

Mt. Stony Brook Radio Observatory Operations Manual

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This document includes instructions on how to set up and operate the Stony Brook Michelson radio inteferometer, built by Prof. Jin Koda and described in Koda et al. (2013, in prep.).

1. Checklist

The necessary equipment for radio observations with the telescope and interferometer includes:

1. an altitude-azimuth mount, with a satellite dish attached; the mount resides on a four-wheeled push-cart;
2. a yellow ladder;
3. one pair of flat aluminum mirrors mounted at 90° to each other;
4. two individual flat aluminum mirrors on 45° mounts;
5. a sturdy chair, on which you can step;
6. power supply for the mount drive;
7. toolbox containing: a Phillips-head screwdriver, Allen tool, extra attenuators, a LabPro A/D converter, and connecting cables;
8. aluminum receiver box;
9. a laptop running Logger Pro;
10. 50ft extension cord and a power strip.
11. a listing of the Sun's altitude and azimuth coordinates at 5-min intervals throughout the day;
12. a listing of geostationary satellite alt-az coordinates, or an alt-az plot of their arc across the sky.

The first four items reside in the S-floor of the Physics building, in hallway next to the Van de Graaff generator. You can find a plastic chair in one of the Physics classrooms (make sure to return it afterwards). Items 6–10 reside on the fourth floor of the Earth and Space Sciences building, together with the 14-inch optical telescope equipment. The last two items should be looked up by the observer.

Note that to cart the telescope mount outside the Physics building, you will need to go through the freight elevator in the loading dock, at the eastern end of the S level of the building. You need the control pad for the elevator, which resides in the Machine Shop. If you are using the radio telescope on a weekend, be sure to make advance arrangements with the Machine Shop staff to leave the control pad somewhere accessible. The Machine Shop is be locked on weekends and outside regular business hours.

Also note that using the telescope in interferometer mode works best when there is a visible shadow on the ground, and when the wind is not too strong (<15 km/h).

2. Radio Telescope Assembly

You will need to take all of the equipment to your desired set-up location—usually on the south side of the Physics building, in the alley east of the main entrance. The following steps describe the assembly process.

- Cart the telescope and mount to your set-up location. You will need to take the freight elevator at the western end of the S-floor in Physics, and push the cart around parking lots and alleyways. The control pad for the freight elevator resides in the Machine Shop nearby. Ask to use it temporarily, and then return it.

Make sure to ease the elevator into stopping at the bottom. If you keep the button pushed until the elevator hits its bottom limit, it will get stuck, and you won't be able to move it. Instead, stop the elevator a little before it reaches bottom; the elevator will gradually come to a halt. If necessary, you can bring it a little lower with quick taps to the button.

- Bring the flat mirrors and ladder to the set-up location. The mirrors will fit in the regular Physics elevators.
- Assemble the interferometer. The ladder lies across the elevation panel of the mount, and is tightened down with the clamps and the Allen tool. The aluminum mirrors are placed either in the center of the ladder (the two-mirror piece) or near the ends of the ladder (the single-mirror pieces). Each mirror mount is also clamped down to the

ladder. Make sure that the two-mirror centerpiece is located directly behind the dish by checking the markings on the mount.

- Check that all flat mirrors are at 45° angles with respect to the ladder. If not, adjust them.
- If the dish is not oriented away from the two-mirror piece and toward the sky, orient it so now.
- Run the extension cord to the nearest outlet. When setting up in front of the Physics building, this will be either in the Physics lobby, or in the hallway toward Harriman. If using the outlet in the lobby, cover the cable with the area rugs to prevent tripping in this high-traffic area.
- Plug the mount drive into the power strip. The two knobs on the drive control box control the speed of the altitude and azimuth motors. The two toggles set each of the motors in motion, backward or forward.
- Connect the receiver to the power strip. Connect the co-axial cable of the receiver to the “LNB-in” outlet on the back of the telescope dish.
- Connect the LabPro A/D converter to the receiver (from the “A/D out” port on the converter to the “ch1” port on the receiver), to the laptop (with a USB cable), and to the power strip (with the adapter in the toolbox).
- Start up the computer. The login password is on the keyboard panel. Start the Logger Pro program - its icon is on the Desktop.

You have now completed the assembly. Before commencing observations, you will need to calibrate the pointing of the telescope in single-dish (§3 and then, inteferometer (§4) mode.

3. Pointing Calibration in Single-Dish Mode

If you will be using the interferometer, it helps to align the elevation plane such that it points toward the Sun. You can use the shadows cast by the assembly, and in particular the shadows of the loops on the ends of the ladder. One end of the ladder has thinner loops, and their shadows allow finer alignment.

- Begin by orienting the telescope assembly approximately North–South. The lines on the concrete slabs in front of Physics are to within a few degrees of N–S.

- Adjust the elevation of the telescope so that the plane on which the dish resides points toward the Sun, and the ladder is oriented perpendicularly to the solar direction. You can judge this by the shadows of the thin loops on the end of the ladder. When the loops overlap, you are pointed correctly.
- Point the radio dish toward the Sun. The dish is an off-axis paraboloid, so the fiber glass pole, which sticks out from its center, will not point toward the Sun. Instead, the dish will be pointed toward the Sun when the tip of the pole shadow falls onto the mark in the center of the white tape on the dish.

Now and only now do this by loosening the bolts along the arc on the back of the dish that hold it on the mount, and pivot it until the tip of the shadow and the mark align. If you have oriented the mount and ladder correctly, you should have to nudge the dish only in the up-down direction. Indications with a permanent marker on the arc should point to the approximate locations of the bolts that hold the dish.

- Tighten the bolts on the back of the dish, and fine-tune the pointing toward the Sun with the mount motors.
- Adjust the Lev-O-Gage on top of the dish so that its reading in degrees matches the elevation of the Sun at the moment, as found on your sheet with the Sun's alt-az coordinates. With the dish pointed toward the Sun, you will likely need to stop on the chair to reach the Lev-O-Gage.
- Adjust the azimuth ring at the bottom of the mount to the current azimuth of the Sun.
- Take a few scans across the Sun, in elevation and azimuth, to find the peak signal on the receiver. If you notice the needle on the receiver staying at consistently high values, you are likely saturating the receiver. To decrease its responsiveness, add or replace one of the attenuators inside the receiver with a stronger one. Adding 2–5 dB net attenuation usually does the trick.

Alternatively, the receiver may hardly be responding, in which case you will need to decrease the total attenuation.

The attenuators are housed inside the receiver box. Open the box if it is not open already - you may need to unscrew the four small screws that hold the top. Attenuators of different transmissivity are found in the toolbox. We have a 1, 2, 6, 10, and a 20 dB attenuators, and space within the attenuator box allows you place at most two in a series. Their attenuation adds linearly.

Experimentation suggests that 12 dB (10+2 dB) of total attenuation allow observations of both the Sun and a TV satellite without saturation on the satellite, and with sufficient dynamic range to record the fringe pattern of the Sun. In interferometer mode you may need to increase the total attenuation to 22 dB (20+2 dB).

Be careful when replacing the attenuators, as they are fragile.

You are now ready to take radio observations in single-dish mode (see §5.1).

4. Pointing Calibration in Interferometry Mode

To obtain interferometric observations, you will need to have first calibrated the telescope pointing in single-dish mode (§3).

- Make sure that you are pointing toward the Sun in single-dish mode.
- Pivot the dish around its axis, so that it now faces the two-mirror center piece. You will need to loosen the bolts that control the axial motion of the dish. Point the dish as closely as possible toward the middle of the two-mirror piece.
- If you were correctly pointed at the Sun or a TV satellite before the dish flip, you should be close to the peak of a fringe pattern with the interferometer. Move the mount up and down, and left and right to find the peak of the fringe. If the mount was properly aligned in the beginning (§3), the peak signal should be close to the orientation where the shadows of the loops on the ladder align.
- Check if the receiver has the correct attenuation. Experimentation suggests that 22 dB attenuation may allow observations of both the Sun and a TV satellite without saturation on the satellite, and with sufficient dynamic range to record the fringe pattern of the Sun. However, the actual measurements were done with 26 dB attenuation on the satellite and 16 dB attenuation on the Sun. You may have to adjust these between slews from the Sun to a TV satellite, and vice versa.
- Once you have secured sufficient dynamic range on the receiver with the proper set of attenuators, scan again for the peak of the fringe pattern.
- Adjust the Lev-O-Gage to the current elevation of the Sun. The azimuth ring should not need adjustment.
- Compare the signal from each of the side mirrors by removing them in turn, and checking the reading on the receiver. Adjust the distance of each mirror from the centerpiece so that the signal seen by the receiver is approximately equal.

Your interferometer is now calibrated for observations (see §5.2).

5. Simple Observations

The only celestial objects detectable with our radio telescope are the Sun and commercial TV satellites.

5.1. Single-Dish Mode

The Sun is barely resolved as a point source in single-dish mode at our observing wavelength (~ 3 cm) and dish size (1 m diameter). You can infer its size by comparing its angular profile to that of a satellite (a point source). The comparison will give the angular size the Sun, modulo a cosine of the elevation.

- Set the azimuth drive speed to moderately fast.
- You will scan the Sun from about $15\text{--}20^\circ$ on one side to $15\text{--}20^\circ$ on the other.
- Make sure to coordinate with the person recording the measurements on the laptop. You will need to agree on a beginning and a final reading of the azimuth. Start scanning with the drive before the beginning reading, and end after the final reading. As the drive passes over the pre-determined beginning and final azimuth values, communicate with the data recorder to commence acquiring data with Logger Pro, and to then stop.
- Data collection in Logger Pro can be done by selecting “Start Collection” from the “Experiment” menu, or by just pressing the green button on the top utility bar. Press the same button to stop collecting data.

Make sure that the “Data Collection” settings under the “Experiment” menu are appropriate. For example, during each scan you will need to collect data for at least 20–30 sec. You could also check the box for “Continuous Data Collection.”

- Once you have scanned the Sun in azimuth, point to the reference point source: the commercial TV satellite.

Note that these geostationary satellites are very closely spaced on the sky, about 1° apart or less. It may be best to choose a satellite in the part of the sky, where their locations are not aligned approximately along the azimuth direction. However, also be mindful of limitations due to the locations of nearby buildings, which very effectively reflect or scatter centimeter radiation.

- **Make sure that you perform the scans of the Sun and the satellite with the same speed setting on the azimuth drive.** Otherwise, you won't be able to infer the size of the Sun from your measurement.
- Also, keep track of the time of your Sun observations, as you will need the Sun's elevation during the observation to infer its true angular size. Similarly, record the elevation of the satellite that you are using for calibration.

5.2. Interferometry Mode

Collecting interferometric data follows the same principle as collecting single-dish data (§5.1): a scan of the Sun, followed by a scan of a TV satellite, while recording data on the laptop. However, in interferometry mode you can change the telescope baseline—the distance between the two side mirrors—and hence the resolution of the measurement. The Sun is very well resolved with all of our baselines. Because the fringes that you will detect in the interferometric observation have a higher spatial frequency, to sample them properly it is recommended that you decrease the speed on the azimuth drive motor by about a factor of two.

To obtain the most accurate estimate of the size of the Sun, measure it with at least 5–6 baselines, ranging from the shortest to the longest possible. The baseline is adjusted by loosening the clamps that hold the side mirrors onto the ladder, and sliding them closer together or farther apart. Record the readings on the ladder ruler at each setting on your radio telescope logsheet.

An efficient procedure would follow a Sun–Satellite–Satellite–Sun–Sun–Satellite... sequence, and changing the baseline between repeated observations of the same target. It may also be necessary to change attenuation between alternate observations of the Sun and the satellite.

Make sure to record the time and elevation of your observations, as you will need these to infer the true size of the Sun.

Note that it is possible that at one of the baseline settings the signal from the Sun will vanish, even if other baselines with the same telescope pointing produce fringe patterns on the Sun. The zero signal corresponds to the first null of the `sinc` function that characterizes the Sun in visibility–baseline space.

6. Telescope Disassembly

Reverse the steps taken to assemble the telescope. When carting the telescope mount back to its resting place in the hallway, be careful of the vertical dimension to avoid collisions with the tops of doorways. Lower the elevation drive to its minimum position. It may also be necessary to nod the dish lower by loosening the screws along the arc behind the dish.

7. Caveats

- Be mindful of scattering or reflection by objects near the line of sight of the telescope. Buildings can reflect very well at centimeter wavelengths, while naked tree branches are diffraction gratings!
- Human bodies emit radiation, and the telescope is sensitive to it at very close range. This is not an issue in single-dish mode, but in interferometer mode the entire field of regard of the assembly should be as empty of humans as possible. Only the telescope drive operator should crouch closely underneath the dish, and as much out of the direct beam path from the Sun or satellite to the flat mirrors.
- It may be difficult to find a single combination of attenuators for the interferometer that works both on the Sun and on the brighter commercial satellites. It may be necessary to switch attenuators in between alternate Sun–satellite observations.
- The commercial TV satellites are very closely spaced along a great circle on the sky, often by $<1^\circ$. When scanning in azimuth, make sure to find a satellite that is in a part of the great circle that contracts as large of an angle with the azimuth direction as is possible, without running into other limitations, such as buildings and trees.