OBSERVATIONS OF D-REGION IONOSPHERE USING TWEEK ATMOSPHERIC AT LOW LATITUDE

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To my beloved Father and Mother

May their soul rest in peace

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ABSTRACT

Tweek atmospherics are electromagnetic pulse signals launched by individual lightning discharges with certain frequency dispersion characteristics at D-region ionosphere. The return strokes of lightning discharges are powerful transmitter of electromagnetic energy over a wide electromagnetic spectrum extended from few Hz to few tens of MHz. Tweeks are observed during nighttime to study the characteristic of D-region parameters in low latitude region. Previously, the measurement of tweek facing many problems in term of high cost and limitation of the signal path to propagation Earth-Ionosphere Waveguide (EIWG). The new technology has been developed to overcome this problem by using AWESOME VLF Receiver. This project is to estimate the night-time ionospheric reflection height (*h*), the D-region equivalent electron density (*ne*), and tweek propagation distance (*d*) from the causative lightning discharge at a low-latitude station. This study analyzes the characteristics of tweek between different stations in low and mid-latitudes and the finding will be developing using Graphical User Interface (GUI) in MATLAB. In the present study tweeks recorded during the night of August to September 2010 at low latitude ground station Allahabad (16.49N; 155.34E). Tweeks up to 4rd modes were observed. Total of 1518 tweeks that occur randomly from first mode until forth mode were extracted from the spectrogram and classified according to their harmonic mode numbers. Tweek duration decreases as mode number increases. Moreover, the distribution of tweek mode numbers reveal that the occurrence of tweeks significantly drops as the mode number increases. It is estimated that the ionospheric electron density varies from 22 to 27 el/cm^3 at the altitude of 79-91 km during the local night. The maximum tweeks having propagation distance in the Earth-ionosphere waveguide from source to receiving station varying in the range of 560-4166 km

ABSTRAK

Tweek atmosferik merupakan gelombang elektromagnetik yang dilancarkan oleh pancaran kilat tertentu dengan ciri-ciri penyebaran frekuensi tertentu di Ionosfera bahagian-D. Pancaran kilat berfungsi sebagai pemancar berkuasa tenaga elektromagnetik yang melepaskan isyarat denyut berjulat frekuensi dari beberapa Hertz (Hz) kepada puluhan Megahertz (MHz). Tweek biasanya diperhatikan pada waktu malam bagi mengkaji ciri-ciri parameter di bahagian D yang berlatitud rendah. Sebelum ini, pengukuran tweek menghadapi pelbagai masalah dari segi kos yang tinggi dan isyarat yang terhad untuk perambatan di antara permukaan bumi dengan kawasan Ionosfera. Teknologi baru telah dibangunkan bagi mengatasi masalah ini dengan penggunaan AWESOME VLF Receiver. Projek ini adalah untuk menganggarkan ketinggian ionosfera refleksi (h) pada waktu malam, ketumpatan elektron setara bahagian-D (ne) dan penyebaran jarak tweek (d) daripada pancaran kilat di kawasan stesen berlatitud rendah. Selain itu, kajian ini menganalisis ciri-ciri tweek antara stesen yang berbeza iaitu latitud pertengahan rendah dan kawasan latitud rendah. Akhir sekali, hasil kajian daripada projek ini diaplikasikan denagn menggunakan Antara Muka Pengguna Grafik iaitu GUI di dalam perisian MATLAB. Di dalam kajian ini tweeks dicatatkan pada bulan Ogos dan September 2010 di stesen Allahabad (16.49N; 155.34E). Sebanyak 1518 tweeks berlaku secara rawak daripada mod pertama hingga mod keempat yang diperhatikan daripada spectrogram dan diklasifikasikan mengikut nombor mod harmonik. Tweek akan berkurangan apabila nombor mod meningkat. Selain itu, pengagihan nombor mod tweek menunjukkan bahawa kejadian tweek menurun dengan ketara apabila nombor mod meningkat. Ketumpatan elektron ionosfera dianggarkan sebanyak 22-27 el/cm3 di ketinggian 79-91 km pada malam waktu tempatan. Maksimum jarak perambatan diantara permukaan Bumi dan Ionosfera dari sumber ke stesen penerima adalah di dalam lingkungan 560-4166 km.

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LIST OF SYMBOLS

λ	–	Wavelength (lamda)
°C	–	Celcius
D	–	Propagation distance
°F	–	Fahrenheit
f	–	Frequency
fc	–	cut-off frequency
GB	–	Giga Byte
h	–	Reflection height
Hz	–	Hertz
KHz	–	Kilohertz
Km	–	Kilometer
km/h	–	kilometer per hours
m	–	Mode number
m/s	–	miliseconds
MB	–	MegaByte
MHz	–	MegaHertz
ne	–	electron density
t	–	time

LIST OF ABBREVIATION

AC	–	Alternating Current
AM	–	Amplitude Modulation
CG	–	Cloud to Ground discharge
EIWG	–	Earth-Ionosphere Waveguide
ELF/VLF	–	Extremely Low Frequency/ Very Low Frequency
FFT	–	Fast Fourier Transform
GC	–	Ground to Cloud discharge
GUI	–	Graphical User Interface
HF	–	High Frequency
IC	–	Intra-Cloud discharge
IST	–	Indian Standard Time
RF	–	Radio Frequency
UT	–	Universal Time

CHAPTER I

INTRODUCTION

1.1 BACKGROUND

Lightning discharges during thunderstorm are the significant natural source of electromagnetic waves. They generate electromagnetic pulses which vary from few Hz to tens of MHz, but the maximum radiated energy is confined in extremely low (ELF: 3-3000Hz) and very low (VLF: 3-30 KHz) frequency band. These electromagnetic pulses in the ELF/VLF band from lightning discharges are called as radio atmospherics or sferics. These waves propagate by the process of multiple reflections through the boundaries of the wave-guide formed between the ground and the lower region of the ionosphere. These waves travel very long distances with lower attenuation rate and the waveguide mode propagation causes an appreciable dispersion near the cutoff frequency of Earth-Ionosphere Waveguide (EIWG) around 1.8 kHz. This dispersed sferics is known as tweeks. The name of tweek is because these wave sound like 'tweet' when the signal is presented to loudspeaker.

Tweek atmospheric is an electromagnetic pulse originating from the return stroke of lightning that is multiply reflected from boundaries of the natural waveguide formed by the Earth's surface and the lower boundary of the ionosphere layer with so small plasma density. Tweeks are formed by series of pulses consecutively reflected from the waveguide boundaries under different incident angles depending on source-observer distance and average effective ionosphere height along a propagation path. Besides that, tweeks are observed during nighttime and represent a response of the Earth-ionosphere waveguide excited by lightning strokes. Tweeks usually occurs between the lower region in ionosphere and the surface of the earth.

The ionosphere is a part of the upper atmosphere from about 85 km to 600 km altitude which comprising portions of the mesosphere, thermosphere and exosphere. The ionosphere is divided into four regions, C, D, E, and F. The differences between these regions are based largely on electron density as you move up in altitude. For the very low frequency (VLF) waves that the space weather monitor track the ionosphere and the ground produce a waveguide through which radio signals can bounce and make their way around the curved Earth. Since these waves are reflected by lower boundary of ionosphere, these are used extensively for probing the D-region ionosphere. D-region is important to the space weather as well as the submarine communication and navigational aid. The D-region is the innermost layer about 50 km to 90 km above the surface of the Earth. This region reflects frequencies in the range of 3-30 kHz which is considered in the range of ELF and VLF frequency band.

In the study, tweeks recorded during the nighttime based on two month period during August – September, 2010 at low latitude ground station Allahabad (16.49N; 155.34E). A tweeks method is used in order to study the characteristic of D-region in EIWG. It also has been utilized have been to measure the nighttime D-region ionospheric reflection height and distance traveled in EIWG. The analysis of the data will be taken every 5 minutes from between 13:00 - 01:00 UTC.

1.2 PROBLEM STATEMENT

In this project, there are a few number of papers have been reviewed and used as a reference in completing this project. Recently, Maurya et. al., (2010) and Khairul et. al., (2011) observed tweek and estimate the equivalent electron density of the D-region, ionosphere reflection height and propagation distance. Besides that, we also used two papers from Kumar et. al., (2008 and 2009); as a references. These papers also observed tweek but they only estimate propagation distance and reflection height of tweek atmospherics.

The measurement of D-region is facing problem in term of the height is typically about 60 km during the daytime and increase about 90 km at nighttime. So, this makes the measurement of D-region difficult. The altitude of the D-region ionosphere is too low for satellite measurement of electron density and high for balloon measurements.

Previously, several methods have been used in this D-region measurement which is by using rocket, ionosondes and incoherent scatter radars. Nevertheless, cost of these methods is expensive compare to VLF Receiver. Besides that, this method also has a very limited to the path of the propagating signal and faced problem especially the spatial and temporal limitations of the measurement. Therefore, there are need to have a measurement with lower in cost and able to measure over wide area.

1.3 SIGNIFICANCE OF STUDY

The main benefit to be gain from this project is to understand about the important of ionosphere to us because among other functions, it influences radio propagation to distant places on the Earth and between satellites and Earth. Besides that, ELF/VLF waves are useful scientifically because they largely reflect at the D-region of the Earth's ionosphere. This signal is also important in penetrate into seawater and submerged submarines at long distances.

1.4 OBJECTIVES OF STUDY

Tweek atmospherics is a unique tool to study the characteristic of D-region ionosphere in low latitudes. The aim of this project is to analyze some important features about tweek atmospherics at station of Allahabad, India. The others objective of this project are as following:

i) To measure the nighttime ionospheric reflection height, the D-region equivalent electron density and tweek propagation distance from the causative lightning discharge at a low-latitude station.
ii) To analyze the characteristic of tweek between low latitudes and middle latitudes
iii) To develop Graphical User Interface (GUI) in MATLAB

1.5 SCOPES OF STUDY

This project is observations of D-region ionosphere using tweek atmospherics at low latitudes. This observation of tweek atmospherics are carried out in Indian low latitudes region at Allahabad (16.49N; 155.34E). The analysis of data will be based on two month period during August – September, 2010. Generally, tweek occurs during the nighttime because D-region ionosphere is better reflector at night than during day. For this project, the analysis of the data will be taken from 13:00 - 01:00 UTC (18:30 pm - 6:30 am IST). The local time is referring to Indian Standard Time (IST) which is 5 hours and 30 minutes behind Universal Time (UT). Data were recorded every 5 minutes between 13:00 - 01:00 UTC. The collection of tweek data will analyze by using Matlab software. Finally, the result will be developing using Graphical User Interface (GUI) in Matlab because GUI applications offer to users who wish to solve complex problems by providing interactivity and visual feedback.

1.6 CHAPTER ORGANIZATION

The study has been outline to five chapters. The explanation of each chapter is as following:

I. **Chapter 1: Introduction**

This Chapter is explained on the introduction of the project. The main contents of this chapter are research background, problem statement, significant of study, objectives of study and scope of study.

II. **Chapter 2: Literature Review**

The outlines of this chapter are the background of the research which is can be related to literature on the project. It is also included an explanation about lightning process, Extremely Low Frequency (ELF) and Very Low

Frequency (VLF) wave, tweek atmospherics, D-region ionosphere and Earth-ionosphere waveguide (EIWG).

III. **Chapter 3: Methodology**

This chapter is briefly discussing the methodology for this study. Data collected were analyzed using MATLAB and the final results will be developing using GUI.

IV. **Chapter 4 : Results**

This is the main part of this project which is discussing on the part of results on the D-region ionospheric parameters. The result will be presented in a figure, graph and tabulated into table with briefly explain and discuss included the comparison between low latitudes and mid-latitudes region.

V. **Chapter 5: Conclusion**

The last chapter will be focus on the finding of the project by making the conclusion and the recommendation for future study.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discussed all the useful theory and data about this project. The literature review was referring the journal, article, reference books and data sheet. Besides that, the reviews of the previous researches project that are related with this project will be discussed. The information will be become additional source for the project in becoming more successful. To have a brief understanding of the researches related to the project, a few literature reviews had been done. The topic will be discusses is about lightning process, Very Low Frequency (VLF) / Extremely Low Frequency (ELF), radio atmospherics, Ionosphere with its layer and Earth-ionosphere waveguide (EIWG). Each topic describes in detail the projects to be implemented. Therefore, through this chapter we can find out what is to be done in this project.

2.2 LIGHTNING

Lightning is a powerful natural electrostatic discharge produced during a thunderstorm [2]. Lightning's abrupt electric discharge is accompanied by the emission of visible light and other forms of electromagnetic radiation. The electric current passing through the discharge channels rapidly heats and expands the air into plasma, producing acoustic shock waves known as thunder in the atmosphere [3].

Lightning is an electric current. Within a thundercloud way up in the sky, many small bits of ice (frozen raindrops) bump into each other as they move around in the air. All of those collisions create an electric charge. After a while, the whole cloud fills up with electrical charges. The positive charges or protons form at the top of the cloud and the negative charges or electrons form at the bottom of the cloud. Since opposites attract, that causes a positive charge to build up on the ground beneath the cloud. The grounds electrical charge concentrates around anything that sticks up, such as mountains, people, or single trees. The charge coming up from these points eventually connects with a charge reaching down from the clouds and zap lightning strikes. The thunder is caused by lightning. When a lightning bolt travels from the cloud to the ground it actually opens up a little hole in the air, called a channel. Once then light is gone the air collapses back in and creates a sound wave that we hear as thunder. The reason we see lightning before we hear thunder is because light travels faster than sound [4].

Figure 2.1: Thundering and Lightning

Source: [4]