Beam Pattern of a Radio Telescope

Aim

In this experiment you will have the opportunity to make total power scans across some bright radio sources with the 7-metre telescope. If the angular scale of the source is much smaller than the beam width then this effectively maps out the shape of the beam itself rather than the shape of the source.

Scanning with the 7-metre

First of all read the general introductory manual on use of the internet observatory. This can be found under the section Documents/Manual on the website.

Click on *Observe* and select *Total Power Scan.*

In this experiment we will use the 7-metre telescope to measure the total power received in a 5MHz band centred on the hydrogen line at 1420MHz.

Make sure you select the option labelled *Equatorial,* this will enable us to pick radio sources from the list of *Target Details* in the Equatorial Coordinates box just below.

Select the radio source Cassiopeia A. This is the remnant of a supernova explosion in our galaxy and is always visible above the horizon.

[You can check visibility by selecting the *Source Track* utility in the navigation bar, selecting the Equatorial coordinate button, clicking on the Cas A button, and selecting the appropriate date. Then click on Submit. You should then see a graph showing the elevation of Cas A above the horizon at Jodrell Bank during the day.]

Leave the next button checked as an Azimuth scan (you could try an elevation scan later).

Now select the number of degrees to offset by before the telescope starts scanning, + or -5 is a reasonable starting value (think about the approximate size of the beam).

We also need to say how long we want the scan to take. In effect this sets the scan rate. So for example if we say the Integration Time is 300 seconds and we'd asked for a scan starting at -5 degrees then the whole scan will cover -5 to +5 degrees i.e. 10 degrees in total in 300 seconds, so the scan rate is 2 degrees per minute.

Now select the time slot in which you wish the observation to take place. These are every 10 minutes, so either pick the nearest next slot or one sometime in the future (try to avoid picking one in the past!). Remember to check the *Schedule* to avoid times when other observations are scheduled.

The time used when scheduling observations is Universal Time at Jodrell Bank – you can find out the current time from clicking the *Monitor* link in the navigation bar. You also need to say how many 10 minute slots you'll need. You are able to pick more than 1 to ensure a longer observation is completed.

Then click *Add to Queue*.

If all the details were correct, a screen will appear saying your observation has been added to the queue. However you must now actively submit it to the telescope for observation. Click on *Schedule*. Your observation should appear as status 0 with a red exclamation mark. If you are happy the details are correct you can click on *Submit*. If something was wrong you can delete it before submission.

The observation will now appear in the queue at status 1. If you manually refresh the queue you should see the status change to 2 once the telescope control computer has received the information. It is now just a matter of waiting until the observation takes place.

The observation

Watch the monitor and webcam when the time approaches for your observation. At the allotted time the monitor should show the telescope slewing towards the demanded coordinates.

When the telescope pointing error reaches zero the observation begins. After 5 minutes (assuming you set Integration Time to be 300 seconds) the Acquisition status will change to Done and after some Calibration the Scan is complete.

Sometime soon after the observation has completed (changing to status 4), the observation will automatically move from the *Schedule* to the *Archive*. You can then click on the *Data* link to see the results.

Measurements and analysis

Your results should reveal a scan showing the total radio power rising and falling as the source moves through the beam. If the source is unresolved i.e. a point source, then this effectively maps out the beamshape.

The plotting applet allows you to click on a point either side of the peak and subtract a sloping background - the colour of the curve changes from red to blue. You can then measure the full width of the beam at half the peak power - the half-power beamwidth (HPBW) in degrees - directly from this graph.

The expected HPBW (in radians) of a radio telescope is proportional to the ratio of the wavelength L and the diameter D of the telescope (when both are measured in the same units e.g. metres). The proportionality constant typically lies between 1 and 1.4 and its exact value depends on the aperture illumination for the particular telescope in use. Find the value of this proportionality constant from your two observations given that the frequency of observation is 1420.406 MHz and the telescope diameter is 6.4 metres.

The applet also plots the theoretical beam profile for a uniformly illuminated circular aperture of diameter 6.4 metres if the checkbox is selected. A real aperture tends not to be uniformly illuminated resulting in a slightly larger beamwidth and lower sidelobes. Of course if the actual source were extended then the profile would appear even broader. Compare your scans with the theoretical profile to assess whether this expectation is correct.

Other sources

Now try making scans across a few other sources. There is a list of individual point sources on the web page setting up observations – Cas A, Cyg A, Tau A, Her A, Vir A. Note some of these sources are much weaker than others.

You could also try making a scan across the plane of the Milky Way. Since the telescope scans either in azimuth or elevation it is best to see if you can pick a time when such a scan cuts nicely across the plane. You should probably make a scan from -10 to +10 degrees across a point with galactic latitude of zero degrees and any galactic longitude which is above the horizon at a reasonable elevation. You should see a scan which rises and falls due to the brighter hydrogen emission in the plane. This is followed up in more detail in the separate experiment to take spectra of the Milky Way.
