UNIVERSITI TEKNOLOGI MARA

MORPHOLOGICAL REGULARITIES OF LOW-FREQUENCY SIGNAL DUE TO SOLAR FLARE EVENTS AT LOW-LATITUDE REGION

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Thesis submitted in fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Radio Frequency (RF) and Electromagnetic)

Faculty of Electrical Engineering

September 2018

CONFIRMATION BY PANEL OF EXAMINERS

I certify that a Panel of Examiners has met on 3rd August 2018 to conduct the final examination of Afifah binti Taat in her **Doctor of Philosophy** thesis entitled "Morphological Regularities of Low Frequency Signal due to Solar Flare Events at Low-Latitude Region" in accordance with Universiti Teknologi MARA Act 1976 (Akta 173). The Panel of Examiner recommends that the student be awarded the relevant degree. The Panel of Examiners was as follows:

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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

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ABSTRACT

Solar flare is one of the main phenomena of space weather that has affected technologies such as radio communication, satellite systems and power grid operations. The interaction process has led to the variations of frequencies which can be observed from the ground station. This research focuses mainly on low frequencies which are Very Low Frequency (VLF) and Ultra-Low Frequency (ULF) within the range of 3 - 30kHz and 1.7-500 mHz respectively. The affected frequency variations were observed during quiet (Q-day) and flare (F-day) day of solar cycle 24. The recorded data of the VLF and ULF signals were extracted from the Atmospheric Weather Electromagnetic System for Observation Modelling and Education (AWESOME) located at Universiti Kebangsaan Malaysia (UKM) and the Magnetic Data Acquisition System (MAGDAS) respectively. Previous researchers have demonstrated the affected frequencies mainly due to geomagnetic storms instead of solar flare events and separately discussed between the frequencies. In contrast, the new method of analysis due to solar flare events at low-latitude region was presented in this research. The combination investigation and observation have been done for both VLF and ULF signals. The modeling of Long Wave Propagation Capability (LWPC) code and International Reference Ionosphere Model (IRI2016) were applied to generate the values of N_e (electron density, m^{-3}), H' (VLF reflection height parameter, km) and β (exponential sharpness factor, km^{-1}). In addition to that, the geomagnetic field components (H and Z) were calculated to observe the correlation of ULF variations associated with solar flare events. In the analysis, the diurnal variations of VLF and ULF signals have been observed. Q-day was selected to measure the Average Amplitude Difference (AAD) for ULF while the method of Average Percentage Difference (APD) has been used for VLF signal during daytime and nighttime for three (3) different transmitter stations which are NWC/19.8kHz, JJI/ 22.2kHz, and DHO/23.4kHz.All the transmitters had different latitudes and distances from the receiver stations (UKM) and propagated within the Earth-ionosphere waveguide (EIWG). It is found that, the NWC signal had lower APD which was 7.72% as compared to JJI (10.14%) and DHO (15.4%). For further investigation on low-frequency signals (VLF and ULF), the affected amplitude (AA) due to solar flares demonstrated different classes of solar fluxes which are C, M, and X-Class. The correlation coefficient (r) of mathematical analysis was used to measure the correlation between the solar x-ray fluxes (X, M, and C-class) and ionospheric parameters. Statistical results showed that the propagation distance between transmitter and receiver has contributed on the affected frequency variations (VLF). For ULF, three difference relationship have been approached which are the intensity of solar flares, local time dependence and location of solar flares on Sun's surface. The result shows the affected of low-frequency signals has been correlated with the intensity of solar flares and dependent to the occurrence of solar flares. At the end of this research, the characterization of the low-frequency signals was presented as an indicator to morphological regularities of low frequency (VLF and ULF) variations with respect to solar flare events at low latitude regions.

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