

## Automation And Signal Processing Of A Radio Telescope

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**ABSTRACT:** The radio telescopes used for radio astronomy are very huge and are manually controlled to detect and capture the radio waves of an extra-terrestrial object. This becomes a tedious task, to manually set them on that particular object and keep it focused on it until we receive and process the signals we need. In this, we have made an amateur radio telescope equipped with RTL-SDR and done this automation of telescope computerized which will minimize the errors and also the manual efforts. Further, we used RTL-SDR for the detection reception of the 21cm hydrogen line and reception of signals from the Outer arm, Perseus arm, Sagittarius arm. The processing of these signals is done in RTL-SDR software.

**KEYWORDS:** RTL-SDR, 21cm Hydrogen line, Outer arm, Perseus arm, Sagittarius arm, Amateur radio telescope, Hour angle, LST

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### I. INTRODUCTION

This can be linked in 3 different parts. First one is the automation of the telescope. The dish is rotated through the Arduino board and with the help of the computer is made to focus the particular extra-terrestrial object. The computer has an inbuilt software which tells the Arduino where to focus and then Arduino taking multiple things under consideration before it commands to move the dish.

The second one is the communication link that is established between the remote telescope and the computer installed at a different place via Bluetooth. This is done because this isn't always possible to mount the telescope at a place which always sufficient with the required resources. Hence communication between the computer and telescope.

And, the last one is the signal processing domain which can be considered as having equivalent importance as of the automation domain. Using RTL-SDR the 21cm hydrogen line is able to be observed and studied. It has multiple arms like the Outer arm, Perseus arm, Sagittarius arm. This 21cm hydrogen line or H I line refers to the electromagnetic radiation spectral line which is created by the changes in the energy states of neutral hydrogen atoms. They have the precise frequency of 1420405751.7667 Hz, equivalent to the vacuum wavelength of 21.206114 cm in free space.

### II. SYSTEM DESIGN

#### 2.1 The Automation Domain

The standalone system designed is based on the Arduino Due board, a computer having Stellarium[1] software installed in it and two stepper motors connected through the motor drivers, driven by the Arduino board. Stellarium is a software which provides real-time coordinates of all the extra-terrestrial objects in real time. These coordinates are in the celestial coordinate system which needs to be converted to the Local Sidereal Time (LST) through some calculations which are done in Arduino board.

##### 2.1.1 Eminent features of Automation:

- i. 1. Calculates the Local Sidereal Time (LST) and Hour Angle (HA) of an object and points the telescope
- ii. 2. Hemisphere independent - works on both sides of the globe
- iii. 3. Auto Tracking, Auto Meridian Flip, Auto Stop when object below the horizon
- iv. 4. Bluetooth connection with "Stellarium"
- v. 5. Joystick For multi-speed manual control

##### 2.1.2 Hardware Components Used:

1. Arduino DUE
2. Neo 6M GPS Module

3. HC-05 Bluetooth Module
4. RTC Module (Real-time clock)
5. DHT-22 Temperature Sensor
6. 2 Bi-polar Nema 17 Stepper Motor
7. DRV8825 (Motor driving IC)
8. TFT Screen(Touch and SD card Equipped)
9. PS2 Joystick Module

## 2.1 BLOCK DIAGRAM:

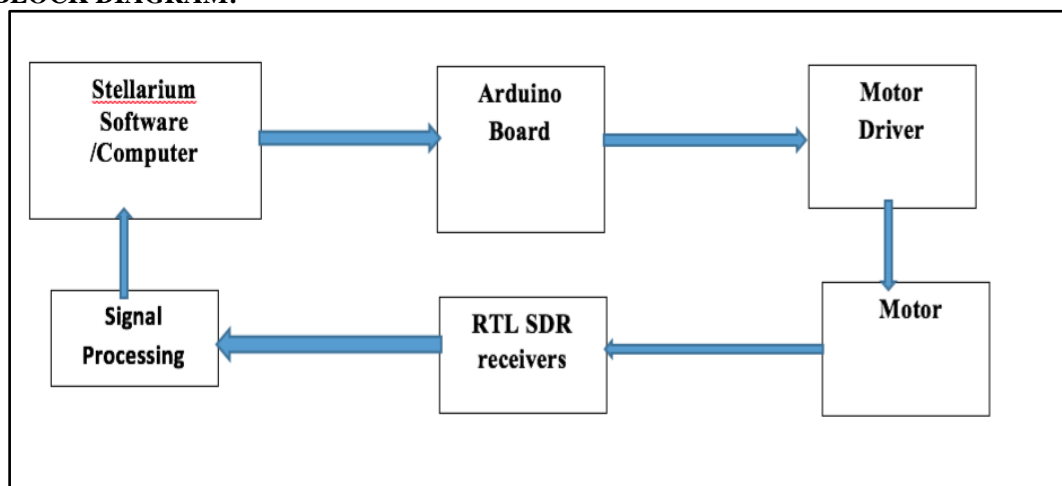


Figure 2.1Block Diagram

### 2.1.3 Sequence of operation:

First of all, the GPS installed in the system will catch the real-time Latitude and Longitude and provide it to Arduino. Then, Arduino system calculates the coordinates. Those coordinates come from Stellarium pushed via Bluetooth or wired connection. The main Process starts with:

1.selectObject\_M() – function to extract the data from Stellarium and cast it to global variables stated in the code,

2. calculateLST\_HA() – function to measures the current LST and Hour Angle (HA), depending on the picked OBJECT\_RA, which later on gives the data to

3.considerSlewTo() – considerSlewTo() – function actually includes the number of steps each turn needs to do (acknowledging that the telescope was polar straightened in the start).

The code measures the micro steps based on the following premise. for HA and DEC drives – particularly the HA shaft moves 180 degrees, outlining  $0:00h < HA \text{ value} < 12:00h$  and  $12:00 < HA \text{ Value} < 24:00h$ . In the very time the DEC axis is moved Left or Right of the Polar star (90 degrees) depending on the rates of HA (e.g.  $12:00h < \dots \text{or} \dots > 12:00h$ ).

## 2.2 The Signal Processing Domain:

For signal processing, RTL-SDR is used. RTL-SDR is Register Transfer Level Software Defined Radio.

It is a radio communication system where components are implemented by software on a PC or embedded system. A fundamental SDR system may consist of a personal computer outfitted with a sound card, or another

Analog-to-Digital converter, introduced by some form of RF front end.

In the digital circuit, RTL is a design concept which shows a synchronized digital circuit in terms of the flow of data among hardware registers, and the logical procedures done on those signals. The frequency range of RTL SDR is 52-2200 MHz

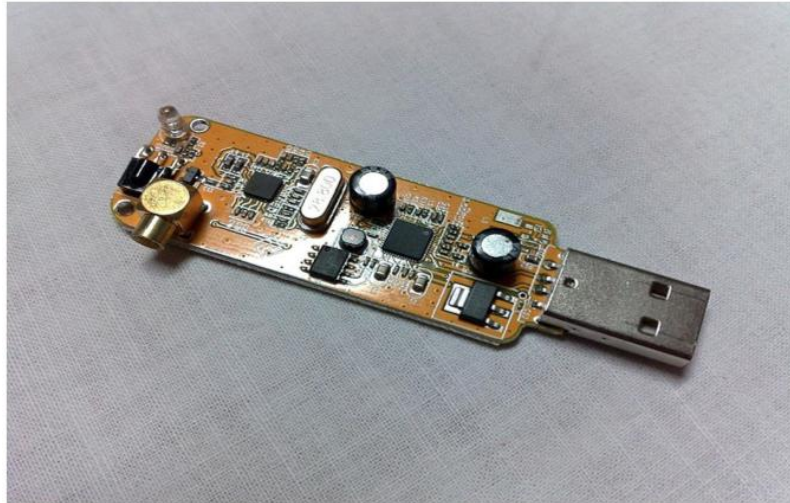


Figure 2.2 RTL-SDR

We use the RTL-SDR as the receiving radio with an LNA (low noise amplifier) and a couple of line amps, a 93cm x 85cm DTH satellite dish. Interstellar space is ample of hydrogen, which rarely emits at photon having a wavelength of 21cm hydrogen line i.e. 1.4204Ghz. Setting up a small dish antenna, and point at a fixed declination in the sky, as that part of the sky moves through your beam, you can see the change in the spectral signature as different regions, with different Doppler velocities move through your beam. Here we tried to observe the Hydrogen line of our milky way in Perseus arm, Sagittarius arm, And Outer Arm. Hydrogen gas naturally emits low energy radio waves, which we can detect back here on earth. If we aim a radio telescope into the plane in our galaxy, we collect radio waves from various hydrogen gas clouds which lie along ourline of sight.

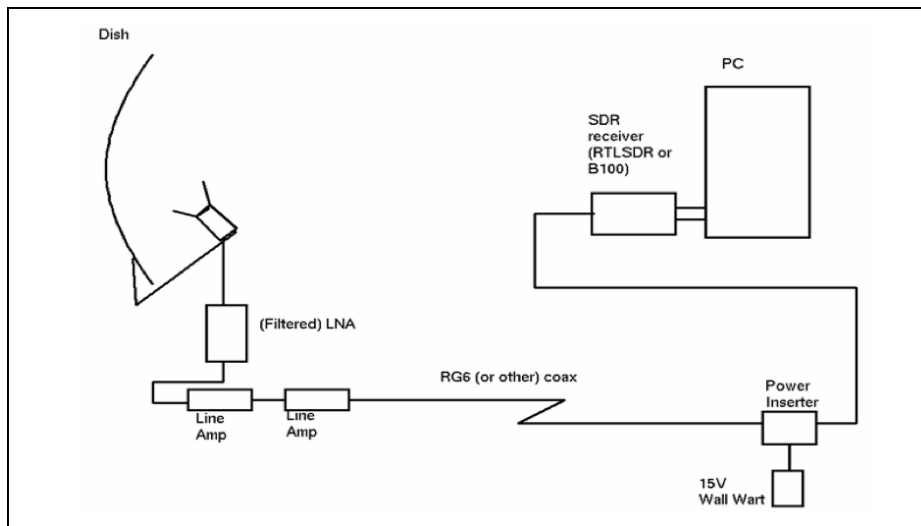


Figure 2.2 The Setup

### III. CALCULATIONS

For automation following are the key calculations which are important for the precise pointing of the telescope.

#### 3.1 Calculations for Redactor(Gears):

1.	86164.0905	sidereal day in seconds
2.	1296000	arcsec(for full earth rotation )
3.	144	RA/DEC Number of gear teeth
4.	4	Gearing belt ratio (4=1:4, 3=1:3)
5.	200	motor steps

6.	16	micro stepping modes

(RA/DEC:right ascension and declination ,)

**3.2 For micro stepping:**

1.	mSteps for 360*	21.39174
2.	1843200	0.70312500 arc sec./mStep i.e. 15.0410 arc sec./sec. when the earth turns
3.	Interruptions	46,747 micro-sec. i.e. 21.39174 mSteps/sec.

(msteps: micro steps)

**3.3 For Arduino code:**

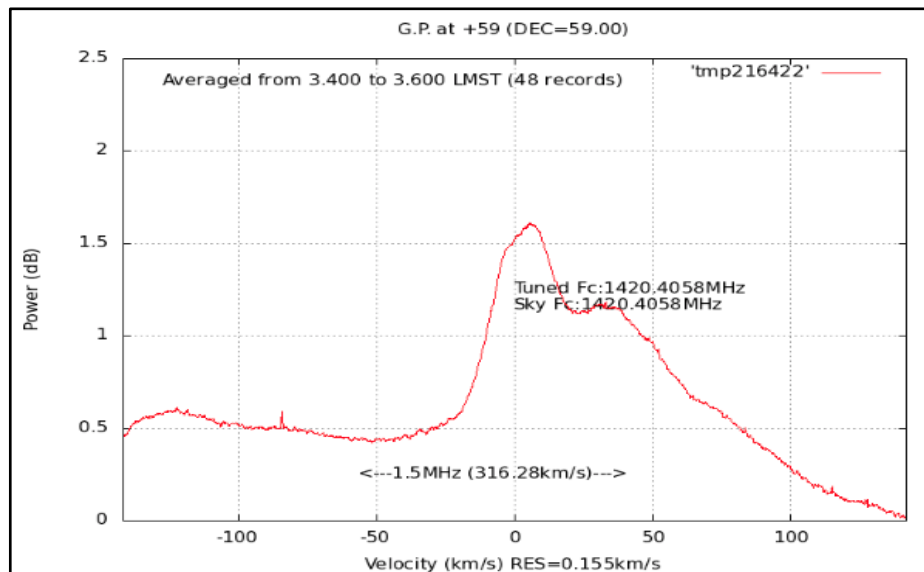
1.	Micro_Steps360	1843200
2.	RA_90	460800
3.	DEC_90	460800
4.	ARCsec_mSteps	0.703125
5.	HA_H_CONST	76800
6.	HA_M_CONST	85.3333
7.	DEC_D_CONST	5120
8.	DEC_M_CONST	85.33333

(RA\_90:How much in mSteps the RA motor have to turn in order to make 6h = 90 degrees ,DEC\_90:How mich in microSteps the DEC motor have to turn in order to make 6h = 90 degrees, ARCsec\_mSteps: ArcSeconds in a Full earth rotation in micro steps,HA: Hour Angle)

**IV. SIMULATION**

Hydrogen gas naturally emits low energy radio waves, which we can detect back here on earth. If we aim a radio telescope into the plane in our galaxy, we collect radio waves from various hydrogen gas clouds which lie along our line of sight which is normally near the frequency of 1420.4 MHz .

But the waves from gas clouds moving away from us are stretched out and are thus t a slightly lower frequency and the opposite is true for the waves from gas which is moving towards us. This can be explained by the following diagram. Thus we get to know that how fast the gas is moving in the direction we are looking.



**Figure 4.1:Detection of the peak of Received Signal**

We can plot these gas concentration along the line of sight we used in the galaxy. If we repeat this process over and over again along a slightly different line of sight into the galaxy disk, we can start to plot where the gas is concentrated in multiple areas and thus begin to map out the shape of the galaxy.

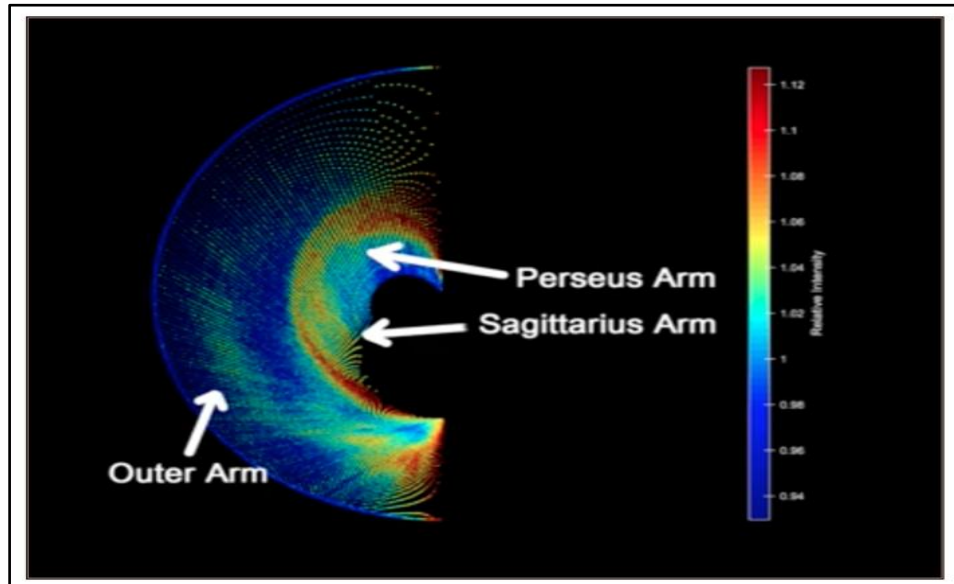


Figure 4.2 Arms of Milky Way Galaxy

## V. CONCLUSION

For our research, we learned about the construction and operation of the RTL-SDR Amateur radio telescope. Using this telescope, we observed the Hydrogen 21-cm line across the galactic plane. Our various readings gave the idea about the area of concentration of hydrogen gasses and arms of our galaxy. Despite the presence of interference, in radio reception, the use of an amateur radio telescope is a useful tool for radio astronomy for armatures.

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