	00:18:50.00	Static
1011	1011553H.22O	January 3 2022 15:04:45.00	00:22:30.00	Static
1012	1012123I.22O	January 3 2022 15:31:10.00	00:19:40.00	Static
1013	1013333J.22O	January 3 2022 15:56:35.00	00:19:30.00	Static
1014	1014373K.22O	January 3 2022 16:19:50.00	00:22:10.00	Static
1001	10015431.22O	January 3 2022 09:56:30.00	00:30:20.00	Static
1002	10021937.22O	January 3 2022 10:36:45.00	00:31:10.00	Static
1003	10030338.22O	January 3 2022 11:13:30.00	00:22:15.00	Static
1004	10040339.22O	January 3 2022 11:39:10.00	00:19:30.00	Static

Processes

Num	Reference	Reference File	Rover	Rover File	Mode
1	1000	10001131.22O	1011	1011553H.22O	Static
2	1000	10001131.22O	1004	10040339.22O	Static
3	1000	10001131.22O	1006	1006573B.22O	Static
4	1000	10001131.22O	1007	1007173C.22O	Static
5	1000	10001131.22O	1008	1008393D.22O	Static
6	1000	10001131.22O	1010	1010373G.22O	Static
7	1000	10001131.22O	1005	1005303A.22O	Static
8	1000	10001131.22O	1012	1012123I.22O	Static
9	1000	10001131.22O	1013	1013333J.22O	Static
10	1000	10001131.22O	1014	1014373K.22O	Static
11	1000	10001131.22O	1001	10015431.22O	Static
12	1000	10001131.22O	1002	10021937.22O	Static
13	1000	10001131.22O	1003	10030338.22O	Static
14	1000	10001131.22O	1009	1009133F.22O	Static

Processed vectors

Vector Identifier	Vector Length	95% Error		Vector Components	95% Error	SV	PDOP	QA	Solution
1000 - 1009	81.392	0.001	X	64.840	0.000	11	1.6		Fixed
22/01/03 14:14:45.00			Y	15.875	0.001				
+00:20:20.00			Z	-46.567	0.000				

```
  1000 - 1003              51.296      0.001   X      25.583     0.000 12  1.6
Fixed
  22/01/03 11:13:30.00                         Y      16.123     0.000
          +00:22:15.00                         Z     -41.435     0.000

  1000 - 1002              93.658      0.001   X      58.735     0.000 12  1.8
Fixed
  22/01/03 10:36:45.00                         Y     -31.482     0.000
          +00:31:10.00                         Z      65.810     0.000

  1000 - 1001             148.246      0.001   X      39.044     0.000 13  1.6
Fixed
  22/01/03 09:56:30.00                         Y     -61.444     0.000
          +00:30:20.00                         Z     129.140     0.000

  1000 - 1014             281.400      0.002   X     267.130     0.001 12  1.9
Fixed
  22/01/03 16:19:50.00                         Y      41.607     0.001
          +00:22:10.00                         Z     -78.082     0.001

  1000 - 1013             251.695      0.002   X     244.777     0.001 12  1.9
Fixed
  22/01/03 15:56:35.00                         Y      26.364     0.001
          +00:19:30.00                         Z     -52.342     0.001

  1000 - 1012             243.656      0.002   X     193.255     0.001 11  1.9
Fixed
  22/01/03 15:31:10.00                         Y      59.128     0.001
          +00:19:40.00                         Z    -136.104     0.000

  1000 - 1005              54.931      0.001   X     -19.543     0.000 10  1.9
Fixed
  22/01/03 12:10:20.00                         Y     -23.216     0.000
          +00:22:15.00                         Z      45.788     0.000

  1000 - 1010             137.715      0.002   X     123.489     0.000 11  1.6
Fixed
  22/01/03 14:41:15.00                         Y      20.979     0.001
          +00:18:50.00                         Z     -57.233     0.001

  1000 - 1008             130.046      0.001   X      -9.134     0.000 11  1.7
Fixed
  22/01/03 13:33:35.00                         Y      52.745     0.000
          +00:21:00.00                         Z    -118.518     0.000

  1000 - 1007             166.376      0.001   X     -45.499     0.001 11  1.7
Fixed
  22/01/03 13:09:30.00                         Y      65.093     0.001
          +00:20:10.00                         Z    -146.198     0.000

  1000 - 1006              65.759      0.001   X     -52.673     0.000 11  1.7
Fixed
  22/01/03 12:40:45.00                         Y      14.376     0.000
          +00:21:10.00                         Z     -36.649     0.000

  1000 - 1004              84.084      0.001   X     -26.065     0.000 11  1.8
Fixed
  22/01/03 11:39:10.00                         Y      32.766     0.000
          +00:19:30.00                         Z     -72.919     0.000

  1000 - 1011             178.797      0.001   X     117.581     0.000 10  2.2
Fixed
  22/01/03 15:04:45.00                         Y      52.228     0.001
          +00:22:30.00                         Z    -124.159     0.000
```

Figure 5. Visualizing SNR of all Satellite Vehicles of Station 1006

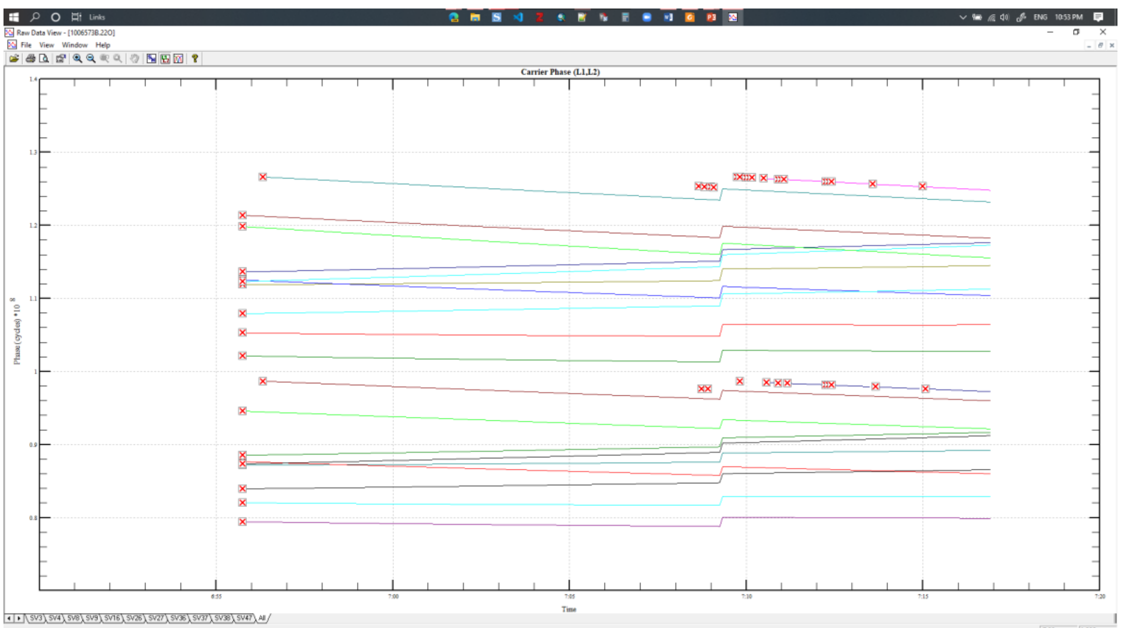

Figure 6. Carrier Phase Signal of Satellites in Station 1006

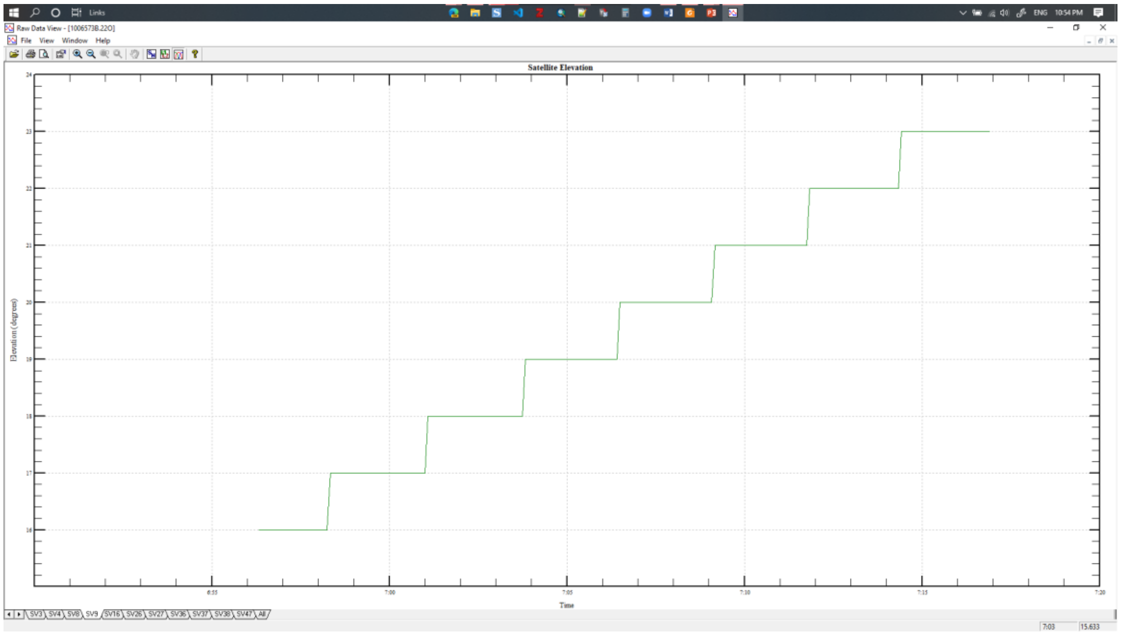

Figure 7. Satellite Elevation of Satellite Vehicle 9 during Observation at Station 1006

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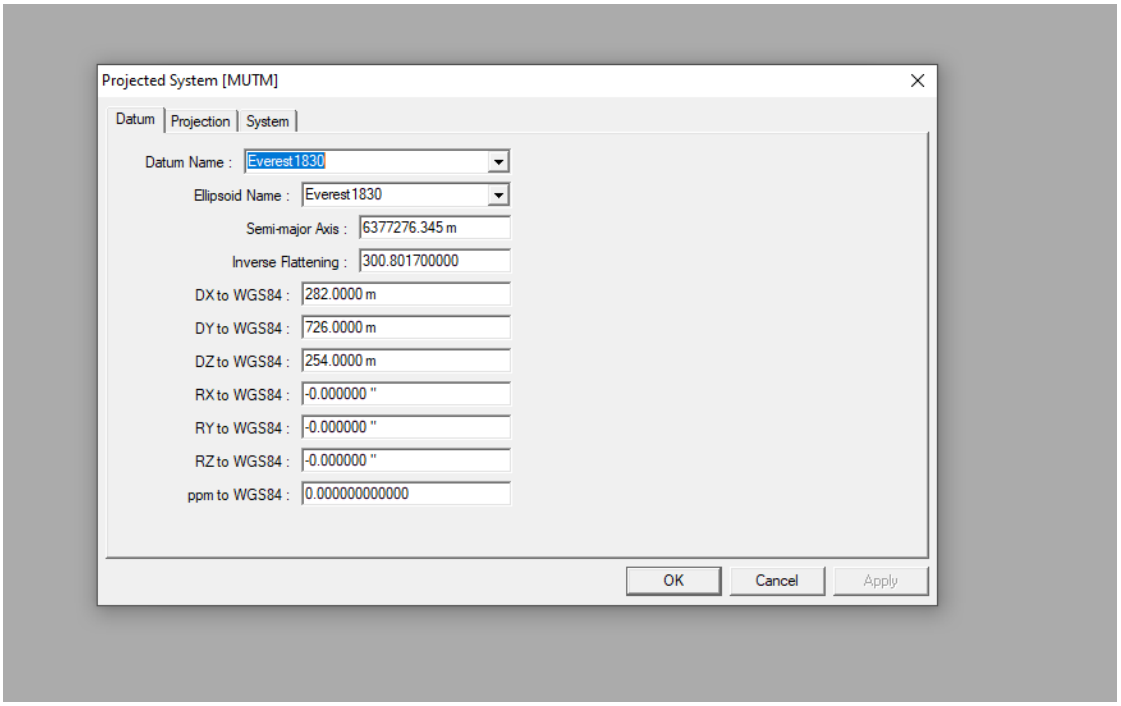
ANNEXES



Projected System [MUTM]
Datum
Projection
System
Datum Name : Everest 1830
Ellipsoid Name : Everest 1830
Semi-major Axis : 6377276.345 m
Inverse Flattening : 300.801700000
DX to WGS84 : 282.0000 m
DY to WGS84 : 726.0000 m
DZ to WGS84 : 254.0000 m
RX to WGS84 : -0.000000 "
RY to WGS84 : -0.000000 "
RZ to WGS84 : -0.000000 "
ppm to WGS84 : 0.000000000000
OK
Cancel
Apply