NIGHTTIME D-REGION IONOSPHERIC CHARACTERISTIC FROM TWEEK ATMOSPHERIC OBSERVED IN THE MID LATITUDE REGION.

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Special dedicate to my family, supervisor, and all my fellow friends to help me to accomplish my report.

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ABSTRACT

Tweek atmospheric is an electromagnetic pulse originating from the return stroke of lightning. The signal is propagate by multiply reflection from boundaries of the natural waveguide formed by the Earth's surface and the lower boundary of the ionosphere layer with small plasma density (1-100cm^{-3}). The majority of this energy is concrete in the range of extremely low frequency (ELF: 3-3000 Hz) and very low frequency (VLF: 3-30 kHz) bands. It is difficult to do the measurements in the D-Region Ionosphere due to the altitude is about 60 km in the daytime and increase up to 95 km in the nighttime. Tweek atmospherics has been used to estimate the nighttime D-region Ionosphere reflection height (*h*), equivalent electron density (*ne*) at reflection height and the propagation distance (*d*) travel by the signal. Then the characteristic of tweek will be compare between different stations in low and mid latitude region, and the finding will be developed using Graphical User Interface (GUI) in MATLAB. The electromagnetic propagation model is used in order to study present the nighttime variation of tweek in this region. This study present the nighttime D-region ionosphere characteristic of tweek observed at USA mid latitude ground station of Juneau (58°23''00''N, 134°11''00''W) during February 2011 and March 2011. The maximum mode number of tweek found in this study is three. Analysis of 620 tweek demonstrates that these ELF/VLF signals travel considerable distance up to 7000km from the causative lightning discharge. The estimated equivalent electron density at the reflection varies from 22.52 to 30.03 el/cm^3. The reflection height is found in the altitude ranged of 70 to 91 km.

ABSTRAK

Tweek atmosferik merupakan gelombang elektromagnet yang berasal dari pancaran kilat. Isyarat disebarkan melalui pelbagai pantulan daripada permukaan bumi dan bahagian paling rendah dalam lapisan ionosfera dengan julat plasma adalah (1-100cm^{-3}). Majoriti tenaga yang dihasilkan adalah dalam julat frekuensi yang sangat rendah iaitu (ELF: 3-3000 Hz) dan frekuensi rendah (VLF: 3-30 kHz). Adalah sukar untuk melakukan pengukuran dalam Ionosfera bahagian-D kerana ketinggiannya kira-kira 60 km pada waktu siang dan meningkat sehingga 95 km di waktu malam. Tweek atmosferik telah digunakan bagi menganggarkan ketinggian pantulan isyarat pada waktu malam di bahagian D Ionosfera (*h*), ketumpatan electron (*ne*) dan jarak isyarat kilat (*d*). Kemudian ciri-ciri tweek dibandingkan antara stesen yang berbeza di kawasan latitud rendah dan pertengahan serta hasil akhir akan diaplikasikan menggunakan perisian grafik (GUI) di dalam MATLAB. Model penyebaran elektromagnetik digunakan bagi mengkaji kewujudan dan kepelbagaian tweek pada waktu malam di bahagian latitude pertengahan ini. Kajian ini menerangkan ciri-ciri tweek di bahagian-D pada waktu malam yang telah dijalankan di pertengahan latitud USA Juneau (58°23’’00’’N, 134°11’’00’’W) pada bulan Februari 2011 dan Mac 2011. Bilangan mod tweek yang paling tinggi dijumpai dalam kajian ini adalah tiga. Analisis menunjukkkan 620 tweek iaitu isyarat ELF/VLF bergerak sejauh 7000 km daripada jarak kilat berlaku. Anggaran ketumpatan electron adalah sebanyak 22.52 sehingga 30.03 el/cm^3. Ketinggian pantulan berada pada jarak 70 hingga 91 km.

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LIST OF ABBREVIATION

WWLLN: World Wide Lightning Location Network

QTM: Quasi-transverse magnetic

QTE: Quasi-transverse electric

QTEM: Quasi-transverse electromagnetic

TM: Tranverse magnetic

GPS: Global Position System

ELF:Extremely low frequency

VLF:Very low frequency

GUI:Graphical User Interface

UTC:Universal time centre

IC: Intra cloud

CG: Cloud to ground

C:Speed of light

f:Frequency

fcm:Cutoff frequency

k:Boltxamann constant

ne:Electron density

V:Electron velocity

Vg:Group velocity

Vp:Phase velocity

d:Propagation Distance

h:Reflection height

m:No of mode

CHAPTER I

INTRODUCTION

1.1 BACKGROUND

Lightning usually occurs in conjunction with thunderstorms and is the result of the accumulation of a large electric charge in cumulonimbus clouds. However, stratocumulus and other cloud types can potentially cause lightning such as snowstorms, volcanic emissions or dust storms [1]. When the negative charge in a cloud becomes great enough, it seeks an easy path to the positively charged ground below. The current looks for a good conductor of electricity or a tall structure anchored to the ground such as a tree or a tall building. The negative charge sends out a feeler called a stepped leader that is a series of invisible steps of negative charges. When the stepped leader approaches the ground, positive streamer reaches up for it. A return stroke runs from the ground to the clouds in a spectacular flash.

Lightning discharge from thunderstorm is one of the most significant sources of electromagnetic radiation, which is the energy of these pulses vary over a wide frequency range from a few Hz to several MHz. The maximum radiated energy is confined in extremely low (ELF: 3-3000Hz) and very low (VLF: 3-30 kHz) frequency bands [2]. The electromagnetic pulses that generate from lightning discharge are called as radio atmospheric or “sferics”. These waves propagate by the process of multiple reflections through the boundaries of the waveguide formed between the ground and the lower region of the ionosphere [3]. This waveguide mode propagation causes an appreciable dispersion near the cutoff frequency of EIWG around 1.8kHz. This dispersed sferics is known as “tweek atmospheric” [4].

Tweek atmospheric is an electromagnetic pulse originating from the return stroke of lightning. The signal is propagate by multiply reflection from boundaries of the natural waveguide formed by the Earth’s surface and the lower boundary of the ionosphere layer with small plasma density (1-100 cm^{-3}) [5]. As these waves show dispersion near cutoff, thereby it accurately analyzing first order mode cutoff frequency. The correlation between sferics and the lower ionosphere makes them a useful tool for ionospheric D-region remote sensing.

This study present the nighttime D-region ionosphere characteristic of tweek observed at USA mid latitude ground station of Juneau (58°23’00’’N, 134°11’00’’W). The electromagnetic propagation model is used in order to study the nighttime variation of tweek in this region. Tweek also have been utilized to estimate the nighttime D-region ionosphere reflection height, equivalent density and the distance travel by the signal in EIWG.

The data collection February until March it is 620 that have be collected from 3:00 to 15:00 UTC. The analysis of tweek atmospheric indicated that mostly tweek occurred during the night. The observation in nighttime D-region, maximum mode number at Juneau is three. The data of tweek atmospheric in February is higher than March. Using VLF Stanford university the data is collect every five minutes that have been save in mat-file and MATLAB software use to simulate and get the spectrogram. To get an accurate cut-off frequency, GetData Graph Digitizer software is uses. The results obtained shows the usefulness of lightning generated tweek atmospheric in studying lower boundary D-region ionosphere covering large geographical area in the range of 432-7000 km from the observation site.

1.2 PROBLEM STATEMENT

The characteristics of D-region ionosphere using tweek atmospheric have been investigate by a number of authors (Ohtsu, 1960,Yano et al ,1989,1991, Hyakawaet al, 1994,1995, Sukhorukov, 1996, Farenez et al 2007, Reznikov et al 1993, Ohya et al, 2003) state that the altitude of the D-region ionosphere is too low for satellite measurements of electron density and too high for balloon measurements. Therefore, a make the rocket has been used but the timing of flights restricts rocket experiments. Grounded based active experiments using ionosondes and incoherent scatter radars in the HF-VFF range can be conducted at any time, but these method cannot received ionospheric enchoes due to the low electron densities about $<10^3$ el/cm^3 in the D-region ionosphere.

The measurement of the D-Region is facing a difficult problem from the point of height typically about 60km during the daytime and increase to about 95km during the nighttime. Previous measurement, they are using radar to measure an electron density of D-region but the facility to build is quite expensive and it is require high cost of regular operations for active radio measurement. Therefore, it is important to have a measurement that is lower in cost and capable to the signal to propagate in very wider area.

1.3 SIGNIFICANCE OF STUDY

The significance of this project is these signal can penetrate into seawater that has led to their use over the past several decades for communication with submerged submarines at long distances. Besides that, it also can be used for worldwide communications since the signals are guided between the Earth and the lower ionosphere and can send the signals around the planet. Then, Lightning geolocation is a lightning detection network capable of locating lightning flashes on a global scale with an accuracy usually associated with dense medium-range networks.

After that, Ground-to-satellite communication that is ELF/VLF waves give us the only reliable and continuous means of monitoring the lower ionosphere, and thereby, inferring communications outages. For instance, we can monitor ionospheric communication outages from gamma ray bursts from outer space. In addition, significance of tweek atmospheric also to use for satellite protection it is ELF/VLF waves from lightning has been shown to be a key driver of the removal of these trapped particles by propagating as a `whistler' wave through the magnetosphere and the Stanford ELF/VLF. Lastly, it also used for Subterranean mapping ELF/VLF waves may in fact be the most reliable means of subterranean mapping or detecting underground structures.

1.4 OBJECTIVES OF STUDY

The main goal of this project is to study characteristic of D-region ionosphere at mid latitude region of Juneau. This project goal is supported by the following objectives:

1. To estimate the nighttime D-region Ionospheric reflection height (h), equivalent electron density (ne) at reflection height and propagation distance (d) propagated by the tweeks in the EIWG.
2. To compare the characteristic of tweek between different stations in low and mid latitude region.
3. To develop Graphical User Interface (GUI) in MATLAB.

1.5 SCOPE OF STUDY

This project is cover by the observation of tweek atmospheric recorded at mid-latitude D-region ionosphere at Juneau in Alaska station (58.23˚N, 134.11˚W) during February 2011 to March 2011. The analysis of data will be recorded between 18.00-06.00 AKDT (03.00-15.00 UTC) using Stanford University developed AWESOME VLF receivers installed in station of Juneau. The data will be used to measure the D-region ionosphere parameters and one-minute data is used to represent the hour of observation. Measurements of tweeks are made during nighttime because of lower attenuation. Lastly, results will be interpreted using Graphical User Interface (GUI) in MATLAB.

1.6 CHAPTER ORGANIZATION

This report is organized into five chapters. All the summary of each chapter are describe as following.

Chapter 1: This chapter will give an overview about the project include the project background, problem statement, significant of study, objectives and scope of project. This chapter will explain briefly about the background of this project.

Chapter 2: This chapter is described about the previous studies, researches and readings process that have been carried out. To supported and understand the literature review of the project.

Chapter 3: This chapter discusses about the methods of investigations, methodology, analysis process and focuses on the designing the system through the methods selection from Chapter 2. This chapter also explains about the method used to analyze the result and provides a technique used to develop Graphical User Interface (GUI) in MATLAB

Chapter 4: This chapter is about result and discussion. This section will explain about the finding of this project and analysis of result.

Chapter 5: This is the final stage which is summarizes the overall process and performance of the project. In addition, it also being discussed the future works that can be improved for future studies based on the results.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is described about the previous studies, research and readings process that have been carried out. It also describes the lightning activity occur in Juneau, Alaska. Thunderstorm and lightning are rare in Southeast Alaska when compared with the Alaska Interior and most of the lower 48. It usually observed along the Outer Coast as strong cold fronts move in form the Gulf of Alaska. Interestingly these storms can occur during the winter month as well as during summer. On some occasions, thunderstorms can develop or spread over the Inner Channel of a Panhandle. The last time this occurred was in June of 2000 when an outbreak of scattered thunderstorms moved through the Juneau area.

In the Alaska, the lightning is responsible about 97 percent of the average lost to wildfires. BLM sensors positioned across the interior have located an average of 26,000 clouds to ground lightning strike per year. The active thunderstorms are 2000 to 5000 lightning strikes that mainly occurring during the late afternoon hours in late

February and early March. The most active thunderstorm area in Alaska based on cloud to ground lightning strikes is the White Mountains north of Fairbanks.

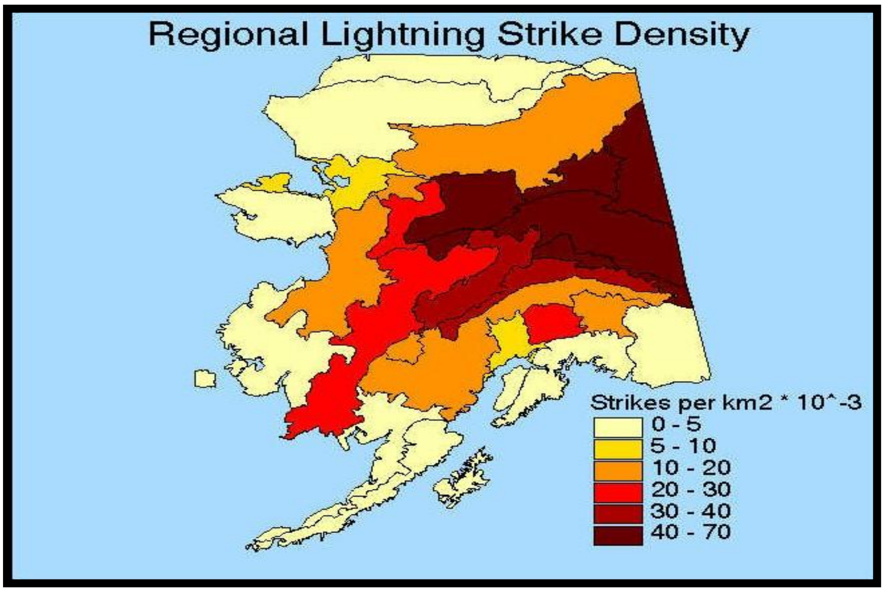

Figure 2.1: Region of lightning in Juneau, Alaska (that is lightning strikes per km^2 (10^{-3}) in the state Alaska)
source [8]

2.2 LIGHTNING

Lightning is an electrical discharge that partially neutralized in a cloud. Lightning discharge produced an electromagnetic pulse due to rapid lightning current pulse that radiates primarily in very low frequency (VLF) part of a spectrum [4]. The channel of lightning current is produced electromagnetic radiation at all frequencies from a few Hz through to the optical band [22]. The different type of lightning detection network also measured specific portion of the electromagnetic spectrum with associated to set of benefits and trade off. Lightning is the transient, high current electric discharge whose path length that generally measured in kilometers. Extracting useful energy from lightning appears to be impractical. The total energy in each cloud to ground lightning flash is only about 360 kilowatt-hours approximately the energy required to operate five 100-watt light bulbs continuously for one month. The energy of lightning is one thousandth to one hundredth to deliver to the strike