GPS based Automatic Antenna Management System and Satellite Tracking

Conference Paper · December 2016

6 authors, including:

Monirul Islam Bappy
North South University

Mohammad Islam
North South University

GPS based Automatic Antenna Management System and Satellite Tracking

Monirul Islam [a], Rezwan Bin Kashem [b], ASM Rashedul Huq [c] and K. M. A. Salam [d]

Our project is to develop a low cost, automatic, smaller and portable Satellite Tracker and Antenna management system useable for Satellite communication. We are using programmable microprocessor and embedded technology to develop this project. This project is based on GPS so that we can calculate, track and communicate with almost all the satellites orbiting the earth from anywhere of the globe. Now it is possible to develop complete portable satellite Ground Station using this technology.

Field of Research: Electrical and Electronic Engineering

1 Introduction

In the present era, many researchers have been studied on satellite communication (Festo Didactic 2015, Erwin C. Hudson, Remberto L. Martin 2007, Arthur R. Tllford, James D. Allen & David J. Kuether 1999, Jason Ragland, Andrew Martino, Sander Middour & Shashwat Kandadai 2013, Junsung Cho, Vinh Pham and Suresh Subasinghe 2004, James_A. Benjamin, Pavld A. Haessig, Peter Lindsay 1999, Mltchell C. Radov 1987.). Satellite communication have three basic parts; Space segment (The satellite), Control segment and Ground segment. Here we are concerned about Ground segment. Satellite Ground station consists of three basic parts: Satellite tracking, Radio & Transmission control and Antenna control. In our project we are focusing on satellite tracking and antenna control (William H. McGuire, Thomas J. Tilden 1990). In a senior design project paper known as “Amateur Satellite Tracking Communication System” (Junsung Cho, Vinh Pham, Suresh Subasinghe, University of Utah, Dec. 17, 2004), they published about a design of an antenna/transmitter module for communicating with LEO amateur satellite using direction controlled antennas. Another senior design project paper known as “Amateur radio Satellite Ground Station” (Jason Ragland, Andrew Martino, Sander Middour & Shashwat Kandadai, University of California, March 19, 2013) proposes a design for a communication satellite ground station operating on ham radio frequencies using software controlled, motor operated antennas. James_A. Benjamin, Pavld A. Haessig, Peter Lindsay. Two-Axis Satellite Antenna Mounting and Tracking Assembly. United States Patent, Patent Number: 5,999,139; Dec. 7, 1999 presents a US Patent that relates to a low-cost mounting and tracking assembly for satellite antenna. It consists of two support sub systems for adjusting two axis angles. Here, different researchers tried to find easy and sophisticated solution for satellite communication. But there is no other device or system that can provide the complete solution for satellite communication.

---

[a]Department of Electrical and Computer Engineering, North South University, Dhaka, Bangladesh, Email: mmonirul.islam@northsouth.edu
[b]Department of Electrical and Computer Engineering, North South University, Dhaka, Bangladesh, Email: rezwan.kashem@northsouth.edu
[c]Department of Electrical and Computer Engineering, North South University, Dhaka, Bangladesh, Email: techbabu@gmail.com
[d]Department of Electrical and Computer Engineering, North South University, Dhaka, Bangladesh, Email: kazi.salam@northsouth.edu

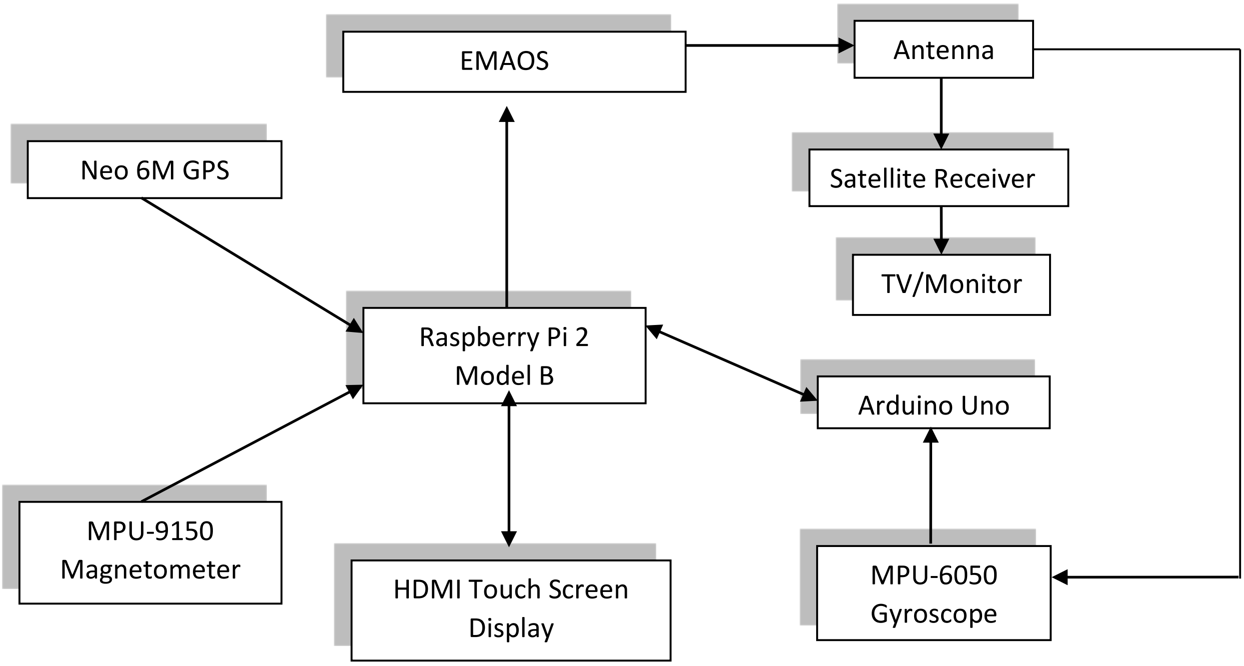
We tried to find an easy and cost effective solution. In our background study we found some device that requires to put the location of the device manually, another device needed to fix direction orientation of the antenna (John E. Wilson 1987) manually. Some other system cannot display the graphical movement of the satellite antenna and most other device cannot operate in moving condition (William J. Sherwood, David W. Wagner 1996). Another important issue is the size and power consumption of the device. Most of the device or system is larger in size and more power hungry. Here, our device comes in play. This device have GPS module so that it can get the location coordinates automatically. This device can display the antenna's graphical movement and fix up the direction orientation using Gyroscope and Magnetometer sensors. This device can track almost all the satellites orbiting the earth from anywhere of the globe. To operate this device, any online or data connection is not required as it is completely an offline based system. We are using programmable Microprocessor Raspberry Pi as our main board. This device is very smaller in size and less power hungry so that it is very easy to transport from one place to another and easy to assemble in a short time with less complexity (James June-Ming Wang, Paul K. Sun, Russell Geoffrey Santora 2003). The main advantage of this device is, it has very low development cost, compare to the other device it is a fraction of other modern devices.

2 Methodology

We are combining several components and systems to build our system which is designed to be completely autonomous. Raspberry Pi 2 is our main Microprocessor board. Arduino Uno is connected with Raspberry Pi as slave. MPU6050 (Gyroscope) module is connected with Arduino Uno analog input port. Magnetometer (MPU9150) is connected with Raspberry pi I2C Bus. GPS module is connected with UART port of Raspberry pi. The servo motor's PWM control cable of Azimuth rotator is connected with GPIO 4 (Pin-7) and Elevation rotator is connected with GPIO 17 (Pin-11). And the display is connected through HDMI port.

When we turn on the system it will boot up the Raspberry Pi with Raspbian OS. Then GPS module will get the device location, tracking software will track the satellites, Magnetometer shows the direction orientation, Gyroscope shows the graphical representation of antenna movement and servo motor rotates the antenna using mechanical system (James_A. Benjamin, Pavld A. Haessig, Peter Lindsay 1999) to make the alignment with the desired satellite. There is also a radio interface to communicate with satellites. This time we are using satellite receiver only.

Figure 1: Block Diagram of the Proposed System



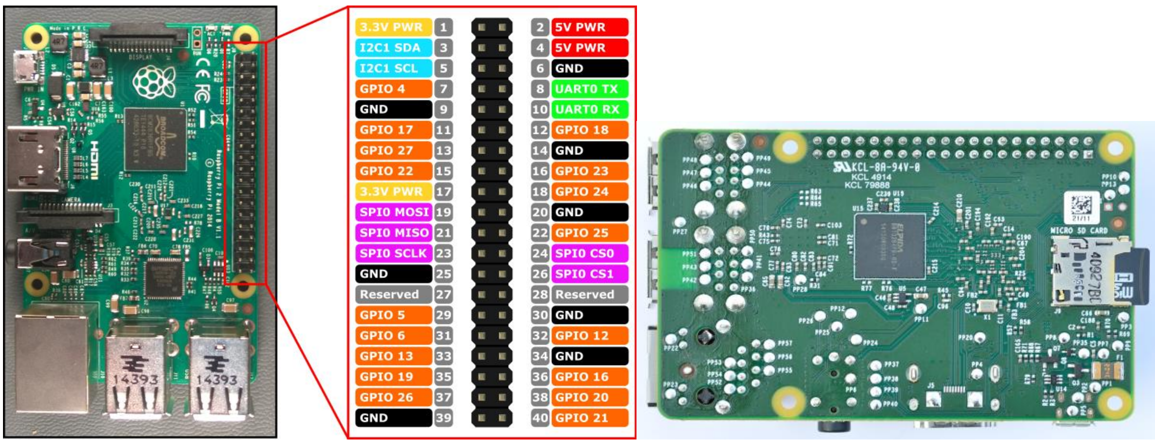
3 Discussion

3.1 Hardware Components Used in the Proposed System

3.1.1 Raspberry Pi 2 Model B Microprocessor board:

Raspberry Pi 2 Model B is a microcontroller which is equipped with a quad core ARM processor and 1GB of RAM. It comes with its own OS with entire set of free open-source programs and system development tools in its libraries. It has 40 digital input/output pins, analog inputs, UARTs (hardware serial ports), 4 USB connections, a LAN connector and a micro USB power port. This was chosen for the proposed system design due to its excellent interfacing capability with different sensors and the built in availability of satellite tracking software in its libraries.

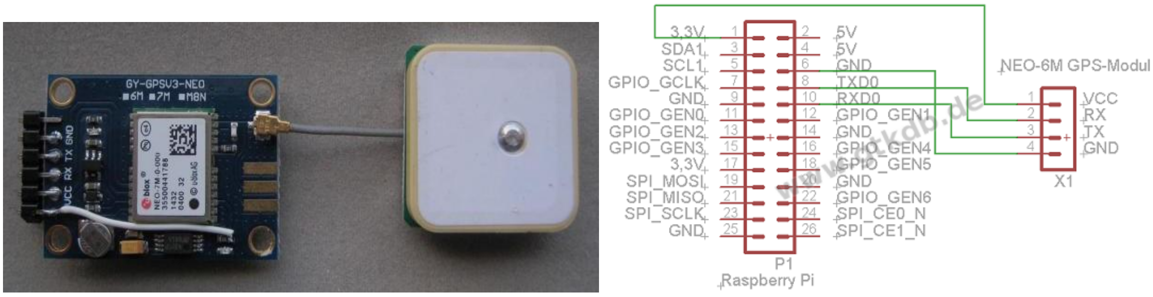
Figure 2: Raspberry Pi 2 Model B Front & Back Side



3.1.2 Neo 6M GPS Sensor:

Neo 6M GPS module is a GPS receiver that can be used with Raspberry Pi 2. This GPS module uses the latest technology to give the best possible position information such as longitude and latitude without being online using mobile network or the internet. It has very high refresh rates and very low power consumption making it ideal for use for the proposed system.

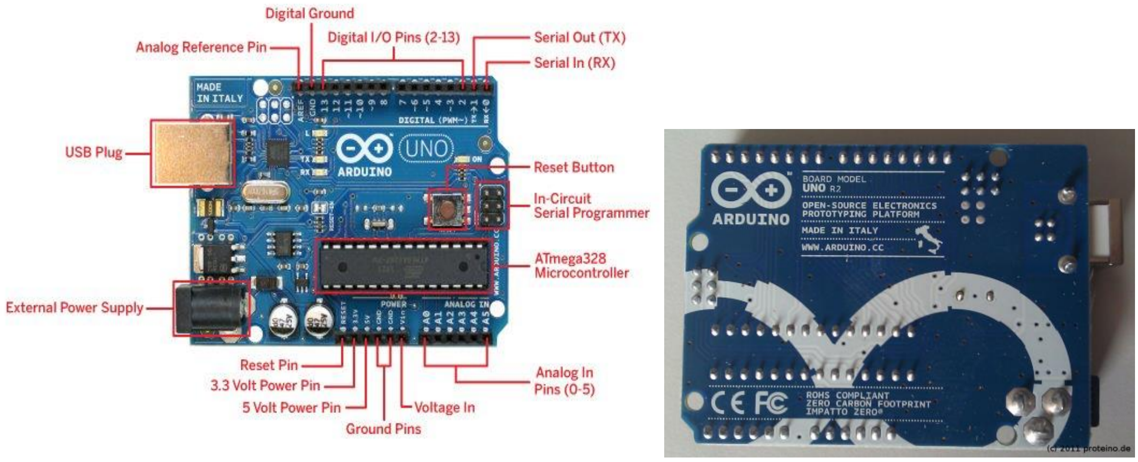
Figure 3: Neo 6M GPS Sensor Front & Back Side



3.1.3 Arduino Uno microcontroller board:

Arduino Uno is a microcontroller board. It has 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It has been used as a slave to the Raspberry Pi 2. This particular board was used because of its excellent compatibility with the MPU6050 sensor as compared to the Raspberry Pi 2.

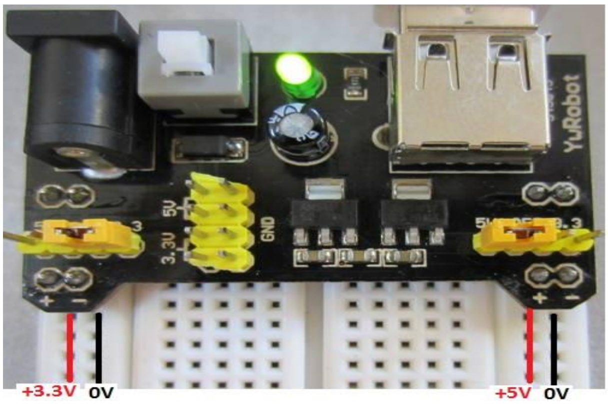
Figure 4: Arduino Uno Front & Back Side



3.1.4 YwRobot 545043 power controller board:

The YwRobot 545043 is a breadboard power supply module. It provides dual 5 V and 3.3 V power rails, and has a multi-purpose female USB socket. This module is used to equally distribute power to the different modules and sensors of the proposed system.

Figure 5: YwRobot 545043 PCB



3.1.5 MG996R servo motor:

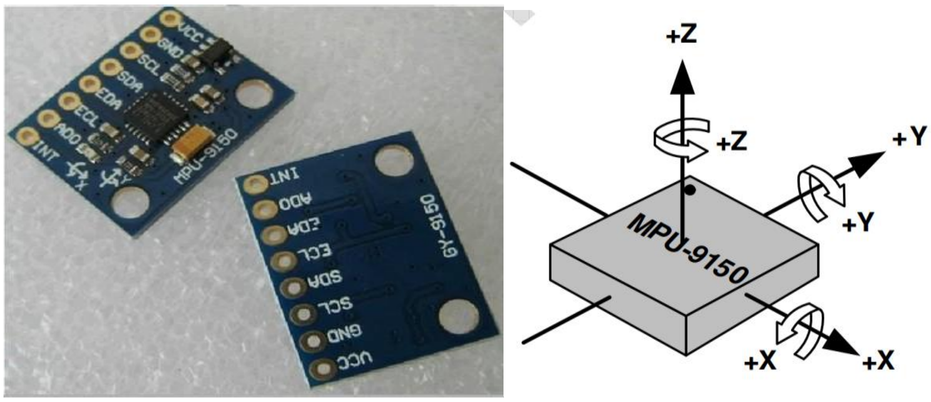
MG996R is a servo motor module that is connected with Raspberry Pi. The motor is used in our system to control and adjust the antenna. It has support from 0 to 180-degree rotational range. This is used in our system to adjust the angles, which can be adjusted very accurately and have very low power consumption.

Figure 6: MG996R servo motor

3.1.6 MPU 9150 sensor:

The MPU-9150 is a System in Package (SiP) that combines two chips: the MPU-6050 contains a 3-axis gyroscope, 3-axis accelerometer, and an onboard Digital Motion Processor™ (DMP™) capable of processing complex Motion Fusion algorithms; and the AK8975, a 3-axis digital compass. This module is used in the proposed system for figuring the directional orientation of the antenna. It is used as a compass and is interfaced with the Raspberry Pi 2.

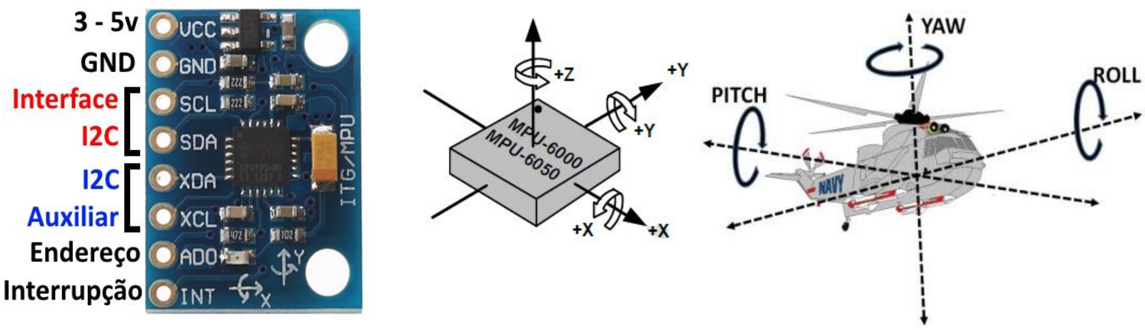
Figure 7: MPU 9150 sensor



3.1.7 MPU 6050 sensor:

The MPU-6050 sensor contains a MEMS accelerometer and a MEMS gyro in a single chip. It is very accurate, as it contains 16-bits analog to digital conversion hardware for each channel. Therefor it captures the x, y, and z channel at the same time. The sensor uses the I2C-bus to interface with the Arduino. This module is used in the proposed system for visual representation of the antenna using Python programming. The module is interfaced with Arduino Uno.

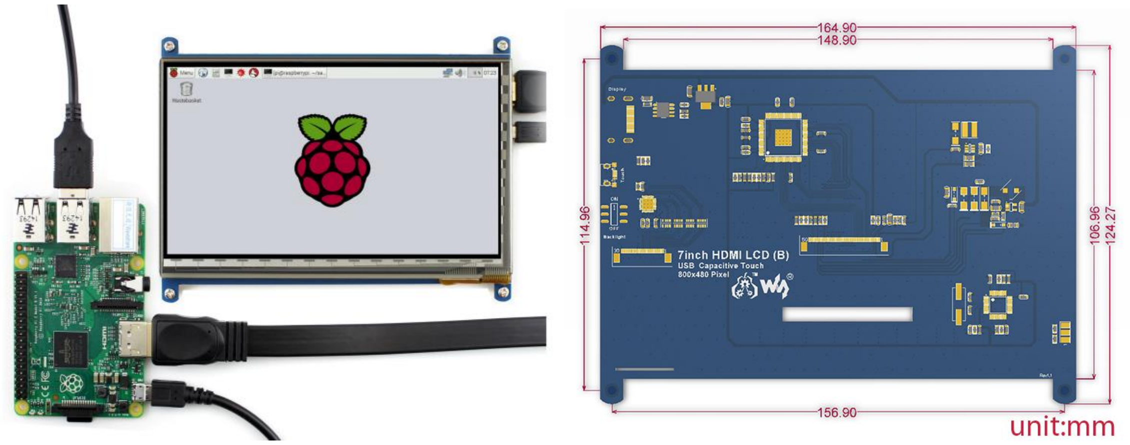
Figure 8: MPU 6050 sensor



3.1.8 7 inch HDMI LCD display:

The 7 inch HDMI LCD display is used to display the OS and different satellite tracking software and programs that is used to operate the proposed system. It is connected and interfaced with the Raspberry Pi 2.

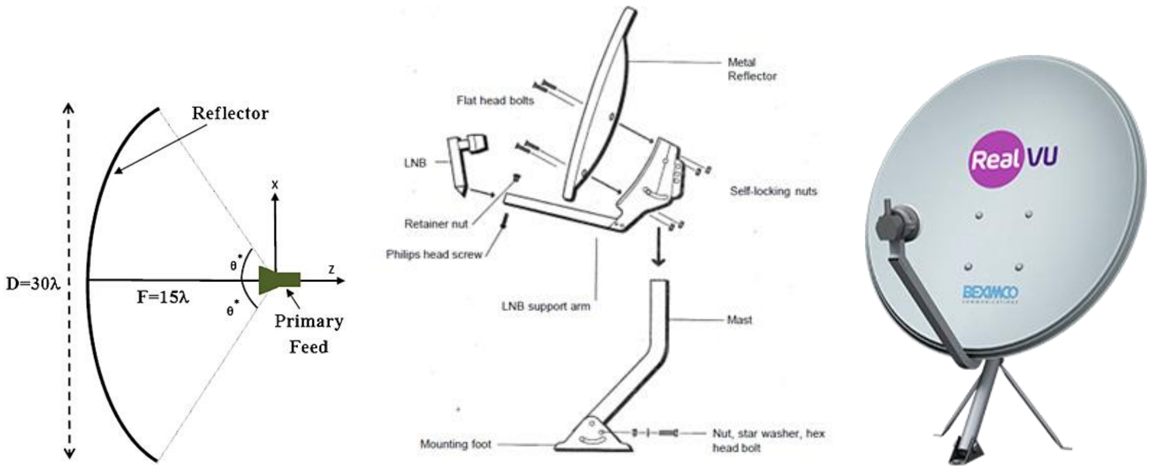
Figure 9: 7 inch HDMI LCD display



3.1.9 Parabolic Antenna Reflector:

Reflector antennas are typically used when very high gain (e.g. satellite transmission or reception) or a very narrow main beam (e.g. secure communication) is required. It transforms an incoming plane wave traveling along the axis into a spherical wave converging toward the focus. It is used in the proposed system to receive and transmit satellite transmissions through it for the system.

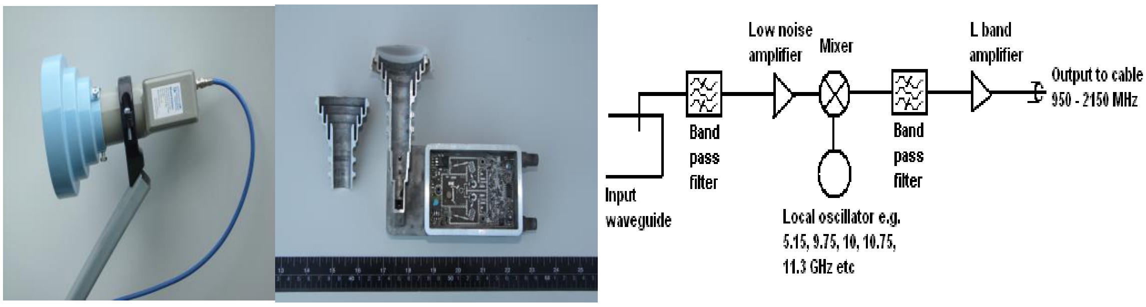
Figure 10: Parabolic antenna reflector



3.1.10 Antenna LNB:

The LNB is a combination of low-noise amplifier, frequency mixer, local oscillator and intermediate frequency (IF) amplifier. It receives the microwave signal from the satellite collected by the dish, amplifies it, and down converts the block of frequencies to a lower block of intermediate frequencies (IF). This down conversion allows the signal to be carried to the indoor satellite TV receiver using coaxial cable, which is the purpose of this module in the proposed system.

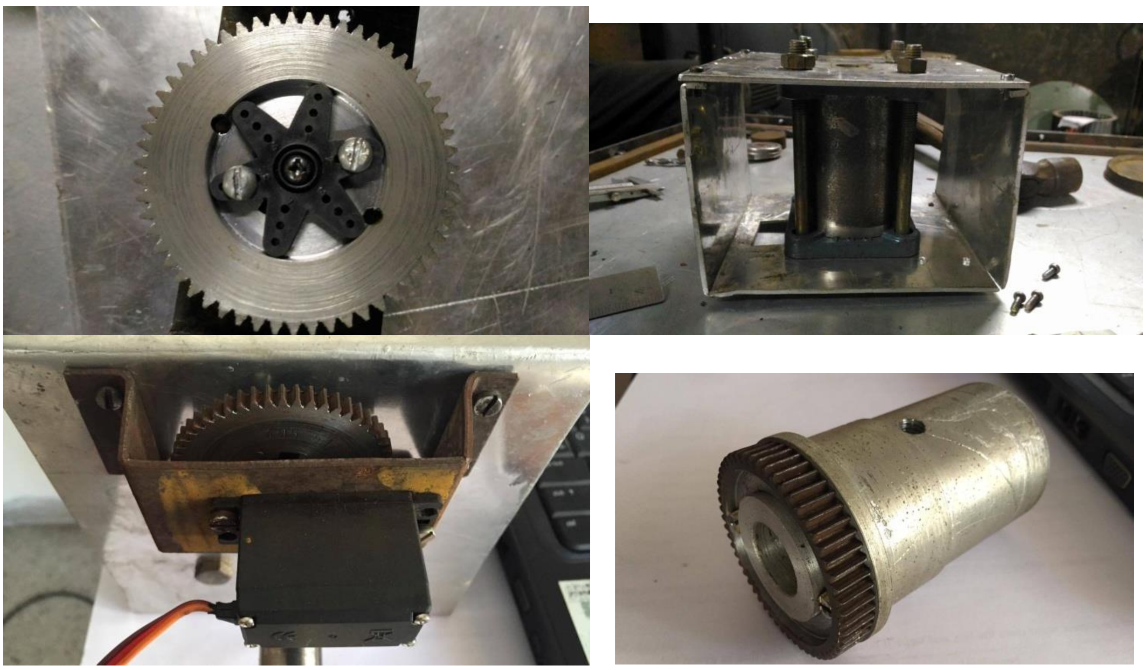
Figure 11: Antenna LNB



3.1.11 Electro-Mechanical Antenna Orientation System (EMAOS):

The EMAOS consists of a stand, two servo motors, a turn table, an antenna mounting and an antenna. The turn table rests on the stand. A spur gear with 55 teeth has been attached to the top-end of the stand. The turn table consists of another spur gear. These spur gears are designed in a 1:1 ratio so that the rotation of the turn table is the same as the angle of rotation of the servo motor. The idea of this spur gear is that these gears are aligned in the same line so that when the motor starts to rotate, the whole turn table rotates. Actually, the gear on the top of the stand is fixed. It does not change its position. As another gear is attached to the shaft of the servo motor, this gear drives the whole turn table in the direction of its rotation. As the servo motor is mounted to the bottom of the turn table, it allows the whole turn table to rotate along the axis of the shaft which was mentioned earlier. So, this axial rotation defines the azimuth angle of the satellite. The purpose of EMAOS in the proposed system is to precisely control and adjust the azimuth and elevation angles of the antenna. The picture of the EMAOS is shown in Figure 13.

Figure 12: EMAOS



3.2 Software Components Used in the Proposed System

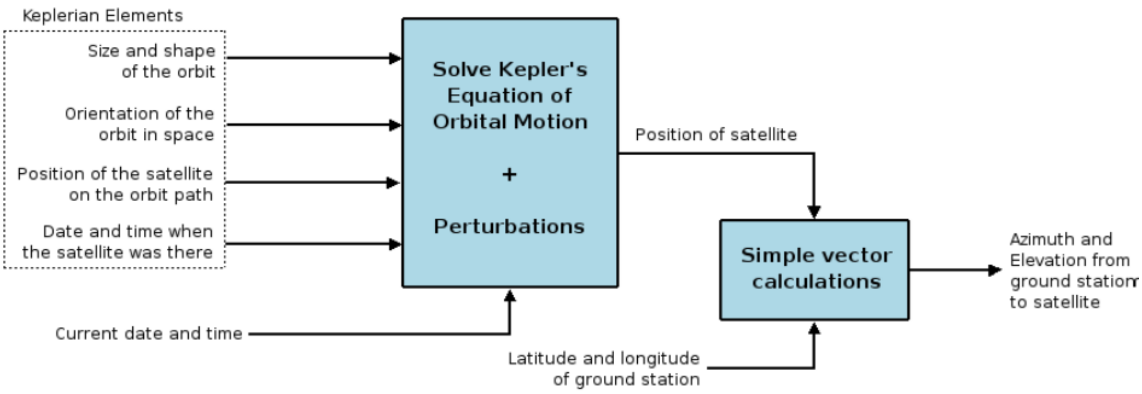
3.2.1 Operating System: Raspbian OS

Raspbian is a free operating system based on Debian optimized for the Raspberry Pi hardware. Raspbian provides more than a pure OS: it comes with over 35,000 packages; pre-compiled software bundled in a nice format for easy installation on Raspberry Pi.

3.2.2 Tracking Software: GPREDICT

GPREDICT is a real-time satellite tracking and orbit prediction program that predicts the position and velocity of a satellite at a given time using a mathematical model of the orbit. Once the position and velocity of the satellite is known other data can be calculated, for example bearing, distance, footprint, and visibility just to mention a few. The figure below shows a diagram of the core functionality of a satellite tracking program.

Figure 13: Working mechanism of GPREDICT software



3.2.3 *Arduino Software (IDE)*

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them.

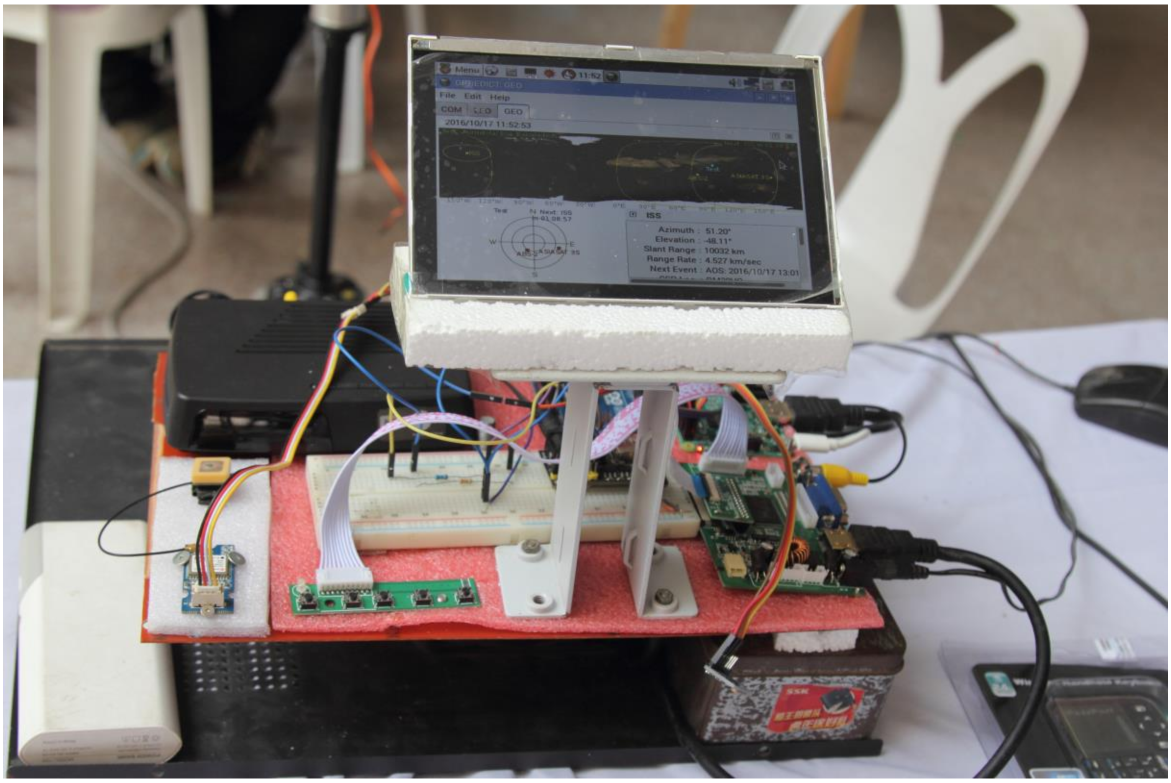
3.3 Prototype of the Proposed System

When we plug in the power to the Raspberry pi, it will boot up with Raspbian OS. An Arduino Uno is interfaced with Raspberry Pi as a slave. MPU6050 module is connected with Arduino Uno that is placed in back side of the antenna reflector. When we input the Gyroscope code to the Arduino IDE or Python programming software, the Raspberry Pi will show the graphical display of the Antenna's angular movement (shows in Figure 18). In this device we are using GPREDICT software for satellite tracking. This software can track all the satellites orbiting the Earth and give us the graphical representation of satellites in maps (shows in Figure 15) with almost all the necessary data required for satellite communication. GPS module give the present coordinate of the device that is the input for GPREDICT software. We are using hamlib antenna library and driver for Antenna rotator control (shows in Figure 16). When we select the desire satellite and push the 'Track' & 'Engage' button of antenna interface control, the servo motor will get command and it will start tracking the satellite. A Magnetometer (MPU9150) is also connected with

Raspberry pi for direction orientation of the antenna. 0 degree Azimuth is the true North of the device. When the device fix the direction orientation of the antenna and get the command from rotator control, it will make the alignment of the antenna to the desire satellite. This device can also operate in moving condition. Magnetometer will check the direction and fix the antenna orientation by rotating the servo motor. In our prototype we are using Real VU satellite receiver for receiving satellite signal and it connected with TV and we can watch the by receiving the satellite signal.

The hardware design of the proposed system is shown in Figure14.

Figure 14: Prototype of the Proposed System



3.4 Results

The proposed device requires 2 power inputs with 5 volt input voltage to function. The voltage source can be a USB powered brick or a battery pack that can deliver the functioning voltage. The system consists of one microprocessor boards and one microcontroller board which is plugged with all the sensors and EMAOS, which consists two servo motors. All the individual components function distinctively and produce their own outputs. The entire device works as a perfect satellite tracking system and the EMAOS motors works in rotating and adjusting the various angles. Once the device is powered on, the sensors will be turned on and will start generating location data as well as the present orientation position of the antenna. The GPREDICT software lists all the available satellite data and when one is selected, it sends signals to the EMAOS motors, which rotates and adjusts the antenna according to the data from GPREDICT. The output seen from the display of the system are shown below in Figure 15 & 16.

Figure 15: Output of GPREDICT real-time satellite tracking

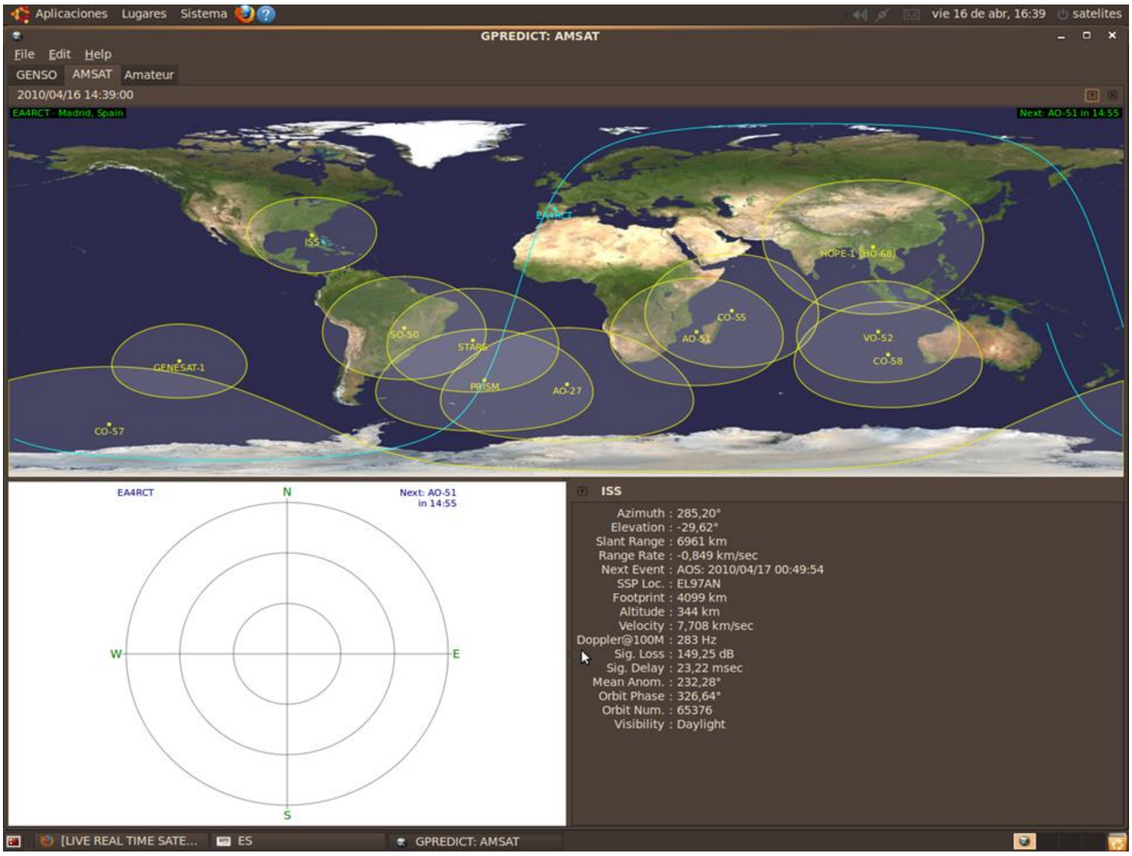


Figure 16: The rotator control interface.

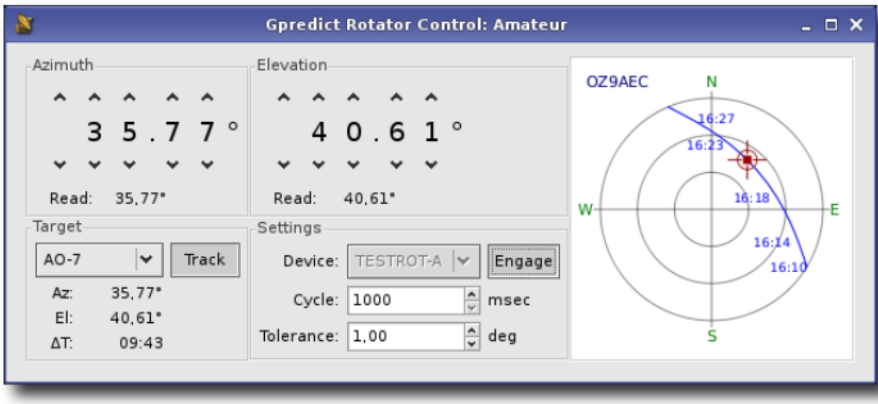


Figure 17: Output Seen of u-center software for Neo 6M GPS

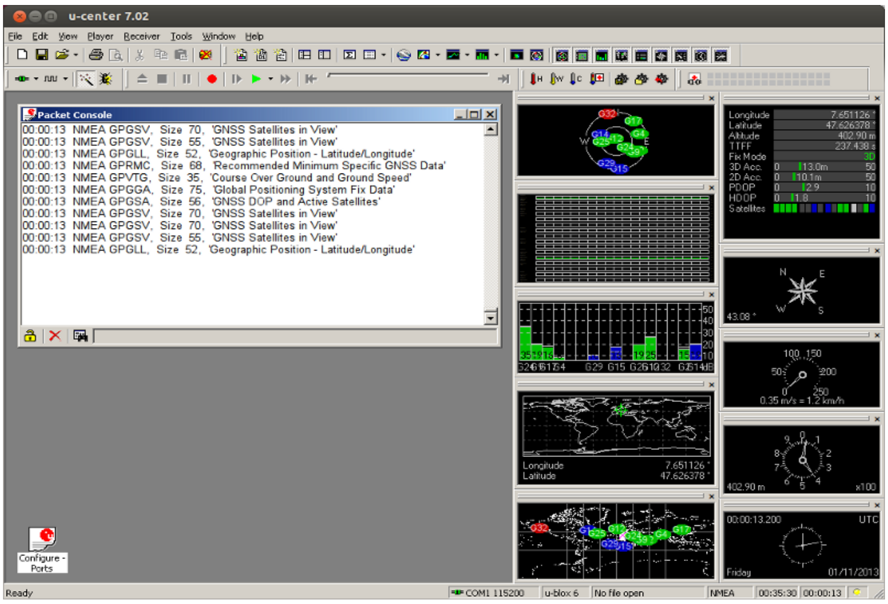
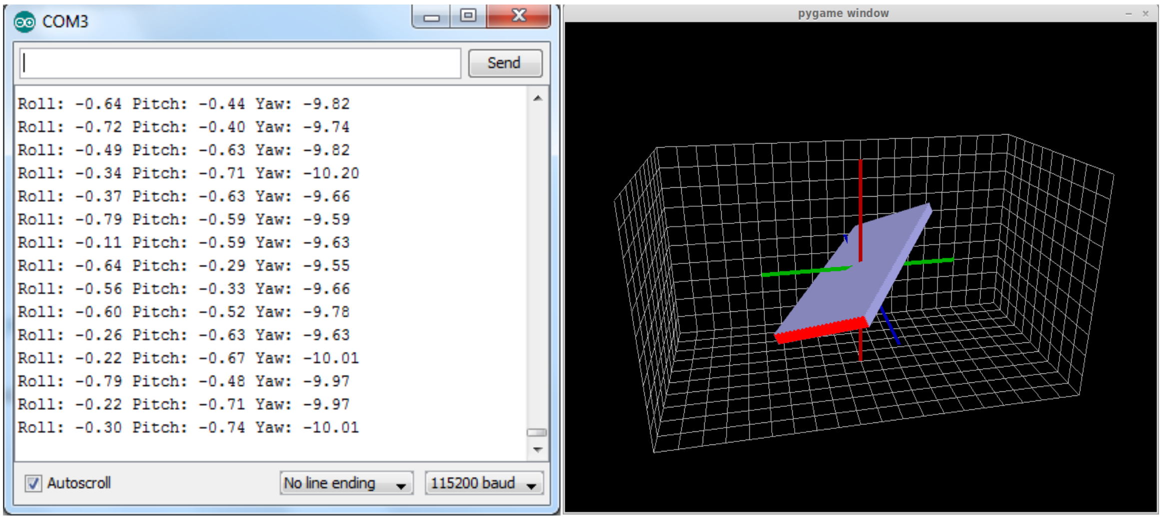


Figure 18: Output Seen for MPU6050 Gyroscope



The device can be placed anywhere in the world and any satellite can be tracked from anywhere. Furthermore, our system is portable and less power hungry, making it ideal for establishing emergency satellite communications in remote areas and after natural disasters. It can be used for military purposes in providing fast and mobile satellite communications, at a fraction of the cost of present devices. In consumer use, our device can also be used for live telecasting for the TV channels. It can also be used to provide quick and affordable satellite communications for moving vehicles such as on trains and water vessels.
This device is affordable and easy to use, and definitely much cheaper than that available in the market.

4 Conclusion

In this paper, Automatic Antenna Management system and Satellite Tracking has been studied. The proposed device can be used to track and communicate with any satellite from anywhere in the world. It can be used for live telecast and military communications. Furthermore, as the device is relatively small and mobile, it can be used in emergency disaster communications and is fully automated. It costs comparatively much less than any other devices in commercial use today. Finally, the proposed device can be used as a mobile ground station for satellite communications and as it is fully automated, does not need high skilled engineers to operate. While developing this prototype, we came across various issues and limitations that we faced. First issue is that the EMAOS has less powerful motors, which is not capable of adjusting the heavy antenna module used for commercial or industrial use. The second limitation we came across is that the device has no central UI or stand-alone program. The Servo motors we used have angular error of around 2 degree and it is not completely stable as the vibration effects the smoother operation of the device. Lastly, the EMAOS module is not designed and built flawlessly to support the heavy antenna for commercial or industrial use. Despite the limitations, all other functions of the device were tested and worked perfectly. Our device can be used for military purposes in providing fast and mobile satellite communications, at a fraction of the cost of present devices. We believe our design could significantly be useful for the field of satellite communications in Bangladesh and maybe even lower the cost of satellite communications in the world.

5 Further Research Prospect

The technology and design is still yet to be applied in the commercial market today as the applications or uses are still not present. A further research in developing military grade encryption can be done to enhance the device for secured military communications. In consumer use, our device can also be used for live telecasting for the TV channels. Therefore, additional research in minimizing the response time and the mechanical movement can be conducted. Also, research in making the device perfectly stable can be conducted. Furthermore, implementing a smart antenna design with real time signal strength measurement can effectively make this design more future proof and efficient.

References:

Arthur R. Tllford, James D. Allen & David J. Kuether. "Portable Satellite Earth Station". *United States Patent,* Patent Number: 5,915,020; Jun. 22, 1999.

David W. Longhurst, Martin A. Weston. "Satellite Tracking Dish Antenna". *United States Patent*, Patent Number: 4,126,865; Nov. 21, 1978.

Erwin C. Hudson, Remberto L. Martin. "Method and Device for Accurately Pointing Satellite Earth Station Antenna"; *United States Patent*, Patent N0.: US 7,289,062 B2; Oct. 30, 2007.

Festo Didactic. "Telecommunications Satellite Communications: Satellite Orbits, Coverage, and Antenna Alignment". First edition, 2015. INSB 978-2-89604-473-5

Fredric C. Anderson, Paul Gaske, Nicholas Moldovan, Peter L. Gardner, Chang S. Kim; "Earth Station Antenna System". *United States Patent*, Patent Number: 5,657,031; Aug. 12, 1997.

James_A. Benjamin, Pavld A. Haessig, Peter Lindsay. "Two-Axis Satellite Antenna Mounting and Tracking Assembly". *United States Patent*, Patent Number: 5,999,139; Dec. 7, 1999.

James June-Ming Wang, Paul K. Sun, Russell Geoffrey Santora. "Easy Set-Up Low Profile, Vehicle Mounted, In-Motion Tracking, Satellite Antenna", *United States Patent*, US Patent No. 6,657,589 B2; Dec.2, 2003.

Jason Ragland, Andrew Martino, Sander Middour & Shashwat Kandadai. "Amateur Radio Satellite Ground Station". *Senior Design Project*, University of California, March 19, 2013.

John E. Wilson, "Vehicle Mounted Satellite Antenna System", United States Patent, US Patent No. 4,663,633; May 5, 1987.

Junsung Cho, Vinh Pham, Suresh Subasinghe. "Amateur Satellite Tracking Communication System". *Senior Design Project*, University of Utah, Dec. 17, 2004.

Mltchell C. Radov. "Satellite Earth Station". *United States Patent*, Patent Number: 4,710,778; Dec. 1, 1987.

William H. McGuire, Thomas J. Tilden, "Satellite Tracking Antenna System", United States Patent, US Patent No. 4,920,350; Apr. 24, 1990.

William J. Sherwood, David W. Wagner, "Deployable Satellite Antenna for Use on Vehicles", United States Patent, US Patent No. 5,554,998; Sep. 10, 1996.