Variations of total electron content during quiet and disturbed geomagnetic conditions over Malaysia

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2022 IEEE 6th International Symposium on Telecommunication Technologies (ISTT) | 978-1-6654-8942-3/22/$31.00 ©2022 IEEE | DOI: 10.1109/ISTT56288.2022.9966546

***Abstract*— Ionosphere behavior is characterized by geographical and temporal changes. It was possible to determine the mobility of the ionosphere by observing how the total electron content (TEC) changed over time. The study on TEC variation was conducted in 2008 and 2009 over Malaysia, where latitude ranged from 1° N to 8° E and longitude ranged from 95° to 120° E, with each year reflecting the same degree of solar activity. The hourly mean vertical TEC (VTEC) is used to monitor the difference of the TEC under various geomagnetic factors such as disturbance storm time (Dst), planetary 3-hour range index (Kp), and solar flux F10.7 variations. This paper considers four cases of geomagnetic disturbances were considered 9 March, 27 March, 4 September 2008, and 22 July 2009. A percentage deviation was calculated to further analyze the geomagnetic disturbances in the equatorial region on quiet days. Results showed the TEC during geomagnetic disturbances was lower than the quiet day, with the percentage deviations between -20% and 10%. An increment of TEC was shown after approximately 24 hours, which is in the storm recovery phase. Also found were that GPS-TEC reaches its highest around post noon and its lowest in the small hours of the morning.**

Keywords*— *Ionosphere; TEC; GPS; Geomagnetic disturbance; equatorial region;

I. Introduction

Ionospheric disturbances are caused by various factors, including sunspots, geomagnetic storms, and atmospheric pressure. These disturbances can cause a few issues with GPS-based technologies, including decreased accuracy and increased latency. Most ionospheric observation methods rely on radio waves whose transmission is perturbed by several processes. To monitor ionospheric activity, the total electron content (TEC) can be measured using dual-frequency GPS measurements. Variable ionospheric electron density significantly perturbs TEC measurements [1].

The ionosphere is necessary for our modern communications and navigation systems to function correctly. This layer of the atmosphere is traversed by radio and GPS signals, or they bounce off the ionosphere. Variations in the density and nature of the ionosphere may impair these signals. At any given place, the ionosphere can change significantly from day to day and hour to hour. The ionosphere's behavior is defined by a variety of time and space scale events that are influenced by the Sun, solar wind, and magnetosphere, as well as atmospheric weather and climate [2]. Variations in the ionosphere may be classified into two broad categories-

1) Generally predictable, working in cycles (such as the daily cycle) that may be predicted with a high degree of accuracy in advance (quiet ionosphere).

2) Unpredictable, primarily due to the sun's unpredictability and space weather induced by solar activity (such as geomagnetic storms) (disturbed ionosphere).

Radio waves, including GNSS signals, move through the ionosphere and are impacted by both regular and unexpected changes in the ionosphere. These signals have helped to the research and comprehension of ionosphere instability caused by solar and geomagnetic activity as well as low-atmosphere and earth-surface events [3]. Because of the equatorial area, it is difficult to recognize and interpret the region's ionosphere, which has various anomalies even during low geomagnetic activity [4]. Examining this scientific behavior of the ionosphere across the low-latitude region will therefore aid in the study, modelling, and forecasting of the dynamics and unexpected behavior of the equatorial and low-latitude ionosphere. Numerous scholars, including [4-6], have investigated the changes in TEC in the Malaysian region over various solar cycles. Their investigation resulted in a better understanding of TEC variation. Globally known solar activity indicators such as the sunspot number (SSN) and the 10.7 cm radio flux index, F10.7, were used to monitor space weather. In contrast, Kp and disturbance storm time (Dst) were used to monitor geomagnetic activity. These indices separate ionospheric disruptions caused by solar and atmospheric events from the regular ionospheric conditions projected to occur from widespread solar activity (flares, coronal mass ejections, atmospheric waves, etc.) [7–10]. Previous studies have shown that the GPS creates unprecedented opportunities for persistent regional and global observation of the ionosphere's total electron content (TEC) [11-18].

Similarly, several studies have examined the nature and distribution of TEC during geomagnetic disturbances [3], [19–21]. Tracking TEC development is crucial because of the current societal trend of heavy reliance on radio navigation