DIGITAL COMMUNICATION BETWEEN GROUND STATION USING RASPBERRY PI

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Abstract

Ground Station or Earth Station has a very important role in performing TT&C for satellite, in addition to that the communication between ground station is also very important for the coordination of operation and data collection from the satellites.

In the event of a disaster at the location where the earth station is there, will might be disruption of coordination between earth stations due to lack of Internet as a communication link between ground stations.
To prepare for these possibilities, I conducted research to find other ways of communicating between a ground stations. Raspberry Pi is a single board computer that is on the rise lately, this device uses minimum energy source, can even using a battery.

This research involves a several devices, among others transceiver VHF / UHF, antenna VHF / UHF, open source software fldigi, interfacing and the relationship between such devices to make another scenario for solve this problem.
This research shows that digital communication between Ground Station can be make via radio frequency without using connection from internet, ie using a Raspberry Pi and radio to send or receive a digital data from each Ground Station.

Key Words: Ground Station, Digital Communication, Raspberry Pi, Fldigi

1. INTRODUCTION

The tracking, telemetry and command (TT&C) subsystem monitors and controls the satellite right from the lift-off stage to end of its operational life in space. The tracking part of the subsystem determines the position of the spacecraft and follows its travel using angle, range and velocity information. The telemetry part gathers information of the health of various subsystems of the satellite. It encodes this information and then transmits the same towards the ground station. The command element receives and executes remote control commands from the control center on earth to effect change to the platform functions, configuration, position and velocity. The TT&C subsystem is therefore very important, not only during orbital injection and the positioning phase but also throughout the operational life of the satellite.

Figure 1-1 shows the block schematic arrangement of the basic TT&C subsystem, tracking is used to determine the orbital parameter of the satellite on a regular basis. This help in maintaining the satellite in the desired orbit and in providing look-angle information to the ground station. Angle tracking can be used to determine the azimuth and elevation angle from the ground station. The time interval measurement technique can be used for the purpose of ranging by sending signal via a command link and getting a return via the telemetry link. The rate of change of range can be determined either by measuring the phase shift of the return signal as compared to that of transmitted signal or by using a pseudorandom code modulation and the correlation between transmitted and received signal

During the orbital injection and positioning phase, the telemetry link is primarily used by the tracking system to establish a satellite to earth station communication channel. After the satellite is put into desire slot in its intended orbit, its primary function is to monitor the health of various other subsystems on board the satellite. It gathers data from variety of sensors and then transmits that data to the ground station. The data include a variety of electrical and nonelectrical parameters. The sensor output could be analogue or digital.

Wherever necessary the analogue output is digitized, with the modulation signal as digital, a various signals are multiplexed using the time division multiplexing technique. Since the bit rates involved in telemetry signal are low, a smaller receiver bandwidth with a good signal-to-noise ratio is used at the end of ground station.

The most visible element of a Ground Station is the outdoor antenna, which can take many forms and sizes to correspond to the application requirement (gain, size) of every Ground Station [2]

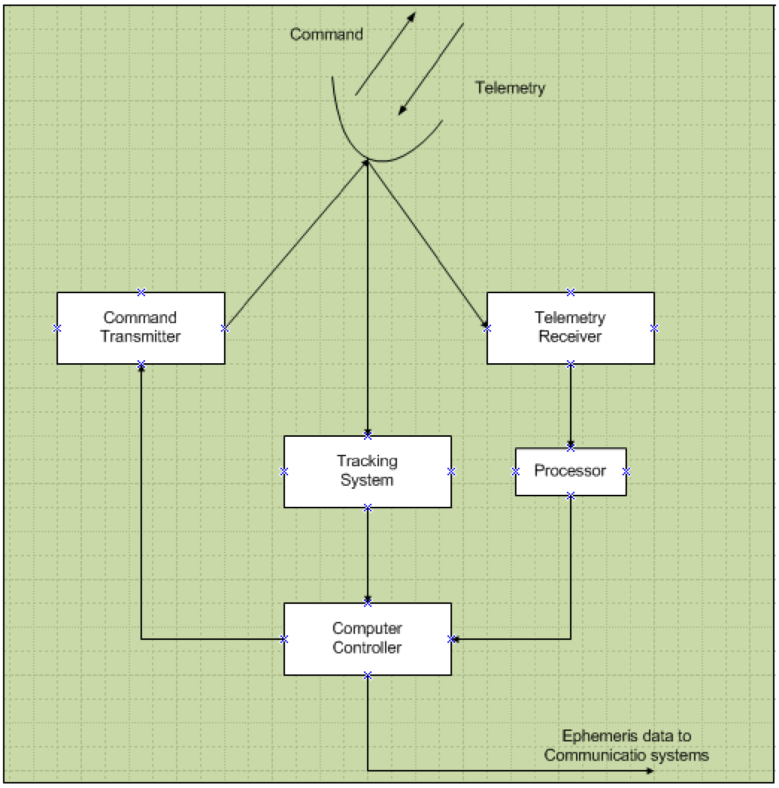

Figure 1-1 Block schematic of the basic TT&C subsystem [1]

1.1 Raspberry Pi

The Raspberry Pi computer is the size of a credit card, completely silent and costs under £30. The operating system runs from an SD flash card, allowing its personality to instantly be switched by swapping cards. Its potential uses are staggering, and as yet, not fully explored, but it has already been tested as a multimedia player with streaming capabilities, a games machine, an internet browser and a hardware development board. It is intended to be used as an educational device for people of all ages and skill levels.

The Raspberry Pi is currently available as two different models, known as the Model A and the Model B. While there are differences, with the Model A sacrificing some functionality in order to reduce its cost and power requirements, both share plenty of similarities that you'll learn about in this chapter. Figure 1-2 shows a Raspberry Pi ver.1 Model B. [5]

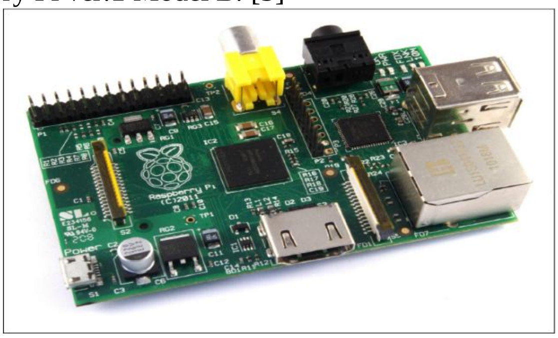

Figure 1-2 Raspberry Pi Ver.1 Model B [4]

In the centre of all Raspberry Pi boards is a square semiconductor, more commonly known as an integrated circuit or chip. This is the Broadcom BCM2835 system-on-chip (SoC) module, which provides the Pi with its general-purpose processing, graphics rendering and input/output capabilities. Stacked on top of that chip is another semiconductor, which provides the Pi with memory for temporary storage of data while it's running programs. This type of memory is known as random access memory

(RAM), as the computer can read from or write to any part of the memory at any time. RAM is volatile, meaning that anything stored in the memory is lost when the Pi loses power or is switched off.

Above and below the SoC are the Pi's video outputs. The silver (bottom) connector is a High Definition Multimedia Interface (HDMI) port, the same type of connector found on media players and many satellite and cable set-top boxes. When connected to a modern TV or monitor, the HDMI port provides high-resolution video and digital audio. The yellow (top) connector is a composite video port, which is designed for connection to older TVs that don't have an HDMI socket.

The video quality is lower than is available via HDMI, and there's no audio; instead, audio is provided as an analogue signal on the 3.5mm audio jack to the right of the composite video socket. The pins to the top-left of the Pi compose the general-purpose input-output (GPIO) header, which can be used to connect the Pi to other hardware.. The GPIO port is extremely powerful, but it's fragile; when handling the Pi, always take care to avoid touching these pins, and never connect anything to them while the Pi is switched on. The plastic and metal connector below the GPIO port is the Display Serial Interface (DSI) port, for connecting digitally driven flat-panel display systems. These are rarely used except by professional embedded developers, as the HDMI port is more flexible. A second plastic and metal connector, found to the right of the HDMI port, is the Camera Serial Interface (CSI) port, which provides a high-speed connection to the Raspberry Pi Camera Module or other Pi-compatible CSI-connected camera system.

To the very bottom-left of the board is the Pi's power socket. This is a micro-USB socket, the same type found on most modern smartphones and tablets, switches the Raspberry Pi on; unlike a desktop or laptop computer, the Pi doesn't have a power switch and will start immediately when power is connected.

On the underside of the Raspberry Pi board on the left-hand side is an SD card slot. A Secure Digital (SD) memory card provides storage for the operating system, programs, data and other files, and is non-volatile; unlike the volatile RAM, it will retain its information even when power is lost. The right-hand edge of the Pi will have different connectors depending on which model of Raspberry Pi we have, the Model A or the Model B. Above these is a series of Light Emitting Diodes (LEDs), the top two of which—marked ACT and PWR and providing an activity notification and power notification respectively—are present on all boards.

1.2 Model A

The least expensive of the Raspberry Pis, the Model A shown in Figure 1-3 is designed to be affordable yet flexible. As well as its lower cost compared to the Model B, the Model A draws less power and is a good choice for projects that use solar, wind or battery power. Although the Model A's BCM2835 SoC is just as powerful as the one found on the Model B, it comes with half the memory at 256MB. This is an important consideration when deciding which model to buy, as it can make more complex applications run slowly—in particular, those applications that turn the Pi into a server.

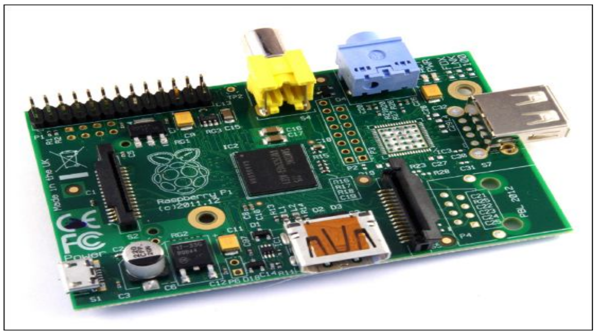

Figure 1-3 Raspberry Pi Ver.1 Model A [4]

The Model A has only a single port on its right-hand edge, a Universal Serial Bus (USB) port. This is the same type of port found on desktop and laptop computers, and allows the Pi to be connected to almost any USB-compatible peripheral. Most commonly, the USB port is used to connect a keyboard for interacting with the Pi. If you also want to use a mouse at the same time, you'll need to buy a USB hub to add more ports to the Model A, or alternatively, a keyboard with built-in mouse functionality.

1.3 Model B

The Raspberry Pi Model B shown in Figure 1-2 is more expensive than the Model A, but comes with considerable advantages. Internally, it includes twice the memory at 512MB, while externally there are additional ports not available on the lower-cost model. For many users, the Model B is a worthwhile investment; only those with particular requirements of weight, space or power draw should consider the Model A for general-purpose use. The Model B has two USB ports on the right-hand edge of the board, providing connectivity for a keyboard and mouse, and still leaving two spare ports for additional accessories such as external storage devices or hardware interfaces. Additionally, it includes an Ethernet port for connecting the Pi to a wired network; this allows the Pi to access the Internet, and allows other devices on the network to access the Pi.

1.4 Raspberry Pi Version 2

The First Raspberry Pi had a 700 Megahertz chip. The chip was a single core with chips very similar to the modern day cell phone. Even though this processor may not seem powerful, it was similar in power to the computers that were commonplace in the late 90s.

Raspberry Pi 2 has a processor chip that is more powerful than all the Pi 1 models including the B+ model, which preceded it. The latest processor is a BCM2836 900 megahertz chip. It is a quad-core chip, unlike all the models that preceded it which were single core.

The other main difference is the memory. The Pi 1 models had 512 kilobytes or less of memory. The new device has a 1 GB board memory, which is double the rating of the Pi 1 B+ model, which had a 512 kilobyte RAM. Despite the differences, the Pi 2 is similar to the previous model in a number of ways. The manufacturers wanted to keep the size, weight and dimension of the original. It is the same 'credit card size computer' but with better features and performance. [7]

There were advantages of maintaining some of the similarities. It was important to maintain backward compatibility with the previous versions. This would make old tutorials useful to those who owned the current version of the Raspberry for the new chip to work. Major changes could also make the new version completely different. After several tests, the BCM2836 900 megahertz chip was the best version that came up, which addressed all these issues.

Just like the previous models, it doesn't have a heat sink or fan. It does not need cooling, unless it is over clocked. Many of the input features remained the same, with only a few modifications to improve performance. Therefore, if you had any of the previous models, getting started with the Pi 2 is going to be much easier.

The following is a summary of the unique features of the Pi 2:

- 14 HDMI video resolution that ranges from 650x350 to 1920x1200.
- BCM2836 quad-core processor running on a 900 Megahertz system.
- 1 GB on board memory for bigger and better applications.
- 40 Pin GPIO to expand.
- Similar layout and Foot print to model B+.
- The only model with A 10/100 Ethernet port for internet connectivity.
- 4 USB ports that can support a number of demanding devices.
- Switching regulators to help conserve power.

Figure 1-4 shows a Raspberry Pi ver.2 Model B. which as we used in this experiment.

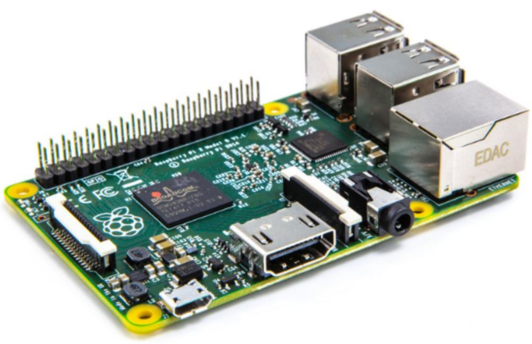

Figure 1-4 Raspberry Pi Ver.2 Model B [6]

2. METHODOLOGY

Modulation is a technique to carry digital data over analog waveform core of signal modulation is to put the message and place it on a carrier signal for transmission. While Demodulation is the reverse process, ie to get the message signal is the split of the carrier signal. To facilitate the operation of the transmission signal frequency used is generally a high frequency for reasons easy to be separated.

In Raspberry Pi we used a usb sound card to connect to Raspberry to modulation a signal that has send from Raspberry Pi to Transmiter.

Figure 2-1 USB Sound Card [12]

2.1 USB sound cards

A sound card also known as an audio card is an internal computer expansion card that facilitates economical input and output of audio signals to and from a computer under control of computer programs. The term sound card is also applied to external audio interfaces that use software to generate sound, as opposed to using hardware inside the PC. Typical uses of sound cards include providing the audio component for multimedia applications such as music composition, editing video or audio, presentation, education and entertainment (games) and video projection

USB sound cards, sometimes called audio interfaces, are usually external boxes that plug into the computer via USB. A USB audio interface may describe a device allowing a computer which has a sound-card, yet lacks a standard audio socket, to be connected to an external device which requires such a socket, via its USB socket.

The USB specification defines a standard interface, the USB audio device class, allowing a single driver to work with the various USB sound devices and interfaces on the market.

Even cards meeting the older, slow, USB 1.1 specification are capable of high quality sound with a limited number of channels, or limited sampling frequency or bit depth, but USB 2.0 or later is more capable.

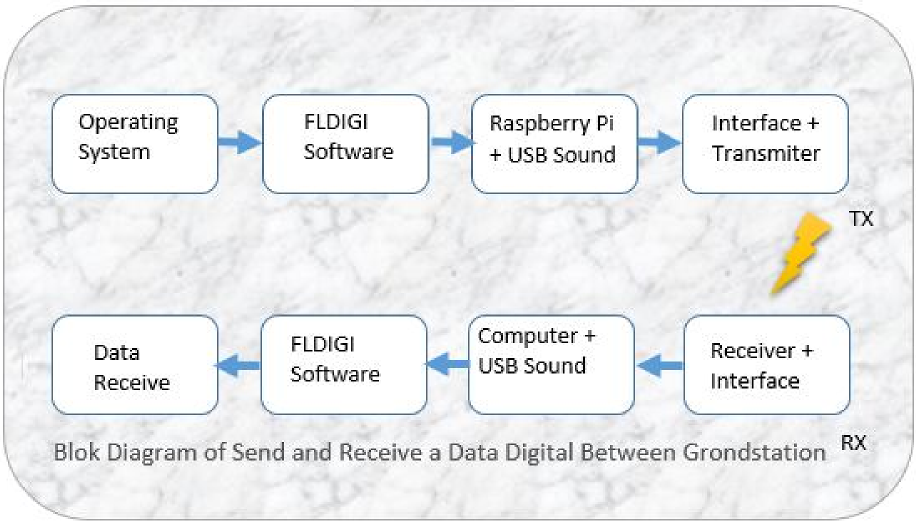

Figure 2-2 Blok Diagram of Send and Receive a Data Via Sound Modulation

2.2 FLDIGI

Fldigi is an open source radioteletype software most commonly used by amateur radio operators which uses a computer's soundcard to modulate and demodulate data. Commonly the software is used to interconnect a computer to a high frequency radio receiver and transmitter.

Fldigi (Fast Light Digital Modem Application) is a cross-platform modem program that supports most of the digital modes used on the amateur radio bands. [11]

Digital Modes Supported

Mode Name	Modes Supported	Custom Modes
Morse Code / CW	5 - 50 words-per-minute	No
BPSK	31, 63, 63F, 125, 250, 500, 1000	No
Contestia	4/125, 4/250, 8/250, 4/500, 8/500, 16/500, 8/1000, 16/1000, 32/1000, 64/1000	Yes
DominoEX	4, 5, 8, 11, 16, 22, 44, 88	No
Hellscreiber	Feld Hell, Slow Hell, Feld Hell X5, Feld Hell X9, FSK Hell, FSK Hell-105, Hell 80	No
MFSK	4, 8, 11, 16, 22, 31, 32, 64, 128	No
MT63	500, 1000, 2000	No
Navtex	Navtex	No
Olivia	4/250, 8/250, 4/500, 8/500, 16/500, 8/1000, 16/1000, 32/1000, 64/2000	Yes
QPSK	31, 63, 125, 250, 500	No
PSKR	125, 250, 500, 1000	No
RTTY	45.45/170, 50/170, 75/170, 75/850	Yes
THOR	4, 5, 8, 11, 16, 22, 25x4, 50x1, 50x2 100	No
SitorB	SitorB	No
Throb / ThrobX	1, 2, 4 / X1, X2, X4	No
WEFAX	IOC576 , IOC288	No

2.3 Radio Interface

There are many brands of interface available to connect a PC to an amateur radio transceiver. Often home-brew interfaces are used. They all do essentially the same thing. They key the radio to transmit, pass a signal based on the mode of operation from the PC to the radio, then un-key to go back into receive mode. Some automatically bypass the microphone during transmission but allow the operator to override the computer simply by keying the mike. Links to suppliers of some interfaces are below. They generally work with any PC soundcard based software, digital or analogue.

The connection to the PC is usually done through a 9 pin RS232 serial connector with connector as in the figure somewhat lower section. Note that the pin is important to be used in the circuit that we created is pin Request To Send (RTS), Data Terminal Ready (DTR) and Ground (GND). With a pin number 7 (RTS), 4 (DTR) and 5 (GND). The main components used in this experiment are:

Opto Coupler. Opto Coupler is basically a relay, but is the electronic relay so no mechanics at all. 4N33 is used here, but we have some other alternatives such as TLP-521-2 or PC817.
Input transformer. This should be in looking at the shops selling second-hand goods.

Other components such as resistors 1K2 Ohm, 1N4148, 100pF, the price is very low IC sockets should be bought at once. Maybe somewhat the more expensive is the connector Mic for HF rig we use.

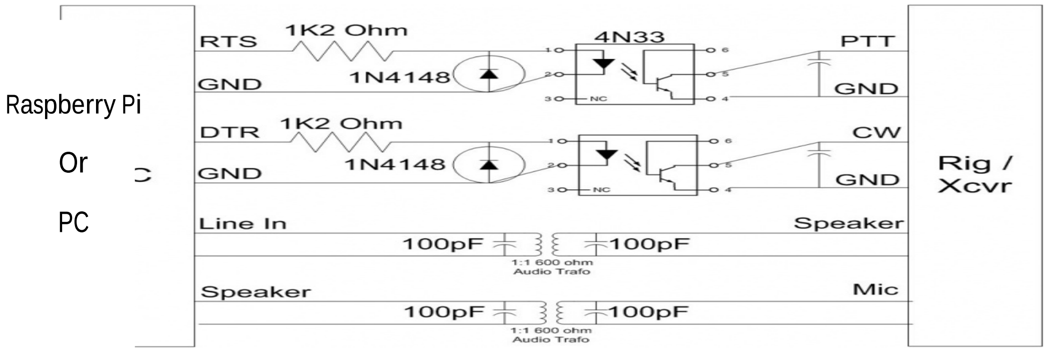

Figure 2-3 Black Box Interface Raspberry Pi to RIG (Transmitter) [14]

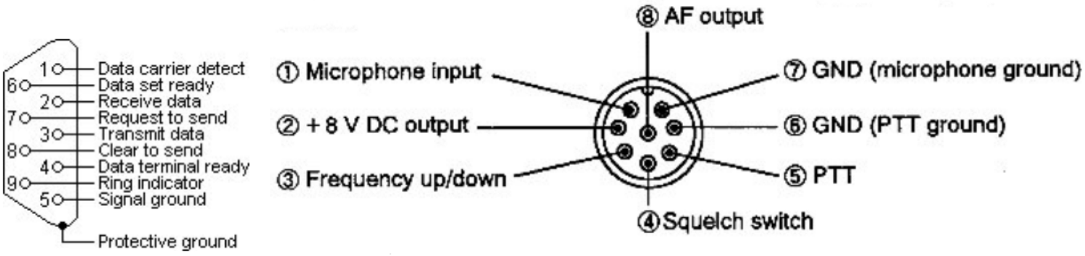

Figure 2-4 Connector Signal Name on Raspberry Pi and RIG (Transmitter) [11]

2.4 USB to RS-232 Interface

A USB adapter is a type of protocol converter which is used for converting USB data signals to and from other communications standards. Commonly, USB adaptors are used to convert USB data to standard serial port data and vice versa.

Most commonly the USB data signals are converted to either RS232, RS485, RS422 or TTL serial data. The older serial RS423 protocol is rarely used any more, so USB to RS423 adapters are less common.

USB to serial RS232 adapters are often used with consumer, commercial and industrial applications and USB to serial RS485/RS422 adapters are usually mainly used only with industrial applications.

Adapters for converting USB to other standard or proprietary protocols also exist; however, these are usually not referred to as a serial adapter.

The primary application scenario is to enable USB based computers to access and communicate with serial devices featuring D-Sub (usually DB9 or DB25) connectors or screw terminals, where security of the data transmission is not generally an issue.

USB serial adapters can be isolated or non-isolated. The isolated version has opto-couplers and/or surge suppressors to prevent static electricity or other high-voltage surges to enter the data lines thereby preventing data loss and damage to the adapter and connected serial device. The non-isolated version has no protection against static electricity or voltage surges, which is why this version is usually recommended for only non-critical applications and at short communication ranges.

Figure 2-5 USB to Serial Converter for Connection Raspberry Pi and Box Interface [12]

3. RESULTS AND DISCUSSION

This result experiment is a data it was get from sending and receiving between Groundstation_1 and Groundstation_2, by using scenario for Groundstation_1 is using Raspberry Pi for sending and receiving data, and for Groundstation_2 is a regular station that was using Computer to receive and sending a data.

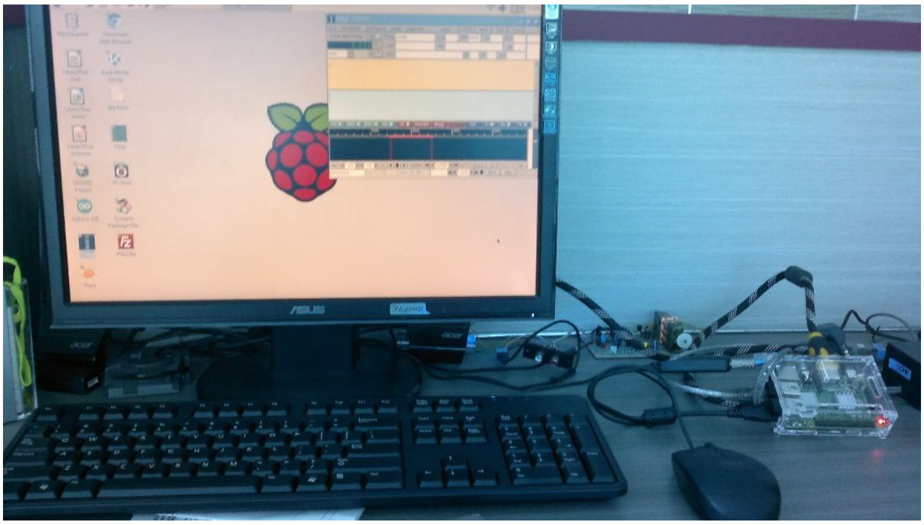

Figure 3-1 GroundStation_1 with Using Raspberry Pi

In Figure 3-1, we can see a Raspberry Pi is running Raspbian_OS, its base on Linux operating system. Raspbian its mean Raspberry + Debian. Because Debian is one of linux operating system so we can install program name FLDIGI, it was open source software, it can be running on linux and windows operating system.

Figure 3-2 Raspberry Pi Connect to Transmitter via Interface

In Figure 3-2, we can see a Raspberry Pi is conneting from box interface to RIG or Transmitter by using USB to Serial converter, a sound data modulation also connecting to transmitter by using USB Sound module.

With this configuration we are ready to send and receiving a data from Groundstation_1 to Groundstation_2 or vice versa.

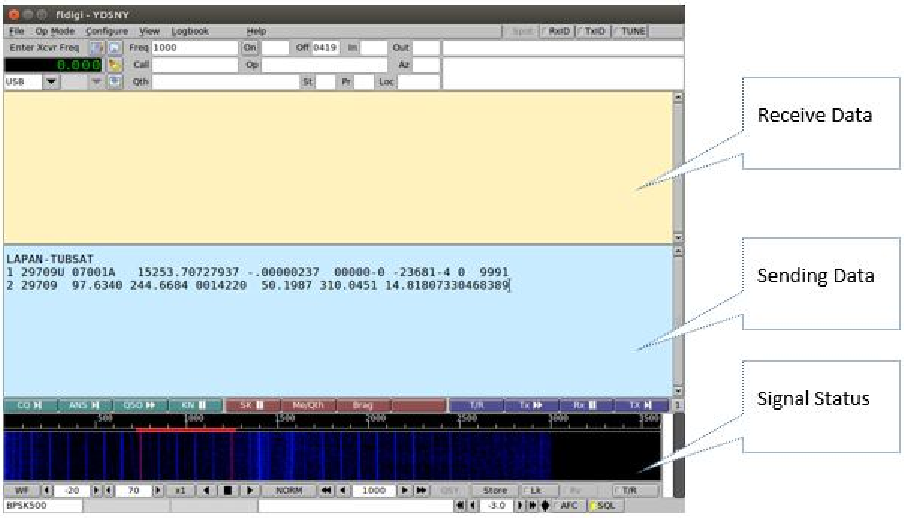

Figure 3-3 Groundstation_1 Sending a Data Two Line Element (TLE)

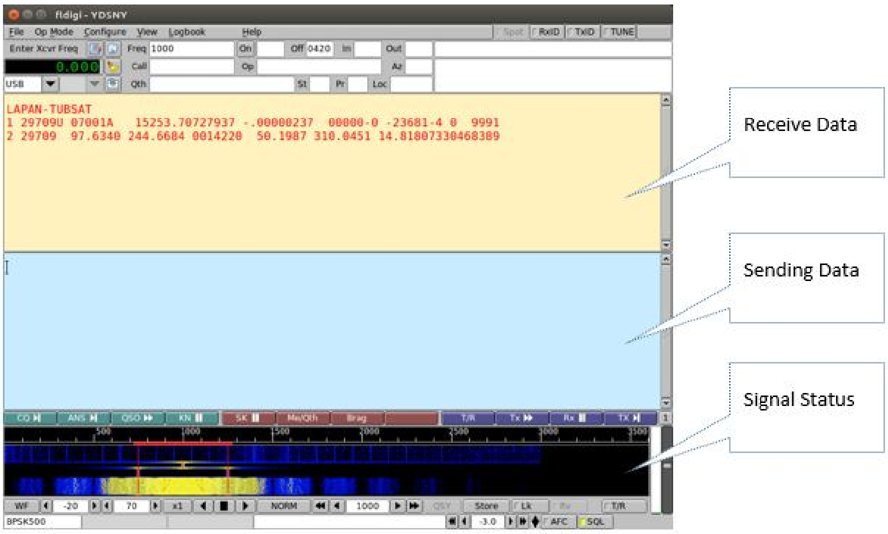

Figure 3-4 Groundstation_2 Receiving a Data Two Line Element (TLE)

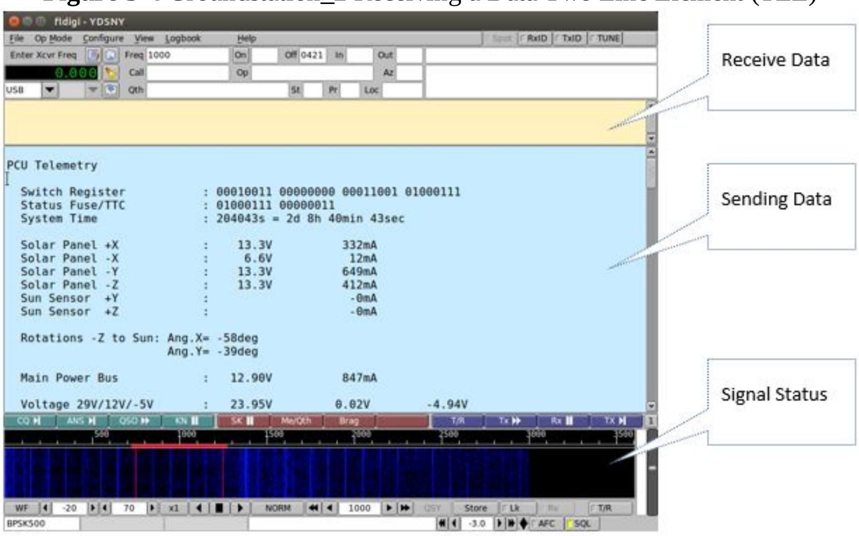

Figure 3-5 GS_2 Sending a Telemetry Data of LAPAN_TUBSAT Satellite To GS_1

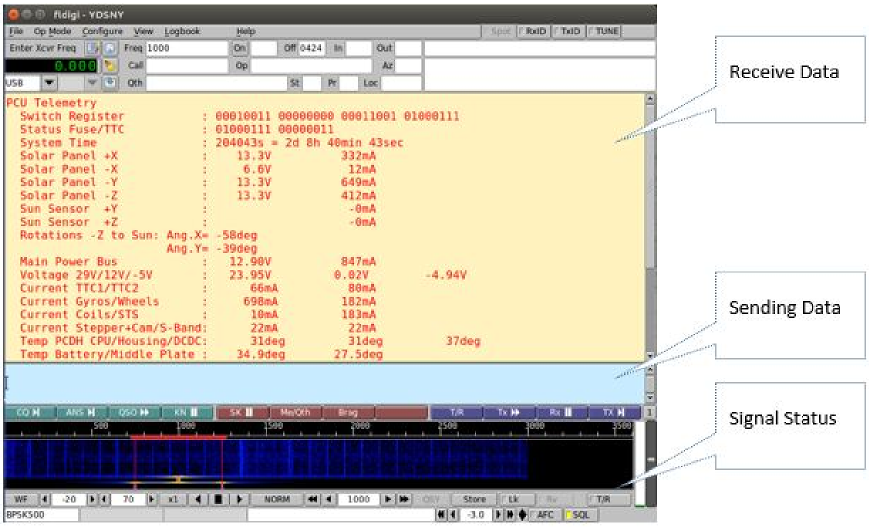

Figure 3-6 GS_1 Receiving a Telemetry Data of LAPAN_TUBSAT Satellite From GS_2

From a result that we got, we can see that of two GroundStation can sending or receive a data digital from each other. The both of GroundStation can be configure to send or to receive a data depending the purpose of task of situation. The connection beetwen Ground Station can be connected as long the two Ground Station can receive a voice signal, for reliability can be measure by read the power signal that we got or hearing a clear of voice signal, this experiment is purpose to transfer digital data like TLE and Telemetry that was important to do TT&C (Tracking, Telemetry & Control) for future experiment can be trying for chat beetwen Ground Station.

Digital communication between Ground Station can be make via radio frequency without using connection from internet, by using a Raspberry Pi and another equipment we can send or receive a digital data from each Ground Station. This scenario can be used when disaster is happen in the Ground Station location that usually other connection like Internet, Telephone and GSM link is cut off.

Raspberry Pi is a single board computer that is on the rise lately, this device uses the energy source. By using modulation sound we can communication between Ground Station via radio amateur wave, the communication not only for voice but it can be a digital communication that can use to transfer a Two Line Element data that was important for predict TT&C Task, and also for transfer data Telemetry from one Ground Station to another Ground Station without using internet connection. Its all best on amateur radio, sound modulation and also Raspberry Pi.

4. CONCLUSION

a. Digital communication between Ground Station can be make via radio frequency without using connection from internet. This connection between Ground Station can be done by using amateur frequency radio.
b. From the results can be seen by using a Raspberry Pi and another equipment like usb interface, usb sound and interface for connected to radio we can send or receive a digital data from each Ground Station.
c. This scenario can be used when disaster is happen in the Ground Station location that usually other connection like Internet, Telephone and GSM link is cut off.

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