Research Project Report

Portable Weather Station using APRS. Protocol with 78 MHz

By

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Research Title: **Portable Weather Station using APRS protocol with 78 MHZ**

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Year: **2021**

Abstract

A Portable Weather Station (PWS) using Automatic Position Reporting System (APRS) protocol on 78 MHz band is presented in this paper. For a licensed amateur radio operator, the PWS data is transmitted on the high VHF licensed band while public or non-licensed radio operators can operate on non-licensed band only. Therefore, with a future objective to establish a Citizen Weather Observer Program (CWOP), a PWS prototype system is proposed and experimented on 78 MHz non-licensed citizen band. The system consists of a PWS and an internet gateway (iGate) on 78 MHz band. With the maximum transmitting power of 300 mW, the experimental result showed that the PWS and iGate can established two points RF wireless communication. The result is also theoretically validated with link budget analysis.

Keywords: APRS, Weather Station, WX, Wireless RF, CB

Acknowledgements

This is a research grant funded by Rajapurk University. The year 2021 Annual Report thank the university administrators for their great care in this research.

This research report is well done. Guiding guide Accuracy adds important issues and encouragement from start to finish, guiding the accuracy of the research report, which is very useful for this research. Researchers are very grateful for this opportunity.

Thank you staffs of Digital Technology for business department encouraged to collect information in this research and provide advice, encouragement, and support in their research, including authors of texts, papers, and research articles. References in this research include: Thank you to all of you who have encouraged and assisted the researcher in all aspects of the project. This was a great success.

However, the value and benefits of this research will be extended to all parents, relatives, teachers, and all of people who cited.

Nimit Hongyim

May 2023

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Chapter 1
Introduction

1.1 Background and Problem

A Portable Weather Station (PWS) or WX station has been used for weather data collection for nearly 200 years [1]. Instead of having a single PWS alone which collect, record, and report a point weather condition, a group of individuals formed a team and create a network covering wider area. Weather condition and related parameters were recorded on paper and then mailed to a weather centralized command center for analysis whether to issue an early warning of natural disaster such as tornado, flash flood, etc. Such a networking becomes the central concept of Citizen Weather Observe Program (CWOP). Presently, modern network communication replaces the paper recording and snail mails. Weather data are collected and stored for further analysis using modern data network such as the internet. While the internet is widely available in urban and many rural areas, some places have limited access to the internet; for examples, a weather station located on a mountain top or a ocean buoy weather station. In such case, weather data are transmitted through a radio frequency (RF) network to a mobile or fixed radio gateway.

The Automatic Packet Reporting System (APRS) Protocol (APRS™) [2] was developed in 1982 by Bob Bruninga, an amateur radio call sign WB4APR (sk) who passed away in Feb 2022 [3]. The APRS protocol utilizes the audio frequency shift keying (AFSK) modulation technique by representing logic 0 and logic 1 with changing of audio tone frequency. The APRS fixed data frame uses the AX.25 data frame format. The modulated audio tone is transmitted via a radio transmitter and received by a radio receiver. The weather data are transmitted with the APRS protocol and received with the reversed demodulation method by an internet connected receiver (iGate). Data are utilized or shared via internet services. For example, data are displayed as an overlay information with Google map API. A PWS is constructed by integrating instruments together in a package depend on objectives of the PWS. Such instruments may be sensors for ambient pressure, humidity, PM2.5, wind speed, etc. Raw data from sensors are packed in the data frame and modulated with the AFSK method by a modem. Modulated audio are fed to a transmitter. Generally, APRS are transmitted on high VHF band such as 144.39 MHz in an amateur radio band which has relatively low natural interference. However, such frequency band is for licensed amateur radio operators only. Therefore, a prototype on low VHF band as in the 78 MHz non-licensed citizen band is proposed and experimented.

The objective of this paper is to construct a PWS using APRS protocol on 78 MHz non-licensed citizen band. The prototype and results of this research is a proof-of-concept (PoC) of using such system on low VHF band especially the 78 MHz non-licensed citizen band and will be submitted for requesting the authority to allocate frequency slot for PWS or other data public usage applications. The remaining of the paper is organized as the following. Section II and section III elaborated on the design concept and design approach of the proposed system.

Fig 1.1 A Portable Weather Station (PWS)

1.2 Research Problems

1.2.1 PWS using APRS protocol on 78 MHz non-licensed citizen band. The prototype and results of this research is a proof-of-concept (PoC) of using such system on low VHF band especially the 78 MHz non-licensed citizen band

1.2.2 The weather data are transmitted with the APRS protocol and received with the reversed demodulation method by an internet connected receiver (iGate). Data are utilized or shared via internet services?

1.3 Research Objectives

1.3.1 The objective of this paper is to construct a PWS using APRS protocol on 78 MHz non-licensed citizen band

1.3.2 The prototype and results of this research is a proof-of-concept (PoC) of using such system on low VHF band especially the 78 MHz non-licensed citizen band and will be submitted for requesting the authority to allocate frequency slot for PWS or other data public usage applications.

1.4 Research Hypothesis

This research scope will focus to construct a PWS using APRS protocol on 78 MHz non-licensed citizen band by designing with small Microcontroller along with other components that used for controller the unit. The weather data are transmitted with the APRS protocol and received with the reversed demodulation method by an internet connected receiver (iGate). Data are utilized or shared via internet services.

To support these objectives, an APRS network was developed to provide:

1.4.1 data are displayed as an overlay information with Google map API

1.4.2 A PWS is constructed by integrating instruments together in a package depend on objectives of the PWS. Such instruments may be sensors for ambient pressure, humidity, PM2.5, wind speed, etc.

1.4.3 Raw data from sensors are packed in the data frame and modulated with the AFSK method by a modem. Modulated audio are fed to a transmitter. Generally, APRS are transmitted on high VHF band, a prototype on low VHF band as in the 78 MHz non-licensed citizen band is proposed and experimented.

1.5 Research Benefits

The prototype and results of this research is a proof-of-concept (PoC) of using such system on low VHF band especially the 78 MHz non-licensed citizen band and will be submitted for requesting the authority to allocate frequency slot for PWS or other data public usage applications.

1.6 Research Scope

A PWS prototype system is proposed and experimented on 78 MHz non-licensed citizen band. The system consists of a PWS and an internet gateway (iGate) on 78 MHz band. With the maximum transmitting power of 300 mW, the experimental result showed that the PWS and iGate can established two points RF wireless communication. The result is also theoretically validated with link budget analysis.

1.7 Definitions

1.7.1 Automatic Packet Report System (APRS) was developed in 1992 by Bob Bruninga. APRS is a digital communications protocol for exchanging information among a large number of stations covering a large (local) area, APRS operates entirely in an unconnected broadcast fashion, using unnumbered AX.25 frames.

1.7.2 AFSK (*Audio frequency-shift keying*) is a modulation technique by which digital data is represented by changes in the frequency (pitch) of an audio tone, yielding an encoded signal suitable for transmission via radio or telephone. Normally, the transmitted audio alternates between two tones: one, the “mark”, represents a binary one; the other, the “space”, represents a binary zero. AFSK differs from regular frequency-shift keying in performing the modulation at baseband frequencies. In radio applications, the AFSK-modulated signal normally is being used to modulate an RF carrier (using a conventional technique, such as AM or FM) for transmission.

1.7.3 Embedded system is a computer system with a dedicated function within a larger mechanical or electrical system, often with real-time computing constraints. It is *embedded* as part of a complete device often including hardware and mechanical parts. Embedded systems control many devices in common use today. Ninety-eight percent of all microprocessors are manufactured as components of embedded systems. Examples of properties of typically embedded computers when compared with general-purpose counterparts are low power consumption, small size, rugged operating ranges, and low per-unit cost. This comes at the price of limited processing resources, which make them significantly more difficult to program.

1.7.4 Microcontroller (MCU for *MicroController unit*) is a small computer on a single integrated circuit. In modern terminology, it is a System on a chip or SoC. A microcontroller contains one or more CPUs (processor cores) along with memory and programmable input/output peripherals. Program memory in the form of electric RAM, NOR flash or OTP ROM is also often included on chip, as well as a small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications consisting of various discrete chips.

1.7.5 Portable Weather Station (PWS) is the Weather data are collected and stored for further analysis using modern data network such as the internet. While the internet is widely available in urban and many rural areas, some places have limited access to the internet; for examples, a weather station located on a mountain top or a ocean buoy weather station.

1.8 Research Structure

1.8.1 Chapter 1 Introduction explains the background and importance of the problem. The basic principles of APRS, the protocol, the problem of application of data communications, the presentation of APRS protocols, goals, research objectives, scope of work and expected results from the research.

1.8.2 Chapter 2 Literature review describes research related to theses. In various protocols the basic system for comparing the present and explain the complexities and constraints of networking. Elaborated on the design concept

1.8.3 Chapter 3 Research Medology involved. It consists of the basic requirements of the system required in the design. Including how the protocols worked and applications are implemented by using this protocol. Design approach of the proposed system.

1.8.4 Chapter 4 the experimental results after the design and installation on the experimental equipment that was designed to be experimental and to compare. The result is also theoretically validated with link budget analysis

1.8.5 Chapter 5 Summary of Experimental Results of Research Experimental and Guidelines for Future Research and Development. Concluded in this chapter

Chapter 2
Literature review

"A smart weather station based on sensor technology." Đorđević, Miloš, and Danijel Danković. *Facta universitatis-series: Electronics and Energetics* 32.2 (2019): 195-210.

This system is primary intended for use in agriculture and meteorological stations, but its application is not limited here. Weather parameters observing plays an important role in human live, so the observing, collecting and storing of information about the temporal dynamics of weather changes is very important. The primary goal is to design a low cost smart system for storing data obtained by measuring various physical parameters in the atmosphere without human involvement. Realized system use Internet of Things technology to storage measured results, and allows the user to access the results anytime and anywhere. In this research Internet of Things is used as technology for storing measured data, because this technology is an advanced and efficient solution for connecting the things to the Internet and to connect the entire world of things in a network. The proposed smart weather station system is based on the following steps: direct environment sensing, measuring and storing data and then allowing user to customize the settings. This research will present the design and implementation of a practical smart weather station system, which can be further extended. The system is based on: group of embedded sensors, Peripheral Interface Microcontroller (PIC) microcontroller as a core and server system and wireless internet using Global System for Mobile Telecommunications (GSM) module with General Packet Radio Service (GPRS) as a communication protocol.

2.1 Theoretical Background

The smart weather station is essentially a data acquisition system remotely able to collect information based on meteorological/ambient parameters and store it in the Cloud or database on the webserver. Data acquisition system such as smart weather station are based on Internet of Things technology. This smart weather station can be called “smart” in relation to research related to so-called non-smart weather stations that do not use Internet of Things technology. Non-smart weather station use only wired connected media to store measurement results, such as Security digital (SD) memory card, flash memory, EEPROM memory, etc. The areas of application point out include, e.g., the smart industry, where the development of intelligent production systems and connected production sites is often discussed under the heading of Industry 4.0.

Main elements of the smart weather station are:

1. Network for communication – wire, cable (Local Area Network (LAN)), wireless.
2. Intelligent control – microcontroller to manage the system.
3. Embedded sensors – products which can be used to observe and measure Meteorological/ambient parameters.

There are many different implementations of smart weather stations, which are reflected in the way in which communications and storage media are realized. Most of the Implementations use wireless technologies for communication between the sensor part and the main unit.

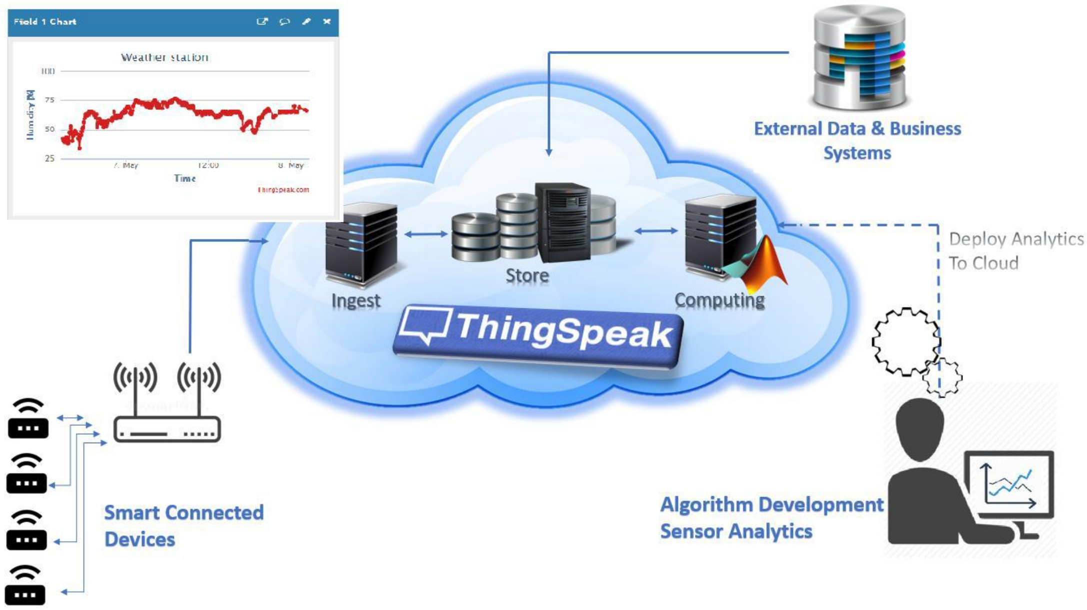

Fig. 2.1 ThingSpeak principle of work

2.2 Implementation (hardware and software)

Realization of the measurement system can be seen on electrical scheme of the smart weather station shown in Fig. 2. The microcontroller used for the realization of the weather station, operates at a frequency of 8 MHz, using an external oscillator. For the speed of the PIC18F45K22 microcontroller, it is possible to use a high-frequency internal oscillator with the highest frequency of 16 MHz, with the possibility of a 4-time multiplier (PLLEN) frequency increase - at 64 MHz. Also, it is possible to use an external oscillator, which also has the ability to operate at a frequency of 64 MHz, using the PLLEN multiplier of the oscillator operating frequency. Master Reset (MCLR) is software off, but a pull-up resistor of 10 kΩ is also installed in the realization, in order to see the possibility of hardware disconnection of the MCLR pin on the microcontroller. This microcontroller has 2 USART (Universal Synchronous Asynchronous Receiver Transmitter) modules. With this it is possible to manage hardware modules communicating with the microcontroller via the I2C or SPI bus, and also via the RX/TX serial terminal.

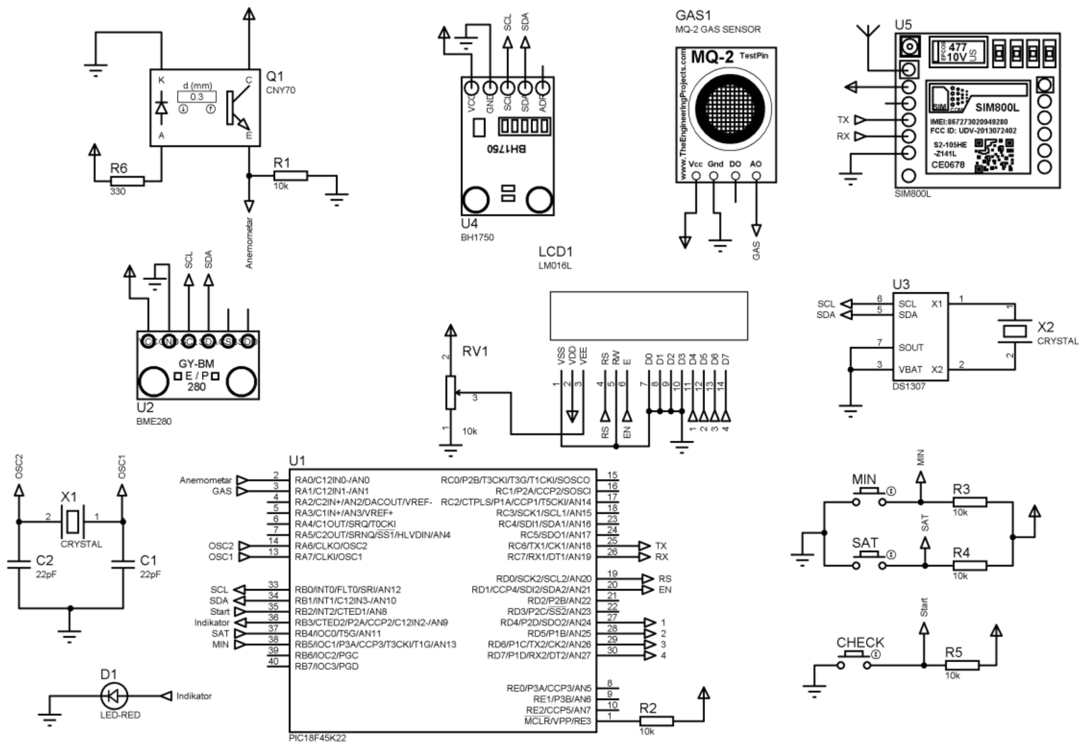

Fig. 2.2 Electrical scheme of weather station

The **Main** thread is responsible for starting the other threads. It also sends diagnostic messages to the LCD display and receives simple commands from the keyboard, effecting the application's execution flow (e.g. stop, restart). The **Main** thread contains all the settings necessary (e.g. settings of A/D converter, the values of registers for the sensors that work through the I2C bus, interrupt routines) for the proper operation of the smart weather station. Also, this thread contain the settings of the measuring time (start/stop) that will be sent to the **Measurement** thread.

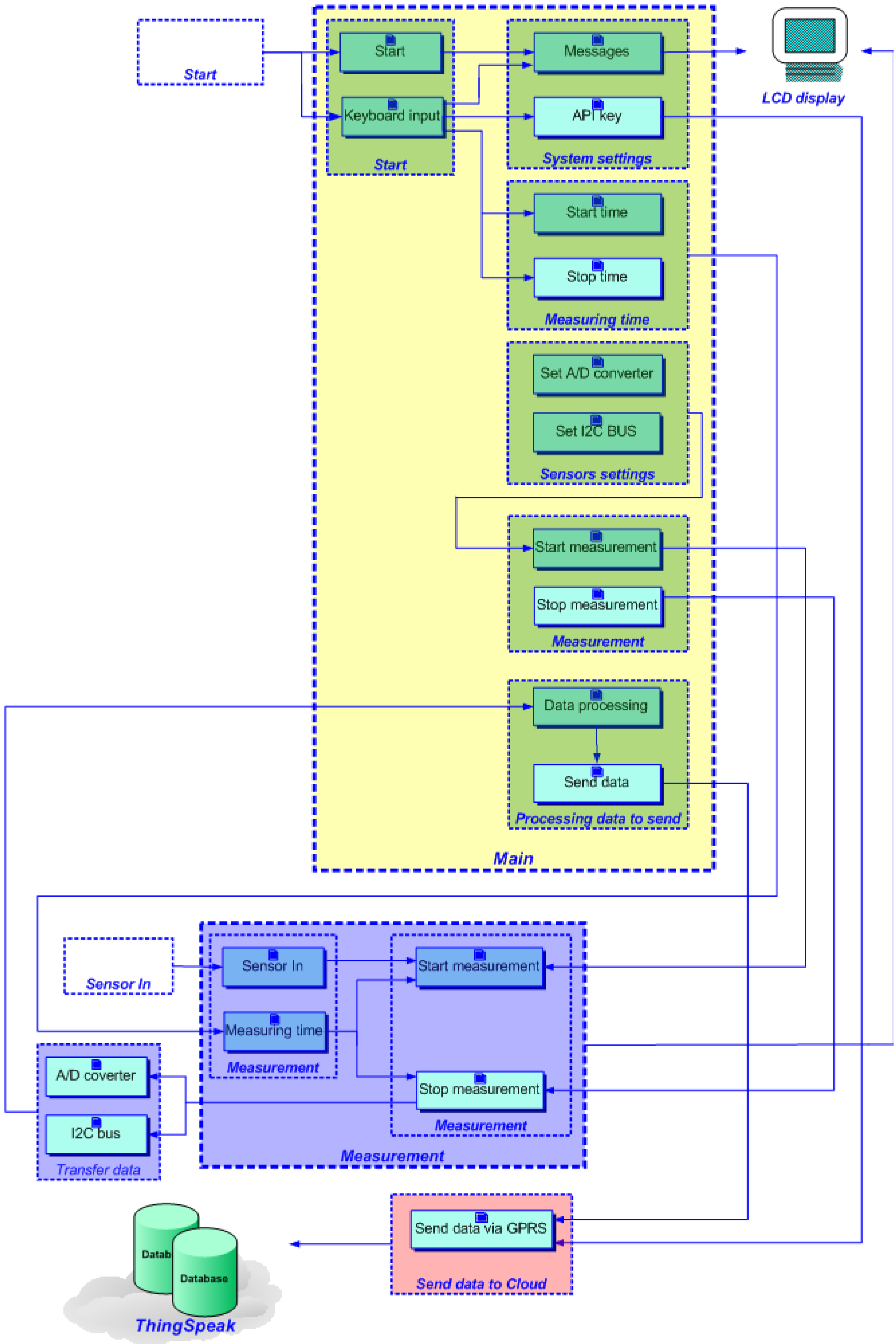

Fig. 2.3 Basic algorithm of the embedded software of smart weather station.

2.3 Conclusions of this

Further development of the device is planned, in the form of simultaneous sending of data from several smart weather stations at the same time to the same channel. In this way, the user would have an insight into the change of measured parameters in multiple locations in order for the user to have an insight into the change of measured parameters in several locations. It is also possible to add new sensors to measure other meteorological/ambient parameters. Some of the sensor can be added as sensor for rain gauge, wind direction, Geiger counter radiation detector, etc.

2.4 Theory and Design Systems Design of APRS

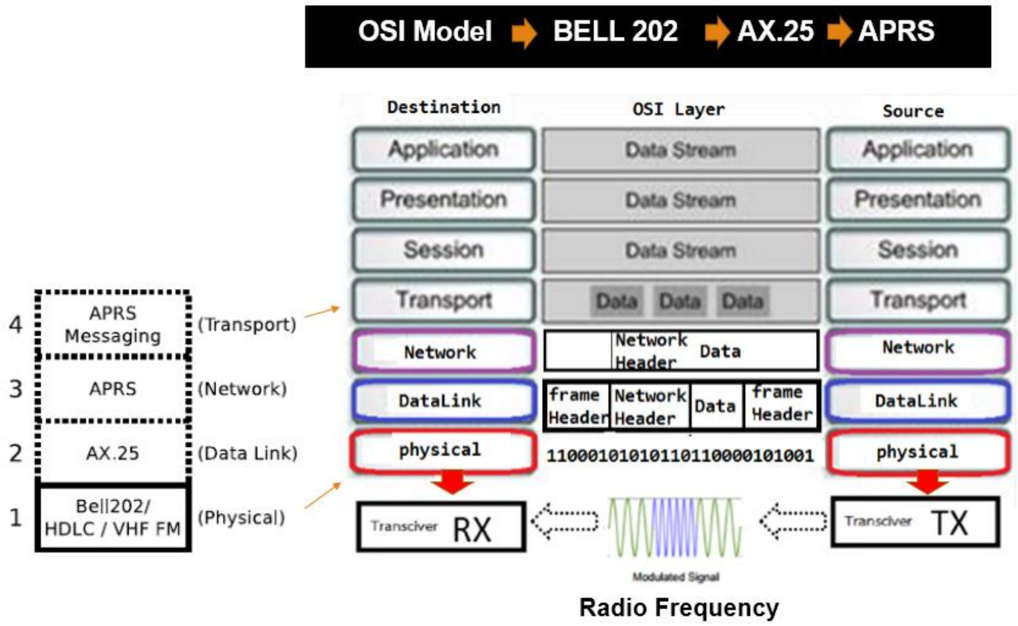

Fig.2.4 Fundamental of APRS Packet Radio (Bruninga, 1992: online)

Current APRS devices can be designed to be small and lightweight and can be deployed on a wide variety of devices, such as small vehicles, unmanned aerial vehicles (UAVs), and distance that can be covered. (Bruninga, 1992: online)

Example of the RAW data

Raw GPS NMEA sentence

*$GPGGA, 052421.00, 3426.0100,N, 13514.5900,E,1,05,1.5,280.2,M,-34.0,M, ,*75*

Raw GPS sentence with call sign

HS1IFU>:$GPGGA, 052421.00, 3426.0100, N, 13514.5900, E, 1, 06, 1.54, 00105, M,-019

APRS sentence

*HS1IFU >:! 3426.01N/13514.59E /*A=00266*

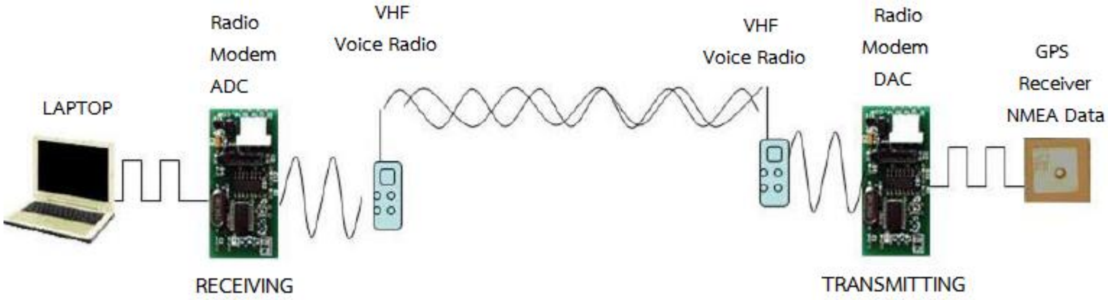

Fig. 2.5 GPS DIGITAL DATA Radio Link (Foutzitzis, 2007)

Basic APRS consist of:

- GPS Module
- Radio Module or Digital Conversion unit for BFSK (Binary Frequency Shift Keying)
- RF Module Transceiver (VOICE Radio)

<u>**Transmission of APRS signals**</u>

On VHF the APRS frames are transmitted in AFSK (Audio frequencies shift keying) or, to be more rigorous, in class F2D which means:

F: frequency modulation

2: Single, digital signal, using a subcarrier

D: Data transmission

The Carrier frequency to be used for APRS in Thailand (NBTC Plan) is 144.390 MHz but in this experiment is 78 MHz

The modulating subcarrier can carry two tones, one corresponding to the Mark (1200Hz) and the other to the Space (2200Hz).

The bit rate is 1200 bits per second, which means that the duration of a mark or a space is 833 milliseconds, which is a period for the mark and a little less than two periods for the space. (Guillaume, 2013: online)

NRZI encoding

This type of encoding makes it possible to transmit binary information with good efficiency. The “0” and the “1” to be transmitted are not translated by different states of the transmitted signal but by changes of states of this signal at the time of a clock top:

- The transmission of a “0” translates to the passage from Mark to Space (if the tone being transmitted was 1200Hz) or from Space to Mark (if it was 2200Hz)

- The transmission of a “1” consists in doing nothing at the time of the clock top.

Of course, the clock has a frequency of 1200 Hz to transmit 1200 bits per second.

The figure opposite shows:

- The clock signal with a pulse every 833 milliseconds
- The byte to be transmitted “10000010”
- The output signal from a logical point of view
- The output signal, a tone whose frequency varies from 1200 to 2200Hz at the time of the clock top if, and only if, a “0” is to be transmitted.

Note: the frequency change of the output signal is done without phase change.

It can be seen that a sequence of 1 does not result in a continuous tone, ie 1200 or 2200 Hz, which does not allow the decoding program to synchronize at the bit. That is why the sequels of more than five “1” are cut into pieces by insertion of “0” (see: “Bit-stuffing”) (Mc Dermont, 2013: online)

Example

In appearance, the content of an APRS frame varies greatly depending on whether certain information (geographical position) is present or not, compressed or not...

Example:

The following information, decoded by UI-View:

08: 21: 30R F4FEB> APFD25, WIDE1-1, WIDE2-2 Port = 2 <UI C Len = 51>: = 4723.26N / 00633.59E-PHG3630 / 73 all. {UIV32N}

Are actually transmitted in the form of a string that resembles:

APFD25pF4FEB 0WIDE1 1WIDE2 2__4723.26N / 00633.59E-PHG3630 / 73 to all. {UIV32N}

But in reality, this string, the frame, is structured in a standardized way into several fields (9 in total), some of which have a fixed length and others a variable length.

Structure

The structure of an APRS frame is of the UI (Unnumbered Information) type defined according to the Amateur Packet-Radio Link-Layer Protocol (AX25)

The PDF document (see section "Documentation below the reference (101) schematically (Guillaume.2013: online)

TABLE 2.1 AX.25 UI-Frame format

AX.25 UI Frame Format								
Flag	Destination Address	Source	Digipeater Address (0-8)	Control Field (UI)	Protocol ID	Information Field	FCS	Flag
1 (Byte)	7	7	0-56	1	1	1-256	2	1

Here are the details:

Flag: length 1 byte (one byte); It detects the start of the frame. Its value is immutable and equal to 7E in hexadecimal, or 01111110 in binary.

It does not appear in our example. In general it is not 1 but a whole series of flags that are issued before the start of the next field.

Destination Address: length 7 bytes. This field can contain a wide variety of values.

Example: APFD25p

Source Address: length 7 bytes. Indicator of the transmitting station of the frame followed by the SSID

Example: **F4FEB 0**

Digipeater Addresses (0-8): Length 0 to 56 bytes, which means that this field may be non-existent. Each digi address is coded on 7 characters.

Example: **WIDE1 1WIDE2 2**

Control Field (UI): length 1 byte. Fixed value 03 in hexadecimal that is 00000011 in binary.

Example: _ (cannot be represented as an ordinary character)

Protocol ID: Fixed value equal to F0 in hexadecimal, or 11110000 in binary.

Example: _ (cannot be represented as an ordinary character)

FIELD INFORMATION: length 1 to 256 bytes. The first character is the identifier, here a “<“ which specifies that the following information relates to the station (here the position

Geographical and the PHG code giving the transmit power, the height and the gain of the antenna)

Example: **<4723.26N / 00633.59E-PHG3630 / 73 all. {UIV32N}**

FCS: length 2 bytes. It contains a 16-bit number to check that the frame has been transmitted without error.

It does not appear in our example

Flag: length 1 byte; It marks the end of the frame. Its value is immutable and equal to 7E in hexadecimal, or 01111110 in binary.

It does not appear in our example

Note: The frame is normally preceded by a series (and not just one) of flags allowing the decoding program to prepare to receive it.

If the signal is to be received and retransmitted from specific Digipeaters, we use their call signs in the corresponding field. By doing so, our transmissions can be controlled in terms of spatial distribution: where and how far the transmission will go (Foutzitzis, 2007)

2.3 System Principle of Packet Radio by using APRS protocol

Bob Bruninga, senior research engineer at the United States Naval Academy, began developing APRS protocols on Apple II computers in 1982. This first version was used to map high frequency fleet navy reports. The first time that APRS was used was in 1984 when Bruninga developed a higher version of the Computer Commadore VIC-20 computer for reporting position and horse status in 100 miles (160 km) of patience. [14, 15]

The APRS protocol uses the principle of transmitting Packet Radio data, called AX-25. Digital data with all GPS signals are converted to two tone frequencies (Binary 1 represents 1200 Hz; Binary 0 represents 2200 Hz). As shown in Fig. 2.10 [15], the dual frequency of the data is transmitted to the microphone of the mobile radio or mobile phone and is transmitted as Binary Frequency Shift Keying (BFSK). At the end of reception, the demodulated data from the radio receiver is sent to the radio modem and is converted back to digital stream and decoded. The newly generated data will be used to tell the coordinates of the station that sent the signal to appear in the mapping system or on the google map, and in many parts of the world will use the digipeaters used in the mapping system. Relay or forward until finally the data is connected to an Internet server (I-GATE) [47] in order to send data to several websites, for example, APRS.FI and Findu.com, which have been developed to allow users to access location information. These and can monitor APRS traffic in real time.

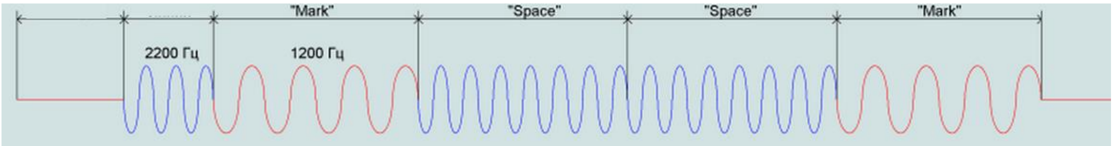

Fig. 2.6 Sample of AFSK, Double Frequency of Binary Data 1001 [50]

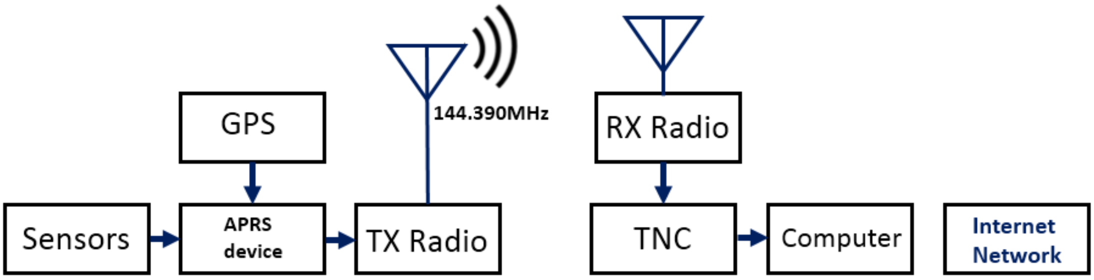

Fig. 2.7 Basic Principle of Packet Radio became APRS [14]

So what is APRS and why is it important? A brief guide to APRS is that the digital communication model used by Amateur radio which is a packet (The content is diverse. But this is usually a GPS position - which is what makes APRS the “Automatic Position Reporting System.” [13-15] Figure 2.11 shows an end to end APRS system, which begins with GPS data communication using NEMA. [28] With the APRS tracker, the tracker then uses this information and configuration settings to determine APRS packets. The APRS packets are encoded by the tracker and the audio is transmitted to the radio transmitter, which sends data. Usually operated at 144.390MHz in Thailand (but in this experiment will be used 78 MHz). The NBTC allows radio receivers to receive the same frequency signal through the received voice to the TNC, which decodes the packets and transmits them to the computer using the same frequency by using RS-232 connection.

APRS It is real-time, suitable for field work as a protocal. Communicatons A digital model for exchanging information between a large numbers of large coverage stations. (Local) area as a data network, many users are quite different from conventional packet radio communications. The APRS differs from the normal packets in four ways. For the first time, by integrating maps and other information displayed in the organizing and display. Second, using one-to-many protocols to update everyone in real life. The third time, using general digipeating, was immediately available without pre-setting, and the fourth was that since 1997, the world has communicated across the Internet, linking everyone around the globe, and APRS is developing an open system in Packet Radio. Real time optimized for tactical communications and display systems for emergencies and with the application of public services. Normal Packet Radio is helpful in passing the traffic of bulk messages (e-mails) from one place to another. But it does not do well in realtime events where data has a very short period of time and the need to get it to everyone quickly. Distributed by APRS. Although the Internet is monitored by APRS worldwide, this is not a primary objective, but APRS in the event of an emergency or special event which is driving the development and design of the APRS protocol. 99% more in terms of data transmission over long distances and Realtime. Protocol conditions are designed to optimize performance for short-term transmission operations in real-time time intervals on radio frequencies.

APRS provides universal connectivity to all stations by avoiding the complexity and limitations of connected networks. By allowing any number of stations to exchange information, as well as voice users, it is on to talk to any station with voice and there is information to be involved, just send it and all the stations get it and input. Sign it. Second, APRS recognizes that, in the greatest real time, any special needs event or emergency case is a track of a major asset. Where do people find activities? Where the station is coordinates? Emergency vehicles? Weather at various points in the field? In order to answer these questions using APRS and capture the position and status of all stations. It can be used via any two-way radio system, including HAM, CB, navigational radio, etc.

In Thailand, the NBTC is required to use conditions that require a minimum radio license. In use by APRS is 144.390 MHz, as in the United States.

Basic APRS consist of:

- GPS Module
- Radio Module or Digital Conversion unit for BFSK (Binary Frequency Shift Keying)
- RF Module Transceiver (VOICE Radio)

2.3.1 Transmission of APRS signals

On VHF the APRS frames are transmitted in AFSK (Audio frequencies shift keying) or, to be more rigorous, in class F2D which means:

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2: Single, digital signal, using a subcarrier

D: Data transmission

The frequency used for APRS in Thailand (NBTC Plan) is 144.390 MHz

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The bit rate is 1200 bits / s, which means that the duration of a mark or a space is 833 milliseconds, which is a period for the mark and a little less than two periods for the space. [58]

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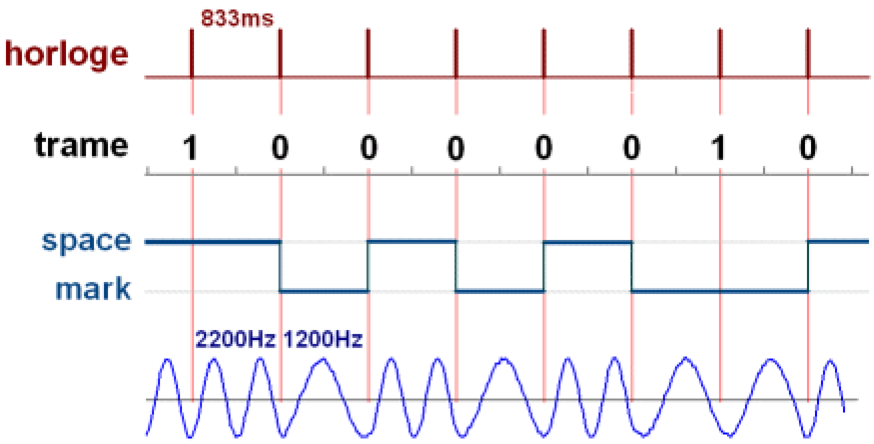

Fig. 2.8 AFSK vs Binary data [50]

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But in reality, this string, the frame, is structured in a standardized way into several fields (9 in total), some of which have a fixed length and others a variable length.

2.5.3 Structure

The structure of an APRS frame is of the UI (Unnumbered Information) type defined according to the Amateur Packet-Radio Link-Layer Protocol (AX25)

The PDF document (see section "Documentation below the reference (101) schematically. [50]

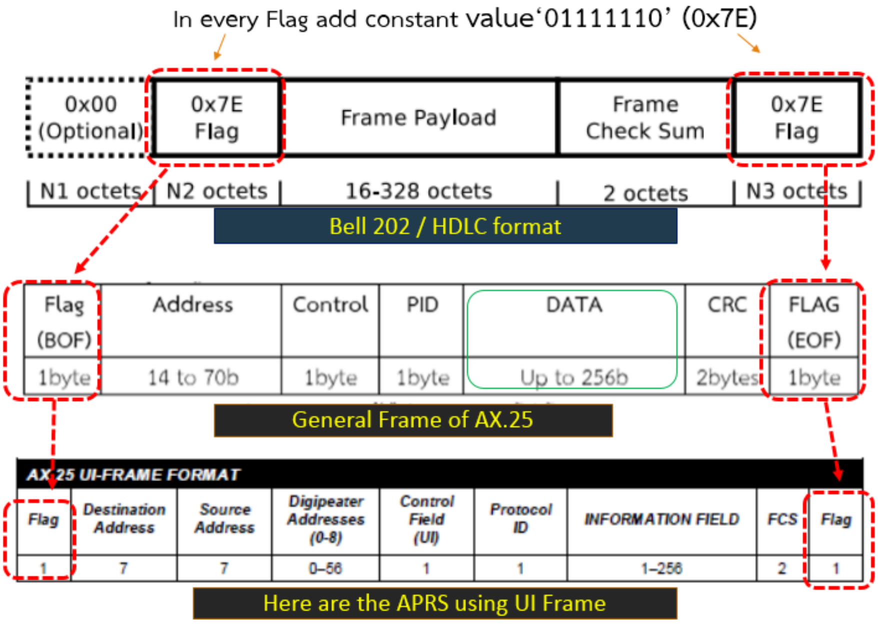

Fig. 2.9 APRS Protocol was built on AX.25 Data Frame

Here are the details:

Flag: length 1 byte (one byte); It detects the start of the frame. Its value is immutable and equal to 7E in hexadecimal, or 01111110 in binary.

It does not appear in our example. In general it is not 1 but a whole series of flags that are issued before the start of the next field.

Destination Address: length 7 bytes. This field can contain a wide variety of values.

Example: APFD25p

Source Address: length 7 bytes. Indicator of the transmitting station of the frame followed by the SSID

Example: F4FEB 0

Digipeater Addresses (0-8): Length 0 to 56 bytes, which means that this field may be non-existent. Each digi address is coded on 7 characters.

Example: **WIDE1 1WIDE2 2**

Control Field (UI): length 1 byte. Fixed value 03 in hexadecimal that is 00000011 in binary.

Example: _ (cannot be represented as an ordinary character)

Protocol ID: Fixed value equal to F0 in hexadecimal, or 11110000 in binary.

Example: _ (cannot be represented as an ordinary character)

FIELD INFORMATION: length 1 to 256 bytes. The first character is the identifier, here a "<" which specifies that the following information relates to the station (here the position

Geographical and the PHG code giving the transmit power, the height and the gain of the antenna)

Example: **<4723.26N / 00633.59E-PHG3630 / 73 all. {UIV32N}**

FCS: length 2 bytes. It contains a 16-bit number to check that the frame has been transmitted without error.

It does not appear in our example

Flag: length 1 byte; It marks the end of the frame. Its value is immutable and equal to 7E in hexadecimal, or 01111110 in binary.

Note: The frame is normally preceded by a series (and not just one) of flags allowing the decoding program to prepare to receive it.

2.4 End of chapter Summary

This chapter presents the options of various types of communication and APRS protocols. The protocol has been developed from the Packet Radio AX.25

since 1992, and this protocol has been developed for data communications with the requirements. Remote data transmission. The development of the device is possible, and large. The guidelines of this study. It is the improvement and design of the equipment using the side-system technology to represent a large device and have the power to not be installed on the device in the actual use. By comparing the size and education of existing systems, developing smaller and less energy-efficient applications, such as balloon delivery or installation work. So size is very important.

Advantages of doing software on embedded systems modulation as it incorporates the necessity of extra hardware; Instead, there are dedicated hardware intended for modifying and modulating APRS packets, with the ability to use TNC (Terminal Node Controller) to do these tasks.

Therefore, in this research, it is interesting to present the development of the device on the embedded circuit to enable data transmission capabilities using APRS protocols and applied in the remote communication network to collect data at the job. Various aspects, which were presented in the research already presented at the conference, such as Agricultural work Tree task tracking and task tracking tasks

The next chapter will present the general theories elaborated on the design concept and design approach of the proposed system. This research focuses exclusively on the APRS UNIT of these signals to see how software can be improved on the basis of an embedded system approach to encoding encoded by the device. APRS.

Chapter 3
Research Methodology

3.1 Constraints and Requirments

3.1.1 General Assumtion and Constraints

a) Microcontroller will handle all the send APRS protocol in term of AFSK

b) The GPS module must be used to report location of the Wildlife Animal.

c) Transceiver Module on VHF 78MHz TX power can be adjusted at 300 mW wraps around animal collar.

d) ¼ λ antenna install for send VHF RF signal on station

e) The battery packed, must be the sole power supply for the Tracking system installed.

3.1.2 Success Criteria

PWS prototype system is proposed and experimented on 78 MHz non-licensed citizen band. The system consists of a PWS and an internet gateway (iGate) on 78 MHz band. With the maximum transmitting power of 300 mW, the experimental result showed that the PWS and iGate can established two points RF wireless communication. The result is also theoretically validated with link budget analysis.

3.2 Design Concept

The proposed PWS system is shown as a diagram in Fig 3.1

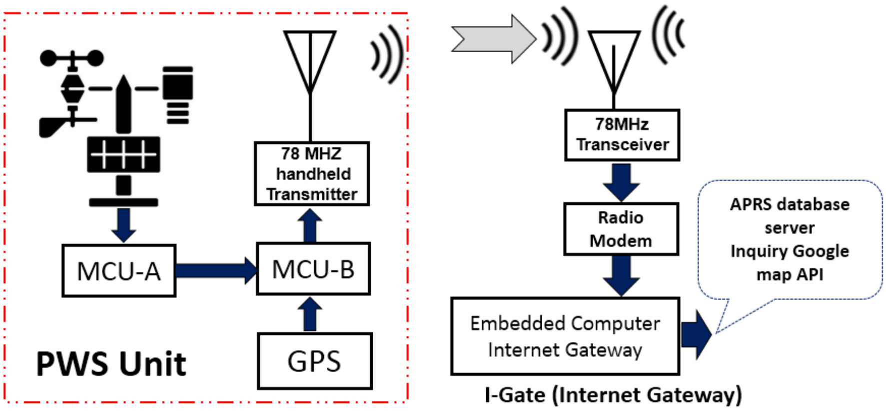

Fig. 3.1 Block diagram of the Portable Weather Station

A PWS unit works in beacon mode or transmitting only. It is programed to transmit data in interval. The more frequent, the more power consumption. For experimental purpose, the transmitting interval is set to once every minute.

As shown in Fig.3.1 a PWS unit consists of an array of weather sensors connected to a GPIO of the MCU-A with 2400 bps in serial with 0.5 second period. The MCU-B combined weather data from the MCU-A and GPS unit by polling the two groups of data using soft-serial technique, which converts digital GPIO to work as a serial port. Both data groups are formed to be an APRS package in the AX.25 data frame format by modulated data using 1,200 Hz for zero (0) and 2,200 Hz for one (1). The modulated audio is fed to an audio input on a transmitter. The transmitter is set to transmit at 300 mW power.

The transmitted signal is detected and demodulated by an internet gateway (called iGate). Data are passed to a cluster of APRS database servers. The weather data and location of the sensors can be inquired by an application such as the APRS.fi {8] in real time.

3.3 Design Approch

The hardware and software of the PWS is shown as a block diagram Fig 2 and system flowchart in Fig 3.2

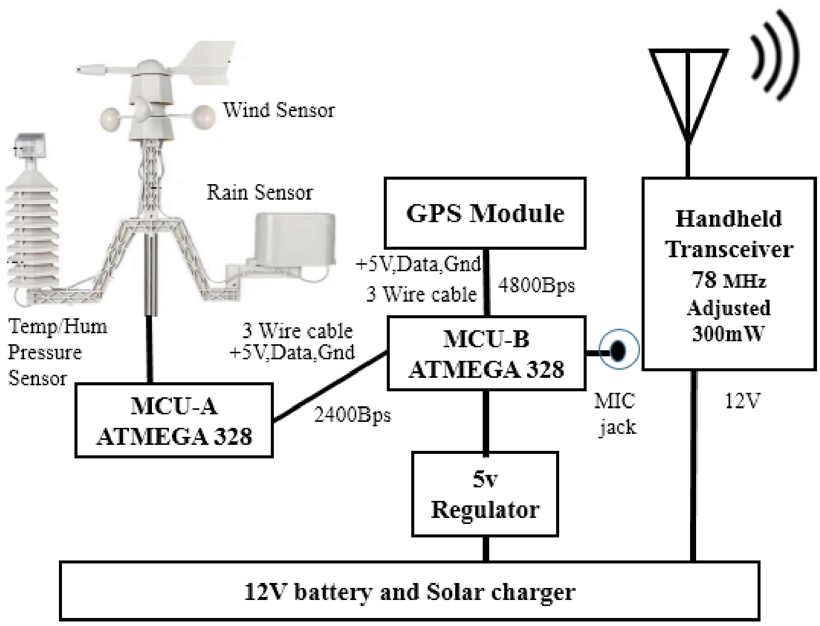

Fig. 3.2 Block diagram of Hardware

Both MCU-A and MCU-B are an ATMEL MCU chip code name ATMEGA 328 [4]. MCU-A works as sensor interfaces for the MCU-B. MCU-B polls data sensor and GPS data using the soft-serial technique, combine the twos, and modulated data using AFSK. The MCUs are programmed using Arduino Bootloader technique, which is convenient for programming with a public-available compiler.

The flowchart of both MCUs is shown in Fig 3. 3 The MCU-A reads data from weather sensors connection and transforms data for serial communication.

Programming calculation for weather sensors are described as the following.

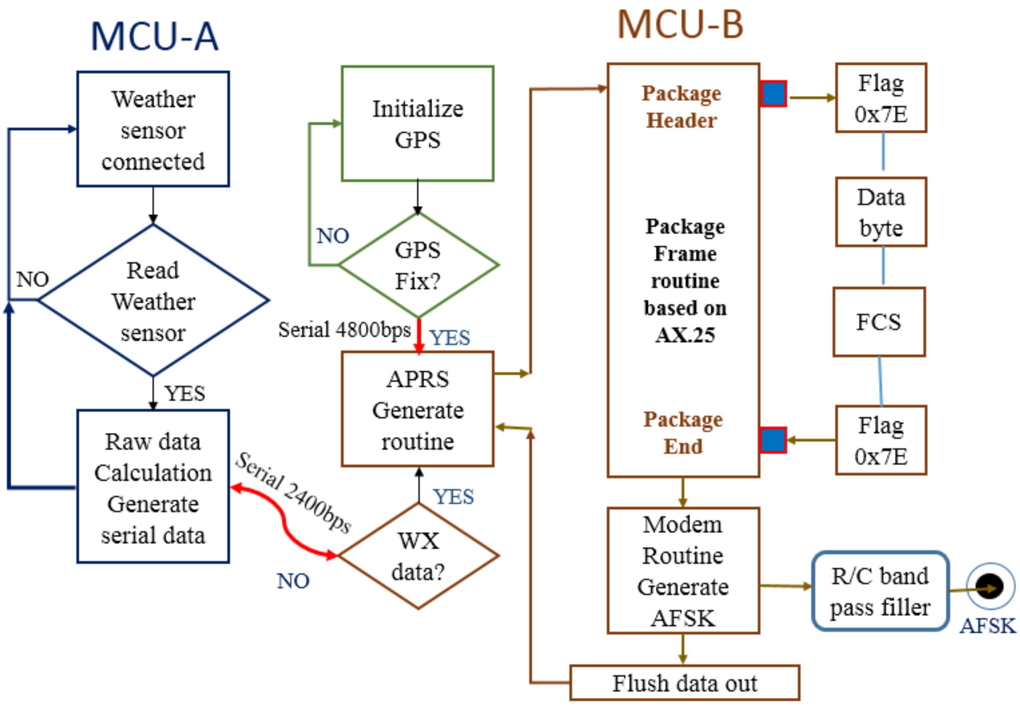

Fig. 3.3 System Flowchart [6-7]

Raindrop: the MCU-A weather interface board has a built-in 1,440 bytes rain-specific data buffer that records an amount of liquid precipitation per minute. An output data stream consists of an amount of rainfall of the last minute, the last hour, and the last 24 hour.

Wind speed: the MCU-A weather interface board has a built-in 300 bytes wind speed data buffer to record real-time wind speed in a second, average wind speed of the last one (1) minute, and highest wind speed of the last five (5) minutes.

The rest of data in sequence are temperature, humidity, and ambient pressure in the interval of five (5) seconds.

Example: serial data of raw weather after sensor were reading:

C000s000g000t082r000p000h48b10022*3C

Total data size is 38 bytes, and data are transmitted at 0.5 seconds interval with the ending carriage/return (CR) data (0D, 0A).

Detail of each weather data:

c000: wind direction, (degree.)

s000: wind speed (1st minute, unit: MPH)

g000: Top wind speed (1^{st} 5 minutes, MPH)

t082: temp (F)

r000: raindrop in the past hour (0.01 inches)

p000: raindrop 1^{st} 24 hrs (0.01 inches)

h48: humidity (%)

b10022: barometer (0.1 hpa)

*3C checksum value, all data XOR sentence data to * (excluding *)

The NMEA format from GPS module provides latitude and longitude after position is fixed. The MCU-B polls data from both GPIOs with different bit rate and encodes to APRS WX data frame format.

The frame is a fixed format with header and ending with flags 0x7E as shown in Table I. The WX frame combines NMEA data as latitude (Lat) and longtitude (Long) as shown in Table II. The modem module modulates data with with ASFK modulation. The AFSK modulated audio signal is fed to a bandpass filter in which it cleans up signal before fed it to the audio input of a 78 MHz band transceiver.

An example of raw data of complete weather report format according to Table 3.1 is shown below as complete raw data along with Lat and Long.

!1350.05N/10039.37E_090/009g013t086r000p000h30b0490

TABLE 3.1 AX.25 Data-Frame format

AX.25 UI Frame Format								
Flag 0x7E	Destination Address	Source Address	Digipeaters Address	Control Field (UI)	Protocol ID	Information Field	FCS	Flag 0x7E
1	7	7	0-56	1	1	1-256	2	1
Amateur Bell 202 / HDLC Frame Format								
Flag	**Frame Payload**						**FCS**	**Flag**
0x7E	16-238 octets						2	0x7E

TABLE 3.2 Completed Weather data format

Complete Weather Report Format — with Lat/Long position, no Timestamp								
! or =	***Lat***	***Sym Table ID***	***Long***	***Symbol Code*** _	***Wind Directn/ Speed***	***Weather Data***	***APRS Software*** s	***WX Unit*** uuuu
1	8	1	9	1	7	n	1	2-4

3.4 Prototype unit

A prototype of the PWS is shown in Fig 4. Major modules in this prototype are a GPS module, MCU-A sensor interface unit, MCU-B WX unit, and a Motorola 78 MHz transceiver.

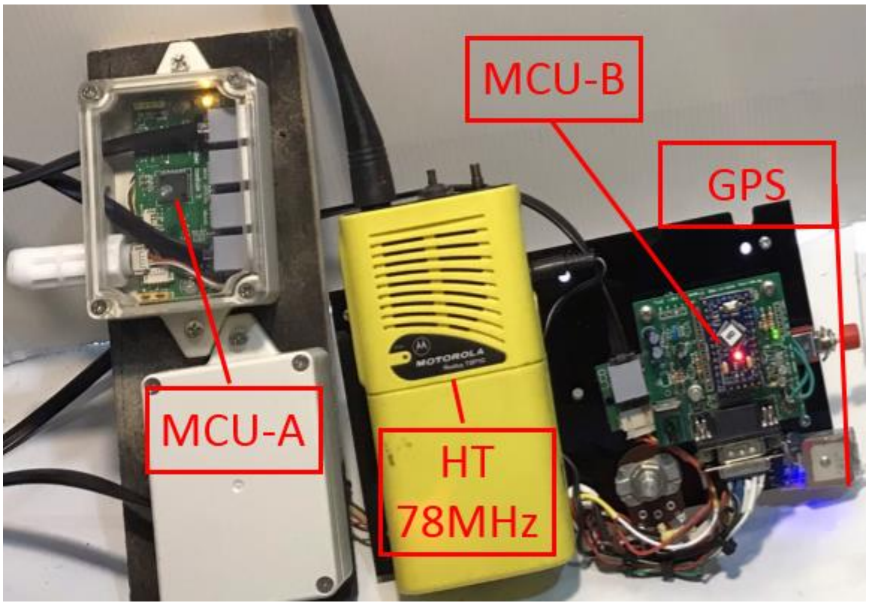

Fig. 3.4 A PWS Prototype unit

3.5 Infrastructure of PWS

The infrastructure of PWS is described in Fig. 3.5

The PWS transmits APRS data on the WX frame format through the audio input of the Motorola 78 MHz handheld transceiver. The transceiver is configured to have 300 mW output using a quarter wave omni-directional antenna with 0 dB gain.

The internet gateway (iGATE) demodulated received audio modulated signal and forwards the received WX data to APRS database clusters, where the data is retrieved and displayed using a web application or a mobile application. An application such as APRS.fi provides data by overlay over the Google map.

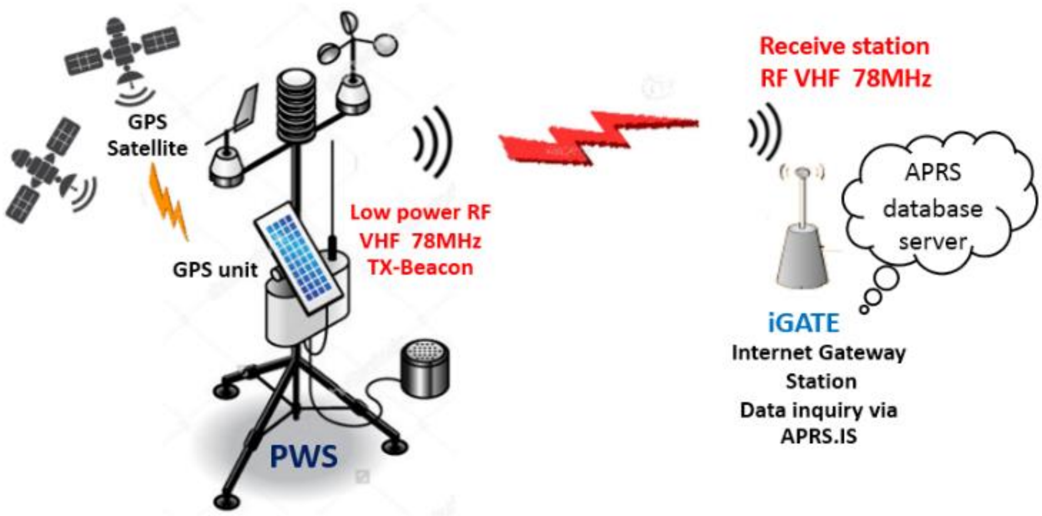

Fig. 3.5 PWS infrastructure

Fig. 3.6 PWS iand Igate for this experiment

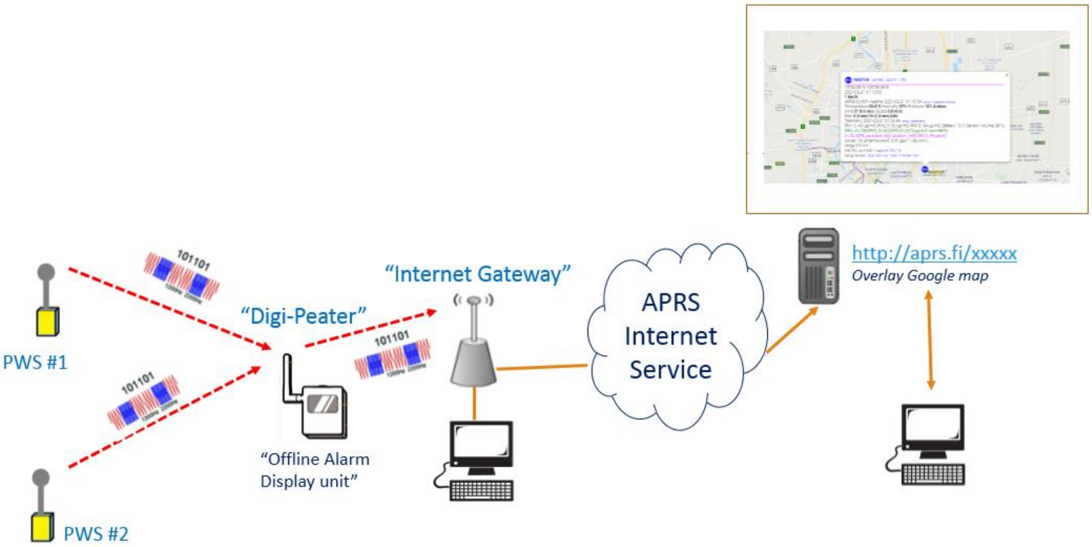

Fig. 3.7 Experiment System infrastructure

Chapter 4

Experimental and Results

4.1 Experiment

For an experimental purpose the MCU-B was programed to transmit WX data beacon once a minute. The received and demodulated signal is shown as a raw data frame is shown in Fig.4.1


```
2022-02-15 12:20:28 +07 RAST02: 123 bytes
0x00 R A S T 0 2 > H S 1 I F U , W I D E 1 - 1 , q A R , 7 8 M H Z :
     5241535430323e4853314946552c57494445312d312c7141522c37384d485a3a
0x20 ! 1 3 5 0 . 0 4 N / 1 0 0 3 9 . 3 9 E _ 0 9 0 / 0 0 8 g 0 1 3 t
     21313335302e30344e2f31303033392e3339455f3039302f3030386730313374
0x40 0 8 6 r 0 0 0 p 0 0 0 h 2 9 b 0 4 9 0   P M 1 . 0 : ( 0 ) P M 2
     3038367230303070303030683239623034393020504d312e303a283029504d32
0x60 . 5 : ( 0 ) P M 1 0 : ( 0 ) u g / m 3   V o l = 8 6 %
     2e353a283029504d31303a28302975672f6d3320566f6c3d383625
```


Fig. 4.1 Screen shot of Decoded RAW WX data frame

WEB Interface APRS Database Query tool that already available by Web Developer, There are Web Access software available online, with this research was accessing to Web Query tool, one of the popular APRS Database query web access called http://aprs.fi/ssid (SSID =**S**ub **S**tation **ID**entifier) The iGATE was assigned with a station ID as "**78MHZ**", and the PWS unit was assigned a station ID as **"RAST02"**.

4.2 Result

The result of this experiment is shown in Fig 4.2 using the APRS.fi web application. The data are stored in the APRS.fi servers and shown over the Google map. More data details can be shown in a pop-up window. On the APRS.fi a line-of-sight (LoS) distance between the PWS and iGate was measured to be 2.7 KM

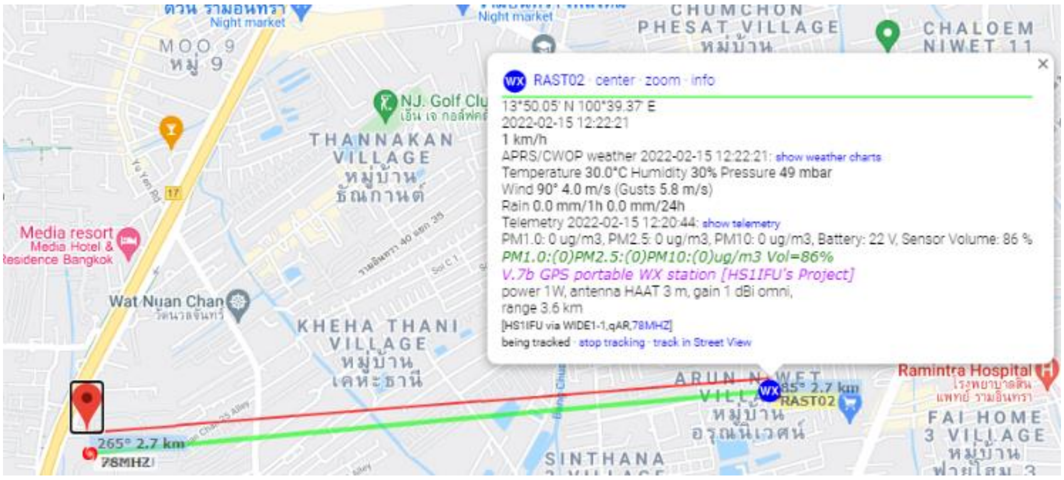

Fig. 4.2 APRS Overlay on Google Map API

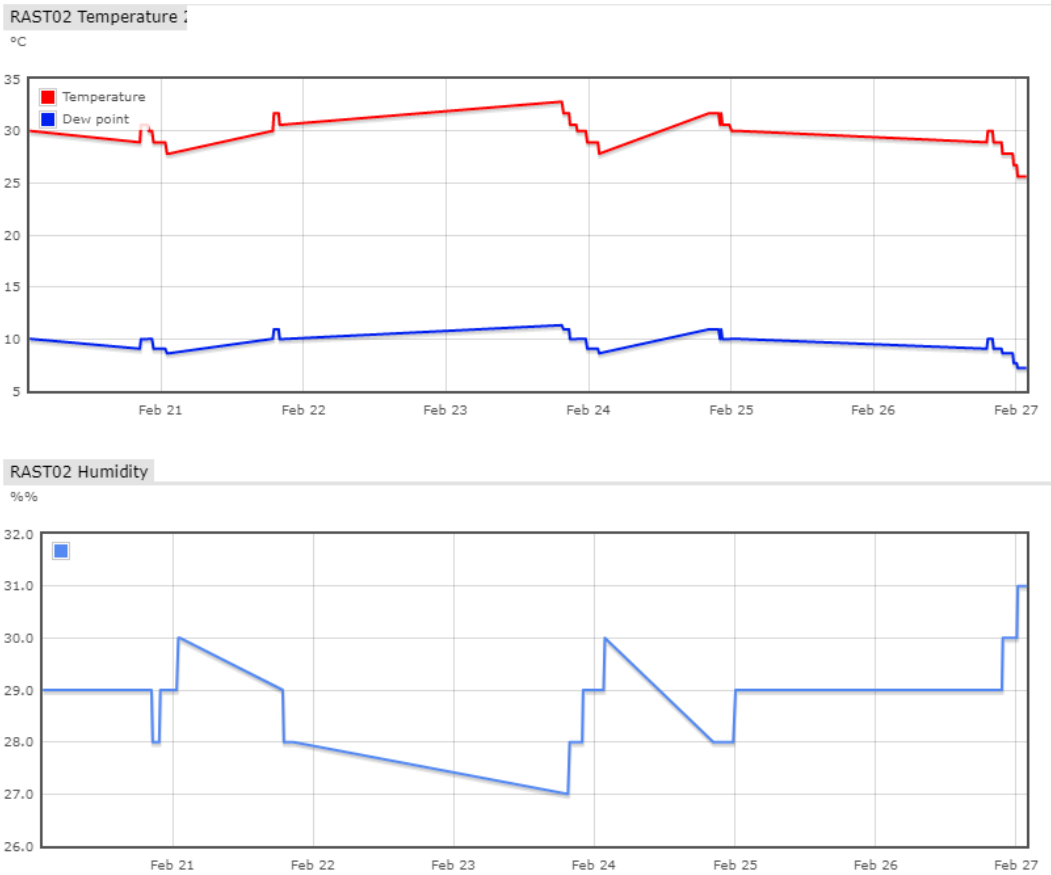

Fig. 4.3 Weather Data (Temperature and Humidity)

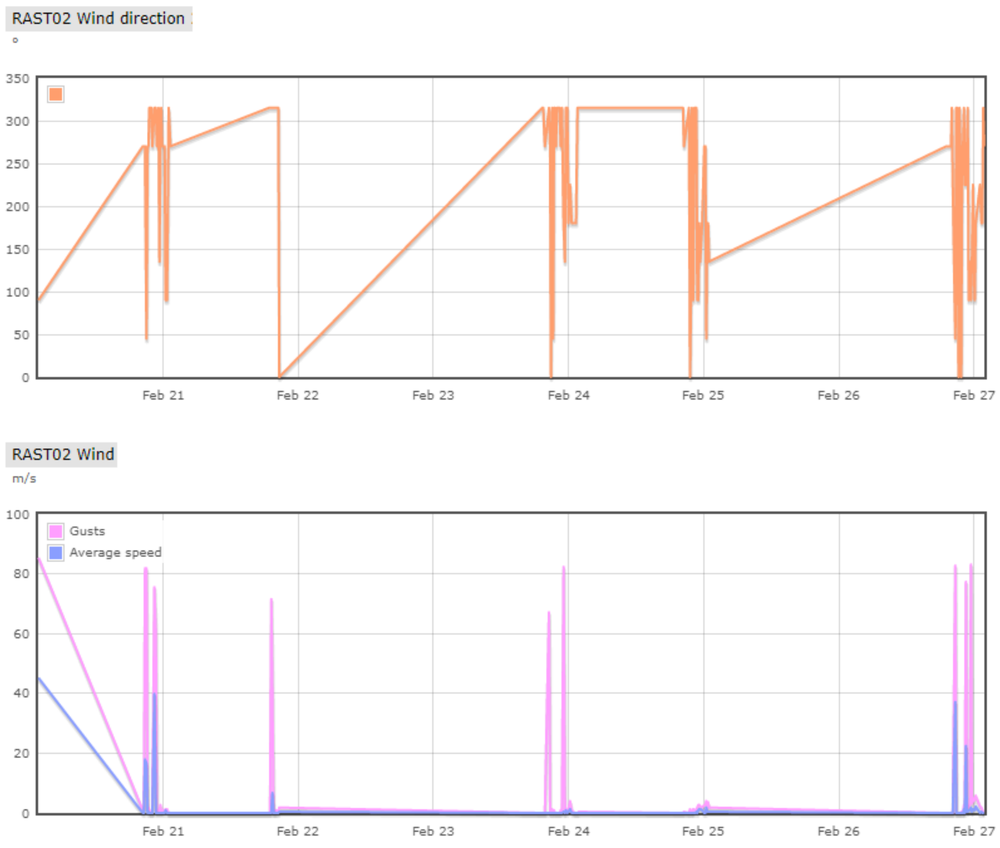

Fig. 4.4 Weather Data (WIND direction and WIND speed)

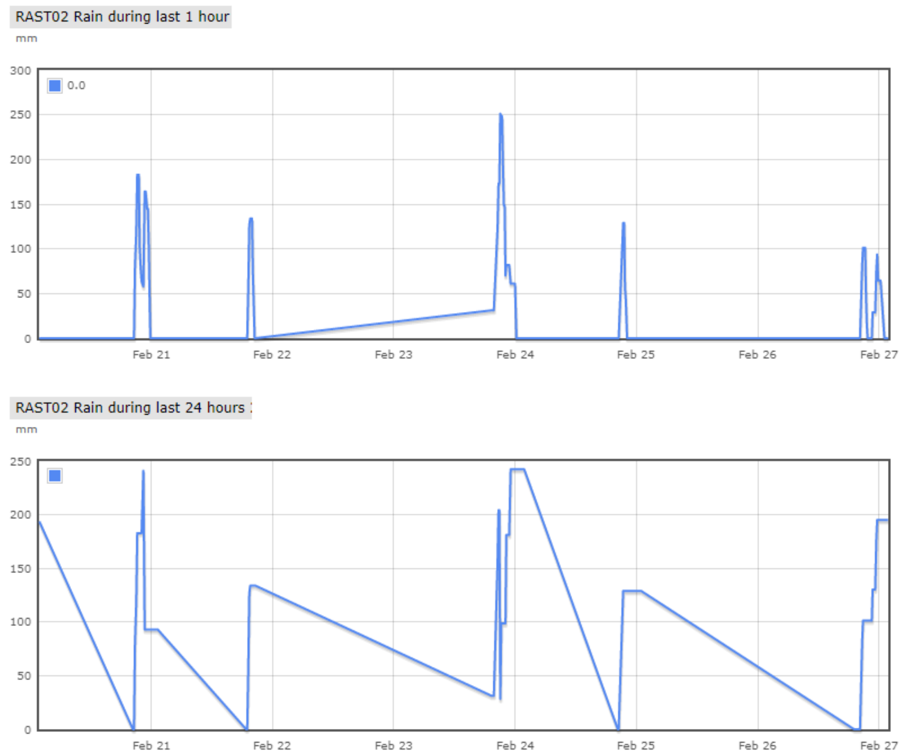

Fig. 4.5 Weather Data (RAIN)

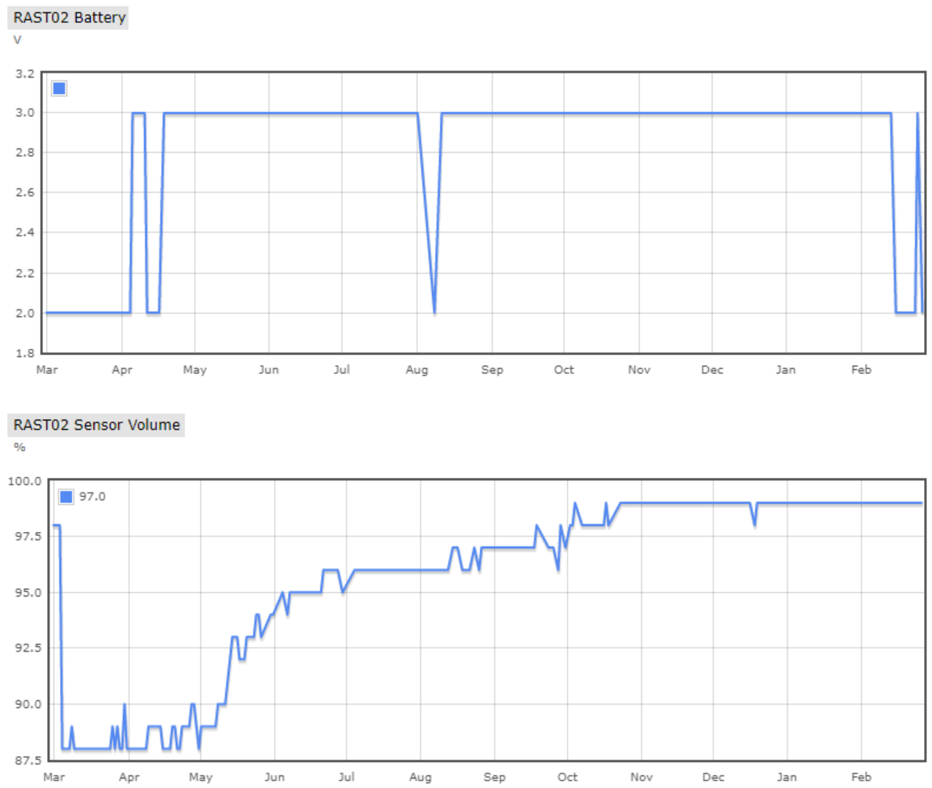

Fig. 4.6 Telemetry Data (Battery level and Sensor detection level %)

4.3 Validation method using Link Budget Calculation

Link budget calculation is a method of theoretical validating two point's wireless communication. Link Budget parameter, for instances, receiver sensitivity (dBm), path loss, antenna gain, and gain loss, etc. [9], for validating are shown in Table III.

The purpose of this calculation is to validate that wireless communication between the PWS and iGate is theoretically possible over the minimum distance of two (2) kilometers. The model of the validation is shown in Fig.4.7

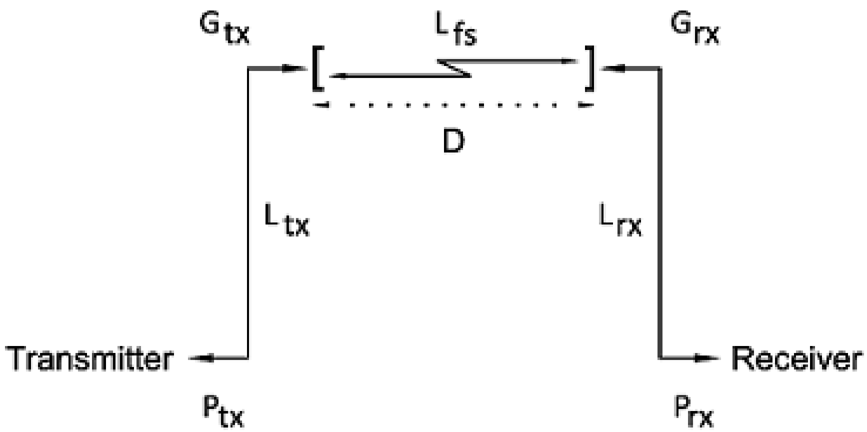

Fig. 4.7 Link Budget parameter [9-10]

TABLE 4.1 Link Budget Variable

Transmit Parameter		
P_{TX}	Transmitter power	*24.77 dBm (300mW)*
G_{TX}	Transmitter gain	*0 dBi*
L_{TX}	Transmitter losses	*1 dB*
Terminal Parameter		
L_{FS}	Free space path loss	*76.30dB*
L_M	Miscellaneous losses	*3dB*
Receiving Parameter		
G_{RX}	Receiving gain	*0 dBi*
L_{RX}	Receiving losses	*3 dB*

D_{max}	Maximum distance	*2000 m (2Km)*
Link Budget		
P_{RS}	Receiver sensitivity	*-64.28 dBm*
P_{RX}	Receiving power	*-58.53 dBm*

According to the transceiver specification the receiver sensitivity (P_{RS}) of the prototype transceiver has signal-to-noise (S/N) and distortion ratio = 0.18 μV or equivalent to -64.28 dBm.

The wireless link communication is qualified or validation when $P_{RX} > P_{RS}$ [9]; in other words, the receiving power is greater than the receiver sensitivity.

L_{FS} = free space loss or path loss in dB

Loss in Free Space Path (L_{FS}) calculations are often used to help predict RF signal strength in an antenna system. Loss increases with distance, so understanding the FSPL is an essential parameter for engineers dealing with RF communications systems.

$$P_{RX} = P_{TX} + G_{TX} - L_{TX} - L_{FS} - L_{M} + G_{RX} - L_{rx} \quad (1)$$

$$L_{FS}(dB) = 20 \log_{10} (4\pi D_{max} / \lambda) \quad (2)$$

Where wavelength $\lambda = c/f$, c is light speed, and f is an operating frequency.

The Link considered reliable reception when

$$P_{RX} > P_{RS} \quad (3)$$

Replace with the values from previous calculation

$$P_{RX} = -58.53 \text{ dBm} > P_{RS =} -64.28 \text{ dBm} \quad (4)$$

According to eq (3) and the parameters in Table III with f = *78 MHz*, the result shows that $P_{RX} > P_{RS}$ Therefore, the wireless communication link between PWS and iGATE is validated.

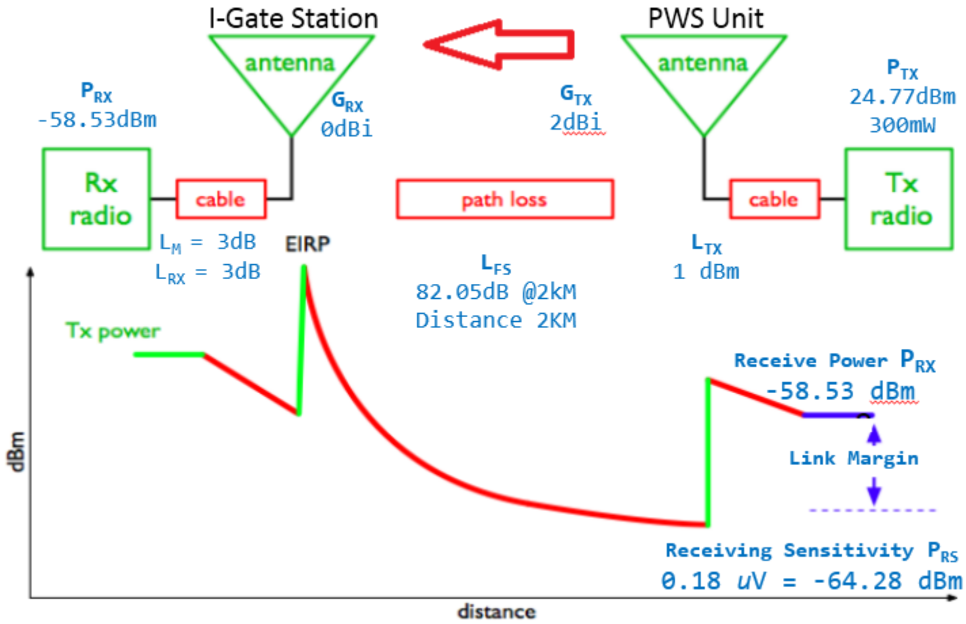

Fig. 4.8 Point to Point wireless Link Budget

Chapter 5

Conclusion

The result of this research from this experiment covered the test area of 2 Km radius on factor such as Antenna Gain, Transmit power and Antenna Propagation between both 2 points were validation by the result of the Link budget calculation that was in the acceptable range comparison between the experiment and Link budget calculation. In this Line of sight (LOS) communication linked will help to communicate as the tracking nodes from the rural area or anywhere such as forest where no other tradition internet network infrastructure service available but APRS network will help data communication possible with not need complexibility setup. The APRS Data connectivity in very low budget can establish long distance communication network.

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Experiment and Deploy

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Biography

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Work experience

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Research Paper

1. **“Risk Perception of foreign tourists from Unrest in Thailand,** The 9th National HUSOC Conference Academic-Research 2016, March 24-25 , 2016 http://www.socsci.nu.ac.th/husoc/downloads/husoc9_online_proceedings.pdf
2. "**Building Automatic Packet Report System to report position and radiation data for autonomous robot in the disaster area**." Control, Automation and Systems (ICCAS), 2015 15th International Conference on. IEEE, 2015.
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7. "**Designing and Implementation Wildlife Tracking System Using APRS Protocol.**" 2019 5th International Conference on Engineering, Applied Sciences and Technology (ICEAST). IEEE, 2019.
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