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Ionospheric flare detection using Raspberry Pi

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Stanford SOLAR Centre of Stanford University introduced the Space Weather Monitoring program with the aim of building and distributing inexpensive ionospheric monitors named Sudden Ionospheric Disturbance or SID for short. These SIDs are used to detect changes to the Earth's ionosphere caused by solar flares and other ionospheric disturbances. In 2009, through collaboration between the Institute of Space Science (ANGKASA), UKM (currently known as Space Science Centre) and Stanford University, U.S., research in remote sensing using Very Low Frequency (VLF) receiver was initiated at UKM using the AWESOME monitor. Later, when the International Space Weather Initiative (ISWI) was established with the main aim of focusing on space weather research, UKM was provided with a set of low cost version of the AWESOME monitor called Super Sudden Ionospheric Disturbance (SuperSID) ionospheric monitor which was designed for high school. In 2012, UKM researchers succeeded in building their own VLF receiver system known as UKM-SID. The UKM-SID system that include a teaching module was developed for the SID Introductory Project aimed to promote awareness and better understanding of space weather among high school students in Malaysia, in addition to cultivating students' interest in research through hands-on activities and usage of the UKM-SID ionospheric monitor.

The UKM-SID system requires a desktop PC to run the SID program and to save the data for further analysis. This made it difficult logistically to carry the system to schools because of the bulky size of the desktop, or for schools to allocate a dedicated PC for the system. The system also incur high cost and high power consumption.

These constraints led UKM researchers to develop a portable VLF data acquisition system using Raspberry Pi, known as the UKM-SIDπ (see Figs. 1 and 2)

The Raspberry Pi is basically an inexpensive and tiny computer, about the size of a credit-card that can be plugged into a TV or computer monitor, and uses any standard keyboard and mouse. Although it is a small device, it is capable of doing almost everything that can be done on a desktop computer, allowing people to explore computing and even learn programming using languages like Scratch and Python. Additionally, the Raspberry Pi also has the ability to interact with the outside world. In addition to its small size and low cost, it is versatile to be used in a wide array of projects, and UKM researchers at ANGKASA utilized these features to develop a portable space weather monitoring system to replace the bulky desktop computers required for the SID program.

The UKM-SIDπ project development was divided into two components, namely the hardware and software. The first component involved the development of the hardware comprising of a loop antenna, a preamplifier, a USB sound card, Raspberry Pi and an LCD display. The second component consisted of development of the SuperSID software which was written using Python. The software, which is an open source and available for download from the website https://github.com/ericgibert/supersid, was downloaded into the Raspberry Pi.

The loop antenna which captures the VLF signal from the transmitter stations was built using inexpensive PVC frames and 20 turns of #26AWG wire of the size of 1 meter square. The antenna output was connected to the UKM-SIDπ preamplifier using a coaxial cable. The preamplifier was based on the SuperSID preamplifier developed by Stanford SOLAR Center but redesigned into a small double layer PCB so that it could be easily connected to the USB external sound card and the Raspberry Pi. The schematic diagram and PCB layout of the preamplifier were drawn using CAD software. It was decided that the surface mounted components were to be soldered onto the preamplifier because of the small form factor of the UKM-SIDπ preamplifier.

The UKM-SIDπ preamplifier, powered by a 9 V adapter, amplified the very low induced output voltage. The amplified VLF signal was then captured and sampled by a USB external sound card at about 44 kHz. This enabled the system to detect signals with maximum frequency of up to half the sampling rate at 22 kHz. The sound card is required to convert the signal from the analog format into a digital one. In the UKM-SIDπ project, Creative Sound Blaster X-Fi Go! Pro sound card was used. To ensure the USB sound card is detected by the Raspberry Pi, the sound card setting was done in the LXTerminal. Using the SuperSID software, the Raspberry Pi then processed and stored the received VLF signal. The Raspberry Pi, which functioned as the desktop computer for this system, used the Raspbian Wheezy operating system which was installed using a 32 Gb class 10 card that supports 10 Mb/s non-fragmented sequential write speed. This enabled high speed bus mode. For the display, an LCD monitor was used via the HDMI interface.

However, to run the SuperSID software on Raspberry Pi, extra modules need to be installed and these were Matplotlib, wxPython, NumPy and alsaaudio. Matplotlib helped with the plotting of the SID data while alsaaudio supported the full capture and playback of the audio signal. NumPy, a Python extension module, is a general purpose array processing package which helped support manipulation of the large multidimensional arrays of arbitrary record of data. wxPython, a GUI toolkit for Python, allowed the system to be created with highly functional graphical user interface, simply and easily. Several configuration files had to be properly configured to monitor the VLF signals before executing the SuperSID software, including the command for the GUI mode, the audio sampling rate and the USB sound card. The preconfigured data path directory was used to save the acquired data.

Compared to the existing PCB boards from Stanford SOLAR Center, the UKM-SIDπ preamplifier PCB board has a smaller form factor at 32.55 x 47.01 mm. It also has low pass filter characteristics with a cut-off frequency at around 25 kHz after testing its performance using a function generator with frequencies swept from 2-200 kHz with amplitude of 20 mV. After installing the VLF data acquisition system using the Raspberry Pi, UKM-SIDπ preamplifier and USB sound card at ANGKASA's laboratory, testing was carried out. Data was logged hourly into the SD card. After configuring the system to monitor VLF signals at 19.8 KHz transmitted from the NWC Australia transmitter station, the VLF acquisition system successfully detected a distinct peak at 19.8 kHz (see Fig. 3)

Comparison between the UKM-SID and the UKM-SIDπ system demonstrated several advantages of the latter. Not only the UKM-SIDπ system is more portable because of the tiny size of the Raspberry Pi that functions as the desktop computer, it also consumes less power at 10 W compared to 500 W for the UKM-SID system. This makes the UKM-SIDπ save cost in the long run. Additionally, this advantage of lesser power consumption also means that it encourages green computing, and indirectly helps in lessening global warming. Another advantage is that the Raspberry Pi uses an SD card for storage, making it fast and it has no moving parts such as fans, unlike the desktop computer. It also has a small form factor and is completely silent. One of the greatest advantage of the UKM-SIDπ system is the cost involved. The UKM-SIDπ is much cheaper to build at around USD30 compared to more than USD400 for the UKM-SID system as it requires the purchase of a desktop computer.

It should be mentioned that the Raspberry Pi is only used to replace the desktop computer motherboard in the VLF data acquisition system, and there is still the need to obtain the monitor display, keyboard, mouse and others. However, with the affordable price, smaller consumption of power, portability, and the lack of need for extra investment of a computer system, the portable VLF data acquisition system using Raspberry Pi or the UKM-SIDπ system is definitely more appealing and cost saving to be used for educational and learning purposes in schools. All these advantages make it a tool that is very useful as teaching aid for promoting and developing interests in science, technology, mathematics and space science education among students in secondary schools in Malaysia, in line with the Malaysian Government's effort and aspiration to encourage more Malaysian children and youth to be interested and to take up STEM education.

Our gratitude to UKM's Electrical Engineering undergraduate student Yean Ling Soon, for her help in integrating and testing the system.

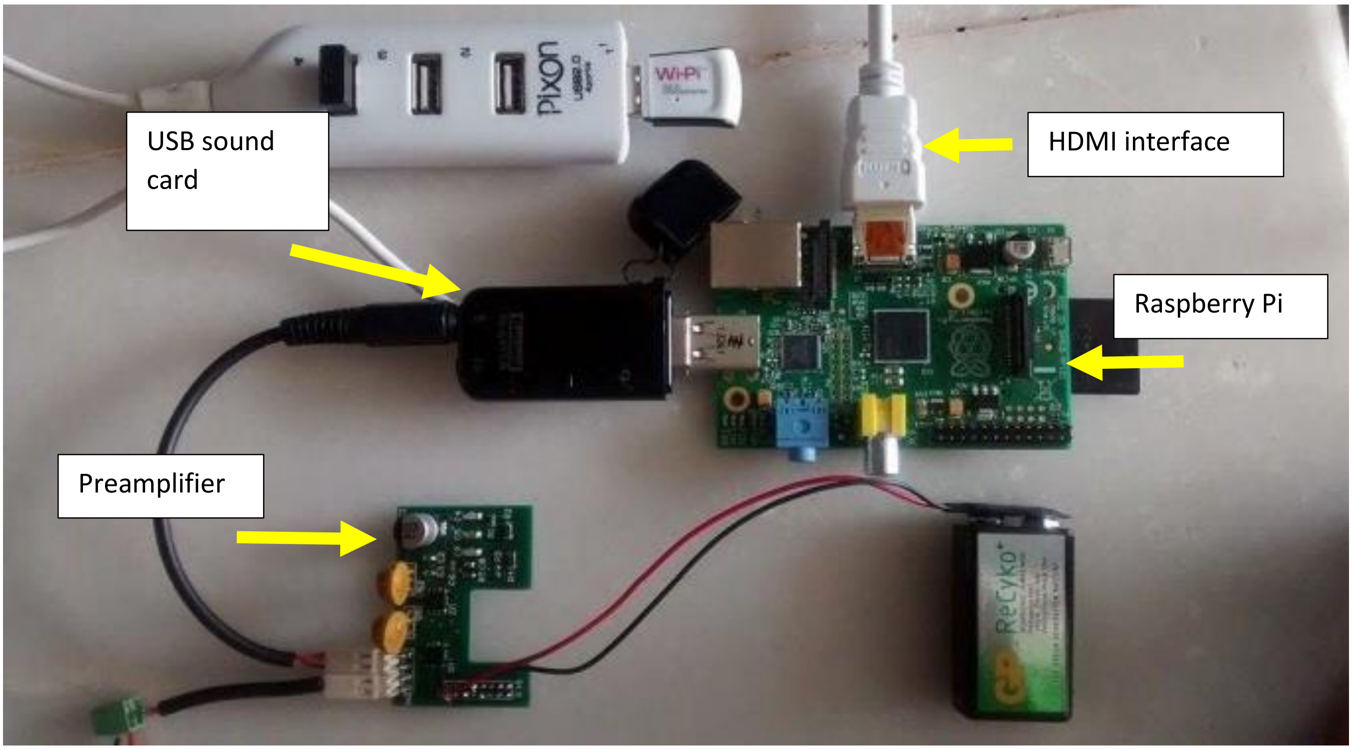

Fig.1 The UKM-SIDπ setup

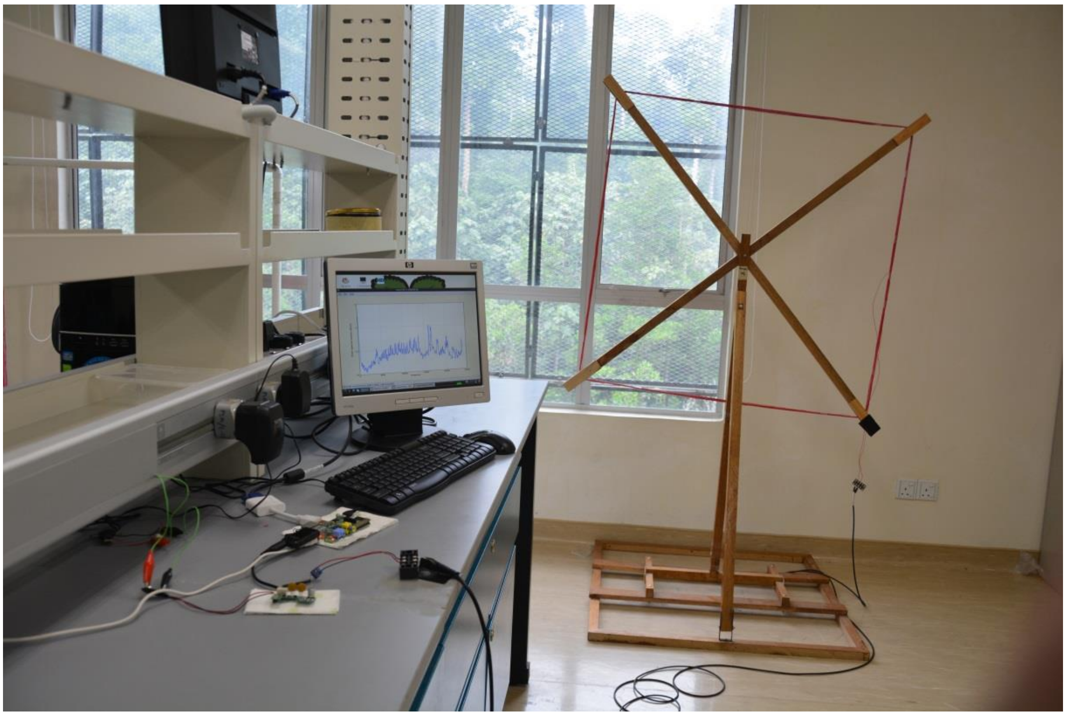

Fig. 2 The overall system

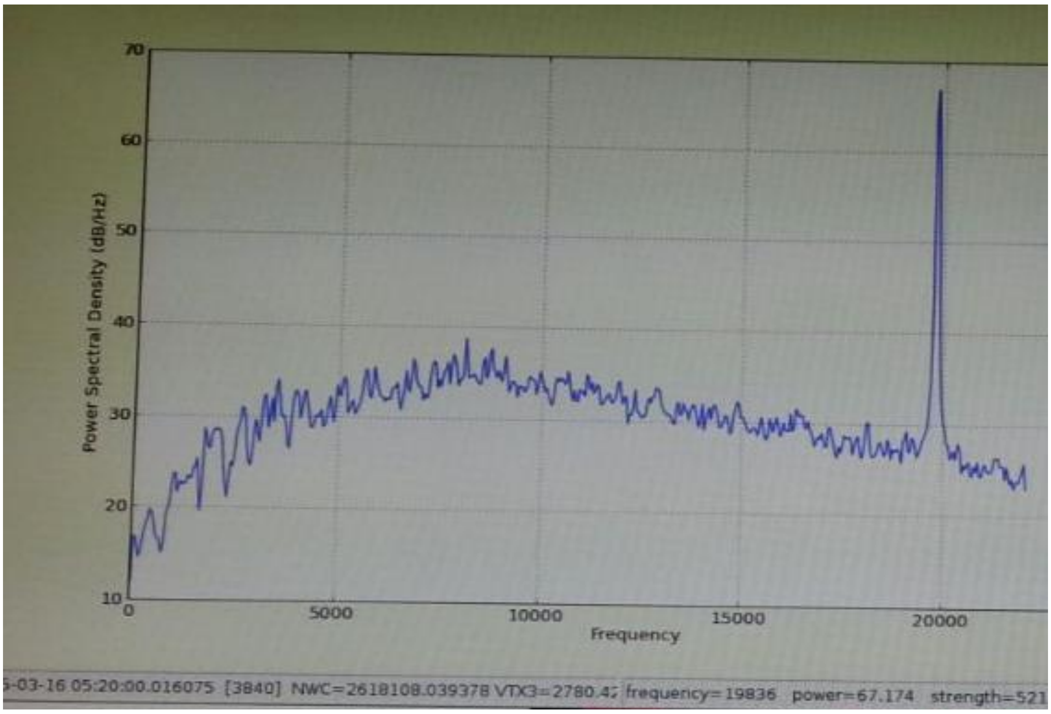

Fig.3 NWC VLF signal at 19.8 kHz detected by UKM-SIDπ