Poratable Radio Telescope

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Abstract:

A method to design a low cost portable radio telescope has been shown, This will help students interested in Radio astronomy to make a telescope of there own and use to do small experiment on radio astronomy. This can be used to observe sun and satellites, as it operates in 12 GHz to 18 GHz. Though the system is not very precise, but things can be improved by doing away with low cost.

1. Introduction:

We all might have seen small optical telescope, but whenever it comes to radio, we never see any small version of it. Due to this many students don't get a chance of using a radio telescope. So here a method has been shown to design a portable radio telescope. The main idea here is to make it as cheap as possible, and use the items, which are available easily in the market. This will help to spur more interest towards radio astronomy. The telescope cost less than Rs1000 and can be designed very easily. It operates in the KU band i.e. 12 GHz to 18 Ghz. The system has no problem detecting the difference between 3K cold sky, the Sun, warm bricks or a person's body.

This will enable many students to make a radio telescope of their own and use it for experiments. This telescope can also be used in schools and colleges to do small experiments.

2. Items required:

- 1 - Satellite dish with LNB and mounts (available with the dish pack)
- 1-Set Top Box (or a DC power supply of 12V with a RF choke, see appendix 1)
- 1- Satellite finder.
- 1-Stand for mounting.
- Coaxial cable
- 4-Type F connector
- 1-Voltmeter
- Computer with radio sky pipe software (This is optional, and only needed if you want to do regular observation)

3. Procedure:

3.1 Assembling the dish:

The satellite dish comes with following equipments, and should be assembled, as shown

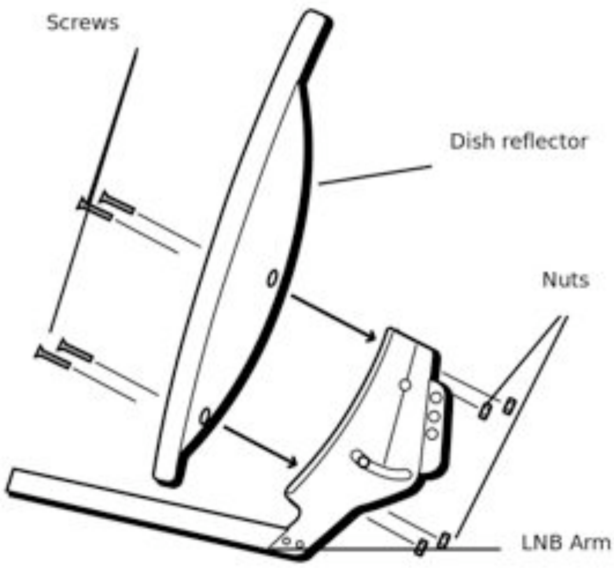


Fig 1

3.2 Making Connections

- Cut the coaxial cable into two pieces
- Fix the Type F connector at the ends
- Connect a coaxial cable (RG6) from LNB to the "LNB in " at satellite finder
- And connect another between the satellite finder and to "LNB In" at STB (or refer to appendix 1 for using a simple 12V DC supply instead of the STB)

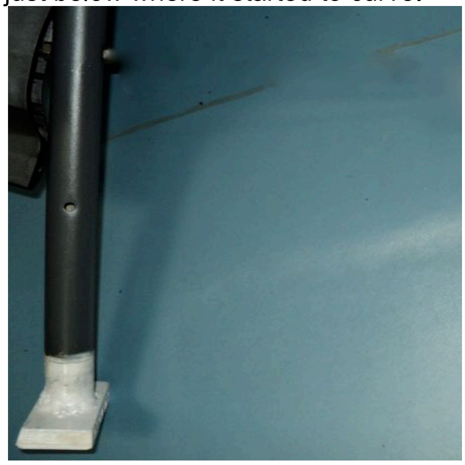
- Open the back cover of the satellite finder and then connect the galvanometer output to the voltmeter or to the mic in of the computer (for observation using skypipe, refer Appendix 2)

3.3 Mounting the dish

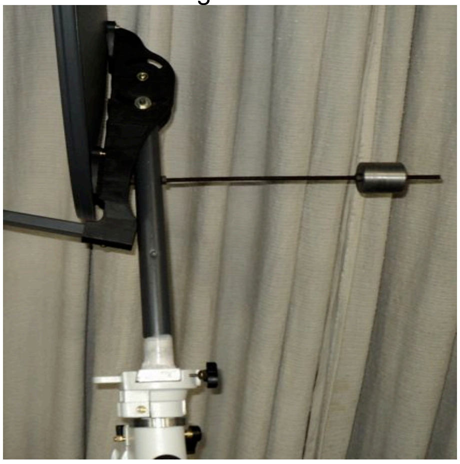
3.3.1 Equatorial Mount

Here we have used a standard eq3 mount for mounting our dish. The dish can be mounted to the eq3 mount by following ways:

- The mast was cut off just below where it started to curve.

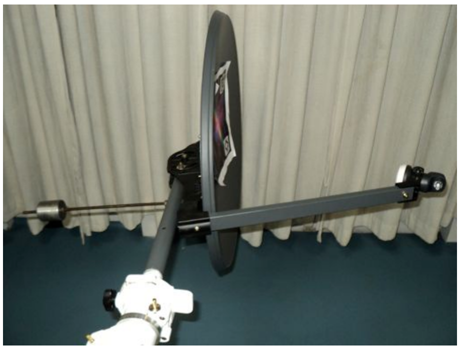


- One end of the mast was welded to a short piece of iron, which was used to connect it to the mount.
- A threaded rod was inserted towards the other end, which is used to put counterweight for Declination balancing



- The other end of the mast was connected to the dish using the supplied stand, and the welded end to the mount.

- The telescope should be balanced in RA



  and Dec by adjusting the counter weight.

3.3.2 Alt-Azimuth Mount
You may also use a simple alt azimuth mount as described below:
1. You have to design a rotating plate.
2. Cut the mast where is starts bending.
3. Fix the cut end of the mast to the rotating plate.

4. Experiments:

4.1 Standardization of Telescope

The telescope readings need to be standardized so that we can get a measure of the power we are receiving from different objects. We can do this comparing this with some known standard radio source.

We know power radiated from different satellites, and this can be used to standardizing. The EIRP (en.wikipedia.org/.../Equivalent_isotropically_radiated_power) of the satellites are known from the footprint map (available at *www.lyngsat-maps.com*) and this can be used to calculate the power per unit area coming from satellite to us. For doing this:

1. Fix the knob of the satellite finder at a given position, so that the pointer is around 3 when pointed to cold sky.
2. Then disconnect the cable between LNB and Satellite finder, and note the reading of the voltmeter, let it be x
3. Now connect the cable between LNB and Satellite finder, and point your satellite to some known satellite operating in Ku band and note the voltage, let it be y. For pointing the satellite you can find their position (alt and azimuth) from the table 1 or from websites like http://www.dishpointer.com/

These readings are used to standardized the telescope, as shown below

For the satellite NSS-6

Distance- 36652000m
EIRP at Pune-55.1 dBW
from website http://www.lyngsat-maps.com/maps/images/nss6_india.gif

We know dBW = 10 log (Power output /1W)
So power = antilog (55.1/10) = 323593.6569 W
Power per unit area received here= Power/4∏R^2
(where R=36652000-Radius of earth=36652000-6378137)
So power received per unit area (P)= 2.80975E-11 W/m^2
So for standardizing power per volt (sf)= P/(y-x)
So when you point at any source and get the voltage as some 'a' volts, you can get the power coming from the source=sf*(a-x)

For example, we did the standardization as follows:

The voltmeter reading with no antenna was 95.6 mV (x=95.6mV)

Satellite	Azimuth	Altitude	EIRP	Distance	Power radiated	Power received per unit area	Measured Voltage	Sf (W/Vm^2)
			dBW	m	W	W/m^2	mV	
NSS 6	130.3	57.5	55.1	36652000	323593.6569	2.80975E-11	237.5	1.98009E-10
Intelsat 12	240.8	50.7	52.3	37041000	169824.3652	1.4374E-11	165.2	2.06523E-10

So for this telescope the standardization factor (Sf)=Mean of the calculated sf

=2.02266E-10W/V

* *You should be careful to choose those satellites, which are alone at a position. If there are more than one satellite in the same position and both of Ku band, then you will get wrong standardization. Like INSAT 3A, 4B.Also the EIRP and Alt, Azimuth of the satellite is dependent on your location.*

Various experiments can be done with this telescope. For getting proper reading you should first point your satellite to cold sky* and fix the knob of satellite finder at fixed position(preferably between 2 to 4) and while doing any experiment you should not change it. The readings can be taken in 3 ways.

1.Satellite finder

The satellite finder gives the deflection, which is proportional to the power received. So the knob can be adjusted and accordingly the deflection varies. (Generally it is better to keep the knob at such a position, so that the source maximum power should cause the full deflection)

2.Multimeter

The multimeter can be used to record the voltage, which is proportional to the power received. It should be adjusted to DC voltage.

3.Computer

This can be done by using software like "radio sky pipe".
http://www.radiosky.com/skypipeishere.html (*Appendix 2*)

4.1.1 Other methods for Standardization

Using a signal generator, which has a known power output and operates in frequency band of 12-18Ghz, the telescope can be standardized.

1. Connect the signal generator to the LNB input of Satellite finder using F-connector.
2. Set the type of wave in signal generator to be sin or cos.
3. Then take few readings of voltage output of satellite finder for various frequency and then plot Voltage output vs frequency of input signal and use this graph for standardizing the system.

The problems with this method are :

1. Getting a signal generator working in this frequency range is difficult.
2. Again one has to consider antenna gain and LNB gain for this process.

A second method, which was told to me by Prof Govind Swarup is as follows

4.1.2 Calibration of the Microwave Solar Radio Telescope using radiation by a Black Body

The value of the measured flux density of the Quit Sun in the 11-12 GHz band by the Sagamore Observatory in USA was about S = 325 SFU on August 1, 2010 .It is a standard practice in radio astronomy and radio engineering (Kraus 1966) to convert the incident power received, p, by a radio telescope to an equivalent 'antenna temperature", Ta, equal to the temperature value of a resistor at the input of its amplifier (equal to its input impedance) that would give the applied input power, p:

$$p = \frac{1}{2} S\ Aeff\ \ BWrec\ = k\ Ta\ BWrec,$$

Where k is Boltzmaan's constant = 1.38 x 10^-23 (W/K), Aeff is the effective area of the parabolic dish of the satellite antenna of diameter D = 50 cm, with estimated efficiency, Eeff of the dish + horn of about 0.5, giving

$$Aeff = Eeff \times \Pi D^2 /4 = 0.5 \times 3.142 \times 0.25 /4 = 0.098 \sim 0.1\ m^2.$$

Therefore, we have

$$Ta\ (K) = S\ Aeff / 2k$$

$$= 325 \times 10^{-22} \times 0.1/ 2.76 \times 10^{-23} = 118\ K.$$

We can adopt the following calibration procedure (also see Maeda, Attachment 2):

1. We first point the Satellite Dish towards the sky. At 12 GHz, the brightness temperature of the sky is about 3 K, of which 2.73 K is that of the microwave background. However, the horn before the LNA of the LNB is likely to have some response not only towards the dish but some spillover radiation, say ~ 10% towards the ground. We may take the temperature of the ground as 300 K = (273 K + 27^0 C). Thus, the input temperature = 300K. Including the noise temperature of ~ 50K of the LNA of the LNB block (can be found from the manufacture of the LNB) , we find that the input temperature of the signal at the input of the LNA = (3 + 30 + 50 = 85 K. For step 1, we then note the voltage output, V1 (mv) of the Satellite Finder for the input temperature, "Tsky" of 85 K. It is assumed that the ground acts as a Black Body, though its absorption would depend upon the loss tangent of the soil (depending on dry or wet soil). I am of the view that ground acts as 250 K. It needs both theoretical and experimental verification. Thus, I consider that the assumed value of Tsky may have an error of ~ 10 to 15 %.

2. Next we point the dish towards a wall of a building or a room or towards the ground, whose temperature can be assumed as 300 K (or 250K) giving an output V2 (mV). Using the two measurements, as per step 1 and 2, we can also estimate the non-linearity of the detector of the satellite finder. The nonlinearity can also be measured using a one GHz signal generator applied at the input of the Satellite Finder.

3. Finally, the dish is pointed towards the Sun and voltage output, V3 (mv), is noted. By interpolation, the value of Ta of the Sun at 12 GHz can be obtained from:

$$S = 2\ k\ Ta/\ A\ eff$$

Brightness Temperature of the Solar Disk: We may also derive the equivalent brightness temperature of the Solar Disk at 12 GHz based on the measured value of 325 SFU on August 1, 2010. For extended celestial sources, it is usual to describe the effective brightness temperature assuming that these radiate as a black body (Kraus 1966). Hence the expected brightness temperature, Tb, of the Sun is given by the Rayleigh Jeans law as,

$$S = (2\ k\ Tb / \lambda^2) \times \Omega_{s,}$$

Where k is the Boltzmann's constant = 1.38 x 10 $^{-23}$ W/Hz/K, λ (m) is the wavelength of the receiver and Ω_s is the solid angle of the Sun in units of steradian. We know that the diameter of the Sun is about 32 arc minute and varies only by a few percent during the year as earth goes around the Sun. Hence,

$\Omega_s = \Pi D^2/4$, where D is the diameter of the Sun in radians = Π (32/60) / 180,

= 6.8 x 10^{-5} steradian.

From the above equation, we calculate the expected brightness temperature, Tb, of the Sun to be about 10,000 degree Kelvin. We know that the temperature of the solar disk is about 6000K. Hence, we note that a further contribution of 4000K is due to the chromosphere above the solar disk. At 12 GHz the contribution to the quiet Sun by solar corona would be relatively smaller.

4.2 Detailed Experimental Procedure for Solar Observation

1. Standardize the telescope.
2. Move the dish slowly towards the sun
3. Note down the voltmeter reading.
4. Now move the dish away from the sun slowly.

You will see increase in the signal strength as you move your dish towards the Sun, and signal strength falls down as you move your dish away from the Sun.

Use the normalization to calculate the power received from Sun.

You can also point your telescope to ground and check the reading is more than that of Sun. This is due to the fact that Sun's angular diameter is .5 degree, while the dish is of 3 degree.

4.2.1 Detecting Solar Flare:

This is a sophisticated experiment and you need a computer and motor driven mount which can track the Sun

1. Standardize the telescope and use the motor driven mount to track the Sun.
2. Use the skypipe software or a digital voltmeter which value can be recorded in a computer.
3. When there is a solar burst you see a rise in the voltage.

4.3 Detecting geo-stationary satellite

The geo-stationary satellite can be detected with this telescope. There are a number of geo-stationary, orbiting earth. Most of these satellites are in the Clarke belt. For their detail position http://www.dishpointer.com/ or many other sites. Most of these satellites orbit above the equator so figure out where your celestial equator is by taking your latitude and subtracting it from 90°. This is rough altitude to look for satellites.

Much of this we would consider radio noise or radio pollution. Doing this activity may help you explain radio noise pollution better and it is always exciting for students to find a satellite they can't see.

4.4 Playing Music

Our body has a temperature of around 300 K, and so it emits radio waves and this telescope can also be used to create music if you wave your hand in front of the LNB, or stand in front of the telescope. You will see that as you move closer, the voltage increases.

4.5 Polarization of satellites

Satellites generally sends polarized signals while Sun emits un-polarized waves. This can be checked using the telescope.

1. Point the telescope at any Ku band Satellite (or Sun) and then note the voltage output
2. Now rotate the LNB and see if the voltage reading changes and note where it gives the maximum voltage.

If the source is polarized then the reading will change as you rotate the LNB, and for un-polarized the reading will not change to a great extent. For example when I tried this with NSS-6, then the reading varied from 201.5 mV to 237.5 mV. While standardization you should keep the LNB so that it shows the maximum reading.

Appendix 1:Power Supply instead of the Set Top Box

Instead of using the receiver to connect the cable coming from the LNB, a simple power supply of 12volt can also do the job. For this the following procedure should be followed:

12 volts of DC is required to operate the satellite finder. Eight AA will provide the power through a battery holder with a connector.

1. Cut off the end of the coaxial cable.

2. Strip off about 2" of the black covering. Be careful not the cut through the silver wire shielding. Comb and pigtail the silver wire braid shielding. Remove the foil shield, exposing the white insulation. Be careful not to score the white insulation. Cut off about 1" of the white insulation, exposing the copper wire.

3. Connect the silver braid shielding of the coax cable to the black, or ground wire of the power supply. Connect the center wire of the coax cable to the positive of the power supply, through a RF choke in series.

Appendix 2:Using Skypipe

1. Open the radio sky pipe software (if not installed)
2. Select 'Options' and in that 'Sound' then select the 'Device' which you are using
3. Select the Sound format, which you want from the "Choose Sound Format". It is better to keep it at 44.1Khz, 16-bit Mono.
   **But you can try with other setting also.*
4. Then go to 'Tools' and then 'Mixer (Input Sound Setting)' and then select 'Microphone'. Then click 'Ok'
5. Again go to 'Tools' and then 'Null Sound Background'. Then click 'Ok' for the 2 new windows which will open
6. Connect the voltmeter output to the mic in of the computer (*proper care should be taken for maintaining proper polarity, or else the software won't work properly*)
7. Now click on 'Start Chart'.

Reference:

1. www.dishpointer.com
2. www.lyngsat-maps.com
3. www.wikipedia.com
4. http://www.dishpointer.com/
5. Affordable Small Radio Telescope
6. Radio Astronomy by John D Kraus