Developments of Real Time and Low Cost VHF/UHF Data Acquisition System

E. Z. Idris,
Faculty of Electrical Engineering, UiTM, Shah Alam, Malaysia

Abstract— **Very High Frequency (VHF)/Ultra High Frequency (UHF) plays a significant and vital role in our daily communications life. Thus, making it crucial to develop a data acquisition system to assist and facilitate further research and studies on VHF/UHF such as in amplitudes variations due to propagations characteristics. Currently, available data acquisition systems are very expensive, complex (non-user friendly), rigid and limited capabilities due to its hardware restrictions/limitations. Consequently, a real-time and low-cost data acquisition system was developed by using microcomputer (Raspberry Pi 3b) and Software Defined Radio (SDR). The system successfully acquired and collected relevant data (frequency amplitudes) that would be resourceful for further analysis and studies of the VHF/UHF signals.**

Index Terms—**VHF, UHF, SDR, Data Acquisition System**

I. Introduction

Radio Frequency plays a significant and vital role in our daily communications life. From voice to data, VHF/UHF applications throughout day-to-day activities has driven us to further studies the VHF/UHF characteristics due to propagations.

A. Radio Frequency Propagations

Signals propagations explain the way radio frequency propagates from an antenna of ta transmitter to the other end of receiving antenna. The propagation is affected by various ways depends on the medium and propagation methods used.

1) Ground wave

Signals that travel along or close to the Earth's surface on their path between transmitting and receiving antenna are called Ground Wave. Due to the Earth poor electrical conductor characteristics, the ground wave strength diminishes rapidly with distance. The attenuation of the surface wave signals also increases rapidly as the frequency increased. Its frequency ranges from VLF (3-30 kHz), LF (30-300 kHz) to MF (300-3000 kHz). Applications varies from Navigations, Space Weather study and long range communications.

2) Sky wave

Travelling signals that reflected back by the ionospheric layers are called sky wave. HF (3-30MHz) operated by Sky Wave and is highly affected by the ionospheric refractions. Amateurs and military are still using it for long-range communications.

3) Direct (Line of Sight – LOS) Wave

Direct wave depends on LOS between transmitting and receiving antenna. Thus, increasing the distance of transmission requires increasing the height of the antenna location above the terrain. However, certain frequencies are still affected by ionospheric refraction and tropospheric ducting. It covers from VHF (30-300 MHz), UHF (300-3000MHz) to SHF (3-30 GHz). Applications ranges from broadcasting, short-range communications, navigations to satellite communications.

Previous data acquisition system on radio frequency requires expensive equipment such as Spectrum Analyzer and with limited capabilities due to hardware limitations. By integrating the microcomputer and SDR, a real-time and low-cost data acquisition system could be developed to reduce and simplify methods for studying radio frequencies.

C. Microcomputer

Microcomputer is a small computer equipped with a microprocessor. In this system, microcomputer was used as an alternative to personal computer (PC) due to its system portability, simplicity and robustness as well as low cost and low powered. Managing the database acquired thru the system will mainly done by the microcomputer. There are various types of microcomputer including the Raspberry Pi. The Raspberry Pi is a credit-card-sized computer (microcomputer) that plugs into a TV and a keyboard. [1]. It is a multipurpose and versatile little computer that can be programmed to perform various tasks such as automation, cloud server and many other more. The Raspberry Pi 3b (hereafter simply referred as Raspberry Pi) is the third generation Raspberry Pi and is equipped with a 1.2GHz 64-bit quad-core ARMv8 CPU, 1GB RAM and others such as Wireless LAN and Bluetooth. It is also requires low power at only 2.5A.

D. Software Defined Radio (SDR)

A simple description of an SDR is that it is a radio which is divided into two parts. One part is the analog front-end, which

deals with antenna transmission and reception, filtering, amplification and frequency shifting to/from an intermediate frequency. The second part is a digital back-end, which processes the baseband signal and is done thru software [2].
SDR receives analog signal and uses the Analog to Digital Converter (ADC) to digitize the signal. Then the digitized signal could be processed via software. It is possible to have a completely different communication system just by replacing the software that is executed, keeping the same hardware [3]. From Frequency Modulation (FM) as an example, a digital modulation can be attained thru software without any modifications on the hardware. Thus its versatility has big impact on the telecommunications field, from students in laboratory to the industrial and researchers in the field. such as in Cognitive Radios.

RTL-SDR is a custom driver software that operates a USB digital TV tuner to function as a software defined radio receiver [4]. It is an open source software developed by Osmocom [5]. The driver works on digital TV tuners based on the Realtek RTL2832U data acquisition chip [6]. The USB digital TV tuner contains two main integrated chips (IC) which are used for receiving signals and data acquisitions and sending it to computer for digital signal processing. The RTL2832U has a 8-bit ADC which can worked up until 28.8MHz. Digitizing higher frequency requires IF mixer to convert it which used the R820T tuner chip. It operated from 20 MHz to 1.7 GHz and has a maximum bandwidth of 3.2 MHz. Its also come up with Low Noise Amplifier.

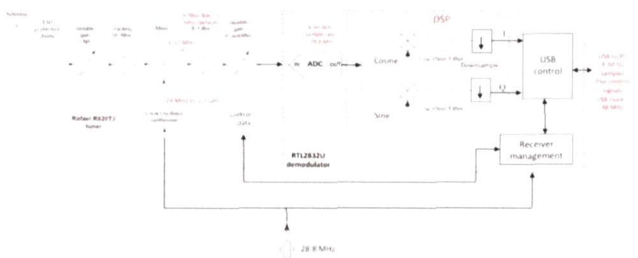

Fig 1. RTL-SDR Diagram Block [7]

There a few other models with broader capabilities such as the HackRF and the Ettus Research USRP (Universal Software Radio Peripheral),. These models are expensive than the RTL-SDR but still at affordable price compared to others high end SDR.

II. METHODOLOGY

Development of the data acquisition system includes setting up the systems - hardware and software. Hardware implementations and set-up include connecting all the required hardware such as an antenna (Omni-Directional used), relevant RF connectors (such as BNC, SMA and MCX) and coax cables, RTL-SDR, Raspberry Pi and relevant network connections.

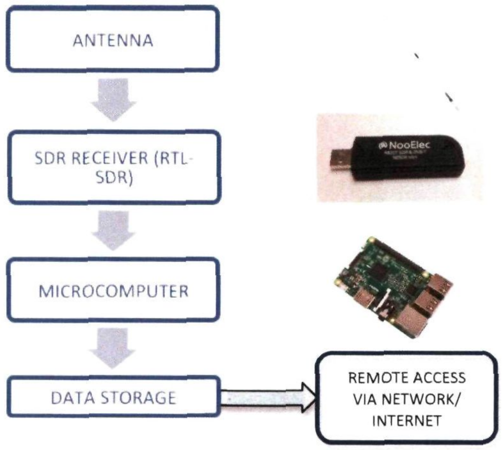

Fig 2. Hardware Set-up.

Fig 3. Location of antenna at an antenna tower in Sg Besi, Kuala Lumpur.

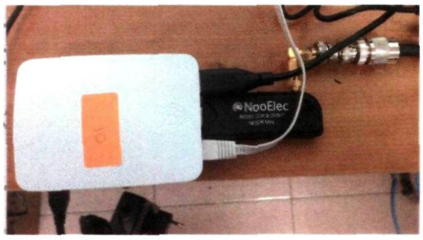

Fig 4. Completed connection to the Rapsberry Pi.

After all hardware impletion had been completed, the appropriate system's software was prepared and set-up. These includes:

1) Installing the Raspbian Jessie (Linux OS).
2) Preparing network connections such as creating as an access point (AP) and setting up a connection via Secure Socket Shell (SSH) server for remote access.
3) Installing relevant software and software packages that include the *rtl-sdr* drivers and packages (includes *rtl_power* function), SDR GUI software and Python.

The *rtl_power* is a new command (tool) in the SDR that allows us to capture a whole band of frequency spectrum base on our requirement. Data obtained using this command includes data and time, frequencies and amplitudes. It will produce a comma separated values (csv) [8].

There are varieties of open source SDR receiver software that are available that came up in Graphical User Interface (GUI) to allow easier access to the SDR receiver. This includes SDR Sharp, GNU Radio and Gqrx. Gqrx is an open source software defined radio receiver (SDR) powered by the GNU Radio and the Qt graphical toolkit [9].

In this system, Gqrx was used as it has compatibility with the Linux. This software will be utilised as a tool for real-time monitoring of the frequency spectrum.

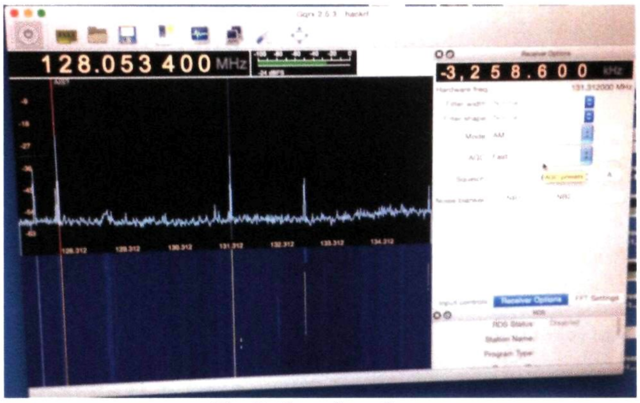

Fig 5. Gqrx interface.

Python is an interpreted, interactive, object-oriented programming language [10]. It has fewer lines code, open source and can run on various OS such as Microsoft Windows, Linux. Few Python commands were used as there were abundant of resources that could be found and used. This includes the heatmap.py [11] command that will render graphics of the overall spectrum (data) collected/acquired.

Once all relevant and necessary software and packages were installed, automation was set up for the Raspberry Pi to execute *rtl_power* command using the *crontab* at a specified interval. In this system, the *rtl_power* command was executed to run for a duration of 23 hours for every day. Example of command executed:

$ rtl_power -f 30M:300M:100k -g 50 -i 10 -e 23h >> /media/pi/Seagate\ Backup\ Plus\ Drive/SDR_Data/AlphaVHF100k$(date +%d%b%Y).csv

Real-time monitoring of the data acquisition could be done by using the command *tail -f filename*. This command will help if we want to check the integrity of the data collected/recorded.

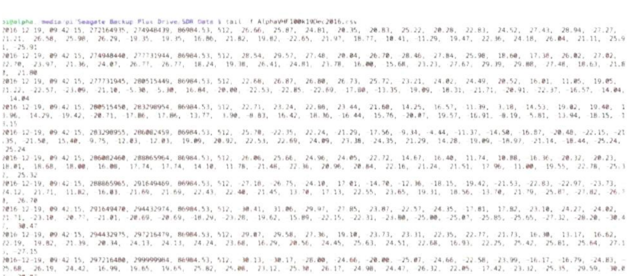

Fig 6. Real-time display of data being acquired/captured.

III. RESULTS

The system operated for more than 10 days to acquired the data. Data collected were in csv (comma separated values) format and could be easily imported to Microsoft excel or Matlab for further analysis.

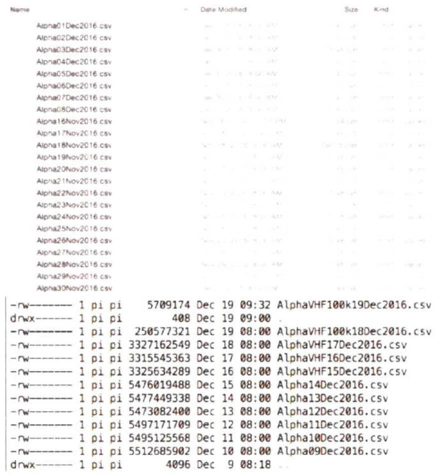

Fig 7. Data collected up until 19 Dec 2016. (Note: Data on 18 and 16 Nov 2016 were incomplete due to problem to the connections).

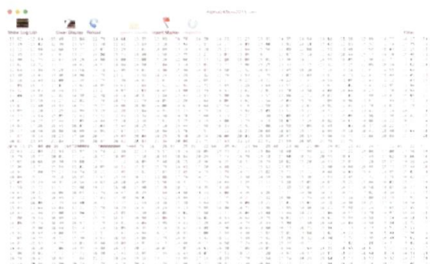

Fig 8. Example of data collected in csv formats.

With the data acquired, an overall visualization of the spectrum could be rendered using the *heatmap.py* installed earlier.

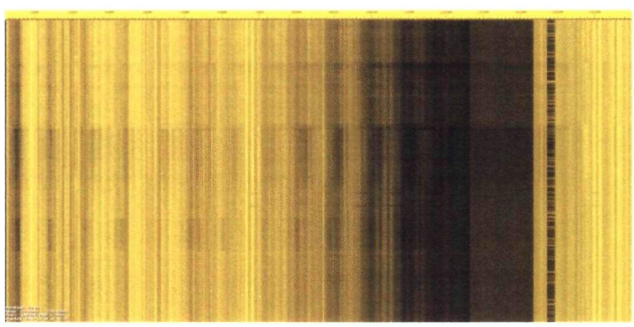

Fig 9. Example of heatmap.py image generated to indicate overall data collected (time, frequencies, amplitudes).

This image will gave an overall visualisation of the data collected (such as time, frequencies and amplitudes) by plotting time vs frequencies vs amplitudes (intensities of the colour represent the amplitudes of the signals).

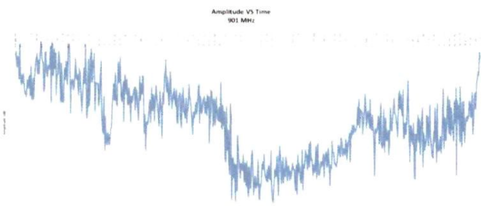

Fig 10. An example of plotted data (Time VS Amplitude) for 901 MHz.

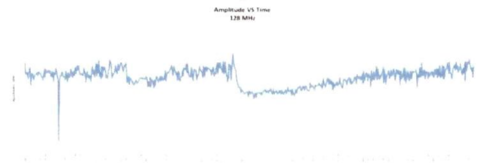

Fig 11. An example of plotted data (Time VS Amplitude) for 128 MHz.

From both plotted data as an example, we could see rapid decreased of amplitudes at around 1920H. Then it increased gradiently at around 0044H

IV. DISCUSSIONS

Data collected could be used in various ways to improve our understanding of the radio frequency signals. Based on the amplitudes of the signals collected, a simple analysis such as amplitudes variations could be identified for study such as amplitudes variations due to ionospheric characteristics. Others application includes:

1) Spectrum survey (determine 4unauthorized/unregistered transmitter beacon.
2) Space Weather or ionospheric impact on radio frequencies signals (such as amplitudes variations).
3) Detecting doppler shift by using high resolution narrow band scans.

Further improvement could be implemented in this systems such as increasing the frequency covering from VLF to UHF. One of the major problem faced in this system is time taken in handling the data. This is due to the size of the data. Thus high performance computer had to be used to process the data.

V. CONCLUSIONS

The data acquisition system has been successfully been develop although with some limitations that include the frequency it can cover. Thus, increasing the frequency range by using improved SDR (higher cost but still cheap compared to others high end units) such HackRF or USRP or SDR Play that could cover from 1KHz until 6 GHz would increased further its capabilities.

REFERENCES

[1] FAQS Raspberry Pi [online]. Available https://www.raspberrypi.org/help/faqs/#topIntro

[2] Miguel Bazdresch "Considerations for the Design of a Hands-On Wireless Communications Graduate Course Based on Software-Defined Radio"Electrical, Computer & Telecom Engineering Technology Dept. Rochester Institute of TechnologyRochester, NY

[3] André L. G. Reis*, André F. B. Selva*, Karlo G. Lenzi†, Sílvio E. Barbin‡ and Luís G. P. Meloni* "Software Defined Radio on Digital Communications: a New Teaching Tool" FEEC – School of Electrical and Computer Engineering UNICAMP – State University of Campinas Campinas, SP – Brazil DRC – Convergent Networks Department, CPqD – Research and Development Center Campinas, SP – Brazil, EPUSP – Polytechnic School, USP – University of São Paulo, São Paulo, SP - Brazil.

[4] Boonyarit Uengtrakull, Dahmmaet Bunnjaweht2, Dept. of Electrical and Computer Engineering Thammasat University, Pathumthani 12120, Thailand "A Cost Efficient Software Defined Radio Receiver for Demonstrating Concepts in Communication and Signal Processing using Python and RTL-SDR"

[5] RTL-SDR wiki. Available http://sdr.osmocom.org/trac/wiki/rtl-sdr

[6] Boonyarit Uengtrakull, Dahmmaet Bunnjaweht2, Dept. of Electrical and Computer Engineering Thammasat University, Pathumthani 12120, Thailand "A Cost Efficient Software Defined Radio Receiver for Demonstrating Concepts in Communication and Signal Processing using Python and RTL-SDR"

[7] RTL-SDR Block Diagram [online]. Available http://aaronscher.com/wireless_com_SDR/rtl_sdr_info.html

[8] RTL_POWER Scripting [online]. Available http://kmkeen.com/rtl-power/

[9] Gqrx SDR Software [online]. Available http://gqrx.dk/

[10] "What is Python" [online]. Available https://docs.python.org/3/faq/general.html#what-is-python.

[11] "Python Heatmap Viewer" [online]. Available https://github.com/keenerd/rtl-sdrmisc/blob/master/heatmap/heatmap.py