CHART Antenna: The Importance of Feed Length

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Summary

CHART is a project aimed to provide high-school classes the opportunity to make galactic observations of the 21 cm spectral line of hydrogen on a budget. The receiver system consists of a commercially bought SDR, LNA and a Raspberry Pi. The receiving antenna is a horn antenna constructed with either cardboard and aluminum foil or sheet metal. The antenna is fed by a wire contained inside a waveguide at the input of the horn. An investigation of the various components of the CHART system was performed after a series of unsuccessful galactic observing sessions. It was discovered that the feed wire was not properly tuned. Simulations of the CHART horn showed that the resonant frequency was inversely correlated to feed length. Changing the feed length from 8 to roughly 5.2 cm (37.5% decrease) changed the resonant frequency of the horn from 900 to 1420 MHz (55% increase). These results were found both in simulation and experimentally, showing that care must be taken when making the feed wire, ensuring it has the correct length of 5.2 cm to be tuned to the observing frequency of 1420 MHz.

Antenna Measured Reflection Coefficient

A horn antenna x by x at its base and x by x at the aperture is used as the CHART antenna. A wire inside a waveguide is used to feed the horn at its base. Although the horn is designed to be resonant at 1420 MHz, the feed wire also has a great impact on the reflections faced at the input of the antenna.

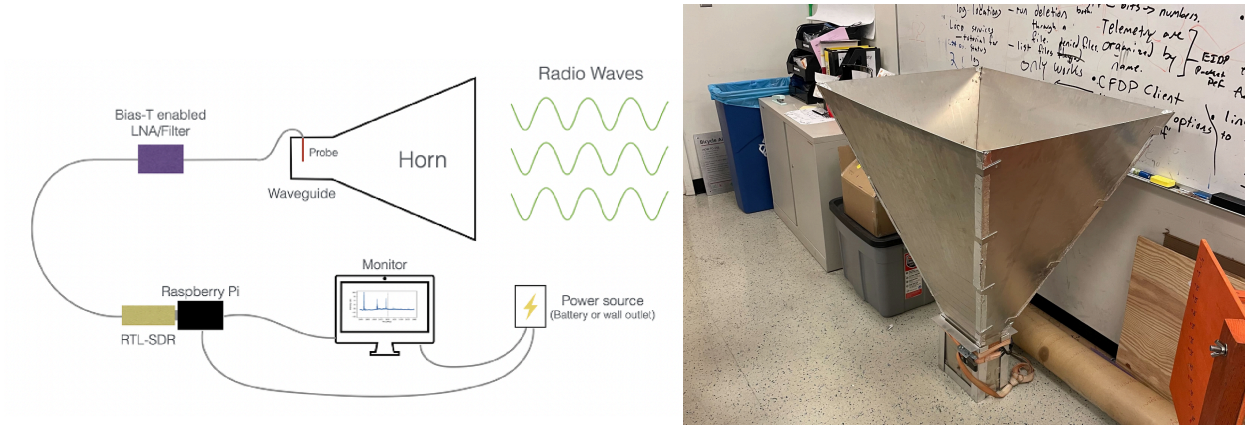

Figure 1: Left: Block diagram of CHART. Right: Sheet metal CHART horn antenna.

To show this, the reflection coefficient of a sheet metal CHART antenna was measured with a Keysight FieldFox. When using a feed wire 8 cm long, the antenna shows a resonance at around 900 MHz and ~75% reflections at the design frequency. To determine the optimal feed length before trimming, we will perform simulations of the horn in FEKO, an electromagnetic simulation software.

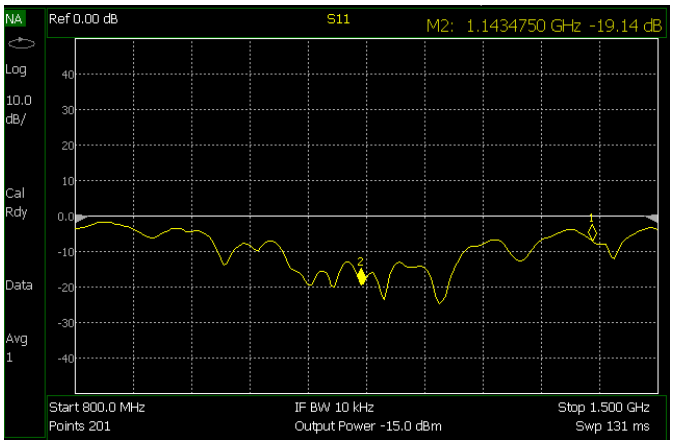

Figure 2: Reflection coefficient of the CHART horn antenna with a feed wire 7 cm long. The graph shows a resonance at 1100 MHz with reflections of 75% at 1420 MHz. Note: the original graph with the resonance at 900 MHz was lost. This graph is from a different untuned horn.

Antenna Simulations

A CAD model designed in FEKO is shown below. A simulation was performed with a feed wire of 8 cm. This simulation shows a resonance at 900 MHz and almost complete reflection at 1420 MHz, similar to lab measurements. Performing optimizations in FEKO. We can obtain a resonance at 1420 MHz with a feed wire length of 5.2 cm, about 3 cm shorter than the feeds in the horns measured in the lab.

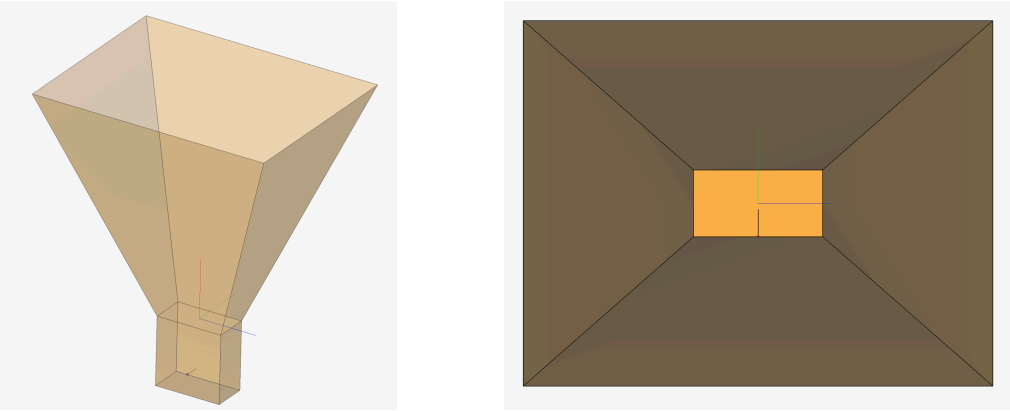

Figure 3: CHART horn antenna CAD model in FEKO. A wire in the waveguide is connected to a wire port and is excited with a voltage source to obtain simulated reflection coefficients.

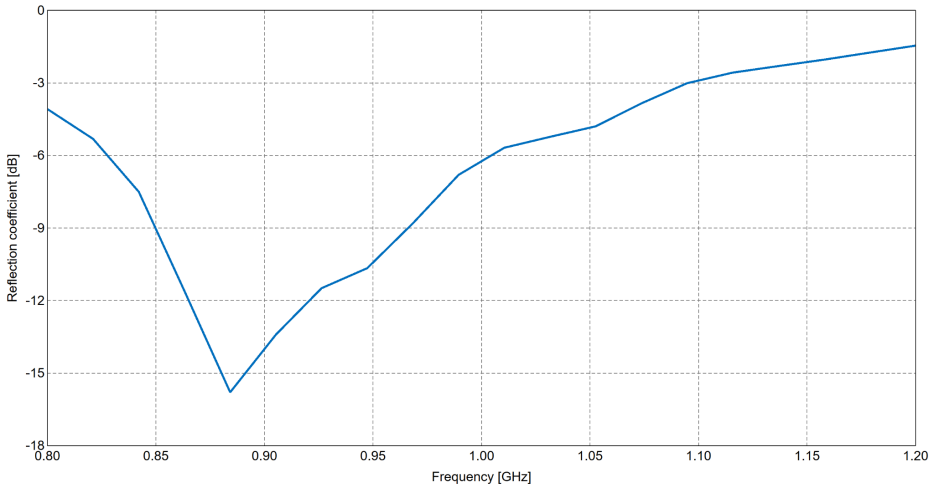

Figure 4: Simulated reflection coefficient of the CHART horn antenna with a feed wire length of 8 cm. Simulations show the same resonance at 900 MHz measured in the lab. Reflections at 1420 MHz are of the same magnitude as measured.

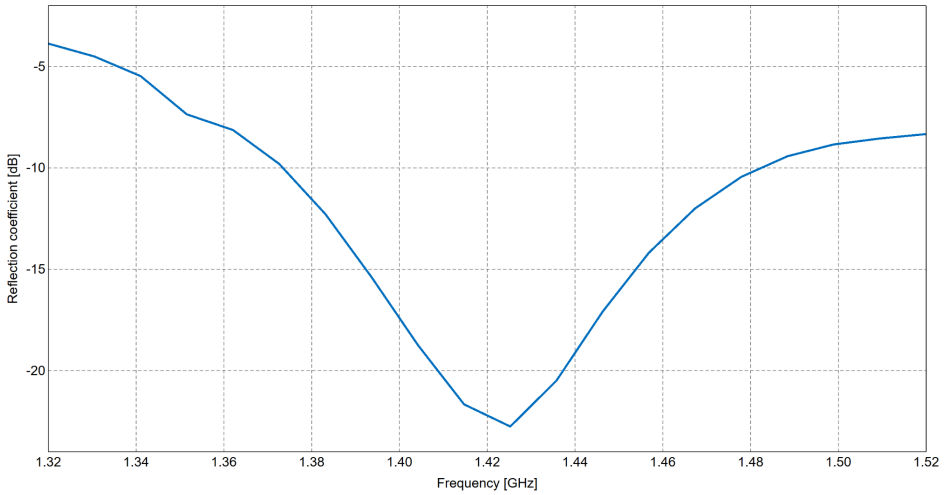

Figure 5: Simulated reflection coefficient of the CHART horn antenna with an optimised feed wire length of 5.2 cm. Simulations show a desired resonance at 1420 MHz.

Antenna Tuning

Tuning was performed on the horn antenna in the lab by trimming the feed wire in the horn. We found a resonance at 1420 MHz when cutting the wire to about 5 cm, similar to results obtained in simulations. This result validates our simulations and shows a tight inverse correlation between the feed wire length and the resonant frequency. Changing the feed length from 8 to roughly 5.2 cm (37.5% decrease) changed the resonant frequency of the horn from 900 to 1420 MHz (55% increase). The measured reflection coefficient is shown below.

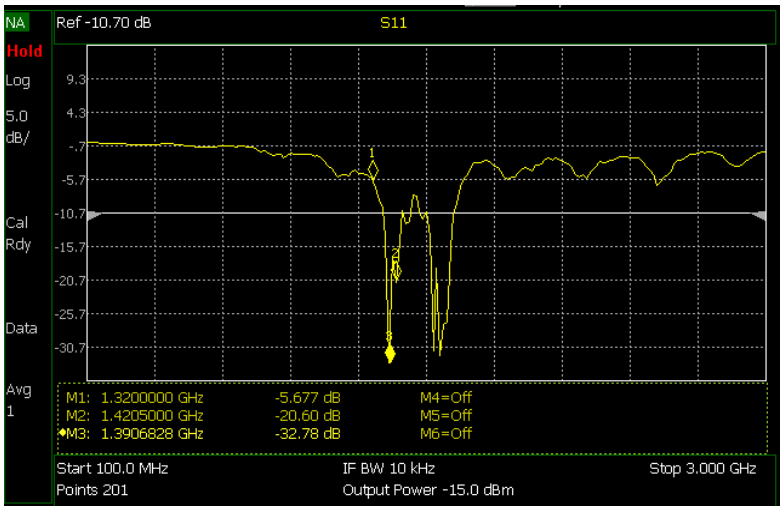

Figure 6: Reflection coefficient of the CHART horn antenna with a tuned feed wire 5 cm long. We see a resonance at 1420 MHz. We also see an unexpected resonance at 1500 MHz

Conclusions

Lab measurements showed that the CHART horn antennas being used for observations were out of tune. Simulations showed that the feed wire length was inversely proportional to the resonant frequency. Both simulation and lab measurements showed that a feed wire 8 cm had a resonance at 900 MHz and that trimming the feed wire to 5 cm gave the desired resonance at 1420 MHz. If galactic observations of the 21 cm spectral line of hydrogen are to be performed by people using the CHART horn antenna, care must be put in assuring the correct feed wire length of 5 cm to reduce reflections and maximize their chances of seeing emission lines coming from our galaxy.

Figure 7: The CHART antenna used for galactic observations on the roof of ISTB4 at ASU.