Development of Near Real-Time Monitoring and Data Archival of UiTM-SID System

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Abstract— **The Stanford Solar Center has reputable partnership with almost 80 countries to form the Space Weather Sudden Ionospheric Disturbance (SID) Monitor Program. SID is a condition of sudden high ionization occurred at the lower ionospheric D-region caused by solar activity namely solar flare. UiTM-SID monitoring system located at Universiti Pendidikan Sultan Idris, UPSI (3.71', 101.53'), is developed to monitor diurnal variation of the lower ionosphere layer and the activity of Solar flare by using Very Low Frequency (VLF) probing technique. Due to several issues with manual collection of data archival purposes, this paper presents near real time data monitoring at established university's website and data archival for the purpose of data monitoring and data backup. The Design and implementation of UiTM-SID system have been done by using MATLAB software. The data was received using File Transfer Protocol (FTP) access and the data is stored in Google Drive cloud storage. The UiTM-SID is enhanced to have a near real-time monitoring system at the official website https://fke.uitm.edu.my/see-uitm/. At the website, it will display two signals strength data from VLF transmitter stations South Vijayanarayanam, India and North West Cape, Australia with frequency 19.2 kHz and 19.8 kHz respectively.**

Index Terms—**Ionosphere, Solar Flare, Sudden Ionospheric Disturbance, Very Low Frequency.**

I. Introduction

A Very Low Frequency (VLF) radio waves that propagate in the Earth Ionospheric Waveguide (EIWG)[1] can be used as a media to monitor the behavior of lower ionosphere (D-region) during daytime [2]. From the past research, there are a few techniques used to measure lower D-region ionosphere comprising balloons and satellites technique. Still, the methods were relatively difficult due to the D-region is too high for high latitude balloon technique [3] and too low for satellite based measurement [4]. Therefore, VLF radio waves probing technique is the subsequent way out to study the lower ionospheric D-region. The VLF signals from the transmitter antenna propagate at the D-region heights, reflected and bounced at the ground or sea level until reached at the receiver station. The stability of the amplitude and phase together with concurrence of the electron density profile makes this technique is a suitable method to study D-region [5].

This manuscript is submitted on 13rd April 2018 and accepted on 14th December 2018. This work was financially supported by Fundamental Research Grant Scheme (Code No. 600-RMI/FRGS 5/3 140/2014). Email: nurainzakaria@yahoo.com. [1]Space and Earth's Electromagnetism Research Group, Universiti Teknologi MARA (UiTM) Malaysia. [2]Department of Physics, Faculty of Science and Mathematics, Universiti Pendidikan Sultan Idris

The phase velocity of VLF signals distinct the nature of ionosphere conductivity profile. It is solar controlled and undergoes regular and irregular variations. The changes of ionization process in ionosphere vary the height reflection of reflected signal as the width of EIWG is decreased or increased [6]. Solar flare produced enhancement of the electron density at the D-region. For the duration of quiet (no solar flare events) the amplitude variation is stable because the solar X-ray flux is too minor to be a significant source of ionization.

On the other hand, when the solar flare events occurred, the ionization rate and electron density increased by ionizing neutral constituents of nitrogen and oxygen. Consequently, the reference height of EIWG is lowered and cause sudden pulse amplitude known as Sudden Ionospheric Disturbance (SID)[7]. This intense solar flare X-ray energy caused SID and additional effects such as ground telecommunication interferences, blackout as well as natural disaster [8].

In Malaysia there are established Sudden Ionospheric Disturbance system developed by Universiti Kebangsaan Malaysia (UKM) known as UKM-SuperSID in 2012 [9] and UiTM-SID system developed by UiTM Applied Electromagnetic Research Group in 2017 [10]. As with other SID installations worldwide, UiTM-SID system at UPSI station is continuously acquired data from VLF transmitter for research purpose. Due to complexity in accessing the physical location of the UiTM-SID, researcher requires a remote online data backup and storing back-dated data logged by the UiTM-SID system. Thus, this paper presents a development of UiTM-SID near real-time monitoring embedded with data archival stored at google drive cloud and displayed data at the official website for monitoring purpose. The design is developed by using MATLAB software and the connection with UiTM-SID system is recognized using File Transfer Protocol (FTP).

II. System Design and Methodology

Fig. 1 shows the UiTM-SID system comprises of hardware and software parts. Signal strength transmitted by VLF transmitter will be detected by the magnetic loop antenna. The signal detected is very low, thus it requires the aid of amplifier to amplify the signal. Signal amplified is then being converted to digital using analogue to digital converter (ADC). Next, the data will be saved at data logger and upload to a web database. Finally, the data is a real-time auto plot to the website using MATLAB software. The user can remotely monitor the data.

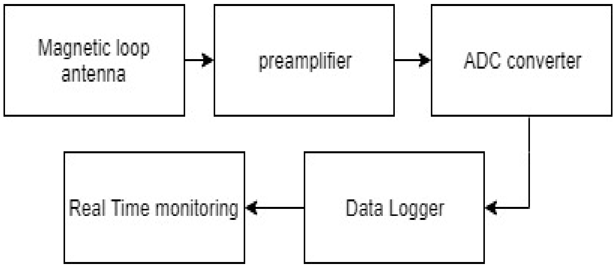

Fig. 1.The UiTM-SID system block diagram

A. Data Logger

Data logger consist of computer with sound card and configuration software. According to [11], the authors recommend to use a High Definition audio card. Thus we use Sound Blaster X-Fi Go Pro! to receive analog VLF signal. The advantage of using data logger is the competency to automatically collect data on a 24-hour. Once the data logger is activated, it can be left unattended to record data. By default, the data is collect every 5 seconds and display VLF spectrum at the main window. The data logger used Solar Stanford SuperSID software to activate and it interfaces with the personal computer. The data can be view at the local personal computer and at the same time, the raw data in comma separated (.csv) file are saved to the cloud.

B. Project Operation

Fig. 2 shows a flowchart of the near real-time monitoring operation system. When the system is turned ON, the magnetic loop antenna starts to receive VLF signals. The analog signals are amplified and sent to the ADC converter. Once the systems receive signals, vertical peak above noise level will appear at VLF spectrum at the main window. Then, the data is saved in a local pc with the.csv format.

Next, in the configuration file, the user can save all the data to cloud using File Transfer Protocol (FTP) directory. Then, all the data starts to save parallel in local pc and cloud. After that, code is generated using MATLAB software to autoplot the data in local time. The data is plot in a Local Time (LT) since to monitor the diurnal variation and the activity of solar flare.

If the data failed to plot in a local time, the coding is rectified. The process of autoplot in real time is a bit challenging because it requires data from two .csv files. Once the data is successfully plotted in local time, the plotted-figure saved in cloud for a second time. After that, line of coding is write to etract the figure to be put on a webpage. Finally, the website will display the plotted data. Finally, the website can be viewed by anyone, but the data in .csv files at database can only be downloaded with the permission by the authorized user.

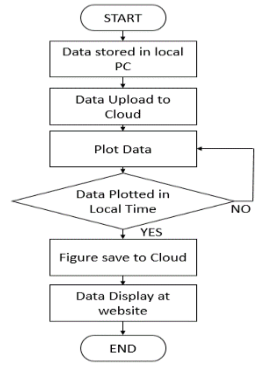

Fig. 2.The Operation flow for the development of near real-time monitoring and data acquisition system.

C. Software Testing and Troubleshooting

Generally software testing and troubleshooting is carry out to test the configuration correctly and resolve source code related problem in software. Fig. 3a) is an example of configuration file of the data logger. The file is used to configure the parameters and setting of the system. The parameters of UiTM-SID are site_name of the receiver, specific location of the receiver. The utc_offset is Greenwich Mean Time (GMT) +08:00 Malaysian Standard Time (MYT). The monitor_id is 34. The audio sampling rate is important to determine the sound card of the particular pc. It also limits the highest frequency component of the signal. In the case of UiTM-SID, it used 44.1 kHz and makes the highest frequency that can be rerceived is up to 22 kHz. If the user intends to receive more than 22 kHz you can upgrade the sampling rate to 96 kHz.

Similarly, in the configuration file, the user can determine the log_interval in order to take the minimum, maximum and average measured data in one block. For this project, we choose 5 seconds for the time interval. Afterward in the configuration file is the File Transfer Protocol (FTP). It is a standard network protocol used to transfer personal computer files between a client and a server on a computer network. The user can put the location of the files they want to save at the FTP directory. Refer to Fig. 3b), the user can select to automatically upload the data to cloud or save to the local pc. Finally for the station set-up, user can write the call sign and the frequency based on the transmitter station. In this case, transmitter station from South Vijayanarayanam (VTX4) from India and North West Cape (NWC) from Australia were choosed. The VTX4 and NWC transmitter transmit 19200 Hz and 19800 Hz respectively.

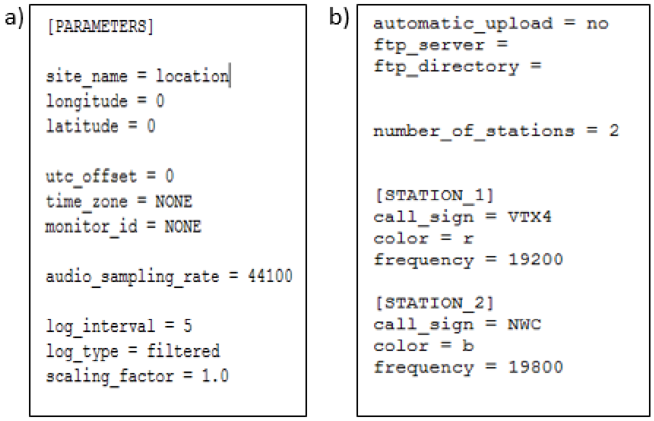

Fig. 3.a).The setting of location, time, audio sampling rate and log type in Configuration files and Fig. 3.b) is for FTP directory and number of VLF transmitter.

III. RESULTS AND DISCUSSIONS

A. DATA ARCHIVAL

The real-time monitoring and data archival of UiTM-SID was tested at Universiti Pendidikan Sultan Idris. Based on Fig. 4, it shows sample plot of VLF spectrum. The y-axis represents power spectral density and x-axis is a frequency in Hz. The signal strengths of the transmitter station appear as vertical spikes standing above the noise floor. The spikes are VLF frequency signals because these spikes continuously raise while the others are fluctuated and sometimes disappear. The UiTM-SID station is able to receive two VLF signals from South Vijayanarayanam, India (19200 Hz) and North West Cape, Australia (19800 Hz) correspondingly.

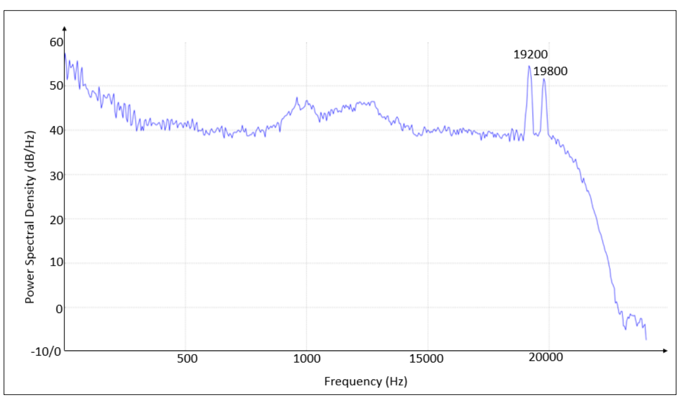

Fig. 4.VLF Spectrum of UiTM-SID System

Subsequently, Fig. 5 shows the data are saved on a local pc and cloud-based. The format for the file name is Receiver location_TransmitterLocation_Year_Month_Day. The size of full data per day is 606 KB.

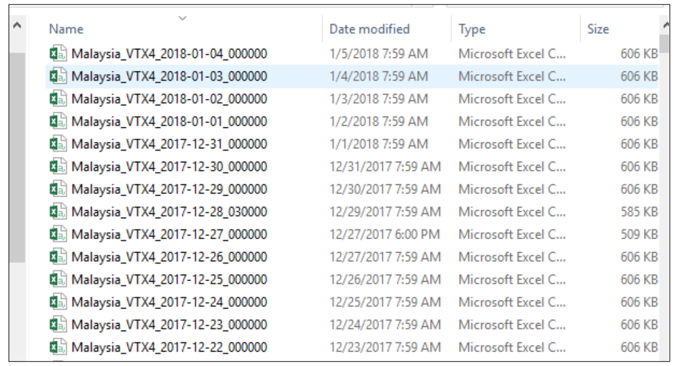

Fig. 5.Data logged in .csv format and stored in local pc and cloud database

The file can be opened using Microsoft Excel. Fig. 6 is an example of signal strength data from NWC station. In a new day, the data is starts logged at 12:00 am and it will be logged every 5 seconds interval until 11:59 pm.

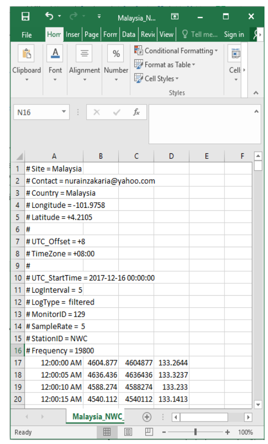

Fig. 6.The signal strength data is logged every 5 seconds

B. DATA ANALYSIS

The formation of D-region during daytime influenced by photoionization of Lyman-alpha photons [12] [13] . As the time near to nighttime or reduction of solar flux at the D-region, the photoionization process become slow and followed by disappearance of the lowest ionospheric region. For the low latitudes D-region, the neutral constituent ionized by Lyman-alpha is constant with season and latitude[14]. The theory can be relates to the Fig. 7, it illustrates a graph of the diurnal variation of UiTM-SID on 4th December 2016. The variation of graph in Fig. 7a) is a signal coming from NWC, Australian transmitter while graph in Fig.7b) is a signal from VTX4, Indian transmitter. The y-axis represents signal strength in decibel (dB) while the x-axis represents Hour in local time. The graph starts to decline from 5:40 am to 6:00 am to indicate sunrise and the graph is decline again at 6:00 am to 7:30 am to indicate sunset. From the time of sunrise and sunset (daytime), the signals are stable due to process of photoionization at the D-region. Thus, the signal propagate through EIWG whose do not vary in horizontal plane.

A minimum value observed at the sunrise and sunset are due to the modal conversion effect as the sunrise and sunset terminator crosses the transmitter-receiver path. The terminator known as twilight zone is a moving line that splits the dayside and night side of planetary body. According to [15], if the condition where the transmitter and receiver is in different time, such the transmitter is in daytime while the receiver is in nighttime, the dominant day mode will converted to nighttime modes.

Agreeing to the data, variation of the NWC, Australia transmitter station shows the minima reading point of sunrise and sunset in a single loop. It is rely on GMT of NWC receiver station in line with the same GMT +8 with the receiver station located at UPSI, Malaysia.

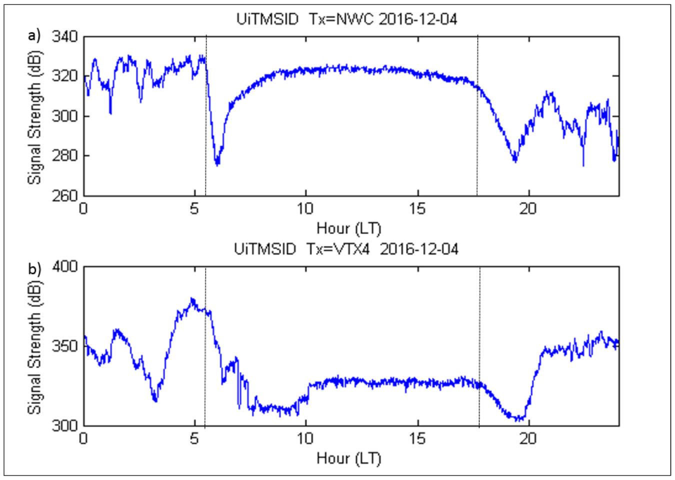

Fig. 7.Graph of UiTM-SID diurnal variation in local time. The Fig. 7 a) graph is signal strength from NWC and the Fig. 7 b) graph is the signal strength data captured from VTX4.

Solar flare is an abrupt brightening and intense energy release from corona[16] and caused major increase in the flux of X-rays. X-rays that wavelength below 1nm can penetrate down to D-region and therefore increased the electron density[17]. Fig.8 gives an example variation of UiTM-SID when there is the event of a solar flare. The event of solar flare happened on 29th November 2016. It occurred at 15:03 pm local time with a sudden peak at 427.4 dB. The presence of solar flare with an intense blast of X-ray or Ultraviolet caused the ionosphere more ionized. When the ionosphere more ionized, it brings the signal reflected at a lower layer. That explained, the sudden impulse at the UiTM-SID pattern in the presence of Solar flare from the Sun.

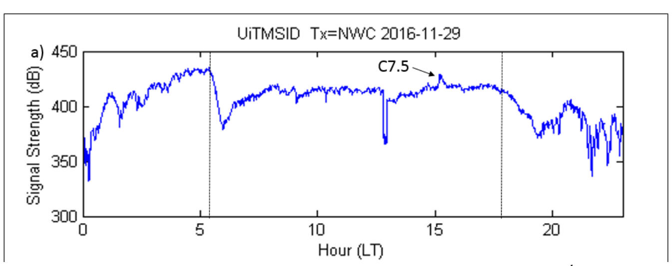

Fig. 8.Sudden peak at the variation signal from NWC station on 29th November 2018.

C. *Website Layout*

Fig. 9 illustrates a map of receiver and transmitter as an info for the user. The receiver is located at Universiti Pendidikan Sultan Idris, UPSI (Lat: 3.71' and Long: 101.53).

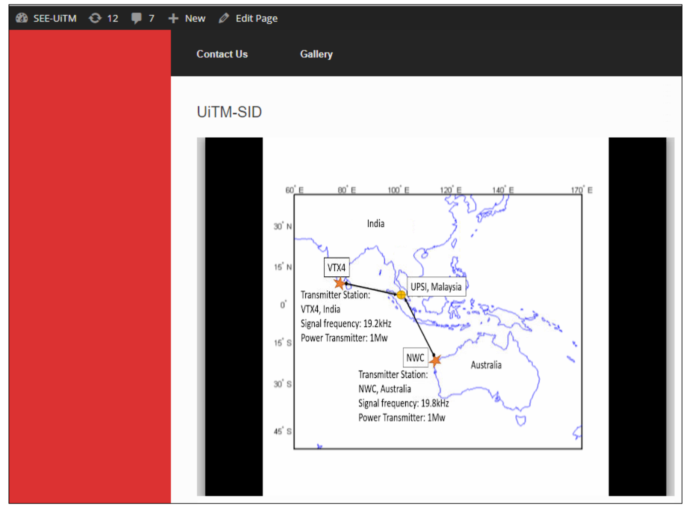

Fig. 9.At the top of the website it has a map of receiver and transmitter.

Fig. 10 shows layout of the remote monitoring database website. The website displayed 4 subplot graph. The Fig. 10 a) and Fig. 10 b) are in real time plot on the present date. While for the Fig. 10 c) and Fig. 10 d) are in the day before. With the aim of identify the diurnal variation, the data of the day before and the present date is needed.

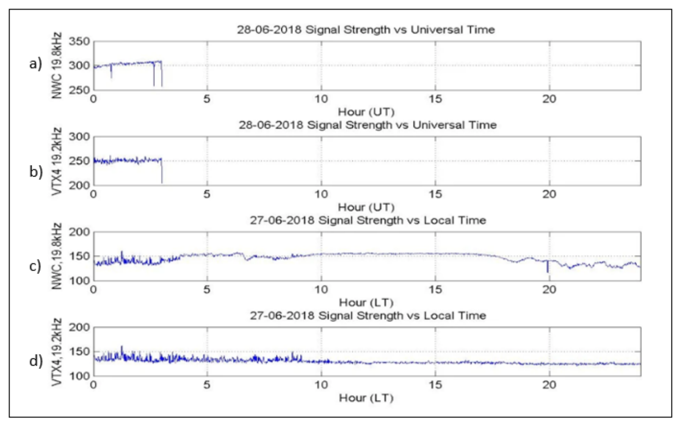

Fig. 10.Remote monitoring database website layout. Fig. 10 a) is a real time variation of NWC signal. Fig. 10 b) is a real time variation of VTX4 signal. Fig 10 c) is a one day variation of NWC signal and Fig. 10 d) is a one day variation of VTX4 signal.

IV. Conclusion

This paper presents the development of near real-time monitoring of UiTM-SID system located at UPSI, Malaysia. This monitoring system allowed the user to monitor the diurnal variation of the system and able to detect solar flare event. Apart from that, the user can monitor the performance of system anywhere as the data will be displayed on the official webpage. The system is able to display graph of UiTM-SID in near real-time and local time signal strength of transmitter station from South Vijayanarayanam, India (19.2 kHz) and North West Cape, Australia (19.8 kHz).

ACKNOWLEDGEMENT

The authors would like to thank Stanford Solar Center, Radio Cosmology Lab, Universiti Malaya (UM), Universiti Pendidikan Sultan Idris (UPSI) and Universiti Teknologi MARA (UiTM) for the technical support and providing alocation. The authors also would like to extend the gratitude to Fundamental Research Grant Scheme (Code No. 600-RMI/FRGS 5/3 140/2014) for the financial support.

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