Designing and Implementation Exploration Vehicle Remote Controller Using APRS Protocol

Nimit Hongyim[1]
Department of Business Computer
Faculty of Business Administration
Rajapruk University Nonthaburi Campus
Nonthaburi 11130, Thailand
nihong@rpu.ac.th

Somsak Mithata[2]
Hybrid Computer Research Laboratory, Department of Computer Engineering, Faculty of Engineering
King Mongkut's Institute of Technology Ladkrabang
Bangkok 10520, Thailand
kmsomsak@hotmail.com

***Abstract*—The main purposed of this research paper was for implementation of APRS (Automatic Position Report System) Protocol in use with remote controller for controlling Exploration Vehicle where cannot be reached by the conventional wireless network. The research experiment expected result on success communicate between point to point distances over 10Km**

Keywords—Embedded; APRS; GPS; Data Communication

I. INTRODUCTION

At present day, Vehicle in the survey or Exploration are very necessary in remote areas or dangerous areas, as well as control of Exploration Vehicle in space. This is a far more distant way of communicating with the existing Technology that exist today, such as Wireless communication over the Internet or via cellular phone communication systems, or even the Digital Radio-Controlled systems ***have limitation of communication range*** and this is the problem which lead to be researched

In this paper, we will use the APRS Protocol, which has the ability to transmit and receive data remotely and with high accuracy. The Protocol Automatic Packet Reporting System (APRS^{TM}) is based on the Protocol It is capable of providing fast, reliable communication between multiple nodes, which can exchange location information in real time and with high accuracy. Remote transmission of data depends on the transmission of data transmitted by AFSK Modulation {Audio Frequency Shift Keying) transmitted and received through Radio Frequency waves. The communication range is based on RF propagation. Upon receipt, the information is displayed as an update on the Electronic Map or Google Map.

In 1990Automatic Packet Reporting System (APRS) [1] was developed by Bob Bruninga, while he worked at the U.S. Naval Academy, during his experiment to used GPS Module gave position in order to track the object during the training.

II. CONSTRAINTS AND REQUIREMENTS

A. General Assumption and Constraints

- Microcontroller will handle all the send/receive APRS protocol in term of AFSK and respond to the validation custom command.
- The GPS module must be used to report position and the direction of the vehicle
- Included with 2 DC motors open loop control using PWM control used to drive and steer the Vehicle
- Transceiver on VHF 144.390MHz TX power at 5 watts at 45 meter above ground must be used in order to send/receive command and respond with point to point communication between vehicle and station.
- ¼ λ antenna install for send/receive VHF RF signal on Vehicle.
- The battery packed, must be the sole power supply for the rover. The rover must hence be able to provide enough torque to carry the payload.
- Control Station must be running on UISS [3] program act as terminal for sending the command to steering the vehicle

B. Success Criteria

- Navigation vehicle from long distance Control station by using APRS Protocol over the radio Frequency VHF 144.390 MHz 5 watts expected distance more than 10 Km range.

III. DESIGN APPROACH

A. General Design Concept

The main idea of controlling vehicle at the long distance by using VHF Radio frequency and 2 ways data communication between ground station with terminal command or joystick and the vehicle module which maneuver the vehicle to move around and give the respond feedback to the ground station with GPS position in real time within the very long distance by using APRS. The AX.25 data Frame packet Radio protocol [2] used data communication speed at

978-1-5386-0787-9/17/$31.00 ©2017 IEEE

1200 bps of APRS The AX.25 is used then the information field by APRS packet radio networks, The AX.25 packets is transmitted using RF as carrier represent in OSI Model at Physical layer. AFSK (Audio Frequency Shift Keying) is used 1200Hz and 2200Hz Frequency Modulation represented logic 0 and 1. From the Figure 1. Explain on how the data link and communication in command mode working by Control station send command over the software UISS [3] which act as the terminal command but this software can generate AFSK and also can decode AFSK from the Vehicle unit sends respond Acknowledge message.

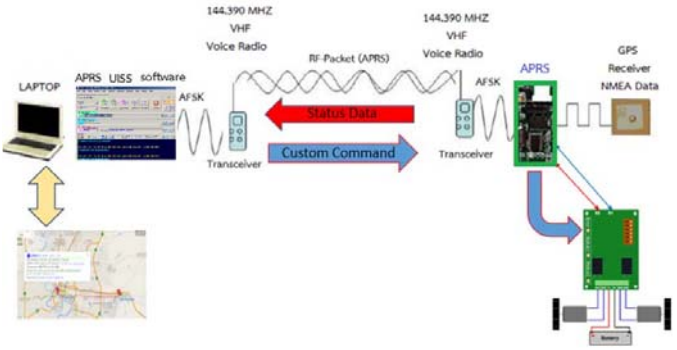

Figure 1. The diagram of APRS vehicle remote control system

B. The vehicle system mode using APRS protocol data Frame

The Vehicle has two modes:

- **Beacon mode**, during the timer was programed that set to vehicle to send data in telemetry format (Temperatures and Battery voltage). This Position and sensor information data is converted into an APRS data frame format. The Position and Sensor Information data will be sent to a APRS.IS database server internet service and then be able to access by WEB Query over internet back to the Google map. In the Beacon mode the vehicle is sending the GPS data and other status of the Vehicle according to the timer parameter from the program APRS Data frame

TABLE I. APRS DATA FRAME BEACON MODE [2]

Field	Info	Time	Status Text
Format	>	DDHHMMz	Lat/Lon GPS Data
Bytes	1	7	0-55
Example	>160900z:*!1350.04N/10039.39E101/000/A=0001*		

- **Command mode**, The Vehicle has been received command set from control station and then Vehicle unit will send acknowledge data from the MCU back to Control Station to let Control Station know the status of the Vehicle in order to maneuver the Vehicle to move left, right, forward, reverse. The Control mode, Receive and then validation the command from control station via VHF Radio frequencies and the command format used in the prototype control unit was transfer to control command for maneuver Vehicle, explain in Table II below:

TABLE II. APRS DATA FRAME CONTROL MODE [2]

Field	Info	Time	Status Text
Format	>	DDHHMMz	Command
Bytes	1	7	0-55
Example	>160900z F300R045F050L045B045E		

This Data in Example field above can be translated to control vehicle command as example here: Forward 300 units, Right 45 degrees, Forward 50 units, left 45 degrees, Backward 45 units, End of command, unit can be arranged as the meter or feet.

C. Hardware Design concept

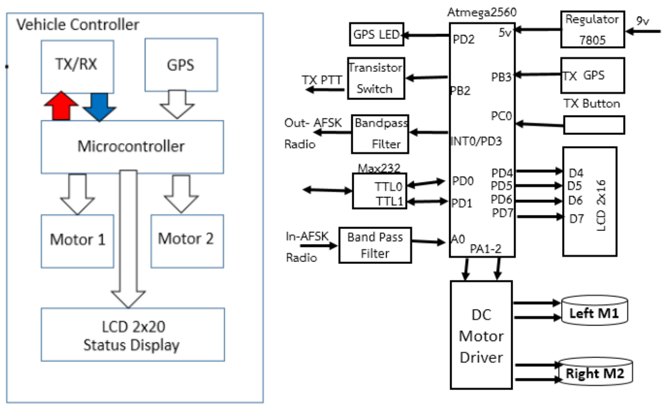

Figure 2. Vehicle Control Hardware Block Diagram

- Microcontroller ATMEGA-2560[4] The 8-bit AVR model of RISC Microcontroller high-efficiency, low consumption power from Microchip 256KB Flash memory, 8KB Static Ram, 86 GPIO, 16-channel 10-bit A/D converter, 4 USARTs. Bootloader software which help to communicate with IDE or complier already stored 5 KB, but most of the APRS protocol which Modem Encoder and Decoder also some of the program Routine that handle Input and output port and also multiple Serial port that can receive NMEA [5] data from GPS Module and also LCD display by selected this MCU still have plenty of memory and extend I/O port for future programming.
- DC Motor Driver Sabertooth 2x25[6] 2 channel DC motor Driver which can drive up to 25A each channel. Maximum loads may be up to 50A per channel after receive input from MCU in PWM which can be programed from MCU.
- Band Pass Filter In order to generate Sinewave from MCU to have dual frequency by using PWM technique and then pass the signal to Band pass filter and then the output from Band pass become Sinewave that Audio needs a low-pass filter (R=8.2kΩ C=0.1u) plus DC Coupling (Cc=1u). This also lowers audio to 500mV peak-peak required by input of Transmitter Module or Transceiver.

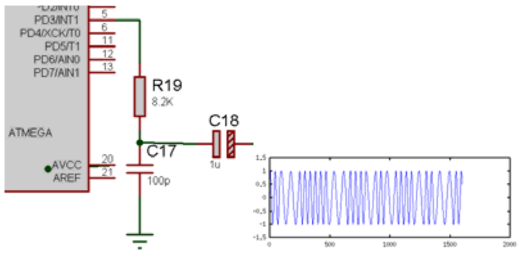

Figure 3 Band Pass filter

D. Software Design

- **Beacon mode**, Programing the unit as the Beacon station which send the Position data (Lat/Lon) along with the health status of the Vehicle such as the Battery voltage level in the one data packet over APRS protocol can be explain in the Figure 4.

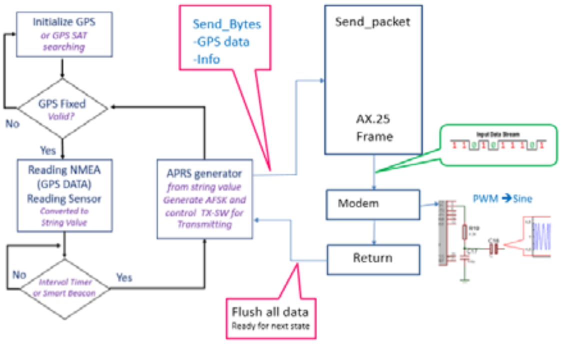

Figure 4. Beacon programming techniques

- **Command mode**, The Vehicle is always in standby to receive command from Control station then decode the valid APRS packet then convert data into the PWM signal [7] send to the Sabertooth DC motor Driver board and after the Motor performed steering as the command required then send back the acknowledge data to the APRS encoder routine in order to let the Control Station know the completed process which explain in Figure 5.

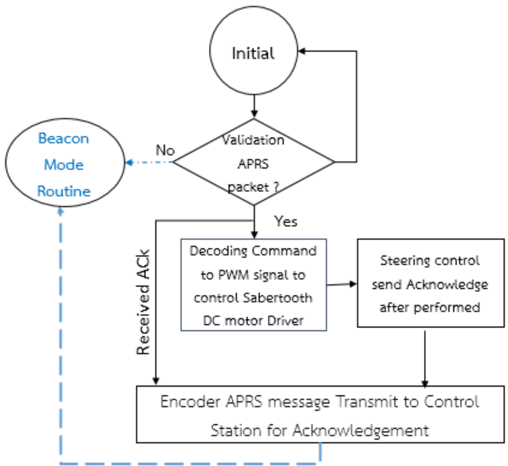

Figure 5. Vehicle steering programming techniques

E. Vehicle Hardware Design

The design for the Vehicle Chassis consist of Aluminum Frame which can be able to hold 2 of 5 Amps DC. Motor installed with 10" rubber wheel and attached 1 small support wheel. In order to steer the Vehicle left and right direction using mixed mode, When the S_1 and S_2 received PWM signal fed to turn left or right of the Motor on each side will turning in the opposite direction same as the Tank Direction controller which help to maneuver to turn in very narrow radius as shown the designed diagram in Figure 6.

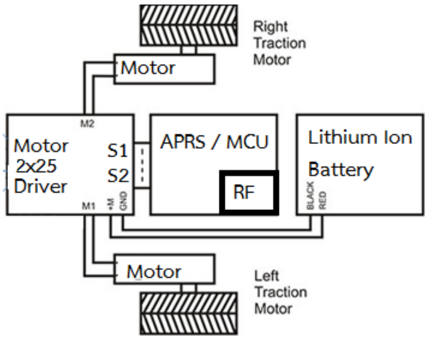

Figure 6. Vehicle Hardware design

F. Control Station Configulation

The center of this operation base on the Terminal Control station send command over the software UISS By connecting an audio cable between the computer sound card microphone and earphone jacks to the Transceiver which attached to the ¼ wave Antenna at 45 meters above ground. The commands transmitted on the computer terminal will be received by the packet program then sent via the VHF transceiver to the vehicle

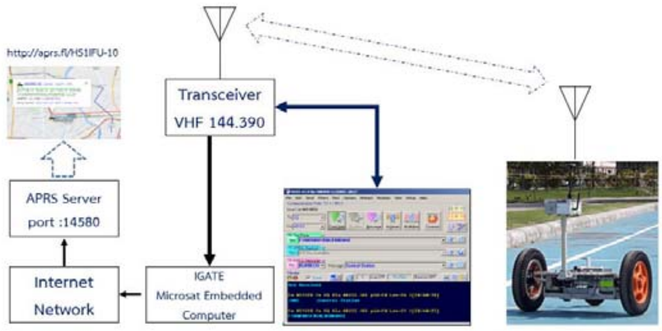

Figure 7. Ground station configuration

IV. Experimental & Result

The Experiment need to do in 2 mode:

A. Beacon Mode experiment

In the beacon mode, the vehicle was programed to send out the position data (Lat/Lon) and other status such as battery level by using APRS protocol using Radio Frequency VHF 144.390 MHz and the Control Station should be able picked up or received the APRS data in the expected range and the data can be queried via WEB tool http;//aprs.fi/HS1IFU-10 [8]

B. Control mode experiment

In this mode, the vehicle was in the main program that looping for receive command sending from the Control station which using UISS terminal software encoding all the command into APRS protocol and then the MCU that performed to decode the APRS packet into the data match to the command set which we assigned for the steering Vehicle and send back the Acknowledge back to Control station as show in Figure 8 below

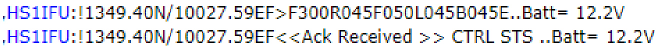

Figure 8. Screenshot of Decoded RAW Data

Raw data which receive by the MCU from the Control station can be decoded in Hex data which example data on Figure 9.

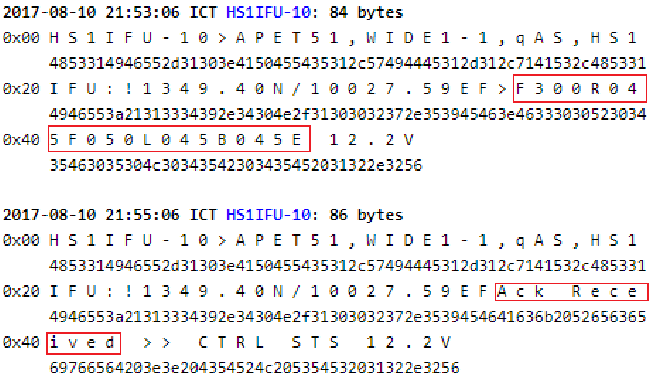

Figure 9. Screenshot of Decoded data in Hex

WEB Interface APRS Database Query tool that already available by other Web Developer that there are several Web Access software available online with but at this time, accessing to Web access will use one of the popular APRS Database query web access called http://aprs.fi/ssid SSID (Sub Station Identifier) of this vehicle is "HS1IFU-10" which is http;//aprs.fi/HS1IFU-10

C. Result

The Testing result as Figure 10 appeared overlay Google Map tool had shown distance of communication from Vehicle to I-Gate (Control Station) range achieved 19 kilometers. between Control Station with antenna installed 45 meters above ground and the vehicle unit location.

Figure 10. Google Map API tools over the Web Query Interface

D. Link Budget Calculation

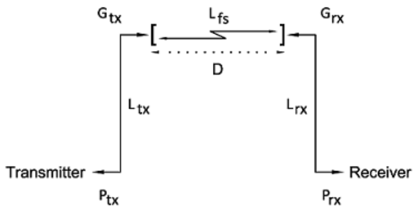

Figure 11. Link Budget parameters [9]

Receiver that installed has sensitivity (P_{RS}) from the manufacture's spec = 0.18 μVfor12 dB called Signal-Including-Noise-And-Distortion or SINAD at 144 MHz. which can be converted dBm to dBμV

$$P_{RS} = 20\log10(0.18) = -15\ \text{dB}\mu\text{V} \qquad)1($$

Then Convert dBμV → dBm in 50 Ω impedance by 107 dB subtraction:

$$P_{RS} = -14.9 - 107 = -122\ \text{dBm} \qquad)2($$

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

$$L_{FS} = (4\pi d \div \lambda)^2 = (4\pi df \div c)^2 \qquad)3($$

λ = Wavelength (meter)
f = Frequency (Hz)
d = Distance between transmitter and receiver (meter)
c = Light speed in vacuum space $3\text{x}10^8$

$$L_{FS}(dB) = 10\log_{10}[(4\pi df \div c)^2] = 20\log_{10}(4\pi df \div c) \qquad)4($$

$$L_{FS}(dB) = 20\log_{10}(d) + 20\log_{10}(f) - 147.55 \qquad (5)$$

From Our Field-test found that result of this peer to peer communication in the maximum distance be able to achieve 19 Km (or 19,000 meters) on VHF frequency 144 MHz (or 144×10^6 Hz). Then enter this value to formula (4) as below:

$$L_{FS} = 20\log_{10}(19000) + 20\log_{10}(144 \times 10^6) - 147.55 \qquad)6($$

$$L_{FS} = 99.21dB \qquad (7)$$

P_{TX} = Transmitter output power = 36.98 dBm (5 Watts)
G_{TX} = Transmitter antenna gain = 2 dBi
L_{TX} = Transmitter losses = 1 dB
L_{FS} = Free space loss = 99.21dB
L_M = Miscellaneous losses = 3dB
G_{RX} = Receiver antenna gain = 0 dBi
L_{RX} = Receiver losses = 3 dB
D_{max} = 19 Km

$$P_{RX} = P_{TX} + G_{TX} - L_{TX} - L_{FS} - L_M + G_{RX} - L_{rx} \qquad)8($$

$$P_{RX} = 36.98 + 2 - 1 - 99.21 - 3 + 0 - 3 = -67.23\ \text{dB} \qquad (9)$$

$$P_{RX} = -67.23 \text{ dBm} \quad (10)$$

The Link considered reliable reception when

$$P_{RX} > P_{RS}. \quad (11)$$

Replace with the values from previous calculation

$$P_{RX} = -67.23 \text{ dBm} > P_{RS} = -122 \text{ dBm} \quad (12)$$

$$\text{Link Margin} = -122\text{dBm} - (-67.23\text{dBm}) = 54.77 \text{ dB} \quad (13)$$

Assumed that Link Margin of 20 dB is the minimum value that set for validation on link for both peer can be acceptable, then can be concluded that the distance of (19,000 meters) mean to the maximum distance for this data communication with Link margin = 54.77 dB

V. CONCLUSION

The result of this research as this experiment 19 Km based on factor such as Antenna Gain, Transmit power and Antenna Propagation between both end which in the Line of sight (LOS) and this research will not limited for remote control but it can be used for Internet of Thing (IoT) [10] will help to communicate as the sensor node from the rural area where no other internet network infrastructure but APRS will help to connect without any of infrastructure setup or based on low budget sensor node which need the long distance communication.

APRS protocol has been around the long time since 1986 which proven for this protocol that stable enough for the long distance communication with no infrastructure or any other protocol cannot be reached such as ground to Satellite more than 600 km and this research proven the concept that we can control Exploration Vehicle that very far away from Earth such as MARS. We can improve this communication range by install the digital repeater or using Low Earth Orbit (LEO) which can be store and forward method also in the International Space Station (ISS) which installed Radio Transceiver in digital mode using 145.825 MHz to help for extend data communication range.

ACKNOWLEDGMENT

This research was granted funding by Rajapruk University and thanking to RAST (Radio Amateur Society of Thailand) allowed to use the HS0AC (Club Station) which located at Rajapruk University as the APRS I-Gate Station and provided greatly assisted the research.

REFERENCES

[1] Bob Bruninga “A Description of APRS by WB4APR, Packet Users Notebook”, CQ Magazine, Dec 1993

[2] TAPR, AX25 Link Access Protocol for Amateur Packet Rdio, TAPR, version 2.2,1997

[3] UISS Software available [online] Available http://users.belgacom.net/hamradio/uiss.htm

[4] ATMEL 8-BIT MICROCONTROLLER WITH 256 KBYTES IN-SYSTEM PROGRAMMABLE FLASH[online].Available:http://www.microchip.com/wwwproducts/en/ATmega2560

[5] J.Parthasarathy Member Technical Staff, Sun Microsystems Pvt ltd, India, Divyasree chambers, off-Langford road, Bangalore-560027, India. “Positioning and Navigation System Using GPS” International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science, Volume XXXVI, Part 6, Tokyo Japan 2006

[6] Dimension Engineering, Sabertooth Intellignet DC motor Driver Module datasheet [online] Available https://www.dimensionengineering.com/datasheets/Sabertooth2x25.pdf

[7] Pinckney, Nathaniel. "Pulse-width modulation for microcontroller servo control." IEEE potentials 25.1 (2006): 27-29.

[8] APRS.fi APRS Database Web-Server [online].Available: http://aprs.fi/page/about_technical

[9] Rappaport, Theodore S. Wireless communications: principles and *practice*. Vol. 2. New Jersey: prentice hall PTR, 1996.

[10] Jayavardhana Gubbi a , Rajkumar Buyya b,∗ , Slaven Marusic a , Marimuthu Palaniswami a “Internet of Things (IoT): A vision, architectural elements, and future directions” Future Generation Computer Systems 29 (2013) 1645–1660 journal homepage: www.elsevier.com/locate/fgcs