

Research on Milky Way HI line celestial body operation system based on a new type of small telescope

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Abstract. With the continuous advancement of science and technology, people have made long-term progress in the development and understanding of astrophysics. This article also designed a new type of small telescope. By using this type of telescope, researchers can effectively align the pointing and spectrum analyzer. The spectrum observed by detailed calibration is also similar to the existing observation data. By making larger aperture speakers, using lower-noise LNAs, and carefully calibrated using pointing and spectrum analyzers, the design of the telescope may be further improved to increase accuracy and performance.

Keywords: Galaxy HI ray, celestial body operation system, telescope design.

1. Introduction

The Milky Way Galaxy as seen from the earth is a starry belt across the sky. This belt looks quite different at various frequency bands throughout the EM spectrum. At visible light, the light from the stars of the Milky Way is heavily blocked by the interstellar dust, thus a dim dust lane across the galactic plane is clearly seen. This dust lane make it difficult to identify the dynamical center of the Milky Way. At radio band, the emission is almost unaffected by the interstellar dust, so even the EM signal from the far end of the milky way could reach us almost unaffected. The 21cm neutral Hydrogen line plays a very important role in providing a useful signal to trace the neutral hydrogen distribution and to study the dynamics of the Milky Way Galaxy. In fact, the spiral arm of the Milky Way was first revealed by the 21cm HI line [1], [2]. The modern picture of the Milky Way galaxy is deduced from the HI line and other observational means.

In this paper, we describe the design and manufacture of a hand-made small radio telescope for observing the HI line emission from the Galactic plane. In the following section, the design, selection of materials, manufacture and performance verification are described. The test observation of the Galactic HI line is described in the third section. A concluding remark is given in the last section.

2. The small radio telescope

In this section, we describe the design, selection of materials, manufacture and performance verification of the small telescope.

2.1 The design of the small telescope

Hydrogen is one of the most abundant elements in the universe. The concentration and movement of the Hydrogen atoms provide a natural tracer of the mass distribution and dynamics of our Milky Way galaxy. Early observations have revealed that the Milky Way is a barred spiral galaxy with a diameter of about 100,000 lys, and our solar system lies at about 25,000 lys away from the galactic center. Most of the stars and Hydrogen atoms are seen to be within a belt with width of about 20 degree on the sky, this belt is normally called as galactic plane. The HI line emission from the Milky Way galaxy is then an extended source as seen from the earth. If the beam width of a telescope is comparable with the width of the galactic plane, the HI line emission would be easily observable.

Considering the wavelength of the HI line (21cm), beamwidth in degrees of telescopes with different diameters is shown in the figure below.

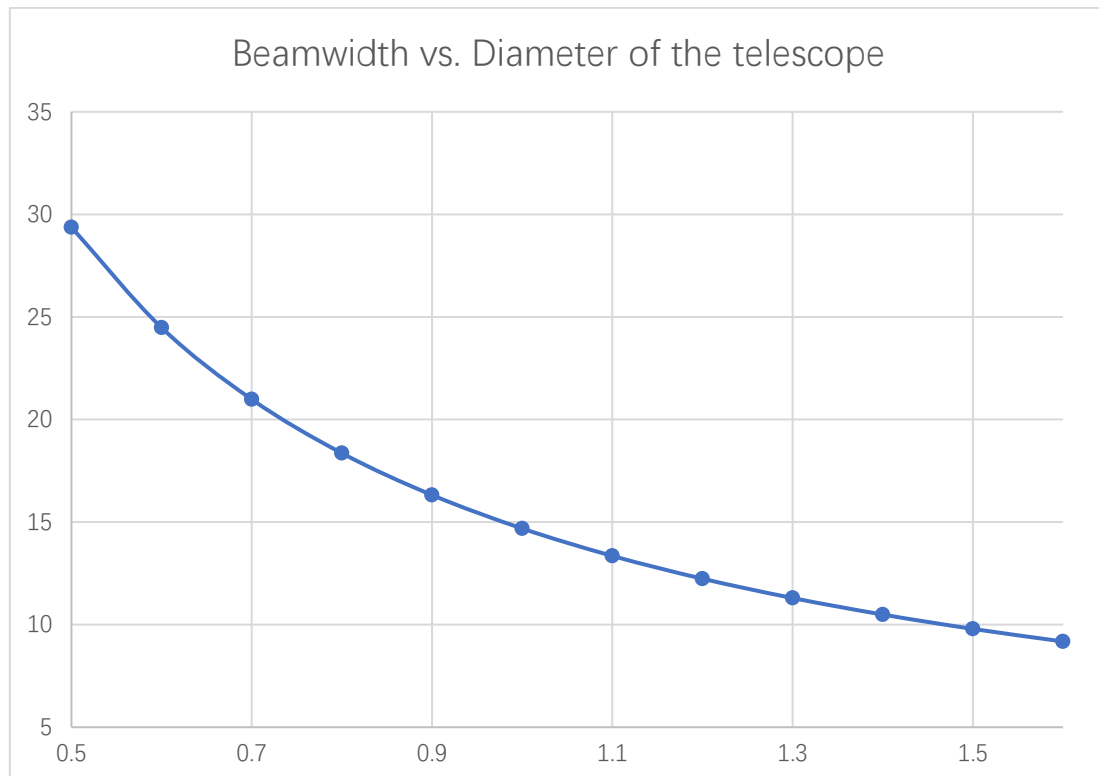


Figure 1. Beamwidth vs. Diameter of the telescope

So, a telescope with an aperture of 0.7m – 0.9m would have a beamwidth of 15-20 degree. If the aperture is 1.5m, the beamwidth would be about 10 degree. We decided to choose 0.8m as the size of the aperture, in order to observe the galactic plane. However, a larger aperture would offer higher resolution for more detailed study of the structure of the Milky Way galaxy.

2.2 Material selection and manufacture of the telescope

The main structure of the passive part of the telescope is a horn and a waveguide to coaxial transition. The function of the horn is to concentrate the incident plane wave intercepted by the aperture into a smaller waveguide at the other end. And the concentrated energy is then guided into a coaxial line at the waveguide to coaxial transition part for further processing. [3]

The frame of the horn and waveguide to coaxial transition is made of angle irons. The upper aperture of the frame is a square with a length of 0.8m for each side. The preparation of the angle iron with various length and the assembly of the frame of the horn are shown in Figure 2 and Figure 3. [4]



Figure 2. Preparing the angle iron with various lengths (left) and the assembly of the frame of the horn (right).

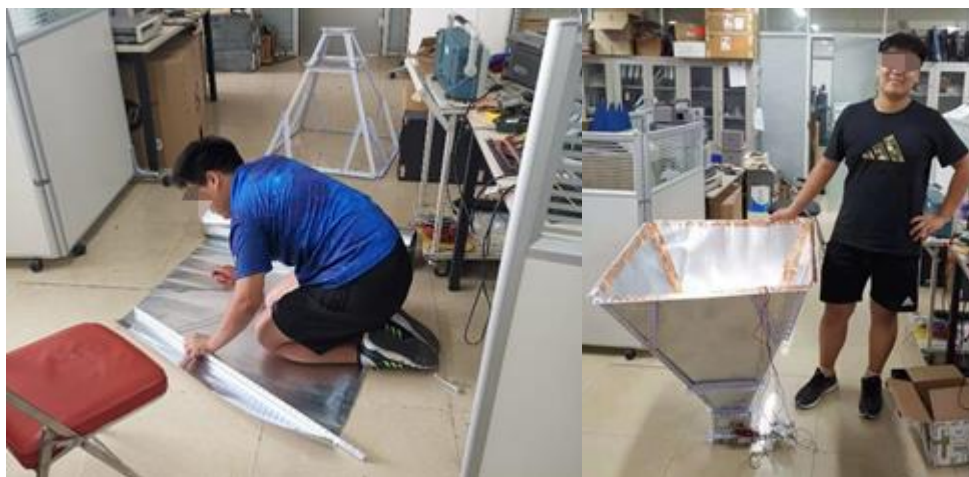


Figure 3. Cutting the thin zinc-coated iron plate (left) and the completed horn (right).

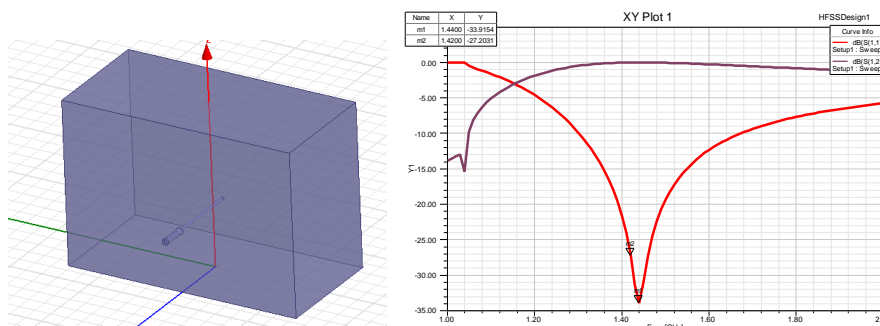


Figure 4. 3D model (left) and the simulated S11 and S21 (right) of the waveguide to coaxial transition.

The 3D model and the simulated S-parameters of the waveguide to coaxial transition is shown in Figure 4. The S11 is below -20dB from 1.4 – 1.5GHz. This part is used to convert

Guided wave within the rectangular waveguide into the coaxial line. The frame of the transition is also made of angle iron, and the wall of the waveguide is made of zinc coated steel sheet. N type

coaxial connector is used, and the probe is made of copper wire. Figure 5 shows the assembly of the transition and the measurement setup of the S11. [5]

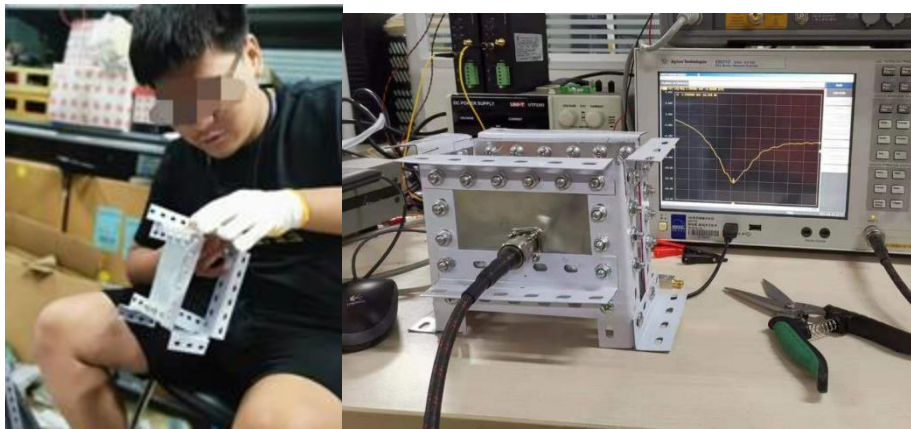


Figure 5. The assembly of the waveguide to coaxial transition and the measurement of the S11.

Commercially available Low Noise Amplifier (LNA) and Radio Frequency Amplifier (RF Amp) is used for amplifying the signal, and the RF spectrum is obtained by using a Spectrum Analyzer.

2.3 Performance verification of the horn and waveguide to coaxial transition

S11 measurement of the combination of the waveguide to coaxial transition is shown in Figure 6. Clearly ripple is seen in the measured S11 data in Figure 6 and Figure 5. This ripple is mainly due to the reflection from the ceiling in the lab. However, the magnitude of the S11 in Figure 6 is between -15dB and -20dB from 1.42 GHz– 1.47 GHz. This will be adequate to observe HI line from the Galactic plane for demonstration purpose.

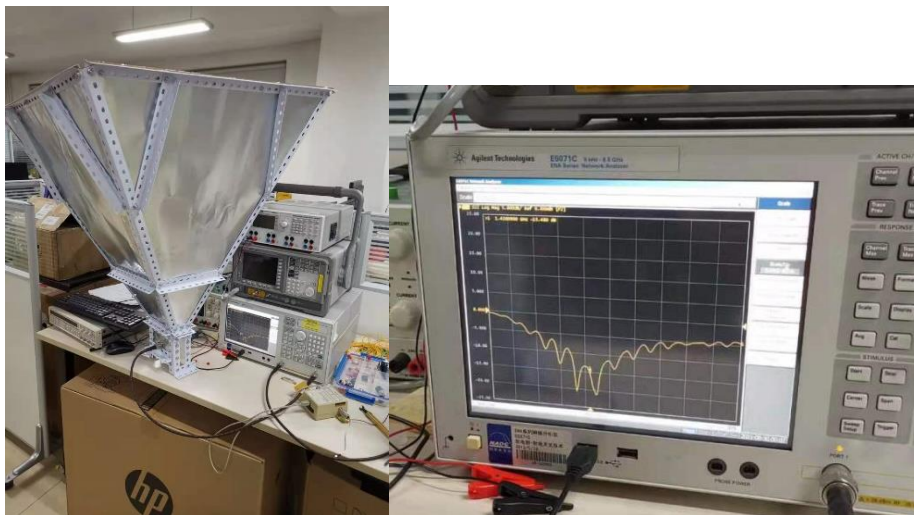


Figure 6. S11 measurement of the horn combined with the waveguide to coaxial transition.

3. Galactic HI observation using the above mentioned small radio telescope

Test observation of the Galactic HI line was carried out outdoors. Due to the limited accessible sky, three positions along the Galactic plane were chosen. The observed spectrum and the comparison with the existing HI line observation are shown in Figure 7.

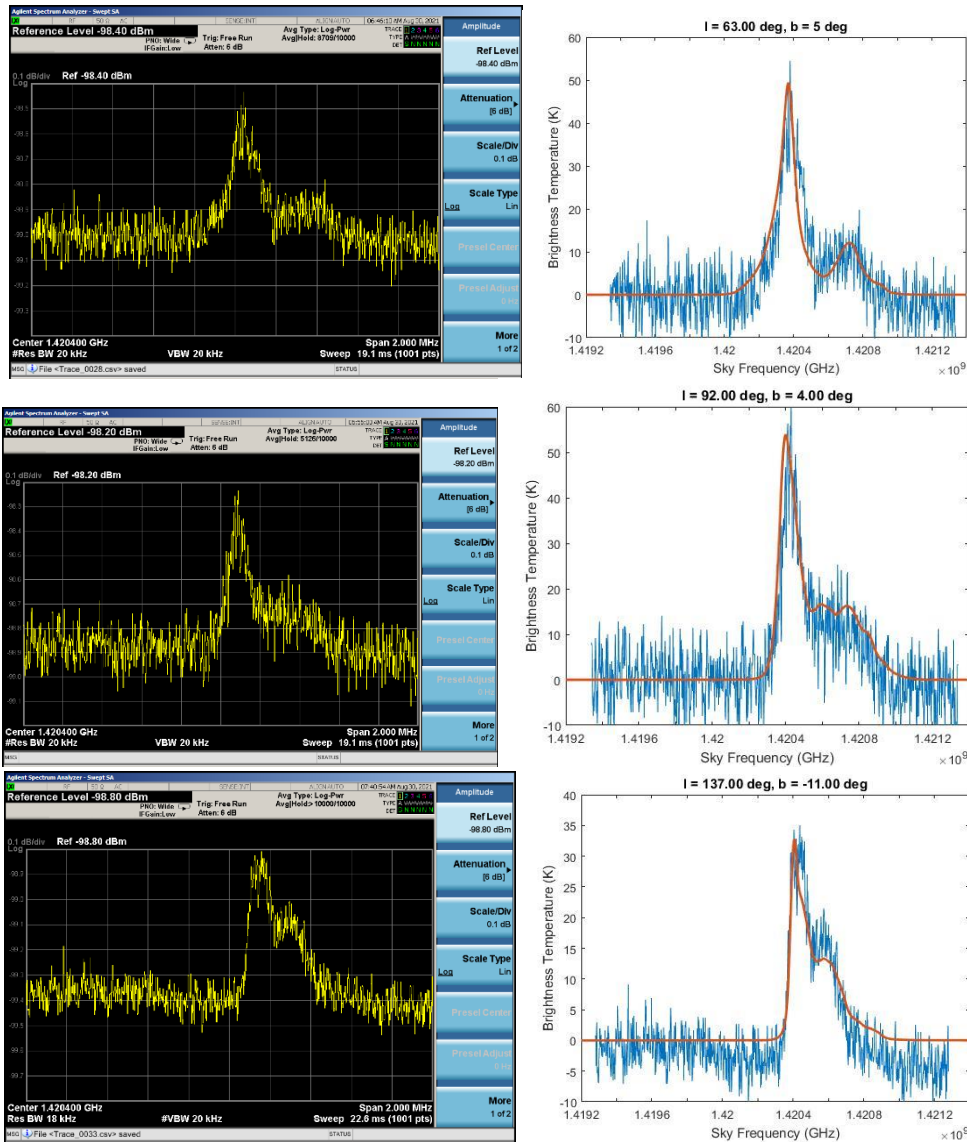


Figure 7. The observed HI line spectrum as seen directly from the spectrum analyzer (left column) and the comparison with the existing data (right column). The galactic coordinates for the three rows are indicated in the title of figure on the right.

It can be seen that signal to noise ratio of the spectrum directly read from the spectral analyzer is fairly good. Comparison with the existing HI line observation shows that the main features of the HI line spectrum is clearly seen even with this hand-made small telescope. More accurate calibration of pointing and the spectrum analyzer itself may be needed for further improvements.

4. Concluding remarks

In this paper, we present a hand-made small radio telescope to observe the Galactic HI line emission. Test observation has detected the HI line spectrum from the Galactic plane successfully. Further improvement may be possible through a larger aperture, more careful calibration of the pointing and the spectrum analyzer.

References

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