Faculty of Engineering

# COMPARISON OF THEORETICAL TOTAL ELECTRON CONTENT (TEC) DURING DISTURBANCE

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Bachelor of Engineering with Honors
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Judul: **COMPARISON THEORETICAL MODEL TOTAL ELECTRON CONTENT (TEC) DURING DISTURBANCE**

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Title : Comparison of Theoretical Total Electron Content (TEC) during Disturbance

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# COMPARISON OF THEORETICAL TOTAL ELECTRON CONTENT (TEC) DURING DISTURBANCE

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# ABSTRAK

Lapisan ionosfera sangat penting bagi sistem komunikasi dan jumlah kandungan elektron (*Total Electron Content, TEC)* memainkan peranan yang penting dalam membuat kajian tentang peranan 'ionospheric'. Projek ini melibatkan perbandingan terhadap jumlah kandungan elektron (*Total Electron Content, TEC)* menggunakan model secara teori dan data yang asal, semasa berlakunya gangguan merujuk kepada keadaan tanpa gangguan dan keadaan dengan kehadiran gangguan di kawasan khatulistiwa dan kawasan garis lintang tengah. Jumlah kandungan elektron (*Total Electron Content, TEC)* ini dikesan dengan menggunakan dua model iaitu *International Reference Ionosphere 2001* secara versi tingkap (IRI-2001) dan *NeQuick* menggunakan contoh pemacu slQu.exe. Kedua-dua model ini merupakan model yang mengikut standard yang ditentukan oleh International Telecommunication Union-Radio Sector (ITU-R). Data asal dalam format *IONospheric map exchange* (IONEX) daripada *Centre for Atmosphere Determination (CODE)* akan digunakan sebagai perbandingan. Keputusan menunjukan nilai jumlah kandungan elektron di kawasan khatulistiwa lebih tinggi berbanding dengan kawasan garis lintang tengah. Dicadangkn untuk pembaikan, kedua-dua model teoritis (IRI-2001 dan NeQuick) harus memasukkan gangguan "*ionospheric"* supaya kiraan jumlah kandungan elektron yang lebih tepat.

# ABSTRACT

The ionosphere layer is very important to the communication system and the Total Electron Content (TEC) plays an important role in the study of ionospheric behavior. This project involves the comparison of TEC simulated using theoretical models and real data during the disturbances due to geomagnetic quiet and the disturbed day at Equatorial region and Middle Latitude Region. Prediction of TEC is carried out using two theoretical models which are International Reference Ionosphere 2001(IRI-2001) PC using window version and NeQuick using the sample driver's slQu.exe. Both theoretical models are the standard model available from the International Telecommunication Union-Radio Sector (ITU-R). The real data in the form of IONospheric map Exchange (IONEX) from the Centre for Atmosphere Determination (CODE) is used for comparison. Results show that the TEC values for Equatorial Region is higher than the Middle Latitude region. It is recommended that for undergo improvement, both theoretical models (IRI2001 and NeQuick) should include ionospheric disturbance for more reliable TEC calculation.

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# ABBREVIATIONS

| | |
|---|---|
| AGWs | Atmospheric Gravity Waves |
| CCMC | Community Coordinated Modeling Center |
| CCIR | International Radio Consultative Committee |
| CODE | Centre for Atmospheric Determination |
| COSPAR | Committee on Space Research |
| DGR | Di Giovanni and Radicella |
| EDP | Electron Density Profile |
| EGNOS | European Geostationary Navigation Overlay Service |
| ESA | European Space Agency |
| EUV | Extreme Ultraviolet |
| FAIM | Fully Analytical Ionospheric Model |
| GPS | Global Positioning System |
| H | Hydrogen |
| He | Helium |
| HF | High frequencies |
| ICTP | International Centre for Theoretical Physics |
| IONEX | IONospheric map Exchange |
| IRI | International Reference Ionosphere |
| ISIS | International Satellites for Ionospheric Studies |
| ITUR | International Telecommunication Union |
| LSTIDs | Large Scale Travelling Ionospheric Disturbances |

| | |
|---|---|
| MSTIDs | Medium Scale Travelling Ionospheric Disturbances |
| $N_2$ | Nitrogen |
| NOAA | National Oceanic and Atmosphere Administration |
| NSSDC | National Space Science Data Center |
| O | Oxygen |
| PCA | Polar Cab Absorption |
| PWs | Planetary Waves |
| SLIM | The Semi-Empirical Low-Latitude Ionospheric Model |
| SID | Sudden Ionospheric Disturbance |
| SSN | Solar Sunspot Number |
| SSTIDs | Small Scale Travelling Ionospheric Disturbances |
| TEC | Total Electron Content |
| TID | Travelling Ionospheric Disturbance |
| URSI | International Union of Radio Science |
| UV | Ultra Violet |
| WAAS | Wide Area Augmentation System |

# CHAPTER 1

# INTRODUCTION

## 1.1 Chapter Introduction

The ionosphere is another atmospheric layer, where represents less than 0.1% of the total electron mass of the earth's atmosphere [1] .The ionosphere regions are broken down into four major layers which are C, D, E and F-layers. Each layers has different approximate height range where C-layer (40-50 km), D-layer (50-90 km), E-layer (90-140 km) and F-layer (140-500 km). The solar wind strongly influences the structure of the ionosphere [2].

From the layers mention above there are a lot of benefit which is their characteristic can influence the reflection of radio wave signal due by the electron content of the layers which is different either during daytime or nighttime. Actually the plasma of ionized gas of the upper atmosphere by solar radiation and high energy particles from the Sun is about 60 km to 1000 km above the earth's surface. The ionized electrons concentrations is depending to the height above earth's surface, location, time of delay, season and amount of solar activity. To determine the state of the ionospheric activities the electron density plays the main important physical in ionosphere. It is also important for predicting space weather and disturbance due to geomagnetic and solar flares [3].

There are many disturbance influences by ionosphere due the solar activity such as *Sudden Ionospheric Disturbance (SID), Ionospheric Storms, Polar cab absorption (PCA), Travelling Ionospheric Disturbance (TID)* and *Earthquake.* This project focuses on the earthquake disturbance, where the earthquake occurs when the rock underground suddenly breaks along a fault because the suddenly release of energy can causes the seismic waves that make the ground shake [4].

Total electron content (TEC) is an important parameter for the ionosphere of the Earth. TEC is the total number of electrons in a cylinder centered on the line of sight between the two points, with units of electron per square meter, where $10^{16}$ electron/$m^2$ equal to 1 TEC unit and measured in TECU and commonly in the range between $10^{15}$ and $10^{18.}$ Generally TEC is minimal during midnight and is maximal around local noon [5].

The main aim of this project is to do simulation during the ionospheric disturbance using two theoretical models which are International Reference Ionosphere (IRI-2001) and NeQuick-ITUR. The result from that models were calculated and compared with the real data in the form of IONospheric map Exchange (IONEX).

## 1.2 Project Objectives

This project concentrates on the following objectives:

I. **To analyze total electron content (TEC) using models on different selected period.**

In this project the ionosphere models such as International Reference Ionosphere (IRI-2001) windows version and NeQuick-ITUR are used to predict the value of TEC during the normal quiet day and the disturbed time.

II. **To compare the result with the actual data called IONospheric map Exchange (IONEX).**

The simulation from the two models above was compared with the actual data in format of IONEX. These data was downloaded from the Centre for Atmospheric Determination (CODE) website. Then, the results were compared to the solar sunspot number (SSN), $R_{12}$.

III. **To simulate the result during normal and disturbance time.**

During normal time and disturbance time, the values of TEC are different. The values of TEC was calculated and simulated on the day before the disturbance time and the result was compared with the result during the disturbance time.

IV. **To analyze advantages and disadvantages of the models as a reference during the ionospheric disturbance.**

## 1.3 Problem Statement

The main expected problem that will be encountered in this project is come from the calculation of IONEX data. The data produced by the Centre for Atmospheric Determination (CODE) not accurate latitude and longitude with the latitude and longitude in study which is LAT1 is 87.5 until LAT2 is -87.5 with DLAT are -2.5. While the LON1/LON2/DLON is -180 and 180.

## 1.4 Proposes Solution

The solution accurate latitude and longitude can be solved by using the interpolating processes between the two latitude and longitude. The other solution can be used which is by introduces appropriate software programming to extract the values of the TEC.

## 1.5 Project Scope

This project involves the simulation and analysis from the different models such as International Reference Ionosphere (IRI-2001) using PC windows version and NeQuick- ITUR, these models were used to calculate and compare the theoretical total electron content (TEC) with the real value in the format of IONEX. The simulation and analysis was done during the ionospheric disturbance at places located in the middle latitude region comparing to the equatorial region.

## 1.6 Project Outline

Chapter 1 briefly introduces ionosphere layer, TEC, ionosperic disturbances, aim of the project, project scope and objective.

Chapter 2 is explains, summarizes and reviews the overall studies and researches which are related to the project. In this chapter the ionosphere layers, ionospheric models, electron density, electron content (TEC), ionospheric disturbance also are discussed.

Chapter 3 describes the method that is used in this project. In this project the ionospheric models are used IRI-2001 and NeQuick-ITUR for predicting the value of TEC during the quiet normal days. Then the predicted data are compared with actual data in the format of IONEX reference to solar flux number, $F_{10.7}$ or sunspot number, $R_{12.}$

Chapter 4 consists of the results, analysis and discussion. This chapter exhibits the results and data obtain from the IRI and NeQuick simulation process. The results are compared with the real data from the IONEX. It also examines whether the simulation results fulfill the predicted or expected results as mention in the early part of the project.

Chapter 5 concludes the overall finding of the project. In addition, further works which can are implemented or future improvement of the project will be discussed.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Chapter Introduction

This chapter is explained, summarizes and reviews the overall studies and researches which are related to the project. In this chapter the ionosphere's layers, electron density, sunspot number (SSN), $R_{12}$, Total Electron Content (TEC), ionospheric models and ionospheric disturbance were discussed.

## 2.2 The Ionosphere

The Earth's atmosphere is divided into several altitude regions, where is defined by the neutral temperature gradients. The lowest region in the Earth's atmosphere is the troposphere with 10 km distance from the surface and containing about 75% of the total mass of the atmosphere. The upper atmosphere and the ionosphere are important because they are absorbing the dangerous solar radiation before it reaches the surface. As shows as figure 2.1, from 60 to 1000 km is the region of the atmosphere where sufficient number of ions and free electrons is are exist to effect the propagation of radio waves [6].

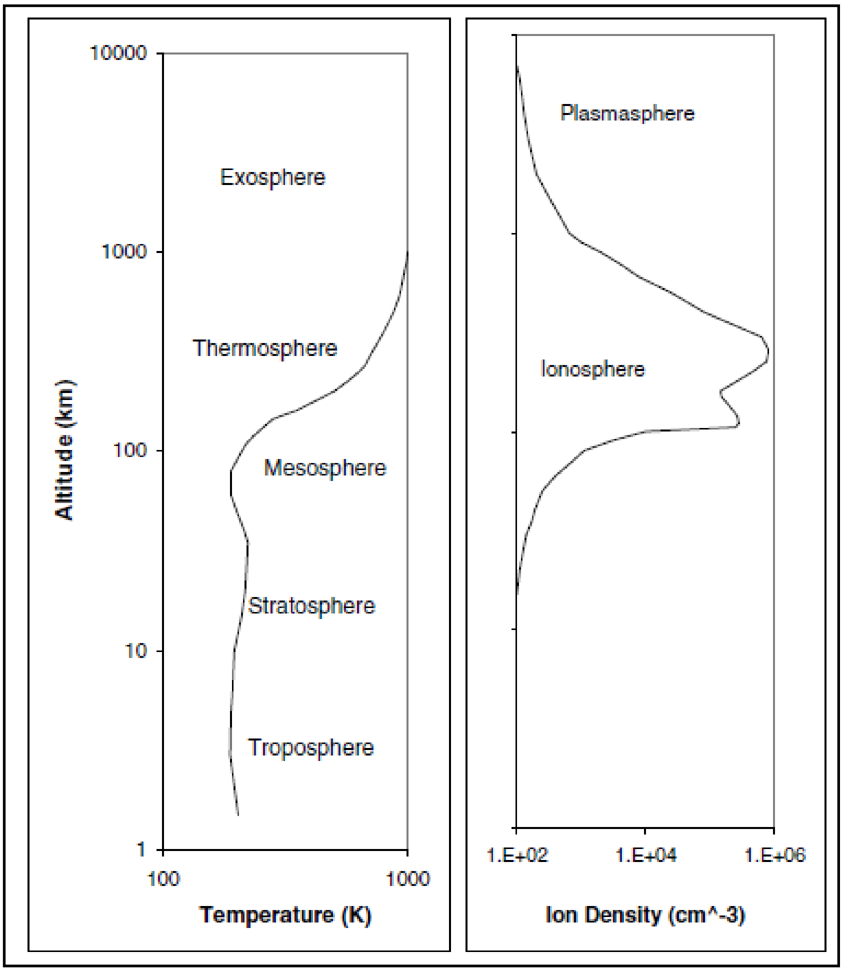


Figure 2.1: Atmospheric Layers [6].

The earth's ionosphere strongly ionised at approximately 90 km. The electrons release the gas molecules and resulting in ions. The plasma is containing the number of positive ions and the negative particles, which is the most common state of the universe. Below the 200 km is represent by the molecular oxygen ($O_2$) and nitrogen ($N_2$), while above the 200 km is represent by the atomic oxygen (O) and above the 600 km altitude is referring to hydrogen (H) and Helium (He). The ionosphere can carry electrical currents as well as reflect, deflect and scatter radio waves. [7].