QUANTIFICATION OF IONOSPHERIC SCINTILLATION ON GLOBAL POSITIONING SYSTEM (GPS)

CHIOW CHUN WEI

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Tajuk Projek : **QUANTIFICATION OF IONOSPHERIC SCINTILLATION ON GLOBAL POSITIONING SYSTEM (GPS)**

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Dedicated to my father, Chiow Choong Choon and my mother, Tan Lay Boey.

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ABSTRACT

The Global Positioning System (GPS) is used extensively in both the military and civilian communities for such diverse activities as navigation, surveying, remote sensing, asset management and precise timing. The tremendous popularity of GPS has stemmed from the low cost and small size of modern GPS receivers, and from the high accuracy and reliability of the system. The second factor has also resulted in GPS being considered as a sole means of navigation for critical safety of life applications such as precision approach and landing for air craft and narrow channel navigation for ships.

A number of environmental factors are known to affect the performance of GPS, including electromagnetic interference, multipath, foliage attenuation, atmospheric delays and ionospheric scintillations.

In this thesis, the ionospheric scintillation is examined by using filtering process.

ABSTRAK

Sistem Kedudukan Global (GPS) digunakan secara meluas dalam tentera dan komuniti awam dalam pelbagai aktiviti seperti navigasi, pengukuran, dan pengurusan asset. GPS semakin popular disebabkan oleh penerima GPS yang bersaiz kecil dan kosnya rendah. Selain daripada itu, ketepatan yang tinggi dan kebolehpercayaan GPS antara factor yang menjadikan ia semakin popular. Faktor kedua menyebabkan GPS dipertimbangkan sebagai cara tunggal untuk navigasi kerana untuk aplikasi keselamatan. Sebagai contoh, pendekatan tepat, pendaratan untuk kapal terbang dan pelayaran bagi kapal-kapal.

Beberapa factor persekitaran yang boleh mempengaruhi prestasi GPS ialah ganguan elektromagnetik, berbilang, pengecilan dedaun, kelewatan atmosfera dan scintillasi ionosfera.

Dalam thesis ini, scintilasi ionofera diuji dengan menggunakan proses penapisan.

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LIST OF ABBREVIATIONS

C/A Code	-	Coarse-Acquisition
DOP	-	Dilution of Precision
ECEF	-	Earth-Centered Earth-Fixed
ENU	-	Local or East, North, Up
GDOP	-	Geometric Dilution of Precision
GISTM	-	Global Ionospheric Scintillation & TEC Monitor
GPS	-	Global Positioning System
HDOP	-	Horizontal Dilution of Precision
LLA	-	Geodetic or Latitud, Longitude, Altitude
NBP	-	Narrow Band Power
P-code	-	Precise Code
PRN	-	Pseudo-Random Noise
RSS	-	Root Square Sum
SA	-	Selective Availability
SI	-	Signal Intensity
TEC	-	Total Electron Count
TOW	-	Time of Week
UERE	-	User Equivalent Range Error
WBP	-	Wide Band Power

CHAPTER 1

INTRODUCTION

This chapter will give an overview of the project such as project background, project objective, project scope, project methodology and a summary of this project. This chapter will explain briefly about the work from the beginning until this project is implemented.

1.1 Project Background

The ionosphere is a significant source of range errors for GPS users who require high accuracy measurements. After the turning off of Selective Availability on 1 May 2000, the ionosphere becomes the largest source of positioning error for satellite navigation. Scintillations are produced by changes in the phase velocity of parts of a satellite signal wave front as it propagates through irregularities in the ionosphere.

The Global Ionospheric Scintillation & TEC Monitor (GISTM), model GSV 4004, collects 50 raw GPS measurements a second. The 50Hz measurement includes the effects of integrated Doppler due to satellite motion, satellite clocks, user clocks, tropospheric delay, ionospheric effects and multipath.

1.2 Project Objective

The main target of the project is to quantify ionospheric scintillation (phase and amplitude) from 50Hz raw data. Besides, it is required to isolate the ionospheric effects from the 50Hz raw data GPS measurement by filtering process. Last but not least, this project aims to study the ionospheric scintillation on GPS receiver.

1.3 Problem Statement

The formation of the Ionosphere depends on the sun. The earth is bombarded continually by high energy radiation, travelling at the speed of light, and by high speed solar particles, mostly charged, which also travel at fairly high speed. Because the earth is moving through this soup of high speed particles, a supersonic shock wave is formed. The charged high speed particles, called the 'solar wind', would pass through the ionosphere and cause much damage if it was not for the earth's magnetic field, which is in turn present only because the earth (uniquely) has a molten iron core. Because the solar wind particles are charged, they are deflected around the earth by the magnetic field. Some enter the Polar Regions to form the auroral layers, but the Magnetosphere, the area where the earth's magnetic field is active, deflects most particles away.

Most of the upper atmosphere ionization results from the interaction with the upper atmosphere gases by powerful UV and X-Rays, which are not affected by the magnetic field. Electrons are split from these gas atoms, leaving active and highly mobile electrons and larger less mobile charged ions. The area of ionization extends from about 60km above the earth, out to about 500km.

The rate of ionization depends on the density of atoms and intensity of radiation, but it also depends on the actual chemistry involved. Some reactions take place quickly, or cause higher ionization, while others act more slowly or result in less ionization.

The rate of subsequent recombination depends only on the density of the ionosphere (how close the atoms are), and what the chemical process is. The sun has little to do with it. So, the electron concentration varies with height, giving us different layers, affected in different ways by the sun, and with different radio properties.

The ionosphere changes by at least 1 order-of-magnitude over the cause of each day. Ionospheric effects on Global Position System (GPS) encompass group delay, scintillation, Faraday rotation, signal propagation delay, ionospheric (magnetic) storms, equatorial (Appleton) anomalies, equatorial depletions (plasma bubbles).

Scintillation is a rapid phase and amplitude fluctuation of radio signals caused by variability in the ionosphere. Although scintillation is more severe during a solar maximum, it can occur at almost any time, particularly in the low latitudes, kicking in shortly after local sunset and lasting until just after local midnight.

Scintillation affects both single and dual frequency GPS receivers in that it prevents the receivers from tracking the signals. No radio signals passing through the ionosphere are immune; for GPS users, scintillation affects both the GPS signals and the communications from the geostationary satellites used to deliver GPS augmentation corrections.

At its worst, scintillation impacts, often dramatically, the performance of all space based communication and navigation system.

1.4 Project Scope

Basically, the scope of work is divided into three parts which are: filtering, measure scintillation parameter (amplitude & phase) and comparison with the index file.

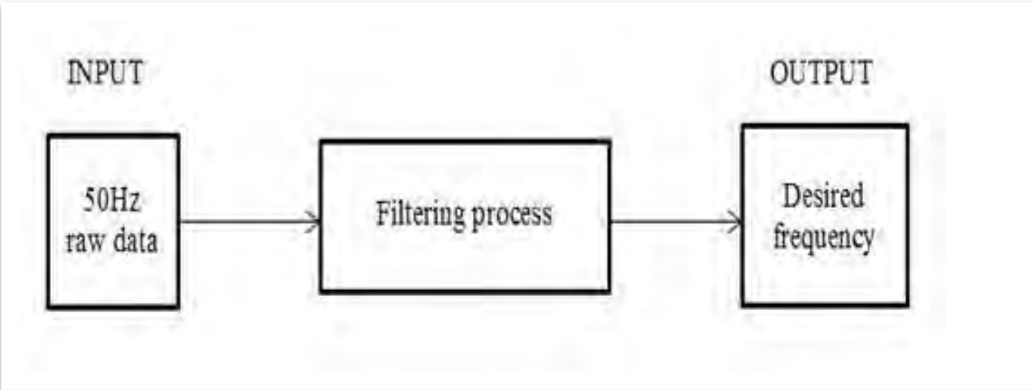

Figure 1.1: Basic Project Block Diagram

1.4.1 Filtering

This is the main part of the project where it is required to design the 3 x 2nd Butterworth filter by using Matlab.

1.4.2 Measure Scintillation Parameter

There are two scintillation parameter namely amplitude parameter and phase parameter. This part is a continuous from the previous filtering process where the output from the filter is determined.

1.4.3 Comparison with Index File

In this part, compare the result from the second part with the index file.

1.5 Methodology

The objectives and purpose of the project had been discussed with the supervisor to make sure fully understanding of the project.

After the project was fully understood, the information and data about the project was collected from the paper study, reference book, and web. The information and the data are studied in order to understanding the specification, the filter and the concept of the filter.

Next, planning of scope of work is done by listing out all the procedures. Firstly, design the Sixth-order Butterworth filter and study about the algorithms need to apply in the filter. Next, develop algorithms by using Matlab software to normalize 3000 data for 1 minute. Lastly, compare the normalize result with the index and analyze the result.

1.6 Thesis Outline

This thesis consists of five (5) chapters; introduction, literature review, methodology, result and discussion. The first chapter is an introduction in which the chapter will provide a brief description of the project is implemented such as the background, problem statement project objectives, project scope, and methodology.

In chapter 2, literature review is discussed where the information from reference book, web and paper study is used as the guide for this project.

The third chapter is a methodology where it will describe the methods and technique selected for implementation of the previous chapter with in depth. In this chapter, it provides the material and equipment were used to doing this project.

The forth chapter is a chapter that will explain the expected result and analysis of the project that that have been studied. From the result, the analysis will be done to see the project is function properly.

The last chapter in this report is conclusion and recommendation. In this chapter, conclusion is made on achieving the objective of the project.

CHAPTER 2

LITERATURE REVIEW

This chapter discusses the theories was used in this project. It used as guideline during this project was do and all theory and research are related with this project.

2.1 Introduction to GPS

2.1.1 Global Positioning System Acronym Nouns

Global Positioning System. A network of satellite that continuously transmit coded information, which makes it possible to precisely identify location on earth by measuring distance from satellites.

2.1.2 History

The Global Positioning System is a space-based navigation and positioning system that was designed by the U.S. Military to allow a single soldier or group of soldiers to autonomously determine their position to within 10 to 20 meters of truth. The concept of autonomy was important in that it was necessary to design a system that allowed the soldier to be able to determine where they were without any other radio communications. In other words, with a single, one-way receiver whose use could not be detected by potential hostiles. Since the U.S. Military is truly a global force, it was further necessary that the system provide worldwide coverage, and that the coverage be available 24 hours a day. At the same time, it had to be militarily safe in that the U.S. Military had to have the ability to deny any hostiles' use of the system without degrading their own use. Ultimately, it is planned that each soldier and each military vehicle will be equipped with a GPS receiver. Therefore, it was necessary that the receivers be sufficiently low in cost to meet this end. Once all soldiers are so equipped, dependence on all other systems could eventually be phased out.

2.2 The Global Positioning System

The first step toward exploring the scintillation on GPS requires an understanding of GPS itself. A constellation of 24 operational GPS satellites surrounds the Earth at an altitude of 20,200 km, in six orbital planes, with an orbital period of 12 sidereal hours. As we imagine the satellites orbiting overhead, several questions come to mind. For instance, how is satellite signals used to determine location? What coordinate systems are used? The signals emitted by the GPS satellites are complex, carrying a great deal of information. Additionally, errors from a variety of sources accumulate as signals travel from the satellites to a receiver and are processed; these must be accounted for. The errors, in turn, influence the precision of the location estimate.

2.2.1 Determining Location

One method of determining location involves transmitting a signal and recording the precise time the signal was sent from the transmitter and the precise time it arrives at a receiver. With knowledge of the signal's velocity through the transmission medium, the range can be extracted. For electromagnetic waves in a vacuum, ignoring relativistic effects and assuming a fixed transmitter and receiver, the distance to the transmitter to the receiver is given by d = ct where c is the speed of light and t is the travel time for the signal to reach the receiver. At this point only the distance from a particular transmitter is known, but not yet the location. Two additional transmitters are needed to produce a unique solution (location). With signals from all three transmitters providing the range to each, the relative position can be determined. The intersection of three circles, each centred on a transmitter with a radius equal to the calculated range, provides the position to the transmitters (for a two dimensional case). This assumes perfect synchronization of all three transmitter clocks and the receiver clock. This case can easily be extended to three dimensions by replacing the circles with spheres.

In practice, GPS receiver clocks are less accurate and not synchronized with the satellites, so clock error, δt, is introduced. This is the offset between the receiver clock and the satellite clock [1]. The distance equation becomes

$$d=d+c\delta t \qquad (2.1)$$

The distance is typically referred to as range, and range with clock error is called pseudo–range, denote by ρ. The consequence of clock error is to require a fourth satellite to accurately determine position. Returning to the three circles and introducing a fourth, the position is now at the centre of a fifth circle, tangent to the other four. The radius of the fifth circle represents the ▲d introduced above. Again, this can be extended to three dimensions.

Approaching the problem from another perspective, in order to know location in three dimensions, three coordinates, x, y, and z are required. With three unknowns, three versions of equation (2.1) are needed to solve for d, hence signals from three satellites. Having introduced a fourth unknown δt, four equations (and consequently four satellites) are necessary in order to produce a navigation solution.

Until now the discussion of pseudo-ranges to GPS satellites has taken place in a Cartesian reference frame cantered on the user. In the long run however, the typical GPS user is not concerned with his or her position relative to a constellation of GPS satellites, but rather his or her position with respect to Earth or locations on the Earth. Before moving further, therefore, three coordinate systems are introduced and discussed.

2.2.2 Coordinate System and Transformation

We are interested in three coordinate systems:

- Earth–Centered Earth–Fixed (ECEF)
- Geodetic or Latitude, Longitude, Altitude (LLA)
- Local or East, North, Up (ENU)

ECEF is a Cartesian reference frame centred on, and rotating with, the Earth. The LLA frame is based on the World Geodetic System 1984 WGS-84 ellipsoid, a global three-dimensional coordinate system used with geospatial data. In the simplest terms, the Earth is represented by a sphere that's"squashed" at the poles and bulges at the equator. The latitude (φ), longitude (λ) and altitude (m), with respect to the ellipsoid, determines position. Finally, the ENU frame is fixed to a point and oriented east, north and up. Later it will be necessary to rotate coordinates from an ECEF to an ENU framework. The ECEF coordinates must be adjusted with respect to the origin of the local level frame. Placing the satellites, as well as the receiver in a particular reference frame is essential because, as noted [1].

"*For single receiver positioning, an orbital error is highly correlated with positional error.*"

Information about a satellite's orbit, also known as ephemerides, is typically obtained from one of three sources, almanac files, broadcast ephemerides and precise ephemerides. Ephemerides allow a satellite to be placed in the desired reference frame. Of the three sources, almanac data are the coarsest with an uncertainty of some kilometres. It is updated weekly at a minimum and included in the broadcast satellite message [1].Software used for this research ingested almanac data in YUMA format (one of two almanac formats) available from the United States Coast Guard Navigation Centre at http://www.navcen.uscg.gov/gps/almanacs.htm.