THE RELIABILITY OF USING GNSS PRECISE POINT POSITIONING PPP IN REPLACING THE TRADITIONAL NETWORK POSITIONING TECHNIQUE

By

WALID ABDALLAH ABOUMANDOUR

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

PUBLIC WORKS ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2014

THE RELIABILITY OF USING GNSS PRECISE POINT POSITIONING PPP IN REPLACING THE TRADITIONAL NETWORK POSITIONING TECHNIQUE

By

WALID ABDALLAH ABOUMANDOUR

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

PUBLIC WORKS ENGINEERING

Under the Supervision of

Dr. Adel H. El-Shazly
Professor of Surveying and Geodesy
Public works Department
Faculty of Engineering, Cairo University

Dr. Moustafa A. Baraka
Professor of Surveying and Geodesy
Public works Department
Faculty of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2014

THE RELIABILITY OF USING GNSS PRECISE POINT POSITIONING PPP IN REPLACING THE TRADITIONAL NETWORK POSITIONING TECHNIQUE

By

WALID ABDALLAH ABOUMANDOUR

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

PUBLIC WORKS ENGINEERING

Approved by Examining Committee:

____
Prof. Ibrahim Fathy Mohamed Shaker, External Examiner
Professor of Photogrametry and Surveying
Faculty of Engineering - Ain Shams University

____
Prof. Mohammed Safwat Mohammed El-Hussainy, Internal Examiner

____
Prof. Adel Hassan Youssef El-Shazly, Thesis Main Advisor

____
Prof. Moustafa Ahmed Baraka, Member

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2014

ACKNOWLEDGEMENTS

First of all, I would like to express my great gratitude to my supervisor, Prof. Adel H. El-Shazly and Prof. Moustafa A. Baraka, for their academic guidance, and encouragement during the period of my graduate study.

I would like to express my thanks to all staff of surveying and land information system division for their all kinds of help.

Finally, thanks would be given to my family for their unconditional love and support all the years.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Establishing Global Navigation Satellite Systems (GNSS) geodetic control networks for subsequent surveys can be a costly, difficult and/or time consuming process, especially for a country with developmental needs like Egypt. Multiple stations (if exist) should be occupied simultaneously and post-processed using scientific software to fix base stations for such networks. Base stations can be observed as single points via trilateration using code range observations, as a simple single point positioning. The accuracy of such point positioning would be limited due to unmodeled errors and biases, reaching few meters. On the other hand, an emerging viable alternative is Precise Point Positioning (PPP) which uses both undifferenced code range and carrier phase measurements, with respect to the international GNSS service (IGNSS), precise GPS orbits, satellite clock corrections. Hence it would be possible to improve the precision of the point position from "dm" level positional accuracy to "cm" level positional accuracy. Accordingly, PPP could provide useable geodetic survey control points in areas where it would costly, difficult or time consuming. As a practical approach, a single survey crew could be deployed to establish a geodetic survey control network across a large area, rather than the adopting complicated logistics and communications needed to organize multiple survey crews to occupy stations of the network simultaneously.

This research presents an assessment of the accuracy of Single Point Positioning (SPP) technique for two points observed within Egypt, with two GNSS dual frequency receivers for 24 hours simultaneously. The assessment was conducted using the broadcast ephemeris and precise ephemeris. Also, the research investigates the effect of combining GPS and GLONASS dual-frequency measurements on the static SPP solution and its sensitivity to different processing strategies. It is shown that GLONASS observations reduce the accuracy of SPP defined by GPS only. However, the improvement full solution, i.e., with 24 hours of observations, is not significant. The relative positioning technique was used for the two points and data sets were solved from IGS tracking stations. These data were processed using Leica Geo office software package, where the accuracy of two points was improved significantly to be within cms. The Precise Point Positioning PPP was introduced and evaluated with different practical data. The results show that PPP concept can deliver a point position with accuracy/precision of cm within 2 to 3 hours observation time.

To check the reliability, accuracy, and stability of PPP solution in Egypt. Daily data for 13 different days were collected for around four hours and processed using RTKLIB software. The reliability analysis was performed using test retest analysis and based on the correlation coefficient between the data sets. The analysis proves that PPP-RTKLIB solution has medium reliability, also after 2 hours of observation the accuracy of PPP was in cm level. It reaches, after four hours of observation, 4 cm in Easting, 2cm in Northing, and 6cm in Height.

The research suggested and tested the use of GNSS network results with more than one receiver to enhance the accuracy of PPP from RTKLIB. With applying unified least squares. The test was carried on a small GNSS network inside Egypt with varies baselines lengths (50 to 150 Km). The test indicated that the accuracy of control points from PPP improved by 50 % for all coordinates components.

CHAPTER ONE: INTRODUCTION

1.1 INTRODUCTION

Differential GNSS (DGNSS) is the most probable technique currently used in Egypt for accurate positioning using double difference process. This technique was used because the common errors cancelled out for short baselines or reduced their impact for long baselines. In addition to eliminate/reduce the impact of common errors, double difference technique leads to constraining double difference ambiguity to integer values.

DGNSS employs two (or more) GNSS receivers simultaneously tracking the same satellites. A major disadvantage of GNSS differential positioning, however, is its dependency on the measurements or corrections from a reference receiver; i.e. two or more GNSS receivers are required to be available. New developments in GNSS positioning show that a user with a single GNSS receiver i.e., precise point positioning, can obtain positioning accuracy comparable to that of differential positioning (El-Rabbany, A., 2006).

This GNSS precise point positioning (PPP) technique with one dual-frequency GNSS receiver, in one of its applications, post processes observations using precise satellite orbits and clock corrections from the International GNSS Service (IGS; Moore and Neilan 2005); see, e.g., Zumberge et al. (1997), Kouba and Heroux (2001) and Cai and Gao (2007). Furthermore, PPP is a special case of zero difference processing, in contrast with double-differencing algorithm in relative positioning.

Precise Point Positioning (PPP) with GPS has attracted the attention of many researchers over the past decade. Recently, the Russian GLONASS system has been modernized and restored to near full constellation status, which made it attractive to positioning and navigation users. Having two healthy systems, namely GPS and GLONASS at present, allows for the integration of both constellations. This in turn arises to test the availability, positioning accuracy, and reliability of the PPP solution.

1.2 STATEMENT OF THE PROBLEM

In Egypt, the Differential GNSS technique is extensively (only) used to determine the point coordinates. Although, DGNSS is expensive, it is only the traditional manner to get the accurate position where continuous GNSS stations like IGS and CORS (Continuously Operating Reference Stations) stations that are not available. When IGS and/or CORS exist DGNSS only requires one receiver same as PPP. At least two GNSS receiver is required to do DGNSS concept where one at known point and others at unknown points, so DGNSS need at least two crews and two GNSS units thus DGNSS technique is very expensive compared with PPP technique.

Base point for DGNSS must be a fully known control point. Three types of points exist in Egypt and used as BASE points for DGNSS i.e., HARN (High Accuracy Reference Network), CORS, and NACN (National Agriculture Cadastre Network).

The new GNSS PPP technique is currently introduced to get the coordinates of unknown points. The main concept for PPP is based on the independence of rover point from base control point, that means safe in time and cost. This PPP technique has raised attention after IGS station published the precise products, clock correction and precise ephemeris for GNSS satellites (.clk .sp3) through the internet, these products are available with different accuracy at various times, rapid and final products are available within 1 to 7 days after observed day respectively.

The current thesis, introduces the problems associated with control points determination in remote areas in Egypt. The Single Point Positioning SPP based on using 24 hrs. GNSS observations and using broadcast and precise satellite ephemeris is to be investigated. The accuracy of SPP is to be determined compared with the long baseline with near IGS stations (international GNSS service) and using precise and broadcast ephemeris. The reliability (stability) of PPP was tested using test retest analysis method and using 13 GNSS sessions at the same point for 13 different days. The accuracy of PPP solution using RTKLIB software is to be studied based on different data. Finally, the accuracy of results for PPP solution is suggested to be improved with integrating DGNSS solution and PPP results.

1.3 OBJECTIVES

The main objective of the thesis is to check the reliability of a PPP solution in Egypt and compare it by the traditional DGNSS and SPP.

To reach this objective, the research addresses the following:

- Investigate the accuracy of SPP as a function of observing time, the combination between GPS and GLONASS data, and primary IGS precise orbit data.
- Investigate the accuracy of long baseline between IGS stations and occupied station as DGPS and compared with using DGPS with IGS precise orbit data.
- PPP accuracy solution compared with a DGNSS solution with post processed precise orbit data.
- Daily data was for a certain point (13 days) was to check PPP-RTKLIB reliability and accuracy in Egypt.
- Enhancement the Accuracy of PPP solution by way of combination between DGNSS and PPP solutions.

1.4 THESIS OUTLINE

This thesis is organized as follows:

Chapter 1 is the introduction to this research. It includes problem statement, research objectives, motivation, and thesis outlines.

Chapter 2 introduces GPS and GLONASS systems. The modernizations of GPS and GLONASS as well as their recent progress are described. Also comprehensive comparison between GPS and GLONASS systems. IGS was introduced and with its products and accuracies is given in this chapter.

Chapter 3 DGNSS technique is introduced and its technique in positioning such as single, double, and triple difference. PPP concept also introduced as a new technique in positioning with the traditional models and special mitigate models in PPP method.

Chapter 4 introduces the investigation and initial result of applied PPP theory and compared with long baseline DGNSS and SPP as traditional solutions, as well as, handling the comparison between GPS only and GPS/GLONASS PPP solutions

Chapter 5 introduces the PPP solution for four CORS stations in Egypt and the DGNSS solution for them, the comparison and integration between two solutions was listed and discussed, finally we check the accuracy and reliability of PPP solution using 13 days of observation for one BASE station inside Egypt.

Chapter 6 summarizes the final conclusion of the results, as well as the recommendation of future works.

CHAPTER TWO: GPS AND GLONASS SYSTEMS

Navigation satellites, such as Global Positioning System (GPS) and Global Navigation Satellite System (GLONASS), are used to determine the user position based on range measurements from satellite to user point. Assuming that the satellite is fixed at a certain second of observation and the range from the satellite to the receiver is measured, also the position of the satellite is well known from the center of gravity of the earth. Three vectors form the triangle from satellite to user and the C.G of the earth, and the unknown vector is from user to C.G of the earth which can be solved by observing at least four satellites ranges at the same epoch. Finally the position of the user is delivered with respect to World Geodetic System 1984 (WGS84), which is the reference of navigation satellites, in latitude, longitude, and height (Hein, 2000).

This chapter provides background on GPS and GLONASS and the various components that are typical and essential for Precise Point Positioning.

2.1 GPS SYSTEM

2.1.1 General Information

The global positioning system (GPS) is designed, built, operated and maintained by U.S Department of Defense (DoD), the first GPS satellite was launched in 1978. GPS system consists of three major sectors; space sector, ground control sector, and user sector (Boonsap, 2000).

Space Sector:

Space constellation has the following characteristics:

- 24 satellites
- 6 orbital planes, with four satellites per plane.
- 55 degree orbital inclination
- 20200 Km orbit height above the earth
- 11 hours 58 minutes satellite time to make one cycle around the earth
- Visibility of 4 to 6 satellites anywhere at any time of a day

Ground Control Sector:

The GPS ground control sector consists of a Master Control Station (MCS) and monitor (tracking) stations distributed around the world: The master control station is located at Schriever Air Force Base, in Colorado, United States, and is the central control node for the GPS constellation. Operations are maintained 24 hours a day, seven days a week.

The master control station is responsible for all aspects of constellation command and control, including the following: