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Full Length Research

CONSTRUCTION AND INSTALLATION OF A SUDDEN IONOSPHERIC DISTURBANCE (SID) MONITOR AT NSUKKA FOR MONITORING SOLAR FLARES

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This work was carried out to design Sudden Ionospheric Disturbance (SID) antenna and install it together with an SID monitor using a solar panel as a source of steady power supply. This was successfully done following internationally acceptable procedures.

During observations, radio signals were received and data were collected, indicating a successful installation at the CBSS site at Nsukka. The results obtained showed some spikes which might be an indication of solar flares, though this might not be concluded unless the data is compared with more reliable sources of observation such as the Geostationary Operational Environmental Satellites (GOES). At last, it was confirmed that there were no outstanding flares seen within the period of the observations. The sunrise and sunset signatures which are one of the indications of a successful SID installation were detected in the graphs.

Keywords: Antenna, SID machine, Solar Flares and general physics.

1. INTRODUCTION

One challenging but important goal of solar and space astronomers is to understand many of the solar phenomena and how they are influencing the Earth's ionosphere. Solar flare is one of these solar phenomena and can be defined as a violent explosion in the sun's atmosphere, releasing energy up to 6.298×10^{25} Joules. It takes place in the solar corona and chromosphere heating up plasma to tens of millions of Kelvins and accelerating electrons, protons and heavier ions to near the speed of light (Onel et al., 2007; Kopp et al., 2005; Hudson, 2004; Low and Wolson, 1988; Zheleznyakov, 1970; Gold and Hoyle, 1960).

These solar flares are directly associated with other sudden ionospheric disturbances and their consequences on life on Earth are overwhelming, hence the vital need for this study. Solar flares and associated Coronal Mass Ejection (CME) strongly influence our local space weather. They affect communication systems, satellites, pipeline, navigation system, geologic exploration, spacecraft and astronauts (Onel et al., 2007; Kopp et al., 2005; Okeke and Soon, 2004; Zheleznyakov, 1970).

Solar flares release a cascade of high energy particles known as a proton storm, which can pass through the human body causing some biological damage. The radiation risk posed by solar flares and CMEs is one of the major concerns in discussions of manned missions to Mars or to Moon. Thus, the study of solar flares is both practically useful as well as intellectually challenging. In this study, we briefly review the main ionospheric changes due to solar flares, construct and installed an SID monitor and its accessories, for monitoring these flares at Nsukka.

1.1. THE EARTH'S IONOSPHERE

The ionosphere is the layer of the Earth's atmosphere that is densely populated by ions and electrons sufficient enough to affect the transmission of electromagnetic waves at radio frequencies. This lies between 75km to 1000km above the Earth (Michael and John, 1990;

Deborah, 2007). The ionosphere is composed of three main parts, the D, E and F regions in the ascending other. The electron density is highest in the uppermost region, F. In the daytime, the sun's x-ray and ultraviolet light increases the ionization of the upper layers of the ionosphere, making the E and F layers to be denser than the D layer. So the signals pass through the D layer, bounce off the E layer, and go back through the D layer to the ground. The signals lose energy as they penetrate through the D layer and hence weaker signals are received from the transmitter during the day.

During solar flares, the flare's x-ray energy increases the ionization of the layer, including the D region causing induced electromagnetic force (emf) at very low altitude. The D region now becomes strong enough to reflect the radio waves at lower altitudes. This time, the waves travel for lesser distances. The signal strength increases because the waves do not lose energy penetrating the D layer.

1.2. THEORIES OF SOLAR FLARES

Solar flares occur producing electromagnetic radiation across the electromagnetic spectrum at all wavelength from long-wave radio to the shortest wavelength gamma-rays. Solar flares occur near the sunspots when twisted magnetic loops of opposite sense and opposite twists meet. Such loop attracts each other and the annihilation of the component of the field leads to a sudden constriction of the geomagnetically induced current (GIC) and through this to a dissipation of the energy associated with that GIC (Gold and Hoyle, 1960; Low and Wolson, 1988; Hudson, 2004; Kopp et al., 2005). Solar flares release energy in the form of electromagnetic radiation (Gamma-rays and X-rays), energetic particles (protons and electrons) and mass flows (Kopp et al., 2005).

The frequency of occurrence of flares varies from two to three per day, when the sun is particularly active, to one each week when the sun is quiet (Kopp et al., 2005). Large flares are less frequent than smaller ones. (Onel et al., 2007; Kopp et al., 2005; Pam, 2004; Michael and John, 1990). Solar flares are classified as A, B, C, M or X according to the peak flux (in watts per square meter, w/m^2) of X-rays near Earth as measured on the Geostationary Operational Environmental Satellites (GOES) spacecraft (Onel et al., 2007; Deborah, 2007; Kopp et al., 2005). Each class has a peak flux of order 10^{-4} W/m^2. The minor flares like class-A and B are very low in strength and cannot be detected using SID monitor and sometimes the satellites neglect these classes due to their low strengths and even their effect on Earth is negligible. While classes M and X are very powerful to the extent that its peak flux cannot fall within the range of data of the SID monitor (Deborah, 2007; Kopp et al., 2005).

1.3. THE EFFECTS OF SOLAR FLARES ON LIFE ON EARTH

As mentioned briefly in secttion1.0, solar flares produce radiation hazards to communication systems (Mewaldt, 2005; Okeke and Soon, 2004; Otto et al., 1961). Shortwave radio communication is absorbed by the increase in the density of electrons in the low altitude ionosphere causing a complete black out of radio communications (Okeke and Soon 2004; Michael and John, 1990; Willian, 1987; Zheleznyakov, 1970). This phenomenon is called short wave fadeout. These fadeouts last for a few minutes to a few hours and are most severe in the equatorial regions where the sun is most directly overhead.

Most of the satellites are in an orbit high enough to avoid the drag of Earth's atmosphere during solar activity. However, an increase in the ultraviolet output during solar flares causes the low orbital satellite environment to heat and expand causing orbital decay (Onel et al., 2007; Kopp et al., 2005).

The high energy particles released by the flares pass through the human body and causes some biochemical damages to the body. The penetration of high energy particles into living cells can cause chromosome damage, cancer and a host of other health problems (Onel et al., 2007 Kopp et al., 2005). Solar flares also have some effects on electric power. During solar flares, a geomagnetically induced current (GIC) is produced. This induced current overheats the coils of the transformers and causes saturation of their cores, constraining their performance.

Solar flares can also produce GIC in pipelines. During this period, flow meters in the pipeline can transmit erroneous flow information and the corrosion rate of the pipeline is dramatically increased (Onel et al., 2007). The hazards cannot be over emphasized since solar flares are solar cycle dependent, hence affecting the element of climate such as temperature, rainfall, pressure e.t.c and hence all aspects of human life (Pam, 2004).

2. MATERIALS AND METHODS

2.1. THE SID INSTRUMENT

The SID instrument installed in this work consists of an SID monitor, SID antenna receiver, and a solar-power system to ensure consistency of power supply. The SID monitor has inputs for power supply and antenna, and outputs for audio powered speakers and signal strength. Inside the SID monitor box, the signals are filtered, amplified, rectified and integrated to measure signal strength. The internals of the SID monitor are divided into different sections and the signals follow these paths.

These sections are power supply, preamp, frequency filter, post-amp, audio output and signal strength output. All these have specific functions to the received signal till finally it is integrated to normal measured signal strength.

An SID antenna receiver and a solar panel are other devices that formed part of the SID monitoring system; the antenna receiver is to enhance the signal reception, and the solar panel is to ensure steady power supply.

Theoretically, an antenna is always constructed to match what it is to be used for. Criteria to be considered are the radiation mechanism, directivity, gain, radiation pattern and efficiency of the antenna (Collins, 1985; Walter, 1965; Kranu, 1950). The radiation mechanism describes the way the electromagnetic fields generated by the source are contained and guided within the transmission line and antenna. The directivity of an antenna measures the directional properties of the antenna and it is controlled by the pattern. The gain of the antenna is a measure of the efficiency of the antenna as well as its directional capabilities.

2.2. CONSTRUCTION AND INSTALLATION OF SID ANTENNA RECEIVER.

An antenna receiver was constructed as illustrated in Figures 2.1-2.6.

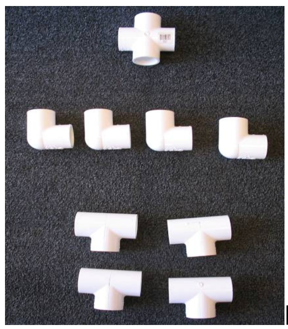
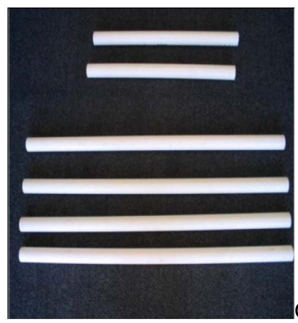
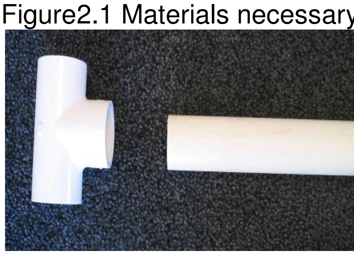

a

b

c

Figure2.1 Materials necessary for construction of the antenna, PVC connectors and PVC pipe.


a

b

Figure 2.2 T-connector attached to each long length of pipe.

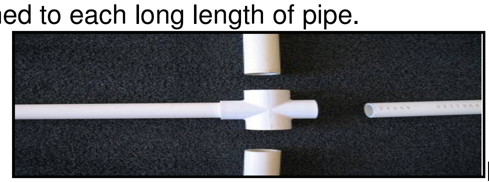
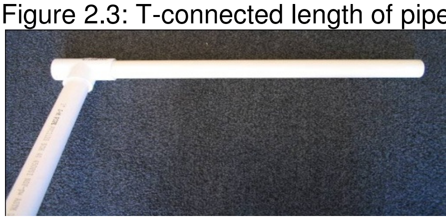

a

b

Figure 2.3: T-connected length of pipe attached to the 4-way connector.


a

b

Figure 2.4: One of the smaller lengths of PVC was placed in each end of the T-connector.

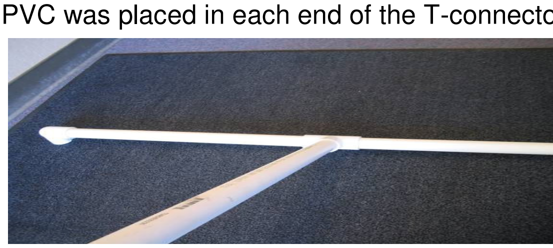

a

b

Figure 2.5: Four elbow connectors were placed on the open ends of the base created. Now the antenna will stand upright and off the ground

.

Figure 2.6: The completed frame.

The frequency of the antenna is 24.0 kHz and it is already indicated on the SID monitor by the manufacturer, showing that the machine was designed to monitor VLF signals from NAA Transmitter only.

The location for this installation is at CBSS Observatory in University of Nigeria Nsukka. First, the antenna was temporarily connected to the SID monitor antenna input jack using the Thread N- Compact (TNC) connector. Two speakers were also connected to the audio port on the SID monitor. The SID monitor was then powered using AC transformer.

During the installation and alignment of SID antenna, a compass was used to locate the direction of the NAA station. The antenna was rotated to obtain the strongest and loudest signals.

2.3. INSTALLATION OF THE SID MONITOR

The materials necessary for this installation are terminal block, coaxial cable, SID monitor, SID antenna receiver and AC power strip. Here, two antenna wires were stripped a few millimeters back. A J-shaped hook was made on the antenna wire and in a clockwise direction attached onto the terminal screw and tightened. The other antenna wire was connected in the same way. All these antenna wires were connected to the same side of the terminal block.

The length of a cable that would be enough to run from the antenna to the SID monitor, plus some slack was cut. The center connector was pulled out and attached to the opposite side on the terminal screw and then screwed tightly. The coaxial cable was fixed to the SID monitor.

The SID monitor and dataQ softwares were then installed in the computer to be used with the SID monitor system. The necessary materials for connecting the SID hardware are computer, DataQ A/D converter (Analogue-to-Digital converter), SID monitor, SID antenna, Transformer, AC power strip and connectors.

The coaxial cable from the antenna was plugged into the antenna input on the SID monitor powered using AC power strip to connect the transformer into the SID monitor. The range of this power input is +5 to -5 volt (Collins, 1985; Deborah, 2007; Kranu, 1950; Walter, 1965). The output of this SID monitor was also connected to the DataQ. It is through this output that the VLF signals goes to the computer from the SID monitor, through the analogue-to-digital converter.

The SIDMON-EXE CONFIGURATION is illustrated below:

Site = CBSS – NSUKKA, Longitude = 7.1 ^{0} E, Latitude = 6.63 ^{0} N, Device D1-194RS,

Port = COM1, Channel = 1, Data type = SOLARSID, Station ID = NAA,

Frequency = 24.0 KHz, Monitor ID = S- 0001 – FB – 0001 and Sample Rate = 5 seconds.

2.4. INSTALLATION OF SOLAR PANEL.

The necessary materials involved are: cable, 24V battery, solar charge controller, converter and solar panel.

The cable was connected to the already existing cable at the back of the solar panel. On one end of the cable about a few inches away, the coated wire was removed. The red wire (the live) was connected to the positive cable of the panel, already indicated by the manufacturer. One end of the brown wire was connected to the negative cable of the panel, and then the panel was carried to a height and mounted. The opposite end of the wire was connected to the solar charge controller inside the house. The controller had three points of connections; one point was for the battery, the second was for panel, and the third was for the load (computer).

2.5. THE WORKING OF THE INSTRUMENT

The SID antenna received radio signals from the transmitter at NAA station in U.S.A. at the frequency of 24.0 KHz. These signals were sent to the SID monitor and finally to the computer. These were interpreted by the help of dataQ analogue-to-digital converter and then displayed on the screen of the computer.

2. CALIBRATION OF THE SID MONITOR AND DATA COLLECTION.

After the installation of hardware, software and antenna, the SID monitor was calibrated to make the system ready for use. The calibration was done by slowly adjusting the Radio Frequency (RF) gain to a value in the range of -1.25volts and -150volts as specified by the manufacturer of the device.

Data was collected with the SID instrument from February, 2008 to August, 2008.
The data were displayed on the screen of the computer as voltage against the time and each of these data were sampled every five seconds. The data were collected for 24hours every day by the aid of solar panel incorporated in this work.

3.1. Analysis of the results.

Graphs 3.1-3.14 were analyzed.

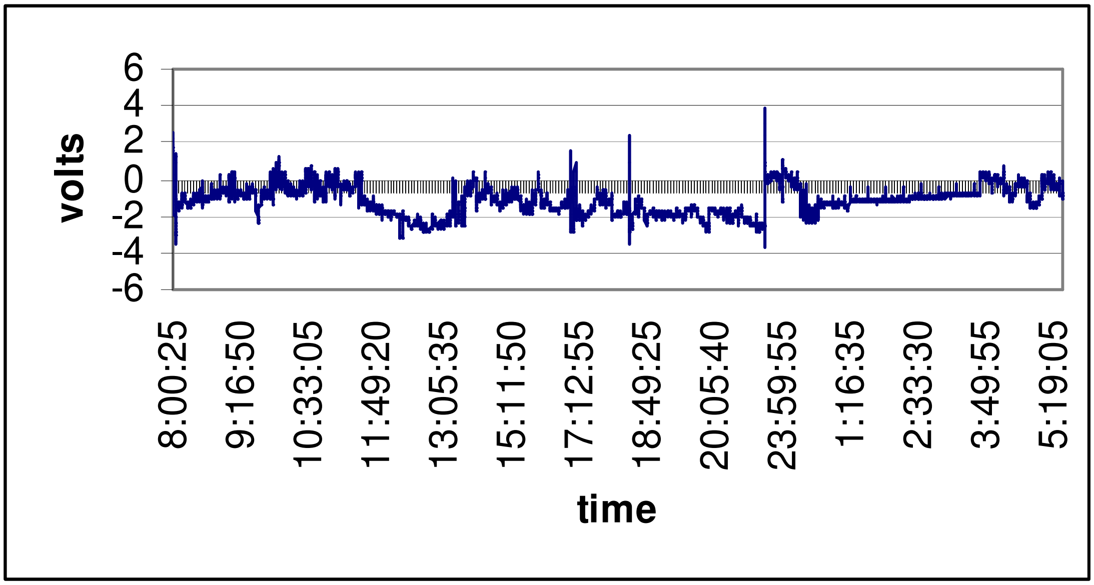


Figure 3.1 SID graph on 23/05/08

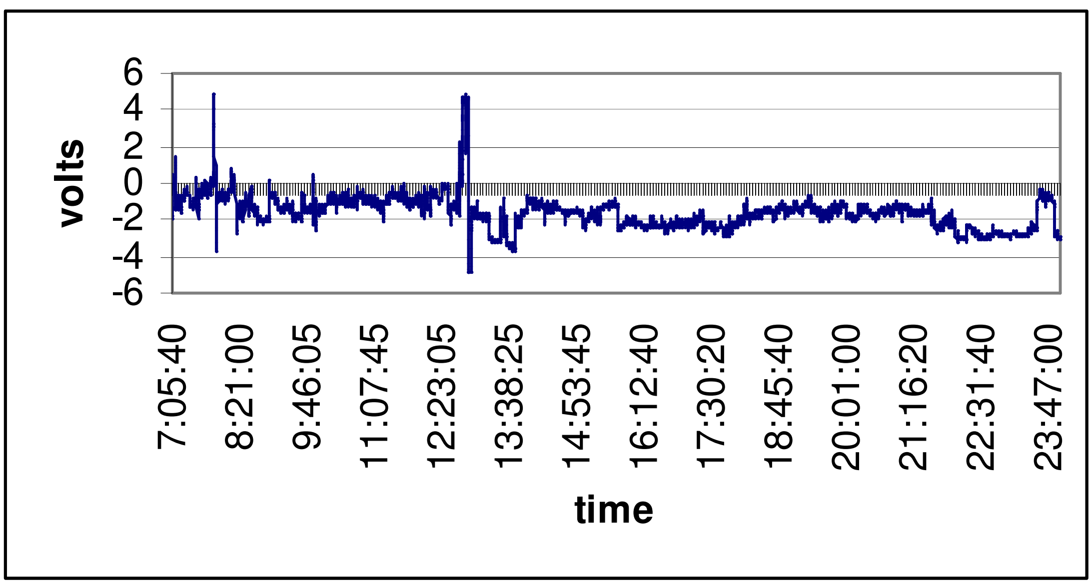


Figure 3.2 SID data graph on 06/06/08

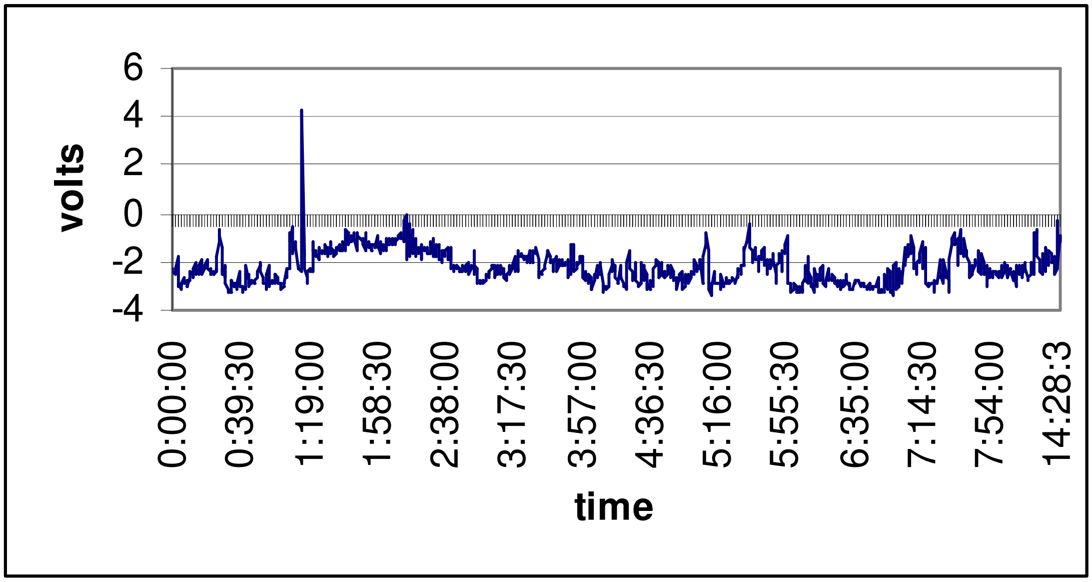


Figure 3.3 SID data graph on 22/06/08

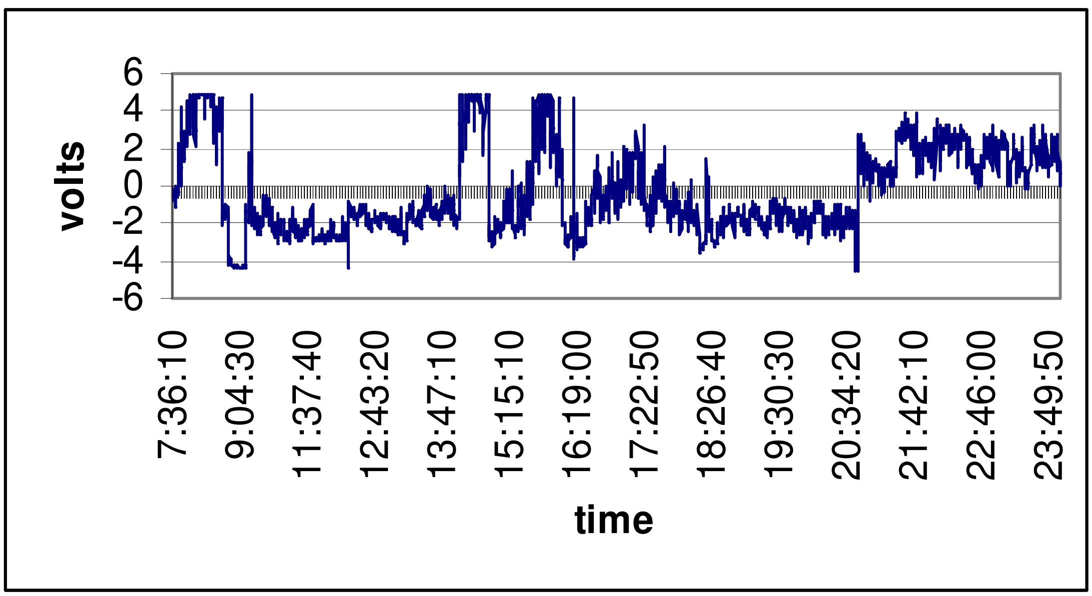


Figure 3.4 SID graph on 25/07/08

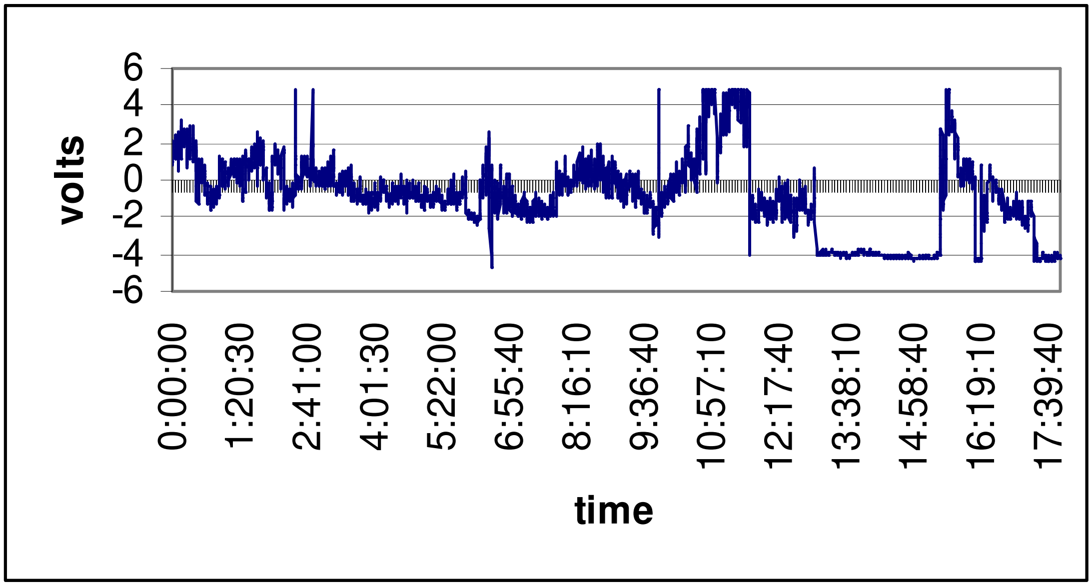


Figure 3.5 SID data graph on 26/07/08

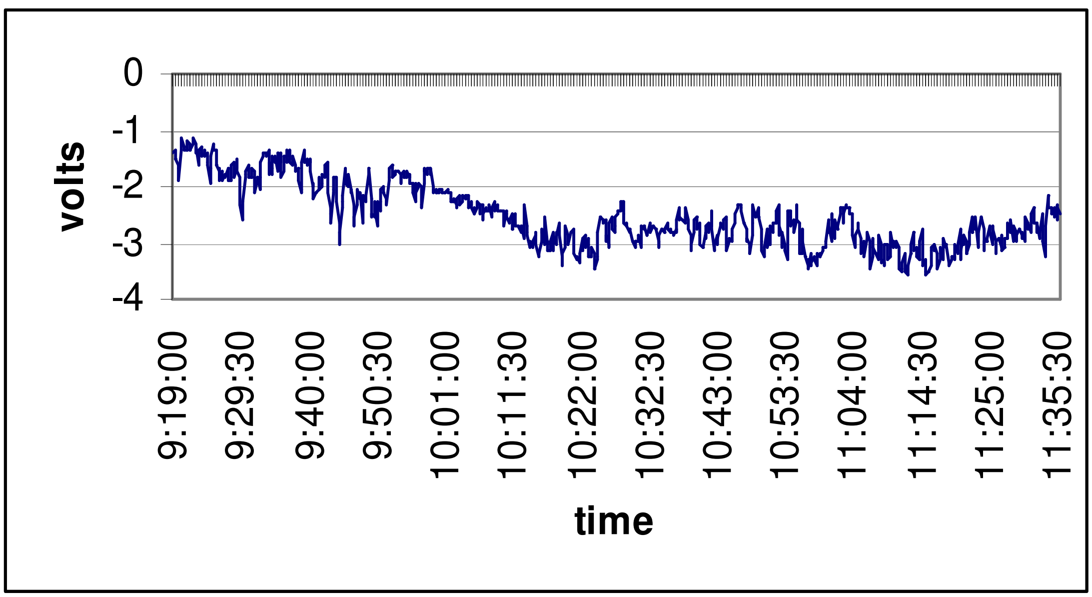


Figure 3.6 SID data graph on 28/07/08

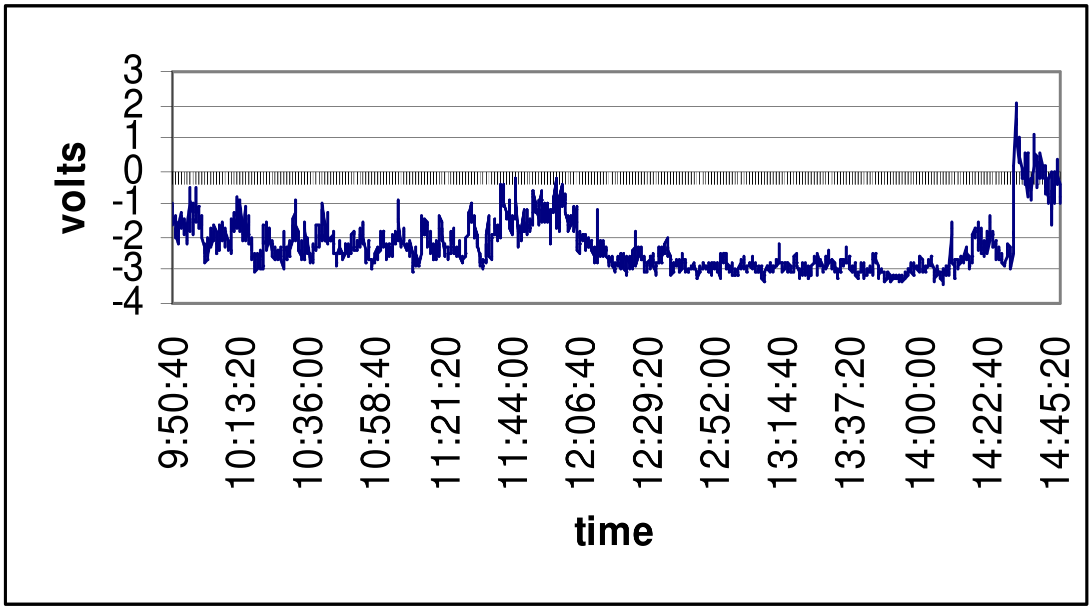


Figure 3.7 SID data graph on 31/07/08

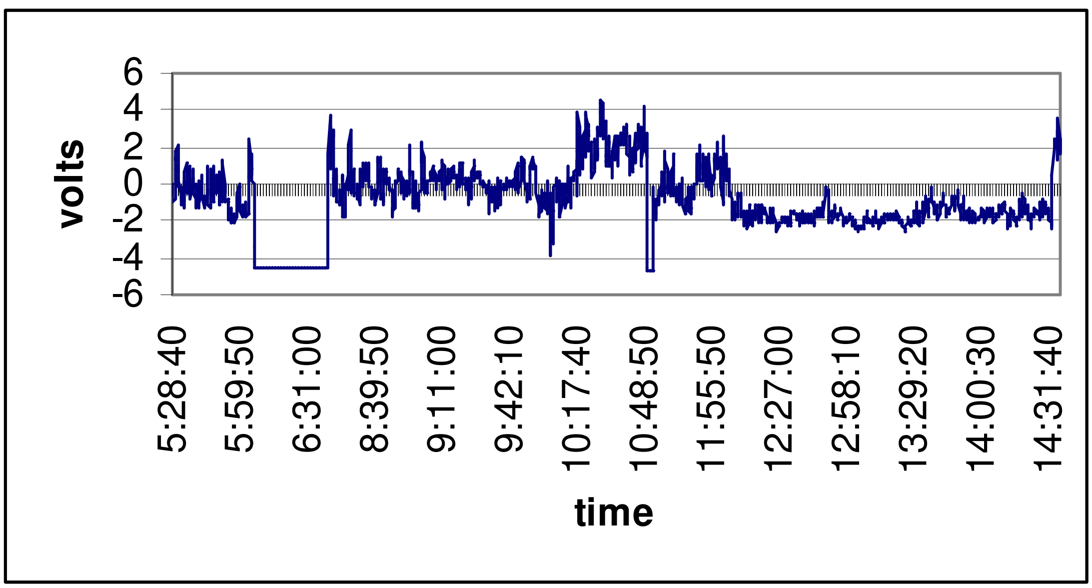


Figure 3.8 SID data graph on 01/08/08

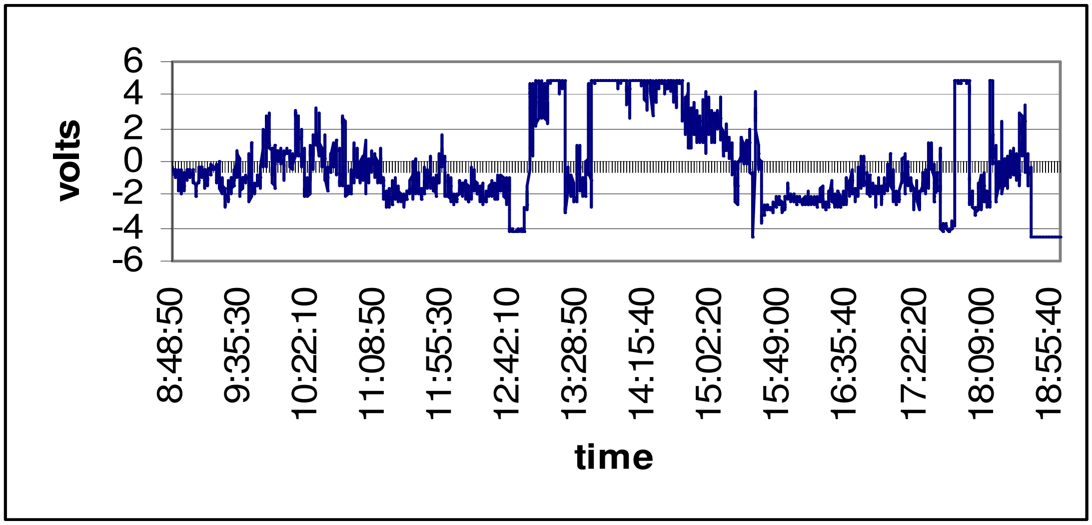


Figure 3.9 SID data graph on 04/08/08

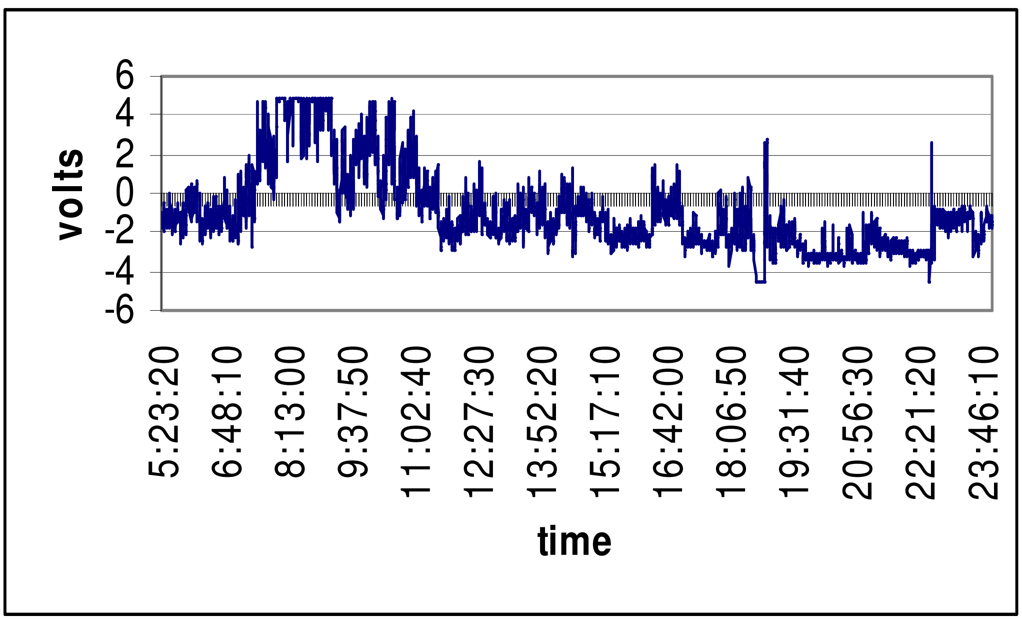


Figure 3.10 SID data graph on 05/08/08

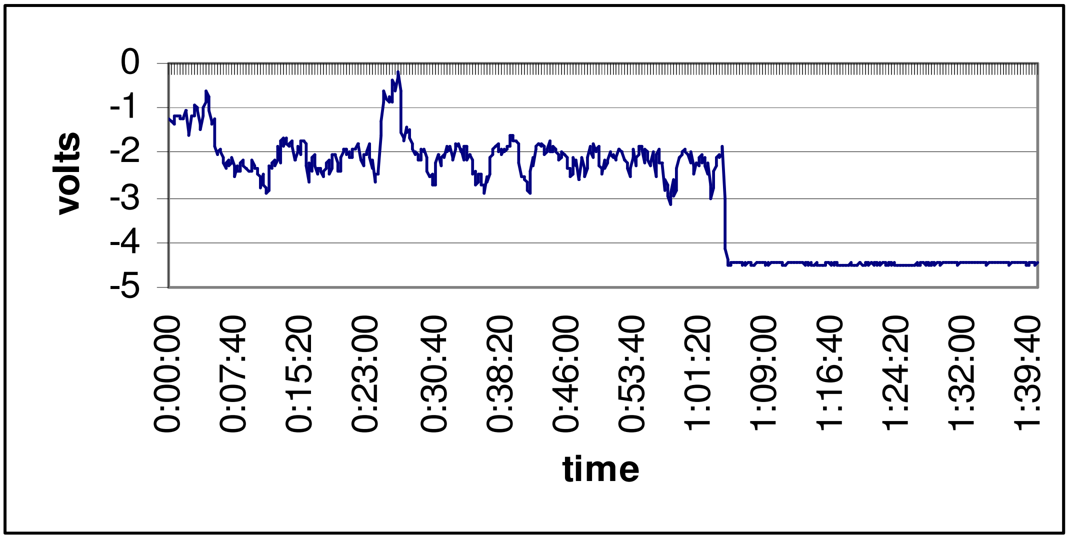


Figure 3.11 SID data graph on 06/08/08

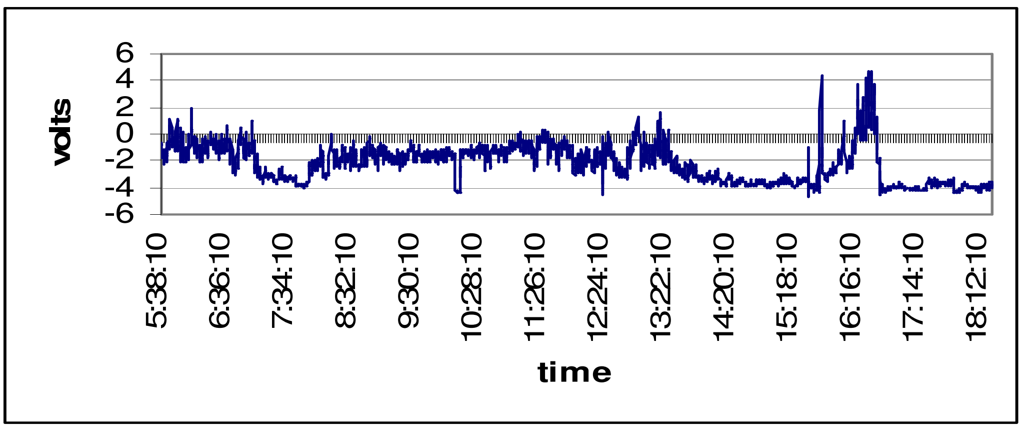


Figure 3.12 SID data graph on 07/08/08

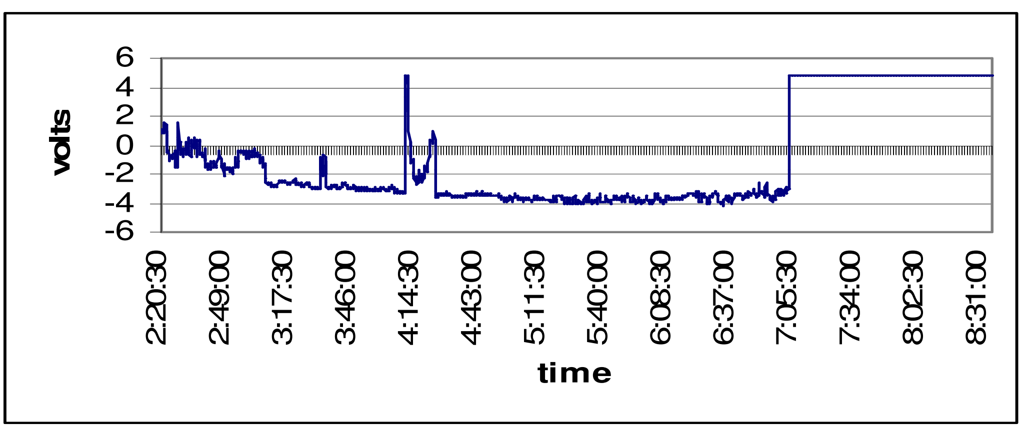


Figure 3.13 SID graph on 08/08/08

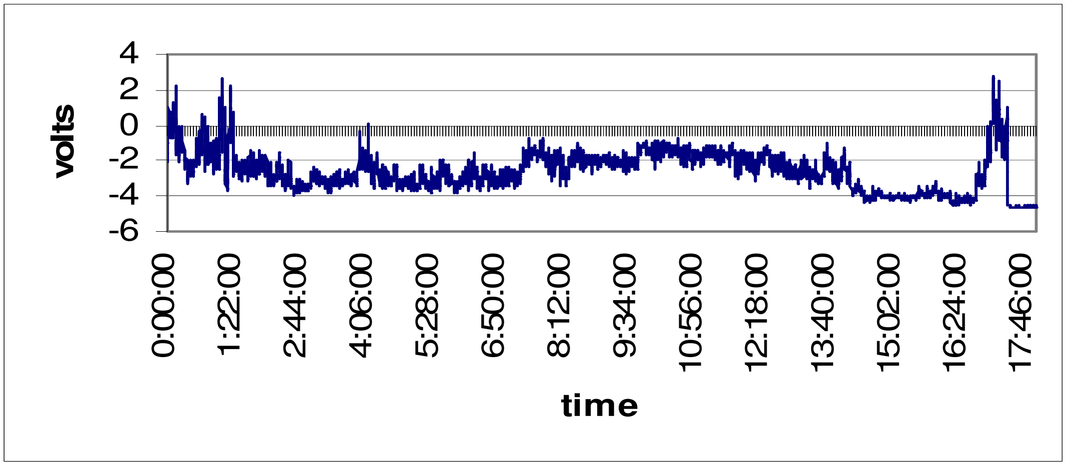


Figure 3.14 SID data *graph* on 09/08/08

3.2. DISCUSSION OF THE RESULTS

On the graphs above, the horizontal axis represents time while the vertical axis represents the voltage signifying the strength of the VLF signal received in volts. The strength of the VLF signals changes depending on the ionization of the Earth's ionosphere. Solar flares show up on SID data graph as spikes above the normal signal strength level. This spike shows ionospheric response to solar flares, however, spikes can occur due to some other interference like electrical interferences, noise e.t.c.

Figure 3.1 illustrates the SID data graph for 23/05/08, from 8:00:25 Universal Time (UT) to 05:19:05UT the following day. At 8:00:25UT, radio signals with signal strength of about -2volts were detected. From, 8:57:35UT, the graph showed a little increase in the signal strength and decreased back again to -2volts at 11:49:20UT. At about 18:49:25UT and 23:59:55UT, there were sharp peaks shown in the graph. This was initially thought to be a low flux density flare but comparison with data collected by other SID monitors (http://sidstanford.edu/database-browser/monitors.jsp) and by GOES revealed that no flare was recorded for the day.

Figures 3.2 and 3.3 are similar that the two graphs showed a horizontal flow of graph with minor background noise except at some points where there were one or two spikes. These probably indicated that 06/06/08 and 22/06/08 were normal days with no flares. These assertions were confirmed with results of Germa-NAA S-0070-FB-0070, Italy-DHO S-0405-FB-0405 and Tunis-NAA S 0096-FB-0096 and GOES which showed normal days with no flares (http://sid.stanford.edu/database-browser/monitors.jsp; Deborah, 2007). This result could also be confirmed on the following website: http://www.sec.noaa.gov/ftpmenu/indices/events.html. The same thing was applicable to Figures 3.7, 3.8, and 3.12. They were normal days with no solar flares indications.

In Figure 3.14, there are some important features on the graph. The observation covered the time range of 0:00:00UT to 17:46:00UT. At 0:00:00UT, signal strength of about -1.50V started and increases to about 2.3V, decreased and increased again to about 2.9V and decreased again to -2V and then made a horizontal flow of graph immediately after 1:22:00UT to 16:24:00UT and started rising again. The interesting features shown here were the sunrise and the sunset at around 1:22:00UT and 16:24:00UT respectively. The sunrise is shown at a point where there is a decrease in the signal strength followed by a long horizontal flow of graph, while the sunset is at a point of increase of this signal strength after the horizontal graph line. The time before the sunrise and after the sunset is called the nighttime while the middle time of sunrise and sunset is the daytime (Deborah, 2007). The sunrise and the sunset features were also seen in Germ-NAA, Italy-DHO, Tunis-NAA and others during comparison with results from the website: http://sid.stanford.edu/database-browser/monitors.jsp. This characteristic of the graph is an important factor in the verification of the sensitivity of the SID monitor.

In Figure 3.13, at 3:14:30UT, there was an increase in the signal strength up to 5volts, but after comparing it with GOES and results from other SID monitors, this indication did not appear which means the peak is not as a result of solar flares rather it might be as a results of interferences. Figures 3.4, 3.5, 3.6, 3.9, .10, and 3.11 also showed cases of interferences. This might be as a result of background noise since the SID is picking the signals due to the earth's response and not signals as it comes directly from the sun.

The absence of solar flares throughout the entire observation period might likely be due to the fact that we are presently in solar minimum and the occurrence of major flares is very rare. This situation has generated a lot of discussion in the science community and a lot of other reasons have been adduced (Deborah, 2007). However, the SID monitor installed is working well and all the results are in agreement with satellite data and data from other ground base observatories. The unusual absence of solar activity during this period is widely reported on http://www.sec.noaa.gov/ftpmenu/indices/events.html.

3.3. CONCLUSION

The SID monitor installed and the antenna constructed have been confirmed to be working accurately as confirmed by comparisons with results from satellite data and other ground base observatories. Though the period of observation witnessed an unusual absence of solar activity, the reason for this is subject to further research work. The data collected showed sunrise and sunset signatures which are indications that the monitor is sensitive to changes in ionospheric electron density. Hence, the installation of the SID monitor at Nsukka was successful.

3.4. RECOMMENDATION.

It is recommended that further work should be carried out with the equipment by other researchers to cover a longer period of time. It is also recommended that the solar power option should be upgraded to enable the monitor to be online always. Finally, it is recommended that the monitor be relocated to a more secluded environment to minimize interference.

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REFERENCES

Collins, R. E., (1985). Antenna and Radio wave propagation. Mc Graw-Hill Inc. New York.

Deborah, S., (2007). Research with Space Weather Monitor Data. An unpublished project work presented to Stanford University for International Heliophysical Year (IHY) program.

Gold, T. and Hoyle, F (1960). Origin of solar flares. Royal Astronomical Society 120, 89.

Hudson, H. S. (2004). Solar flares, Microflare, Nanoflares and Coronal heating, 133, 357

Kopp, Lawrence and Rottman, (2005). “The total Irradiance Monitor (TIM) Science Results”. Solar Physics 230, 139.

Kranu, J.O. (1950). Antenna, Mc Graw-Hill Block Company, Inc. New York.

Low, B. C. and Wolson, R. (1988). Spontaneous formation of electric current sheets and the origin of solar flares. Astrophysical journal, 324, 574.

Mewaldt, R. A., (2005). Space Weather Implications of the 20th January, 2005 solar energetic particle event, 410, 50.

Michael, Z. and John, G., (1990). Astronomy. The Cosmic Perspective, John Wily & Son, Inc, New York.

Okeke, P. N. and Soon, (2004). Introductory to Astronomy. SAN Press ltd, Nigeria.

Onel, H., Mann, G. and Sedimayr, E., (2007). “Propagation of energetic electrons through the Solar Corona and Interplanetary Medium” 463, 1143.

Otto, S., Beverly, L. and Helen, P. (1961) Elementary Astronomy, Oxford University Press, Inc. New York.

Pam, S., (2004). Sun Observer’s guide, Firefly Books U.S.A.

Walter, C.H., (1965). Traveling wave Antenna, Mc Graw-Hill, New York.

Willian, K. H., (1987). Astronomy. The Cosmic Journey, Wadsworth Publishing Company Belmont, California.

Zheleznyakov, V.V., (1970).”Radio Emission of the Sun and Planets”, Pergamon, Press ltd, London.

Space Weather Monitor from http://sid.stanford.edu/database-browser/monitors.jsp

SWPC Anonymous FTP Server, Indices, Events and Region Data, Solar Event reports-last 90 days from http://www.sec.noaa.gov/ftpmenu/indices/events.html