Further Investigation of the *Karahi* Antenna for Galactic Hydrogen Measurement

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1 Abstract

This study aimed to evaluate the performance of the radio *karahi* antenna — an inexpensive, portable telescope design intended to be used for 21 cm hydrogen line detection. Building upon previous research conducted on such designs, the telescope was thoroughly tested through various observations to assess its long-term capabilities and review data analysis techniques used with it. Despite technical issues such as software stability and interfering digital artifacts, the radio *karahi* was able to conduct extended observations, and capture signals from prominent stars such as Vega. The ease of use of such a telescope makes it a valuable tool in promoting astronomy education and research in Pakistan.

2 Introduction

The purpose of this study was to further investigate the possible uses of the radio *karahi* antenna, whose design was first proposed at the Hong Kong University of Science and Technology (1), and then further improved upon at the AstroLAB (2).

The investigation was carried out in two ways. First, observations were conducted in short durations of time (20 minutes to an hour) to determine any software issues or inefficiencies. After such issues were resolved, observations were then conducted for extended periods of time (up to 24 hours) to determine the long-term capabilities of the *karahi* antenna.

3 Setup and methodology

The galactic dish system used for this study is the exact same model used in the original AstroLAB report (2). It consists of a *karahi* (a deep, circular cooking pot similar in shape to a wok), a dipole antenna, a pre-amplifier, and a software-defined radio (SDR) device enclosed in a metal container.

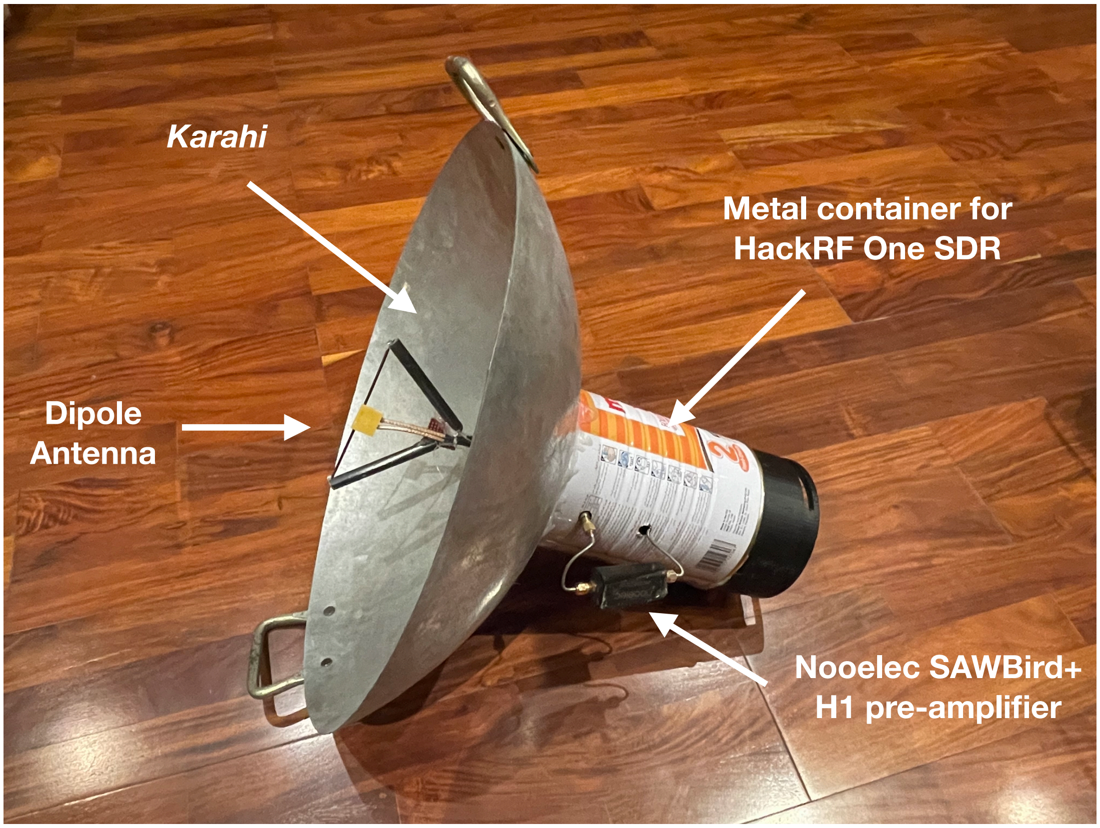


Figure 1: The setup of the galactic dish system (dubbed the *karahi*).

The *karahi* was used as it closely resembles a small dish reflector, and its focal point was calculated for the correct placement of the dipole antenna, which was constructed out of 2 mm copper wires and coaxial cables running in parallel. Any radio signals detected by the dipole antenna was directed towards the pre-amplifier, (Nooelec SAWBird+ H1) which would boost the signal (3). The signal would then be channelled towards the HackRF One SDR (4), which was used in conjunction with SDRSharp, a user-friendly software. The software was used to make the signal undergo Fast Fourier Transform (FFT) processing, after which multiple data samples underwent averaging and were finally displayed graphically with the help of the IF Average Plugin (a software extension for SDRSharp) (5).

Stellarium was also used during observations to ensure the galactic dish system was aimed correctly towards the object of interest (6). After an observation was conducted, the data was saved in text files, which were then extensively processed through the Galactic Neutral Hydrogen Plot Python script (available on the AstroLAB website) (7). The script worked to detect and remove noise spikes (either through the derivative method or the Savitzky-Golay SG method), after which it performed a baseline correction. The final output is a graphical representation of the data, along with an inset based on a ROI (range of interest) defined by the user.

All observations were conducted within Lahore's DHA Phase 5 (in the vicinity of the Lahore University of Management Sciences).

4 Observational results

4.1 Initial observations

The first ten observations were conducted over a period of three weeks, with each observation lasting around half an hour, or an hour at most. The focus of these observations was to identify and resolve any software-related issues. These included repeated software crashes due to save paths being unrecognized, especially upon invoking the option for saving multiple files. These observations also helped identify recurring digital artifacts (which often appeared at 1419.00 and 1420.00 MHz), as well as giving an idea of where to expect the signals of a star (roughly between 1420.50 and 1421.00 MHz). Most of the software-related issues were eventually resolved and their solutions were incorporated into the original AstroLAB report.

4.2 Nine-hour observation

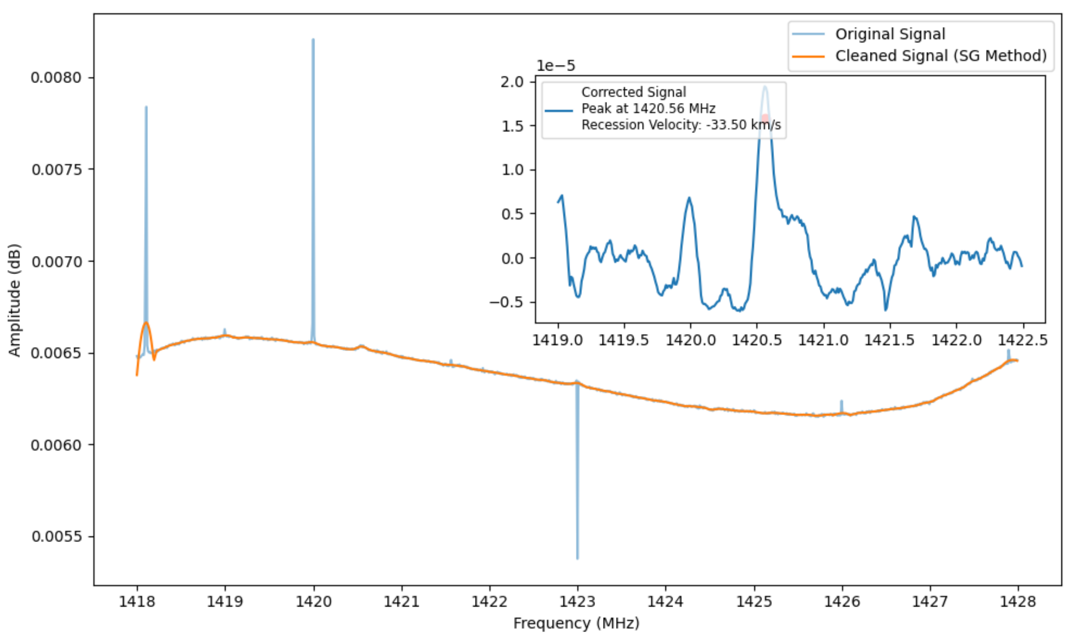


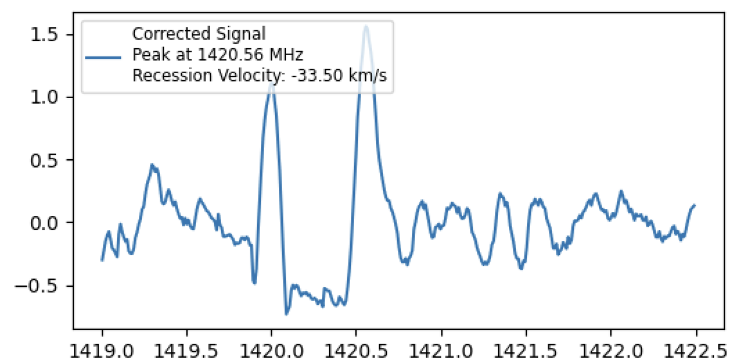
Figure 2: Graph of all data files from the August 12th session. The ROI Inset shows peak at 1420.56 MHz with a recession velocity of −33.50 km/s.

The eleventh session was conducted as a 9-hour fixed position observation, starting from 8:30 PM (12th August) and finishing at 5:30 AM (13th August). With the telescope pointing north, 50 data files were saved in intervals of 10 minutes (with $902,000$ dynamic averaging). After the observation, the Python script was set to the SG method for signal cleansing, and the plot in Figure 2 was produced.

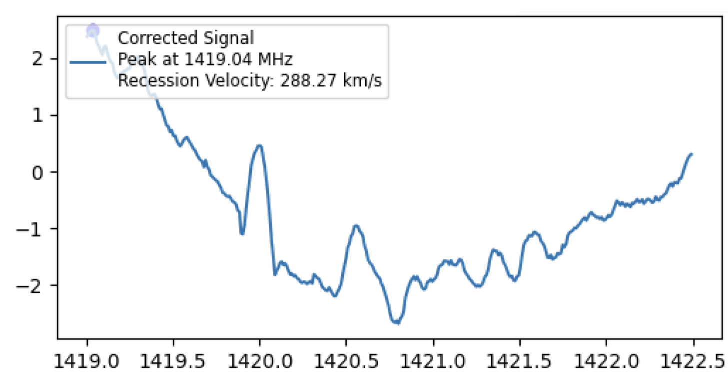
The peak was detected at 1420.56 MHz with a recession velocity of -33.50 km/s. Though many stars were within the range of the telescope, (including Sadr, Deneb and Caph), this result was mostly attributed to the star Vega. In general, Vega was found to be the most detectable star in all observations, due to its proximity to Earth (it being 25 light years away while others being in the range of thousands). This result was considered a success, and showed that the telescope was ready for yet longer observation session.

4.3 Twenty four-hour observations

The 24-hour observation sessions were conducted in a similar manner to the 9-hour observation; as a fixed-position observation. Due to the duration of such an observation, the weather forecast was regularly checked before observations were conducted. The setup was also closely monitored during such a lengthy observation run to ensure there were no software glitches.



(a) ROI Dark Plot (after sunset and before sunrise).



(b) ROI Day Plot (after sunrise and before sunset).

Figure 3: ROI plots of processed data from the August 31st/September 1st observation session.

After several attempts, an observation was conducted on 8:00 PM of 31st August, lasting till 8:00 PM of 1st September. All in all, 115 data files were saved in intervals of 12 minutes (keeping the dynamic averaging at $902,000$ as before).

Figure 3 shows the results for the 24-hour observation run (including night and day). The results of night are quite similar to that of the 9-hour observation, but the day plot shows the maximum value at 1419.04 MHz. Two prominent bumps are also noted in the graph. One is the digital artifact at $\approx$ 1420.00 MHz, and the second is the potential signal of the star(s) at $\approx$ 1420.50 MHz, but these signals are undermined during the day because of the effect of the ionosphere. Increased ionization in the ionosphere absorbs radio waves and hence diminishes the signal (refer to Chapter 4 of 'Radio and Radar Astronomy Projects for Beginners' for a detailed explanation of this phenomenon (8)).

5 Discussion and conclusion

The radio *karahi* telescope was developed in such a way that most users would be able to comfortably conduct astronomical observations by simply following the material on the AstroLAB website (7). However, users would benefit from having prior knowledge of Python to conduct and understand the data analysis from the observations.

Users will be able to use the telescope to detect the hydrogen signals of many stars in the night sky, but there are limitations. As seen in the observations conducted, stars in the range of thousands of light years did not give prominent signals in the data plots, and therefore cannot be easily detected by the radio *karahi*. Meanwhile the Sun (the closest star to Earth) is a powerful radio source, and it can overwhelm the radio *karahi*, as shown in the daytime plot of the twenty four-hour observation.

However, the use of the radio *karahi* is not limited to the detection of stars, as they could also be potentially used for the detection of neutral hydrogen in planets within the Solar System. The ideal candidate would be Jupiter; being a gas giant, it is known to be rich in hydrogen content. This would allow amateur astronomers to explore the compositions of planetary atmospheres with the radio *karahi*.

There are numerous possible implementations of such a radio *karahi* telescope in education. For starters, observation sessions can be conducted with these telescopes at science fairs and exhibitions, such as the Lahore Science Mela, where the capabilities of this telescope design could be demonstrated. The radio *karahi* could also be implemented into experimental laboratory courses at the college level, following the lead of teaching laboratories such as the Introductory Physics Laboratory at Northeastern University (9). At LUMS, a radio astronomy module could be initially integrated into either ENGG 100 Measurement and Design or PHY 300 Experimental Physics 2, and then be followed by a more comprehensive exploration in an AstroLAB-supported astronomy course.

Furthermore, collaborations with schools could be setup, where schools would be supplied with these telescopes, and their students would attend workshops and gain hands-on experiences with the telescopes. This would help establish a network of radio telescopes across the country, and perhaps encourage institutions to participate in large-scale radio astronomy projects.

Such efforts would advance astronomical research and public understanding of telescopes in Pakistan.

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